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Moving warm-season forage bermudagrass (*Cynodon* sp.) into temperate regions of North America.

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Key words: Breeding; Bermudagrass; cold tolerance

Abstract

Warm-season (C4) perennial grasses are grown over millions of hectares in the Southeastern United States. These grasses produce optimal growth at 30 to 38°C diurnal temperature. Bermudagrass (*Cynodon* sp.) has been adopted as the preferred forage for many livestock and hay producers. Compared to other native and introduced warm-season perennial grass species, improved bermudagrass varieties produce high biomass with enhanced digestibility for ruminant grazing or feed. Until the 1930's pastures in the region consisted of unimproved 'common' bermudagrass (*Cynodon dactylon* (L.) Pers.) that had been introduced earlier. However, in the early 20th century, new germplasm, including stargrass (*C. nlemfuënsis* Vanderyst) was collected, primarily from Africa. This germplasm provided a source for major improvements in yield and digestibility. Unfortunately, stargrass is not cold tolerant, limiting it to regions between 30°N and 30°S. Intercrossing of *C. nlemfuënsis* with *C. dactylon* has produced highly successful cultivars, such as Tifton 85, which can survive at northern latitudes of at least 35°. However, there has been a desire to extend adaptation further north into the warm-season/cool-season grass transition zone. This would require a combination of breeding to improve cold tolerance in clonally-propagated varieties and development of seeded varieties that could be re-seeded following extremely cold winters. Earlier work at Oklahoma State University indicated that some cultivars had significantly different tolerance to freeze. Screening the Tifton, GA, USA core collection of 175 accessions in a northern, high-altitude location, has identified germplasm with promising cold tolerance. A breeding line (Tifton 79-16) had significantly higher yields at the northern Georgia location than the cold tolerant cultivar (Tifton 44). A number of plant introductions had higher yields as well.

Introduction

As the overall climate throughout the world changes to warmer, drier conditions, it will be important to identify forages with greater adaption. In many parts of the temperate world, cool-season grasses predominate due to adaptation to colder temperatures (5°C to 25°C). However, warm-season grasses that produce biomass using C4 photosynthesis are much more productive during the hot, dry months of summer. They thrive in temperatures between 20°C to 35°C and are much more drought tolerant (Moore et al., 2004). In the transition zones between warm season and cold season perennial grasses of North America, C4 grasses can maintain productivity while C3 grasses are transitioning to a reproductive stage with minimal vegetative growth. For this reason, warm season grasses could replace a portion of the pastures at latitudes greater than 35°. Worldwide, there are several warm-season forage grass species. Some of these perennial grasses have adapted to more northern climates such as upland switchgrass (*Panicum virgatum* L.). However, bermudagrass (*Cynodon* sp.) is considered the most valuable C4 forage in the southern United States (Taliaferro et al., 2004) due to its ability to be used for grazing, green chop, or stored forage production. Cultivars have been developed that produce over 20 Mg/ha dry matter per year with high forage quality (Burton et al, 1993). Adaptation of bermudagrass to the transition zone is limited due to its intolerance of extended freezing temperature during winter. Since the most productive bermudagrass cultivars are propagated vegetatively, the expense of reestablishment on a yearly or biannual basis is prohibitive.

Cynodon dactylon L has adapted to colder climates and landraces have been collected in many temperate areas (Taliaferro et al., 2004). The cold tolerance is primarily due to the presence of rhizomes that are underground structures that can survive cold winters. However, stargrass (*C. nlemfuënsis* Vanderyst) is more productive and has better nutritive value. This species generally lacks rhizomes and does not survive above 30° latitude. Developing cold-tolerant and productive forage bermudagrass cultivars will require screening and selecting parental lines in latitudes higher than 30.

Work on cold tolerance in turf-type and forage-type bermudagrass has been performed at Oklahoma State University. A laboratory freeze screening method was developed to assist in evaluating genotypes (Anderson et al., 1993; Anderson and Taliaferro, 1995). Studies were conducted in the laboratory with plant material being established and acclimated in growth chambers. These cloned plants were then subjected to a range of temperatures in a freeze chamber. The laboratory evaluations corresponded well with field observations and has given geneticists and plant physiologists useful information on characteristics associated with freeze tolerance in turfgrasses. Cold tolerant turf-types were identified using this technique (Anderson et al., 2002, 2007; Munshaw et al., 2006). Most of the cold tolerant lines can be traced to species and germplasm originating from northern climates. Laboratory results from Oklahoma State University resulted in significant freeze tolerance by cultivars developed in Oklahoma (Fig. 1). Tolerant cultivars were developed from parents originating from temperate origins including 'Ozark' developed from a cross between Coastal and an accession from Afghanistan (PI 253302). 'Midland 99', 'Goodwell', and 'Hardie' all have genetic background from Afghanistan, as well as some other accessions from temperate climates.

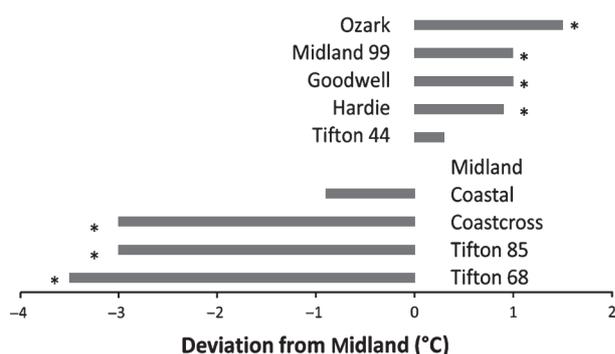


Figure 1. Freeze tolerance of forage bermudagrass cultivars compared to Midland ($P = 0.05$). (Anderson and Wu, 2011). (Negative values reflex less cold tolerance than Midland)

Other than this, relatively little work has been done on forage cultivars or germplasm. More work to screen larger numbers of germplasm was needed. For this purpose, a core collection of 175 accessions was evaluated at Blairsville, GA, US over two years.

Research on cold tolerance in forage bermudagrass

Three replications of the entire core collection were randomized in the field in the mountains of North Georgia at Blairsville, GA, (34.84 Lat., -83.93 Long., 590 m Elev.) with average minimal temperatures of -3.9°C . One plant (8 cm pot) was transplanted on June 28, 2007 for each experimental unit, allowed to establish and clipped in September. Emergence in the spring was rated on a 0 to 5 scale (0 = not emerged; 1 = 1-5 green stems or stolons; 2 = 6-15; 3 = 16-30; 4 = 30-50; 5 = greater than 50 stems or stolons) on April 15, 2008 and May 11, 2009. Percentage plot cover was recorded on April 30, 2008 and June 29, 2009. Plant height (to last fully expanded leaf) was recorded May 12 and June 6, 2008 and again on August 6, 2008. Plant diameter was measured June 6, 2008. Plots were clipped June 30, 2008 and June 29, 2009, leaving a 5 cm stubble. In 2008, the entire above ground plot was harvested since there was variation in cover for individual plots. Material was dried at 50°C and weighed to determine dry mass. Herbage accumulation was calculated in 2008 by determining the dry weight for the area of the harvested plot ($Y = A * \text{dry matter weight of plot}$) where area ($A = \pi r^2$). Yield was determined in 2009 by clipping a 929 cm^2 area in the centre of the plot. Height of regrowth was recorded August 6, 2008 and August 5, 2009. Dry plant material from 2008 was ground with a Wiley Mill through a 1-cm screen. *In vitro* dry matter digestibility (IVDMD) and fiber components were determined by using previously calibrated NIRS equations (Barton and Windham, 1988).

Results

Due to the cold winters of 2008 and 2009, 31 entries did not survive. Of the remaining 142 entries 20 accessions had a higher average yield than Tifton 44. A few exhibited greater IVDMD than Tifton 44 including PI 290660. Among the most cold-tolerant lines from Blairsville, PI 225809 and PI 291724 might be used in breeding to improve seed set, germination and cold tolerance (Table 1). Emergence on these lines were similar

to Tifton 44 and Coastal. Most had fine texture leaves and stems and one line (PI 290660) had superior IVDMD.

Table 1. Cultivar name or plant introduction number (PI), *Cynodon* species, and mean performance for spring emergence, plant height (cm), herbage accumulation per year and average for two years (kg/ha), leaf and stem texture, and IVDMD for 13 bermudagrass genotypes grown in Blairsville, GA between 2007 and May 2009.

Entry/PI	Species	Emergence Rating		Pl. height (cm)	Yield kg/ha			Stem texture	IVDMD
		2008	2009	9/17/2009	2008	2009	2Y Avg		
Tifton79-16	<i>C. dactylon</i>	3.3	3.3	14.7	9841	10182	10012	Fine	56.1
293606	<i>C. dactylon</i>	2.7	3.7	16.3	6516	11400	8959	Fine	56.5
290660	<i>C. dactylon</i>	2.3	3	7.5	7599	10074	8837	Fine	65.0
289917	<i>C. dactylon</i>	4.2	4.7	12.7	8732	8820	8775	Coarse	56.1
289748	<i>C. polevansii</i>	3.3	4.3	10	7823	9537	8680	Fine	56.8
212293	<i>C. dactylon</i>	3.8	4.3	13.7	5720	11114	8417	Medium	55.7
206553	<i>C. dactylon</i>	3.7	3.3	13.3	7037	9250	8144	Fine	54.4
225809	<i>C. spp</i>	1.7	2	14.3	7202	8784	7992	Fine	54.9
291575	<i>C. bradleyi</i>	2	2.3	12.7	6589	9393	7991	Fine	54.0
292544	<i>C. dactylon</i>	3.7	3.3	11.7	6206	9393	7800	Fine	56.2
Tifton 44	<i>C. dactylon</i>	3.2	5	14.3	4504	9465	6984	Medium	57.1
Coastal	<i>C. dactylon</i>	2.6	3.7	14.7	3572	8497	6035	Medium	61.3
Tifton 85	<i>C. spp</i>	1.8	1.3	13.5	4726	4517	4622	Coarse	65.3
	Means	1.8	2.1	10.9	3881	5310	4370		58.7
	MSD	1.4	1.6	3.6	534	2388	2211		4.5

Discussion

The development of forage bermudagrass for the transition zone between sub-tropical and temperate climates in the United States has progressed for the past 80 years. Coastal bermudagrass became a standard cultivar starting in the 1940's. 'Tifton 44' then was released as a more cold-tolerant cultivar, and for more than half a century was the cultivar recommended for the transition zone. More recently, a number of cultivars were developed at Oklahoma State University that had greater freeze tolerance. However, all of these cultivars were derived from *C. dactylon* parents which did not confer improvements in forage quality. For quality improvements, *C. nlemfuënsis* or selected *C. dactylon* accessions need to be used to increase digestibility. The PI 290660 is a candidate for use as a parent based on field evaluation in the mountains of North Georgia. More accessions need to be tested and used for further advancement. Climate change may make a larger area of the United States more conducive to growing forage bermudagrass and combined with greater freeze tolerant cultivars, more cattlemen and hay producers will reap the benefits.

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