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Dr. Charles Taliaferro and his colleagues at Oklahoma State University are developing high quality seed- and vegetatively propagated bermudagrasses for the turfgrass industry.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 225 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
904 Highland Drive
Lawrence, KS 66044
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

Broadening the Horizons of Turf Bermudagrass

Charles M. Taliaferro, Dennis L. Martin, Jeffrey A. Anderson, Michael P. Anderson, and Arron C. Guenzi

SUMMARY

Turf bermudagrass breeding at Oklahoma State University began in the mid-1980s with an initial objective to breed cold hardy, seed-propagated varieties suitable for turf use in the U.S. transition zone. The program has produced both seed- and vegetatively propagated cultivars that have received broad acceptance in the golf course industry. Among the program's achievements:

- The horizons of turf bermudagrass use have been expanded by the breeding of seed-propagated, cold hardy, varieties with high turf quality and transition zone adaptation.
- New vegetatively propagated turf bermudagrass varieties that encompass cold hardiness, high turf quality, good sod strength, and tolerance to biotic and abiotic stress agents broaden the horizons of use in the transition zone.
- Acquisition, evaluation, and maintenance of bermudagrass germplasm enhances the ability to further improve turf bermudagrass.
- Fundamental research of genetic mechanisms is adding to the knowledge base of bermudagrass biology.

Bermudagrass is a staple of the turfgrass industry in the southern U.S. and throughout other warm regions of the world. Characteristics that make bermudagrass an attractive choice include its long-lived perennial sod-forming nature, aggressive spreading ability, tolerance to close defoliation, and adaptation to a wide range of growing conditions. It has few serious insect or disease pests and has high heat, drought, and wear tolerance compared to many other cool- and warm-season turfgrass species. These combined traits make it a tough, resilient grass for turf use.

Historical Perspective

The improvement of bermudagrass for turf and the development of the modern turfgrass industry have been parallel events unfolding over the past century. Incremental improvements in turf bermudagrass varieties were achieved during this period by turfgrass enthusiasts searching for plants with superior characteristics relating to turf use (11, 12, 13). Improvement methodologies progressed from initial prospecting for superior plants occurring naturally in bermudagrass germplasm to the inclusion of scientific selective breeding that began in the mid-1900s.

Each cycle of breeding encompassed growing 700 to 1000 plants, evaluating them for desirable characteristics over two to three years, and intercrossing about 10% of the plants judged best for the selection traits.

CHARLES M. TALIAFERRO, Ph.D., Regents Professor, Plant and Soil Sciences Department; DENNIS L. MARTIN, Ph.D, Professor, Horticulture and Landscape Architecture Department; JEFFREY A. ANDERSON, Ph.D., Professor, Plant and Soil Sciences Department; MICHAEL P. ANDERSON, Ph.D., Associate Professor, Horticulture and Landscape Architecture Department; and ARRON C. GUENZI, Ph.D., Adjunct Accociate Professor, Plant and Soil Sciences Department, Oklahoma State University, Stillwater, OK.

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With USGA financial support, turf bermudagrass breeding at Oklahoma State University began in the mid-1980s with an initial objective to breed cold hardy, seed-propagated varieties suitable for turf use in the U.S. transition zone. Acquisition and evaluation of *Cynodon* germplasm from around the world is an important part of the bermudagrass improvement program at OSU.

The high quality turf bermudagrass cultivars in commerce today are testaments to the progress achieved. But challenges and opportunities remain in developing new bermudagrass varieties combining enhancements associated with geographic adaptation, turf quality, and other performance features. Such improvements will expand the horizons of bermudagrass use.

The Germplasm Cafeteria

Bermudagrass used as turf is predominantly from two of the nine species of the genus *Cynodon*. *Cynodon dactylon* var. *dactylon* is the most widespread and economically important species. It is distributed over much of the world between northern and southern latitudes of approximately 45º. Plants within the species vary enormously in adaptation and morphological characteristics. Though most widely distributed and prevalent in tropical and subtropical climates, temperate forms have evolved that persist in relatively cold climates. The species is also found in arid environments where plants usually persist in micro-sites that accumulate moisture.

Morphologically, forms of *C. dactylon* var. *dactylon* range from large, coarse-textured types forming loose sods to small, fine-textured types forming dense sods. By virtue of its widespread distribution and prevalence, the term "common" bermudagrass is frequently used to connote plants of this species. In contrast, *C. transvaalensis* is endemic only to parts of South Africa and contains plants distinctive in their small size, fine texture, and yellow-green color. Both *C. dactylon* and *C. transvaalensis* have contributed varieties for turf use and the most widely used industry standard bermudagrass varieties are interspecific hybrids derived from crossing plants of these two species.

OSU's Breeding Program

Turf bermudagrass breeding at Oklahoma State University began in the mid-1980s with USGA financial support. The initial objective was to breed cold hardy, seed-propagated varieties suitable for turf use in the U.S. transition zone. This represented a pioneering effort for the following reasons. Prior turf bermudagrass breeding had largely concentrated on developing interspecific vegetatively-propagated (clonal) varieties for the southern states where bermudagrass is generally best adapted and most widely used. These efforts were immensely successful in producing varieties that became industry standards in southern states (3), but whose levels of winter hardiness placed them at risk when grown in the transition zone (1).

As northern latitude of use of these varieties increased, so did the risk of winter injury. Although a bermudagrass seed production industry developed in the desert southwestern U.S. in the early 1900s as naturalized common bermudagrass invaded irrigated crop lands (2) , there was no sustained breeding efforts within this germplasm prior to the mid-1980s. The common bermudagrass seed from this region has been widely sold and used as turf, but is deficient in turf quality compared to the best clonal varieties and lacks the winter hardiness to be reliably used in transition zone climates. Accordingly, the goal of breeding cold hardy, seed-propagated, bermudagrass varieties with market acceptable turf quality was indeed aimed at broadening the horizons of this important turf species.

We viewed the seeded variety breeding effort as important in providing an alternative establishment option that would supplement, rather than supplant, the use of vegetatively propagated varieties. Accordingly, the breeding effort was expanded in the early 1990s to include clonal variety development for the transition zone.

Seeded Bermudagrass: From Sow's Ear to Silk Purse

The goal of breeding better seeded turf bermudagrass varieties was spurred by the discovery of plants that incorporated good cold hardiness and relatively good basic fertility (seed set). The germplasm collection containing these plants was amassed at Oklahoma State University in the late 1950s and early 1960s by Jack R. Harlan,

Morphologically, forms of *C. dactylon* var. *dactylon* range from large, coarse-textured types forming loose sods to small, fine-textured types forming dense sods.

'Riviera' plantings on golf courses, playing fields, and lawns have garnered acclaim based on its rapid establishment, high turf quality, winter survival, and ease of management. Shown above is Baum Baseball Stadium at the University of Arkansas. The photo was taken four weeks after planting with 'Riviera'. *Photo courtesty: Stan Stoner, Inc. Advertising Agency.*

Wayne W. Huffine, J.M.J. de Wet, and others. Harlan and colleagues used the collection in a comprehensive biosystematic study of *Cynodon* that added much information to the knowledge base concerning the distribution and biology of the genus. Their work culminated in a taxonomic revision of *Cynodon* (4, 5).

The task of developing market-acceptable turf varieties from the breeding stock plants was formidable and time-consuming. The cold hardy fertile plants chosen as founding parents of a breeding population varied in morphology, but generally were relatively coarse types with inferior turf quality. The initial breeding population formed from intercrossing the genetically heterozygous parent plants was highly heterogeneous for morphological features and fertility, providing the variation needed for selective breeding.

Refinement of plant morphology and enhancement of fertility, both genetically complex quantitative traits, required cycles of recurrent selection to increase the frequencies of favorable genes in the population. Each cycle of breeding encompassed growing 700 to 1000 plants, evaluating them for desirable characteristics over two to three years, and intercrossing about 10% of the plants judged best for the selection traits. Each selection cycle required up to five years to complete, but achieved incremental improvements that now are at a level capable of providing transition zone-adapted varieties with turf quality on par with the better vegetatively propagated industry standard varieties.

The incremental improvements achieved thus far are reflected in the characteristics of the two varieties that have been licensed from the program. 'Yukon', the initial variety released from this breeding effort, was a top performer among the seeded varieties in the 1992 National Turf Evaluation Program (NTEP) bermudagrass test (6). Though cold hardy and very well adapted to the transition zone, it lacks the turf quality of the best clonal standard varieties. Additionally, seed yields of 'Yukon' have been lower than desired.

'Riviera', licensed for commercial production in 2001, was a top performer among all varieties in the 1997 NTEP bermudagrass test (7). 'Riviera' represents a significant advance by combining the attributes of seed propagation, good cold tolerance, and high turf quality. 'Riviera' seed yields in Oklahoma over the past three years have exceeded threshold economic levels with some production sites attaining over 700 pounds of pure seed per acre.

'Riviera' plantings on golf courses, playing fields, and lawns have garnered acclaim based on its rapid establishment, high turf quality, winter survival, and ease of management. Plantings of 'Riviera' as far north as Warrensburg, MO and Evansville, IN have had minimal or no winter injury to date, greened up early, and produced a high quality turf fully acceptable to turf managers and sport participants.

These results point to the effectiveness of the breeding process and to the likelihood of continued progress as the effort continues. Newer experimental varieties from the breeding process are in various stages of testing. We expect the incremental improvements achieved by the breeding process to continue.

Vegetatively Propagated Varieties

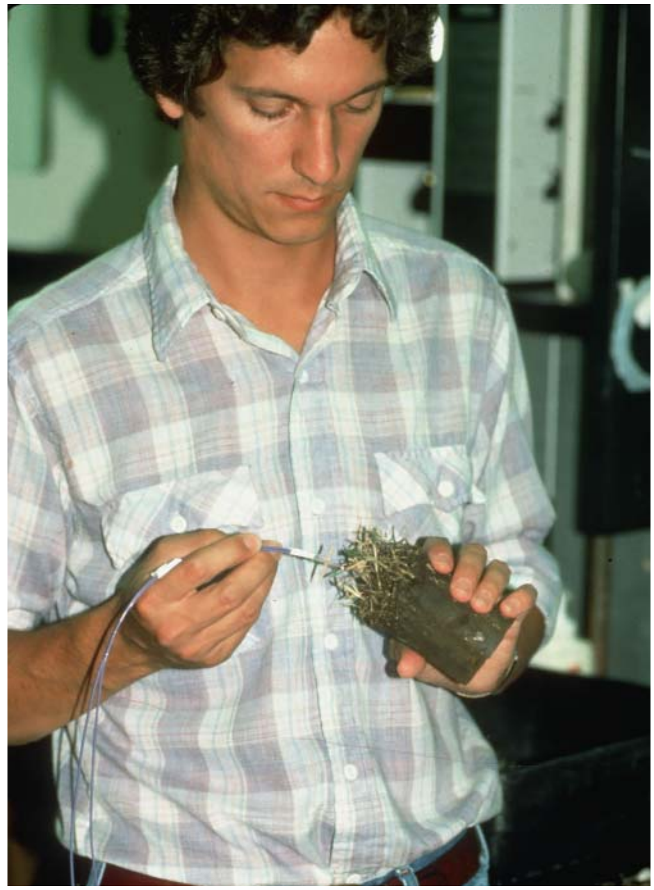
Our efforts to improve vegetatively propagated turf bermudagrasses for the transition zone are focused on producing new varieties that incorporate enhancements for a range of performance traits. Important traits include winter hardiness, high turf quality, high tolerance to spring dead spot disease, good sod strength, and drought tolerance. The traditional turf bermudagrasses used in the transition zone possess some, but not all, of these characteristics. For instance, 'Midiron' and 'Midlawn' turf bermudagrasses bred by Ray Keen at Hays, Kansas rank near the top in cold hardiness compared to other bermudagrass varieties (8, 9). 'Midlawn' has significantly improved turf quality and sod strength compared to its predeces-

A critical need for improved germplasm of bermudagrass is resistance to spring dead spot, a potentially devastating disease of bermudagrass, especially in the transition zone.

sor 'Midiron', but its sod strength is not sufficient to meet the needs of sod growers. 'Midlawn' is also drought sensitive.

The breeding methodology being used is the traditional one of interspecific hybridization between selected parents of *C. dactylon* var. *dactylon* and *C. transvaalensis*. This breeding strategy relies on the identification of good parent plants from the respective species and on producing many crosses and large numbers of progeny plants that increase the chances of finding elite plants possessing the range of desired characteristics. Screening of the large progeny populations is a critical component of the breeding process requiring observation of plants under mowed conditions for at least two years. Plants selected from initial screenings are advanced through testing stages of increasing intensity in the field and laboratory. The effort is analogous to the proverbial search for the needle in the haystack.

The identification of parent plants to use in interspecific crosses has benefited from other aspects of the overall effort. Superior *C. transvaalensis* plants identified in screening tests conducted on golf courses under putting green management have been used extensively as parents in crosses with selected *C. dactylon* parents (10).



A comprehensive breeding and selection program requires a multi-discipline approach. Above, Dr. Jeff Anderson inserts a thermocouple into a pot of improved bermudagrass as he prepares it for artificial freeze testing. Such testing is necessary to select for germplasm with improved cold hardiness.

Recent improvements in bermudagrass cold hardiness have allowed golf courses well into the transition zone to successfullly establish and maintain bermudagrass fairways from seed. Shown above is Hidden Pines Country Club in Warrensburg, MO. Fairways were in play in less than eight weeks following seeding of 'Riviera'. *Photo courtesty: Stan Stoner, Inc. Advertising Agency.*

Elite *C. dactylon* parents identified from the recurrent selection breeding program for seeded varieties and from germplasm procurement have added to the overall quality of triploid hybrids produced.

'Patriot' was recently licensed as a product of this effort. It is an F_1 hybrid from the cross of 'Tifton-10' and a *C. transvaalensis* parent. 'Patriot' has transition-zone adaptation and high turf quality as indicated in extensive testing including NTEP trials (7). The cold hardiness level of 'Patriot' is equivalent to that of 'Midlawn'. It has dark green color approaching that of the 'Tifton 10' parent, sod-strength competitive with 'Tifway', and aggressive growth allowing for rapid establishment and rapid healing from injury such as divoting on golf course fairways.

Developing bermudagrass culitvars with increased resistance to spring dead spot (SDS) requires field testing. Field inoculation techniques using inoculum from SDS causal organisms ensures that selections are exposed to these potentially devasting pathogens in order to assess their inherent resistance. Dr. Dennis Martin (left), Dr. Ned Tisserat (center), and a graduate student assistant (right) are shown artificially inoculating bermudagrass plots to evaluate for resistance to SDS.

'Patriot' differs from other interspecific F_1 hybrid turf bermudagrass varieties in its chromosome number. It has the tetraploid chromosome number of 36 compared to triploid F_1 hybrid varieties with 27 chromosomes. 'Patriot' is tetraploid because it received 27 chromosomes (three basic genomes) from the 'Tifton 10' parent and 9 chromosomes (one basic genome) from the *C. transvaalensis* parent. 'Tifton 10' is a hexaploid with 54 chromsomes. Although 'Patriot' has the same chromosome number as most *C. dactylon* var. *dactylon* plants, it is highly sterile only rarely producing a seed.

Some hybrid plants from the cross of 'Tifton 10' and *C. transvaalensis* were more fertile than 'Patriot' and have been employed in the breeding effort with interesting results. Progeny resulting from use of these plants as parents are highly variable, but include desirable plants of standard and dwarf morphology. The quest for better vegetatively propagated plants is ongoing with large numbers of hybrid plants being produced and evaluated on a continuous basis. As an example, 30 F_1 hybrid plants were placed in a final in-house replicated test this year at the OSU Turf Research Center. These plants trace to crosses made in 1998 and 1999.

Approximately 3000 progeny plants resulting from these crosses were grown in screening nurseries established in 1999 and 2000. Approximately 200 of the 3000 plants were initially selected as candidate varieties and further observation and testing reduced the number to the

30 plants included in the OSU Turf Research Center test. This final in-house test will evaluate these 30 plants for a number of traits including relative cold hardiness, stand persistence, sod strength, spring dead spot resistance, recovery from divoting, and overall visual turf quality.

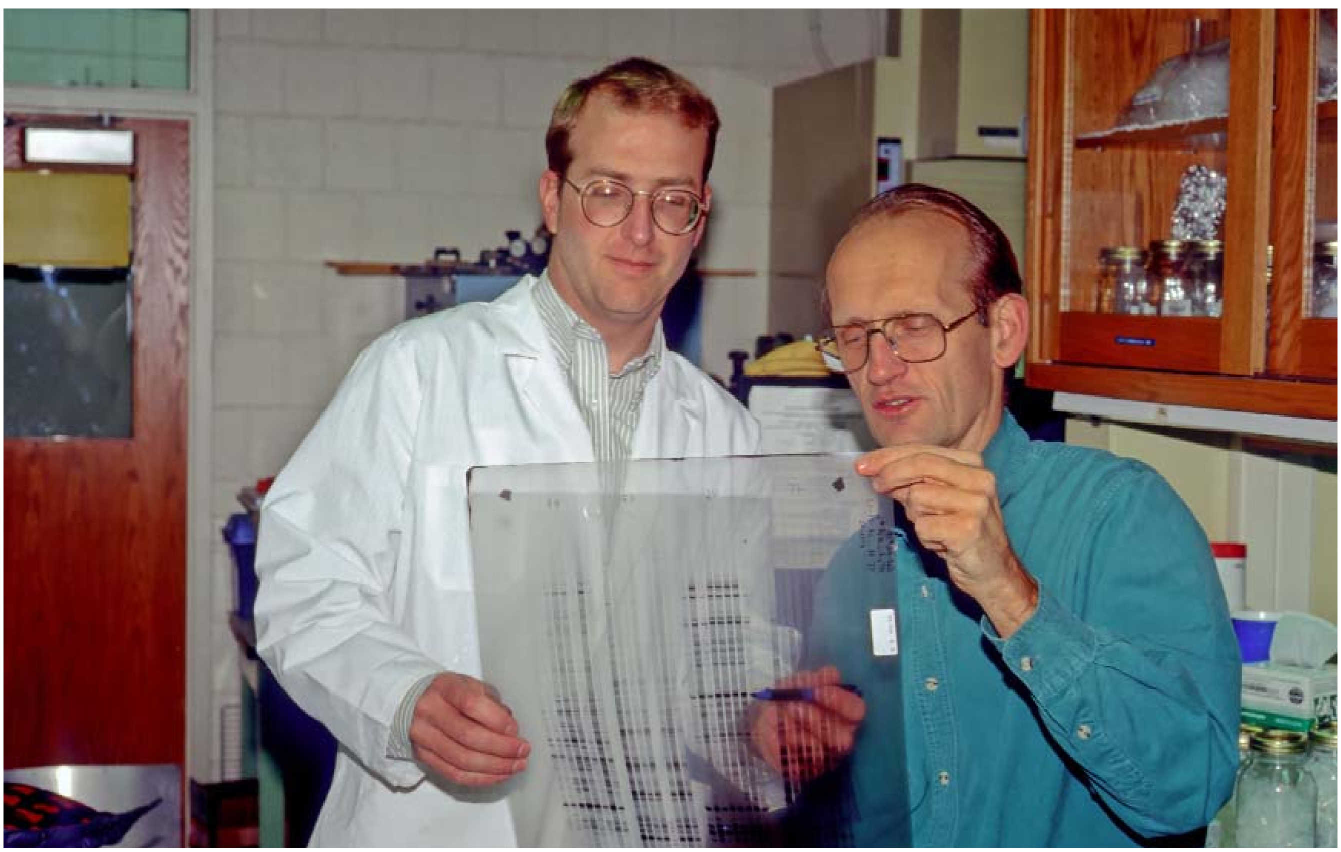
Mining the Germplasm

Access to good germplasm is essential to the success of any plant breeding effort. The availability of the large *Cynodon* germplasm storehouse assembled by J. R. Harlan and associates at OSU was key to the achievements made to date. We have added to that collection over the duration of the current breeding effort and have incorporated elite germplasm accessions into the breeding of both seed- and vegetatively propagated varieties. *Cynodon* germplasm accessions from Africa, Australia, Europe and Asia have been added to the Harlan collection.

Recently acquired germplasm contains accessions with traits of substantial importance to the breeding effort. These include accessions that may be useful in improving seed yield and seed quality of seeded varieties and visual color as an important component of turf quality in both seed- and vegetatively propagated varieties. Hexaploid and pentaploid (45 chromosomes) plants were among the accessions that add to the cytogenetic diversity of the germplasm collection.

A Multidisciplinary Collaborative Effort

Bermudagrass breeding at OSU is part of a multidisciplinary cooperative effort encompassing a range of basic and applied research. Turfgrass scientists play an integral role in the field evaluation of breeding products for the many traits influencing overall performance. Cold tolerance research ranges from laboratory evaluation of plants for relative tolerance to identification and



Dr. Mark Gatschett (left) and Dr. Mike Anderson (right) use advanced biotechnological and molecular genetic tools to understand the genetic control of how bermudagrass responds to two major stresses: infection by a causal organism of spring dead spot and cold.

elucidation of physiological and molecular genetic mechanisms associated with plant response to freezing temperatures. Stress physiologists and molecular geneticists lead this research.

Genes and gene products in the form of chitinase proteins associated with cold response have been identified from this research. Research is underway to determine if the genes can be used in transformation of bermudagrass to increase cold hardiness. Other research seeks to develop a method of biocontrol of spring dead spot disease and identify genes associated with spring dead spot disease and additional genes associated with cold tolerance. It is through this multidisciplinary approach that significant improvements can be made to this highly valuable turfgrass.

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