Investment Yields Bermudagrass Cultivars with High Quality and Improved Cold-Hardiness

Oklahoma State University scientists continue to improve this crucial turfgrass for the golf course industry.

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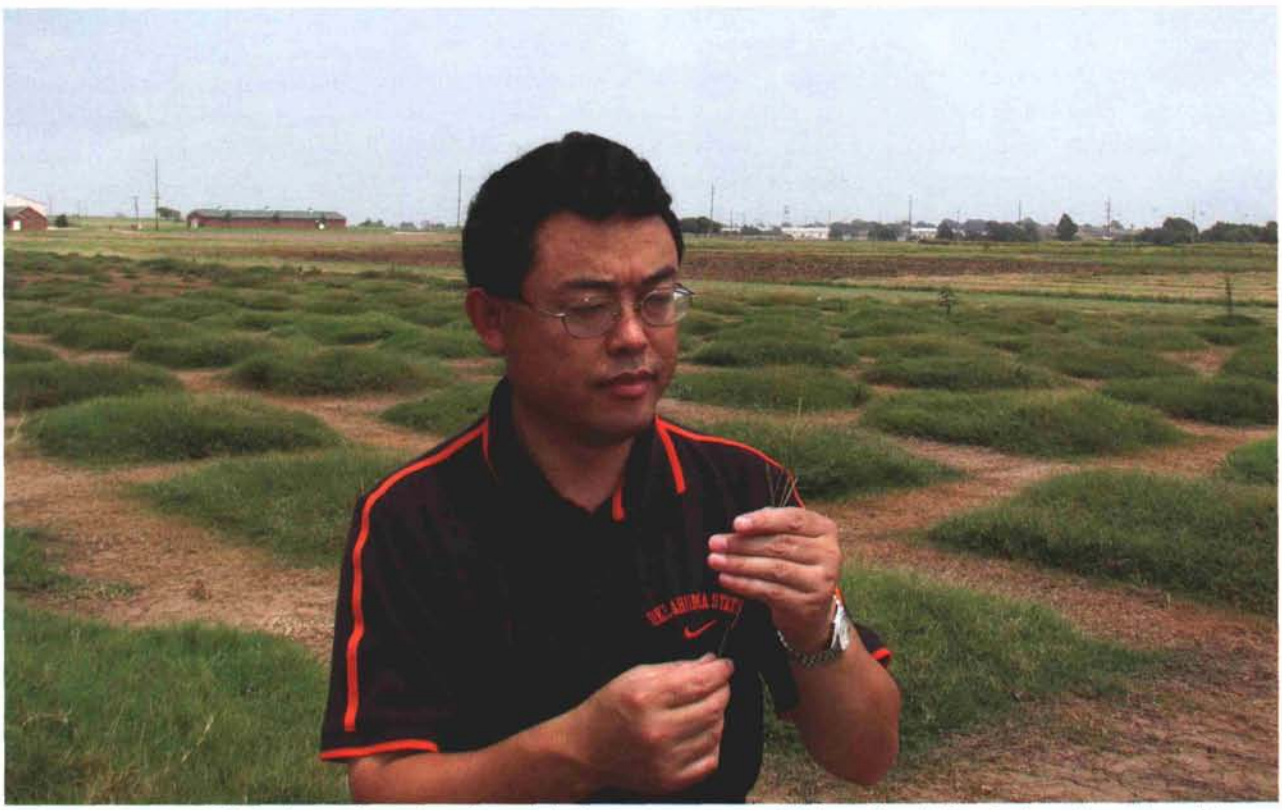

Since its inception in 1986, the bermudagrass breeding and development program at Oklahoma State University has released five cultivars with improved quality and winter-hardiness. These cultivars have reduced the risk of winterkill when using bermudagrass in the transition zone. An extensive bermudagrass germplasm collection has been formed, breeding populations improved, and a steady stream of promising experimental lines has been developed. Dr. Yanqi Wu, turf/forage/biofuels breeder, examines flowers of experimental bermudagrass lines in a field space planting.

Bermudagrasses (*Cynodon spp.*) are the most widely used turfgrasses for golf courses, athletic fields, and lawns in the southern U.S. Tolerance to close mowing, as well as favorable heat, drought, and traffic tolerance and few serious pests makes bermudagrass an attractive choice in tropical and subtropical areas. Although widely adapted, its susceptibility to freeze injury has been a continuing threat in many areas of its use. Thus, there has been a long-term need for high-quality bermudagrasses that have reduced risk of winterkill.

Oklahoma State University (OSU) began a joint venture in 1986 with the USGA to improve the cold-hardiness,

Table 1
Turfgrass cultivars released by the Oklahoma State University bermudagrass development program.

Cultivar	Year Released	Propagation Method	Ploidy Level
Guymon	1982	Seed	Tetraploid
Midlawn*	1991	Vegetative	Triploid
Midfield*	1991	Vegetative	Triploid
Yukon	2000	Seed	Tetraploid
Riviera	2001	Seed	Tetraploid
Patriot	2002	Vegetative	Tetraploid

*Midlawn and Midfield were developed by the Kansas State University turf program and were jointly released with Oklahoma State University

as well as the visual and functional performance qualities, of seeded bermudagrasses. At that time, the only choices available for seeded bermudagrass cultivars were the less-winter-hardy Arizona Common (*C. dactylon* var. *dactylon*) or the more cold-hardy but coarse-textured Guymon (*C. dactylon* var. *dactylon*). The bermudagrass breeding effort at OSU eventually grew to encompass vegetatively propagated types, as well as seeded grasses. This article provides a brief overview of the OSU turf bermudagrass development effort.

HISTORY

Collection of *Cynodon* germplasm for culture and scientific use began around the start of the 20th century in South Africa and the United States. Bermudagrass germplasm collection and taxonomic characterization at OSU was underway in the 1950s and '60s with noted accomplishments by Drs. Jack Harlan, Johannes de Wet, and Wayne Huffine. Turf bermudagrass improvement began in earnest in 1986 under the direction of Dr. Charles Taliaferro. The initial broad objective was to develop finer-textured, seed-propagated, cold-tolerant bermudagrasses (*C. dactylon* var. *dactylon*) for the U.S. transition zone. The initial efforts involved collecting additional germplasm, characterizing appearance and performance, improving the fertility and texture of breeding populations that were known to be cold tolerant, and improving the cold-hardiness in populations known to be highly fertile.

By 1990, the effort at OSU was expanded to include the development of high-quality, cold-hardy, vegetatively-propagated materials for golf course fairways/tees and to examine the possibility of generating improved African bermudagrasses (*C. transvaalensis*) for use on putting greens. Field plantings of improved African bermudagrasses in tropical areas of the U.S. revealed the species performed well in fall, winter, and spring but declined substantially in the summer months in both tropical and the more southern subtropical planting sites. Many African bermudagrass selections also suffered substantially more nematode problems on the sandy gulf coastal plain compared with the interspecific hybrid Tifdwarf (*C. dactylon* X *C. transvaalensis*) and its derivatives. Although by early 1997 efforts to generate putting green types of African bermudagrass were discontinued, the breeding and selection effort in that species resulted in improved types that had value in generating improved interspecific hybrid crosses (*C. dactylon* X *C. transvaalensis*) for the golf turf industry.

Dr. Taliaferro led the turf and forage bermudagrass breeding and development effort from its inception until his retirement in January 2006. Guymon, Yukon, Riviera, and Patriot turf bermudagrasses (Table 1), as well as a number of promising experimental types (still under study) were developed under his leadership. Additionally, his familiarity with cultivar development helped facilitate cooperative releases of Midlawn and Midfield hybrid bermudagrasses between Kansas State University (KSU) and OSU in 1991 (Table 1). Midlawn and Midfield were developed by Dr. Ray Keen of KSU with field-testing assistance by Drs. John Pair, Jeff Nus, and others.

The successes of the OSU turf bermudagrass development program are not only due to USGA investment, but can also be attributed to the leadership of Dr. Charles Taliaferro in concert with a number of past and current faculty (Table 2), staff, graduate students, and cooperating industry scientists. Following the retirement of Dr. Taliaferro, an extensive search was conducted that resulted in the hiring

Table 2
The Oklahoma State University bermudagrass breeding and development team has expertise in several crucial areas. Current team members and their areas of expertise are listed below.

Faculty Working Group Member	Area of Expertise
Charles Taliaferro	Team Coordinator (retired), Breeding & Genetics
Yanqi Wu	New Coordinator, Breeding & Genetics
Dennis Martin	Cultural Management
Jeff Anderson	Physiology & Cold Tolerance
Mike Anderson	Molecular Biology & Genetics
Greg Bell	Cultural Management, Herbicide & Shade Tolerance
Nathan Walker	Plant Pathology, Entomology & Molecular Biology
Tom Royer	Entomology

Table 3

Mean turfgrass quality ratings of seeded bermudagrasses during 2006 from 9 transition-zone locations, 2002-2006 NTEP Bermudagrass Trial.*

Seeded Entry	Mean
Yukon	6.2
Riviera	5.8
Contessa	5.8
SWI-1046	5.7
SWI-1012	5.7
SWI-1044	5.6
CIS-CD6	5.4
Veracruz	5.4
SWI-1014	5.4
CIS-CD7	5.3
SWI-1003	5.2
Sunbird	5.1
SWI-1001	5.1
Princess 77	5.0
Tift No. 2	5.0
Transcontinental	5.0
CIS-CD5	4.9
Tift No. 1	4.8
SR 9554	4.8
Panama	4.7
LaPaloma	4.7
FMC-6	4.7
Arizona Common	4.7
Southern Star	4.7
NuMex Sahara	4.6
Mohawk	4.6
Sundevil II	4.5
Sunstar	4.5
B-14	4.5
LSD (0.05)	0.3
Coeff. of variation (%)	12.3

*Excerpted from Tables 3b, p. 14, of the 2006 NTEP Progress Report NTEP No. 07-6. Quality rated on a 1-9 scale, where 1 is poor and 9 is excellent.

of Dr. Yanqi Wu in July 2006 to head up the OSU bermudagrass breeding and development effort. Dr. Wu completed his Ph.D. under the tutelage of Dr. Taliaferro in 2004. A substantial portion of the newer bermudagrass germplasm in our program was collected by and is in an ongoing state of characterization by Dr. Wu.

BERMUDAGRASS CULTIVARS DEVELOPED AT OSU

In 1982, preceding the USGA-funded turf development effort at OSU, the forage/pasture effort resulted in the release of Guymon bermudagrass (*C. dactylon* var. *dactylon*) (Table 1). Guymon was arguably the first seeded bermudagrass with improved cold-hardiness over Arizona Common. Guymon found favor in soil erosion control areas, roadsides, rangeland, and pastures. With only the non-cold-hardy Arizona Common bermudagrass seed being available during the 1980s, the coarse-textured, but cold-hardy and vigorous Guymon was often used on lower-maintenance sports fields and lawns in the transition zone.

Yukon bermudagrass (*C. dactylon* var. *dactylon*), tested as OKS 91-11, was released in 2000. It was the first turf bermudagrass from OSU developed with grant funding from the USGA. Yukon is a high-quality seeded turf-type bermudagrass with improved cold-hardiness and improved spring dead spot disease tolerance.

Yukon found favor on some golf courses, sports fields, and in the lawn/landscape industry. It performs well at the 0.5-inch mowing height typical of bermudagrass fairways. The divot recovery rate of Yukon varies from intermediate to rapid. Although Yukon seed availability has been limited in recent years, increased availability of seed is anticipated in the near future. Yukon continues to provide excellent quality in transition-zone climates (Table 3).

Riviera bermudagrass (*C. dactylon* var. *dactylon*), tested as OKS 95-1, was released in 2001. Riviera is a high-quality (Table 4), medium-fine-textured seeded bermudagrass. Riviera seed production yields are typically higher than those of Yukon. Riviera has improved cold-hardiness and improved tolerance to spring dead spot. The Riviera divot recovery rate varies from intermediate to rapid. Riviera is now receiving increased use on fairways, tees, athletic fields, and lawns when a high-quality seeded bermudagrass with improved cold-hardiness is desired.

Patriot bermudagrass (*C. dactylon* X *C. transvaalensis*), tested as OKC 18-4, was released in 2002. Patriot is a vegetatively propagated hybrid characterized as having improved color, quality (Table 4), and cold-hardiness. Its divot recovery rate has been characterized as medium to rapid. Licensed producers have reported rapid sod production cycles from planting to harvest. Improved tolerance to spring dead spot disease is also a desirable characteristic of Patriot. We believe Patriot to be the first commercialized interspecific hybrid turf-type bermudagrass that is a tetraploid. It was created by a cross of the hexaploid Tifton 10 and an improved African bermudagrass (a diploid) from our collection. Patriot is well adapted to golf course tee and fairway use and is currently experienc-

Table 4

Mean bermudagrass quality from multiple locations during the 1997-2001 National Turfgrass Evaluation Program Bermudagrass Trial.*

Entry	Regime A**	Regime B
Arizona Common	4.7	4.5
Blackjack	5.3	5.4
Blue-Muda	5.1	5.0
Cardinal	5.4	5.7
CN 2-9	6.1	5.8
J-540	5.3	5.2
Jackpot	5.0	4.9
Majestic	5.3	5.3
Midlawn	5.8	6.5
Mini-Verde	5.6	5.1
Mirage	5.1	4.9
NuMex-Sahara	5.0	5.0
OKC 19-9	5.8	6.1
Patriot	6.1	6.6
Princess 77	6.5	6.1
Pyramid	5.2	5.0
Riviera	6.4	6.6
Savannah	5.4	5.3
Shanghai	5.6	6.1
Shangra La	5.2	5.1
Southern Star	5.4	5.4
Sundevil II	5.3	5.0
SWI-11	6.1	5.5
Sydney	5.2	5.2
Tifgreen	6.1	6.3
Tifsport	6.5	6.1
Tifway	6.4	6.2
Transcontinental	6.0	5.6
LSD (0.05)	0.2	0.2
Coeff. of variation	14.0	14.9

*Excerpted from Tables 1a and 2a of the 1997-2001 NTEP Bermudagrass Trial Final Report NTEP No. 97-9. Quality rated on a 1-9 scale, where 1 is poor and 9 is excellent.

**The 9 Regime A trials were mowed at 0.5 to 0.75 inch and fertilized with 0.75-1 lb. of N per 1,000 sq. ft. per growing month. The 11 Regime B trials were mowed at 0.75 to 1.0 inch and fertilized with 0.5-0.75 lb. of N per 1,000 sq. ft. per growing month. Both regimes included irrigation to prevent visual drought stress.

ing increased use by the golf course industry.

EXPERIMENTAL OKLAHOMA SELECTIONS WITH PROMISE

OKC 70-18 bermudagrass, developed in part with funding from the USGA, has recently undergone intensive internal as well as external testing (2002-2006 NTEP bermudagrass trial). This variety ranked first in overall quality at nine transition-zone test sites during several years of the 2002-2006 NTEP trial. OKC 70-18 has several meritorious characteristics, and a decision concerning possible release is forthcoming.

Three promising experimental bermudagrasses from our program were entered into the 2007-2011 NTEP bermudagrass trial. These included OKC 11-19 and OKC 11-34, vegetatively propagated types and a seeded type, OKS 2004-2. Sixteen NTEP testing sites are in place for the 2007 NTEP trial. Besides the traditional parameters of color, quality, texture, density, green-up, and living cover, additional parameters monitored at selected sites will include sod tensile strength as well as tolerance to spring dead spot disease, salinity, and traffic.

CURRENT BREEDING AND DEVELOPMENT WORK

A new broad-based breeding population was recently formed using desirable Chinese *Cynodon* material selected from a collection by Dr. Wu made in 11 provincial regions of China. Selections were made based on extensive evaluation of chromosomal, morphological, seed yield potential, and DNA marker investigations completed in 2004. The population contains favorable traits for turf cultivar development, including darker green color, relatively fine texture, good winter-hardiness, and good sod density. Study of genetic relatedness assists the turf breeder in elimination of possible duplication of breeding efforts due to close relatedness of parents. Additionally, this work may help in locating crosses that have increased likelihood of compatibility. Complementary to this work, Dr. Kevin Kenworthy (now of the University of Florida Turfgrass Program) recently completed an assessment of the variability in 21 performance traits of African bermudagrass while in our program. The work determined which traits can most easily be improved in the African bermudagrass parents that are subsequently useful for developing interspecific crosses.

Applied field trials comparing later-stage promising experimental entries and industry standards are ongoing for turf quality, divot recovery, spring dead spot resistance, and sod tensile strength. Due to inability to eradicate pre-existing aggressive *C. dactylon* var. *dactylon* types from many installation sites, some superintendents choose not to renovate to improved bermudagrass cultivars. In order to address this issue, a preliminary study investigating the resistance of hybrid bermudagrasses to encroachment by common bermudagrass was initiated in 2006 by M.S. candidate Holly Han.

Above left: An interspecific hybrid and an aggressive common bermudagrass "duke it out" during the establishment phase. Inability to eradicate on-site aggressive common bermudagrass leads to mixtures with diminished playing surface quality. Work is underway at Oklahoma State University to determine if rapid-spreading improved types can better compete against common bermudagrass. Above right: Patriot is a high-quality, vegetatively propagated, interspecific hybrid bermudagrass with improved cold-hardiness and rapid divot recovery rate.

ADDITIONAL BERMUDAGRASS PERFORMANCE FEATURES

Development of bermudagrasses with high turf quality and suitable cold-hardiness will remain a key focus of our efforts, although pursuit of additional improvements has begun. Limited freshwater resources threaten the vitality of the golf turf and landscape industries. Work commenced in late summer 2007 by M.S. candidate Santanu Thapa to evaluate the water use rate of several experimental OSU bermudagrasses. Evaluation of leaf firing resistance under drought will also be incorporated into our screening program in future years. Development of bermudagrasses with delayed leaf firing may help superintendents maintain quality turf during periods of limited natural rainfall and during irrigation restrictions.

Lack of suitable shade tolerance is a key limitation of bermudagrass. As the golf course landscape matures, increased shading of turf occurs. Breeding and selection for improved shade tolerance in bermudagrass has been successfully conducted by turfgrass scientists at the University of Georgia. Screening of bermudagrass germplasm for improved shade tolerance was initiated in the summer of 2007 by Drs. Greg Bell and Yanqi Wu. The work incorporates the use of a combination of natural and artificial shade.

CONCLUSIONS

USGA support has been instrumental in supplementing a long-term turf bermudagrass development effort at Oklahoma State University. A comprehensive, interdisciplinary team of scientists has been assembled, focusing on turf bermudagrass improvement. The effort has resulted in extensive collection, characterization, and improvement of breeding populations of bermudagrasses from the *Cynodon dactylon* and *C. transvaalensis* species.

Studies have aided in the understanding of fundamental mechanisms of stress tolerance. Improvements have been made in turf quality, cold-hardiness, and spring dead spot tolerance. The improved turf bermudagrasses Yukon, Riviera, and Patriot were direct results of the USGA investment. Training a number of graduate students can also be attributed to USGA contributions. Two clonally propagated selections and one seed-propagated selection with improved characteristics for the golf industry were entered into the 2007 NTEP bermudagrass trial. New germplasm from China has recently been introduced into our program. Incorporation of increased water use efficiency, leaf firing resistance under drought, and improved shade tolerance in bermudagrass are future goals of our development effort.

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EDITOR'S NOTE: An expanded version of this paper can be found at *USGA Turfgrass and Environmental Research Online* (http://usgatero.msu.edu/v06/n17.pdf).

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CONNECTING THE DOTS

An interview with Drs. Dennis Martin, Yanqi Wu, Nathan Walker, and Greg Bell regarding the bermudagrass germplasm enhancements at Oklahoma State University.

Q: *Oklahoma State University has been breeding and developing bermudagrasses with USGA support since the mid-1980s. Is there one achievement or cultivar that stands out over the rest as proof of significant achievement?*

A: Our goal was to produce high-quality seeded and vegetative varieties with improved cold-hardiness. Our vegetative bermudagrass products OKC 70-18 and Patriot held the top two positions for turf quality among vegetative types in 2005 and 2006 when summarized over the nine transition-zone climates of the NTEP bermudagrass test. Likewise, Yukon and Riviera held the top two positions for turf quality among seeded types during 2005 and 2006 when summarized over the nine transition-zone climates. We believe we have met the original goal, but we have no intention of resting on our laurels. Hopefully we can continue to make advancements that will benefit the golf and turf industry. (Dr. Martin)

Q: *Improving cold-hardiness of bermudagrass is a very worthy goal by anyone's standards. Do you have a feel for how far north the transition zone can be pushed by these newer, more cold-hardy cultivars?*

A: We are uncomfortable with bermudagrass actually being used farther north in the U.S. than where it is already deemed appropriate by local experts. What we hope our impact will be is (1) that we have produced cultivars that offer improved quality/winter-hardiness where only lower-quality/winter-hardy types were in use before, and (2) where high-quality cultivars were already in use, but they suffered occasional winterkill. Use of the newer products will further reduce the risk of serious winterkill. (Dr. Martin)

Q: *Do you think the seeded bermudagrasses will eventually have the same level of acceptance had by the vegetative types that cover most of the southern golf courses in the U.S. and many tropical and subtropical locales worldwide? What are the main obstacles to overcome that would enable seeded types to garner that level of acceptance by golf course superintendents?*

A: Realistically, I doubt that bermudagrass seed will ever be used as extensively as vegetative types on golf courses in the southern U.S. Seeded types have been experiencing more extensive use, though. But it is just so easy to propagate bermudagrass from sprigs in most instances. Certainly, seeded types can rival the quality and performance of vegetative types on tees, fairways, surrounds, and rough. Seeded types are experiencing increased use in international markets in areas where local sod/sprig production is not well developed and when shipping costs and/or restrictions on shipping vegetative material presents roadblocks. (Dr. Martin)

Q: *Spring dead spot (SDS) is the most serious disease of bermudagrass and seems to be linked with cold-hardiness. Do you find that to be true in your work? In other words, do bermudagrass cultivars that are more cold-hardy tend to be more resistant to the pathogens that cause SDS?*

A: Yes, research conducted on both commercially available and experimental bermudagrass lines continues to support earlier observations that, in general, those varieties with improved cold-hardiness have improved tolerance to SDS. When we state that a variety has improved SDS tolerance, it can, in fact, still get the disease, but the disease tends to be less severe than it is on more susceptible varieties. Of course, poor management practices by the end user, such as allowing excessive thatch to accumulate and/or use of excessive late-season nitrogen fertilization, can encourage severe SDS symptoms on both susceptible and tolerant varieties. (Drs. Martin, Walker, and Bell)

Q: *How far has your work with shade tolerance of bermudagrass progressed? Does the OSU bermudagrass breeding and development program have selections that are considerably more shade tolerant? If they are developed, to what extent do you think they will impact the golf course industry in the southern U.S.?*

A: Our first screening of germplasm for response to shade was planted in summer of 2007. If improved shade tolerance is found, additional breeding and recurrent selection can then proceed, followed by more extensive field testing. Superintendents tell us they want bermudagrasses with improved shade tolerance. If such types existed, one could envision cases where shade-tolerant types would be used in more shaded areas, with other varieties predominating in the more sunny areas. Other courses might try to use a "wall-to-wall" application of the more shade-tolerant types if they had general widespread adaptation. (Drs. Bell, Wu, and Martin)

Q: *What characteristic of the Chinese collection of bermudagrass germplasm is particularly appealing? How long will it be before your program is able to incorporate those characteristics into new selections?*

A: Our genetic studies indicated Chinese bermudagrass is highly diverse. Some of the germplasm accessions contain desirable traits for the development of improved turf cultivars, including seed yield and quality, leaf texture, and color, as well as adaptation. Normally 10 to 15 years are required to develop improved selections incorporating the desirable new traits. (Dr. Wu)

Q: *Have you been able to use information from the bermudagrass "genetic roadmap" being constructed by Dr. Andrew Paterson and his colleagues at the University of Georgia in your bermudagrass development program? If so, how?*

A: Scientists at the University of Georgia have published the first bermudagrass molecular marker linkage map using a cross of two important turf species, common and African bermudagrasses. The work is significant in that it provides a "genetic roadmap" to locate genes responsible for important turf traits. Thus far, we have not used this information. However, if important genes are mapped and further tagged to markers, which are easily used by breeders, then marker-assisted selection can be added to conventional breeding programs. (Dr. Wu)

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