Advances in bermudagrass research involving new cultivars for beef and dairy production[1]

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ABSTRACT: Bermudagrass (*Cynodon dactylon*) has been the most popular warm-season perennial grass for hay production and pastures in the southern United States for several decades. It persists on sandy, acidic soils, and N fertilization increases yields. Many new cultivars thrive in the United States and are being established in South America and other tropical environments. Hybrid bermudagrasses, including 'Coastal,' released in 1943, are sterile and require establishment from roots and rhizomes, which may increase establishment costs. Vigorous hybrid cultivars may be established using spring top-growth cut at advanced maturity and planted in moist soils. Seeded bermudagrasses have been developed, but few compare with hybrid cultivars, including 'Tifton 44,' 'Tifton 78,' 'Midland,' and 'Tifton 85,' for yield, persistence, or quality. Tifton 85 offers hay production potential in the establishment year, whereas most cultivars do not produce enough forage for hay production or heavy grazing until the 2nd yr. After 8 yr, Tifton 85 has increased acceptance and popularity among hay and cattle producers in the United States, and more than 1×10^6 ha have been planted in Brazil. Dry matter yield and forage digestibility have been consistently higher for Tifton 85 than for Coastal and other cultivars, which allows increased stocking rates and greater gain/hectare. Tifton 85 hays have consistently had higher in vitro and in vivo digestibility than Coastal or Tifton 78 hays, even when NDF of the Tifton 85 hay was above 70%. Recent experiments confirmed lower concentrations of ether-linked ferulic acid in Tifton 85 than in Coastal forage, which explains the higher digestibility of Tifton 85 than of Coastal hays. Dairy research indicated that during cool weather, comparable milk yields occurred when Tifton 85 hay was substituted for alfalfa hay in a total mixed ration. In tropical countries 'Coastcross-1' and Tifton 85 have been rotationally grazed by dairy cows. Bermudagrasses will continue to be primary perennial grasses for much of the southern United States, and research efforts may provide cultivars with more digestible fiber, greater cold tolerance, and wider adaptability for hay production and grazing for beef and dairy cattle.

Key Words: Cattle, *Cynodon dactylon*, Forage, Grazing, Hay

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Introduction

In the southern United States, beef cattle and dairy farms depend on bermudagrass (*Cynodon dactylon*) as a primary grazed forage from early spring until autumn. Thousands of tons of bermudagrass hay are fed to beef and dairy herds during winter and drought periods annually. Many southern dairy producers graze milking herds on bermudagrass pastures for varying intervals, along with other higher-quality forages and limited grain supplementation. Some dairies incorporate bermudagrass hay in total mixed rations (**TMR**), and many dairies rely on bermudagrass pastures and hay for development of replacement heifers and maintenance of nonlactating, pregnant cows. Numerous bermudagrass cultivars and selections are grown in the United States, but none are as widely used as Coastal bermudagrass. More than 4×10^6 ha of Coastal bermudagrass are grown from the Carolinas to California, a tribute to the adaptability, persistence, yield, and quality of this grass, which was released in 1943 by Glenn Burton, USDA-ARS, Tifton, GA. Coastal remains the standard for comparison with new bermudagrass selections and hybrids in most of the South. Midland bermudagrass (Harlan et al.,1954), a cross made by Dr. Burton between Coastal and a selection from Indiana and released in 1954, is the standard for new cultivar comparisons in the upper South and Southern Plains. Bermudagrass stands often persist and remain productive for more than 35 yr if properly managed. Most are tolerant to

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acidic and sandy soils, moderate to heavy grazing pressure, variable rainfall distribution, and differing management. Almost all are dual-purpose, producing pasture forages and hay. This paper discusses some of the current research and management practices used with various bermudagrasses and new forage quality and production efficiency discoveries that will enhance these forages.

Discussion

Perspectives on Bermudagrass Cultivars

Many people in South America and the United States refer to 'Tifton 85' bermudagrass as "Tifton." Terminology should be more specific, because there are many bermudagrass, turfgrass, bahiagrass, and other forages with "Tifton" in the name, often followed by a number. Many of the "Tifton" cultivars have distinct growth, appearance, and quality attributes. Popular "Tifton" bermudagrasses include 'Tifton 44' (Burton and Monson, 1978), 'Tifton 68' (Burton and Monson, 1984), 'Tifton 78' (Burton and Monson, 1988), and 'Tifton 85' (Burton, et al., 1993). 'Coastcross-1' (Burton, 1972) is widely used in Cuba, Mexico, Puerto Rico, Central America, Venezuela, and Brazil, but it is only used in a limited area in the United States because it has very little cold tolerance. Many additional bermudagrasses were developed by Dr. Burton at Tifton, Georgia, and some were released by experiment stations in other states ('Midland' in Oklahoma; 'Brazos' in Texas; 'Grazer' in Louisiana; 'Florikirk' in Florida). Most bermudagrasses released by Dr. Burton and his associates were successfully adapted by producers over a wide region because of the systematic procedure that involved greenhouse and small-plot experiments and IVDMD analyses, and finally persistence, digestibility, and animal performance with grazed forages over a number of years. Dr. Burton was one of the first plant geneticists to incorporate IVDMD as a key screening criterion of quality of new plant selections.

A brief description of "Tifton" bermudagrasses reveals large differences among these grasses. Tifton 44 has small stems and leaves and is similar in quality to Coastal but it has superior cold tolerance, resulting from huge numbers of rhizomes. Tifton 44 is slow to establish, often taking more than a year at Tifton, Georgia. It is preferred by many horse producers in the United States. Tifton 44 is grown all across the South and Southern Plains. Tifton 68 is a large plant, with an open canopy, large stems, and wide leaves, and it is often pale green in color. Tifton 68 has the highest quality and is one of the higher-yielding bermudagrasses released by Dr. Burton. It is not grown on farms in the United States because it has very few, if any, rhizomes, resulting in poor cold tolerance, but it is maintained and used as a parent in crosses to increase yield and quality.

Perhaps the crown jewel of Dr. Burton's more than 60-yr forage breeding career is 'Tifton 85' bermudagrass (Burton et al., 1993). It is a hybrid resulting from crossing Tifton 68 with a plant introduction from South Africa. It is darker green in color, taller, has larger stems and wider leaves than Coastal and Tifton 44, and it is considerably higher in quality than Coastal (Burton et al., 1993). Tifton 85 is more productive than Coastal or Tifton 44 during the establishment year, and it can be established from top-growth forage if soil moisture is adequate. It has been more productive in beef cattle grazing trials than Tifton 78 (Hill et al., 1993) or Coastal and Tifton 78 (Hill et al., 1997a). Although NDF concentrations are often very high in Tifton 85, this grass has been highly digestible in beef and dairy cattle digestion experiments (Hill et al., 1997b; West et al., 1997; Mandebvu et al., 1999a,b).

More than 500,000 ha of Tifton 85 have been established in Brazil since 1995, and Tifton 85 is being established in Mexico, Venezuela, and other tropical countries. A new research initiative has begun in Brazil with primary emphasis on evaluation of new bermudagrass cultivars, including Tifton 85 and Florikirk compared with Coastcross-1 under grazing, with measurements of plant and animal responses to different stocking rates and forage mass. Pedreira et al. (2000) grazed Florikirk pastures at different stocking rates and rest periods. They reported postgrazed light interception of 22% for an 8-cm stubble height but 78% or greater light interception at a stubble height of 24 cm. Fagundes et al. (1999b) reported similar rates of DM accumulation when Tifton 85, Florikirk, and Coastcross-1 pastures were grazed to 5, 10, 15, or 20 cm by sheep. There was no advantage in DM production when sward heights exceed 20 cm, and the 20-cm swards presented the highest values for leaf area index and light interception. In a related study, Fagundes et al. (1999a) found that proportion of live material in the sward differed among cultivars, with a ranking of proportion of live material of Tifton 85 > Coastcross-1 > Florikirk. Leaf proportions in swards were ranked as Tifton 85 > Coastcross-1 = Florikirk. De Carvalho et al. (1999) observed higher tiller turnover rates, higher tiller population, and higher population densities in Tifton 85 swards subjected to higher grazing intensity than under lower grazing intensity. Tillers that began the grazing season in August were almost entirely replaced by January. Carnevalli et al. (1999) kept Tifton 85 sward heights at 5, 10, 15, or 20 cm with grazing Santa Inez crossbred lambs (18 kg initial BW), paired by sex and BW. Nutritive value of forage was different for sward heights ($P < 0.05$); short swards (5 cm) had the highest CP and IVDMD, but lamb performance was more dependent on carrying capacity and herbage allowance, with lambs performing better on longer swards (15 to 20 cm). Additional research is being conducted with bermudagrass selected as a focal point of necessary research for this country.

Many additional cultivars and selections of bermudagrass are grown across the southern United States. Some are naturally occurring crosses, usually of limited distribution but often having greater persistence and yield than released cultivars in the immediate vicinity of the new bermudagrass origins. Many of these selections do not compare well with hybrid bermudagrasses in controlled yield trials, even in the same region. Even though Tifton 85 is highly persistent and productive in the deep South, production declines as it is moved northward. Tifton 44, is not as productive as Tifton 85, but it enjoys wider distribution across the region, extending well into the Carolinas, Oklahoma, and Missouri. The list of released bermudagrass cultivars that are vegetatively propagated and selections from research stations, farmers, and companies other than USDA-ARS at Tifton, Georgia is quite lengthy. Most notable are 'Midland' (Harlan et al., 1954), 'Greenfield' (Elder, 1955), and 'Hardie' (Taliaferro and Richardson, 1980). Midland and Greenfield, along with Tifton 44, are the standards for comparison of new selections in Oklahoma, Missouri, Arkansas, and the southern plains. A promising new cultivar, 'Midland 99,' was released in Oklahoma last year (Taliaferro et al., 2000), and it displays good cold hardiness, has had consistently greater DM yields than Greenfield and Midland, and has greater nutritive value than Midland and Tifton 44. In a 5-yr grazing experiment, McMurphy et al. (1982) reported higher ADG, slightly higher stocking rates, and higher gain per hectare for Hardie than for Midland bermudagrass pastures grazed by stocker steers. 'Alicia' bermudagrass became available through private development in 1966 in Texas and is used in most states in the Southeast. Although establishment ease is an attribute of Alicia and yields may equal those of Coastal, its quality tends to deteriorate rapidly with plant maturity. Eichhorn et al. (1983) reported similar yields for Coastal and Coastcross-1, and Coastal yields were higher than those of Alicia and Common in a 7-yr study. The 7-yr average IVDMD was higher for Coastcross-1 (58.3%), which was higher than that for Coastal and Common (54.7 and 54.8%, respectively), but Alicia had the lowest IVDMD (52.2%). Grazer has limited use in Louisiana and East Texas, and Brazos has good yields and persistence, and it is more tolerant of heavier clay soils than other cultivars. The South Florida plains have sandy soils with poor drainage on flat surfaces, but Florikirk (Mislevy et al., 1995) shows persistence in this environment. Additional relatively new or regionally localized cultivars and farmer selections include 'Midland 99,' 'Quickstand,' 'Guymon,' 'Russell,' 'Jiggs,' 'Lancaster,' and 'Summerall.' 'Worldfeeder' was released in 1987 by a group in Oklahoma, and although advertising is prolific and producer testimonials abound, yields have not been impressive in university comparisons (C. Teliaferro, 1999, unpublished circular), in which Worldfeeder produced yields that were 71.2, 54.0, 66.8 and 72.7%, respectively, of the yield of Tifton 44 grown on three stations in Oklahoma and one in Arkansas. In the same tests, Worldfeeder had slightly higher yields than Midland in only one of the four test locations.

In addition to the hybrid vegetatively propagated selections and cultivars, there are many kinds of seeded bermudagrass, most related to common bermudagrass. Common bermudagrass includes one or several unselected ecotypes, and productivity and persistence may be highly variable. Several seed companies market blends of different kinds of seeded bermudagrass, some of which are improved, selected genotypes developed through private, state, or federal breeding programs. Four current blended seeded bermudagrasses include 'Cheyenne,' 'Texas Tough,' 'Tierra Verde,' and 'Rancho Frio' (Evers et al., 2000). A few seeded varieties exceed Coastal in yield, including Texas Tough (Evers et al., 2000), but most produce less forage than Coastal, and considerably less than Tifton 85 and other hybrids. Persistence and lower establishment costs are strong attributes of these grasses. Common and seeded varieties of bermudagrass pose problems to producers because they often become weedy, especially in the establishment year, they encroach on other perennial grass stands, they compete for nutrients, and their continued reseeding increases difficulty in controlling or removal of these grasses from the sward. Hybrid bermudagrasses are sterile, produce few if any seeds, and reduce the risk of additional weed problems in pastures and hay meadows. Research is needed to develop seeded varieties that compete with the better hybrids, such as Tifton 85, for yield and quality.

Proper management, including attention to fertilization, maturity of forage, grazing pressure, and soil and climate conditions, may be as important as changing cultivars within a specific locality. With the costs involved with establishment of hybrid bermudagrass fields, management of existing grasses may be more economical than moving to an "improved" cultivar. Many old fields of Coastal and other cultivars have been renewed by intensive K fertilization. Additionally, with good management and fertility practices, the high initial costs may be amortized over extended periods, ranging up to 30 yr or longer.

Tifton 85 Bermudagrass Pastures for Cattle

Tifton 85 bermudagrass was developed as a high-yielding, high-quality forage for grazing cattle and for hay production. It can also be used in the same manner by horses. The quality, persistence, and feeding value of this forage have been questioned, but experiments conducted since 1988 have indicated few problems with this grass. Overstocked pastures subjected to several years of drought at high stocking rates resulted in low forage mass, but no measurable stand loss occurred. Tifton 85, after the establishment year, has a remarkable ability to respond to N fertilization and adequate rainfall. No encroachment of other grasses occurred after stands were established in pastures that were overgrazed during drought periods, and the open canopy has not encouraged weed encroachment. Yearling stocker steers were used in our experiments that were

Table 1. Three-year mean performance of steers grazing Tifton 78 and Tifton 85 bermudagrass pastures[a]

Item	Bermudagrass pasture		
	Tifton 78	Tifton 85	SE
No. of pastures	2	2	
Pasture area, ha	0.81	0.81	
Average forage mass, kg DM/ha	2,350	2,440	34.6
No. of grazing days	169	169	
Steer performance			
Tester steer ADG, kg	0.65	0.67	0.07
Steer grazing days/ha, d	1,319.9[c]	1,823.2[b]	42
Gain/ha, kg	789.1[c]	1,156.4[b]	45.9

[a]Adapted from Hill et al. (1993).

[b,c]Means on same line bearing different superscript letters differ ($P < 0.01$).

conditioned to provide adequate growth response to evaluate different forages; however, rate of gain on bermudagrasses is not sufficient for producers to purchase spring steers and sell cattle for a profit in autumn in most years. Examination of 3-yr total season (169 d) gains of steers grazing high-quality bermudagrass pastures (Hill et al., 1993) revealed that steer ADG were 0.90 and 0.88 kg, respectively, from April to July, but only 0.30 and 0.43 kg, respectively, for Tifton 78 and Tifton 85 pastures from July to October, consequences of increased maintenance requirements of heavier growing steers and lower forage quality later in the season. Adequate gains can be achieved for cow-calf herds and older replacement heifers grazing hybrid bermudagrass pastures that are properly managed and fertilized with N.

Three grazing trials compared Tifton 85 with other cultivars. The first trial compared Tifton 85 bermudagrass with Tifton 78 (Hill et al., 1993). In this classic grazing experiment, very limited quantities of Tifton 85 existed. Available forage DM was targeted at 2,800 kg/ha, with stocking rate adjustments made at 14-d intervals based on ground-level forage samples used to estimate total DM per hectare in each pasture. Tester steers (16/yr; initial BW 269 kg) and grazer steers were used to graze pastures. Forage mass in the grazed pastures averaged 2,453 and 2,744 kg/ha for Tifton 78 and Tifton 85, respectively (Table 1). The test years (1989–1991) included two wet years (1989 and 1991) and one record drought year (1990). Tester average daily gains were similar ($P > 0.10$) for steers grazing the two grasses. Steer grazing days per hectare were 38% higher ($P < 0.01$) for Tifton 85 than for Tifton 78. Consequently, gain per hectare was 46% higher ($P < 0.01$) for Tifton 85 than for Tifton 78. The reduced steer grazing days per hectare for Tifton 78 resulted in similar ADG for Tifton 78 and Tifton 85. Regardless of rainfall distribution during the 3 yr, Tifton 85 pastures were stocked at higher rates each year than Tifton 78 pastures, and gain per hectare increased for Tifton 85 pastures in each succeeding year. Pedreira (1995) and Pedreira et al. (1999) reported higher cattle stocking rates, higher gain per hectare and higher IVDMD for Tifton 85 than for Florikirk bermudagrass, a cultivar genetically similar to Tifton 78.

In a related 3-yr grazing study (Table 2; Hill et al., 1997a), replicated 0.81-ha pastures of Coastal, Tifton 78, and Tifton 85 were compared, using yearling steers (tester steers = 24/yr; 295 kg initial BW). Pasture fertility, targeted forage mass (2,800 kg/ha in all pastures), and stocking rate adjustments at 14-d intervals were similar to those described for the initial experiment (Hill et al., 1993). Weather conditions greatly affected forage production in both years, especially in 1993, when all cattle were removed from pastures for 42 d in June and July because of drought and forage mass estimates below 800 kg DM/ha. Consequently, steers grazed 126 d in 1993. Daily gains were similar for the three kinds of pastures over the 2 yr of the study (Table 2). Grazing days per hectare were highest ($P < 0.10$) for Tifton 85, followed by Coastal and Tifton 78. Consequently, gain per hectare was highest ($P < 0.10$) for Tifton 85, intermediate for Coastal, and lowest for Tifton 78. This experiment indicates the ability of Tifton 85 to support higher stocking rates than other bermudagrasses, even under adverse conditions. The superiority in growth rate of grass and steer gain per hectare reported for the original study (Table 1) were verified.

Forage quality of Coastal, Tifton 78, and Tifton 85 pastures was estimated by analyzing esophageally cannulated steer extrusa samples (Table 3). In this study, NDF was higher ($P < 0.10$) for Tifton 85 and Tifton 78 than for Coastal in May samples, but a trend ($P > 0.10$) was observed for higher IVDMD for Tifton 78 and Tifton 85. In September, NDF was similar for all cultivars, but IVDMD was higher ($P < 0.05$) for Tifton 85 than Coastal and intermediate for Tifton 78. Year of study affected crude protein ($P < 0.05$), NDF ($P < 0.05$), and IVDMD ($P < 0.05$). The phenomenon of high NDF along with high IVDMD in grazed Tifton 85 forage extrusa occurred in this study and in September esophageal extrusa of Tifton 85 pastures in the original experiment (Hill et al., 1993).

In a study conducted in1996 and 1997 (Hill et al., 1998a), Angus cows and calves were assigned to three bermudagrass pasture treatments: Coastal with volunteer ryegrass (**CR**), Tifton 85 (**T85**), or Tifton 85 pasture with an additional 0.81-ha creep grazing area for calves (**T85-A**). Calves averaged 73 d of age when grazing began in April, and the experiment continued for 135 d each year. Calf final weights and 135-d ADG were similar ($P > 0.10$) for the treatments. Cows were milked with a portable milking machine in late May (d 43) and late August (d 134). Cow milk production (Table 4) was higher in May than in August, which was a function of the lactation curve for these cows. The 12-h milk production tended to be higher ($P > 0.10$) for both T85 and T85-A than for CR in May. Milk fat was similar for treatments in May but tended to be higher ($P > 0.10$) for T85 and T85-A. Milk protein was higher ($P <$

Table 2. Grazing steer performance on Coastal, Tifton 78, and Tifton 85 pastures[a]

Steer performance	Coastal	Tifton 78	Tifton 85	SE	Effect[b]
Tester initial BW, kg	294	295	295	0.5	Not significant
Tester ADG, kg	0.65	0.74	0.72	0.03	Not significant
Grazing d/ha, d	874	761	1019	64.0	Y**,C†
Gain/ha, kg	566	550	747	48.3	Y**,C†

[a]Adapted from Hill et al. (1997a).
[b]Abbreviations: Y = year of experiment; C = cultivar (Coastal, Tifton 78, or Tifton 85).
†$P < 0.10$.
**$P < 0.01$.

0.01) for all treatments in August than in May, and milk protein was higher ($P < 0.05$) for T85 and T85-A at both dates. Although milk yield was similar for treatments, one might expect higher calf gains resulting from increased milk fat and milk protein on T85 and T85-A treatments, but calf gains were similar for treatments (Table 4). The relatively low stocking rates and high quality of CR pastures in April and May allowed cows and calves to get an early growth advantage that was maintained during the remainder of the grazing period. Allowing T85-A calves to graze the alfalfa creep area did not improve calf gains, indicating that milk and Tifton 85 forage were supplying adequate nutrition for the calves before weaning. Fike et al. (1997a) reported lower milk production in Holstein dairy cows grazing Tifton 85 pastures compared with rhizoma peanut, but higher DM production allowed higher stocking rates on Tifton 85 pastures, resulting in greater total milk production for cows on Tifton 85 pastures. Cows on Tifton 85 responded with higher milk production than cows on rhizoma peanut when supplemented with grain mixtures.

Table 3. Forage quality of Coastal, Tifton 78, and Tifton 85 pastures[a]

	Quality of forage masticate (DM basis, %)			
Item	CP	ADF	NDF	IVDMD
Sampling date				
July				
Coastal	14.6	33.1[d]	71.6[f]	62.5
Tifton 78	14.2	32.3[d]	72.5[ef]	65.3
Tifton 85	15.1	34.8[c]	74.6[e]	66.9
September				
Coastal	17.0	32.0[cd]	70.5	60.2[d]
Tifton 78	18.3	31.3[d]	69.5	62.9[cd]
Tifton 85	18.1	32.9[c]	71.8	65.2[c]
SE	0.61[b]	0.40	0.84	1.24
Year				
1992	14.9[w]	33.1	72.5[w]	61.6[w]
1993	17.5[x]	32.4	71.0[x]	66.1[x]
SE	0.39	0.31	0.34	0.56

[a]Adapted from Hill et al. (1997a).
[b]Sampling dates are different for each treatment ($P < 0.05$).
[c,d]Means within a sampling date differ ($P < 0.05$).
[e,f]Means within a sampling date differ ($P < 0.10$).
[w,x]Year means within a column differ ($P < 0.05$).

Dairy Production Using Bermudagrass Pastures, Silages and Hays

Total dairy production has declined across the southern United States during the last three decades, and dairy operations have generally increased in size. Although some dairies in the South have continued to use pasture grazing, usually for limited intervals, a growing number are discovering that grazing can increase health of the milking herd and often increase returns to the operation compared with total confinement during lactation. As costs of heifer replacements continue to rise, use of high-quality forages is essential to economically producing these heifers. Use of high quality hybrid bermudagrasses by lactating, nonlactating, and replacement females on dairies has increased in recent years. Hay and grass silage (haylage, balage) are used

Table 4. Two-year performance of calves and cow milk production when grazing Coastal-ryegrass (CR), Tifton 85 (T85), or Tifton 85 with alfalfa in a calf creep grazing area (T85-A)[a]

Item	CR	T85	T85-A	SE
Calf performance				
No. of calves				
Males	23	20	22	
Females	19	22	21	
Initial age, d	76	73	70	
Initial wt (April), kg	110.2	103.4	100.2	5.3
Final wt (August), kg	252.2	249.4	245.8	3.1[bc]
135-d ADG, kg	1.09	1.07	1.05	0.02[bc]
Cow milk production				
No. cows	42	42	42	
12-h milk wt. kg				
May	3.59	3.70	3.84	0.11[d]
August	3.00	2.79	2.82	0.11[d]
Milk fat, %				
May	3.23	3.31	3.24	0.28
August	3.00	3.91	3.78	0.28
Milk protein, %				
May	2.99	3.17	3.13	0.09[e]
August	3.40	3.55	3.70	0.05[e]

[a]Adapted from Hill et al. (1998a).
[b]Means were affected by year of study ($P < 0.05$).
[c]Least squares means adjusted for initial calf weight.
[d]Milk yield affected by year ($P < 0.01$).
[e]Milk protein affected by year ($P < 0.07$), milking date ($P < 0.01$), and grazing treatment ($P < 0.05$).

by various classes of dairy cattle on many farms. One very large dairy (more than 900 lactating cows) in southern Georgia has converted to irrigated Tifton 85 bermudagrass rotational grazing for about 9 to 10 mo of the year with limited grain supplementation in the parlor. Cool-season annuals are planted for winter-spring grazing, and some hay and balage are produced from excess forage to be fed as needed during drought or winter. The dairy incorporates some New Zealand-style management, and cows are naturally bred on a seasonal basis. After approximately 8 yr in business, this unconventional dairy is maximizing grazing and continues to operate with little equipment, three or four full-time employees, extremely low feed purchases, and reported annual profits with milk production averaging between 5,000 and 6,000 kg/cow. Altough few dairies are expected to duplicate management of this grazing dairy in Georgia, higher-quality bermudagrass pastures will allow more producers to use grazing in their operations, at least on a limited basis.

Fike et al. (1997b) grazed lactating dairy cows on Tifton 85 bermudagrass stocked at 4.9 or 7.4 cows/ha compared with rhizoma peanut (*Arachis glabrata*) stocked at 2.5 or 4.9 cows/ha, and a supplement was provided at two levels in the parlor. Differences in milk production favored rhizoma peanut, and increasing supplement rate increased milk, milk fat, and milk protein production on both forages, but rhizoma peanut decreased cow BW and body condition. Rhizoma peanut's nutritive value was higher than that of Tifton 85, but higher stocking rates were achieved on Tifton 85 pastures. In studies conducted in Florida (Sollenberger et al., 2000), cows grazing grass-clovers with pearl millet or rye-ryegrass with Tifton 85 bermudagrass and provided with shade on pasture were compared with cows managed in free-stall barns. Barn-fed cows produced 20% more milk and lost less weight, but feed costs were twice those of pastured cows, and somatic cell counts were higher. Pastured cows were fed grain after each milking at 0.45 kg/1.13 kg milk produced in winter, and 0.45 kg/ 0.91 kg milk produced. Milk income minus feed cost, respectively, for cows on barn, grass-clover with millet, and rye-ryegrass plus bermudagrass, were $5.32, $5.56, and $5.84/cow daily. Tifton 85 was a good option in these studies providing grazing during summer and autumn and could be stocked at 3.36 cows/ha.

Alfalfa and grass hays have been incorporated into TMR on many dairies to increase fiber to recommended levels to stimulate milk production, increase milk fat, and improve ruminal digestion, especially when concentrates are added to the diet. Bermudagrass hay has received little consideration by many nutritionists because of the lower digestibility rates and higher NDF content generally found in bermudagrasses. In much of the South, dependable legume production is not an option because of climate, sandy and acid soils, insect pests, and unpredictable rainfall patterns. Therefore, bermudagrasses adapted to this region may become a viable option, especially when transportation costs of legume hays from the Midwest to the Southeast are considered. With proper management, hybrid bermudagrasses can compete with grasses and legumes in protein content, but even at lower maturities fiber content is generally higher than that of legumes and some immature grasses, including orchardgrass, fescue, and ryegrass.

Table 5. Chemical composition of forages used in total mixed diets[ab]

Item	Alfalfa	SD	Tifton 85	SD	Corn silage	SD
DM, %	91.0	2.4	87.9	1.7	37.6	1.7
CP, %	16.6	1.7	17.3	1.1	8.4	0.5
ADF, %	38.6	3.5	35.0	0.5	25.8	0.8
NDF, %	48.1	4.8	80.7	1.1	45.8	1.5

[a]Dry basis.
[b]Adapted from West et al. (1997).

The concept of including locally grown bermudagrass hays in TMR for lactating dairy cattle in Georgia was encouraged by the development of high-quality Tifton 85 bermudagrass, displaying high IVDMD and good live weight gains in grazing steers (Hill et al.,1993). Tifton 85 hays had higher NDF but higher IVDMD and in vivo digestibility than other bermudagrasses, especially at early maturity when fed to growing steers (Hill et al., 1997b). Tifton 85 hay was fed at two levels compared with two levels of alfalfa hay and a control diet of corn silage in TMR for lactating Jersey and Holstein cows (West et al., 1997; Hill et al., 1998b). Chemical analyses of the Tifton 85 hay, alfalfa hay, and corn silage are shown in Table 5. The CP content of Tifton 85 hay and alfalfa hay were similar, and the Tifton 85 hay was harvested at 4-wk maturity, contributing to the 17.3% CP of this hay. The NDF content of the Tifton 85 hay was above 80%, much higher than that of alfalfa hay or corn silage. Diets 1 through 5 contained corn silage (% of diet DM), respectively, at 45, 30, 15, 30, and 15, and Tifton 85 hay (% of diet DM), respectively, at 0, 15, 30, 0, and 0 for Diets 1 through 5, and alfalfa hay (% of diet DM), respectively, at 0, 0, 0, 15, and 30. The NDF content of Diets 1 through 5 (DM basis, %) were 33.5, 39.5, 46.6, 35.5, and 33.5.

The DMI was greater for cows fed diets with alfalfa than for those fed Tifton 85 hay diets (Table 6), and DMI was greater for low vs high Tifton 85 diets and for control vs Tifton 85 diets. Jersey cows had lower DMI for Tifton 85 hay diets, but the breed × treatment interaction was not significant. The hay source × hay level interaction was significant, but that seemed to result primarily from the response of Jersey cows to the treatments. The DMI declined as Tifton 85 hay increased in the diet, but DMI increased with increasing alfalfa hay in the diet. The decline in DMI for Jerseys with increasing Tifton 85 hay in the TMR probably resulted from gut fill limitations, because of the high

Table 6. Effect of forage source and hay addition on DMI , apparent digestibility, and milk production[a]

			Dietary treatment						Contrast significance				
			Tifton 85		Alfalfa								
Item	Breed	Control	Low	High	Low	High	Source[b]	SE	Level[c]	SE	Source × level	Hay[d]	SE
DMI, kg/d	H[e]	22.9	22.1	22.0	22.5	22.5	0.001	0.2	0.10	0.2	0.01	0.01	0.2
	J[f]	19.3	17.7	14.4	19.3	20.5							
DMI/BW,													
kg/100 kg[g]	H	4.29	4.16	4.19	4.38	4.27	0.10	0.06	NS	0.07	NS	NS	0.07
	J	4.63	4.23	3.62	4.58	4.85	0.001	0.06	0.10	0.07	.001	0.01	0.07
Milk, kg/d	H	34.1	33.0	31.8	34.1	32.6	0.001	0.2	0.01	0.2	NS	NS	0.2
	J	20.7	20.8	19.5	23.3	22.5							
3.5% FCM, kg/d	H	33.6	33.9	33.5	34.3	34.0	0.01	0.2	0.05	0.2	NS	NS	0.3
	J	25.8	26.0	23.7	26.9	26.3							
Milk fat, %[g]	H	3.33	3.73	3.72	3.54	3.99	NS	0.06	0.05	0.06	0.05	0.01	0.08
	J	4.98	5.01	4.83	4.84	4.59	0.05	0.06	0.05	0.06	NS	NS	0.07
Apparent digestibility, %													
DM		56.7	62.7	58.5	59.1	56.6	NS	1.4	NS	1.4	NS	NS	1.5
CP		64.0	64.3	59.2	61.3	59.9	NS	1.3	0.1	1.3	NS	NS	1.3
ADF	.006	24.6	47.9	56.2	35.9	41.1	0.006	2.7	NS	2.7	NS	0.001	2.9
NDF		32.2	54.1	62.6	37.7	40.8	0.001	2.1	0.08	2.1	NS	0.001	2.2

[a]Adapted from West et al. (1997) and Hill et al. (1998b).
[b]Hay source; bermudagrass vs alfalfa.
[c]Level of hay addition; low vs high.
[d]Hay diets vs no hay diet (control).
[e]Holstein.
[f]Jersey.
[g]Breed × treatment interaction occurred.

DMI/BW for these cows (Table 6). Milk and fat-corrected milk (**FCM**) were greater for alfalfa diets than Tifton 85 diets, and for low- vs high-hay diets (Table 6), reflecting trends for DMI. However, milk and FCM yields were not different for hay diets vs the control diet, despite differences in DMI. The control diet and diets containing alfalfa resulted in the greatest DMI and milk yield, but DMI/100 kg BW for Holsteins was equal for diets containing Tifton 85 or alfalfa.

Apparent digestion of diets (Table 6) indicated that treatments did not affect DM or CP digestibility. However, ADF and NDF digestion coefficients were significantly higher for Tifton 85 than for alfalfa diets, and in the hay diets compared with the control diet. Diets containing high levels of hay had higher NDF digestibility than low-hay diets. In vitro digestion (West et al., 1997) was most rapid for Tifton 85 hay, intermediate for corn silage, and lowest for alfalfa hay. Ruminal turnover rates were unaffected by treatments, hay sources, or dietary hay levels. Apparently, NDF from Tifton 85 hay was digested more rapidly and completely than NDF from corn silage or alfalfa hay, which improved rate of passage despite the high NDF of diets containing the Tifton 85 hay. These results indicated that high-quality bermudagrasses might be used in rations for lactating cows.

In a related study (Mandebvu et al., 1998) TMR were compared that included corn silage (30% of DM) or Tifton 85 hay harvested at 3.5 or 7 wk, fed at 8.7% (Low NDF diet) or 17.5% (High NDF diet), and subjected to in situ digestion. Rate of digestion (%/h) was similar for the corn silage TMR and the hay TMR, but both in vitro and in situ digestion of DM and NDF declined significantly with increasing maturity of hays. Tifton 85 bermudagrass hay and Tifton 85 silage were fed in increasing quantities in TMR fed to increase dietary NDF in lactating cows (West et al., 1998). The Tifton 85 hay and silage CP, NDF, and in vitro NDF digestion at 96 h, respectively, were 13.1, 12.6, 6.3% of DM; 76.6, 71.9, and 46.6% of DM; and 60.7, 53.3, and 53.5% of DM. Tifton 85 was added as hay or silage at 8.5, 15.9 or 23.3% of dietary DM, substituted for equal amounts of corn silage. Storage method did not affect DMI, but increasing the amount of Tifton 85 and NDF in the diet reduced DMI. Milk yield was unaffected by storage method but it declined with increasing dietary NDF. Increasing level of Tifton 85 in the diet improved digestion of dietary DM, ADF, and NDF, but milk yield declined because of depressed DMI.

These studies confirm that high-quality bermudagrasses such as Tifton 85 may be used in diets for lactating dairy cows. Caution is in order in selection of cultivars that have highly digestible fiber and that are properly managed, harvested at low maturity (usually 3.5 to 4 wk), and properly stored. These studies indicate that Tifton 85 may be used in grazing or stored forage TMR diets, and that although milk production might be reduced compared to conventional TMR diets using alfalfa hay or corn silage, the lower costs of production and local or on-farm availability of bermudagrass forage could potentially increase returns from milk sales.

Table 7. The NDF content and digestibility of Tifton 85 from various forage sources[a]

Reference	Grass	Source	NDF %	Digestibility, %			
Hill et al., 1993	T78	Pasture	71.0	53.1^{c}	I		
	T85	(Esophageal)	71.4	57.1^{b}			
Hill et al., 1997a	C	Pasture	70.5	60.2^{c}	I		
	T78	(Esophageal)	69.5	62.9^{bc}			
	T85		71.8	65.2^{b}			
Mandebvu et al., 1999a	C	Clipped	66.4^{c}	57.3^{c}	I		
	T85	(2–7 wk)	69.2^{b}	61.1^{b}			
Hill et al., 1997b	C	Hay	79.3	48.8^{c}	I	47.8	T
	T78	(4, 6 wk)	80.2	50.9^{c}		51.0	
	T85		83.3	57.0^{b}		54.3	
Mandebvu et al., 1999a	C	Hay	70.9	59.4^{c}	I	54.2^{c}	T
	T85	(3, 5, 7 wk)	75.0	63.2^{b}		59.1^{b}	
Mandebvu et al., 1999b	C	Silage	60.9	48.9^{c}	I	46.7^{c}	IS
	T85		61.9	55.6^{b}		53.6^{b}	

[a]Abbreviations: C = Coastal; T78 = Tifton 78; T85 = Tifton 85; I = IVDMD; IS = in situ digestion; T = in vivo digestion.

[b,c]Within reference, means bearing different superscript letters are different ($P < 0.05$).

Investigating Reasons for High Digestibility of High-NDF Tifton 85 Forages

Tifton 85 bermudagrass has been involved in a number of yield, grazing, digestion, and lactating dairy experiments. From the earliest yield trials, the characteristically high IVDMD set Tifton 85 apart from other selections and cultivars (Burton et al., 1993; Hill et al., 1993). Subsequent analyses indicated a high NDF content, even at early maturity, and NDF often increased with maturity of hay (Hill et al., 1997b; Mandebvu et al., 1998, 1999a). Hill et al. (1993) observed increased IVDMD of esophageal extrusa of Tifton 85 pastures compared with Tifton 78 pastures, regardless of increased NDF content of the September samples. Maturity of bermudagrasses reduced digestibility of hays (Hill et al., 1997b; Mandebvu et al., 1998; 1999a), especially after 4 to 5 wk of growth. In most studies Tifton 85 had higher NDF than other cultivars, but invariably Tifton 85 had higher digestibility in all studies, regardless of how the digestibility or DM disappearance was measured (Table 7). This phenomenon was contrary to most nutritional theory, especially that based on, or influenced by, familiarity with cool-season legumes and grasses. Certainly forage NDF content above 65% with digestibility consistently ranging above 55%, and as high as 65% in Tifton 85 from different sources, years, and management, was remarkable.

Phillip Mandebvu, a postdoctoral researcher with Joe W. West on our team of University of Georgia and USDA-ARS forage researchers, initiated cooperative studies with R. D. Hatfield, U.S. Dairy Forage Research Center, University of Wisconsin, Madison, WI. This research investigated basic carbohydrate chemistry of bermudagrass cell wall fractions, including acid insoluble lignin, total neutral sugars, total uronysyls, and neutral sugars. Additional analyses included ferulates and *p*-coumarates. Coastal and Tifton 85 were grown in adjacent plots and harvested after 3 or 6 wk of regrowth (Mandebvu et al., 1999b). The nutrient composition of the forages (Table 8) indicated relatively high CP in all forages, ranging from 14 to 18% of DM, and NDF was high for all forages, tending to be highest for Tifton 85

Table 8. Selected composition, cell wall components and disappearance of DM and NDF in Coastal and Tifton 85 forages harvested at different ages[a]

	Coastal		Tifton 85		
Item	3 wk	6 wk	3 wk	6 wk	SE
	% DM				
Composition					
OM	86.1	88.6	92.0	91.6	
CP	16.3	14.2	18.2	16.4	
NDF	66.9	68.9	68.6	72.3	
ADF	29.9	29.9	32.7	35.0	
Lignin	6.6	6.8	4.7	5.8	
Cell wall components					
Cell walls (CW), g/kg DM	840.9	847.4	814.2	852.9	
	g/kg CW				
Acid insoluble lignin	200.5	191.1	164.7	174.7	
Ester ferulic acid	10.6	10.6	11.6	10.0	
Ether ferulic acid	8.1	7.6	6.2	4.9	
Disappearance	%				
IVDMD (48 h)	51.4^{d}	50.8^{d}	61.7^{b}	56.9^{c}	1.1
IVNDFD (48 h)	42.6^{d}	41.0^{d}	60.6^{b}	55.6^{c}	1.6
ISDMD (72 h)	51.4^{d}	51.3^{d}	65.9^{b}	56.3^{c}	1.0
ISNDFD (72 h)	48.9^{d}	43.7^{d}	63.8^{b}	53.1^{c}	1.2

[a]Adapted from Mandebvu et al. (1999b). Abbreviations: IVNDFD = in vitro NDF disappearance; ISDMD = in situ DM disappearance; ISNDFD = in situ NDF disappearance.

[b,c,d]Means within a row with different superscript letters differ ($P < 0.05$).

Table 9. Composition, cell wall components and digestion of Coastal and Tifton 85 hays harvested at three ages[a]

Item	Cultivar		SE	Age, wk			SE
	Coastal	Tifton 85		3	5	7	
Composition	%						
OM	93.8	93.7	0.1	93.5	93.7	94.0	0.1
CP[b]							
Coastal				14.7	15.8	13.1	
Tifton 85				15.8	14.5	12.6	
NDF	70.9	75.1	0.2	72.9[e]	75.2[d]	71.0[f]	0.3
ADF	40.3	42.3	0.3	31.7	31.9	31.5	0.2
ADL[d]							
Coastal				4.3	4.1	4.4	
Tifton 85				3.4	4.1	4.4	
Cell wall (CW) components							
CW, g/kg DM	708.2	737.4	2.4	711.9	731.9	724.7	2.9
	g/kg CW						
Acid insoluble lignin	202.8[d]	174.5[e]	1.4	187.8	192.7	185.6	1.7
Ester ferulic acid	12.6[e]	13.9[d]	0.2	13.8	12.8	13.2	0.3
Ether ferulic acid	8.12[d]	6.9[e]	0.4	6.6[e]	8.5[d]	7.4[de]	0.5
In vivo intake and digestion[c]							
OM intake, kg/d	4.4	4.5	0.1	4.3[f]	4.3[f]	4.7[e]	0.1
	Digestibility, %						
OM	54.2[e]	59.1[d]	1.3	58.2	55.6	56.1	1.6
NDF	57.8[e]	65.5[d]	1.2	64.1[d]	62.4[de]	58.6[e]	1.5
ADF	51.4[e]	61.3[d]	1.3	58.7[d]	57.3[de]	53.1[e]	1.7

[a]Adapted from Mandebvu et al., 1999a.
[b]Interaction (cultivar × age), ($P < 0.01$).
[c]Growing beef steers (n = 36) individually-fed six kinds of hay in 2 × 3 factorial digestion study using Cr as a marker.
[d,e,f]Means in same row with different superscript letters differ ($P < 0.05$).

at 6 wk maturity. A trend was reported for greater concentrations of acid insoluble lignin in Coastal than in Tifton 85 forage, and Coastal tended to have higher concentrations of ether-linked ferulic acid (monomers and dimers) than Tifton 85 bermudagrass (Table 8). Once again, IVDMD and in vitro NDF digestion after 48 h and in situ DM and NDF digestion after 72 h were all higher for Tifton 85 at either forage maturity compared with Coastal bermudagrass, even though NDF was highest for Tifton 85 forages (Table 8). A comprehensive study on bermudagrass cultivar and maturity effects on forage quality, digestibility, and cell wall chemistry (Table 9) was conducted by Mandebvu et al. (1999a). In this study, Coastal and Tifton 85 hays were harvested at 3-, 5-, and 7-wk maturity, and NDF concentrations were 70.9 and 75.1%, respectively, for Coastal and Tifton 85 hays. Rainfall patterns in late summer affected regrowth, resulting in variable NDF concentrations for different maturities, and there was no cultivar × maturity interaction for ADF and NDF. As in the previous study (Table 8; Mandebvu et al., 1999b), acid insoluble lignin and ether-linked ferulic acid were lower for Tifton 85 hays than for Coastal hays (Table 9), but ester-linked ferulic acid was higher for Tifton 85 than for Coastal. Maturity of the forage when harvested resulted in no cultivar × maturity interaction, but a trend was observed for higher ether ferulic acid as maturity increased. When the hays were fed to growing steers, cultivar had no effect on OM intake, and OM intake was elevated on the 7-wk hays. Steers fed Tifton 85 hays had higher digestibility coefficients for OM, NDF, and ADF than steers fed Coastal hays. Both NDF and ADF digestibility coefficients decreased with advancing maturity. Hill et al. (1997b) reported similar DMI but higher OM, ADF, and NDF digestibility in Tifton 85 hays compared with Tifton 78 and Coastal hays fed to growing steers, and OM, CP, ADF, and NDF digestibility coefficients were higher for hays at 4 wk than for those at 6 wk of maturity.

The research reported in Tables 8 and 9 (Mandebvu et al., 1999a,b) is believed to be the first reports of ester- and ether-linked ferulic acid concentrations in bermudagrass, although many different grasses and legumes have been analyzed for these components. We suggest that the lower ether-linked ferulic acid concentrations explain the higher digestibility of Tifton 85 compared with Coastal. We know that lignin concentration is a key factor in forage digestibility because lignin content limits cell wall digestion (Van Soest, 1965), but lignin content has not necessarily been highly correlated with digestibility of bermudagrasses. Jung and Allen (1995) showed that ferulic acid linkages between lignin and cell wall polysaccharides may be required before lignin can exert its effect. They reported that arabinoxylan, which is a component of hemicellulose in cell walls of grass, forms bonds directly with ferulic acid by an ester linkage. In turn, ferulic acid as monomers or dimers then bonds with lignin by ester or ether linkages. Ruminal bacteria and fungi have esterases that can break the ferulate ester linkages, but cleavage of ether linkages by anaerobic microorganisms is not known to occur (Jung and Allen, 1995). Because the majority of *p*-coumaric acid is esterified to lignin, it probably does not directly affect polysaccharide digestion (Jung and Allen, 1995). Therefore, the higher concentration of ether-linked ferulic acid in Coastal bermudagrass (Tables 8 and 9) is thought to be the primary cause of lower digestibility of this grass compared with that of Tifton 85. If this proves to be the correct theory, ether-linked ferulic acid concentration could explain the consistently lower digestibility of other bermudagrasses such as Alicia (Eichhorn et al. 1983) and the higher digestibility of others, including Coastcross-1 (Burton, 1972) and Tifton 68 (Burton and Monson, 1984) and could become an important tool for plant breeders to use in screening new entries, crosses, and selections.

Implications

Improved hybrid bermudagrasses have been primary forages for beef and dairy cattle for more than 50 yr in the southern United States. They are persistent and productive over a wide range of soils, nitrogen applications, and grazing and climatic conditions. Most hybrids offer better yields, persistence, and quality than unselected ecotypes. Tifton 85 forages may be used in total mixed rations for lactating dairy cows and in grazing systems for milking herds. New nutritional challenges are presented by Tifton 85, because its neutral detergent fiber might be a less important quality indicator than are digestion coefficients and ether ferulic acid concentrations. Goals for future bermudagrass cultivars include lower neutral detergent fiber concentrations with advancing maturity, lower ether ferulic acid concentrations, and increased cold tolerance. Bermudagrasses will continue to be the primary perennial warm-season grass used in the southern United States and other countries.

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