DEVELOPMENT AND EVALUATION OF HYBRID BERMUDAGRASS VARIETIES WITH COLD HARDINESS FOR GOLF COURSE PUTTING GREENS

By

WENWEN LIU

Bachelor of Science in Landscape Architecture

Northeast Agriculture University

Harbin, Heilongjiang Province, CHINA

2008

Bachelor of Science in Crop Science

Michigan State University

East Lansing, MI

2010

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by Wenwen Liu

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Thesis Approved:

Dr. Dennis L. Martin

Thesis Adviser

Dr. Justin Q. Moss

Dr. Gregory E. Bell

Dr. Yanqi Wu

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Name: WENWEN LIU

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Title of Study: DEVELOPMENT AND EVALUATION OF HYBRID BERMUDAGRASS VARIETIES WITH COLD HARDINESS FOR GOLF COURSE PUTTING GREENS

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Abstract: Conversion from creeping bentgrass (*Agrostis stolonifera* L.) to hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy] on golf course putting greens in Oklahoma and other transition zone states is on the rise. In many instances, bermudagrass has proven well adapted and more economical on putting greens than creeping bentgrass in the transition zone and farther south in the USA. With increased use, a need and opportunity for development of new advanced hybrid bermudagrasses has developed. Improvement in shade and cold tolerance is desired. Work has been conducted to develop a number of bermudagrass lines with apparent improved winter hardiness at Oklahoma State University (OSU). This research was designed to test seven promising OSU experimental bermudagrasses (OKC) and three advanced experimental types from Mississippi State University (MSB) against five industry standards. In addition to screening for the best performing experimental bermudagrass lines for putting greens, the study was to provide more information regarding the performance of commercially available bermudagrasses in Oklahoma. Results showed 'MSB-264', 'MSB 281' and 'MSB 285' have outstanding density, quality and color retention but demonstrated aggressive seed head expression. Amongst OSU experimental types, 'OKC 70-18' had the highest mean visual quality at a value of 6 while 'OKC 1-75-2' had the fastest establishment rate, high density and a dark green hue during summer months in addition to the lowest seed head expression. 'OKC 13-78-5', which was in the group of varieties to first reach 100% coverage, exhibited rapid green up, second only to OKC 70-18 and had good performance in regard to color retention and visual color during the growing season. 'OKC 7-20-22' and 'OKC 18-4-Powell were two of the worst performers with respect to all parameters measured except for green speed. Amongst commercially available types, 'Champion Dwarf' and' TifEagle' ranked the highest in color, quality and density while having minimum seedhead expression. However, TifEagle performed slightly better in early green up and late season color retention. The newly released commercially available cultivar 'Sunday' bermudagrass was also in the group of good performance with the second lowest amount of winterkill, very fine texture, high density and quality. Commercial standards generally had superior performance over all experimental entries in every parameter measured other than establishment rate and late-season color retention. Based on the findings of this work, golf course superintendents are advised to carefully consider all cultivar performance attributes of newer lines before making a decision to switch from existing commercially available standards to any new or future releases.

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CHAPTER I

A REVIEW OF SCIENTIFIC LITERATURE ON THE SUBJECT OF BERMUDAGRASS PUTTING GREENS

Introduction

There has been an increasing need in the golf industry to reduce maintenance budgets on golf course facilities while maintaining playing conditions that golfers find satisfactory. The most prevalent grass species used on golf greens in the USA is Creeping bentgrass (*Agrostis stolonifera* L. [synonym = *A. palustris* Huds.]). This cool-season perennial turfgrass has been selected for tolerance to low mowing height, dark green color, fine texture, uniformity, aggressiveness and density (Beard, 1973). However, the main drawbacks of creeping bentgrass have been its high maintenance cost and relatively poor performance under extreme heat and drought stress. The catastrophic loss of bentgrass over much of the USA in the summer of 2010 further accelerated a move toward superior genetics (O'Brien, 2011). Bermudagrasses (*Cynodon* spp.) also have many desirable features such as tolerance to low mowing height and high shoot density that make it a supreme grass for establishing a high quality putting green. In fact, bermudagrass has many desirable qualities that fit today's needs and environmental concerns (Keeley, 2001). As a perennial warm-season grass, bermudagrass is adapted to tropical or subtropical climates, thus it is the most commonly used lawn grass in the southern region of the United States. It can prosper in areas where creeping bentgrass declines under heat and drought stress and where bentgrasses must be closely monitored and intensely maintained to achieve acceptable quality. Bermudagrass has been used as a putting surface south of the transition zone since the 1930s because of its successful adaptation to the region's climate (Beard and Sifers, 1996; Maples, 2001). Moreover, bermudagrass has such high nitrogen responsiveness that it recovers quickly from damage caused by pests or physical wear.

Before making a final decision on whether to transition from bentgrass to bermudagrass putting greens, golf course owners and operators must consider both the pros and cons of these two grasses carefully. As mentioned earlier, following the economic decline of the late 2000s and early 2010s, the operational paradigm of the golf industry has largely altered toward more economical choices and procedures. In attempts to reduce maintenance budgets while preserving high quality player-friendly putting greens, many golf courses have switched from bentgrass to bermudagrass putting greens in the southern U.S. The financial benefits of these changes have been surveyed and documented. For instance, a two-year study conducted at the Highlands Course in Atlanta by their own personnel found that the club spent about $60,000 less per year maintaining interspecific hybrid ultra-dwarf type bermudagrass (*C. dactylon* (L.) Pers X *C. transvaalensis* Burtt Davy) greens than was spent maintaining bentgrass greens. They also suggested that bermudagrass provided better playing conditions through the key months of play (Slape, 2012). This difference in financial efficiency is mainly due to reduction of labor and mowing costs.

However, bermudagrasses grown in the transition zone are susceptible to winter injury (Fry, 1990; Hiscock, 1996). Another less desirable feature of bermudagrass is the unpleasant appearance of the turf as it enters dormancy for the winter. For years turfgrass scientists have been working on developing new ultradwarf types of hybrid bermudagrass cultivars which can significantly improve playing quality. Most ultradwarf types are selections of naturally occurring mutations in the dwarf interspecific hybrid bermudagrass cultivar 'Tifdwarf'. Tifdwarf itself was a natural mutation out of a standard putting green interspecific hybrid bermudagrass called 'Tifgreen'. Tifgreen was the first vegetative cultivar to be sprigged on putting greens (Burton, 1966; Hein, 1961).

Since 2010, at least six golf courses in Oklahoma have converted from creeping bentgrass to ultradwarf or dwarf bermudagrass putting greens, one to 'TifEagle', one to 'Mini-Verde', one to Tifdwarf, and three to 'Champion Dwarf' (Personal Communication, Dennis Martin, 12 January 2012). Conversions were made in hopes of providing improved summer playing conditions at the same or reduced maintenance costs. Due to the inferior winter tolerance of bermudagrass as compared to creeping bentgrass, these courses must cover their greens with protective geotextile fabrics during periods of severe winter weather. One golf course superintendent has communicated that approximately six human labor hours are required to cover each acre of bermudagrass putting green, with a corresponding six labor hours required to remove the cover from each acre of green (Personal Communications from Charles Wise, Windstar GC to Dennis Martin, 12 January 2012).

It is believed that with the breeding and development of new bermudagrass cultivars with higher resistance to winterkill, the need for covering greens with a piece of woven fabric in some transition locations may be reduced. In addition, with introduction of advanced bermudagrass lines, we can perhaps enlarge regions benefiting from the adoption of bermudagrass to as far as the northern portion of the transition zone.

Adaption and Biology

Bermudagrass was introduced to the United States from Africa by 1751 (Hanson, 1972). The genus *Cynodon* contains nine species and 10 botanical varieties within those species (de Wet and Harlan, 1970; Harlan et al. 1970). Common bermudagrass (*C. dactylon* (L.) Pers. var. *dactylon*) is typically a tetraploid (2n=4x=36 chromosomes), and African bermudagrass a diploid (2n=2x=18 chromosomes) (Harlan et al., 1970). The common bermudagrass taxon and African bermudagrass as well as the crosses between the two species (interspecific hybrids or *C. dactylon* x *C. transvaalensis*) are generally acknowledged to be of the most economical importance to the golf industry (Beard, 1973; Taliaferro, 2003; Taliaferro et al., 2004). Bermudagrass tolerates a wide range of environmental stresses including drought, close and frequent mowing and excessive traffic. The growth habit of bermudagrass is stoloniferous and rhizomatous with uneven internodes (Christians, 2004). It is generally considered to be very aggressive and recuperates quickly following injury.

Bermudagrass grows well in sandy-loam, a soil type common in central and eastern Oklahoma. It is best-adapted between 45 degrees north to 45 degrees south latitude in climates with humid to semi-arid growing conditions (Taliaferro et al., 2004). As a warm-season grass, bermudagrass usually stops growing when air temperature drops below approximately 60℉ (16℃) and shows significant discoloration and degradation in turf quality when temperature drops below 50℉ (10℃) but above 32℉ (0℃). This cold temperature stress that may occur when temperatures are below about 50℉ (10℃) is referred to as chilling stress and occurs much more often in warm-season grasses versus cool season plants (Hale and Orcutt, 1987).

As a C4 warm-season species, Bermudagrass has several advantages over C3 cool-season turfgrasses in regard to usage in the transition zone. Advantages include a resistance to high temperature stress, increased photosynthetic efficiency during warm periods, reduced water requirements, and decreased susceptibility to fungal pathogens (Beard, 2002). Warm-season turfgrasses experience dormancy during winter time and are often overseeded with cool-season species or painted for winter play (Goatley et al., 2007). It has been reported by Atlanta Athletic Club in Georgia that ball roll and putting quality are just as good on bermudagrass greens painted with turf colorants during the winter as they are in the summer (O'Brien, 2011).

Direct low temperature exposure is often defined as the course of severe or even lethal injury to turfgrass after experiencing a rapid temperature decrease below 5 ℃. Indirect low temperature exposure is more common than direct low temperature exposure and occurs when cold acclimated grasses are subject to cold temperatures for prolonged periods (Fry, 1990). Both of these exposures can lead to winter injury in bermudagrass.

Findings of a freeze chamber study conducted by Anderson et al. (2002) aimed at identifying the freeze tolerance of fairway, seeded, and putting green bermudagrasses are shown in Table 1. Only the freeze tolerance of vegetatively propagated cultivars intended for putting green use is presented here with test results and rank. Cold hardiness is reported as T_{mid}, which means the temperature at which 50% of the test population is dead. The higher a cultivar's T_{mid} value, the poorer its freeze tolerance is considered to be.

Anderson et al. (2002) found Champion Dwarf most susceptible to low temperature with a T_{mid} value as high as -4.8 ℃. MiniVerde had a T_{mid} value around -5.8 ℃, whereas the T_{mid} of Tifgreen was -6.5 ℃, significantly hardier than MiniVerde and Champion Dwarf. According to Anderson et al. (2002), Champion Dwarf could be regarded as a standard for low temperature susceptibility and Tifgreen as a standard for low temperature tolerance. However, since these results of relative freeze tolerance were concluded from observation in a highly-controlled environmental setting they cannot be considered the same as acclimation and exposure to low temperatures stress under field conditions. These findings may not accurately reflect the maximum genetic potential of all genotypes (Anderson et al., 2002).

Tolerance to disease/pest

While bermudagrass greens can suffer seriously from spring dead spot (SDS) caused by *Ophiosphaerella herpotricha* (Fr.) and take-all patch caused by *Gaeumannomyces graminis* var. *tritici* (Sacc.) in the southern region of the USA, they suffer considerably less from diseases such as brown patch (*Rhizoctonia solani* Kuhn), dollarspot (*Sclerotinia homoeocarpa* F.T. Bennett), basal anthracnose (*Colletotrichum cereale* Manns), as well as pythium root and crown rot (*Pythium* spp.) compared with creeping bentgrass (D.L. Martin, Oklahoma State University, personal communication, 2013). In a study of African bermudagrass and creeping bentgrass putting greens, black cutworms (*Agrotis* *ipsilon* Hufnagel) affected the African bermudgrass entries considerably less than they did the bentgrass (Gerken, 1994). Bermudagrass roots can also be seriously damaged by uncontrolled sting nematode (*Belonolaimus longicaudatu*s Rau) populations on well-managed sand based sites such as golf course putting greens (Trenholm et al., 2005). In these cases the injured turf will require greater amounts of fertilization and irrigation to provide acceptable surface quality as the stunted roots cannot function effectively to take up all of the nutrients and water required (Trenholm et al., 2005). Glass house trial research on Tifdwarf bermudagrass grown in lysimeters filled with U.S. Golf Association (USGA) specification root-zone sand has shown increased NO_3^- leaching under nematode pressure suggesting that nematode damage leads to nitrogen losses to ground water and potential contamination.

Golf Course Putting Green Maintenance

The putting green is arguably the most important area on a golf course and its playability and visual quality are critically important to the golfer's experience during a game of golf. Thus, a large portion of the budget and management effort of the turfgrass maintenance team is invested in putting green quality. In most of the world, putting greens are planted with a variety of either creeping bentgrass or hybrid bermudagrass with fine leaf texture and dwarf growth habit depending on the climate zone in which these courses are built or on the personal preference of the owner. No matter which grass is used, proper management protocols that are designed based on environmental circumstances at the site can maximize both the aesthetic and functional value of the putting green.

In most cases, a sand-based soil profile is preferred for building a putting green. One of the most commonly used construction techniques follows the protocol provided by the USGA Green Section (Anonymous, 1993). Another construction method, the California Green, recommended by the University of California (Davis et al., 1990) is also frequently adopted in certain areas depending on the landscape.

While judging the quality of a golf course putting green, attention mainly goes to features such as consistency, smoothness, firmness, resiliency and absence of turf grain and thatch (Beard, 2002). These features directly affect the ball roll and thus the playing quality of the green. In order to improve the performance of their greens, superintendents mow and roll the surface regularly and adjust the mowing height constantly throughout the year to prevent too much mowing stress. As an approach to control grain and thatch, topdressing, spiking and verticutting can be performed regularly on golf course greens. Topdressing, in the form of sandy soil added to the surface can smooth out the contour of a green that may have been pitted over time. The added loose soil material with good structure can also relieve the compaction caused by traffic and help restore the soil profile and alleviate thatch to a certain degree (Ferguson et al, 1969). However, intense physical cultivation for the purpose of thatch control may not be necessary for ultradwarf bermudagrass cultivars currently used on putting greens as it may affect the quality and recuperation in a negative way (Hollingsworth et al., 2005). Actually, it is suggested to have a small portion of thatch or mat layer intermixed with the root zone to help relieve external forces such as foot traffic applied to greens (Beard, 2002).

Irrigation is required when natural rainfall cannot meet the requirements of a crop system, especially those crops such as putting greens that are intensely maintained and where clipping yield is harvested. Irrigation scheduling should be adjusted for topography, exposure, soil texture, turfgrass species, traffic intensity, rooting depth and evapotranspiration (Beard, 2002). However, 100% evapotransporation (ET) replacement is not typically necessary. Past studies have shown that deficit irrigation practiced at a rate below 100% ET does not result in a significant loss of turfgrass playing quality and aesthetic value (Shearman, 2008). Fertility also needs to be adjusted accordingly in a balanced relationship with irrigation to provide satisfactory color and cover. Studies show that nitrogen applications can increase ET rates by encouraging the development of more transpiring leaf area causing increases in water loss (Barton et al., 2009).

In regard to fertilization, it is suggested to apply 0.5 to 1.2 lb N 1,000 ft^{-2} (0.25-0.6 kg 100 m^{-2}) to bermudagrass putting greens per growing month adjusted depending on the requirement of specific sites. Phosphorus and potassium application rates will be based on soil test results. Phosphorus application is suggested to be applied at regular intervals based on soil tests as part of a complete analysis fertilizer program. Potassium fertilization programs vary based on soil texture (higher sand = more frequent applications) and applications are normally split into 4-6 times per growing season (Beard, 2002). Generally speaking, deficiencies of the trace elements other than iron are rare on golf putting greens. Thus timely application of iron sulfate can be made as a fast fix to correct chlorotic conditions on putting greens (Ferguson et al., 1969).

Response to Plant Growth Regulators

Plant Growth Regulators (PGR) application regimes have been regularly used as part of routine putting green management to provide a smoother putting green surface and to promote overall higher turf quality (Fagerness and Yelverton, 2000).

Currently available PGR products can be divided into two categories, Type I products that work by stopping cell division and Type II that function by interfering with gibberellin biosynthesis, thus reducing cell elongation and subsequent plant organ expansion (Kaufmann, 1986). It is apparent that Type I chemical suppression of turfgrass growth cannot be accomplished without negatively impacting the ability of treated turf to recover from any form of stand loss (Watschke et al., 1992). As a matter of fact, use of Type I PGRs such as maleic hydrazide (SloGro) or mefluidide (Embark) have already become limited due to observed reductions in root quality and turf injury (Watschke et al., 1992). Typically, Type I growth regulators are only used on putting greens to discourage seed head expression in annual bluegrass.

Trinexapac-ethyl (TE), derived from cyclohexanecarboxylate, is a widely used Type II growth regulator in the turfgrass industry. Numerous studies have shown that TE can improve the turf quality, color, ball speed, root mass production, photosynthetic efficiency, and late season color retention of various turfgrasses used for putting greens and other uses (Bunnell et al., 2005; Qian and Engelke, 1999; Qian et al., 1998). For these reasons, TE has become one of the most commonly used and widely commercialized PGRs for use on golf courses. It has also been found that by adjusting TE and reducing N regime, performance of ultradwarf bermudgrass putting greens under reduced light or shaded conditions can be improved (Baldwin et al., 2009). Another study on TifEagle bermudagrass found that TE use increased root length density and quality with no observed negative effects (McCarty et al., 2011).

Due to physiological and morphological differences, bermudagrass cultivar responses vary for the same PGR application rate. Ultradwarf bermudagrasses appear to have higher sensitivity to PGRs than creeping bentgrass and more traditional bermudagrasses such as Tifgreen and Tifdwarf (McCullough et al., 2004). More field or lab studies are needed to explore how different bermudagrass varieties react to PGR application and how to maximize the profit it brings to the management of golf course putting greens.

RESEARCH PURPOSE AND OBJECTIVES

This project was conducted in order to collect a two year data package concerning some of the most commonly requested performance parameters on hybrid putting green bermudagrass cultivars. It was also intended to provide us with further knowledge on the adaption of commercially available bermudagrasses to north central Oklahoma. With information gathered through this project, we believed that selection of elite performing lines within the OSU germplasm could be made readily. This research was also intended to generate data packages that can be used in supporting patent submission on OSU or MSU experimental materials.

Improved cold hardiness and freeze tolerance are very desirable features of bermudagrass varieties. Our objective was to screen these presumably cold hardy OSU experimental lines for potentially advantageous genotypes by comparing their performances to those of five commercial standards. Another objective of this study was to use our findings to establish a data package for future commercialization of one or more of the currently experimental OSU and MSU cultivars included in this research. Finally, it was also our objective to collect further information on the commercially available varieties in regard to their performance in Oklahoma.

Even if none of these experimental varieties can make its way to market as a putting green type, they may hold promise for use at other heights of cut such as on golf course fairways or tee boxes or they could possibly still be used as potential donor parents carrying desirable resistance genes to be incorporated into new cultivars in the future.

Table 1. Freeze tolerance of putting green bermudagrasses. The T_{mid} values represent the midpoint of the survival versus temperature response curve.

Genotype	T_{mid} (℃)
Champion	-4.8a
Mini Verde	-5.8bc
TifEagle	-6.0cd
Tifdwarf	-6.5d
Tifgreen	-6.5d

† Column means are separated by Duncan's New Multiple Range Test at *P* = 0.05.

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CHAPTER II

EVALUATION OF 10 EXPERIMENTAL HYBRID BERMUDAGRASSES FOR USE AS PUTTING GREEN SURFACES

Abstract

Disadvantages of bermudagrass as a turfgrass are its susceptibility to low temperature injury and intolerance of even very light shade compared to creeping bentgrass. Geotextile covers are frequently used to cover bermudagrass putting greens during severe winter days to prevent low temperature injury. Another solution to offset the lack of cold tolerance is the use of a plant growth regulator (PGR) such as trinexapac-ethyl (Primo Maxx^{TM}), which works by inhibiting gibberellic acid biosynthesis. Other benefits of incorporating PGRs into fertility programs include higher nutrient use efficiency and overall better quality of putting surfaces. Ultradwarf bermudagrasses currently in use on putting greens in Oklahoma include: 'Champion Dwarf', 'MiniVerde' and 'TifEagle'. Some 'Tifgreen' and 'Tifdwarf' were used on putting greens in the near past with common bermudagrasses having been used in the distant past. Six of the seven experimental OSU putting green bermudagrass types have documented improved winter

hardiness at higher heights of cut. The objectives of this study were to screen 10 experimental bermudagrass selections from Oklahoma State University and Mississippi State University for their performance as putting green surfaces compared with five commercialized industry varieties. Information gathered through this project will improve the selection of elite performing lines within the OSU germplasm bank. Our original hypothesis was that the OSU putting green types had improved winter tolerance compared to the commercial industry standard types. Results demonstrated that all three experimental lines from Mississippi State University, 'MSB-264', 'MSB 281' and 'MSB 285', had outstanding density, quality and color retention but all had aggressive seed head expression. Amongst OSU experimental types, 'OKC 70-18' had the highest mean quality of six experimental lines while 'OKC 1-75-2' had the fastest establishment rate and the lowest seed head expression. 'OKC 13-78-5', which was amongst the first group of varieties to reach 100% coverage, greened up rather fast, ranking second only to OKC 70-18 and had good performance in regard to both density and color. 'OKC 7-20-22' and 'OKC 18-4-Powell', two of the worst performers in all parameters except for green speed, will not be advancing to the next stage of product development. Additionally, it has also been shown through this research that all commercial standards included in this study, which are 'Sunday', Champion Dwarf, Tifgreen, TifEagle and Mini Verde, performed well and are adapted to be used as putting surfaces in Oklahoma when managed the same as in our study. There may be little need for golf courses located in Oklahoma to replace any of the five commercial varieties of putting green-type bermudagrass with any of the experimental types of bermudagrass tested in this trial.

Introduction

Bermudagrass (*Cynodon dactylon* (L.) Pers.) is a commonly used warm-season turfgrass that can be propagated by seed, rhizomes, and stolons. It also has excellent recuperative ability and wear tolerance (Turgeon, 2005). Turf-type bermudagrass cultivars are used throughout the tropical and subtropical regions of the world on sites that include roadsides, ditch banks, pond dams, home lawns, general grounds, golf courses and sports fields (Beard, 1973). Due to its relatively poor tolerance to cold temperature, overall bad color retention late in the growing season and tendency to enter dormancy during the winter months, turfgrass managers at golf courses located in the southeastern United States often paint their greens with turf colorant or overseed their greens and fairways with a cool season grass such as perennial ryegrass (*Lolium perenne* L.) in order to maintain an acceptable turf color.

To meet this demand for improvement in cold temperature adaptation of bermudagrass, researchers at Oklahoma State University have been working on breeding, screening and identifying cold tolerant genotypes as well as the genes that confer improved cold tolerance (Wu et al., 2013). The effort to improve cold tolerance in high quality, turf-type bermudagrass first began in 1986 at Oklahoma State University.

This research was conducted as a part of the overall goal to develop cold hardy bermudagrasses that also provide high quality putting green surfaces. The specific objectives of this research were to evaluate 10 experimental bermudagrass cultivars against five commercialized industry standard bermudagrasses under close-cut putting green surface conditions and to acquire more information regarding the performance of commercially available bermudagrasses planted in Oklahoma and similar climates.

Materials and Methods

This field study was initiated on a sand-based research putting green at the Oklahoma State University (OSU) Turfgrass Research Center located at the OSU Botanic Garden Complex 1.6 km west of Stillwater, OK. On that site two bermudagrass putting green variety trials were established, with each trial containing 15 varieties (Appendix A). The research putting green was built in 1982 using a 90:10 (V:V) sand and rice hull construction profile with no intermediate layer (choker layer) component. A total of 25.4 centimeters of this top mix was placed over a geotextile mat which was placed over a coarse layer of gravel. The sand in the root zone mix as well as the topdressing sand used since 2012 on this site were USGA specification putting green sand from Lightle Sand Pit in Hennessey, OK. The report from a soil textural analysis conducted at the OSU Soil, Water & Forage analytical laboratory at Oklahoma State University showed that the root zone soil as sampled on 25 Oct 2013 to a depth of seven inches was composed of 99.35 percent mineral fraction and 0.65 percent organic matter. The mineral fraction was determined to be comprised of 95.0 percent sand, 2.5 percent silt and 2.5 percent clay.

Production of Planting Stock

On 2 November 2011, single plugs (7.6 cm diameter) were pulled from each of five promising OSU experimental entries growing in a putting green nursery trial located in Block 23 at the OSU Botanic Garden -Turfgrass Research Center (TRC) Complex. Two additional experimental entries were harvested from other trials at the TRC Complex. The OKC 70-18 entry is a clonally-propagated interspecific hybrid bermudagrass that ranked first in overall mean quality in the 2002-2006 NTEP bermudagrass trial at nine transition zone test sites (Morris, 2013). OKC18-4-Powell is a radiation mutant of Patriot bermudagrass created through work conducted by Dr. Jerrel Powell. It was included in this trial as there was not any previous research on this experimental line evaluating its value as a putting green surface. Selected materials were transplanted into greenhouse flats for expansion. Soil was washed from plugs and sprigs were separated then planted in flats filled with soil mixture. A no-tree bark greenhouse soil medium, Metro-Mix 300 (Sun Gro Horticulture Canada Ltd., Agawam, MA, 01001), was mixed with a fine textured sand at a ratio of 3:4 V:V using a small cement mixer to make a prototype growing medium for expansion of our grass materials in the greenhouse. This mix was developed to reduce the likelihood of introducing contamination into the sand-based putting green from organic materials used in the stock greenhouse propagation mix.

All materials were cut into individual sprigs with vegetative nodes/internodes planted in the growing medium. New roots and tillers grew from each node and filled in each standard greenhouse tray (28 cm W x 54 cm L x 6 cm D). We acquired most of our greenhouse supplies including mixes, thermoformed trays and watering wand from American Plant Products in Oklahoma City, OK. Expansion of planting stock occurred through fall and winter of 2011 supplying us with enough transplant stock to conduct an early May 2012 field planting. Information regarding all the entries evaluated in this study is shown in Appendix A.

During the winter of 2011 and spring of 2012, all 15 materials were harvested and then expanded into 30 flats of each entry. The grasses were propagated in the TRC turf greenhouse. Newly expanded flats were kept on a mist bench for the first two weeks so as to help keep the newly grown roots moist. The mist bench was set to turn on for 15 seconds every 30 minutes during the 24 hour period of each day. Regarding fertilization, 250 ppm N (1.23 g l^{-1}) of Jack's Professional fertilizer 20-20-20 (N-P_2O_5-K_2O) (20-8.8-16.6 actual N-P-K) was used for grass propagation in the greenhouse. The volume of fertilizer water suspension was recorded to calculate the amount of nutrient applied to each flat. The fertilizer rate used was 55 kg ha^{-1} N twice a week. After the first two weeks, these flats were taken off the mist bench and kept in the greenhouse under the same maintenance program for three months until May of 2012.

Four soil subsamples, each measuring 2.54 cm in diameter by approximately 7 cm deep, were obtained from each of the plot sand mixed to form a single composite sample. The sample was submitted to the OSU Soil, Water and Forage Testing and Analysis Service Laboratory for routine N, P, K, and pH analysis on 6 December 2011. The P and K analysis utilized was the Mehlich 3 procedure developed by Mehlich (1984). Subsequent soil fertility tests were conducted on 9 May 2012, 20 Nov 2012, 3 July 2013, and 4 Sep 2013. Results from these tests provided P and K indices for each site which were then used in designing the fertilization program.

Preparation and Establishment

Each of the 15 bermudagrass trial entries was sprigged on the block eight green located at the TRC (36° 07' 06" N, 97° 06' 10" W). Sprigs were placed into an area measuring 1.22 m x 4.27 m within each 1.52 m x 4.57 m plot for entries in the multi-parameter (MP) trial and an area measuring 1.22 m x 1.22 m within each 1.52 m x 1.52 m plot in the winter-tolerance (WT) trial. The experiment had three replications and five replications in a randomized complete block design for the MP and WT trials, respectively. In the MP trial, the 5.2 m^2 size of each plot allowed for a center area of 4.27 meters in length without a border effect for measuring ball roll speed using a standard USGA Stimpmeter. The initial 15.24 cm bare soil borders surrounding each plot inhibited encroachment of growing stolons from other plots during the establishment phase. These intervals of bare area between adjacent plots were maintained by hand pruning at the initial stage and were allowed to fill in from adjacent plots once full establishment of the plot centers occurred. Sprigs of all varieties were planted in late spring 2012 with the WT trial sprigged beginning on 1 June and the MP trial sprigged starting on 13 June. The exact order of dates in which each of the replications was planted was: rep five of WT trial on 24 May, rep four of WT trial on 25 May, rep three and rep two of WT trial on 31 May, rep one of WT trial on 1 June, rep three of MP trial on 5 June, rep two of MP trial on 8 June, and rep one of MP trial on 13 June 2012.

Site Preparation

An irrigation audit, irrigation head replacement and spray head adjustment were performed prior to planting to help ensure uniform irrigation distribution. The previous creeping bentgrass trial growing on the test site was killed with glyphosate (Roundup Pro, Monsanto Company, St. Louis, MO, 63167) using 5 kg ha^{-1} Glyphosate, N-(phosphonomethyl) glycine in the form of its isopropylamine salt to eliminate potential contamination. Dead bentgrass sod was then removed with a sod cutter 14 days after glyphosate application. Additional shaping and leveling procedures were performed to make sure the site surface was level and firm enough for sprigging.

All grass materials were torn into pieces of 15-20 cm in length and with at least two vegetative nodes before they were used in planting. Plots were planted at a 1:8 flat to plot area ratio which was higher than the standard 1:10 ratio often used by the sod industry to establish putting greens. Use of higher sprigging rates caused faster establishment and allowed for the maximum amount of data collection periods after reaching a 100% stand of bermudagrass. Sufficient irrigation was applied as needed to ensure no drought stress occurred during grow-in. The ultimate purpose of the irrigation was to keep the sprigs constantly moist until rooted.

Site Maintenance

After the establishment phase, the study entered the maintenance stage. Turf was irrigated regularly to encourage maximum growth and to minimize wilting due to soil moisture deficit. Based on soil test results, soil pH ranged from 6.2 to 6.8 during the trial. Table 2 at the end of this chapter shows detailed fertilization information of this putting green study.

Prior to sprigging, 48.4 kg ha^{-1} N of slow release nitrogen from a 17-17-17 ($N-P_2O_5-K_2O$) formulation (17-3.5-14.1 actual N-P-K) was worked into the upper 76.2 mm (3 inches) of soil with a bunker rake. For the first 8 weeks after sprigging, a fertilizer program consisting of 48.4 kg ha^{-1} N using a quick release source was applied at 10 days' intervals After 8 weeks the amount and frequency of application was changed to 24.2 kg N ha^{-1} every two weeks. Following grow-in, conventional maintenance fertilization protocols with a yearly amount of 341.6 kg ha^{-1} N were followed.

Cyfluthrin was applied at a rate of 34.26 gram acre^{-1} using Tempo SC Ultra (Bayer Environmental Science, Montvale, NJ) on 2 Aug 2012, Lambdabcyhalothrin applied at 70.05 kg ha^{-1} via Scimitar GC (Syngenta Crop Protection, Inc., Greensboro, NC) on 24 June 2013, 8 Aug 2013, Bifenthrin at 0.01 g m^{-2}(49.9 g acre^{-1}) applied using Bifen I/T (Control Solutions, Inc., Pasadena, TX) on 24 June 2013 to control black cutworm and prevent army worm damage. For help control of localized dry spot, a wetting agent (Tri Cure AD, Mitchell Products, Millville, NJ) was applied at 9.5 liter acre^{-1} on 15 April and 15 Aug 2013.

The first mowing at 12 mm (0.475 inches) occurred on 25 June 2012, and rolling was conducted immediately prior to mowing. As the bermudagrasses began to cover the plots, mowing height was gradually reduced to the lowest maintenance height of 3.2 mm (0.125 inch bench setting). This target mowing height, 3.2 mm, was then maintained by mowing six days week^{-1} until mid-September during which period the mowing height was again gradually increased to 3.937 mm (0.155 in) as winter approached (Table 3).

Covering of turf is a procedure commonly used to improve bermudagrass winter survival on putting greens. It is understood that the protective covering material only holds heat by reflection of infrared radiation exiting the earth (Goatley, 2005). Covers form a buffer zone between the cold ambient air and the soil and also help to maintain moisture in the air surrounding the surface of the turf. Pine straw was used as early as 1929 to protect bermudagrass putting greens in the winter (Beckett, 1929). Numerous studies demonstrated the benefits of covering bermudagrass greens during cold winters including significant enhancement of fall color retention, winter survival and spring regrowth especially when the turf is maintained at heights higher than 19 mm (Sowers and Welterlen, 1988; Shashikumar and Nus, 1993).

In the fall and winter of 2012, the multi-parameter performance (MP) west trial was covered with a black colored Xton brand (Xton Inc.,Florence, AL) woven geotextile fabric cover (17.68 m x 24.99 m) when temperature was projected to fall below 25F based on the local National Weather Service Forecast for the Stillwater Regional Airport site located at Lat: 36.16 °N Lon: 97.09 °W. However, the winterkill assessment (WT) trial was left uncovered. The MP trial was covered to ensure the existence of a perennial trial on which various multiple performance parameters could be measured and observed. The WT trial was evaluated for winter kill ratings in the spring of 2013. The MP trial provided adequate survival of all genotypes so that ratings for the grasses could be obtained for aesthetic and functional parameters in spring, summer and fall of 2013, following the winter of 2012/2013. Dates on which the MP trial was covered were 9 Dec to 12 Dec, 20 Dec to 21 Dec in 2012, 23 Dec 2012 to 4 Jan 2013, 5 Jan to 8 Jan 2013, 21 Feb to 25 Feb, 2 Mar to 4 Mar, 27 March to 28 March, 12 Nov to 14 Nov, 27 Nov to 28 Nov, 5 Dec to 15 Dec and 20 Dec to 31 Dec in 2013.

Aerification and topdressing were conducted on an as-needed basis. During both growing seasons in 2012 and 2013, topdressing was performed at 82.3 m^3 ha^{-1} on a biweekly basis from April through September. Aerification was started in 2013 using a Verti-drain aerifier with 1.27 cm (0.5 inches) solid tines at 6.4 cm (2.5 inches) spacing and up to 15.23 cm (6.0 inches) deep. Aerifications were conducted on 11 June, 16 August, and 24 September of 2013. Following each aerification, topdressing and brooming were performed to distribute topdressing sand.

At the start of second growing season, each MP trial plot was split into two sub-plots of equal size to accommodate a control plot and a plot that received biweekly trinexapac-ethyl applications at a rate of 673.21 g ha^{-1} (Primo Maxx™, Syngenta Crop Protection, Inc., Greensboro, North Carolina 27419-8300). A CO^2-pressurized bicycle sprayer equipped with a single boom and three XR TEEJET 8005VS nozzles (TeeJet Technologies, Wheaton Facility, Wheaton, IL) (50.8 cm nozzle interval and 53.3 cm from the ground while spraying) was used for PGR applications. Applications were made at 200 kPa (29 psi) using a carrier rate of 416.72 L ha^{-1} (45.6 gallon $acre^{-1}$). No irrigation was applied immediately after each application for four hours to facilitate efficient absorption of the chemical by the grass tissue. In total, seven applications were made occurring on 28 June, 9 July, 19 July, 4 Aug, 21 Aug, 3 Sep and 23 Sep of 2013.

Data Collection

Evaluating visual characteristics of turfgrass can be subjective. However, the National Turfgrass Evaluation Program (NTEP) has established specific procedures, guidelines and criteria for use in visual cultivar evaluation studies (Morris, 2013). Most visual ratings collected on our trials were based on a 1 to 9 rating scale with 1 as poorest or lowest and 9 as best or highest. However, a few characteristics, such as winter kill or percent living ground cover, were rated on a percentage basis, again using the evaluator's judgment. Most disease ratings found in NTEP reports use the 1-9 scale, 9 = no disease. If percent disease data is used, it should be in separate tables and is normally included with disease data rated using the 1-9 scale (Morris, 2013). Ideally, to elucidate the cold hardiness of different varieties, regrowth is evaluated in the spring following a harsh winter. A minimum of two years data collection is required because temperature, moisture, and snow cover differences between years may alter survival rates (Anderson et al., 2002).

Turf Quality

Visual Turfgrass Quality was evaluated biweekly from May to December in 2012 and March to December in 2013 using the standard NTEP 1-9 rating scale, where 9 was outstanding turf and 1 was dead turf. Various factors concerning the functional and the aesthetic features of the turf such as solid color, density, uniformity, texture, presence of weed species and disease or environmental stress were taken into account while rating the turf quality. In total 11 quality ratings were made in 2012 and 2013 respectively.

Green Speed

As defined by the USGA, ball roll distance or green speed is inversely proportional to the coefficient of friction between the ball and the putting surface. To date there are not many studies that have been conducted on the green speed of a bermudagrass putting surface. This parameter was measured using a standard USGA Stimpmeter (United States Golf Association, Far Hills, N.J.). A green speed assessment was conducted monthly during each growing season. Results were then calculated by averaging 6 readings acquired from ball rolls in two different directions within each plot. Six ratings were conducted in 2012 and nine in 2013.

Establishment Rate

Establishment is a visual estimate of percent ground cover, plant height, etc. that reflects the relative speed of coverage (entry develops into a mature sod) (Morris, 2013). This index was evaluated on a visually rated percentage basis. Digital image analysis (DIA) on each plot was used as a supplemental procedure to evaluate this parameter. Digital image analysis to determine turfgrass cover and color was refined by Richardson et al. (2001) and Karcher and Richardson (2003) via the macro add on for batch analysis. The macro written specifically for turf analysis can be downloaded at the University of Arkansas website: http://www.uark.edu/campus-resources/turf/turfmacro; verified 07 November 2013. Sigma Scan Pro 5 software (Systat Software, Inc., San Jose, CA 95110) was utilized to determine percent ground cover from digital photographs with the hue threshold set at 35 to 100, and saturation set at 0 to 100. In total eight ratings were taken before all entries reach 100% cover.

Living Cover

Living ground cover is based on surface area covered by the originally planted species rated by percent. It is generally used to express damage caused by disease, insects, weed encroachment, or environmental stress (Morris, 2013).

Percent living cover of the entry during turf establishment was evaluated biweekly via digital image analysis based on a percentage scale. During the two growing seasons, percentage of living ground cover was visually rated on a weekly basis also. There were 15 sampling dates in 2012 and 23 in 2013.

Visual Color

Visual color was evaluated biweekly starting in July of 2012 and May in 2013 based on a standard NTEP 1-9 rating scale with 1 representing brown and 9 standing for dark green. Ratings were done during a period that grasses were in good condition and actively growing. Seven color ratings were collected in 2012 while 17 were done in 2013.

Late Season Color Retention

Late season color retention is an important assessment of turfgrass coloration as nights cool and day lengths shorten. It is useful in estimating warm-season grasses' tolerance to seasonal temperature changes, shortening day length and even light frost.

This index was evaluated using the standard NTEP 1-9 rating scale with 1 being straw brown and 9 being dark green starting at the end of October, 2012. Late season color retention ratings assessed with the aid of digital imagery to provide an objective rating. Four color retention ratings were conducted in 2012.

Spring Greenup

Spring Greenup is a measure of the transition from winter dormancy to active spring growth. Breaking winter dormancy of bermudagrass as quickly as possible each spring may encourage earlier sports field use, make play more enjoyable in the early season and allow the harvest of green bermudagrass to start earlier on sod farms. Spring greenup was rated visually based on the standard 1-9 rating scale with 1 being straw brown and 9 being completely green. Greenup was assessed once every two weeks from the first week of March through complete greenup of each cultivar in 2013. In total, there are six sampling dates for spring greenup in 2013.

Leaf Texture

Turfgrass leaf texture is a measure or estimate of leaf width. Leaf texture was evaluated twice every season based on the standard NTEP 1-9 visual rating scale with 1 being very coarse and 9 equaling very fine. Visual ratings of leaf texture were used instead of physical measurement on leaves of similar age and development, because as an early-stage screening project for potential marketing value amongst varieties, visual rating is considered sufficient to separate cultivars within species. Also care was taken while rating such that all assessments were made during a period when grasses were actively growing without being faced with any major biotic or abiotic stress. There were four leaf texture sampling dates for each year.

Shoot Density

Shoot density was determined quantitatively in the early winter of 2012 by counting shoots in a specified sampling area. Shoot density ratings were assessed weekly because it requires much less time and labor input and the index is an overall indicator of grass performance. Biweekly evaluation was conducted based on the standard NTEP visual 1-9 rating scale where 9 = maximum density. Shoot density varies seasonally; data was collected in summer and fall as a response to seasonal variation. There were ten sampling dates in 2012 and 15 in 2013.

Scalping

The scalp damage (SCDM) rating, a measurement of degree of visual disruption and damage to the turf resulting from an aggressive mowing event, was rated on a 1 to 9 scale where 9 indicated that no scalp damage was present and 1 indicated severe scalping damage. All incidents of scalping occurred in August of 2013 due to intended drop of mowing heights. The SCDM was then evaluated based on degrees of recovery on five sampling dates which were 11 Aug, 18 Aug, 25 Aug, 2 Sep and 21 Sep of 2013.

Nematode Monitoring

Both common and hybrid bermudagrasses are susceptible to plant parasitic nematodes (Riffle, 1964). Scouting for visible nematode damage was held three times per year. Samples from the worst performing entries were sampled and pooled before they were submitted to the OSU Plant Disease and Insect Diagnostic Laboratory (PDIDL) in October, 2013 for a nematode assay. In 2013, it was observed that nematode damage might be present on some varieties thus two tests for nematode presence were conducted, one in October and one in November of 2013.

Analysis of Data

The experimental planting design was a randomized complete block design including 15 treatments with three replications in the MP trial (cover trial) and five replications in the WT trial (non-covered trial). For parameters having more than one data collection date in 2012, the analytical design was a split plot in time. In 2012 cultivars were main plots, rating dates were subplots and cultivar by rating dates were sub-subplots. In 2013, due to the addition of a PGR vs no-PGR main treatment, the experimental design was changed to a split-block, split in time with PGR treatment as the main plot, cultivars as subplots and rating dates within PGR x entries as sub-subplots. An analysis of variance (ANOVA) was conducted using the Proc GLM (General Linear Models Procedure) in Statistical Analysis Systems (SAS) software (SAS Institute Inc., SAS 9.1.3, Cary, NC) [SAS, 2004]. An F-test was used to test the main and interactive effects. When main or interactive effects were significant at the $P \leq 0.05$ level, Fisher's protected Least Significant Difference Test was used at the $P = 0.05$ level to separate treatment means (Weber and Skillings, 2000).

RESULTS AND DISCUSSION

Multi-Parameter (MP) Trial

Establishment Rate as Determined by Percentage Living Ground Cover (PLC) Assessed by Digital Image Analysis.

Although DIA was conducted throughout this two-year study, only images from the first two months prior to all varieties reaching 100% coverage (by 03-Aug, 2012) were included in the establishment rate data set. For the establishment rate, Fisher’s LSD test was conducted to separate cultivar means within each sampling date due to existence of a significant cultivar by rating date interaction (Table 4a). As seen in Table 5, percent establishment ratings were significantly different amongst 15 varieties on five of eight rating dates except for July 26 and August 3 in 2012. In addition, all entries reached full cover on 17 Jul, 2012. The first topdressing procedure caused the PLC data collected on 10 Jul to have a drop from both previous and subsequent ratings. MSB-281 appeared in the top LSD groups on five sampling dates while Sunday, Champion Dwarf, TifEagle and Mini Verde were never ranked in the statistically highest group on any of these five sampling dates. Commercial standards Champion Dwarf and Mini Verde ranked in the lowest statistical group on all five rating dates on which significant differences were present. However establishment from 13 Jun and 19 Jun was at or less than 1%. That data is not as important as data collected on 5 Jul, which was prior to the sand topdressing or after 17 Jul, which showed recovery from topdressing, or 26 Jul when essentially all entries had equal coverage.

Percentage Living Ground Cover (PLC) Assessed by Digital Image Analysis

The PLC of a cultivar is the morphological manifestation of the cultivar's inherent genetic characteristics, which can be affected by the prevailing environment. Parameters such as PLC fluctuate in response to changes in management routines such as fertility, irrigation schedule, mowing height and frequency, topdressing, aerification as well as pesticide applications.

2012 Percent Living Ground Cover

In 2012, 15 sets of photos were taken on the MP trial and then evaluated by Sigma Scan Version 5.0 as shown in Table 6. MSB-281, MSB-285 and MSB-264 were in the highest ranking group amongst all entries on 11 of 15 rating dates where significant differences occurred. All MSB types maintained a high PLC in the MP trial throughout the winter with an overall average PLC ranging from 32 percent for MSB-281 to 53 percent for MSB-285 (data not shown). Essentially, these MSB types didn't enter full dormancy and stayed photosynthetically active during that time. No significant difference was observed on any sampling dates amongst the three commercial standards Champion Dwarf, Tifgreen, TifEagle, and Sunday with the occasional exception of Mini Verde (91 percent on 11-Aug, 80 percent on 21-Oct, 49 percent on 07-Nov). Champion Dwarf and TifEagle both ranked in the top group on nine sampling dates, Tifgreen and Mini Verde appeared in the top group for eight and six times respectively. This also matches the findings shown in the 1997-2001 NTEP Bermudagrass Trial collected on non-putting green vegetatively propagated trials across 12 locations within the United States. In that report, Mini Verde ranked amongst the lowest for PLC of all varieties. More often than not, Tifgreen had intermediate live coverage ratings in that trial (Morris, 2002). Within the Oklahoma State University experimental lines, OKC 1-75-2 and OKC 13-78-5 ranked in the top PLC group amongst all entries on eight rating dates. OKC 18-4-Powell had the lowest PLC on ten sampling dates. OKC 18-4-Powell was the first and also the fastest variety to discolor as the growing season progressed into late summer and fall as measured by PLC.

2013 Percent Living Ground Cover

All data collected before and after July were sorted into two categories: pre-PGR and post-PGR for those sampled before and after July, 2013 respectively. Regarding the post-PGR PLC data set after July 2013, no cultivar by date by PGR effect was found (Table 4a) but significant cultivar, cultivar by PGR, date, date by PGR and cultivar by date interactions were present. Thus, PLC data collected on treated and non-treated plots were pooled and analyzed within each sampling date using Fisher's Protected LSD Test. PLC collected before introducing PGR treatment is also shown in Table 7.

Overall, MSB-285 and MSB-264 ranked in the top statistical group for PLC the most times amongst all varieties tested in 2013, which was 20 out of 23 rating dates. MSB-281 appeared in the top statistical group 18 times. Also, Sunday ranked in the top statistical group on 17 sampling dates while OKC 7-20-22 ranked in the lowest group on 12 of 23 rating dates.

Quality

Numerous factors affect turfgrass quality, and many parameters comprise individual components of quality (Turgeon, 1991).Some of these parameters have been separately assessed in this study such as color, texture, density, as well as parameters representing the characteristic features of certain genotypes such as uniformity, growth habit and smoothness. Visual turf quality [TQ] were evaluated on 11 dates in 2012, as well as five dates before and 15 dates after starting of PGR treatment in July 2013 for a total of 31 rating dates.

The ANOVAs conducted on 2012 and 2013 pre-PGR application TQ data revealed significant cultivar, date and date by cultivar interactions (Table 4a, Table 4c and Table 4e). ANOVAs for post-PGR TQ data in 2013 showed significant cultivar, date, and cultivar by date by PGR interaction.

2012 Quality

As plots matured in 2012, TQ increased to reach its highest average (6.8) on 29 September across the 15 varieties (Table 8). During 11 sampling dates in that year, MSB-285 had the highest TQ rating on nine sampling dates and OKC 18-4-Powell ranked the lowest for TQ on eight rating dates. Sunday ranked in the statistically highest group on seven sampling dates.

Within the OSU experimental types, OKC 1-75-2 was rated highest for TQ on seven sampling dates, and OKC 13-78-5 ranked in the top statistical group on six sampling dates. OKC 16-13-8 had unacceptable TQ on 10 of 11 sampling dates, while OKC 7-20-22 and OKC 18-4-Powell had unacceptable TQ on eight sampling dates.

2013 Quality

Before introduction of the PGR treatment in July 2013, Sunday, TifEagle, MSB-281 were in the highest performance group for TQ on all five sampling dates, Champion Dwarf and Mini Verde appeared in the top group on four sampling dates while OKC 13-78-5, OKC 16-13-8 and MSB-264 ranked in the top group twice. MSB-285 and Tifgreen both appeared as the top quality lines on one sampling date. OKC 7-20-22, OKC 8-16-10, OKC 70-18 never appeared in the top group and OKC18-4-Powell ranked in the lowest group on four sampling dates (Table 9).

For TQ data collected after initiation of the PGR treatment as shown in Table 10, TifEagle was in the top statistical LSD group on all 15 sampling dates and 13 of 15 sampling dates for non-PGR treated and PGR treated turf, respectively. TQ of non-PGR treated Mini Verde was in the top statistical group on all 15 sampling dates and on 11 sampling dates when PGR treated turf was considered. The TQ of Champion Dwarf was in the top performing group on 13 sampling dates from both treated and non-treated regimes. Without PGR treatment, the TQ of Sunday was in the highest ranking group on 12 sampling dates while PGR treatment resulting in its appearance in the top ranking group on 13 sampling dates. The TQ of OKC 18-4-Powell was in the bottom group on 13 sampling dates within the PGR-treated regime and 11 sampling dates within the non-PGR control regime. When considering only experimental cultivars, MSB-281 ranked in the highest quality group on five sampling dates when considering both treated and non-treated regimes respectively. All commercial standards had an acceptable TQ value of 6 across all sampling dates, while the worst performing line amongst all entries as defined by having the most mean ratings below the acceptable quality level was OKC 18-4-

Powell. MSB-281 appeared five times in the top group within both treatments. MSB-264 appeared twice in the top group within PGR-treated regime while MSB-285 appeared three times in the top group within PGR-treated regime and twice within the non-PGR control regime. Amongst OKC varieties, OKC 1-75-2 and OKC 13-78-5 have appeared in the group and this all happened in July, 2013. OKC 70-18 appeared twice in the top group within both PGR treatments.

Visual Density Rating

Visual density was evaluated 10 times in 2012 and two times before and 13 times after initiation of the PGR treatment in July, 2013 for a total of 25 rating dates. Significant differences in density existed amongst the 15 genotypes on all rating dates except for 07 Aug 2012.

Density 2012

In 2012, MSB-285 and MSB-264 ranked in the highest group on nine of 10 total sampling dates (Table 11). The entries with the second most frequent appearance in the top statistical group for density was Sunday and Champion Dwarf, appearing on five out of 10 sampling dates. With respect to density, OKC 18-4-Powell and OKC 7-20-22 appeared in the lowest ranking group on five sampling dates in 2012. MSB264, MSB 285 and Champion Dwarf were the first entries to reach a mean turf density value of 9 which occurred on 04 Sep 2012. In addition, MSB-264 and MSB-285 were the only two grasses that maintained acceptable mean density ratings across all sampling dates.

Amongst the OSU experimental types, OKC 1-75-2 had numerically the highest mean density over all ten sampling dates in 2012 but it only was present in the top statistical group on two sampling dates when all trial entries were considered.

Density 2013

In 2012, two density ratings were taken before introducing PGR treatment as a factor. MSB-281, Sunday, Champion, TifEagle and Mini Verde were ranked in the top LSD group on both dates (Table 12).

As for the post-PGR application shoot density data in 2013, the entry by sampling dates by PGR effect was significant at the p=0.001 level, thus cultivar means were separated by PGR treatment within dates as shown in Table 13. The 2013 analysis of data with two PGR treatments again revealed that Champion Dwarf had an extremely dense canopy as it ranked in the highest density group on all 13 sampling dates within both the non-PGR and the PGR treated trials. Sunday, TifEagle and Mini Verde both appeared in the top statistical group 13 times under non-PGR regime and 12 times under the PGR treatment regime. Amongst OSU selections, OKC 13-78-5 ranked in the top group on two and zero sampling dates under the PGR and non-PGR regimes, respectively. OKC 18-4-Powell ranked in the bottom statistical group 11 times within the non-PGR regime and 13 times within the PGR-treated regime (Table 13).

Overall all commercial standards showed superior performance in regard to canopy density. The experimental genotypes from Mississippi State University showed high visual density at the Oklahoma Turfgrass Research Center in Stillwater, OK. The best performer amongst OSU experimental selections was OKC 13-78-5.

Shoot Count Density

Counting the number of shoots per unit area is a relatively time consuming but objective way to measure turf density. Samples for shoot numbers were taken one time in each year. Based on the findings presented in Table 14, mean shoot counts of MSB-285 and OKC 16-13-8 were in the top LSD group on both sampling dates while OKC 70-18 and OKC 18-4-Powell had mean counts in the lowest ranking groups on both dates. On the first sampling date, all commercial standards and Sunday were ranked in the bottom group while three commercial standards, Champion Dwarf, Tifgreen and TifEagle, appeared in the top statistical group on the second sampling date.

Visual Color Ratings

Color is one of the most important factors that determine the aesthetic appearance of turfgrasses. Providing a number of varieties performed satisfactorily in the entire cadre of performance parameters, only the entries with mean color ratings above 6 would likely be considered for use as a putting green surface. Visual color ratings were evaluated on seven sampling dates in 2012, five and 12 dates in 2013 before and after PGR treatment were applied, respectively.

Color 2012

In 2012, TifEagle and Champion appeared in the top statistical group on six of seven sampling dates (Table 15). No significant differences were present amongst the three Mississippi State experimental cultivars on any sampling dates in 2012. The best line amongst ten experimental varieties was MSB-285. It appeared three times in the top group. All commercial standards except for Mini Verde maintained acceptable mean visual color ratings across all sampling dates in 2012. OKC 1-75-2, OKC 13-78-5 and OKC 8-16-10 all appeared in the top group on one sampling date while OKC 7-20-22 and OKC 18-4-Powell appeared twice in the top group. OKC 18-4-Powell also ranked in the bottom group on five sampling dates. This was mainly due to its purplish colored stolons and leaves which obviously rendered it inappropriate for use on sites requiring turfgrass with high aesthetic value.

Color 2013

Amongst the five sampling dates in 2013 before PGR treatment, TifEagle appeared in the top LSD group on all dates while OKC 7-20-22 and OKC 18-4-Powell appeared in the bottom group on all five sampling dates. Mean color ratings from Sunday appeared twice in the top LSD group and zero times in the bottom group respectively. Significant differences existed amongst 15 varieties throughout all sampling dates with respect to visual color (Table 16).

After initiation of PGR treatment, Champion Dwarf and Mini Verde ranked in the top statistical group on all 12 sampling dates within both the non-PGR control group and PGR-treated group (Table 17). Sunday ranked in the top statistical group for mean turfgrass color on seven and 10 times under non-PGR and PGR treated regimes, respectively. On the other hand, OKC 18-4-Powell was again the poorest performing line from the perspective of color, appearing 21 times in the bottom ranking group in both PGR treatment regimes. When comparisons were made solely amongst experimental varieties, MSB-281 ranked in the top statistical group of experimental lines on eight sampling dates under the non-PGR regime and on seven dates under the PGR treatment regime. The higher rated performance of Mini Verde relative to Tifgreen in regard to genetic color in this study was consistent with findings from eight locations of the 1997-2001 NTEP vegetatively propagated bermudagrass trial (Morris, 2002).

Generally speaking, OKC 7-20-22 and OKC 18-4-Powell tended to present a purplish appearance in early spring and late fall while consistently having a lower shoot density compared to other varieties. MSB 281, MSB-264 and MSB-285 were similar in their overall peak green hue throughout the two year period of this trial.

Color Retention

Color retention is a parameter used to assess the ability of a turfgrass to hold color prior to and just after the first frosts in the autumn. Color ratings collected in late fall and early winter before full canopy frost damage and dormancy can be used to quantify the response of warm-season grasses to temperature changes or frost occurring in fall.

In total, four color retention ratings were taken during October to December in 2012. The ANOVAs performed on this data showed significant entry, date and date by entry effects at p=0.001 level (Table 4b). On all four sampling dates in 2012, significant differences existed amongst the 15 cultivars (Table 18). MSB 285 and MSB-264 ranked in the top statistical group on all four sampling dates while OKC 7-20-22 ranked in the bottom group on all four sampling dates. Amongst the OSU varieties, OKC 1-75-2 appeared in the top statistical group for one time on 30- Oct and never in the bottom group.

Spring Green Up

Spring green up is a measure of when turfgrass begins to regenerate new green tissue. This is considered to be of high importance for bermudagrass putting greens located in temperate and sub-tropical regions. Six green-up ratings were conducted in 2013 beginning on 4 February and extending through 15 April as shown in Table 19.

MSB-285 and OKC 70-18 ranked in the top statistical group on all six sampling dates and the mean greenup rating of MSB-264 appeared four times in the top statistical group. Sunday appeared in the top group three times and the bottom group, one time, respectively, while OKC 18-4-Powell appeared in the bottom group for greenup on all six sampling dates.

Leaf Texture

Texture was evaluated four times in each year. Overall OKC 1-75-2, MSB-285 and MSB-264 ranked in the top statistical group for texture on seven sampling dates while OKC 7-20-22 and OKC 18-4-Powell ranked in the bottom group on seven sampling dates (Table 20). OKC 7-20-22 and OKC 18-4-Powell had an overall mean texture below 6, the satisfactory level, on four and three dates, respectively. Thus, these lines were deemed to be not commercially acceptable for putting green use unless they exhibited other meritorious performance traits to overcome this deficiency.

Seed Head Production

Seed head production 2012

Seed head ratings were evaluated on four dates in 2012. The commercialized varieties Sunday, Tifgreen, TifEagle and Mini Verde generally had very little seed head production in both years and within both PGR-treatment groups (Table 21). All commercial standards maintained an overall mean seed head rating of 9 on all four sampling dates in 2012 with the exception of Tifgreen. Tifgreen only appeared once in the top LSD group, that being on 30-Sep, 2012.

Amongst all of the experimental cultivars, MSB-264 and MSB-281 were found to be in the lowest ranking group as they had the highest seed head production on a total of three of four sampling dates in 2012. OKC 1-75-2 ranked in the top statistical group on all four sets of data collected, exhibiting a low frequency of seed head expression.

Seed head production 2013

Seed heads were evaluated on two and seven dates, respectively, in 2013. These evaluations were before and after introducing PGR treatments. During the two sampling dates in 2013 before PGR treatment, Champion Dwarf, TifEagle and Mini Verde were in the top LSD group while MSB-264 was ranked in the bottom group on both dates (Table 21).

After initiation of PGR treatment as shown in Table 22, MSB-285 and OKC 8-16-10 appeared in the group with the greatest expression of seed heads on three out of seven sampling dates within both the non-PGR control plots and PGR treated plots. OKC 1-75-

2 ranked in the top group three times within both the non-PGR treated regime and PGR-treated regime. OKC 13-78-5 appeared in the top group twice within non-PGR treated regime and four times within PGR-treated regime. OKC 16-13-8 ranked in the top group three times within the non-PGR control regime and twice within the PGR-treated regime. OKC 7-20-22 appeared twice in the top group in the non-PGR control regime and four times within the treated regime. OKC 8-16-10 appeared twice in the top group within both regimes and OKC 70-18 appeared one time in the top group within both regimes. OKC 18-4-P ranked in the top group two times under the non-PGR control regime and three times under the PGR treated regime. Champion, TifEagle and Mini Verde were ranked in the top LSD group on six sampling dates under both PGR treatments. Sunday appeared in the top statistical group five times under the non-PGR regime and six times under the PGR treatment regime

Green Speed

Green Speed 2012

In 2012, green speed was assessed on five dates. Significant entry, date and date by entry effects were present in 2012 (Table 4a). OKC 18-4-Powell and Mini Verde appeared in the top LSD group on four of six sampling dates while OKC 18-4-Powell also appeared one time in the bottom group (Table 23). Ball roll distances were not significantly different amongst the 15 varieties on 23 Sep 2012. MSB-264 and MSB-285 were rated in the bottom group on five sampling dates. It is noteworthy that OKC 18-4-Powell ranked as the fastest cultivar only in November and December 2012 after it entered dormancy, which was most likely due to an extreme lack of live tissue above ground.

Amongst OKC experimental types other than OKC 18-4-Powell, OKC 7-20-22 appeared three times in the top statistical group and one time in the bottom group. OKC 13-78-5 and OKC 16-13-8 both appeared one time in the top statistical group. OKC experimental varieties with the slowest green speed ratings were found to be OKC 1-75-2 and OKC 70-18 since both of these two grasses were ranked in the bottom group on four sampling dates.

When comparisons were solely made within commercialized varieties except for Mini Verde, Champion Dwarf appeared four times in the top groups. Both Sunday and Tifgreen appeared three times in the top group and one time in the bottom group. TifEagle appeared two and one times in top and bottom groups respectively.

Green Speed 2013

Based on ANOVAs results, significant entry, date and date by entry effects were present amongst ball roll (green speed) measured in 2013 before implementation of PGR treatments and entry, date and date x PGR effects were present in data collected after PGR treatment (Table 4c and Table 4e). Although two ANOVAs were developed (pre and post PGR regime), it is important to note that neither PGR nor PGR x entry or PGR x entry x date effects were found significant. Because of this finding, mean green speed from each variety were pooled over PGR regimes and analyzed within sampling dates using Fisher's Protected LSD test in 2013. Results for cultivar green speed are collectively discussed across rating dates.

Nine measurements were made in total during 2013, six measures prior to implementation of PGR treatment and three after initiation of PGR treatment. Green speeds were not significantly different among 15 varieties on 16 May, 28 Jul and 29 Sep, 2013. Amongst the six rating dates before initiation of PGR treatment, OKC 7-20-22 ranked as in the fastest group on five sampling dates. OKC 16-13-8 and OKC 18-4-P both appeared three times in the top statistical group. MSB-281 appeared five times in the bottom group for green speed while MSB-264 and MSB-285 both were ranked in the bottom group four times. In regard to the commercialized varieties, Sunday was ranked in the top and bottom groups for one and four times, respectively, for green speed. Champion Dwarf appeared three times in the top group and one time in the bottom group while TifEagle appeared three and two times in the top and bottom group, respectively, for greens speed. After initiation of the PGR treatment, all experimental varieties except for OKC 1-75-2 and OKC 18-4-P appeared in the bottom group for greens speed on both sampling dates on which significant differences were present among 15 varieties. Champion Dwarf appeared in the top statistical group for greens speed on both sampling dates while other commercialized varieties except for Tifgreen appeared on one date.

Scalping Damage

Scalping damage was evaluated with respect to degrees of recovery from scalping damage that happened in 11 Aug, 2013, five sets of scalping ratings were collected in 2013 as shown in Table 25. When no PGR was used, OKC 7-20-22 and all commercial standards were ranked in the highest statistical group by having the least amount of scalping damage on all five sampling dates. MSB-285 was ranked as having the most scalping damage on all five sampling dates. Under the PGR treated regime OKC 7-20-22 and all commercial standards except for Champion Dwarf most often appeared in the top statistical group. They appearing in that group on three out of six sampling dates. MSB-

264 and MSB-285 were ranked in the group having the most scalping injury on two sampling dates. No significant differences existed amongst the 15 varieties on 11 Aug and 25 Aug under the PGR-treatment regime. There was a visible drop in overall mean scalping damage of each cultivar from non-PGR to PGR treated entries, suggesting PGR applications took effect and changed the growth habit of cultivars. This was due to inhibition of gibberellic acid (GA) that promotes vertical shoot growth (Adams et al., 1992). Thusly, lateral growth became dominant. Many previous studies on Trinexapac-ethyl (TE) effects have showed that it can increase canopy density in prostrate turfgrasses and leaf chlorophyll density in Kentucky bluegrass (Ervin and Koski, 2001; Fagerness et al., 2001). The overall mean scalping damage ratings when pooled over cultivars, treatments and dates was an 8.0 for PGR treated turf and a 7.5 for the non-PGR treated control group.

Observations of Nematode Populations:

The first assessment was conducted on samples pooled over two of the worst performing varieties, OKC 7-20-22 and OKC 18-4-Powell. Results from the first analysis showed that there were spiral nematode (*Helicotylenchus pseudorobustus* Steiner), root-knot nematode (*Meloidogyne incognita* Goeldi) and ring nematodes (*Criconemella xenoplax* De Grisse and Loof) at levels of 112, 312, and 4 per 100 cm^3, respectively. For the second nematode test, we sent in two samples from one of the worst performing entries (OKC 7-20-22) and one of the best performing entries (Champion Dwarf). A Root knot nematode population of at least 80 per 100 cm^3 were found in both samples (100 /100 cm^3 for OKC 7-20-22, 80/100 cm^3 for Champion Dwarf) while ring (140 /100 cm^3 for OKC 7-20-22, 40/100 cm^3 for Champion Dwarf) and spiral (40 /100 cm^3 for OKC 7-20-

22, 80/100 cm^3 for Champion Dwarf) nematodes were also present in samples collected in November. Additionally, *Tylenchus* nematodes were found in Champion Dwarf at a population of 160/100 cm^3 in November 2013. Also the drop in nematode populations from first test to the second could be due to less favorable root zone environmental conditions for nematode survival and reproduction due to cold weather.

Since multiple species of nematodes were present in all samples tested, a compounding effect may have occurred as a result of pressure from several species. Turf parasitic nematodes are a common problem on sandy putting green sites in the southern US (Crow, 2005). To be successfully used on a wide geographic basis, any commercialized cultivars should ideally have acceptable tolerance to multiple species that will likely be present in putting green rootzones throughout the southern US.

Winter Kill Trial

Percentage Winterkill

Percentage winterkill, also termed as turf loss from winter damage, was evaluated on the non-covered Winter Tolerance (WT) assessment trial located on the middle of block 8, just east of the Multi-Parameter trial at the OSU TRC. Winter kill was rated on 15 Apr 2013. As shown in Table 26, OKC 7-20-22 and OKC 18-4-Powell ranked in the top statistical group, the group having the greatest amount of grass tissue lost to winter injury while OKC 1-75-2, OKC 13-78-5, OKC 16-13-8, OKC 8-16-10, OKC 70-18, MSB-264 and all five commercial standards were ranked in the group with the least tissue loss attributable to winterkill. The differences between these findings and our earlier hypothesis based on the chamber study results of Anderson et al. (2002) may be attributed to stress from the low mowing height and differences between field and lab conditions. OSU experimental entries, OKC 1-75-2, OKC 13-78-5, OKC 16-13-8, OKC 8-16-10, OKC 70-18 were selected from a nearly decade long putting green trial that was mowed regularly at 0.64 cm whereas the trials discussed in this thesis were mowed to as low as 0.32 cm. Additionally, no episode of severe winter kill occurred during this study as even the most severely injured entries were able to recover to a mean PLC higher than 90% by May of 2013except for OKC 7-20-22.

SUMMARY

This study evaluated 10 experimental bermudagrass lines against five commercialized cultivars of bermudagrass under simulated golf course putting green conditions at Stillwater, OK, USA. Entries were planted in late spring of 2012 and evaluated for multiple performance parameters over the 2012 and 2013 growing seasons. Table 27 shows the number of times each grass appeared in the top statistical group (p=0.05 level) for six major parameters over sampling dates and years. TifEagle appeared in the top statistical group 159 times in total suggesting it was the best performing line. As individuals have different expectations and standards for a golf green and some value a certain parameter over another, individual comparisons across entries for a given performance parameter can now be made. In regard to turfgrass quality, TifEagle had the highest number of appearances in the top statistical group, appearing in the top statistical group on 42 out of 46 rating dates.

Results of this research suggest that some experimental cultivars such as OKC 7-20-22 and OKC 18-4-Powell are not suitable for use on putting greens at a 3.2 mm mowing height due to their propensity to winter-kill and their overall poor performance in our trials. The MSB series of entries from Mississippi State University were found to have outstanding color retention, density and turfgrass quality but had excessive seed head expression. However, the seed expression may be able to be suppressed in some instances by use of certain plant growth regulators. Use of the three MSB series of putting green type bermudagrasses in subtropical climate zones similar to that of Stillwater, OK would be limited due to their susceptibility to winter-kill. Use of geotextile covers can help reduce the risk of winter-kill. However, under conditions similar to those at Stillwater the

MSB series bermudagrasses do not appear to offer enough merit to justify their use in replacement of the commercially available ultradwarf types such as TifEagle, Champion Dwarf, Mini Verde and Sunday which were less susceptible to winter-kill. Again this conclusion on cold hardy commercial standards may not be completely accurate since only one year's winterkill data has been collected from this two-year study. In 2013 MSB-264 received its patent as a bermudagrass named 'MSB-4-264' which is suitable for use on putting greens use or sites alike (Philly et al., 2013).

Based on suitable turfgrass quality results found in 2012 in this work, the three OSU experimental lines OKC 1-75-2, OKC 13-78-5, and OKC 16-13-8 were selected for inclusion in the 2013 – 2018 National Turfgrass Evaluation Program putting green trial. These three OSU types had a faster establishment rate than all commercial standards and had a relatively low percentage of winterkill although not significantly different from the five commercialized entries Tifgreen, TifEagle, Sunday, Champion Dwarf and Mini Verde. At maturity in 2013, most OSU experimental types had lower quality than the commercialized standards and MSB types. OSU experimental lines were selected for winter tolerance over 10 years in a sand-based putting green nursery managed at a 6.4 mm (0.25 in) mowing height. Results from these two-year duration trials suggest that the 3.2 mm (0.125 in) mowing height appeared to be too low for the OSU bermudagrass selections which are not ultradwarf types. Also, documentation of an infestation of turfgrass parasitic nematodes in the second year of this research could have been a factor contributing to the poor performance of the OSU experimental lines.

Champion Dwarf and TifEagle were the best performers with respect to most parameters monitored in this work. Sunday, a newly commercialized putting green-type bermudagrass, had similar overall performance as Mini Verde in regard to density and quality but on one of six rating dates had significantly more seed heads than Champion Dwarf, TifEagle, and Mini Verde. Also, in regard to genetic color, Tifgreen and Sunday had a yellowish green hue compared to the dark green hue of the other three commercial standards. Among all five commercialized cultivars, Sunday had the finest texture while TifEagle and Tifgreen were the coarsest in texture.

Although the three most promising OSU experimental lines advanced to NTEP testing, they offered somewhat lower quality than the five commercial cultivars tested at the 3.2 mm (0.125 inch) mowing height. Consequently, targeting the OSU releases for the extreme low-mowed putting green market is not justified. Future work with the most promising OSU types may be justified in testing regimes where mowing heights above 3.2 mm are utilized such as low maintenance putting greens and on sites where higher clay or silt content prevails and where high levels of turfgrass pathogenic nematodes are not expected to be a problem.

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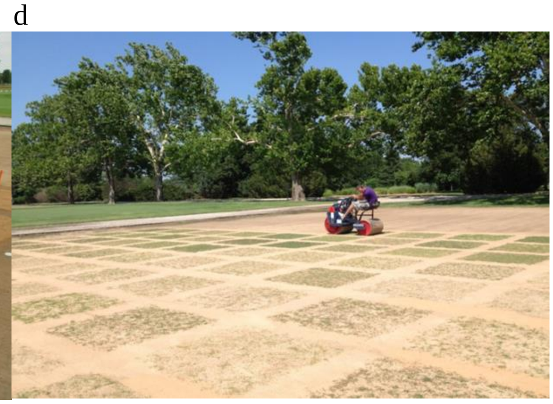
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Figure 1. a) Plant materials were propagated and maintained in the green house on a mist bench. b) All plots were raked in two directions before being sprigged. c) & d) Plant material was hand washed clean of soil and then spread evenly into a box composed of plywood which was designed to prevent the material from being blown by wind and causing contamination of adjacent plots. e) A soil tamp was used to firm up the newly applied sand layer and then water was applied. f) Topdressing and rolling was performed immediately after sprigging to further smooth out the surface for future mowing.

Table 2. Application dates and rates of annual total N fertilization in 2012 and 2013. Greens grade granular fertilizers were applied using a LESCO drop spreader with numbered settings. The potassium nitrate (13-0-44, $N-P_2O_5-K_2O$) solution was applied as liquid using a carrier rate of 416.72 L ha^{-1}.

2012				2013			
Application Date	Source ($N-P_2O_5-K_2O$)	N Rate (kg ha^{-1})		Application Date	Source	N Rate (kg ha^{-1})	
21 May	17-17-17	48.8	G††	6 Feb	7-14-14	24.4	G
25 June	19-0-15 & 4-6-4	48.8	G	13 March	19-0-15	24.4	G
2 July	21-0-0	24.4	S	29 March	19-0-15	24.4	G
9 July	19-0-15	24.4	G	13 May	19-0-15	24.4	G
16 July	21-0-0	48.8	S	3 June	19-0-15	24.4	G
23 July	18-9-18 & 0-0-25	61.0	G	15 June	19-0-15&0-0-25	24.4	G
5 Aug	21-0-0	24.4	S	23 June	19-0-15	24.4	G
20 Aug	19-0-15	24.4	G	14 July	19-0-15& 0-0-25	24.4	G
27 Aug	19-0-15	24.4	G	20 July	12-3-12	24.4	G
2 Sep	19-0-15	24.4	G	27 July	12-3-12	24.4	G
9 Sep	Mor-Green	5.9	S	15 Aug	Mor-Green	1.5	S
16 Sep	19-0-15	24.4	G	19 Aug	19-0-15	24.4	G
23 Sep	13-0-44 Pro Sol	4.9	S	29 Aug	12%N Mor-Green	1.5	S
12 Oct	12%N 13-0-44 & 0-0-25	12.2	S	10 Sep	19-0-15	24.4	G
6 Nov	12%N 13-0-44 & 0-0-25	12.2	S	17 Sep	12%N Mor-Green	1.5	S
20 Nov	12%N 13-0-44	12.2	S	22 Sep	19-0-15	24.4	G
29 Nov	18-9-18 & 0-0-25	12.2	G	1 Oct	19-0-15 &0-0-25	24.4	G

† All 0-0-25 fertilizer was applied at a rate of 24.4 kg ha^{-1}.

†† G= Granular fertilizer, S= Soluble fertilizer.

Table 3. Detailed mowing schedule showing dates and mower bench settings used in management of the Winter Tolerance and Multi-Parameter putting green trials.

2012		2013†	
Date	Mowing height	Date	Mowing Height
25 June	12.065 mm (0.475 in)	12 March	3.937 mm (0.155 in)
28 June	9.525 mm (0.375 in)	13 March	3.556 mm (0.140 in)
6 July	6.35 mm (0.25 in)	15 March	3.302 mm (0.130 in)
9 July	4.7498 mm (0.187 in)	20 March	3.937 mm (0.155 in)
19 July	3.937 mm (0.155 in)	25 June	3.81 mm (0.150 in)
9 Aug	3.429 mm (0.135 in)	28 June	3.683 mm (0.145 in)
17 Aug	3.302 mm (0.130 in)	1 July	3.556 mm (0.140 in)
24 Aug	3.175 mm (0.125 in)	2 July	3.429 mm (0.135 in)
17 Sep	3.937 mm (0.155 in)	8 July	3.302 mm (0.130 in)
		9 July	3.175 mm (0.125 in)
		29 July	3.429 mm (0.135 in)
		30 July	3.175 mm (0.125 in)
		8 Aug	3.429 mm (0.135 in)
		17 Aug	3.81 mm (0.150 in)
		26 Aug	3.937 mm (0.155 in)

† Mowing height was only kept at 3.175mm (0.125 in) for 20 days in 2013 due to the occurrence of serious scalping damage on certain varieties (damage was visually rated and logged).

Table 4a. Analysis of variance results on quality, density, percentage living ground cover (PLC), color and ball roll speed (BR) from the multiple parameter bermudagrass trial in 2012.

	Quality		ER		PLC		Color		BR	
Source	df	sign	df	sign	df	sign	df	sign	df	sign
Entry	14	***	14	***	14	***	14	***	14	**
Rep	2	NS	2	NS	2	NS	2	**	2	NS
Rep * Entry [error a]	28		28		28		28		28	
Date	10	***	7	***	14	***	6	NS	5	***
Date * Entry	140	***	98	***	196	***	84	***	70	**
Rep*Date (Entry) [error b]	300		210		420		180		150	

***, **, *** significant at p=0.05, 0.01, and 0.001 respectively.**
†NS, not significant at the p=0.05 level.

Table 4b. Analysis of variance results on shoot density identified as shoot counts (SC), late season color retention (CR), seedheads (SH), texture and establishment rate (ER) from the multiple parameter trial in 2012.

	SC		CR		SH		Texture		Density	
Source	df	sign	df	sign	df	sign	df	sign	df	sign
Entry	14	**	14	***	14	***	14	***	14	***
Rep	2	*	2	NS	2	NS	2	NS	2	NS
Rep * Entry [error a]	28		28		28		28		28	
Date	N/A		3	***	3	*	3	***	9	***
Date * Entry	N/A		42	***	42	***	42	**	126	***
Rep * Date (Entry) [error b]	N/A		90		90		90		270	

***, **, *** significant at p=0.05, 0.01, and 0.001 respectively.**
†NS, not significant at the p=0.05 level.

Table 4c. Analysis of variance on quality, density, percentage living ground cover (PLC), color, and ball roll speed (BR) from the multi-parameter trial in 2013 before plant growth regulator treatments.

	Quality		Density		PLC		Color		BR	
Source	df	sign	df	sign	df	sign	df	sign	df	sign
Entry	14	***	14	***	14	***	14	***	14	**
Rep	2	*	2	NS	2	NS	2	NS	2	NS
Rep * Entry [error a]	28		28		28		28		28	
Date	4	***	1	***	11	***	4	***	5	***
Date * Entry	56	***	14	***	154	***	56	***	70	**
Rep*Date (Entry) [error b]	120		30		330		120		150	

***, **, *** significant at p=0.05, 0.01, and 0.001 respectively.**

†NS, not significant at the p=0.05 level.

Table 4d. Analysis of variance on spring green up (SGU), shoot density identified as shoot counts (SC), seed heads (SH) and texture from the multi-parameter trial in 2013 before plant growth regulator treatments.

	SGU		SC		SH		Texture	
Source	df	sign	df	sign	df	sign	df	sign
Entry	14	***	14	**	14	***	14	***
Rep	2	NS	2	NS	2	*	2	**
Rep * Entry [error a]	28		28		28		28	
Date	5	***	N/A		1	NS	3	**
Date * Entry	70	***	N/A		14	**	42	**
Rep * Date (Entry) [error b]	150		N/A		30		90	

***, **, *** significant at p=0.05, 0.01, and 0.001 respectively.**

†NS, not significant at the p=0.05 level.

Table 4e. Analysis of variance on seedheads (SH), scalping, quality, color, density, ball roll speed (BR) and percent live coverage (PLC) from the multi-parameter trial in 2013 following inclusion of a plant growth regulator (PGR) treatment.

	SH		Scalping		Quality		Color		Density		BR		PLC	
Source	df	sign	df	sign	df	sign	df	sign	df	sign	df	sign	df	sign
Rep	2	NS†	2	NS	2	NS	2	*	2	NS	2	NS	2	NS
PGR ‡	1	**	1	*	1	*	1	**	1	*	1	NS	1	NS
Rep*PGR [error a]	2		2		2		2		2		2		2	
Entry	14	***	14	***	14	***	14	***	14	***	14	**	14	***
Rep*Entry [error b]	28		28		28		28		28		28		28	
Entry*PGR	14	NS	14	**	14	*	14	*	14	**	14	NS	14	***
Rep*Entry*PGR [error c]	84		64		196		154		168		28		140	
Date	6	***	4	***	14	***	11	***	12	***	2	***	10	***
Date * PGR	6	*	4	**	14	NS	11	***	12	**	2	*	10	***
Entry * Date	84	NS	56	NS	196	NS	154	NS	168	NS	28	NS	140	***
Entry * Date * PGR	84	***	56	***	196	***	154	***	168	***	28	NS	140	NS
Rep*Date (Entry*PGR) [error d]	360		240		840		660		719		120		600	

***, **, *** significant at p=0.05, 0.01, and 0.001 respectively.**

†NS, not significant at the p=0.05 level.

‡ PGR=Plant growth regulator treatment effect.

Table 5. Establishment rate of 15 bermudagrasses shown as mean percent live coverage during 2012 using digital image analysis†.

	Establishment Rate							
Entry	**13-Jun**	**19-Jun**	**26-Jun**	**05-Jul**	**10-Jul**	**17-Jul**	**26-Jul**	**03-Aug**
	%							
OKC 1-75-2	0.06bc	0.46	7.07c-f	86.48a	81.14a	98.65a	99.47	99.93
OKC 13-78-5	0.03c	0.20	4.27ef	83.41ab	37.89b-f	94.24ab	97.39	99.87
OKC 16-13-8	0.04bc	0.80	13.67abc	85.75a	45.80a-e	84.27ab	97.37	99.98
OKC 7-20-22	0.01c	0.76	13.94abc	83.61ab	69.45abc	92.37ab	98.83	99.76
OKC 8-16-10	0.01c	0.16	12.33a-d	81.45ab	46.66a-e	97.95a	98.30	99.99
OKC 70-18	0.21a	1.32	4.89d-f	59.57c	28.34d-f	69.15bc	98.49	99.99
OKC 18-4-P	0.02c	0.72	12.22bcd	87.25a	72.88ab	98.28a	98.95	99.57
MSB-281	0.16ab	0.52	13.86abc	85.36a	57.51a-d	98.72a	98.73	99.99
MSB-264	0.02c	0.52	9.66cde	85.92a	51.34a-d	99.19a	99.94	100.00
MSB-285	0.03c	0.87	17.98ab	94.38a	69.40abc	96.57a	99.96	99.96
Sunday	0.00c	0.11	3.42ef	59.46c	29.84c-f	51.32cd	97.20	100.00
Champion Dwarf	0.00c	0.00	0.27f	22.18d	4.18f	33.26de	89.48	99.98
Tifgreen	0.04bc	1.31	19.88a	86.24a	59.80a-d	98.60a	99.40	99.95
TifEagle	0.02c	0.13	3.50ef	62.49bc	8.69ef	70.34bc	99.02	100.00
Mini Verde	0.00c	0.01	0.49f	18.84d	4.14f	10.97e	84.26	99.60
LSD(0.05)†	0.12	NS	7.67	21.43	39.83	25.13	NS	NS

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 6. Mean percent live coverage of 15 bermudagrasses during 2012 using digital image analysis†.

	Percent Live Coverage									
Entry	**11-Aug**	**19-Aug**	**23-Aug**	**01-Sep**	**09-Sep**	**18-Sep**	**23-Sep**	**30-Sep**	**08-Oct**	**14-Oct**
						%				
OKC 1-75-2	99.96a	99.94	99.96	99.99	95.71	98.71a	92.5ab	100.00a	99.59a	98.06a
OKC 13-78-5	99.64a	100.00	99.89	100.00	98.05	99.98a	99.56a	100.00a	99.86a	97.19a
OKC 16-13-8	99.97a	99.95	97.78	100.00	99.92	98.96a	97.95a	99.99a	98.68a	90.56a
OKC 7-20-22	99.64a	99.66	98.39	97.13	99.69	81.75b	80.38bc	99.97a	93.92a	68.94b
OKC 8-16-10	99.33a	99.75	95.56	99.94	99.89	96.22a	87.35ab	100.00a	94.29a	52.19b
OKC 70-18	99.99a	99.99	99.85	100.00	99.96	100.00a	100.00a	100.00a	99.97a	99.99a
OKC 18-4-P	100.00a	99.98	99.89	99.90	99.79	82.06b	67.04c	96.24b	63.24b	30.44c
MSB-281	99.92a	99.88	95.31	100.00	99.71	100.00a	100.00a	100.00a	99.98a	99.96a
MSB-264	100.00a	100.00	100.00	100.00	100.00	100.00a	100.00a	100.00a	100.00a	100.00a
MSB-285	100.00a	99.99	100.00	100.00	100.00	99.99a	100.00a	100.00a	99.99a	100.00a
Sunday	99.94a	100.00	99.96	100.00	100.00	99.99a	100.00a	100.00a	100.00a	99.99a
Champion	99.94a	99.99	99.99	100.00	100.00	99.99a	100.00a	100.00a	99.97a	99.80a
Tifgreen	99.99a	99.99	99.20	99.99	99.96	99.99a	99.97a	100.00a	100.00a	99.94a
TifEagle	99.99a	100.00	99.99	100.00	96.81	99.98a	100.00a	100.00a	100.00a	99.99a
Mini Verde	91.76b	99.63	99.50	100.00	99.96	100.00a	99.92a	100.00a	99.99a	99.60a
LSD(0.05)†	3.02	NS	NS	NS	NS	5.41	15.32	1.90	11.83	19.40

† Means within columns followed by the same letters are not statistically different at P =0.05 level based on Fisher's LSD test.

Table 6. (Continued)†.

	Percent Live Coverage				
Entry	**21-Oct**	**28-Oct**	**07-Nov**	**18-Nov**	**03-Dec**
			%		
OKC 1-75-2	90.91ab	99.22a	28.98d	3.50c	0.02b
OKC 13-78-5	89.87ab	99.11a	2.24e	0.07c	0.05b
OKC 16-13-8	31.30c	70.96c	0.00e	0.01c	0.01b
OKC 7-20-22	6.64d	34.03d	0.02e	0.02c	0.01b
OKC 8-16-10	41.35c	87.39b	0.04e	1.75c	0.03b
OKC 70-18	99.77a	99.93a	96.91ab	22.87bc	0.09b
OKC 18-4-Powell	0.43d	0.78e	0.01e	0.02c	0.06b
MSB-281	99.93a	100.00a	99.68a	38.32ab	32.69a
MSB-264	100.00a	100.00a	99.96a	63.63a	53.85a
MSB-285	99.98a	100.00a	99.64a	60.44a	40.36a
Sunday	99.53a	100.00a	64.07c	9.86c	0.03b
Champion Dwarf	93.77a	99.98a	86.06ab	0.30c	0.04b
Tifgreen	95.33a	99.97a	82.94b	0.16c	0.02b
TifEagle	98.30a	100.00a	91.56ab	16.25bc	0.00b
Mini Verde	80.99b	99.63a	49.40c	0.92c	0.02b
LSD(0.05)†	11.87	6.65	16.46	28.28	28.87

† Means within columns followed by the same letters are not statistically different at P =0.05 level based on Fisher's LSD test.

Table 7. Mean percent live coverage of 15 bermudagrasses during 2013. †

	Percent Live Coverage‡									
Entry	**04-Feb**	**06-Mar**	**13-Mar**	**28-Mar**	**05-Apr**	**15-Apr**	**23-Apr**	**05-May**	**13-May**	**26-May**
					%					
OKC 1-75-2	0.01c	0.02c	0.08c	0.07d	63.49b	96.89a	92.27a	99.90a	99.98a	100.00
OKC 13-78-5	0.09c	0.00c	0.00c	0.00d	32.36c	96.49a	90.87a	99.80a	99.92ab	100.00
OKC 16-13-8	0.03c	0.08c	0.05c	0.06d	22.83cd	88.42a	37.84b	99.80a	99.98a	100.00
OKC 7-20-22	0.01c	0.09c	0.05c	0.05d	2.98e	39.17c	7.60c	89.38a	93.80a	99.72
OKC 8-16-10	0.10c	0.09c	0.06c	0.01d	11.45de	65.17b	12.26c	95.24a	99.85a	99.99
OKC 70-18	0.04c	14.31b	23.58b	69.78a	99.78a	99.94a	100.00a	100.00a	100.00a	100.00
OKC 18-4-P	0.13c	0.12c	0.07c	0.04d	21.62cd	86.85a	47.71b	66.48b	98.54ab	99.99
MSB-281	21.96abc	3.94bc	7.84c	25.73c	97.79a	99.51a	99.72a	100.00a	99.82ab	100.00
MSB-264	43.91a	83.2a	77.24a	55.17b	99.63a	100.00a	99.99a	100.00a	100.00a	100.00
MSB-285	27.76ab	79.64a	79.33a	55.23b	99.03a	99.98a	99.99a	100.00a	99.81ab	100.00
Sunday	3.67bc	0.17c	0.28c	5.06d	92.67a	100.00a	100.00a	100.00a	100.00a	100.00
Champion	0.03c	0.07c	0.04c	7.10d	92.74a	99.89a	99.44a	99.98a	99.98a	100.00
Tifgreen	0.00c	0.70c	0.06c	3.34d	98.42a	99.95a	100.00a	100.00a	98.13b	100.00
TifEagle	0.13c	0.00c	0.00c	0.69d	97.72a	99.97a	99.84a	100.00a	100.00a	100.00
Mini Verde	0.03c	0.19c	0.19c	2.35d	73.08b	98.98a	91.30a	99.96a	99.76ab	100.00
LSD(0.05)†	27.02	13.17	15.14	14.00	18.27	13.31	14.85	11.46	1.81	NS

† Means within columns followed by the same letters are not statistically different at P ≤ 0.05 level based on Fisher's LSD test.

‡ Trinexapac-ethyl (PGR) treatment applications of 0 and 673.21 g ha-1 were made on 28 June, 9 July, 19 July, 4 Aug, 21 Aug, 3 Sep and 23 Sep of 2013. Percent live coverage means represent those averaged over plant growth regulator treatments within dates within entries since PGR, entry and entry x date effects were significant but no entry x date x PGR interaction effect was significant once PGR treatments were initiated.

Table 7. (Continued)†.

Entry	Percent Live Coverage										
	06-Jun	15-Jun	01-Jul	14-Jul	18-Jul	01-Aug	17-Aug	29-Aug	09-Sep	21-Sep	29-Sep
	%										
OKC 1-75-2	99.99a	99.95a	99.99a	100.00a	100.00	98.10a	58.77bc	70.29b	77.89c	79.60bc	84.74b
OKC 13-78-5	99.94a	99.99a	99.98a	99.99a	100.00	97.81a	94.05a	95.86a	95.01ab	87.00ab	92.67ab
OKC 16-13-8	99.76b	99.98a	99.90ab	99.97a	100.00	97.52a	87.76ab	84.00ab	82.90bc	68.13c	68.17c
OKC 7-20-22	99.09c	99.78b	98.73c	99.84b	100.00	74.91b	36.11c	66.37bc	58.87d	29.42d	31.25d
OKC 8-16-10	99.95a	99.99a	99.95a	99.99a	100.00	74.57b	46.82c	48.82c	70.90cd	78.58bc	86.94b
OKC 70-18	100.00a	99.99a	100.00a	100.00a	99.99	99.93a	96.81a	97.73a	96.77a	97.76a	99.37a
OKC 18-4-P	99.92a	99.94a	99.69b	99.90b	99.91	92.83a	52.04c	26.50d	30.40e	5.70e	21.87d
MSB-281	99.99a	100.00a	100.00a	100.00a	100.00	100.00a	89.51a	97.80a	99.73a	99.91a	99.99a
MSB-264	100.00a	100.00a	100.00a	100.00a	100.00	100.00a	99.70a	97.07a	99.15a	99.77a	99.84a
MSB-285	100.00a	100.00a	100.00a	100.00a	100.00	99.68a	90.77a	82.99ab	93.99ab	96.80a	99.18a
Sunday	100.00a	100.00a	100.00a	100.00a	100.00	100.00a	99.99a	100.00a	100.00a	99.99a	100.00a
Champion	99.98a	100.00a	100.00a	100.00a	100.00	100.00a	100.00a	99.98a	100.00a	100.00a	100.00a
Tifgreen	100.00a	100.00a	99.99a	100.00a	100.00	99.85a	99.64a	99.91a	99.99a	99.99a	99.99a
TifEagle	100.00a	100.00a	100.00a	100.00a	100.00	99.99a	100.00a	99.98a	100.00a	100.00a	99.92a
Mini Verde	100.00a	100.00a	100.00a	99.97a	100.00	100.00a	100.00a	99.58a	100.00a	100.00a	99.94a
LSD(0.05)†	0.13	0.06	0.24	0.06	NS	9.90	2.05	21.40	13.80	13.55	10.97

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.

‡ Trinexapac-ethyl (PGR) treatment applications of 0 and 673.21 g ha-1 were made on 28 June, 9 July, 19 July, 4 Aug, 21 Aug, 3 Sep and 23 Sep of 2013. Percent live coverage means represent those averaged over plant growth regulator treatments within dates within entries since PGR, entry and entry x date effects were significant but no entry x date x PGR interaction effect was significant once PGR treatments were initiated.

Table 7. (Continued)†.

Entry	Percent Live Coverage‡	
	14-Oct	24-Oct
	%	
OKC 1-75-2	96.09a	06.93e
OKC 13-78-5	93.24a	08.62e
OKC 16-13-8	32.49c	00.35e
OKC 7-20-22	40.28c	00.25e
OKC 8-16-10	82.04b	00.60e
OKC 70-18	99.83a	78.62bc
OKC 18-4-Powell	18.25d	01.08e
MSB-281	100.00a	98.49a
MSB-264	100.00a	92.76ab
MSB-285	99.89a	92.25ab
Sunday	99.99a	87.03ab
Champion Dwarf	99.96a	61.41d
Tifgreen	99.97a	61.11d
TifEagle	100.00a	70.12cd
Mini Verde	99.81a	58.67d
LSD(0.05)†	9.63	14.66

† Means within columns followed by the same letters are not statistically different at P =0.05 level based on Fisher's LSD test.
‡ Trinexapac-ethyl (PGR) treatment applications of 0 and 673.21 g ha-1 were made on 28 June, 9 July, 19 July, 4 Aug, 21 Aug, 3 Sep and 23 Sep of 2013. Percent live coverage means represent those averaged over plant growth regulator treatments within dates within entries since PGR, entry and entry x date effects were significant but no entry x date x PGR interaction effect was significant once PGR treatments were initiated.

Table 8. Mean visual quality ratings of 15 bermudagrasses during 2012†.

	Visual Quality Rating‡										
Entry	**12-Jul**	**03-Aug**	**13-Aug**	**01-Sep**	**15-Sep**	**29-Sep**	**09-Oct**	**22-Oct**	**06-Nov**	**20-Nov**	**24-Nov**
OKC 1-75-2	4.7a	6.7ab	5.7	7.3ab	5.3c	7.3a	6.7a-d	7.3bcd	6.3a	6.3ab	3.7b
OKC 13-78-5	4.7a	6.3ab	7.3	7.0abc	7.3ab	7.0ab	7.3ab	6.7cd	4.3bc	4.3c	1.7de
OKC 16-13-8	4.7a	6.0b	5.3	5.7de	5.7c	5.3d	5.7cde	4.7e	2.7d	2.3d	1.3e
OKC 7-20-22	5.0a	6.3ab	6.7	4.7ef	4.0d	6.3bc	5.0e	5.0e	2.7d	2.0d	2.0cde
OKC 8-16-10	4.7a	6.3ab	6.3	4.0f	5.3c	7.0ab	5.3de	6.3d	3.7cd	4.3c	2.0cde
OKC 70-18	3.0bc	5.3b	7.3	6.0cd	5.3bc	6.3bc	6.7a-d	6.3d	5.3ab	5.7abc	3.0bc
OKC 18-4-P	4.3ab	6.3ab	7.0	6.0cd	4.0d	4.3e	3.3f	3.0f	1.0e	1.0d	1.0e
MSB-281	4.3ab	6.3ab	6.7	6.3bcd	5.7c	6.0cd	6.0b-e	7.3bcd	6.3a	6.0ab	3.7b
MSB-264	4.7a	7.7a	6.3	6.3bcd	7.3ab	6.3bc	7.0abc	8.3ab	6.3a	6.3ab	5.3a
MSB-285	5.0a	7.7a	6.0	7.0abc	7.3ab	6.7abc	7.7a	9.0a	6.7a	6.7a	5.7a
Sunday	3.0bc	6.3ab	6.3	7.3ab	7.7a	7.3a	7.0abc	7.3bcd	5.7ab	5.7abc	1.7de
Champion	3.0bc	6.7ab	6.0	7.3ab	7.7a	6.3bc	7.7a	7.7bc	5.7ab	5.3abc	1.7de
Tifgreen	4.0abc	6.7ab	6.3	6.3bcd	7.3ab	7.3a	6.3a-e	7.7bc	5.3ab	6.3ab	2.7bcd
TifEagle	3.7abc	7.7a	6.7	8.0a	7.7a	7.3a	7.7a	8.0ab	5.3ab	6.0ab	2.7bcd
Mini Verde	2.7c	5.3b	5.7	6.7bcd	7.3ab	6.3bc	7.0abc	7.3bcd	4.7bc	5.0bc	1.7de
LSD(0.05)†	1.4	1.4	NS	1.2	1.2	1.0	1.5	1.0	1.5	1.4	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

‡ Ratings are based on a scale of 1 – 9 (1 = poor, 6= acceptable, 9 = excellent).

Table 9. Mean visual quality of 15 bermudagrasses during 2013 before growth regulator treatment†.

	Visual Quality Rating‡				
Entry	**09-May**	**23-May**	**09-Jun**	**19-Jun**	**26-Jun**
OKC 1-75-2	6.3abc	6.0cd	5.7de	6.0c	6.3bc
OKC 13-78-5	6.0a-d	5.3d	5.7de	6.3c	7.3ab
OKC 16-13-8	6.3abc	5.7d	5.7de	6.3c	6.7ab
OKC 7-20-22	4.7de	4.3e	6.3cd	6.0c	5.3c
OKC 8-16-10	5.3b-e	5.7d	6.3cd	6.7bc	6.3bc
OKC 70-18	6.3abc	6.7bc	6.7bc	6.3c	6.3bc
OKC 18-4-P	4.3e	5.3d	5.0e	5.0d	5.3c
MSB-281	5.7a-e	7.3ab	6.3cd	7.3ab	7.3ab
MSB-264	6.7ab	6.0cd	5.0e	6.3c	7.0ab
MSB-285	7.0a	6.7bc	5.7de	6.0c	6.3bc
Sunday	6.3abc	7.7a	7.3ab	7.3ab	7.7a
Champion	4.3e	7.3ab	8.0a	8.0a	7.3ab
Tifgreen	7.0a	6.7bc	6.0cd	6.7bc	6.3bc
TifEagle	6.7ab	7.7a	8.0a	8.0a	6.7ab
Mini Verde	5.0cde	7.0ab	7.3ab	8.0a	7.3ab
LSD(0.05)†	1.6	0.9	0.8	0.7	1.2

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = poor, 6= acceptable, 9 = excellent).

Table 10. Mean visual quality ratings of 15 bermudagrasses during 2013 following growth regulator treatment (PGR) where P1= no PGR and P2= PGR treated †.

	Visual Quality Rating‡											
	04-Jul		11-Jul		19-Jul		26-Jul		12-Aug		19-Aug	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	6.0bcd	7.0	6.3cd	7.3ab	6.0cde	7.0b-e	6.7bcd	6.7	6.3cde	6.7fg	5.7cde	7.0cde
OKC 13-78-5	6.7abc	7.0	6.3cd	7abc	6.3cd	6.7c-f	6.3cde	6.3	6.0de	7.0ef	5.7cde	7.0cde
OKC 16-13-8	5.3d	7.0	6.3cd	6.7bcd	6.3cd	6.7c-f	6.0c-f	7.0	6.0de	7.0ef	5.7cde	6.7de
OKC 7-20-22	5.7cd	6.0	5.3de	6.0d	4.3f	5.7ef	5.0f	6.3	5.7e	6.7fg	5.0de	6.3ef
OKC 8-16-10	5.3d	6.7	5.3de	6.3cd	5.0ef	7.0b-e	5.7def	6.7	3.7g	6.0gh	5.0de	5.7f
OKC 70-18	7.0ab	6.7	6.0cd	7.0abc	6.3cd	6.7c-f	6.3cde	6.7	5.7e	7.0ef	5.7cde	7.3bcd
OKC 18-4-P	5.3d	6.0	4.7e	6.3cd	5.7de	5.3f	5.3ef	6.3	4.7f	5.7h	4.7e	4.3g
MSB-281	6.7abc	7.3	6.0cd	7.7a	7.7ab	8.7a	7.0bc	8.0	6.7cd	7.7cde	6.7abc	7.3bcd
MSB-264	6.0bcd	7.0	5.3de	7.3ab	6.7bcd	7.3a-d	6.0c-f	7.0	6.0de	7.3def	6.3bcd	7.3bcd
MSB-285	6.7abc	6.3	6.0cd	7.3ab	6.7bcd	7.3a-d	5.7def	7.0	5.7e	7.3def	5.7cde	7.0cde
Sunday	7.0ab	7.3	6.7bc	7.3ab	7.0bc	7.7a-d	6.7bcd	7.0	7.7ab	8.3abc	7.3ab	8.0ab
Champion	7.0ab	7.0	6.7bc	7.3ab	7.7ab	8.3ab	7.0bc	7.7	7.7ab	9.0a	7.3ab	8.3a
Tifgreen	6.7abc	7.0	6.7bc	6.7bcd	6.3cd	6.3def	7.0bc	7.0	7.0bc	8bcd	7.0abc	7.7abc
TifEagle	7.7a	7.7	7.7ab	7.3ab	7.7ab	8.0abc	7.7ab	8.0	7.7ab	8.7ab	7.7ab	8.3a
Mini Verde	7.0ab	7.7	8.0a	7.7a	8.7a	8.0abc	8.3a	8.0	8.3a	9.0a	8.0a	8.0ab
LSD(0.05)†	1.1	NS	1.2	1.0	1.3	1.4	1.1	NS	1.0	0.8	1.3	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = poor, 6= acceptable, 9 = excellent).

Table 10. Continued.†.

	Visual Quality Rating‡											
	24-Aug		02-Sep		13-Sep		21-Sep		28-Sep		05-Oct	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	5.3def	6.0d-g	5.7b	6.3fgh	5.3d	6.3cd	5.3fg	6.0de	5.3ef	6.0cd	5.3def	6.7cd
OKC 13-78-5	5.7cde	6.0d-g	6.0b	7.3c-f	5.7d	7.0bcd	5.0g	6.7cde	5.3ef	7.0bc	5.7de	7.3bc
OKC 16-13-8	4.7efg	5.3fg	5.3b	6.7efg	5.0d	6.3cd	4.7g	5.7e	4.7fg	5.7d	4.3efg	5.0g
OKC 7-20-22	4.3fg	5.7efg	5.3b	6.7efg	5.3d	6.0de	3.0h	3.7f	3.0h	3.7e	3.7g	4.0h
OKC 8-16-10	4.3fg	6.0d-g	3.7c	5.3h	3.7e	5.0e	3.3h	4.0f	4.0gh	4.3e	4.0fg	5.3fg
OKC 70-18	5.3def	6.3c-f	6.0b	7.0d-g	5.3d	6.7cd	5.7efg	6.7cde	5.7def	6.7cd	5.3def	6.3de
OKC 18-4-P	4.0g	5.0g	3.3c	3.3i	3.3e	3.3f	1.0i	1.0g	1.3i	1.0f	1.7h	1.7i
MSB-281	5.7cde	6.7b-e	5.7b	7.7b-e	7.0bc	7.3bc	7.0bcd	7.0bcd	6.7bcd	7.0bc	6.3cd	7.3bc
MSB-264	5.3def	6.7b-e	5.7b	6.7efg	6.0cd	6.3cd	6.7cde	6.3de	6.3cde	6.3cd	6.0d	5.7efg
MSB-285	4.7efg	6.3c-f	5.3b	6.0gh	5.7d	6.0de	6.3def	6.3de	6.3cde	6.7cd	6.7bcd	6.0def
Sunday	6.7abc	7.0a-d	8.0a	8.7ab	8.0ab	8.7a	7.7abc	7.7abc	7.7ab	8.0ab	8.3a	8.7a
Champion	7.0ab	7.7ab	8.3a	8.3abc	8.3a	8.7a	8.7a	8.7a	8.0a	8.7a	7.7abc	8.0ab
Tifgreen	6.3bcd	7.3abc	8.0a	8.3abc	8.0ab	8.0ab	7.7abc	8.0ab	7.3abc	8.0ab	7.7abc	8.7a
TifEagle	7.7a	8.0a	8.3a	9.0a	8.3a	9.0a	8.0ab	8.7a	7.3abc	8.0ab	8.0ab	8.0ab
Mini Verde	7.3ab	7.3abc	8.7a	8.0a-d	8.0ab	9.0a	8.0ab	8.3a	7.7ab	8.3a	8.3a	7.7b
LSD(0.05)†	1.1	1.2	1.3	1.2	1.3	1.1	1.3	1.1	1.2	1.0	1.4	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = poor, 6= acceptable, 9 = excellent).

Table 10. Continued †.

	Visual Quality Rating‡					
	12-Oct		19-Oct		26-Oct	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	5.3cd	6.0de	4.7c	5.3e	4.3d	6.3bcd
OKC 13-78-5	5.7cd	6.7b-e	5.3bc	6.0de	4.7cd	5.7d
OKC 16-13-8	3.0e	4.3f	1.3ef	2.3fg	1.7f	2.3f
OKC 7-20-22	3.0e	3.3f	3.0d	3.0f	1.7f	2.0f
OKC 8-16-10	3.0e	4.0f	2.7de	3.0f	3.0e	3.7e
OKC 70-18	5.0d	6.0de	4.7c	6.0de	6.3ab	6.7a-d
OKC 18-4-P	1.3f	1.3g	1.0f	1.0g	1.0f	1.3f
MSB-281	5.7cd	7.0a-d	5.7abc	7.3a-d	7.0a	7.7a
MSB-264	5.0d	6.3cde	5.0bc	6.3cde	5.7bc	5.7d
MSB-285	5.3cd	5.7e	5.7abc	5.3e	6.7ab	6.0cd
Sunday	7.0a	8.0a	7.0a	8.3a	7.0a	7.3ab
Champion	7.0a	7.3abc	7.0a	8.0ab	6.3ab	7.0abc
Tifgreen	6.0bc	7.0a-d	5.7abc	6.7b-e	6.3ab	7.3ab
TifEagle	7.0a	7.7ab	7.0a	7.7abc	6.7ab	7.3ab
Mini Verde	6.7ab	7.0a-d	6.3ab	7.0a-d	6.3ab	6.3bcd
LSD(0.05)†	1.0	1.1	1.5	1.4	1.3	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = poor, 6= acceptable, 9 = excellent.)

Table 11. Mean for visual estimates of density of 15 bermudagrasses during 2012†.

	Visual Density Rating‡									
Entry	**26-Jul**	**07-Aug**	**21-Aug**	**04-Sep**	**20-Sep**	**08-Oct**	**16-Oct**	**28-Oct**	**18-Nov**	**28-Nov**
OKC 1-75-2	5.0abc	7.7	6.7abc	7.3c	6.7de	7.0cde	7.7b	7.3cde	6.3bc	4.7b
OKC 13-78-5	5.3abc	7.0	7.0abc	7.3c	7.0de	7.0cde	6.3cde	6.0ef	5.7c	2.0de
OKC 16-13-8	5.0abc	7.0	5.7cd	7.3c	6.3e	5.7ef	5.3e	5.3fg	3.0d	1.0e
OKC 7-20-22	4.7bcd	6.7	5.7cd	6.0d	3.7g	5.0gf	5.3e	4.3g	3.3d	2.3cde
OKC 8-16-10	5.3abc	6.0	6.0cde	6.0d	5.0f	6.0d-f	6.0de	6.0ef	5.3c	2.0de
OKC 70-18	4.0cd	5.7	6.3abc	7.7bc	6.3e	6.7cde	6.3cde	6.0ef	5.3c	3.7bc
OKC 18-4-Powell	5.0abc	6.7	6.3abc	7.3c	5.0f	4.0g	4.0f	2.7h	1.0e	1.0e
MSB-281	5.3abc	7.3	6.0cde	8.0abc	7.7cde	7.7abc	7.7b	7.7a-d	7.7a	6.3a
MSB-264	6.3a	7.7	8.3a	9.0a	8.7ab	8.0ab	8.0ab	8.3ab	8.0a	6.7a
MSB-285	6.3a	8.0	8.0ab	9.0a	9.0a	8.7a	9.0a	8.7a	8.0a	6.7a
Sunday	4.0cd	6.3	6.7abc	8.3abc	8.3abc	8.0ab	7.0cde	7.3cde	7.0ab	2.3cde
Champion Dwarf	4.7bcd	6.7	7.0abc	8.7ab	8.7ab	8.0ab	7.3bc	7.3cde	7.0ab	2.7cd
Tifgreen	5.0abc	6.3	6.0cde	7.7bc	6.7de	7.0cde	7.0cde	7.0cde	6.3bc	3.0cd
TifEagle	5.7ab	7.3	8.0ab	9.0a	9.0a	8.3a	7.0cde	8.0abc	7.0ab	3.0cd
Mini Verde	3.3d	4.7	4.0d	8.0abc	7.3cde	7.0cde	5.7e	6.7de	6.0bc	2.3cde
LSD(0.05)†	1.6	NS	2.1	1.2	1.3	1.0	1.2	1.1	1.1	1.5

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 -9 (1 = very thin, 6 = acceptable, 9 = very dense).

Table 12. Mean visual estimates of density of 15 bermudagrasses during 2013 before plant growth regulator treatment†.

	Visual Density Rating‡	
Entry	**19-Jun**	**26-Jun**
OKC 1-75-2	6.3def	6.7def
OKC 13-78-5	6.3def	6.7def
OKC 16-13-8	6.0ef	6.7def
OKC 7-20-22	5.7fg	5.7fg
OKC 8-16-10	7.0bcd	7.7bcd
OKC 70-18	6.3def	6.3efg
OKC 18-4-Powell	5.0g	5.3g
MSB-281	7.7ab	8.7ab
MSB-264	6.3def	8.0abc
MSB-285	6.7cde	7.7bcd
Sunday	7.7ab	8.0abc
Champion Dwarf	7.7ab	9.0a
Tifgreen	6.7cde	7.3cde
TifEagle	7.3abc	8.7ab
Mini Verde	8.0a	8.3abc
LSD(0.05)†	0.8	1.1

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 -9 (1 = very thin, 6 = acceptable, 9 = very dense)

Table 13. Mean visual estimates of density of 15 bermudagrasses during 2013 following plant growth regulator (PGR) treatment (P1= no PGR, P2= PGR treated) †.

	Visual Density Rating‡											
	04-Jul		14-Jul		12-Aug		24-Aug		02-Sep		10-Sep	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	7.3cd	7.3a-d	7.0bc	7.3cd	7.7cd	8.0bc	6.7def	7.7cde	5.0de	6.7de	6.7bc	7.0de
OKC 13-78-5	7.7bcd	7.3a-d	6.0cd	6.7de	7def	7.7cd	6.0fg	7.0efg	5.0de	6.7de	6.3cd	8.0bc
OKC 16-13-8	7.0de	7.3a-d	7.0bc	7.3cd	6.7efg	7.0de	6.0fg	7.3def	5.3cde	6.7de	5.3de	7.0de
OKC 7-20-22	5.7f	6.7cd	5.3d	6.3ef	6.0gh	6.7e	6.0fg	6.3g	5.3cde	6.7de	5.0e	6.3ef
OKC 8-16-10	7.0de	7.7abc	6.3cd	7.0de	5.3h	6.7e	5.0g	6.3g	4.3e	5.7ef	3.7f	6.0f
OKC 70-18	7.0de	7.0bcd	6.3cd	6.7de	6.3fg	7.0de	6.3ef	6.7fg	6.3bcd	7.0cd	6.3cd	7.7cd
OKC 18-4-P	6.3ef	6.3d	6.3cd	5.7f	6.7efg	7.0de	5.7fg	6.3g	4.7e	5.0f	4.3ef	4.7g
MSB-281	8.7a	8.0ab	9.0a	9.0a	8.0bc	9.0a	7.3cde	8.3abc	6.7bc	7.7bcd	7.7b	8.7ab
MSB-264	7.3cd	8.0ab	9.0a	8.7ab	7.7cd	8.3abc	7.3cde	8.0bcd	7.0b	8.0abc	7.7b	8.3abc
MSB-285	7.0de	7.7abc	8.0ab	8.3ab	7.0def	8.3abc	6.7def	8.0bcd	6.3bcd	7.0cd	6.3cd	7.0de
Sunday	8.0abc	8.0ab	8.3a	8.7ab	8.7ab	8.7ab	8abc	8.0bcd	8.7a	9.0a	9.0a	9.0a
Champion	8.3ab	8.3a	9.0a	9.0a	9.0a	9.0a	8.7ab	8.7ab	9.0a	9.0a	9.0a	9.0a
Tifgreen	7.0de	7.3a-d	6.7c	7.0de	7.3cde	8.0bc	7.7bcd	8.0bcd	7.7ab	8.3ab	9.0a	9.0a
TifEagle	8.0abc	8.0ab	8.7a	8.0bc	8.7ab	9.0a	8.3abc	9.0a	9.0a	9.0a	9.0a	9.0a
Mini Verde	8.0abc	7.7abc	9.0a	9.0a	9.0a	9.0a	9.0a	8.7ab	8.7a	8.3ab	9.0a	9.0a
LSD(0.05)†	0.9	1.1	1.2	1.0	1.0	0.8	1.3	1.0	1.5	1.1	1.1	1.0

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 -9 (1 = very thin, 6 = acceptable, 9 = very dense).

Table 13. Continued †.

	Visual Density Rating‡													
	12-Sep		21-Sep		28-Sep		05-Oct		12-Oct		19-Oct		26-Oct	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	6.0de	6.3de	5.0cd	5.3fg	5.3d	6.0def	6.3de	6.7cd	5.3d	6.3b	5.3d	6.3bc	5.3cd	6.7d
OKC 13-78-5	5.7e	7.7bc	5.7c	7.7c	6.7c	7.7abc	7.3cd	8.3ab	5.7cd	6.3b	5.3d	6.3bc	6.7bc	7.7bcd
OKC 16-13-8	5.0e	6.7de	4.3de	5.7ef	4.7de	5.7ef	5.0f	6.7cd	2.3fg	3.0d	2.0fg	2.0ef	3.7e	4.0f
OKC 7-20-22	5.0e	6.0ef	4.3de	4.7gh	4.7de	5.0f	5.7ef	6.3cd	4.3de	4.7c	3.7e	4.0d	4.3de	5.3e
OKC 8-16-10	3.7f	5.3f	3.7e	4.3h	3.7e	5.3f	4.7f	5.7d	3.3ef	3.3d	3.3ef	3.3de	3.7e	5.0ef
OKC 70-18	6.0de	7.7bc	5.3c	6.3de	5.3d	7.0cd	6.3de	7.3bc	5.7cd	6.3b	5.3d	6.0c	5.7cd	6.7d
OKC 18-4-P	2.7f	3.0g	1.0f	1.0i	1.3f	1.3g	2.0g	2.3e	1.3g	1.3e	1.0g	1.3f	1.3f	1.7g
MSB-281	7.7bc	8.3ab	8.7a	8.7ab	8.7a	8.7a	9.0a	9.0a	8.3ab	8.7a	8.3ab	8.7a	8.3a	9.0a
MSB-264	7.7bc	8.3ab	7.7b	7.7c	8.0ab	7.3bc	7.7bc	7.3bc	8.0ab	7.7a	8.0abc	8.0a	8.0ab	7.7bcd
MSB-285	7.0cd	7.0cd	7.3b	6.7d	7.3bc	6.7cde	7.3cd	7.0c	7.0bc	6.3b	6.7cd	6.3bc	7.7ab	7.3cd
Sunday	8.7ab	8.7a	8.7a	8.7ab	8.3ab	8.3ab	8.0abc	9.0a	8.0ab	8.7a	8.7a	8.7a	8.0ab	8.3abc
Champion	9.0a	8.7a	9.0a	8.7ab	8.3ab	8.7a	8.7ab	9.0a	8.7a	8.3a	8.7a	8.7a	8.3a	8.3abc
Tifgreen	8.0abc	8.3ab	7.7b	8.0bc	8.0ab	8.3ab	8.3abc	8.3ab	7.3ab	8.0a	7.0bc	7.7ab	8.0ab	8.3abc
TifEagle	8.7ab	9.0a	8.7a	8.7ab	8.0ab	8.7a	8.3abc	8.7a	7.7ab	7.7a	7.7abc	7.7ab	8.3a	8.7ab
Mini Verde	9.0a	9.0a	9.0a	9.0a	8.3ab	8.7a	8.7ab	8.7a	8.0ab	8.3a	8.7a	8.3a	7.7ab	7.7bcd
LSD(0.05)†	1.3	1.0	0.9	1.0	1.2	1.0	1.3	1.2	1.4	1.3	1.6	1.4	1.4	1.3

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 -9 (1 = very thin, 6 = acceptable, 9 = very dense).

Table 14. Mean shoot count per unit area of 15 bermudagrasses during 2012 and 2013†.

	Shoot Count	
Entry	**05-Nov 2012**	**26-Jun 2013**
	Shoots cm^{-2}	
OKC 1-75-2	16.9bcd	25.0b-e
OKC 13-78-5	16.6cde	28.2a-d
OKC 16-13-8	20.2ab	27.6a-d
OKC 7-20-22	17.6abc	15.4f
OKC 8-16-10	17.2a-d	20.0ef
OKC 70-18	14.3c-f	21.7def
OKC 18-4-Powell	13.0ef	14.8f
MSB-281	14.7c-f	30.9ab
MSB-264	16.1c-f	26.6a-e
MSB-285	20.7a	28.2a-d
Sunday	15.6c-f	24.5b-e
Champion Dwarf	12.9ef	28.9abc
Tifgreen	15.7c-f	28.7a-d
TifEagle	14.6c-f	33.2a
Mini Verde	13.8def	23.6cde
LSD(0.05)†	3.6	7.1

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 15. Mean visual color ratings of 15 bermudagrasses during 2012†.

	Visual Color Rating‡						
Entry	**26-Jul**	**07-Aug**	**21-Aug**	**20-Sep**	**08-Oct**	**16-Oct**	**28-Oct**
OKC 1-75-2	6.7bc	6.7ab	5.7	6.3c	6.7bc	8.0abc	7.7bcd
OKC 13-78-5	5.7de	6.3ab	7.3	6.3c	6.3bcd	7.0b-e	6.7efg
OKC 16-13-8	6.3cd	6.0b	5.3	7.0bc	6.3bcd	5.3fg	4.3i
OKC 7-20-22	7.3ab	6.3ab	6.7	4.3d	4.3ef	5.0g	4.0i
OKC 8-16-10	5.3e	6.3ab	6.3	4.7d	5.3de	6.7c-f	6.0gh
OKC 70-18	6.7bc	5.3b	6.7	6.7c	6.7bc	6.3d-g	5.7h
OKC 18-4-Powell	7.7a	6.3ab	7.0	4.0d	3.7f	3.0h	2.3j
MSB-281	6.3cd	6.3ab	6.7	6.7c	6.3bcd	6.7c-f	7.0def
MSB-264	6.7bc	7.7a	6.7	7.0bc	6.7bc	7.0b-e	7.0def
MSB-285	6.7bc	7.7a	6.0	7.3abc	7.3ab	7.0b-e	7.3cde
Sunday	5.7de	6.3ab	6.3	6.3c	6.0cd	6.0efg	6.3f-h
Champion Dwarf	7.7a	6.7ab	6.0	8.7a	8.0a	8.7a	8.7a
Tifgreen	6.0cde	6.7ab	6.3	7.3abc	6.0cd	6.7c-f	6.7efg
TifEagle	7.3ab	7.7a	6.7	8.7a	8.3a	8.3ab	8.3ab
Mini Verde	7.3ab	5.3b	5.7	8.3ab	7.3ab	7.7a-d	8.0abc
LSD(0.05)†	0.8	1.4	NS	1.4	1.1	1.4	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw, 6= acceptable, 9 = dark green).

Table 16. Mean visual quality ratings of 15 bermudagrasses during 2013 before plant growth regulator treatment†.

	Visual Color Rating‡				
Entry	**05-May**	**12-May**	**28-May**	**06-Jun**	**13-Jun**
OKC 1-75-2	6.3bcd	7.7ab	5.3efg	6.3bcd	7.0bc
OKC 13-78-5	7.3ab	7.0a-d	4.3g	5.3e	6.3cd
OKC 16-13-8	6.0cde	7.0a-d	5.3efg	5.7de	7.0bc
OKC 7-20-22	5.3de	6.0cde	4.7fg	5.7de	6.3cd
OKC 8-16-10	6.0cde	6.3b-e	5.7def	6.7bc	7.0bc
OKC 70-18	7.7a	7.3abc	7.3ab	7.0b	7.7ab
OKC 18-4-Powell	5.0e	5.3e	5.3efg	6.0cde	6.7cd
MSB-281	7.3ab	6.7a-e	7.3ab	7.0b	7.0bc
MSB-264	7.0abc	8.0a	7.0abc	6.0cde	6.0d
MSB-285	7.0abc	7.3abc	7.0abc	7.0b	6.7cd
Sunday	7.7a	7.3abc	6.7bcd	7.0b	7.0bc
Champion	7.0abc	5.7de	8.0a	8.0a	8.3a
Tifgreen	7.7a	8.0a	6.0cde	6.3bcd	6.3cd
TifEagle	7.3ab	7.7ab	8.0a	8.0a	7.7ab
Mini Verde	7.0abc	6.7a-e	7.7ab	7.0b	8.0a
LSD(0.05)†	1.1	1.5	1.1	0.9	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw, 6= acceptable, 9 = dark green).

Table 17. Mean visual color ratings for 15 bermudagrasses during 2013 following plant growth regulator treatment (PGR) (P1= no PGR, P2= PGR treated) †.

	Visual Color Rating‡											
	04-Jul		14-Jul		12-Aug		24-Aug		02-Sep		10-Sep	
Entry	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
OKC 1-75-2	7.0ab	7.0a	6.3de	7.3ab	6.0ef	6.7fgh	6.0def	7.3bc	5.0gh	6.3ef	6.0def	6.3ef
OKC 13-78-5	7.0ab	6.7ab	6.7cde	6.7bc	5.7efg	7.7cde	6.3cde	7.3bc	5.7efg	7.0cde	5.3ef	7.0de
OKC 16-13-8	6.7abc	6.7ab	6.0ef	6.7bc	5.7efg	7.0efg	5.0f	6.7cd	5.0gh	6.7def	5.7def	6.3ef
OKC 7-20-22	5.7c	5.7b	4.0g	6.0cd	6.0ef	6.0h	5.7ef	6.3d	5.3fgh	6.3ef	6.3cde	6.7ef
OKC 8-16-10	6.0bc	6.7ab	5.3f	6.7bc	4.7g	5.0i	5.0f	5.3e	5.0gh	5.7f	5.0f	6.0f
OKC 70-18	7.0ab	7.3a	6.0ef	5.3d	6.3de	6.7fgh	6.0def	6.7cd	6.0d-g	6.7def	5.3ef	6.7ef
OKC 18-4-P	5.7c	5.7b	7.3bc	5.7cd	5.0fg	6.3gh	5.0f	5.0e	4.3h	4.0g	3.0g	4.0g
MSB-281	7.0ab	7.7a	8.0ab	7.7ab	7.3bcd	8.0bcd	7.0bcd	7.3bc	6.0d-g	7.3b-e	6.3cde	7.7cd
MSB-264	7.0ab	7.0a	7.0cd	6.7bc	6.7cde	7.3def	6.0def	7.7ab	6.7b-e	6.7def	6.3cde	6.0f
MSB-285	6.7abc	7.3a	7.0cd	7.3ab	6.3de	7.7cde	5.3ef	7.7ab	6.3c-f	5.7f	6.7bcd	6.3ef
Sunday	7.0ab	7.3a	6.7cde	6.7bc	7.3bcd	7.7cde	7.0bcd	7.7ab	7.3abc	8.0abc	7.3abc	8.3abc
Champion	7.7a	7.0a	8.0ab	7.7ab	8.7a	8.7ab	8.3a	8.0ab	8.0a	8.7a	7.7ab	9.0a
Tifgreen	7.0ab	7.0a	6.0ef	6.0cd	7.7abc	8.0bcd	7.3abc	8.0ab	8.0a	8.3ab	7.7ab	8.0bc
TifEagle	7.0ab	7.0a	7.3bc	7.7ab	8.3ab	8.3abc	8.0ab	8.3a	7.7ab	8.0abc	8.0a	8.3abc
Mini Verde	7.0ab	7.7a	8.3a	8.3a	8.3ab	9.0a	7.7ab	8.3a	7.0a-d	7.7a-d	7.7ab	8.7ab
LSD(0.05)†	1.1	1.1	0.9	1.2	1.1	0.9	1.2	1.0	1.2	1.2	1.1	1.0

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw, 6= acceptable, 9 = dark green).

Table 17. Continued†.

	Visual Color Rating‡											
	21-Sep		28-Sep		05-Oct		12-Oct		19-Oct		26-Oct	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	5.3ef	6.0d	6.7bcd	6.3def	6.7cde	6.7cde	6.7bc	6.3c	5.7cd	6.0b	5.3c	6.0c
OKC 13-78-5	5.7def	7.3bc	6.0cde	7.0b-e	6.3de	7.3bcd	6.0cd	6.7bc	6.0bc	6.7ab	4.3d	6.3bc
OKC 16-13-8	4.7fg	6.3cd	5.7de	6.7c-f	5.7ef	6.3de	4.3f	5.0d	3.0f	3.7c	1.7f	2.0e
OKC 7-20-22	3.7g	4.3e	5.0e	4.3g	5.0f	5.0f	4.3f	4.7d	3.7ef	4.3c	1.7f	2.0e
OKC 8-16-10	6.3cde	6.0d	6.0cde	6.0ef	5.7ef	6.0ef	5.0ef	5.0d	4.7de	4.7c	3.0e	4.0d
OKC 70-18	6.3cde	6.3cd	6.7bcd	6.3def	7.3a-d	7.3bcd	5.7de	6.3c	5.7cd	6.0b	7.0a	7.0abc
OKC 18-4-P	1.0h	1.0f	1.0f	1.3h	1.0g	1.3g	1.0g	1.3e	1.0g	1.0d	1.0f	1.0e
MSB-281	7.3abc	7.3bc	7.3ab	7.7abc	8.0ab	8.3ab	7.7a	7.7ab	7.7a	7.7a	7.0a	7.7a
MSB-264	6.7cd	5.7d	6.7bcd	5.7f	6.3de	5.7ef	6.7bc	6.7bc	7.0ab	7.3a	7.0a	7abc
MSB-285	6.7cd	6.0d	6.3bcd	6.0ef	6.7cde	6.0ef	6.7bc	6.7bc	7.0ab	7.3a	7.3a	7.3ab
Sunday	7.0bc	8.0ab	7abc	7.3a-d	7.0bcd	7.7abc	7.3ab	7abc	7.7a	7.3a	7.3a	7.3ab
Champion	8.3a	8.7a	8.0a	8.0ab	7.3a-d	8.3ab	7.0ab	7.3abc	7.3a	7.7a	7.0a	7.3ab
Tifgreen	7.3abc	8.0ab	7.3ab	8.3a	7.7abc	8.3ab	7.0ab	7.0abc	7.0ab	7.0ab	7.3a	7.7a
TifEagle	8.0ab	8.7a	8.0a	8.3a	7.3a-d	8.3ab	7.3ab	7.3abc	7.3a	7.3a	6.0bc	6.7abc
Mini Verde	8.0ab	8.7a	8.0a	8.3a	8.3a	8.7a	7.7a	8.0a	7.7a	7.7a	6.7ab	7.0abc
LSD(0.05)†	1.1	1.2	1.3	1.2	1.1	1.1	0.9	1.1	1.2	1.3	0.8	1.1

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw, 6= acceptable, 9 = dark green).

Table 18. Mean visual color retention ratings from 15 bermudagrasses during 2012†.

	Color Retention Rating‡			
Entry	**30-Oct**	**08-Nov**	**27-Nov**	**31-Dec**
OKC 1-75-2	6.7ab	5.0a	3.0b	2.7b
OKC 13-78-5	6.0bc	3.0cd	1.3c	1.3de
OKC 16-13-8	4.7de	3.0cd	1.0c	1.0e
OKC 7-20-22	3.7e	2.0ef	1.0c	1.3de
OKC 8-16-10	5.3cd	3.0cd	1.0c	1.0e
OKC 70-18	6.0bc	4.0b	3.0b	2.3bc
OKC 18-4-P	2.0f	1.3f	1.0c	1.3de
MSB-281	7.0ab	5.3a	4.3a	2.7b
MSB-264	7.3a	5.3a	5.0a	4.3a
MSB-285	7.3a	5.7a	5.3a	4.0a
Sunday	5.3cd	3.7bc	1.7c	1.0e
Champion Dwarf	7.0ab	3.3bc	1.3c	2.0bcd
Tifgreen	6.7ab	3.7bc	2.0bc	1.3de
TifEagle	6.7ab	3.3bc	1.7c	1.7cde
Mini Verde	6.3abc	2.3de	1.3c	1.3de
LSD(0.05)†	1.2	0.9	1.2	0.9

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw, 6= acceptable, 9 = dark green).

Table 19. Mean visual green-up ratings from 15 bermudagrasses during 2013†.

	Green-up Ratings‡					
Entry	**04-Feb**	**19-Feb**	**05-Mar**	**01-Apr**	**15-Apr**	**23-Apr**
OKC 1-75-2	1.7bc	4.3bc	2.3bc	5.0ef	6.0bc	6.3bcd
OKC 13-78-5	1.3c	2.7de	2.7b	6.0cde	6.0bc	7.0ab
OKC 16-13-8	1.0c	2.3de	1.7bcd	5.7de	5.0cd	5.7cde
OKC 7-20-22	1.0c	2.0e	1.3cd	4.0fg	4.0d	5.0e
OKC 8-16-10	1.0c	2.3de	2.3bc	5.0ef	4.7d	5.3de
OKC 70-18	2.3a	4.0c	5.0a	6.7a-d	6.7ab	8.0a
OKC 18-4-Powell	1.0c	1.0f	1.0d	3.7g	4.3d	5.3de
MSB-281	3.3a	4.3bc	4.3a	5.7de	6.0bc	6.7bc
MSB-264	3.3a	5.0ab	5.3a	6.3bcd	6.7ab	7.0ab
MSB-285	3.3a	5.3a	5.3a	6.7a-d	6.7ab	7.3ab
Sunday	1.0c	2.3de	2.7b	7.0abc	6.7ab	7.3ab
Champion Dwarf	1.3c	2.3de	2.3bc	7.3ab	7.0ab	7.3ab
Tifgreen	1.7bc	3.0d	2.7b	7.3ab	6.7ab	7.3ab
TifEagle	1.0c	2.0e	2.3bc	7.7a	7.3a	7.3ab
Mini Verde	1.3c	2.3de	2.0bcd	6.7a-d	6.7ab	6.7bc
LSD(0.05)†	0.7	0.8	1.1	1.0	1.1	1.1

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = straw brown and 9 = completely green).

Table 20. Mean visual texture ratings from 15 bermudagrasses during 2012 and 2013†.

	Visual Texture Ratings‡							
	2012				2013			
Entry	**26-Jul**	**28-Aug**	**30-Sep**	**23-Oct**	**28-May**	**19-Jun**	**18-Jul**	**19-Sep**
OKC 1-75-2	6.7abc	7.3ab	7.3ab	8.0ab	6.7bcd	7.0ab	7.0abc	7.7a
OKC 13-78-5	6.3bc	8.0a	8.0a	8.3a	6.3cde	7.0ab	7.3ab	7.7a
OKC 16-13-8	7.7a	7.3ab	7.0bc	8.0ab	6.7bcd	7.0ab	7.0abc	7.3a
OKC 7-20-22	6.3bc	6.3cd	4.3e	6.3ef	5.7e	6.0c	5.7e	5.0e
OKC 8-16-10	6.7abc	7.3ab	7.0bc	7.7abc	6.7bcd	6.7bc	6.3cde	6.3bc
OKC 70-18	5.0d	6.3cd	6.3cd	6.7d-f	6.7bcd	6.7bc	6.0de	5.7cde
OKC 18-4-P	5.0d	6.0d	6.3cd	6.7d-f	6.0de	6.0c	5.7e	5.3de
MSB-281	6.3bc	7.0bc	7.0bc	7.0cde	7.3ab	7.3ab	7.0abc	7.0ab
MSB-264	6.7abc	7.0bc	8.0a	8.0ab	7.0abc	7.0ab	7.3ab	7.7a
MSB-285	7.0ab	8.0a	8.0a	7.3bcd	7.3ab	7.7a	7.7a	7.7a
Sunday	7.0ab	7.3ab	6.7bcd	7.7abc	7.7a	7.7a	6.7bcd	6.3bc
Champion	6.0bcd	6.3cd	6.0d	6.0f	7.7a	6.7bc	7.0abc	6.0cd
Tifgreen	7.0ab	6.3cd	6.0d	6.0f	6.7bcd	6.7bc	6.3cde	6.3bc
TifEagle	6.0bcd	6.0d	6.0d	6.7d-f	7.3ab	6.7bc	6.3cde	5.7cde
Mini Verde	5.7cd	6.0d	6.3cd	7.0cde	7.3ab	7.3ab	6.7bcd	6.0cd
LSD(0.05)†	1.1	0.8	0.9	0.8	1.0	0.8	0.8	0.9

†Means with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = coarse and 9 = fine).

Table 21. Mean visual seed head ratings from 15 bermudagrasses during 2012 and 2013 prior to plant growth regulator treatment†.

	Visual Seed Head Rating‡					
	2012				2013	
Entry	**30-Jul**	**13-Aug**	**28-Aug**	**30-Sep**	**28-May**	**19-Jun**
OKC 1-75-2	9.0a	9.0a	9.0a	8.3ab	5.7de	7.3bc
OKC 13-78-5	6.0c	6.3cd	6.7c	7.3c	4.7e	6.7cd
OKC 16-13-8	8.0ab	7.3bc	8.0b	7.0cd	6.3d	7.3bc
OKC 7-20-22	8.7a	8.0ab	8.3ab	7.7bc	7.0bcd	7.7b
OKC 8-16-10	5.7c	6.0d	6.7c	5.7ef	6.7cd	6.7cd
OKC 70-18	8.7a	6.7cd	6.3c	7.0cd	6.7cd	7.0bcd
OKC 18-4-P	8.7a	9.0a	9.0a	5.0f	8.0abc	6.7cd
MSB-281	5.7c	4.7e	5.3d	5.7ef	8.0abc	6.3de
MSB-264	3.7d	4.3e	6.3c	5.7ef	6.0de	5.7e
MSB-285	5.7c	6.0d	6.7c	6.3de	6.3d	5.7e
Sunday	9.0a	9.0a	9.0a	9.0a	8.3ab	7.0bcd
Champion	9.0a	9.0a	9.0a	9.0a	9.0a	9.0a
Tifgreen	6.3bc	6.0d	7.0c	8.7a	7.0bcd	7.3bc
TifEagle	9.0a	9.0a	9.0a	9.0a	9.0a	8.7a
Mini Verde	9.0a	9.0a	9.0a	9.0a	9.0a	9.0a
LSD(0.05)†	1.7	1.2	1.0	0.9	1.6	0.8

† Means within columns followed by the same letters are not statistically different at P ≤ 0.05 level based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = no seed head).

Table 22. Mean visual seed head ratings from 15 bermudagrasses during 2013 following plant growth regulator (PGR) treatment (P1= non PGR treated, P2= PGR treated) †.

	Visual Seed Head Rating‡													
	04-Jul		14-Jul		24-Jul		14-Aug		24-Aug		02-Sep		16-Sep	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	6.7ab	7.0	8.7ab	9.0a	7.3bc	7.0cd	6.0cd	7.3bcd	7.0cde	8.0bcd	8.3ab	8.7a	7.7	8.7a
OKC 13-78-5	6.7ab	7.0	7.3cde	8.3ab	7.0cd	7.7abc	6.7cd	7.7bc	7.0cde	7.3de	8.3ab	8.7a	7.7	8.7a
OKC 16-13-8	6.7ab	6.7	8.0a-d	8.0bc	7.3bc	7.3bcd	6.3cd	7.3bcd	7.3bcd	7.3de	8.0abc	8.3ab	8.3	8.7a
OKC 7-20-22	5.7bc	6.0	8.3abc	8.7ab	7.0cd	7.7abc	6.7cd	7.3bcd	7.3bcd	7.3de	8.3ab	9.0a	8.7	9.0a
OKC 8-16-10	6.7ab	6.7	7.3cde	8.0bc	5.0f	6.3d	4.0e	5.0e	6.3ef	7.0e	8.3ab	8.3ab	8.3	9.0a
OKC 70-18	7.0a	6.7	7.0def	7.3cd	6.7cde	8.0abc	7.0bc	7.7bc	6.7def	7.7cde	6.0d	7.3b	7.7	7.7b
OKC 18-4-P	5.3c	6.0	8.7ab	9.0a	8.0ab	8.3ab	5.7d	6.3d	6.0f	7.3de	7.0cd	7.3b	8.7	8.3ab
MSB-281	7.0a	7.3	7.7b-e	9.0a	6.7cde	8.0abc	6.3cd	7.7bc	6.3ef	7.7cde	7.3bc	8.7a	8.3	9.0a
MSB-264	6.7ab	7.0	5.7g	7.0de	6.0e	7.3bcd	6.7cd	7.7bc	7.3bcd	7.3de	8.0abc	8.0ab	8.3	9.0a
MSB-285	6.7ab	6.3	6.7efg	7.0de	6.3de	7.0cd	4.3e	7.0cd	6.7def	7.7cde	8.0abc	8.7a	7.7	7.7b
Sunday	7.3a	7.3	8.7ab	9.0a	8.3a	8.3ab	8.0ab	8.3ab	7.7bc	8.3abc	9.0a	9.0a	8.0	8.7a
Champion	7.0a	7.0	8.7ab	9.0a	8.0ab	8.3ab	8.7a	9.0a	8.0ab	8.7ab	8.7a	8.7a	8.3	9.0a
Tifgreen	6.7ab	7.0	6.0fg	6.3e	7.3bc	7.3bcd	7.0bc	7.7bc	7.3bcd	8.3abc	8.3ab	8.7a	8.3	9.0a
TifEagle	7.7a	7.7	8.3abc	8.3ab	8.7a	8.7a	9.0a	9.0a	8.7a	9.0a	9.0a	9.0a	9.0	9.0a
Mini Verde	7.0a	7.7	9.0a	9.0a	8.7a	8.7a	9.0a	9.0a	8.7a	9.0a	9.0a	9.0a	8.7	9.0a
LSD(0.05)†	1.1	NS	1	0.8	1.0	1.0	1.2	1.2	0.8	0.9	1.3	1.1	NS	0.8

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = no seed head).

Table 23. Mean USGA Stimpmeter readings from 15 bermudagrasses during 2012†.

	USGA Stimpmeter Readings					
Entry	**24-Aug**	**07-Sep**	**23-Sep**	**23-Oct**	**20-Nov**	**18-Dec**
	cm					
OKC 1-75-2	263.0cd	284.9bcd	281.6	271.4hi	301.3bcd	280.7c-f
OKC 13-78-5	273.1abc	293.2bcd	285.5	300.1b-e	292.6cd	278.7c-f
OKC 16-13-8	266.5bcd	282.0bcd	299.0	299.8b-e	292.2cd	308.5ab
OKC 7-20-22	279.6abc	289.4bcd	305.5	308.1bc	332.7a	297.4abc
OKC 8-16-10	246.4d	275.9cd	269.1	288.1d-h	324.7ab	267.4d-g
OKC 70-18	263.9cd	282.3bcd	278.4	269.6i	281.7d	272.3d-f
OKC 18-4-P	269.8abc	274.8cd	289.5	326.5a	309.4abc	313.5a
MSB-281	269.2abc	270.4d	285.3	276.2g-i	297.3cd	246.2g
MSB-264	264.2cd	271.7d	286.8	281.6f-i	299.5bcd	260.5fg
MSB-285	263.4cd	272.6cd	268.1	282.8e-i	292.8cd	262.0e-g
Sunday	285.0ab	318.7a	303.6	312.6ab	301.7bcd	286.1bcd
Champion	278.0abc	303.2ab	319.0	301.7bcd	306.7a-d	280.4c-f
Tifgreen	271.9abc	301.8ab	285.2	293.5c-g	309.6abc	262.4e-g
TifEagle	278.2abc	296.8abc	280.2	298.1b-f	302.3bcd	285.0b-e
Mini Verde	288.8a	318.1a	306.7	312.3ab	316.9abc	283.8c-f
LSD(0.05)†	20.1	24.4	NS	18.0	26.2	23.6

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 24. Mean USGA Stimpmeter readings from 15 bermudagrasses during 2013†.

	USGA Stimpmeter Readings					
Entry	**23-Jan**	**08-Feb**	**13-Mar**	**25-Apr**	**16-May**	**23-Jun**
	cm					
OKC 1-75-2	308.0c	279.1b-e	307.2ab	279.1b-e	253.1	300.0bcd
OKC 13-78-5	302.5c	258.1e	318.1ab	258.1e	254.9	286.8cde
OKC 16-13-8	309.2c	297.3abc	336.4a	297.3abc	271.5	294.7b-e
OKC 7-20-22	336.4ab	301.3ab	333.2a	301.3ab	289.2	308.7abc
OKC 8-16-10	343.3a	276.6cde	315.4ab	276.6cde	280.9	323.1a
OKC 70-18	293.5c	258.7e	251.1c	258.7e	254.7	275.9e
OKC 18-4-P	316.0bc	306.5a	319.8ab	306.5a	278.8	296.4b-e
MSB-281	300.1c	265.9de	288.8bc	265.9de	275.2	284.2de
MSB-264	303.1c	274.5cde	300.3ab	274.5cde	261.5	293.2b-e
MSB-285	299.9c	272.3de	293.2b	272.3de	268.2	287.2cde
Sunday	311.6bc	274.6c-e	323.0ab	274.6cde	270.8	297.1b-e
Champion	302.9c	283.6a-d	293.9b	283.6a-d	288.2	309.3abc
Tifgreen	309.9c	275.6cde	313.8ab	275.6c-e	280.8	297.6b-e
TifEagle	305.0c	303.9a	313.7ab	303.9a	281.4	292.3b-e
Mini Verde	314.3bc	278.1b-e	336.7a	278.1b-e	290.3	313.1ab
LSD(0.05)†	25.7	24.3	37.9	24.3	NS	22.8

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 24. Continued†.

Entry	USGA Stimpmeter Readings		
	28-Jul	29-Aug	29-Sep
		cm	
OKC 1-75-2	192.7	235.7bc	277.3b
OKC 13-78-5	202.3	226.1cde	269.5b
OKC 16-13-8	252.3	228.9cde	278.3b
OKC 7-20-22	191.1	221.7cde	266.7b
OKC 8-16-10	180.0	233.5bcd	273.2b
OKC 70-18	183.2	218.0de	259.1b
OKC 18-4-P	187.6	215.1e	260.1b
MSB-281	194.8	221.2cde	236.4b
MSB-264	199.8	226.1cde	244.6b
MSB-285	187.9	219.3de	248.10b
Sunday	205.5	248.8ab	264.8b
Champion	226.2	261.93a	335.2a
Tifgreen	204.7	227.8cde	248.3b
TifEagle	233.3	248.1ab	271.7b
Mini Verde	229.5	254.0a	262.7b
LSD(0.05)†	NS	16.30	NS

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 25. Mean visual scalping ratings of 15 bermudagrasses evaluated as degrees of recovery from scalping damage that happened in 11 Aug, 2013 following plant growth regulator (PGR) treatment (P1= non PGR treated, P2= PGR treated)†.

	Visual Scalping Rating‡									
	11-Aug		18-Aug		25-Aug		02-Sep		11-Sep	
Entry	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**
OKC 1-75-2	6.7cde	7.3	7.0bc	7.7ab	7.3abc	7.7	6.7c	7.7bc	9.0a	9.0a
OKC 13-78-5	7.0b-e	8.3	6.7cd	7.7ab	6.3cde	7.3	6.3c	7.7bc	7.3abc	6.3d
OKC 16-13-8	6.3def	7.3	7.0bc	7.7ab	6.3cde	7.3	7.3abc	8.0ab	9.0a	8.3ab
OKC 7-20-22	8.0a-d	8.3	8.0abc	8.0ab	7.7ab	7.7	9.0a	9.0a	9.0a	9.0a
OKC 8-16-10	4.0g	7.3	4.3e	6.7bc	5.7de	7.7	7.3abc	9.0a	9.0a	8.7a
OKC 70-18	8.0a-d	8.0	8.3ab	7.3abc	7.7ab	7.3	9.0a	9.0a	9.0a	9.0a
OKC 18-4-P	4.7fg	6.3	5.3de	5.7c	7.0bc	7.0	8.7ab	8.7ab	9.0a	9.0a
MSB-281	7.0b-e	8.0	6.7cd	8.3ab	6.7bcd	8.0	7.0bc	7.7bc	7.3abc	7.3bcd
MSB-264	6.0ef	7.7	6.7cd	7.3abc	6.7bcd	7.0	5.7c	6.7cd	6.7c	8.0abc
MSB-285	5.3efg	8.7	5.3de	8.3ab	5.3e	7.0	5.7c	6.0d	7.0bc	7.0cd
Sunday	8.7ab	8.7	8.3ab	8.3ab	7.3abc	8.0	9.0a	9.0a	8.7ab	8.3ab
Champion	9.0a	9.0	8.3ab	9.0a	7.7ab	7.7	7.3abc	7.7bc	7.7abc	7.3bcd
Tifgreen	8.3abc	9.0	8.3ab	8.3ab	8.3a	7.7	9.0a	9.0a	9.0a	9.0a
TifEagle	9.0a	9.0	8.7a	8.7a	8.3a	8.7	8.7ab	8.7ab	8.3abc	8.7a
Mini Verde	8.7ab	8.7	8.7a	8.7a	8.3a	8.7	9.0a	9.0a	9.0a	9.0a
LSD(0.05)†	1.9	NS	1.5	1.7	1.2	NS	1.7	1.3	1.7	1.2

† Means within one column followed with the same letters are not statistically different at P = 0.05 based on Fisher's LSD test.
‡ Ratings are based on a scale of 1 – 9 (1 = no scalping).

Table 26. Mean percentage winterkill for 15 bermudagrass varieties on 15 April 2013†.

Entry	Percentage Winterkill Rating‡
	%
OKC 1-75-2	7.6d
OKC 13-78-5	4.2d
OKC 16-13-8	6.0d
OKC 7-20-22	54.0a
OKC 8-16-10	22.0bcd
OKC 70-18	3.6d
OKC 18-4-P	34.0ab
MSB-281	29.0bc
MSB-264	11.6cd
MSB-285	28.6bc
Sunday	2.4d
Champion Dwarf	2.0d
Tifgreen	4.4d
TifEagle	2.6d
Mini Verde	3.4d
LSD(0.05)†	20.6

† Means within columns followed by the same letters are not statistically different at P = 0.05 level based on Fisher's LSD test.

Table 27. Number of times in which an entry appears in the top LSD group for each parameter during 2012-2013.

Entry	Quality	Color	Density	BR†	SH	PLC	Total times in Top Statistical Group††
OKC 1-75-2	9	6	3	1	11	21	51
OKC 13-78-5	10	6	5	2	7	25	55
OKC 16-13-8	3	3	2	4	7	19	38
OKC 7-20-22	2	2	0	8	10	9	31
OKC 8-16-10	3	2	2	4	5	15	31
OKC 70-18	8	9	1	0	4	27	49
OKC 18-4-P	2	2	2	7	10	9	32
MSB-281	18	16	38	1	7	34	114
MSB-264	12	11	23	1	5	34	86
MSB-285	16	14	14	0	4	35	83
Sunday	39	20	32	5	17	25	138
Champion	36	34	33	8	19	25	155
Tifgreen	26	24	19	4	7	27	107
TifEagle	42	33	34	6	19	25	159
Mini Verde	32	33	28	7	19	21	140
Total groups of data	46	36	38	15	20	46	

†BR=Ball roll speed, SH= Seed head production, PLC= Percent live coverage.

††Total number of times that the entry's mean appeared in the A statistical ranking group at the p=0.05 level.

APPENDICES

APPENDIX A

List of Entries and Background Information

1. OKC 1-75-2
2. OKC 13-78-5
3. OKC 16-13-8
4. OKC 7-20-22
5. OKC 8-16-10
6. OKC 70-18
7. OKC 18-4-Powell
8. MSB-281
9. MSB-264
10. MSB-285
11. Sunday
12. Champion Dwarf
13. Tifgreen
14. TifEagle
15. Mini Verde

Entries 1 -5: These 5 experimental types were selected from a putting green bermudagrass study established on Block 23 at the OSU Turfgrass Research Center by Drs. Dennis Martin and Charles Taliaferro in 2003. Dr. Charles Taliaferro is credited as the Breeder of the materials. Materials were irrigated as needed and mowed at 0.25 inches during the years of the trial. All OSU experimental entries in the original trial survived the 9 years of selection pressure on the sand putting green. Only elite performers were selected for use in the trials being conducted by Wenwen Liu. In spring of 2010 substantial winter kill was seen on bermudagrasses around Oklahoma, including those in the NTEP bermudagrass trial at Stillwater, OK (Morris, 2013). Substantial loss of aerial shoots occurred on the sand based trial during the winter of 2009/2010 but all OSU bermudagrasses regenerated rapidly from dormant lateral buds on stolons and rhizomes. This trait suggests that the elite 5 lines will have superior cold hardiness and survivability. Champion was lost during the course of the 9 years of the trial and only very small amounts of TifEagle and Tifgreen survived the 9 year trial period.

Entries 6~7: These two are also promising experimental cultivars harvested from trials at the turf scien

ce research center at OSU. OKC70-18 is reported to show superior performance at 9 transition zone sites during 2002-2006 NTEP trials. OKC18-4-Powell is a radiation mutant of Patriot bermudagrass by Dr. Jerrel Powell.

Entries 8~10: Experimental bermudagrass cultivars from Dr. Wayne Philly at Mississippi State University.

Entries 11~15: Five commercially available bermudagrasses selected as industry standards. Champion Dwarf and Tifgreen are provided by Dr. Yanqi Wu at OSU. Materials Mini Verde is sponsored by Pike Creek Turf Inc. in Adel, Georgia and Sunday by Sod Solutions.

APPENDIX B

PLOT PLAN OF 2012 MP&WT PUTTING GREEN BERMUDAGRASS TRIALS

West North =>

					1 REP1	2	3	4	5
6	7	8	9	10	11	12	13	14	15
14 REP2	9	3	12	6	15	2	7	8	11
10	4	5	1	13	4 REP3	8	1	12	15
3	11	13	10	9	6	7	5	14	2
3 feet border									
13 REP1	9	12	14	8	3	7	5	2	10
4	11	1	6	15	1 REP2	2	3	4	5
6	7	8	9	10	11	12	13	14	15
12 REP3	15	2	14	8	13	3	5	7	4
11	1	6	9	10	2 REP4	10	14	3	12
9	5	11	8	4	7	15	1	13	6
15	13	3	12	9	2	10	14	5	7
11	4	6	8	1					

VITA

WENWEN LIU

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT AND EVALUATION OF HYBRID BERMUDAGRASS VARIETIES WITH COLD HARDINESS FOR GOLF COURSE PUTTING GREENS

Major Field: Horticulture

Biographical:

Education:

Completed the requirements for the Bachelor of Science in Turfgrass Management at Michigan State University, East Lansing, Michigan in June, 2010.

Completed the requirements for the Bachelor of Science in Landscape Architecture at Northeast Agriculture University, Harbin, Heilongjiang Province, China in June, 2010.

Experience:

Maintenance Crew Member at Desert Mountain golf club in Scottsdale, Arizona. 2009.

Turf management trainee at the Imperial Spring Golf Course in Guangzhou, P.R. China, duties mainly include scouting the grass fields for potential hazards, keeping records for turf health status, maintaining of equipment, application of agrochemicals and additional tasks as needed. 06/2010-08/2010.

Designer Assistant at China office of Robbins & Associates International, responsibilities mainly included: 1) Assist Dr. Rick Robbins in communication related to the designing of golf courses, accompany him during each of his site visits. 2) Translate and finalize selected CAD drawings initiated by the designer so as to achieve the maximum legibility for the constructors. 3) Liaise with clients on contract terms and provide technical and coordination support to the project team on behalf of the designer. 09/2010-03/2011.

Professional Memberships: Crop Science Society of America, 2013-present
American Society of Agronomy, 2013-present
Soil Science Society of America, 2013-present