Stockpiled “Tifton 85” bermudagrass for cow-calf production as influenced by nitrogen fertilization¹

Courteney McNamee Holland^{*,2}, Kaleb Marchant^{*}, Lisa Kriese-Anderson^{*}, Brian Gamble,[†]
and Russell Muntifering^{*}

^{*}Department of Animal Sciences, Auburn University, Auburn, AL 36849; [†]Wiregrass Research and Extension Center, Headland, AL 36345

ABSTRACT: A 2-yr study was conducted to determine the effects of rate of N fertilization on productivity and nutritive value of stockpiled “Tifton 85” bermudagrass for lactating-cow and calf performance. On 31 October 2012 (year 1) and 11 November 2013 (year 2), 16 Angus × Simmental cows (mean initial BW for both years, 647 ± 23 kg) and their calves (mean age for both years, 16 ± 3 d) were assigned randomly to 0.76-ha paddocks (2 cow-calf pairs/paddock) of stockpiled “Tifton 85” bermudagrass pasture that had been cut to a 10-cm stubble height in early August and fertilized with either 56 (56N), 112 (112N), or 168 (168N) kg N/ha (2 paddocks/treatment), or to replicate 0.41-ha paddocks (2 cow-calf pairs/paddock) of dormant pasture with free-choice access to August-cut “Tifton 85” bermudagrass hay plus 2.7 kg whole cottonseed daily (HAY). Cows were allowed access to strips of ungrazed forage by moving polytape every 3 to 4 d to maintain a DM harvest efficiency of approximately 75%. In year 1, forage mass (6,113 kg DM/ha), IVDMD (60.9%), and grazing d/ha (314) were not different ($P > 0.05$) among the stockpile treatments over a 116-d grazing period; mean forage IVDMD (60.1%) and CP (12.7%) in the stockpiled treatments were greater ($P < 0.05$) than the HAY

treatment. Stockpiled forage CP concentration was greater ($P < 0.05$) for the 168N than 56N and 112N treatments and was greater ($P < 0.05$) for the 56N than 112N treatment. In year 2, mean forage CP concentration was greater ($P < 0.05$) for the 168N (14.5%) than 56N (11.3%), 112N (12.0%), and HAY (9.0%) treatments; mean stockpiled forage IVDMD (59.5%) was greater ($P < 0.05$) than the HAY treatment (46.3%); and mean forage mass for the 168N treatment (5,017 kg DM/ha) was 378 kg and 298 kg DM/ha greater ($P < 0.05$) than the 112N and 56N treatments, respectively. Mean cow BW (611 ± 147 kg), body condition scores (5.5 ± 0.6), and milk production (9.0 ± 6.0 kg/d) were not different ($P > 0.05$) among treatments. Mean blood urea-N (BUN) concentrations (11.2 mg/mL) were not different among treatments, but mean BUN across treatments for the last sampling date was greater ($P < 0.05$) than the first and second sampling dates. Mean 205-d adjusted weaning weight (249 kg ± SD) was not different among treatments. Economic evaluation revealed that input costs/cow were 66%, 61%, and 56% greater for HAY than 56N, 112N, and 168N, respectively. Stockpiled forages were of sufficient nutritive quality to support lactation without supplementation.

Key words: bermudagrass, cow-calf, economics, lactation, nutrition, reproduction

© The Author(s) 2018. Published by Oxford University Press on behalf of the American Society of Animal Science. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.

J. Anim. Sci. 2018.96:2907–2922

doi: 10.1093/jas/sky190

¹Financial support for this study was provided by the Alabama Agricultural Experiment Station and Alabama Cattlemen’s Association.

²Corresponding author: cem0022@auburn.edu

Received March 27, 2017.

Accepted May 16, 2018.

INTRODUCTION

Bermudagrass (*Cynodon dactylon*), a perennial warm-season forage, is one of the major forage species used in beef cattle production systems in the Southeast, and it is ideally suited for

fall stockpiling (Ball et al., 2007). Stockpiling bermudagrass forage for fall and winter grazing has the potential to reduce cow-calf production costs (Ball et al., 2007). Although the use of stockpiled bermudagrass for fall/winter grazing is not an especially novel practice, nearly all of the published research to date has been conducted in the Lower Great Plains and Upper South with dry, pregnant, spring-calving cows using older, less improved varieties of bermudagrass (Lalman et al., 2000). Based on these studies, the conventional wisdom posits that stockpiled bermudagrass would have limited applicability for fall-calving, lactating cows due to their greater nutrient requirements. However, improved hybrid bermudagrasses provide superior yield potential, persistence, and quality compared with unselected ecotypes (Hill et al., 2001). Compared with “Coastal” and “Tifton 78” bermudagrass, “Tifton 85” is higher yielding, more digestible (Hill et al., 1993), and supports greater milk production (Corriher et al., 2007). Digestibility of NDF is also greater due in part to lesser concentrations of lignin and etheral linkages between ferulic acid and cell-wall carbohydrates.

With use of improved varieties and the goal of increasing stocking capacity, unit cost per animal for stockpiled bermudagrass systems may be affected more by forage management than by N-fertilizer and feed input variables. For these reasons, a late fall/early winter grazing study was conducted to determine the effects of rate of N fertilization on productivity, nutritive value, and economic feasibility of stockpiled “Tifton 85” bermudagrass for fall-calving, lactating cows as assessed by production and reproductive performance.

MATERIALS AND METHODS

Research Site

All procedures were approved by the Auburn University Institutional Animal Care and Use Committee for the use of live vertebrate animals in experiments (PRN 2013-2204). An existing “Tifton 85” bermudagrass pasture located at the Wiregrass Research and Extension Center (WREC) in Headland, AL (31.35° N, 85.34° W) was utilized for this experiment. The pasture had been utilized for hay production prior to the initiation of the experiment, and the soil beneath the pasture was a kaolinitic, Dothan fine sandy loam.

Forage Treatments and Grazing Management

Forage in the pasture was clipped to a 10-cm stubble height on 1 August in both 2012 (year 1) and 2013 (year 2), and the study area was subdivided into six 0.76-ha paddocks for stockpiling and deferred grazing. Two adjacent 0.42-ha plots of dormant summer pasture were utilized for the control treatment. On 17 August 2012 and 28 August 2013, “Tifton 85” bermudagrass paddocks (2 plots/treatment) were fertilized with 56 (56N), 112 (112N), or 168 (168N) kg N/ha in the form of ammonium nitrate (NH_4NO_3) and stockpiled for deferred grazing until 31 October in year 1 and 11 November in year 2, respectively. The control treatment consisted of ad libitum access to round bales of bermudagrass hay from the 1 August harvests and supplementation with 2.7-kg whole cottonseed/cow daily. Bales were weighed prior to placing in paddocks, and hay refusals were weighed before new bales were placed into hay rings.

For each year of the 2-yr grazing study, 16 Angus $\times$ Simmental cows and their calves were randomly assigned to 1 of the 4 treatments (4 cow-calf pairs per treatment). A cow with a heifer calf and a cow with a bull calf were randomly assigned to each paddock (2 cow-calf pairs per paddock). Cows and their calves were grouped by initial cow BW, age of dam, calf sex, initial calf age, and initial calf weight. Pairs were placed in their paddocks on 31 October 2012 in year 1 of the study and on 11 November 2013 in year 2. The same cows were not necessarily used in both years of the study, but there was some overlap. A total of 26 different cows were used over the course of the experiment. The primary criterion for inclusion in the study was that cows calved early in the calving season. Initially, all cows were to be at least 4 yr old. However, due to the limited number of cows located at the WREC, some 3-yr-old cows had to be utilized in the study. Grazing of stockpiled forage was initiated in both years when the forage had achieved a mean mass across all paddocks of approximately 4,000 kg DM/ha. A commercial salt-mineral mix (Ca [max.] 16.00%, P [min.] 6.00%, NaCl [max.] 24.00%, Na [max.] 10.50%, Mg [min.] 0.50%, K [min.] 0.50%, Cu [min.] 650 ppm, I [min.] 50 ppm, Se [min.] 12 ppm, Zn [min.] 750 ppm, Vitamin A [min.] 33,000 IU/kg; Producer's Pride, Tractor Supply Company, Dothan, AL) was provided free choice along with water in each paddock for the duration of the grazing seasons that extended through 14 February in 2013 (116 d) and 1 February in 2014 (82 d).

Stockpiled paddocks were strip grazed to maximize harvest efficiency, using a temporary front grazing electrified fence (Polytape, Gallagher, Oswego, IL). Temporary front grazing fence was moved every 3 to 4 d to provide the equivalent of $1.33 \times$ cows' daily requirement (NRC, 1996) for forage DM (13.6 kg, 10% CP, 55% TDN) and maintain a minimum harvest efficiency of 75% as determined by pre- and post-graze forage mass. Grazing d/ha was calculated as $\text{kg forage DM/ha} \div [1.33 \times \text{daily forage DM requirement}]$.

Forage Sampling and Laboratory Analyses

Four forage samples were taken randomly from each paddock prior to the initiation of the experiment to estimate forage DM mass and chemical composition. Samples were harvested using a 0.25-m² quadrat and hand clippers to cut forage to a 5-cm height. After cows had been turned out for grazing, 4 pregraze forage samples were taken randomly from each paddock biweekly until cows were removed from paddocks. Following the initiation of the experiment, 4 samples were taken every 21 d from the grazed portion of strips previously grazed. Fresh-cut forage was placed into plastic, zip-closure bags and stored on ice for transportation to the Ruminant Nutrition Laboratory at Auburn University where it was dried at 50 °C for 48 h.

Dried, air-equilibrated forage samples were weighed, and subsamples were mixed thoroughly for uniformity and ground to pass a 1-mm screen in a Wiley Mill (Thomas Scientific, Philadelphia, PA). Forage concentrations of CP and DM were determined according to procedures of AOAC (1990), and concentrations of NDF, ADF and ADL were determined sequentially according to procedures of Van Soest et al. (1991). Forage IVDMD was determined according to the Van Soest et al. (1991) modification of the Tilley and Terry (1963) procedure using the Daisy II incubator system (Ankom Technology Corporation, Fairport, NY). Ruminal fluid was collected mid-morning from a fistulated Holstein cow that had free access to bermudagrass pasture and was limit-fed a supplement containing cracked corn, distillers dried grains, corn gluten feed, soyhull pellets, soybean meal, cottonseed meal, and cottonseed hulls. Fluid was stored in pre-warmed thermos containers and transported to the Ruminant Nutrition Laboratory where it was then processed for the batch-culture IVDMD procedure.

Cow Parameters and Calf Performance

Cow body condition scores (BCS) and weights, and calf weights and hip heights were measured every 21 d in both years. BCS were assigned using visual observations and a scoring system from 1 to 9, with 1 being extremely thin and 9 being extremely fat (Lowman et al., 1976). Milk production was measured by the weigh-suckle-weigh technique at 31-, 45-, and 161-d postpartum each year (Totusek et al., 1973). Calves were separated from their dams for 8 h, allowed to suckle until full, and separated again for 12 h. Calves were then weighed, allowed to suckle until full, and reweighed. Milk yield was calculated as the difference between the pre- and post-suckling weights, and milk yield was multiplied by 2 to estimate 24-h milk production. Calf weaning weights (WWs) were taken when calves averaged 218 d of age in Yr 1 and 204 d of age in Yr 2. Actual calf WWs were adjusted to 205-d weights (205-d WW) (BIF, 2018) and then to a bull basis. Assessment of body energy status was estimated during lactation by measuring blood urea-N (BUN) concentrations in whole-blood samples collected via jugular venipuncture on days 31, 45, and 123 postpartum in both years. Immediately after blood collection, 10-mL samples were placed on ice and, following centrifugation ($1,500 \times g$ for 20 min), sera were harvested and stored in 1.5-mL microcentrifuge tubes at -20 °C for subsequent analysis of serum urea-N. Serum urea-N concentration was measured spectrophotometrically (Roche Diagnostics, Indianapolis, IN) at the Pathology Laboratory at the Auburn University Small Animal Veterinary Clinic.

Estrous synchronization of cows was initiated on 7 January (day 0) both years of the study. Cows received GnRH (100 µg, i.m.) and an intravaginal progesterone-releasing insert (CIDR, Zoetis, Florham Park, NJ) for 7 d. On day 7, the CIDR was removed and PGF_{2α} (25 µg, i.m.) was administered. A second GnRH injection was administered 60 h after the PGF_{2α} injection (17 January), and cows were bred using timed artificial insemination (TAI). Twenty-eight days (14 February) after TAI, cows were placed with bulls for 76 d. Cows were pregnancy-checked at weaning on 28 May of both years, and final pregnancy status was determined using transrectal ultrasonography (Aloka SSD 500 with 7.5-MHz linear probe, Aloka Co. Ltd., Wallingford, CT) by a licensed veterinarian after bull removal. Days pregnant were determined by ultrasound, and projected calving intervals were calculated for both years.

Economic Evaluation

An economic evaluation of the pasture and hay systems was conducted comparing the stockpiled-forage system at each N fertilization rate with the hay system in terms of savings on a total input cost per cow basis. Costs per cow included variable costs of N fertilizer, grazing costs, labor, hay, supplements, and machinery. The hourly cost of equipment (\$25.00/h) used during the experiment was previously determined by [Prevatt et al. \(2008\)](#) and multiplied by the number of hours actual use time as recorded for each feeding system. Diesel costs were calculated by using the average amount of fuel per piece of equipment used per hour multiplied by the average retail price of fuel during the experiment. A labor rate of \$9.00/h was used and multiplied by the number of actual hours recorded for each treatment. The price of ammonium nitrate, whole cottonseed, and hay was \$465, \$420, and \$132/ton, respectively, during the experiment. The price per ton of ammonium nitrate and whole cottonseed were determined from the Alabama Weekly Feedstuff/Production Cost Report ([USDA, 2013](#)). Nitrogen cost for each treatment was calculated on the basis of the amount of needed N applied per ha. Grazing costs of the “Tifton 85” pastures for stockpiling were obtained from the records of input costs for sprigging, fertilizer application, grazing waste, and sprigs. The price of hay per ton was previously calculated by [Prevatt et al. \(2008\)](#) and multiplied by the amount of hay the cows consumed.

Statistical Analyses

Forage mass, forage nutritive quality parameters, and animal performance data were analyzed as a completely randomized design with 2 replicates per treatment. Because of extreme weather differences between years, forage mass and quality data from each year were analyzed separately. Data were treated as repeated measures using the PROC MIXED procedures of SAS 9.3 (2003) for forage characteristics. For each year, the statistical model included treatment, sampling date, and treatment $\times$ sampling date interaction as independent variables for forage-mass metrics, grazing d/ha, and forage concentrations of CP and percentage IVDMD. The experimental unit was considered to be paddock.

Cow and calf data were analyzed as a randomized complete block with 2 replicates per treatment using PROC MIXED procedures of SAS 9.3 (2003). Cow BW, cow BCS, calf BW, calf hip height, BUN, and milk production were treated

as repeated measures over time. Independent variables included year, treatment, sampling date, and calf sex. Interactions of year $\times$ treatment and treatment $\times$ time were included in the model. Cow age was used as a covariate. Either cow or calf was treated as a random effect in the model, depending on whether the dependent variable was a cow trait or calf trait. Dependent variables of 205-d WW, 205-d WW adjusted to a bull basis, days pregnant, and projected calving date were also analyzed as a completely randomized design with 2 replicates per treatment. Independent variables of year, treatment, and sex of calf were included in the model. The interaction of year $\times$ treatment was included in the model along with a covariate for age of dam. These traits were also analyzed using PROC MIXED procedures of SAS 9.3 (2003). Means were separated using least squares means with a Bonferroni adjustment. The significance level was set at $P < 0.05$ for all analyses. Repeated measures traits were also tested for linear, quadratic, or cubic responses using orthogonal contrasts.

RESULTS AND DISCUSSION

Minimizing amounts of mechanically harvested and purchased feed and maximizing grazed forages are the most economical system for a cow-calf operation ([Lalman et al., 2000](#)). However, the most economical feed resource must be matched to the biological type of the cow ([Lusby et al., 1991](#)). Advantages of bermudagrass, including high biomass potential, drought tolerance, insect tolerance, and exceptionally favorable responses to N fertilization, make it a popular species in the southern United States. However, the nutritive quality of certain bermudagrass cultivars can be limiting to animal performance ([Ball et al., 2007](#)). Prior to the present study, the grazing of stockpiled “Tifton 85” bermudagrass compared with feeding hay and supplement with fall-calving, lactating cows had not been investigated. “Tifton 85” is one of the improved cultivars that provides superior yield potential, persistence, and quality compared with unselected ecotypes ([Hill et al., 2001](#)).

Temperature and Precipitation

Rate of bermudagrass growth is considerably greater when the temperature is above 24 °C, and very little growth occurs when temperature is 15 to 18 °C ([Burton and Hanna, 1995](#)). First killing

Table 1. Monthly mean air temperatures (°C) for years 1 and 2, and 30-yr averages for Headland, AL

Month	Avg. High, °C			Avg. Low, °C			Mean, °C		
	Year 1	Year 2	30-yr	Year 1	Year 2	30-yr	Year 1	Year 2	30-yr
Jul	35	23	34	23	22	29	29	22	31
Aug	32	23	34	22	26	27	27	25	30
Sep	33	22	31	6	24	20	20	23	25
Oct	26	18	26	14	18	20	20	18	23
Nov	21	19	21	7	8	14	14	13	16
Dec	18	20	17	7	9	13	13	14	15
Jan	20	8	15	8	-1	4	14	4	10
Feb	14	14	18	11	4	11	13	9	15

frost occurred on 18 February 2013 (year 1) and 10 November 2013 (year 2). Monthly mean air temperatures (Table 1) in July, August, October, and November of year 1 were comparable with 30-yr averages for Headland, AL; however, the mean temperature in September was 5 °C less than the 30-yr average. In contrast, monthly mean air temperatures in year 2 were considerably less than 30-yr average values in the early to mid-summer and early fall months. In year 1, monthly mean precipitation (Table 2) was 162%, 104%, 71%, and 27% of the 30-yr average for the months of August, September, October, and November, respectively. In year 2, monthly mean precipitation was 43%, 7%, 97%, and 38% less than the 30-yr average for the months of August, September, October, and November, respectively. The timing of precipitation and warm weather created optimal conditions in the late summer and early fall of year 1 for an exceptionally favorable response to N application, and moderate weather conditions in winter of year 1 resulted in a longer grazing season than in year 2 of the study (116 vs. 88 d, respectively). Yr 2 had colder (especially January 2014), drier conditions that greatly reduced forage growth and productivity.

Forage Mass and Grazing Days

In year 1, there were no differences ($P = 0.50$) in pregrazed forage DM mass among treatments (Table 3). Because weather conditions were wetter and warmer than average, favorable growing conditions persisted and N rates exceeding 56 kg/ha did not result in increased forage mass or grazing-d/ha (mean across treatments = 314 grazing-d/ha). Given that January was 4 °C warmer than the 30-yr average, weather conditions were supportive of increased growth, even during the winter months.

Johnson et al. (2001) reported an increase in forage mass as N application rate increased from 0 to 78 kg/ha; however, a plateau was reached at

Table 2. Monthly total precipitation for years 1 and 2, and 30-yr averages and differences from 30-yr averages for Headland, AL

Month	Total Precipitation, mm			Differences, mm	
	Year 1	Year 2	30-yr	Year 1	Year 2
Jul	58	86	154	-96	-68
Aug	172	61	106	66	-45
Sep	110	99	106	4	-7
Oct	57	5	86	-29	-81
Nov	29	66	106	-77	-40
Dec	104	211	111	-7	100
Jan	36	57	133	-97	-76
Feb	445	139	127	318	12

78 kg of N/ha. In year 2 (Table 3), a treatment $\times$ sampling date interaction ($P < 0.05$) was detected such that the 112N treatment was greater ($P < 0.05$) than the 56N treatment throughout the grazing period except on 7 January when the 56N treatment was greater ($P < 0.05$) than the 112N treatment. Across all sampling dates, forage mass in the 168N treatment was greater ($P < 0.05$) than the 56N and 112N treatments, equivalent to 277, 201, and 218 grazing-d/ha, respectively. Forage mass reached a peak in early January and then experienced a sharp decline due to record low temperatures (-1 °C), which was the case in year 2. Given the cooler autumn temperatures in year 2, less forage growth was observed than in year 1. Rate of bermudagrass growth may decline in temperatures below 18 °C (Burton and Hanna, 1995).

For both years, herbage accumulation rate in response to N fertilization was comparable to that in a study in Florida where Vendramini et al. (2008) indicated that monthly herbage accumulation rate of "Tifton 85" bermudagrass increased from 57 to 93 kg·ha⁻¹·d⁻¹ as N rate increased. However, in mid-January of year 2 of the present study, forage DM availability declined considerably. Weather conditions under which forage for fall and winter grazing is stockpiled are major determinants of

Table 3. Mean pre-grazed forage mass (kg forage DM/ha) of stockpiled “Tifton 85” bermudagrass receiving different N fertilization treatments in years 1 and 2

Year	Sampling date	Treatment ¹			Mean
		56N	112N	168N	
1	Oct 24	5,145	6,020	5,550	5,571 ^a
	Nov 28	5,435	4,700	5,690	5,275 ^a
	Dec 13	5,900	5,670	6,720	6,096 ^{a,b}
	Jan 4	5,800	7,310	6,370	6,493 ^{a,b}
	Jan 16	6,600	7,121	7,660	7,127 ^b
	Mean	5,776	6,164	6,398	
2	Nov 11	3,030 ^c	3,899 ^d	4,380 ^e	3,785 ^f
	Nov 25	2,880 ^c	3,082 ^d	4,528 ^e	3,636 ^f
	Dec 10	3,560 ^c	4,260 ^d	5,339 ^e	4,386 ^g
	Jan 7	5,200 ^c	4,690 ^d	6,260 ^e	5,383 ^g
	Jan 21	3,560 ^c	3,810 ^d	4,251 ^e	3,843 ^f
	Mean	3,646 ^h	3,948 ^h	4,952 ⁱ	

^{a,b}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 817; $n = 6$).

^{c-e}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 162; $n = 2$).

^{f,g}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 228; $n = 6$).

^{h,i}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 228; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha.

rate and extent of forage deterioration (Burton and Hanna, 1995). In the present study, record freezing temperatures in early January likely contributed to greater forage deterioration than in year 1. Also, the N application and forage accumulation period in year 2 did not begin until the end of August compared with mid-August in year 1. Hart et al. (1969) concluded that deterioration from weathering was greater for forage that entered the winter dormancy period in a less mature state. Mean forage accumulation across all treatments was 6,190 and 4,207 kg/ha for years 1 and 2, respectively, which are comparable to values from a previous study in which the average forage accumulation ranged from 2,000 to 8,400 kg/ha for stockpiled “Tifton 85” bermudagrass fertilized with 125 kg N/ha (Scarborough et al., 2001). In year 1, forage mass across all sampling dates was not different ($P = 0.51$) among N-fertilization treatments, which indicates that application of 56 kg N/ha yielded maximum amounts of DM availability and that fertilization above that rate was not necessary.

Factors affecting the accumulation of bermudagrass forage during late summer and fall include variety, availability of moisture and timing of precipitation, temperature, available soil N, timing of N application, and the interaction of these factors (Lalman et al., 2000). Average forage accumulation per kg N for 56N, 112N, and 168N was 98.9, 58.7, and 36.4 kg, respectively, for year 1 and 63.5, 35.3, and 29.9 kg, respectively, for year 2. In a 2-yr study in Georgia, Hart et al. (1969) used 3 N fertilization

rates (0, 56, and 112 kg/ha) and 3 final hay-harvest dates (30 July, 15 August, and 1 September) to apply the fall N and begin the stockpiling period. Earlier N application dates combined with greater rates of N fertilization increased biomass yield. For their 112-kg N/ha treatment, DM yield per kg of applied N was 32, 19, and 21 kg for the July, August, and September application dates, respectively, for both years. Wilkinson and Langdale (1974) reported that standing crop accumulation ranged from 25 to 60 kg DM/kg added N. In a study in northwestern Arkansas, Scarborough et al. (2001) reported a 45% increase in stockpiled bermudagrass accumulation between 17 October and 14 November. Maximum mean forage mass was 3,069 kg DM/ha, and the authors concluded that accumulation may continue after mid-October. In a 3-yr trial that averaged 169 d of grazing by stocker cattle (Hill et al., 1993), “Tifton 85” produced 46% more gain per ha than “Tifton 78” bermudagrass (1,156 vs. 789 kg) and 38% more grazing-d/ha (1,823 vs. 1,319).

Forage Chemical Composition and Nutritive Value

There was a treatment $\times$ year interaction ($P < 0.05$) for forage CP concentration (Table 4). In year 1, forage CP concentration in the 112N treatment was greater ($P < 0.05$) than the 56N treatment on 28 November. However, the 56N treatment was greater ($P < 0.05$) than the 112N treatment on 24 October, 13 December, and 4 January, but was not different ($P = 0.13$) from 112N on 16 January. Also,

Table 4. Concentration of CP (% DM basis) in stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, and in “Tifton 85” bermudagrass hay in years 1 and 2

Year	Sampling date	Treatment ¹				Mean
		56N	112N	168N	HAY	
1	Oct 24	19.1 ^a	16.1 ^b	19.0 ^a	9.7 ^c	16.0 ^e
	Nov 28	10.1 ^c	11.2 ^b	12.3 ^a	9.4 ^d	10.8 ^f
	Dec 13	12.2 ^b	10.2 ^c	13.2 ^a	8.5 ^d	11.0 ^f
	Jan 4	12.3 ^a	11.3 ^b	12.1 ^a	8.9 ^c	11.1 ^f
	Jan 16	10.0 ^b	9.7 ^b	12.0 ^a	8.0 ^c	10.0 ^g
	Mean	12.7 ⁱ	11.8 ^j	13.7 ^h	8.9 ^k	
2	Nov 11	17.7 ^m	16.0 ⁿ	22.3 ^l	10.2 ^o	16.6 ^p
	Nov 25	11.5 ^m	11.0 ⁿ	16.1 ^l	9.2 ^o	12.0 ^q
	Dec 10	9.1 ^m	11.2 ^l	11.4 ^l	8.9 ⁿ	10.1 ^r
	Jan 7	9.1 ^m	11.2 ^l	11.4 ^l	8.6 ⁿ	10.1 ^r
	Jan 21	9.0 ⁿ	10.1 ^m	11.4 ^l	8.2 ^o	9.7 ^r
	Mean	11.3 ^u	12.0 ^t	14.5 ^s	9.0 ^v	

^{a-d}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.31; $n = 2$).

^{e-g}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.22; $n = 8$).

^{h-k}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.22; $n = 10$).

^{l-o}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.04; $n = 2$).

^{p-r}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.04; $n = 8$).

^{s-v}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.06; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in August prior to stockpiling.

forage CP concentration in the 168N treatment was greater ($P < 0.05$) than 56N in November, December, and mid-January, but was not different ($P \geq 0.19$) from 56N in October and early January. Across all sampling dates, mean forage CP concentration for the 168N treatment was greater ($P < 0.05$) than the 56N, 112N, and HAY treatments, and CP concentration in HAY was less ($P < 0.05$) than in stockpiled forages at all sampling dates. The amount of precipitation in the month of August presumably allowed for favorable plant N uptake response to N fertilization. In year 2, mean CP concentration for the 168N treatment was greater ($P < 0.05$) than the 56N treatment at all sampling dates and was greater ($P < 0.05$) than the 112N treatment in November and late January.

Concentration of CP in HAY was less ($P < 0.05$) than in stockpiled forages at all sampling dates. The greater forage N concentration in late fall of year 2 compared with year 1 is presumably a result of less DM mass, causing a concentration of N because rate of decline in CP is more rapid in forages that experience greater fall and winter precipitation from October through January (Lalman et al., 2000). Forage CP concentrations in the present study are comparable to values from a study in which Johnson et al. (2001) reported late-September CP concentrations of 10.4%, 12.1%, 14.6%, 17.8%, and 19.8% of DM for N application rates of 0, 39, 79, 118, and 157 kg/ha, respectively. The authors

concluded that CP concentrations increased with increasing N fertilization in bermudagrass.

The ability of stockpiled bermudagrass to maintain elevated CP concentration after first frost and under varying dormant season environments has been reported in only a few experiments (Hart et al., 1969; Taliaferro et al., 1987; Scarbrough et al., 2001; Mislevey and Martin, 2007). Highly soluble N in cured standing forage may be more susceptible to leaching during extended periods of grazing deferral and (or) with high levels of precipitation (Lalman et al., 2000). In a study in Florida, Alexander et al. (1961) applied 56 or 112 kg N/ha to “Coastal” bermudagrass during late August and allowed it to accumulate until October or December. Mean CP concentrations were 6.9% and 8.4% across all harvest dates for 56 and 112 kg N/ha, respectively.

In both years 1 and 2, NDF concentrations (Table 5) across all sampling dates were greater ($P < 0.05$) for the HAY than stockpile treatments. A sampling date $\times$ treatment interaction ($P < 0.05$) in year 1 resulted from the HAY treatment having greater ($P < 0.05$) NDF concentration than the stockpile treatments in late October. NDF concentrations for the HAY treatment were not different ($P \geq 0.15$) from 56N at all other sampling dates. NDF concentrations for the HAY treatment were not different ($P \geq 0.15$) from the 112N and 168N treatments in early January. There were differences ($P < 0.05$) among the

Table 5. Concentration of NDF (% DM basis) in stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, and in “Tifton 85” bermudagrass hay in years 1 and 2

Year	Sampling date	Treatment ¹				Mean
		56N	112N	168N	HAY	
1	Oct 24	64.8 ^b	65.0 ^b	62.0 ^b	72.5 ^a	66.1 ^e
	Nov 28	70.5 ^{a,b}	67.0 ^a	67.3 ^a	72.4 ^b	69.3 ^d
	Dec 13	70.6 ^{a,b}	67.3 ^a	65.2 ^a	72.6 ^b	69.1 ^d
	Jan 4	73.6	71.2	70.3	72.3	71.8 ^c
	Jan 16	69.5 ^{a,b}	69.8 ^{a,b}	68.0 ^b	72.6 ^a	70.0 ^d
	Mean	69.8 ^g	68.2 ^h	66.6 ⁱ	72.5 ^f	
2	Nov 11	65.9 ^k	63.5 ^{k,l}	63.3 ^l	68.5 ^j	65.3 ^o
	Nov 25	62.8 ^k	61.4 ^k	60.7 ^k	69.4 ⁱ	63.6 ^p
	Dec 10	65.4 ^k	64.6 ^k	63.0 ^k	70.4 ⁱ	65.9 ^o
	Jan 7	67.8 ^k	69.1 ^{j,k}	66.5 ^l	70.6 ⁱ	68.5 ⁿ
	Jan 21	67.9 ^k	72.7 ^j	64.7 ^l	70.2 ^k	69.0 ⁿ
	Mean	66.0 ^f	66.3 ^f	63.8 ^s	69.8 ^q	

^{a,b}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.17; $n = 2$).

^{c-e}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 1.17; $n = 8$).

^{f-i}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.66; $n = 10$).

^{j-m}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.77; $n = 2$).

^{n-p}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.77; $n = 8$).

^{q-s}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.10; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in August prior to stockpiling.

3 stockpile treatments, with 56N having the greatest ($P < 0.05$) NDF concentration across all sampling dates followed by the 112N and 168N treatments. Across all treatments, forage NDF concentration was 3.2 percentage units greater ($P < 0.05$) in the month of November than October, but increased ($P < 0.05$) in early January. In year 2, there was a treatment $\times$ date interaction ($P < 0.05$) which resulted from differences in NDF concentration among the stockpile treatments in early November and January, but lack of differences among them in late November and early December. Forage NDF concentration was less ($P < 0.05$) for the 168N than the 56N, 112N, and HAY treatments in January, and the HAY treatment was greater ($P < 0.05$) than the stockpiled treatments prior to January. The HAY treatment was not different ($P = 0.17$) from the 112N treatment on 7 January. On 21 January, the HAY treatment was not different ($P = 0.26$) from the 56N treatment, but was less ($P < 0.05$) than the 112N treatment and greater ($P < 0.05$) than the 168N treatment. Forage NDF concentrations were 2.2, 2.5, and 6.0 percentage units greater ($P < 0.05$), respectively, for the 56N, 112N, and HAY treatments than the 168N treatment across all sampling dates. Across all treatments, mean NDF concentrations increased over time beginning on 25 November and were, on average, 2.6 and 3.1 percentage units greater ($P < 0.05$) in early and late January, respectively, than in December. Overall mean forage NDF concentrations for years 1 and 2

were 69.3% and 66.4%, respectively, which are comparable to those from a study in which [Mandebvu et al. \(1999\)](#) reported an average NDF concentration of 69.2% for “Tifton 85” bermudagrass across all harvest dates, and in which “Tifton 85” bermudagrass yielded 80 g/kg more digestible NDF than “Coastal” bermudagrass. In another study, [Burns and Fisher \(2007\)](#) reported an average NDF concentration of 67.7% for “Tifton 85” bermudagrass hay in the central Piedmont of North Carolina. “Tifton 85” is a larger-stemmed plant than “Coastal,” which may account for greater NDF concentrations in these hybrids ([Hill et al., 1993](#)).

In year 1, there was a treatment $\times$ sampling date interaction ($P < 0.05$) for ADF concentration ([Table 6](#)). Mean ADF concentrations across all sampling dates were greater ($P < 0.05$) for the HAY than the stockpile treatments, but were not different ($P = 0.26$) between the 168N and 112N treatments and not different ($P = 0.71$) between the 56N and 112N treatments. There was an increase ($P < 0.05$) in ADF concentration from 28 November to 4 January and, for the months of December and January, ADF concentrations across all treatments were greater ($P < 0.05$) than in the other months. In year 2, a treatment $\times$ sampling date interaction ($P < 0.05$) resulted largely from the 112N treatment being greater than the 56N and 168N treatment on January 21, but not at the other sampling dates, and greater ($P < 0.05$) for HAY than stockpiled forages

in November and December, but not in January. Forage ADF concentrations across all treatments were less ($P < 0.05$) in late November than at other sampling dates except early December. Stockpiled forage treatments diverged during late January, at which time the 112N treatment had 2.6 and 4.7 percentage units greater ADF concentration than

the 56N and 168N treatments, respectively. Forage concentrations of ADF in the present study averaged 32.7% and 29.8% in years 1 and 2, respectively, across all treatments and sampling dates.

In year 1, concentrations of ADL (Table 7) across all sampling dates were greater ($P < 0.05$) for the HAY treatment than the 56N, 112N, and 168N

Table 6. Concentration of ADF (% DM basis) in stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, and in “Tifton 85” bermudagrass hay in years 1 and 2

Year	Sampling date	Treatment ¹				Mean
		56N	112N	168N	HAY	
1	Oct 24	27.9 ^b	27.4 ^b	26.9 ^b	36.6 ^a	30.1 ^e
	Nov 28	31.2 ^b	28.6 ^b	29.2 ^b	34.7 ^a	30.5 ^e
	Dec 13	34.1 ^a	32.7 ^{a,b}	31.3 ^b	34.3 ^a	33.1 ^d
	Jan 4	36.1	34.7	34.3	34.0	34.8 ^c
	Jan 16	34.7	36.5	34.5	34.6	34.7 ^c
	Mean	32.8 ^g	31.9 ^{g,h}	31.2 ^h	34.8 ^f	
2	Nov 11	30.8 ^k	29.8 ^k	29.7 ^k	38.0 ^j	32.1 ⁿ
	Nov 25	28.1 ^k	26.7 ^k	27.7 ^k	33.0 ^j	28.9 ^o
	Dec 10	30.0 ^k	28.5 ^k	29.6 ^k	34.2 ^j	30.6 ^{n,o}
	Jan 7	31.7 ^k	32.1 ^{j,k}	32.1 ^{j,k}	34.1 ^j	32.5 ⁿ
	Jan 21	31.1 ^{j,k}	33.7 ^j	29.0 ^l	33.1 ^{j,k}	31.7 ⁿ
	Mean	30.3 ^r	30.2 ^r	29.6 ^r	34.5 ^q	

^{a,b}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.93; $n = 2$).

^{c-e}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.93; $n = 8$).

^{f-i}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.31; $n = 10$).

^{j-m}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.75; $n = 2$).

^{n-p}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.75; $n = 8$).

^{q-s}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.06; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in August prior to stockpiling.

Table 7. Concentration of ADL (% DM basis) in stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, and in “Tifton 85” bermudagrass hay in years 1 and 2

Year	Sampling date	Treatment ¹				Mean
		56N	112N	168N	HAY	
1	Oct 24	1.6 ^b	1.4 ^{b,c}	1.3 ^c	2.1 ^a	1.6 ^f
	Nov 28	1.8 ^b	1.9 ^b	1.9 ^b	2.9 ^c	2.1 ^f
	Dec 13	3.1 ^b	3.0 ^b	3.0 ^b	3.5 ^c	3.2 ^e
	Jan 4	4.3 ^b	4.2 ^b	4.2 ^b	4.4 ^c	4.3 ^d
	Jan 16	4.5 ^b	4.9 ^c	4.9 ^c	5.3 ^a	4.9 ^d
	Mean	3.1 ^h	3.1 ^h	3.1 ^h	3.6 ^g	
2	Nov 11	1.8 ⁱ	1.7 ^j	1.9 ^k	3.7 ^l	2.3 ^m
	Nov 25	3.7 ⁱ	3.4 ^j	3.9 ^k	4.7 ^l	3.9 ⁿ
	Dec 10	4.1 ⁱ	3.7 ^j	4.4 ^k	6.5 ^l	4.7 ^o
	Jan 7	4.2 ⁱ	4.3 ^j	5.1 ^k	6.8 ^l	5.1 ^p
	Jan 21	5.7 ⁱ	5.6 ^j	6.7 ^k	6.7 ^k	6.2 ^q
	Mean	3.9 ^r	3.7 ^s	4.3 ^t	5.7 ^u	

^{a-c}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.17; $n = 2$).

^{d-f}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 1.17; $n = 8$).

^{g-h}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.66; $n = 10$).

^{i-l}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.03; $n = 2$).

^{m-q}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.03; $n = 8$).

^{r-u}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.04; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in August prior to stockpiling.

treatments. Across all sampling dates, ADL concentrations were not different ($P = 0.71$) between the 56N treatment and the 112N and 168N treatments. However, in late January, 56N was less ($P < 0.05$) than 112N and 168N. In year 2, forage concentration of ADL in the HAY treatment was greater ($P < 0.05$) than all 3 stockpile treatments, and the stockpile treatments were different ($P < 0.05$) from each other at all sampling dates. Mean lignin concentrations for years 1 and 2 were 3.2% and 4.4%, respectively; year 2 results are comparable to those from a study in which [Burns and Fisher \(2007\)](#) reported an overall mean lignin concentration in bermudagrass of 4.7%. Concentrations of lignin increased considerably more in year 2 than in year 1, presumably as a result of weathering. For dormant forage, [Wheeler et al. \(1999\)](#) observed no change in concentrations of NDF, ADF, or lignin in esophageal masticate samples collected from cows grazing stockpiled bermudagrass pastures between November and February in Oklahoma. Mean concentrations of NDF, ADF, and lignin in masticate samples over 4 sampling dates were 611, 337, and 80 g/kg DM, respectively. There was a treatment $\times$ sampling date interaction for percentage IVDMD in year 1 ([Table 8](#)) such that there were no differences ($P \geq 0.10$) among treatments on 4 January and 16 January, but all 3 stockpile treatments were greater ($P < 0.05$) than the HAY treatment on 24 October. Mean initial IVDMD was 11.7, 16.9, and

16.8 percentage units greater ($P < 0.05$) for the 56N, 112N, and 168N treatments than the HAY treatment, respectively, in year 1. Mean IVDMD across all treatments declined 6.1, 3.2, and 3.3 percentage units from the preceding sampling date in November, early January, and mid-January, respectively. In year 2, there was a treatment $\times$ sampling date interaction ($P < 0.05$) largely because the 168N treatment was not different ($P \geq 0.15$) from the other stockpile treatments at any sampling date, except in late November when the 168N treatment was greater ($P < 0.05$) than the other stockpile treatments. There were no differences ($P \geq 0.10$) among treatments in mean IVDMD on 7 January, but mean IVDMD was greater ($P < 0.05$) for all 3 stockpile treatments than the HAY treatment at all other sampling dates. Mean IVDMD across all treatments declined considerably (14.6%) from November to December.

The stockpiled treatments in year 2 remained at values that met cows' requirement for TDN ([NRC, 1996](#)) throughout the experiment; however, the HAY treatment declined below that required, warranting supplementation with whole cottonseed. [Mandebvu et al. \(1999\)](#) reported average IVDMD to be between 61.7 (3-wk harvest) and 56.9% (6-wk harvest), which is in agreement with values in the present study. [Alderman et al. \(2011\)](#) indicated that percentage IVDMD was increased by N fertilization, but was greatly diminished once N rate was

Table 8. Percentage IVDMD in stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, and in “Tifton 85” bermudagrass hay in years 1 and 2

Year	Sampling date	Treatment ¹				Mean
		56N	112N	168N	HAY	
1	Oct 24	69.2 ^b	74.4 ^b	74.3 ^b	57.5 ^a	68.1 ^c
	Nov 28	61.4 ^{a,b}	63.9 ^a	65.7 ^a	56.9 ^b	62.0 ^d
	Dec 13	56.8 ^b	58.3 ^{a,b}	64.4 ^a	56.9 ^{a,b}	59.1 ^d
	Jan 4	56.4	57.1	52.0	57.9	55.9 ^e
	Jan 16	53.7	52.0	51.0	53.7	52.6 ^f
	Mean	59.6 ^e	61.1 ^g	61.4 ^g	56.6 ^h	
2	Nov 11	71.8 ⁱ	73.5 ⁱ	74.5 ⁱ	50.0 ^j	67.5 ^l
	Nov 25	62.0 ⁱ	63.0 ⁱ	69.6 ^j	46.4 ^k	60.1 ^m
	Dec 10	54.2 ⁱ	58.0 ⁱ	54.5 ⁱ	44.7 ^j	52.9 ⁿ
	Jan 7	49.5	51.5	51.0	45.2	49.3 ⁿ
	Jan 21	51.0 ⁱ	52.5 ⁱ	55.4 ⁱ	45.3 ^j	51.1 ⁿ
	Mean	57.7 ^o	59.7 ^o	61.0 ^o	46.3 ^p	

^{a,b}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 2.10; $n = 2$).

^{c-f}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 2.10; $n = 8$).

^{g,h}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 2.97; $n = 10$).

^{i-k}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.55; $n = 2$).

^{l-n}Within a column, means without a common superscript differ ($P < 0.05$; SEM = 1.55; $n = 8$).

^{o,p}Within a row, means without a common superscript differ ($P < 0.05$; SEM = 2.20; $n = 10$).

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in August prior to stockpiling.

increased beyond 90 kg/ha. Despite relatively high NDF concentrations in “Tifton 85” bermudagrass in the present study, the observed IVDMD values suggest that its fiber fraction was highly digestible, in agreement with previous research (Hill et al., 1993; Mandebvu et al., 1998a). Mandebvu et al. (1998b) reported declines in the digestibility of DM, OM, and NDF with increased NDF concentration in “Coastal”; however, even though NDF concentration was greater than that of “Coastal,” there was a positive correlation between NDF concentration and digestibilities of DM, OM, and NDF in “Tifton 85.” The authors concluded that this observation may have been related to the greater network of indigestible ethereal linkages between ferulic acid and arabinoxylans in “Coastal” than in “Tifton 85.”

In year 1, a warmer, wetter late summer and fall combined with a warmer winter caused a favorable response in forage mass and contributed to greater stability of the stockpiled treatments and less forage deterioration. All 3 rates of N were successful in maintaining acceptable amounts of forage mass throughout the grazing season, and there was a lack of divergence in forage mass among treatments. Colder, drier conditions in year 2 contributed to decreased mass and greater forage deterioration. Treatment divergence occurred in year 2 with the greatest amount of forage mass resulting from the application of 168 kg N/ha. Considerable declines occurred in CP concentration and percentage IVDMD in both years. Forage CP concentrations in both years were adequate for meeting the CP requirement (10.0% CP) of a 591-kg mature,

lactating beef cow during peak lactation. Percentage IVDMD in both years, with the exception of the 168N treatment in year 2, was slightly less than the requirement for digestible DM, or TDN (55.0%).

Cow Parameters and Reproductive Performance

Simple means of initial cow BW (647 ± 23 kg), BCS (5.8 ± 0.5), and age (5.2 ± 2.1 yr) are shown in Table 9 for each treatment and year. Cow weight declined ($P < 0.05$) over time (Table 10). Analysis for cow weight indicated that the response was cubic in nature ($P < 0.05$). Cow BW was greatest at the initiation of the study each year, but was less ($P < 0.05$) by the next weigh date. However, cow BW was not different ($P \geq 0.71$) from late November through January. Cow BW then declined ($P < 0.05$) again by the end of the study such that mean cow final BW in February was 78.9 kg less than mean initial BW. The amount of BW loss in the present study is comparable to lactating-cow BW losses in a stockpiled tall fescue grazing experiment in which Curtis et al. (2008) reported an average cow BW loss of 105 kg for the grazing treatments and 43 kg for a control hay treatment. Timing of BW loss in the present study is comparable to that from a previous report in the literature. Wheeler et al. (2002) reported greater cow BW loss from days 31 to 79 (November through January) of their study in year 1, and from days 64 to 90 (December and January) in year 2.

Cow BCS (Table 10) declined linearly ($P < 0.05$) over time. Total BCS loss was 0.67 units, with the greatest BCS loss occurring during peak lactation.

Table 9. Age and body measurements of cows and calves wintered on stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, or on “Tifton 85” bermudagrass hay plus supplement during years 1 and 2

Trait	Treatment ¹							
	56N		112N		168N		HAY	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Cow parameters								
Age, yr	6.5	5.0	5.0	5.0	5.5	4.8	4.8	5.5
Initial BW, kg	670	641	620	612	705	641	638	634
Initial BCS	6.0	5.8	5.8	5.1	6.0	5.7	6.0	5.8
Calf parameters								
Birth weight, kg	45.5	39.3	41.3	42.0	43.7	38.5	46.9	40.8
Initial BW, kg	41.3	60.4	47.7	52.4	49.4	53.7	44.4	66.6
Initial hip height, cm	71.4	66.7	76.5	76.8	74.6	69.2	74.0	73.6
Actual weaning weight, kg	269	220	261	241	273	240	291	251
Age at weaning, d	212	202	215	207	213	203	224	203

¹56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; HAY = “Tifton 85” hay cut in.

August prior to stockpiling.

Table 10. Body weight and body condition score of cows, and body weight and hip height (hh) of their calves wintered on stockpiled “Tifton 85” bermudagrass receiving different rates of N fertilization, or on “Tifton 85” bermudagrass hay plus supplement during years 1 and 2

Trait	Month ¹				
	Early-Nov	Late-Nov	Dec	Jan	Feb
Cow BW and BCS ²					
BW, kg	647.2 ^a	610.0 ^b	615.4 ^b	615.6 ^b	568.3 ^c
BCS	5.8 ^a	5.7 ^a	5.5 ^{a,c}	5.3 ^{b,c}	5.2 ^b
Calf BW and hh ³					
BW, kg	52.0 ^c	71.0 ^d	87.6 ^c	104.0 ^b	126.0 ^a
hh, cm	72.9 ^c	81.2 ^d	87.4 ^c	90.8 ^b	95.8 ^a

^{a-c}Within a row, means without a common superscript differ ($P < 0.05$).

¹Early-Nov = November 1, 2012 and November 11, 2013; Late-Nov = November 25, 2012 and November 28, 2013; Dec = December 13, 2012 and December 10, 2013; January 7, 2012 and January 7, 2013; Feb = February 14, 2012 and February 1, 2013.

²Cow BW SEM = 11.0 kg; cow BCS SEM = 0.60.

³Calf BW SEM = 5.9 kg; calf hh SEM = 0.29 cm.

However, in a similar study, [Wheeler et al. \(2002\)](#) reported slightly greater BCS losses (0.70 and 0.42 for years 1 and 2, respectively) over a similar time period. Even though all treatments experienced marginal declines in BW and BCS, stockpiled “Tifton 85” bermudagrass was as effective in minimizing BW and BCS loss as ad libitum access to “Tifton 85” hay plus 2.7 kg of whole cottonseed. Fall-calving cows are expected to lose BCS over winter ([Coffey et al., 2005](#)). However, the cows in the present study began the experiment in excellent body condition (5.5 to 6 units and were able to withstand marginal loss in BW and BCS. In the previously referenced stockpiled tall fescue grazing experiment, [Curtis et al. \(2008\)](#) reported an average BCS loss of 0.79 and 0.42 in years 1 and 2, respectively. In the present study, forage CP concentration was not limiting in the stockpiled forage grazed by lactating cows ([NRC, 1996](#)). Forage TDN was limiting only in late January ([NRC, 1996](#)), at which point IVDMD declined in all stockpile treatments. In other studies under similar conditions where cows consumed stockpiled forage ([Lusby et al., 1991](#); [Marston et al., 1998](#); [Steele et al., 2007](#)) or low-quality hay ([Banta et al., 2006](#)) and fed a concentrated CP supplement, beef cows continued to experience BCS loss during the winter feeding period.

Mean milk production at 31-, 54-, and 161-d postpartum was 8.7, 9.3, and 9.0 kg/d, respectively. Milk production did not differ ($P \geq 0.25$) due to

treatment or sampling date in this study, and mean milk production across all treatments and sampling dates was 9.0 kg/d. Also, there were no effects ($P \geq 0.89$) of age of cow or sex of calf on milk production. Several other studies ([Reynolds et al., 1978](#); [Chenette and Frahm, 1981](#); [Daley et al., 1987](#)) reported little or no effect of calf sex on dam’s milk production. [Rutledge et al. \(1971\)](#) reported an increase of milk production for dams of heifers. However, [Pope et al. \(1963\)](#), and [Daley et al. \(1987\)](#) reported that dams of bull calves produced more milk than dams of heifer calves. For 591-kg mature weight beef cows, peak milk production at 9.1 kg/d requires a diet containing 10.0% CP and 55.0% IVDMD at 3- to 4-mo postpartum ([NRC, 1996](#)). Although cows were losing BW and BCS postpartum in the present study, milk production was expected to increase; however, estimated daily milk production in both years remained largely unchanged. Across all stockpile treatments, mean percentage CP and IVDMD of the forage during peak lactation was 11.0% and 57.5% in year 1, respectively, and 10.1% and 51.1% in year 2, respectively, which meet the CP and TDN requirements of cows utilized in the present study except for TDN as reflected by IVDMD in year 2 on the last forage sampling date.

Mean BUN levels at 31-, 54- and 116-d postpartum were 10.6, 10.2, and 13.0 mg/mL, respectively. Cow BUN levels differed ($P < 0.05$) among sampling dates. There were linear and quadratic ($P < 0.05$) responses over time for BUN levels. There were no differences ($P = 0.62$) in BUN levels 31- or 45-d postpartum. However, at 116-d postpartum, BUN levels were greater ($P < 0.05$). In terms of N fertilization effects on BUN levels, in the present study, there were no observed effects.

Compared with the first 2 sampling dates, mean forage CP concentration across all treatments had declined only to 10.0% by the last sampling date. When BUN levels were least, mean forage CP concentration in years 1 and 2 was 11.0% and 10.1%, respectively. When BUN levels were greatest, mean CP concentrations were 10.0 and 9.7 in years 1 and 2, respectively. Although the HAY treatment includes CP from whole cottonseed supplementation, in terms of BUN levels, it was still comparable to the stockpile treatments. However, when BUN levels were greatest, TDN was least for all treatments, which explains why the BUN levels were increased at the end of the study due to the decline in energy to protein ratio ([Hammond et al., 1993](#)). Cow BUN levels in the present study are comparable to ranges of values found in other studies.

Hammond et al. (1993) summarized data from 8 grazing trials in Florida to determine whether BUN could predict the biological response (change in average daily body weight gain, ADG) to protein and/or energy supplementation in steers and heifers grazing warm-season grass pastures. In these studies, animals grazed bahiagrass (*Paspalum notatum*) and limpograss (*Hemarthria altissima*), and comparisons between protein supplement treatments and various controls were evaluated. Change in ADG (-0.05 to 0.30 kg/day) due to protein supplementation was correlated with BUN concentration (6.2 to 15.5 mg/mL) in control cattle ($r = 0.69$). Concentrations of BUN between 9 and 12 mg/mL were within a transition range, below which ADG response to protein supplementation was greater, and above which ADG response was less than the response within this range. Other studies in the literature have shown that BUN values were affected by N fertilization rate, lactation states, and cow age. da Lima et al. (1994) indicated that increasing N fertilization in common bermudagrass increased BUN in yearling heifers from 4.2 to 9.2 mg/mL and increased ADG from 0.06 to 0.36 kg/d. In the present study, at the end of the grazing season in February, BUN levels increased 2.3 mg/mL. BUN levels did not differ ($P > 0.05$) due to age. In dairy cows, BUN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period, and BUN increased with increasing age (Peterson and Waldern, 1981).

Treatment did not influence overall pregnancy rate, and overall mean rebreeding rate was 88% . Adams et al. (1996) reported that BCS and pregnancy rates of cows consuming stockpiled forage in the Nebraska Sandhills and cows consuming hay-based diets were not different, but prebreeding weights were less for cows grazing stockpiled forage. Even with declines in BW and BCS at the time of breeding, conception rates did not seem to have been affected. In the present study, year 2 included 3 open cows which began the study in lower body condition than the other year-2 cows, and they were also 3 yr old. Houghton et al. (1990) evaluated the BCS of cows at critical junctures and reported that fertility was greater for cows maintaining or approaching a BCS of 5 than cows deviating from moderate BCS, including cows getting thinner or fatter, regardless of the energy intake treatment to which each cow had been assigned. In the present study, the nutritional plane was adequate for cows to maintain milk production with only modest losses in energy reserves, which should not have affected rebreeding.

Calf Performance

Simple means of calf birth weight (42.3 ± 9.8 kg), initial BW (52.1 ± 0.5 kg), and initial hip height (72.9 ± 1.8 cm) are shown in Table 9. Independent variables of year, treatment, and sampling date were sources of variation ($P < 0.05$) in calf performance measures. There was a year $\times$ treatment interaction ($P < 0.05$) for calf BW and a linear effect ($P < 0.05$) of time on calf BW (Table 10). At each time period, calf weight was greater ($P < 0.05$) than the previous weigh date. These results were expected because calves are in a linear ($P < 0.05$) growth pattern from birth to weaning. In year 1 of this study, there were no differences ($P = 0.27$) in calf BW across treatments. However, for year 2, calf BW for the HAY treatment was greater ($P < 0.05$) than the stockpile treatment calves, but there were no differences ($P \geq 0.13$) for calf BW among the 3 stockpile treatments. Also, year-2 calf BW was 31 kg greater ($P < 0.05$) than year-1 calf BW at the end of the study. In year 2, all calves utilized in the study were sired by low-birth weight, high-growth EPD bulls. In year 1, all calves were sired by a natural-service sire. The AI bull possessed greater growth potential than the natural-service bull.

Differences in calf BW could not be explained on the basis of differences in milk production of cows. Rutledge et al. (1971) showed that a dam's milking ability describes 66% of the variation in calf WW. Adams et al. (1996) observed that calves from cows grazing stockpiled forage in the sandhills of Nebraska were lighter at birth than calves from cows fed a hay-based diet, but there were no differences in calf weight at weaning.

For calf hip height, sources of variation ($P < 0.05$) included year (Table 9) and time (Table 10). The standard equation to convert hip height to frame score also includes a quadratic component (BIF, 2018). A linear and quadratic effect ($P < 0.05$) of time was detected, which was expected. Calf hip height was greater ($P < 0.05$) at each subsequent weigh period, as expected. In year 2, calves were 3.4 cm shorter ($P > 0.05$) than calves in year 1, which can be explained by sire-of-calf differences.

Mean calf 205-d WW for years 1 and 2 was 268 and 248 kg, respectively. Mean calf 205-d WW adjusted to a bull basis for years 1 and 2 was 279 and 257 , respectively. Year was the only source of variation ($P < 0.05$) for 205-d WW or 205-d WW adjusted to a bull basis. Mean calf 205-d WW in year 1 (268 kg ± 5.7) was 20 kg heavier ($P < 0.05$) than year 2 and mean calf 205-d WW adjusted to a bull

basis in Yr 1 was 21 kg heavier ($P < 0.05$) than year 2. Although yearly fluctuation in WW was expected, year-1 calves were not expected to weigh more ($P < 0.05$) than year-2 calves. In year 2, calf BW was greater ($P < 0.05$) at the end of the stockpile period; however, calves grew poorly from February through May. Milk production does not provide a satisfactory explanation for the differences found in WWs, because no differences were detected among treatments or between years. However, year-1 calves were placed on ryegrass pasture with their dams at the end of the grazing period, whereas year-2 calves had to remain on the test pastures with hay due to lack of available ryegrass pasture in year 2. WWs in the present study were greater than those from a similar study in which [Curtis et al. \(2008\)](#) reported average WW from calves nursing cows grazing stockpiled fescue to be 195 ± 8 kg when cows were given access to strips of forage to meet 2.25% of $\text{BW} \cdot \text{d}^{-1} \cdot \text{cow}^{-1}$.

Economics of Winter Feeding Systems

Economic evaluation of the stockpiled treatments compared with the HAY treatment and an additional comparison of feeding hay without supplement were conducted. Input variables included cost of N (ammonium nitrate), forage establishment, herbicide, labor, harvest, supplement, and machinery. Hay-feeding wastage was calculated throughout the study and averaged 20%. Input costs/cow were 66.0%, 61.0%, and 56.0% greater for HAY than 56N, 112N, and 168N, respectively. In addition, hay alone was 11% less in cost than hay plus supplement.

The strategy of applying financial resources toward feeding and supplementing the cow herd is an enterprise-specific decision. The key is to find the point at which cattle performance and cost outlays are optimized ([Hersom et al., 2008](#)), which will be affected by many variables including expected cow performance, previous cow condition, forage conditions, supplement type, and environmental conditions.

Results of this study indicate that fertilized stockpiled "Tifton 85" bermudagrass was of sufficient productivity and nutritive value to support lactating beef cows and reproductive performance without supplementation. Whether to supplement cows during the grazing season is a critical management decision, and implementation of a strategic supplementation program must have a measurable positive outcome in order to have biological relevance and justify its continued use. Cow weight and body condition were fairly consistent from year to

year. Adjusted weight of calves showed dramatic changes, which could have been due to the considerable variation that occurred from year to year in meteorological conditions and in quantity and quality of forage available, which were associated with the variation in response from year to year.

LITERATURE CITED

- Adams, D., R. Clark, T. Klopfenstein, and J. Volesy. 1996. Nutritional value of grazed forages and how it fits the cow's requirement. Range Beef Cow Symposium. Paper 192. <http://digitalcommons.unl.edu/rangebeefcowsymp/192>
- Alderman, P. D., K. J. Boote, and L. E. Sollenberger. 2011. Regrowth dynamics of 'Tifton 85' bermudagrass as affected by nitrogen fertilization. *Crop. Sci.* 51:1716–1726. doi:10.2135/cropsci2010.09.0515
- Alexander, R. A., J. F. Hentges, Jr., J. T. McCall, H. W. Lundy, N. Gammon, Jr., and W. G. Blue. 1961. The nutritive value of fall-harvested coastal bermudagrass hay as affected by rate of nitrogen fertilization and state of maturity. *J. Anim. Sci.* 20:93–98. doi:10.2527/jas1961.20193
- AOAC. 1990. Official methods of analysis. 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.
- Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 2007. Southern forages. 4th ed. Williams Printing Company, Atlanta, GA.
- Banta, J. P., D. L. Lalman, C. R. Krehbiel, and R. P. Wettemann. 2006. Whole soybean supplementation and cow age class: effects on intake, digestion, performance, and reproduction of beef cows. *J. Anim. Sci.* 86:1868–1878. doi:10.2527/jas.2007-0383
- BIF. 2018. Animal evaluation. In: L. V. Cundiff, L. D. VanVleck, and W. D. Hohenbohen, editors, Guidelines for uniform beef improvement programs. 9th rev. ed. Prairie (MS): Beef Improvement Federation; p. 16–56.
- Burns, J., and D. S. Fisher. 2007. Dry matter intake and digestibility of 'Coastal', 'tifton 44', and 'tifton 85' bermudagrass hays grown in the U.S. Upper south. *Crop. Sci.* 47:795–810. doi:10.2135/cropsci06.04.0253
- Burton, G. W., and W. W. Hanna. 1995. Bermudagrass. In: R. F. Barnes, D. A. Miller, and C. J. Nelson, editors, Forages – an introduction to grassland agriculture. Vol. 1. Iowa State University Press, Ames. p. 421. doi:10.1017/S0014479700001563
- Chenette, C. G., and R. R. Frahm. 1981. Yield and composition of milk from various two-breed cross cows. *J. Anim. Sci.* 52:483–492. doi:10.2527/jas1981.523483
- Coffey, K. P., W. K. Coblenz, D. A. Scarbrough, J. B. Humphry, B. C. McGinley, J. E. Turner, T. F. Smith, D. S. Hubbell, III, Z. B. Johnson, D. H. Hellwig, et al. 2005. Effect of rotation frequency and weaning date on forage measurements and growth performance by cows and calves grazing endophyte-infected tall fescue pastures over seeded with crabgrass and legumes. *J. Anim. Sci.* 83:2684–2695. doi:10.2527/2005.83112684x
- Corriher, V. A., G. M. Hill, J. G. Andrae, M. A. Froetschel, and B. G. Mullinix, Jr. 2007. Cow and calf performance on coastal or Tifton 85 bermudagrass pastures with aeschyromene creep-grazing paddocks. *J. Anim. Sci.* 85:2762–2771. doi:10.2527/jas.2007-0015

- Curtis, L. E., R. L. Kallenbach, and C. A. Roberts. 2008. Allocating forage to fall-calving cow-calf pairs strip-grazing stockpiled tall fescue. *J. Anim. Sci.* 86:780–789. doi:10.2527/jas.2007-0525.
- Daley, D. R., A. McCuskey, and C. M. Bailey. 1987. Composition and yield of milk from beef-type *bos taurus* and *bos indicus* x *bos taurus* dams. *J. Anim. Sci.* 64:373–384. doi:10.2527/jas1987.642373x
- Hammond, A. C., W. E. Kunkle, D. B. Bates, and L. E. Sollenberger. 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. In: *Proc. XVII Int. Grassl. Congr. Rockhampton, Australia*. p. 1989–1991.
- Hart, R., W. Monson, and R. Lowrey. 1969. Lowrey. Autumn-saved coastal bermudagrass (*Cynodon dactylon* (L.) Pers.): effects of age and fertilization on quality. *J. Anim. Sci.* 61:940–941. doi:10.2134/agronj1969.00021962006100060034
- Hersom, M. J. 2008. Opportunities to enhance performance and efficiency through nutrient synchrony in forage-fed ruminants. *J. Anim. Sci.* 86 (14 Suppl.):E306–E317. doi:10.2527/jas.2007-0463
- Hill, G. M., R. N. Gates, and G. W. Burton. 1993. Forage quality and grazing steer performance from Tifton 85 and Tifton 78 bermudagrass pastures. *J. Anim. Sci.* 71:3219–3225. doi:10.2527/1993.71123219
- Hill, G. M., R. N. Gates, and J. W. West. 2001. Advances in bermudagrass research involving new cultivars for beef and dairy production. *J. Anim. Sci.* 79 (E. Suppl.):E48–E58. doi:10.2527/jas2001.79E-SupplE48.
- Houghton, P. L., R. P. Lemenager, L. A. Horstman, K. S. Hendrix, and G. E. Moss. 1990. Effects of body composition, pre- and postpartum energy level and early weaning on reproductive performance of beef cows and preweaning calf gain. *J. Anim. Sci.* 68:1438–1446. doi:10.2527/1990.6851438
- Johnson, C. R., B. A. Reiling, P. Mislevy, and M. B. Hall. 2001. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. *J. Anim. Sci.* 79:2439–2448. doi:10.2527/2001.7992439
- Lalman, D. L., C. M. Taliaferro, F. M. Epplin, C. R. Johnson, and J. S. Wheeler. 2000. Review: grazing stockpiled bermudagrass as an alternative to feeding harvested forage. *J. Anim. Sci.* 79:1–8. doi:10.2527/jas.00.079ES1001h
- Lowman, B. G., N. A. Scott, and S. H. Somerville. 1976. Condition scoring of cattle. *East of Scotland College of Agr. Bull. No. 6*. Edinburgh School of Agriculture: Edinburgh.
- da Lima, G. F. C., L. E. Sollenberger, W. E. Kunkle, J. E. Moore, and A. C. Hammond. 1994. Improving limpograss forage quality and utilization using nitrogen fertilization and supplementation. In: *Natl. Conf. For. Qual. Eval. Util., Univ. Nebraska, Lincoln*. p. 90.
- Lusby, K. S., R. P. Wettemann, K. H. Ovenell, and D. A. Cox. 1991. The value of wheat middlings in winter supplements for beef cows. *Prof. Anim. Sci.* 7:24–29. doi:10.15232/S1080-7446(15)32172-0
- Mandebvu, P., J. W. West, and G. M. Hill. 1998a. Effect of hay maturity, forage source, or 697 neutral detergent fiber content on digestion of diets containing Tifton 85 bermudagrass 698 and corn silage. *Anim. Feed Sci. Technol.* 73:281–290. doi:10.1016/S0377-8401(98)00152-7
- Mandebvu, P., J. W. West, and G. M. Hill. 1998b. In vitro digestion kinetics of neutral detergent extracted from Tifton 85 bermudagrass and coastal bermudagrass. *Anim. Feed Sci. Technol.* 73:263–269. doi:10.1016/S0377-8401(98)00155-2
- Mandebvu, P., J. W. West, G. M. Hill, R. N. Gates, R. D. Hatfield, B. G. Mullinix, A. H. Parks, and A. B. Caudle. 1999. Comparison of Tifton 85 and coastal bermudagrasses for yield, nutrient traits, intake, and digestion by growing beef steers. *J. Anim. Sci.* 77:1572–1586. doi:10.2527/1999.7761572
- Marston, T. T., D. A. Blasi, F. K. Brazle, and G. L. Kuhl. 1998. Beef cow nutrition guide. Kansas State University Agricultural Experiment Station and Cooperative Extension 707 Service Publication C-735: Manhattan.
- Mislevey, P., and Martin, F. 2007. Yield and nutritive value of stockpiled grasses as influenced by cultural practices and a freeze. *Forage and Grazing lands FG-2007-0206-01-RS*. doi:10.1094/FG-2007-0206-01-RS
- NRC. 1996. Nutrient requirements of beef cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.
- Peterson, R. G., and D. E. Waldern. 1981. Repeat abilities of serum constituents in holstein-friesians affected by feeding, age, lactation, and pregnancy. *J. Dairy Sci.* 64:822–831. doi:10.3168/jds.S0022-0302(81)82653-7
- Pope, L. S., L. Smithson, D. F. Stephens, D. Pinney, and M. Velasco. 1963. Factors affecting milk production of range beef cows. In: *Oklahoma Agric. Exp. Sta. Misc. Publ. 70:69*. Oklahoma State Univ., Stillwater.
- Prevatt, W., M. Runge, D. Ball, M. Davis, and C. Prevatt. 2008. Budgets for major forage crop enterprises in Alabama. Alabama Cooperative Extension. Auburn University: Alabama. BUM 1–2.
- Reynolds, W. L., T. M. DeRouen, and R. A. Bellows. 1978. Relationships of milk yield of dam to early growth rate of straightbred and crossbred calves. *J. Anim. Sci.* 47:584–594. doi:10.2527/jas1978.473584
- Rutledge, J. J., O. W. Robison, W. T. Ahlschwede, and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. *J. Anim. Sci.* 33:563–567. doi:10.2527/jas1971.333563
- Scarborough, D. A., W. K. Coblenz, K. P. Coffey, J. E. Turner, G. V. Davis, D. W. Kellogg, and D. H. Hellwig. 2001. Effects of calendar date and summer management on the in situ dry matter and fiber degradation of stockpiled forage from bermudagrass pastures. *J. Anim. Sci.* 79:3158–3169. doi:10.2527/2001.79123158
- Steele, J. D., J. P. Banta, R. P. Wettemann, C. R. Krehbiel, and D. L. Lalman. 2007. Drought-stressed soybean supplementation for beef cows. *Prof. Anim. Sci.* 23:358–365. doi:10.15232/S1080-7446(15)30989-X
- Taliaferro, C. M., S. W. Coleman, and P. L. Claypool. 1987. Relative winter forage quality of selected bermudagrass cultivars. *Crop. Sci.* 27:1285–1290. doi:10.2135/cropsci1987.0011183X002700060039x
- Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the *in vitro* digestion of forage crops. *J. Br. Grassl. Soc.* 18:104–111. doi:10.1111/j.1365-2494.1963.tb00335.x
- Totusek, R., D. W. Arnett, G. L. Holland, and J. V. Whiteman. 1973. Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. *J. Anim. Sci.* 37:153–158. doi:10.2527/jas1973.371153x
- USDA. 2013. AL dept of ag market news. Alabama Weekly Feedstuff/Production Cost Report. https://www.ams.usda.gov/mnreports/mg_gr210.txt (Accessed 6 March 2013.)
- Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch

- polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583–3597. doi:10.3168/jds.S0022-0302(91)78551-2
- Vendramini, J. M. B., L. E. Sollenberger, A. T. Adesogan, J. C. B. Dubeux, Jr., S. M. Interrante, R. L. Stewart, Jr., and J. D. Arthington. 2008. Protein fractions of Tifton 85 and rye ryegrass due to sward management practices. *Agron. J.* 100:463–469. doi:10.2134/agrojn12007.0143
- Wheeler, J. S., D. L. Lalman, G. W. Horn, L. A. Redmon, and C. A. Lents. 2002. Effects of supplementation on intake, digestion, and performance of beef cattle consuming fertilized, stockpiled bermudagrass forage. *J. Anim. Sci.* 80:780–789. doi:10.2527/2002.803780x
- Wheeler, J., D. L. Lalman, C. A. Lents, and L. A. Redmon. 1999. Supplemental degradable protein requirement of spring calving beef cows grazing stockpiled bermudagrass. *Okla. Agr. Exp. Sta. Res. Rep.* 973:92.
- Wilkinson, S. R., and G. W. Langdale. 1974. Fertility needs of the warm-season grasses. In: D. A. Mays, editor, *Forage fertilization*. 1st ed. Chap 6. In: *Am. Soc. Agron.*, Madison, Wise. p. 119–145. doi:10.1080/00103628709367