Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

Oklahoma State University researchers continue their efforts to develop improved bermudagrass varieties for the turfgrass industry. These efforts not only benefit golf courses but playing fields, home lawns, and all turfgrass sites where bermudagrass is adapted. Above, 'Riviera' bermudagrass turf provided excellent playing conditions on two of the 2008 Beijing Summer Olympics baseball fields (image courtesy of Murray Cook, President, Brickman Sports Turf).

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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 350 projects at a cost of $29 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***.

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Recent Progress in Turf Bermudagrass Breeding Research at Oklahoma State University

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SUMMARY

The turf bermudagrass breeding and genetics research program at Oklahoma State University was initiated in 1986 with initial objective to develop seed-propagated varieties of turf bermudagrass with improvements in cold hardiness and turf performance quality. A few years late, the program was expanded to include vegetatively propagated varieties. The program's milestones include:

- 'Guymon' bermudagrass (*Cynodon dactylon*) was released in 1982. 'Guymon' was the first seed-propagated bermudagrass variety which had greater cold hardiness and was persistent in more northern latitudes than the common bermudagrass produced in Arizona or California.
- 'Yukon' bermudagrass (*C. dactylon*) is a seed-propagated turf-type cultivar released by the Oklahoma Agricultural Experiment Station (OAES) in 1997. 'Yukon's exceptional winter hardiness makes it especially desirable and useful in the transition zone.
- 'Riviera' bermudagrass (*C. dactylon*) is a newer seed-propagated variety released in 2001 and represents a new level of breeding progress in the development of seed-propagated bermudagrass varieties.
- 'Patriot' bermudagrass is a vegetatively propagated F1 hybrid variety derived from a cross of 'Tifton 10', a common bermudagrass (*C. dactylon*) by an OSU African bermudagrass (*C. transvaalensis*) selection made in 1992. 'Patriot' was released by the OAES in 2002.
- Genetic variation and diversity of common bermudagrass are associated with their geographic origins.
- Recently, 114 indigenous Chinese bermudagrass (*C. dactylon*) germplasm accessions are being characterized for genetic diversity, ploidy, morphological and adaptive traits, and seed yield and related component traits.

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Bermudagrass is the predominant species used as turf in the southern United States and many other warm regions in the world. Bermudagrass is extensively used on golf courses, sports fields, parks, as well as on residential and commercial lawns. The popularity of bermudagrass for turf is due to its many desirable features including a sod-forming growth habit, long-lived perennial nature, tolerance to frequent low mowing, resistance to many abiotic stresses such as heat and drought, and few major wide-spread biotic pests. High quality, widely adapted, turf bermudagrass cultivars developed by breeding programs have contributed significantly to the widespread use and popularity of the species.

Turf bermudagrass improvement and varietal development began in the 20th century (12). Many improved and superior cultivars were developed and released to the turf industry over the past half century. Turf quality, adaptation, and other traits of the currently used cultivars, especially the industry standards, compared to those of Arizona common bermudagrass can clearly measure the genetic progress made in the bermudagrass breeding programs (1, 2, and 14).

A new turf bermudagrass germplasm nursery containing more than 300 genotypes were established at the OSU Agronomy Farm in 2008.

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Bermudagrass Varieties	Area of Spring Dead Spot		
	1997	1998	1999
	..... (cm^2)		
Mirage	130 a†	990 ab	2,570 a
Yukon	50 b	890 b	1,470 b
Jackpot	130 a	1,360 a	2,870 a

†Different letters in a column indicate significant difference at P=0.05 level.

Table 1. Response of three bermudagrass cultivars to spring dead spot disease. Adapted from Martin et al. (7).

However, challenges and opportunities continue to exist in developing new bermudagrass varieties for two reasons. First, turfgrass end consumers, sod farmers, seed producers, and turf managers have a wish list of improvements in new bermudagrass varieties. Desired improvements include ever increasing expectations for higher turf quality, as well as greater cold tolerance, spring dead spot resistance, shade tolerance, greater drought resistance, sod tensile strength, and seed yield. Second, bermudagrass is so genetically diverse that collecting and screening the world wide germplasm for desirable genes provides extensive opportunity for discovery and incorporation of value-added traits into developing improved cultivars. Incorporating desirable genes from various sources to developing new cultivars is the science and art practiced by turfgrass breeders.

The turf bermudagrass breeding and genetics research program at Oklahoma State University was initiated in 1986 with the financial support from USGA, under the direction of Dr. Charles M. Taliaferro until his retirement in 2006. The initial objective of the program was to develop seed-propagated varieties of turf bermudagrass with improvements in cold hardiness and turf performance quality, which would allow for greater use of the species in the U.S. transition zone (14). The effort was novel as prior turf bermudagrass cultivars performed best in the far southern states and their use in the transition zone was at high risk due to winterkill (2, 14).

Just a few years later, the breeding effort was expanded to include the development of vegetatively propagated varieties. Development of

No.	Entry name	Mean rating
1	Riviera	6.0
2	Yukon	6.0
3	Contessa (SWI-1045)	5.9
4	Sovereign (SWI-1012)	5.8
5	SWI-1044	5.8
6	SWI-1046	5.5
7	SWI-1014	5.4
8	CIS-CD6	5.4
9	Veracruz (SWI-1041)	5.4
10	CIS-CD7	5.2
11	Sunbird (PST-R68A)	5.2
12	CIS-CD5	5.1
13	Transcontinental	5.1
14	Princess 77	5.0
15	SWI-1001	5.0
16	FMC-6	5.0
17	SWI-1003	5.0
18	Lapaloma (SRX 9500)	5.0
19	Southern star	4.9
20	SR 9554	4.9
21	Panama	4.8
22	Sundevil II	4.8
23	Tift No.1	4.8
24	Sunstar	4.6
25	Tift No.2	4.6
26	Mohawk	4.5
27	Numex Sahara	4.5
28	B-14	4.4
29	Arizona common	4.3

LSD value = 0.3
Coefficient of variation (%) = 12.3

Table 2. Turfgrass quality ratings of seeded bermudagrass entries grown at nine locations in the transition region from 2003-06. Turfgrass quality ratings 1-9; 9=ideal turf, data excerpted from Table 3B of the NTEP final report.

cultivars for golf course, especially fairways, was emphasized with performance of experimental selections evaluated under simulated fairway management conditions in the OSU breeding program. The possibility of using African bermudagrass (*Cynodon transvaalensis*) on putting greens was examined as well. Over the years this pioneering research generated several superior turf cultivars. The cold hardy and high turf quality varieties produced by the OSU program have broadened the horizons of this important turf species (14). The improved varieties have been embraced not only by the turf industry in the U.S. transition zone, but also by other nations in the world.

No.	Entry name	Mean rating
1	Riviera (OKS 95-1)	6.6
2	Patriot (OKC 18-4)	6.6
3	Midlawn	6.5
4	Tifgreen	6.3
5	Tifway	6.2
6	Tifsport (Tift 94)	6.1
7	Shanghai	6.1
8	Princess	6.1
9	OKC 19-9	6.1
10	CN 2-9	5.8
11	Cardinal	5.7
12	Transcontinental (PST-R69C)	5.6
13	SWI-11	5.5
14	Southern Star (J-1224)	5.4
15	Blackjack	5.4
16	Majestic	5.3
17	Savannah	5.3
18	J-540	5.2
19	Sydney (SWI-7)	5.2
20	Shangri la	5.1
21	Mini-verde	5.1
22	Pyramid	5.0
23	Sundevil II	5.0
24	Blue-muda	5.0
25	Numex Sahara	4.9
26	Mirage	4.9
27	Jackpot	4.5
28	Arizona common	
	LSD value = 0.2	
	Coefficient of variation (%) = 14.9	

Table 3. Turfgrass quality ratings of bermudagrass entries grown at eleven locations in the USA and maintained using "schedule B"† from 1997-2001. Turfgrass quality ratings 1-9; 9=ideal turf. Data excerpted from Table 2A of the NTEP final report.

Updated Information on Turf Bermudagrass Cultivars Developed and Released at OSU

The discovery and use of bermudagrass plants having good cold hardiness and relatively acceptable seed set ability in forming turf bermudagrass breeding populations led to the development of 'Guymon' bermudagrass (*Cynodon dactylon*) released in 1982 (11). 'Guymon' was the first seed-propagated bermudagrass variety which had greater cold hardiness and was persistent in more northern latitudes than the common bermudagrass produced in Arizona or California (11). Three newer turf bermudagrass cultivars superior in performance, 'Yukon', 'Riviera', and 'Patriot', developed by Taliaferro and colleagues, are currently in commercial production (13, 14).

'Yukon' bermudagrass (*C. dactylon*), tested under the experimental designation OKS 91-11, is a seed-propagated turf-type cultivar released by the Oklahoma Agricultural Experiment Station (OAES) in 1997. The variety has dark green color, relatively fine texture, and produces a dense sod (13). 'Yukon's exceptional winter hardiness makes it especially desirable and useful in the transition zone between the cool-season turfgrass belt in the northern states and warm-season turfgrass belt in the southern states.

In addition to its exceptional cold tolerance field experiments indicate 'Yukon' bermudagrass also has improved spring dead spot disease tolerance (Table 1) (7). 'Yukon' bermudagrass was a top performer among seed-propagated entries in the 1992-1997 and 2002-2007 Bermudagrass Trials in the National Turfgrass Evaluation Program (NTEP) (8, 9). Its high turf quality was best demonstrated in the transition zone (Table 2) (9). 'Yukon' bermudagrass is licensed to Seed Research of Oregon, a Division of Pick Seed USA, for seed production and marketing.

'Riviera' (OKS 95-1) bermudagrass (*C. dactylon*) is a newer seed-propagated variety

No.	Name	Mean Rating
1	Patriot	6.1
2	OKC 70-18	6.0
3	Premier (OR 2002)	6.0
4	Midlawn	6.0
5	Aussie Green	5.9
6	Tifsport	5.9
7	Tift No. 4	5.8
8	Tifway	5.8
9	Contessa (SWI-1045)	5.8
10	Tift No.3	5.7
11	Riviera	5.7
12	SWI-1044	5.7
13	Sovereign (SWI-1012)	5.6
14	GN-1	5.6
15	Yukon	5.5
16	SWI-1046	5.5
17	Veracruz (SWI-1041)	5.5
18	Celebration	5.4
19	MS-Choice	5.3
20	SWI-1014	5.3
21	SWI-1003	5.2
22	CIS-CD6	5.2
23	Princess 77	5.1
24	Ashmore	5.1
25	CIS-CD5	5.1
26	Sunbird (PST-R68A)	5.1
27	CIS-CD7	5.0
28	Tift No.1	5.0
29	Transcontinental	5.0
30	SWI-1001	5.0
31	Lapaloma (SRX 9500)	5.0
32	Southern Star	4.9
33	SR 9554	4.9
34	FMC-6	4.9
35	Tift No.2	4.8
36	Sundevil II	4.8
37	Panama	4.7
38	Sunstar	4.6
39	Mohawk	4.5
40	Numex Sahara	4.5
41	Arizona Common	4.4
42	B-14	4.4
	LSD value (5%)	0.3
	Coefficient of variation (%)	11.8

Table 4. Turfgrass quality ratings of bermudagrass cultivars in the 2002 NTEP National Test managed using "schedule B". Data excerpted from Table 2A, 2003-06 Data: Final Report NTEP No. 07-10.

released by the OAES in 2001. 'Riviera' was a top performer in NTEP bermudagrass tests for 1997-2001 and 2002-2006 (Table 2 and Table 3). Subsequently it was selected as a standard variety in the 2007 NTEP bermudagrass test (9). 'Riviera' combines the attributes of increased seed production, improved cold tolerance, and high turf quality (14). The variety represents a new level of breeding progress in the development of seed-propagated bermudagrass varieties. 'Riviera' bermudagrass is used on golf courses, sports fields, and lawns.

Notably, 'Riviera' was used in the 2008 Beijing Summer Olympics baseball field construction (cover photo). The grass performed very well in 32 matches as indicated in a letter to the senior author by W. Harvey, President of International Baseball Federation. 'Riviera' is licensed to the Johnston Seed Company for commercial production.

'Patriot' bermudagrass, tested as OKC 18-4, is a vegetatively propagated F1 hybrid variety derived from a cross of 'Tifton 10', a common bermudagrass (*C. dactylon*) by an OSU African bermudagrass (*C. transvaalensis*) selection made in 1992. 'Patriot' was released by the OAES in 2002. 'Patriot' has unique dark green color, high turf quality, and wide adaptation including the transition zone. It has provided superior performance on many sports fields (14). Its aggressive growth habit allows for rapid establishment and rapid healing from injury as occurs with divots on golf course fairways and teeboxes (14).

Licensed sod producers indicated rapid sod production cycles from planting to harvest (6). Because of its excellent characteristics, 'Patriot' bermudagrass currently is experiencing increased use in golf courses and on sports fields in transition climates in the USA. Sod producers have recently produced or tested 'Patriot' bermudagrass in Italy, S. Africa, and Australia. 'Patriot' was a top performer in the NTEP bermudagrass tests maintained using "schedule B" for the last 10 years (Table 3 and Table 4).

Three Promising Experimental Selections in NTEP

Three new promising experimental bermudagrass selections developed by the OSU turf bermudagrass breeding program are currently being trialed in the 2007 NTEP Bermudagrass National Test. The three selections include two vegetatively propagated hybrids, OKC 1119 and OKC 1134, and one seed-propagated entry, OKS 2004-2. The two clonal bermudagrasses are interspecific hybrids derived from crosses of common bermudagrass (*C. dactylon*) by African bermudagrass (*C. transvaalensis*) parents. They were

No.	AMMI Group 1		AMMI Group 2	
	Entry	Mean Rating	Entry	Mean Rating
1	OKC 1119	7.1	Tifway	6.9
2	OKC 1134	6.8	Premier	6.7
3	Tifway	6.7	OKC 1119	6.6
4	Premier	6.6	OKC 1134	6.3
5	Patriot	6.5	SWI-1070	6.2
6	SWI-1113	6.1	SWI-1113	6.2
7	OKS 2004-2	6.1	SWI-1057	6.1
8	Riviera	6.1	Veracruz	6.1
9	SWI-1070	6.0	PSG 9Y20K	6.1
10	Midlawn	6.0	SWI-1122	6.0
11	PSG 9Y20K	5.9	RAD-CD1	6.0
12	SWI-1122	5.8	Princess 77	6.0
13	SWI-1057	5.8	OKS 2004-2	5.9
14	PSG 9BAN	5.8	Hollywood (J-720)	5.8
15	RAD-CD1	5.8	Riviera	5.8
16	Princess 77	5.7	Pyramid 2 (IS-CD10)	5.8
17	SWI-1083	5.7	IS-01-201	5.7
18	Veracruz	5.7	Patriot	5.7
19	IS-01-201	5.7	SWI-1083	5.7
20	Hollywood (J-720)	5.7	PSG 9BAN	5.7
21	Yukon	5.7	SWI-1081	5.6
22	SWI-1081	5.6	PST-R6FLT	5.6
23	Pyramid 2 (IS-CD10)	5.6	PSG PROK	5.5
24	PST-R6FLT	5.5	Yukon	5.4
25	BAR 7CD5	5.5	PSG 91215	5.3
26	PSG PROK	5.5	SWI-1117	5.3
27	PSG 91215	5.3	PSG 94524	5.2
28	SWI-1117	5.2	BAR 7CD5	5.2
29	PSG 94524	5.2	Midlawn	5.1
30	Sunsport	5.2	Sunsport	5.1
31	Numex-Sahara	5.1	Numex-Sahara	4.9
	$LSD_{(0.05)}$	0.6		0.6
	Coefficient of variation (%)	6.7		6.8

Table 5. Turfgrass quality ratings of bermudagrass entries in the 2007 NTEP National Bermudagrass Test in VA, NC, MS, TN, LA, OK, TX (College Station), OK, AMMI Group 1, and FL, KY, TX (Dallas), AMMI Group 2 (Excerpted from Table 1A and Table 2A of 2008 Progress Report NTEP No. 09-1).

selected in space-planted nurseries, and then comprehensively evaluated in-house before their entering into the national test (3, 6, and 14).

'OKC 1119' and 'OKC 1134' bermudagrasses have fine texture, and are improved in turf quality and cold hardiness, and have outstanding sod tensile strength (3). The two experimental bermudagrasses are top performers at seven locations in VA, NC, MS, TN, LA, OK, TX (College Station site), and their quality approaches that of the top performer 'Tifway' bermudagrass at three locations in FL, KY and TX (Dallas site) in the 2007 NTEP National Bermudagrass Test (Table 5). 'OKC 1119' and 'OKC 1134' are also top performers in the 2007 NTEP test under saline stress at Las Cruces, NM. 'OKS 2004-2' is a top performer among seeded entries at seven locations in the AMMI Group 1 and one location, CA in the AMMI Group 4 in the 2007 NTEP national test (Table 5). The three OSU experimental entries

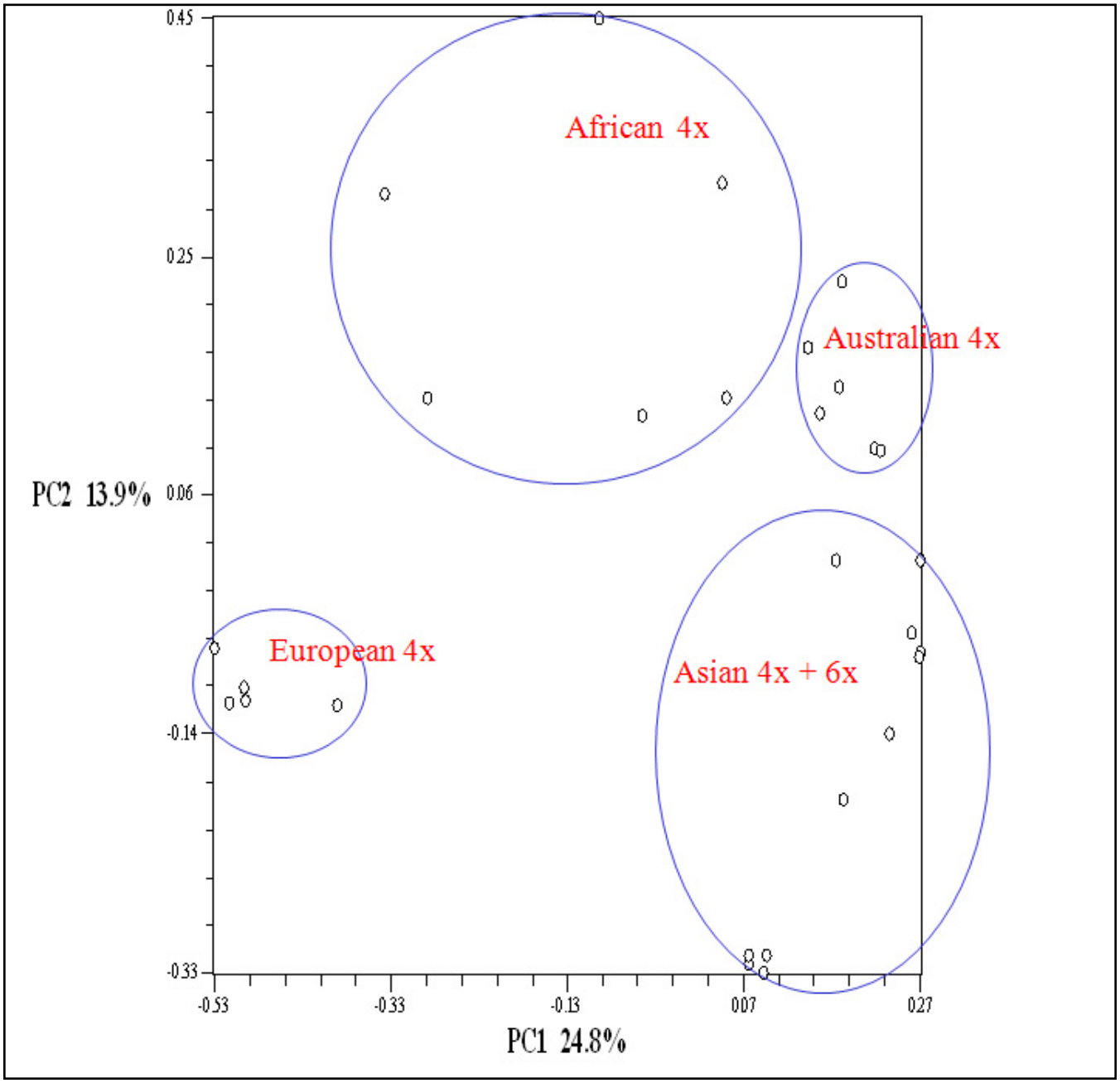

Figure 2. Genetic diversity groupings for 28 *Cynodon dactylon* var. *dactylon* accessions from Africa, Australia, Asia, and Europe using 443 molecular markers suggest that bermudagrass genetic variation is fragmented by continent. Adapted from Wu (15).

have the highest ratings for spring green-up trait across all NTEP testing sites.

New Information on Turf Bermudagrass Germplasm

Two of nine *Cynodon* species are the most utilized for the development of turf bermudagrass varieties. They are *C. dactylon* var. *dactylon*, often called 'common bermudagrass', and *C. transvaalensis*, 'African bermudagrass'. Access to genetically elite germplasm of both species is critical for a turf bermudagrass breeding program (14). A worldwide *Cynodon* collection was amassed at Oklahoma State University, and used for a comprehensive biosystematic investigation leading to a revised taxonomy of *Cynodon* genus by J.R. Harlan, J.M.J. de Wet, W.W. Huffine, and associates in the 1960s (4). Over the past 40 years, C.M. Taliaferro and associates added more *C. dactylon* var. *dactylon* and *C. transvaalensis* germplasm collected from Africa, Australia, Europe, and Asia to the initial pool. The large germplasm collection provided genetic stocks for the development of the OSU superior turf bermudagrass cultivars and is being used in the current breeding efforts.

Common bermudagrass is geographically widely distributed between about 45° south and 45° north latitudes, extending to about 53° N latitude in Europe. Our genetic diversity and relatedness analysis of common bermudagrass from Africa, Australia, Asia, and Europe using Amplified Fragment Length Polymorphism (AFLP) markers indicates that the genetic variation and diversity of common bermudagrass are

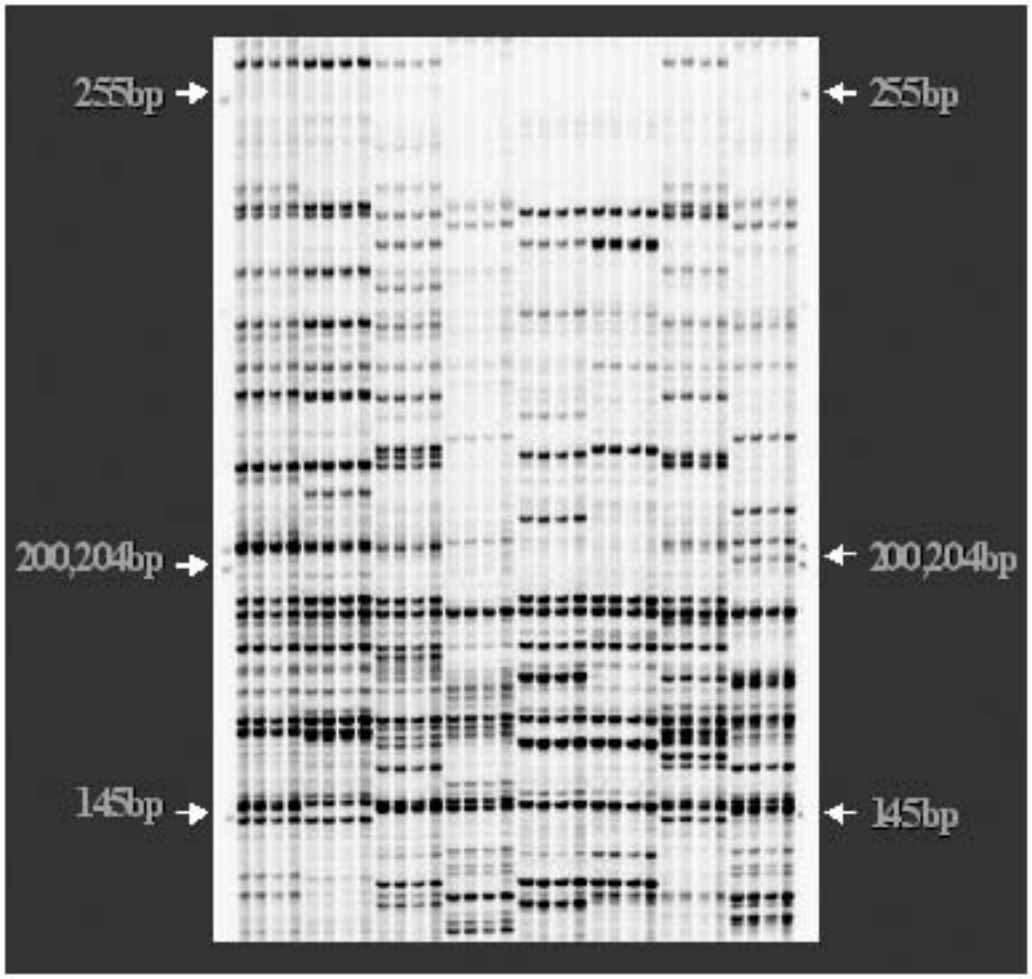

Figure 3. A typical gel image of bermudagrass DNA bands generated by a selective primer pair of amplified fragment length polymorphism system indicates the marker system produces multiple bands which are highly reproducible. Adapted from Wu (15). Note that four replicates for each of eight DNA samples.

Ploidy (chromosomes per somatic nucleus)	Accessions	Genetic Similarity Coefficient Range†
4x (36)	103	0.69-0.99
5x (45)	3	0.95-0.98
6x (54)	8	0.77-0.99

† Genetic similarity coefficient range represents genetic diversity.

Table 6. Ploidy and genetic diversity of 114 native Chinese bermudagrass accessions.

associated with their geographic origins (Figure 2). For example, bermudagrass from Asia is clearly genetically different from that of Africa, Europe and Australia. AFLP is an excellent molecular marker system, especially for genetic diversity analysis as one selective primer pair produces multiple reproducible polymorphic DNA bands (Figure 3).

Our research results suggest the need for an expansion of the current collections from the major geographic regions of its distribution range in order to take advantage of the world wide genetic diversity (15). Recently, 114 indigenous Chinese bermudagrass (*C. dactylon*) germplasm accessions were characterized for genetic diversity, ploidy, morphological and adaptive traits, and seed yield and related component traits (16, 17, and 19). Our study indicates there are three ploidy levels (tetraploid, pentaploid and hexaploid) in the native Chinese bermudagrass collections and tetraploid bermudagrasses contain the largest genetic variation among the three ploidy levels within the Chinese collection (Table 6).

Figure 4. Chinese bermudagrass accessions are diverse in morphology.

The Chinese germplasm is not only diverse in molecular marker polymorphisms, but also contains desirable turf quality related traits (Figure 4). For example several Chinese bermudagrass accessions consistently produced more seeds than other accessions (Figure 5). The collection will be useful in genetic improvement and development of seeded and clonal turf bermudagrass cultivars.

African bermudagrass is valued as turf and for use in interspecific hybridization with common bermudagrass to produce hybrid cultivars. The species is endemic to a region in South Africa. Plants of African bermudagrass are small in size and have yellow-green, erect narrow leaves. Although African bermudagrass is important for new hybrid variety development, information on the magnitude of genetic variation in the species is limited. Our investigation on molecular marker variation of 14 African bermudagrass accessions using AFLP polymorphisms indicates substantial presence of genetic diversity in the species (18). Variation for morphological and adaptation traits has been observed in segregating populations of African bermudagrass (10).

A recent study using field and greenhouse experiments indicates that African bermudagrass contains genetic variation for many turf performance traits and broad sense heritability estimates are moderate to high (5). Not surprising, those results collectively suggest the genetic potential in African bermudagrass could be exploited in intra-

and inter-specific improvement using conventional breeding selection methods.

Current Breeding Efforts and the Collaborative Team

Specific objectives of our current breeding work are multi-fold. These include 1) assembly and maintenance of *Cynodon* germplasm with potential for contributing to the breeding of improved turf cultivars, 2) improvement of bermudagrass germplasm for seed production potential, cold tolerance, and other traits that influence turf performance, and 3) development, evaluation and release of improved seed- and vegetatively-propagated turf bermudagrass varieties. In support of the efforts, a new turf bermudagrass germplasm nursery containing more than 300 genotypes was recently established on the OSU Agronomy Farm.

Two broad-based common bermudagrass populations were formed to initiate recurrent phenotypic selection, one being tetraploid planted in 2006 and another being hexaploid established in 2007. Twenty-four clonal plants and five experimental seed propagated entries have been selected for comprehensive field evaluation at the OSU Turf Research Center. The clonal plants were selected from a screening nursery of more than 1,000 plants, established in 2006. The clonal and seeded selections were derived from crosses made in previous years. A new screening nursery of about 1,500 clonal plants, established in 2008, is now being screened for desirable traits. The newer clonal plants are putatively hybrids from crosses of Chinese common bermudagrass by OSU African bermudagrass selections.

Our in-house comprehensive evaluation of the promising turf bermudagrass selections from the breeding program involves research characterization for many turf performance and adaptation traits including turfgrass quality, freeze tolerance, sod tensile strength, spring dead spot disease resistance, and drought tolerance. Field-based evaluation of shade tolerance of selected bermudagrass germplasm has been initiated and led by Dr. Greg Bell at the Turf Research Center.

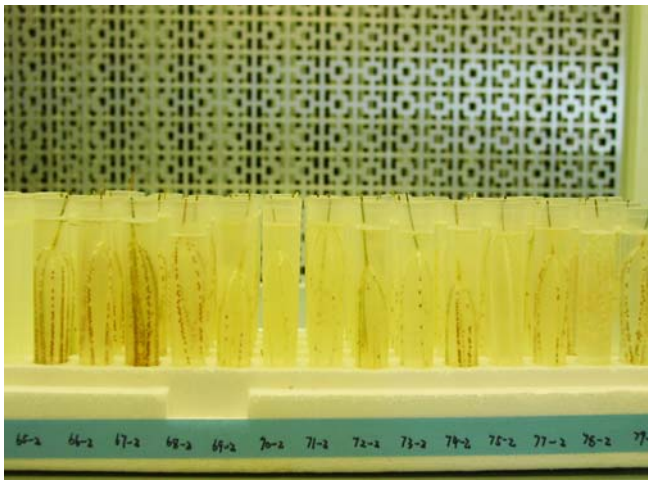

Figure 5. Some native Chinese bermudagrass accessions are prolific in seed setting.

Dr. Justin Moss joined OSU turf team in 2008 leads on expanded drought tolerance and related research. The turf bermudagrass breeding and development group is part of the OSU multidisciplinary turf team conducting both basic and applied research.

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