Warm-season annual forages in forage-finishing beef systems: I. Forage yield and quality

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ABSTRACT: The demand for a year-round supply of fresh, locally grown, forage-finished beef products has created a need for forage-finishing strategies during the summer months in the southeast. A 3-yr study was conducted to evaluate four warm-season annual forages in a southeastern forage-finishing beef production system. Treatments were four forage species and included brown-midrib sorghum × sudangrass (*Sorghum bicolor* var. *bicolor***bicolor* var. *sudanense*; BMR), sorghum × sudangrass (SS), pearl millet [*Pennisetum glaucum* (L.) R. Br.; PM], or pearl millet planted with crabgrass [*Digitaria sanguinalis* (L.) Scop.; PMCG]. Treatments were distributed in a randomized complete block design with four replicates. Pastures (0.81 ha, experimental unit) were assigned to one of four forage treatments, subdivided, and rotationally stocked with a variable stocking density. British-cross beef steers (n = 32; 3-yr average: 429 ± 22 kg) grazed for 70, 63, and 56 d in 2014, 2015, and 2016, respectively. Put-and-take animals were used to maintain a forage allowance of 116 kg forage dry matter /100 kg body weight. Forage mass was measured by clipping a 4.3-m^2 area in triplicate on d 0 and on 14-d intervals. Hand grab samples for forage nutritive value determination and quadrat clippings for species compositions were measured on d 0 and on 34-d intervals until termination of the trial. Forage mass was lowest (P < 0.01) for PMCG at the initiation of the grazing trial, whereas BMR was greater (P < 0.01) than SS at wk 6. Total digestible nutrients in 2014 were greater for SS compared to BMR and PM at the middle harvest (P < 0.01) and BMR, PM, and PMCG at the final harvest (P < 0.01). At the middle and final harvests in both 2015 and 2016, PM and PMCG contained greater (P < 0.01) concentrations of crude protein than SS. These results suggest that BMR, SS, PM, and PMCG may all be used in southeastern forage-finishing beef production systems, as long as the producer strategically accounts for the slight growth and nutritive value differences throughout the season.

Key words: beef, forage-finishing, grass-fed, warm-season annuals

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INTRODUCTION

Demand for locally produced, forage-finished beef products has increased in popularity among consumers. This demand has primarily been stimulated by reports that grass-fed beef has a beneficial impact on human health due to an altered fatty acid profile when compared to conventionally raised beef (Duckett et al., 2009). To provide a year-round supply of pasture-finished beef, producers must match the nutrient needs of finishing cattle with the forage nutritive value found in available forage. In the spring, fall, and winter months in the southeastern United States, the use of cool-season annual and perennial forages allows for rapid muscle and adipose deposition needed to produce a high-quality, forage-finished product. However, limited forage options in combination with challenging weather conditions during the summer months can make finishing cattle on pasture difficult. Many forage programs in the southeast use warm-season perennial grasses, but these forages are higher in fiber and lower in digestible energy than annual grasses (Hill et al., 1999), limiting their value and use in finishing programs.

In many regions of the world, warm-season annual grasses, such as sorghum × sudangrass [*Sorghum bicolor* (L.) × *S. Arundinaceum* (Desv.); SS] and pearl millet [*Pennisetum glaucum* (L.) R. Br.; PM] are used extensively as forage crops due to their high productivity during a short period of time. In addition, there has been a growing interest in the utilization of crabgrass as a high-quality forage during the summer months in the southeastern United States. In Florida, Fontaneli et al. (2001) reported seasonal forage dry matter (DM) accumulation of SS and PM to range from 7,980 to 5,010 kg/ha when planted between March and May. In Arkansas, SS has been reported to yield up to 7,430 kg/ha just 63 d after planting (Beck et al., 2007a) whereas crabgrass produced 9,790 kg/ha in 49 d (Beck et al., 2007b).

With the combination of high yields, nutritive value, and drought tolerance, opportunity exists for warm-season annual forages to fill the nutritional gap that often occurs in summer forage-finishing beef production. Little information is available on distribution of DM, forage nutritive value, and stocking rate and animal performance of grazed warm-season annual forages. Thus, the objective of this study was to compare herbage mass, forage distribution, nutritive value, and stocking rate of four, rotationally grazed, warm-season annual grass forage systems in southeastern forage-finishing beef operations.

MATERIALS AND METHODS

All animal procedures used in this study were approved by the University of Georgia's Institutional Animal Care and Use Committee (IACUC approval number A2014 05-002).

Forage Treatments and Management

Forage treatments of SS, brown-midrib sorghum × sudangrass (BMR), PM, and a mixture of pearl millet and crabgrass (PMCG; *Digitaria sanguinalis*) were assessed during the summers of 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Sciences Eatonton Beef Research Unit in Eatonton, GA (33°24′N, 83°28′W; elevation 163 m). Forage treatments were compared in a randomized complete block design with four replications. Sixteen 0.81-ha pastures were blocked based on production history, soil type, and topography, and forage treatments were randomly assigned within each block.

The study site, which had previously been in permanent pasture and cool-season annual forages, consisted of Davidson loam and Wilkes sandy loam soils (Soil Survey Staff 2019) and in the spring of 2014 before planting of experimental units, 17-17-17 (N-P-K, %) granular fertilizer was spread at 448 kg/ha to all pastures to meet or exceed all soil test-based recommendations. Soil core samples were also taken in the spring of 2015 and 2016 but results did not indicate a need for phosphorus and potassium fertilizer and thus a granular fertilizer was not applied. However, due to soil compaction issues and soil erosion from heavy winter rains, all pastures were disked and cultipacked in the spring of 2015.

Pastures were seeded mid-May of each year with a no-till drill (Haybuster 107; Jamestown, ND) in 17.8 cm row spacings and 7 d after the paddocks were sprayed with glyphosate at 1.1 kg/ha (Helosate Plus Advanced; Helm Agro US, Inc., Tampa, FL). SS (cv. "Sugargrazer" in 2014 or cv. "AS5201" in 2015 and 2016; Alta Seeds, Irving, TX) and BMR ("Honey Graze" in 2014; Arrow Seed Co., Broken Bow, NE; or "AS6201" in 2015 and 2016; Alta Seeds) were planted at 22.4 kg/ha and at a soil depth of 2.54 cm. The use of different SS and BMR varieties in 2014 was due to the lack of availability of the desired AS5201 and AS6201 varieties. In

2014, selected varieties were chosen as a result of their similar performance in the University of Georgia's Statewide Variety Testing Program and is unlikely that changing varieties resulted in any confounding effects. PM (cv. "Tifleaf III"; Coffey Forage Seeds, Inc., Plainview, TX) was seeded at 16.8 kg/ha and at a soil depth of 1.27 cm, and the PM (cv. "Tifleaf III") plus CG (cv. "Red River"; R.L. Dalrymple Farm, Thomas, OK) mixture was planted simultaneously at 11.2 kg/ha at 1.27 cm and 5.6 kg/ha at 0.64 cm, respectively. Crabgrass was planted in a 1:1 ratio with sand to reduce static cling and allow a consistent flow of crabgrass from the small seed box through the drop tubes. In addition, half of each pasture was fertilized with a liquid nitrogen fertilizer ("19E"; R.W. Griffin, Attapulgus, GA; or 32% Urea Ammonium Nitrate) at a rate of 45 kg/ha of nitrogen on d 30 and 34 in 2014 and 2015, respectively, and at a reduced rate of 34 kg/ha of N on d 37 in 2016. The reduced rate of nitrogen application in 2016 was done in an effort to prevent the incidence of nitrate poisoning during drought conditions. Nitrogen fertilizer was applied to the second half of each pasture approximately 7 to 14 d thereafter.

Each year, forages were scouted weekly for chinch bug [*Blissus leucopterus leucopterus* (Say) (Heteroptera: Blissidae)] and sugarcane aphid [*Melanaphis sacchari* (Homoptera: Aphididae)] damage. In August of both 2015 and 2016, PM and PMCG pastures were sprayed with dimethylcyclopropanecarboxylate (Mustang Maxx; FMC Corporation, Philadelphia, PA; or Lambda-Cyhalothrin 1 EC; Nufarm Americas, Inc., Burr Ridge, IL) at a rate of 28 g/ha to control chinch bug infestation. Pastures were sprayed for chinch bugs once a threshold of 100 bugs/leaf had been reached. In the summer of 2015 and 2016, a section 18 emergency exemption label was issued in Georgia for the use of Transform (Dow Chemical Company, Indianapolis, IN) to control the sugarcane aphid in sorghum pastures. In July of 2015 and 2016, once a sugarcane aphid threshold had reached 50 aphids on 25% or more of infected leaves, sulfoxaflor was applied to SS and BMR pastures at a rate of 53 g/ha.

Cattle Management

Each year, 32 angus-crossbred steers (*Bos taurus*; 429 ± 22 kg) were randomly assigned to one of four forage treatments 1 wk prior to the initiation of the project. Upon initiation of the grazing trial, steers were fasted for 12 h before being weighed. During this time, cattle were also treated for parasites (Eprinex; Boehringer Ingelheim, Ontario, Canada) before being immediately turned out into their assigned pastures. Initiation of grazing was June 25 in 2014 and 2015, and June 29 in 2016 and was based on the combination of plant height and forage mass of 1,000 kg/ha. A target plant height of 51 cm for PM treatments and 61 cm for SS treatments was used out of concern for prussic acid and nitrate accumulation in young plants.

All steers had ad libitum access to shade, water, and mineral (McNess Bova Breeder 6; Furst-McNess Co., Cordele, GA). Each 0.81-ha pasture was subdivided into two 0.405-ha paddocks with temporary fencing and stocked rotationally, allowing forage to rest at 9 to 14 d intervals. Rotational decisions were made based on pre-grazed herbage mass (measured every 2 wk) and residual height of pastures adequate for optimal regrowth potential (Allen et al., 2011). Put-and-take stocking was used to maintain herbage mass of greater than 1,000 kg/ha, and steers that were added or removed were from the same contemporary group as the 32 test steers. Put-and-take stocking decisions were also made based on herbage mass measurements, and for every 500 kg/ha above or below the targeted herbage mass of 1,000 kg/ha, a steer was either added or removed to the pasture to allow for a forage allowance of 116 kg forage DM/100 kg body weight (BW). Stocking decisions were based off of the work by Redmon et al. (1995), where a forage allowance of 23 kg forage DM/100 kg BW resulted in a plateau in average daily gain (ADG) of steers grazing wheat pasture. The initial forage allowance of each tester steer, as well as for all put-and-take steers was over 4 times as much as Redmon et al. (1995) reported was needed, and done in order to account for differences in leaf to stem ratios between cool-season and warm-season annual forages.

Prior to the initiation of grazing or the addition of a steer, put-and-take steers were fasted for 12 h before being weighed. As BW measurements were not available for some put-and-take steers once they were removed from the pastures, gains were determined by taking the average ADG for the tester steers in the respective pasture and multiplying that by the number of days a put-and-take steer spent grazing a specific pasture. In late summer, once regrowth of vegetative tissue had ceased and forage mass consisted primarily of stem material, the study was terminated and the steers were transported (71 km) to the University of

Georgia's Meat Science Technology Center (Athens, GA) for harvest. End dates were September 03, August 27, and August 31 in 2014, 2015, and 2016, respectively.

Forage Sampling

Forage mass was measured by clipping in triplicate, a 4.3-m^2 area every 14 d with a custom-made plot harvester (University of Missouri, Columbia, MO) mounted on the three-point hitch of a tractor. Forage samples were taken from pre-grazed paddocks and were weighed, subsampled, and placed in a 55 °C forced air dryer for 7 d for DM determination. At the beginning, middle, and end of the grazing trial, estimates of both forage botanical composition and forage nutritive value were made from the pre-grazed side of each pasture. Forage botanical composition was measured by cutting and separating desirable and undesirable species from 0.1-m^2 quadrats in three locations per pasture. Samples of desired and non-desired forages were immediately weighed and placed into a 55 °C forced air dryer for 7 d. Sampling for forage nutritive value was conducted by hand grab samples that mimicked the grazing selections made by the cattle. After forage samples for nutritive value were dried, samples were double ground, first through a 2-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) and then through a 1-mm screen in a Cyclotec 1093 Sample Mill (FOSS, Eden Prairie, MN). Samples were then sent to the University of Georgia's Feed and Environmental Water Lab (Athens), a certified laboratory by the National Forage Testing Association. Determination of crude protein (CP), nitrates, fat, ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, total digestible nutrients (TDN), dry matter intake (DMI), relative forage quality (RFQ), and in vitro true DM digestibility at 48 h (IVTDMD48) was done by near-infrared (NIR) reflectance spectroscopy using a model 6500 (FOSS NIRS System, Inc., Laurel, Maryland) NIR analyzer. In reflectance mode, 5 g of homogenized samples were packed into ring cups and scanned from 400 to 2,498 nm to collect spectra every 2 nm. The reflectance energy readings were referenced to corresponding readings from an internal ceramic disk. The recorded spectrum of each sample was the average of 32 successive scans. All spectral data were recorded as the logarithm of the reciprocal of reflectance (log 1/R, R: reflectance). Satisfactory instrument performance was confirmed through instrument response, photometric repeatability (noise) and wavelength accuracy tests, and check cell scan. Absorption of radiation in the region of 400 to 2,498 nm, the visible plus NIR region, was used to predict forage quality using the 2013 NIRS Consortium level 2 equation release statistics for grass hay (13GH50-2.eqa; NIRS Consortium, 2013).

Drought Management

During the summer of 2015 and 2016, the Eatonton Beef Research Unit experienced moderate to extreme drought conditions, and measures to prevent a total loss of the experiment were taken. In 2015, an extra 0.81-ha area of each forage treatment was planted for use as supplemental feed for tester steers. Forage was cut with a mower-Conditioner (John Deere, Moline, IL) and allowed to wilt for 18 h before being harvested for baled silage at 50% moisture. Bales were then wrapped with an individual bale wrapper (RB-400; Anderson Group Co., Chesterville, Qc GOP 1JO [Canada]) in six layers of Sunfilm silage wrap (AEP, Montvale, NJ). Bales were ensiled for a minimum of 21 d before drought conditions progressed to a point where supplemental feed was needed to maintain adequate DMI in test steers. Steers were fed baleage supplement from their respective forage treatments every 3 d from August 08 to August 23. On each feeding day, one bale was equally split among the four pastures of the respective forage treatment using a chainless bale feeder (Hustler, Hastings, NZ).

In 2016, extreme drought conditions limited the growth of extra paddocks that were planted in each forage treatment for use as baleage. Thus, baleage was not available to be fed as emergency forage when the lack of moisture limited forage availability. Instead, cattle were removed from their respective treatments, weighed, and placed together in a holding pasture for 7 d from August 2 to 9. The pastures were not equipped with an irrigation system capable of providing continuous irrigation for the remainder of the trial, but during this hiatus, all pastures received two rounds of 19 mm of water using a retractable traveling reel and gun in an attempt to keep the forage alive. After one round of irrigation and a 7 d rest period, cattle were weighed and placed back into their respective pastures. Approximately 7 d after the first round of irrigation, pastures were re-irrigated with another 19 mm of irrigation, which exhausted the supply of impounded water. To ensure DMI would not be a limiting factor for growth, a 1.5 × 1.2 round bale of bermudagrass [*Cyndon dactylon* (L.) Pers.] hay from the same field and harvest was placed into each pasture for ad libitum feeding until arrangements could be made to harvest the steers at an earlier date than expected.

In Situ Forage Disappearance

Samples collected for forage nutritive value were composited by treatment within year, and harvest date to determine in situ DM disappearance after 0, 6, 12, 24, and 48 h of incubation. For each timepoint, 5 g of forage was weighed in quadruplicate into dried and weighed nylon bags (10 × 20 cm; ANKOM Technology, Macedon, NY) of 50 µm porosity and were triple sealed using an impulse sealer (TISH200; TEW Electric Heating Equipment Co., Ltd., Taipei, Taiwan). One replicate of each sample was placed sequentially into two ruminally cannulated Holstein steers (1,095 ± 7 kg) in a completely randomized design with two incubation periods, allowing for a total of four replications of forage incubation in the Holstein steers. During the incubation period, steers were fed a diet consisting of ad libitum access to both bermudagrass [*Cynodon dactylon* (L.) Pers.] hay and mixed grass pasture consisting of 68% mature annual ryegrass (*Lolium multiflorum* Lam.), 19% bermudagrass, and 13% weed species. Steers were fed this diet for 10 d prior to the initiation of the first 2 d in situ trial and were then rested on the same diet for approximately 72 h before the start of the second incubation period.

All year by harvest date samples of SS, BMR, PM, and PMCG were soaked in 36 °C water for 30 min prior to being placed inside the rumen for incubation for 0, 6, 12, 24, and 48 h in nylon mesh lingerie bags. Samples were placed inside the rumen at their respective timepoint such that all samples could be removed collectively. Upon removal from the rumen, samples were immediately placed into an ice bath for 30 min to inhibit microbial activity. Bags were then rinsed by hand until the rinse water was clear, placed in an oven and dried at 90 °C for 48 h, and weighed for calculation of DM disappearance.

Statistical Analysis

All statistical analyses were conducted using the GLIMMIX procedure in SAS 9.4 (SAS Institute, Inc., Cary, NC) to determine interaction and main effects of treatment and year. In this analysis, each forage treatment was replicated in four fields for 3 yr. When applicable, day and/or harvest was used as a main effect and analyzed with interactions. Pasture and block were considered random effects. Least squares means were separated by pairwise comparisons using a *t*-test.

Nonlinear regression was used to analyze forage DM disappearance curves using the NLIN procedure in SAS (SAS Institute, Inc.). Fractions of DM were partitioned based on relative susceptibility to ruminal degradation as described by Ørskov and McDonald (1979). Forage was broken into fractions A, B, and C with A representing the immediately soluble fraction, B describing the fraction that disappeared at a measurable rate, and fraction C depicting the undegradable portion (NRC, 2000). Disappearance rate (Kd) was determined by the nonlinear regression model for fraction B. Fraction C was then calculated by difference [100 − (A + B)].

RESULTS AND DISCUSSION

Environmental Conditions

Historical climate data as well as monthly precipitation and average maximum temperatures from May to September during the 3-yr trial were obtained from the University of Georgia's Automated Environmental Monitoring Network (Network, 2017) weather station located on the University of Georgia's, Animal and Dairy Sciences Eatonton Beef Research Farm near Eatonton, Georgia. Monthly maximum temperatures for this study are presented in Figure 1. Relative to the 100-yr average, temperatures were below normal in 2014 but above normal in 2015 and 2016. There was approximately 29, 44, and 54 d during the grazing trial in which maximum daily

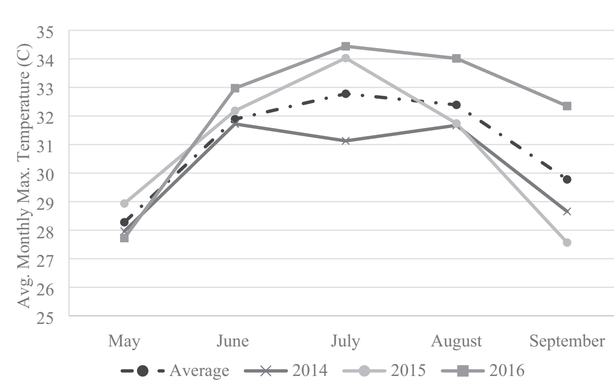

Figure 1. Actual and 100-yr normal average monthly maximum temperature from May to September in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia.

temperatures exceeded 32.2 °C in 2014, 2015, and 2016, respectively. Cumulative precipitation during the summer months followed a similar pattern to monthly maximum temperatures, with precipitation exceeding the 100-yr average in 2014 followed by drought and extreme drought conditions in 2015 and 2016, respectively (Figure 2). Table 1 shows the number of days that received rain and the monthly average precipitation per rainfall event. Overall, there were more rainy days with larger precipitation totals per rainfall event in 2014 compared to 2015 and 2016. Although there were more than 15 rainfall events in August 2016, the average rainfall event produced less than 2 mm of precipitation.

Pre-grazed Forage Mass

There was an interaction between year and week ($P < 0.01$) and treatment and week ($P < 0.01$) on pre-grazed forage mass during the grazing seasons. Main effects of year ($P < 0.01$) and the interaction of year and week ($P < 0.01$) were expected and can be attributed to differences in rainfall distribution events both between and within years. Pre-grazed forage mass was greatest ($P < 0.01$) for 2014, followed by 2015, and least for 2016 (3,090, 2,582, and 2,327 kg/ha, respectively). Upon the initiation

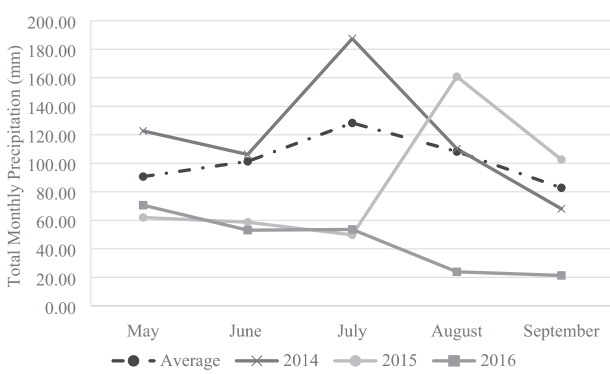

Figure 2. Actual and 100-yr average total monthly precipitation from May to September in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia.

of the grazing trial, PMCG had less ($P < 0.01$) pre-grazed forage mass than SS, BMR, and PM (Table 2). Thereafter, pre-grazed forage mass was not different ($P > 0.07$) among the treatments, except at 6 wk into the grazing trial, when pre-grazed forage mass in the SS paddocks was less ($P < 0.01$) than that of BMR, though PM and PMCG treatments were intermediate.

Near the end of the grazing trial (wk 8), when the largest between year variation in moisture occurred, treatment and year interacted to have an effect on pre-grazed forage mass ($P < 0.01$). Forage mass for SS, BMR, and PM was greater ($P < 0.01$) in 2014 than 2015 (2,980, 4,027, and 3,419 kg/ha vs. 1,953, 1,931, and 2,276 kg/ha). Likewise, pre-grazed forage mass was least ($P < 0.04$) for SS and BMR in 2016 compared to 2015 (1,200 and 1,013 kg/ha vs. 1,953 and 1,931 kg/ha). In addition, forage mass of PMCG was greater ($P = 0.03$) in 2014 compared to 2016, with 2015 as an intermediate (2,956, 2,164, and 2,312 kg/ha, respectively). At wk 8 in 2014, pre-grazed forage mass was greater for BMR ($P < 0.01$) compared to SS and PMCG, with PM as an intermediate (4,027, 2,980, 2,956, and 3,419 kg/ha, respectively). However in 2015, no difference ($P > 0.37$) was observed between treatment and pre-grazed forage mass. During the extreme drought year of 2016, forage mass of PMCG was greater ($P < 0.01$) than that of SS and BMR, with PM as an intermediate (2,164, 1,200, 1,013, and 1,614 kg/ha, respectively).

Species Composition

Changes in pasture composition of warm-season annual forages throughout the 3-yr grazing trial is shown in Table 3. Percent desirable species of the swards was affected by the main effects of treatment, year, harvest date, and the interactions ($P < 0.01$). In both the first grazing year, where precipitation exceeded the 100-yr average, and the 2016 grazing season, where an extreme drought occurred, a

Table 1. Average precipitation per rainfall event and total number of rainy days from May to September in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Average precipitation, mm			Rain events, d		
Month	2014	2015	2016	2014	2015	2016
May	13.6	8.9	7.1	9	7	10
June	8.2	5.3	5.9	13	11	9
July	15.6	5.5	6.7	12	9	8
August	11.0	12.4	1.6	10	13	15
September	5.2	6.4	3.6	13	16	6

Table 2. Pre-grazing forage mass in SS, BMR, PM, and PMCG pastures harvested every other week in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Forage treatment, kg/ha of DM					Effect		
Week	SS	BMR	PM	PMCG	SEM	Trt	Year	Trt × year
0	2,314[a]	2,130[a]	2,028[a]	1,591[b]	167	<0.01	<0.01	0.17
2	3,323	3,547	3,074	2,418	379	0.07	<0.01	0.08
4	3,343	3,363	3,051	2,756	366	0.58	<0.01	0.41
6	2,267[b]	3,139[a]	2,699[ab]	2,746[ab]	194	0.01	<0.01	0.91
8	1,960	2,193	2,354	2,446	194	0.39	<0.01	<0.01

[ab]Means within a row without a common superscript differ ($P < 0.05$).

Table 3. Botanical composition in SS, BMR, PM, and PMCG pastures harvested at three dates in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Sciences Eatonton Beef Research Unit in Eatonton, Georgia

	Treatment					
	SS	BMR	PM	PMCG		
Year/harvest	Desirable species, % of DM				SEM	*P* value
2014[1]						
Initial	82.8[ab]	68.2[bc]	55.5[c]	93.1[a]	8.3	0.01
Middle	58.3[b]	13.3[c]	58.1[b]	96.5[a]	10.9	<0.01
Final	65.6[b]	4.5[d]	31.5[c]	90.9[a]	6.6	<0.01
2015[2]						
Initial	96.0[a]	90.4[ab]	84.8[b]	96.5[a]	2.6	0.01
Middle	79.5[b]	78.5[b]	73.6[b]	100.0[a]	6.0	0.02
Final	14.3[c]	17.0[c]	55.9[b]	99.3[a]	6.9	<0.01
2016[3]						
Initial	69.9[b]	56.3[bc]	51.8[c]	88.0[a]	5.1	<0.01
Middle	28.5[c]	27.3[c]	51.2[b]	81.2[a]	7.7	<0.01
Final	24.9[bc]	13.8[c]	32.0[b]	88.0[a]	5.1	<0.01

[abcd]Means within a row without a common superscript differ ($P < 0.05$).
[1]Initial = June 25, 2014; Middle = July 29, 2014; Final = September 03, 2014.
[2]Initial = June 24, 2015; Middle = July 28, 2015; Final = August 25, 2015.
[3]Initial = June 27, 2016; Middle = August 03, 2016; Final = August 30, 2016.

reduction ($P < 0.01$) in the SS and BMR content of pastures was observed between the initiation of the grazing trial and the intermediate harvest at 34 d. A similar pattern ($P = 0.02$) occurred between initial and middle harvests in 2015 for SS, with a further reduction ($P < 0.01$) in desirable species of both SS and BMR from the second to the third harvest in that year. On the first harvest date of each year, the SS and PMCG pastures contained a greater ($P < 0.01$) percentage of desirable species than PM pastures, with BMR as an intermediate. Observations of pastures at emergence and the following weeks thereafter showed that SS and PM emergence was similar but growth rate after emergence appeared greater for SS than for PM. Testing the germination rate and radicle length of forage and weed seeds under drought stress, Hoveland and Buchanan (1973) reported that under drought conditions, PM forage germinated at a more rapid rate than SS seeds. However, 96 h after germination, radicle length did not differ between the two forages with the exception of the most extreme drought treatment, where PM seedlings had a longer radicle than SS seedlings. These findings suggest that once germination occurs, SS may have a more rapid growth rate than PM and is similar to observations made in this study.

In each of the 3 yr, composition of PMCG did not differ ($P > 0.78$) between harvests, meaning pastures maintained a constant ratio of desirable species in the sward. However, this effect was not seen in the PM forage treatment where desirable species declined ($P < 0.01$) by the end of the grazing trial from harvest two to harvest three in all trial years. In addition, PMCG pastures contained a greater ($P < 0.01$) level of desirable species at the middle and final harvest each year compared to treatments of SS, BMR, and PM. This effect may be explained by the addition of the crabgrass in the PMCG and the compatibility of the two species to provide a larger distribution of forage throughout the entirety of the grazing season. In the field, it was observed that crabgrass plants filled in the gaps between the PM plants. This coexistence of forage species not only provided tonnage but also provided ground coverage, making it hard for other weed species to penetrate the canopy. Finally, the addition of crabgrass to PM allowed for a greater level of desirable species to be maintained during the drought conditions that was experienced during this experiment. Therefore, the addition of crabgrass to warm-season annual swards during expected drought years may help maintain a desirable sward species and alleviate decreases in forage production due to limited moisture availability.

Although weed species in samples were not individually identified and measured, observational identification of pasture weed species concluded that undesirable species primarily consisted of broadleaf signalgrass (*Brachiaria decumbens* Stapf.). Although little research has been conducted on broadleaf signalgrass in the United States, Roberts (1970) reported that it outyielded seven other grass species in Fiji, and produced a total of 33,850 kg/ha over an 11 mo growing season. Broadleaf signalgrass contributed to the total DM found in pastures, allowing pre-grazed forage mass in those pastures with a low proportion of desirable species to maintain similar levels of forage availability.

Nutritive Value

Most nutritive value variables were affected by multiple interactions, including an interaction of treatment, year, and sampling date. Therefore, nutritive value means for each treatment were analyzed and presented by year and sampling date (Tables 4–6). Changes in, CP, nitrates, fat, and ash content of forage treatments are presented in Table 4. In both 2015 and 2016, CP concentration across all treatments decreased ($P < 0.01$) from the initial to the middle sampling date as plants grew and matured. However, the CP concentration increased ($P < 0.01$) in all treatments between the middle and final sampling date. This increase at the final sampling date may be a result of young, vegetative tissue produced as a result of late season rainfalls and irrigation as well as the timing of the second nitrogen fertilization shortly after the middle sampling date but before the final sampling. Teutsch et al. (2005) reported a linear increase in CP concentration in drought stressed plants fertilized with increasing rates of ammonium nitrate. PM and PMCG had greater ($P < 0.01$) CP levels than SS and BMR during the final sampling date of 2015 and 2016, indicating that the PM systems can maintain forage nutritive concentrations longer into the season than the SS treatments. Each year at the middle sampling date, CP concentration was greater ($P < 0.01$) for PMCG than BMR, with PM as an intermediate in 2016. Although crabgrass was not singularly tested for forage nutritive value, the high concentration of CP found in PMCG is likely the result of the added nutritional value of crabgrass forage and is common with other reports in the literature (Dalrymple, 2001; Beck et al., 2007b).

Concentrations of nitrate nitrogen are presented in Table 4. Although concentrations did not differ between harvests in 2014 ($P > 0.21$), a decrease ($P < 0.01$) from the initial to the middle harvest and an increase ($P < 0.01$) between the middle and final harvests were observed in 2015. In 2016, an increase ($P < 0.01$) in nitrate nitrogen occurred between the initial and middle harvests but did not differ ($P = 0.11$) from the middle to the final harvests. However, as the drought intensified in the summer of 2016, an increase ($P < 0.01$) in nitrate nitrogen was measured between the initial and final harvests. Nitrate nitrogen was highest for PMCG at both the initial harvest in 2014 ($P < 0.04$) and the middle harvest in 2015 ($P < 0.01$) compared to either SS, BMR, or PM. At the initial harvest of 2016, PMCG also had greater ($P < 0.01$) nitrate concentrations than SS or BMR but did not differ ($P = 0.08$) from PM, which did not differ ($P = 0.08$) from BMR. Although no signs of nitrate poisoning were observed in cattle, BMR, PM, and PMCG at the final harvest in 2015 contained more than 8,000 ppm NO_3 and is in the upper critical limit in which acute toxicity and clinical signs can be observed (Gadberry and Jennings, 2016).

It is well established that a ruminant's diet can alter lipid profiles of beef (Daly et al., 1999; Realini et al., 2004; Leheska et al., 2008). Fat concentration of pastures decreased ($P < 0.01$) from the initial to the middle sampling date in all three trial years. In 2014, fat concentration of forages was maintained ($P = 0.20$) between the middle and final sampling date whereas an increase ($P < 0.01$) was observed during this time for pastures in 2015 and 2016. Pastures of PMCG contained greater concentrations of fat at the middle sampling date in 2014 ($P = 0.02$), 2015 ($P = 0.03$), and 2016 ($P < 0.01$) compared to SS and BMR, with PM as an intermediate of PMCG and BMR. Concentration of fat found in forage in this

Table 4. Concentrations of CP, nitrates, fat, and ash, as measured by near-infrared spectroscopy of SS, BMR, PM, and PMCG pastures harvested at three dates in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Forage treatment					
Item/year/harvest	SS	BMR	PM	PMCG	SEM	*P* value
CP, g/kg[1]						
2014[2]						
Initial	226	217	226	224	5.4	0.58
Middle	198[a]	159[b]	163[b]	182[a]	5.3	<0.01
Final	175	162	181	159	12.7	0.55
2015[3]						
Initial	218	208	213	222	6.7	0.45
Middle	128[c]	141[b]	159[a]	161[a]	4.7	<0.01
Final	208[b]	208[b]	231[a]	225[a]	4.9	0.02
2016[4]						
Initial	141[c]	152[bc]	164[ab]	178[a]	5.2	<0.01
Middle	96[c]	119[bc]	140[ab]	157[a]	8.9	<0.01
Final	155[c]	173[b]	196[a]	208[a]	5.8	<0.01
Nitrates, ppm						
2014[2]						
Initial	111[a]	315[a]	717[a]	1,747[b]	300	0.02
Middle	1,164	1,265	426	2,643	647	0.18
Final	1,420	965	1,870	1,730	450	0.53
2015[3]						
Initial	3,633	7,814	4,483	4,043	1,364	0.12
Middle	1,723[a]	2,074[a]	1,540[a]	4,700[b]	785	0.01
Final	5,645	8,117	8,380	9,683	1,667	0.43
2016[4]						
Initial	223[a]	437[ab]	1,226[bc]	2,028[c]	282	0.01
Middle	3,718	1,755	2,553	3,142	501	0.06
Final	3,514	4,064	3,919	3,540	659	0.91
Fat, g/kg						
2014[2]						
Initial	22.6[b]	25.0[a]	23.7[ab]	22.5[b]	0.6	0.05
Middle	16.4[c]	17.9[bc]	19.8[ab]	20.9[a]	0.9	0.02
Final	19.1	18.9	21.3	18.8	0.8	0.14
2015[3]						
Initial	26.9	26.8	28.4	29.4	0.9	0.19
Middle	18.7[c]	19.9[bc]	21.0[ab]	22.4[a]	0.7	0.03
Final	27.1	25.6	26.3	27.6	1.1	0.62
2016[4]						
Initial	25.1[b]	27.1[a]	27.3[a]	28.5[a]	0.6	0.02
Middle	20.6[c]	22.6[bc]	24.2[ab]	26.3[a]	0.7	<0.01
Final	25.3[b]	26.7[ab]	28.9[a]	29.4[a]	0.9	0.03
Ash, g/kg						
2014[2]						
Initial	81.5[b]	89.0[ab]	102.0[a]	91.8[ab]	4.3	0.05
Middle	95.9[b]	123.9[a]	89.7[b]	89.6[b]	4.1	<0.01
Final	78.9	84.2	91.2	94.9	4.1	0.08
2015[3]						
Initial	96.0	119.0	122.5	99.9	10.6	0.26
Middle	76.1[b]	99.8[a]	98.0[a]	91.3[a]	3.6	<0.01
Final	98.8[c]	107.5[b]	113.0[ab]	114.0[a]	2.0	<0.01
2016[4]						
Initial	61.6[b]	72.5[a]	79.5[a]	81.9[a]	3.3	0.01
Middle	67.1	79.0	79.0	76.7	3.6	0.13
Final	87.9	92.8	92.2	93.3	2.2	0.35

[abc]Means within a row without a common superscript differ ($P < 0.05$).

[1]CP = % of N × 6.25.

[2]Initial = June 25, 2014; Middle = July 23, 2014; Final = August 20, 2014.

[3]Initial = June 24, 2015; Middle = July 22, 2015; Final = August 25, 2015.

[4]Initial = June 27, 2016; Middle = July 25, 2016; Final = August 30, 2016.

Table 5. Concentrations of NDF, ADF, and lignin as measured by near-infrared spectroscopy of SS, BMR, PM, and PMCG pastures harvested at three dates in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Forage treatment[1]					
Item/year/harvest	SS	BMR	PM	PMCG	SEM	*P* value
NDF, g/kg						
2014[1]						
Initial	547[bc]	562[c]	511[a]	521[ab]	10.9	0.03
Middle	535[a]	603[b]	637[c]	605[b]	7.0	<0.01
Final	580	605	595	617	18.4	0.56
2015[2]						
Initial	523[b]	525[b]	503[ab]	485[a]	10.4	0.03
Middle	647[b]	610[a]	632[ab]	611[a]	9.6	0.02
Final	565	565	529	539	9.9	0.06
2016[3]						
Initial	602[b]	598[b]	594[b]	572[a]	7.0	0.03
Middle	668[b]	642[ab]	645[ab]	622[a]	8.3	0.03
Final	589[b]	557[a]	548[a]	541[a]	9.6	0.03
ADF, g/kg						
2014[1]						
Initial	300	308	292	291	5.4	0.16
Middle	329[a]	366[c]	362[c]	344[b]	4.8	<0.01
Final	343	354	344	355	12.0	0.84
2015[2]						
Initial	286	300	288	272	9.5	0.16
Middle	338	327	327	328	3.7	0.13
Final	322[b]	322[b]	302[a]	304[a]	5.6	0.05
2016[3]						
Initial	320[b]	322[b]	312[ab]	302[a]	4.5	0.03
Middle	369[b]	358[b]	349[ab]	333[a]	6.7	0.02
Final	330[b]	309[ab]	292[a]	288[a]	7.1	0.01
Lignin, g/kg						
2014[1]						
Initial	10.7[b]	5.1[a]	13.5[b]	10.8[b]	1.3	0.01
Middle	7.8[a]	15.5[b]	20.9[c]	17.8[bc]	1.5	<0.01
Final	15.1	16.6	22.2	21.8	3.5	0.39
2015[2]						
Initial	4.0[ab]	3.6[a]	8.9[bc]	9.4[c]	1.7	0.05
Middle	15.7[b]	6.5[a]	14.2[b]	15.1[b]	1.5	<0.01
Final	13.3	9.7	9.8	1.1	1.5	0.37
2016[3]						
Initial	55.8[b]	49.2[a]	47.1[a]	47.3[a]	1.4	<0.01
Middle	72.3[c]	57.6[ab]	60.1[b]	51.7[a]	2.6	<0.01
Final	60.9[b]	56.0[ab]	53.0[a]	51.5[a]	1.8	0.02

[abc]Means within a row without a common superscript differ ($P < 0.05$).

[1]Initial = June 25, 2014; Middle = July 23, 2014; Final = August 20, 2014.

[2]Initial = June 24, 2015; Middle = July 22, 2015; Final = August 25, 2015.

[3]Initial = June 27, 2016; Middle = July 25, 2016; Final = August 30, 2016.

study is comparable to reports by Schmidt et al. (2013) who found that fat content of warm-season grasses ranged from 17.8 to 28.7 g/kg. Ash was greatest ($P = 0.05$) for PM and lowest for SS at the initial sampling date in 2014. As pastures became more mature, BMR contained greater ($P < 0.01$) ash levels at the middle sampling date than the other forage treatments. Ash content was least for SS at the middle ($P < 0.01$) and final ($P < 0.01$) sampling dates in 2015 and the initial ($P < 0.01$) sampling date in 2016.

Fiber parameters of warm-season annual pastures are presented in Table 5. Similar to results found in CP concentrations, concentrations of NDF and ADF in forage pastures increased between the initial and middle sampling dates in 2015 ($P < 0.01$) and 2016 ($P < 0.01$). A decrease ($P < 0.01$) between the middle and final sampling dates each year was also observed for NDF and ADF, again emphasizing that immature forage was produced during the second half of the trial after overgrazing of pastures during the drought occurred. BMR had greater ($P < 0.01$) NDF levels than PM at the initial sampling date in 2014, however, by the middle sampling date, NDF concentrations of PM exceeded ($P < 0.01$) those of SS, BMR, and PMCG. A treatment effect for NDF was also found during the initial and middle sampling dates in 2015 ($P < 0.03$) and all three sampling dates in 2016 ($P = 0.03$). At the initial sampling date in 2015, SS and BMR had greater ($P < 0.01$) levels of NDF than PMCG, with PM as an intermediate. Levels were also greater ($P < 0.02$) for SS than BMR and PMCG at the middle sampling date with PM, again, as an intermediate. SS pastures contained greater ($P < 0.03$) levels of NDF compared to PMCG at the initial, middle, and final sampling dates in 2016. At the initial sampling date, BMR and PM also contained greater ($P < 0.03$) NDF levels than PMCG but by the final sampling date, NDF concentrations did not differ ($P > 0.05$) between BMR, PM, and PMCG and were all lower ($P < 0.04$) than SS.

A treatment effect on ADF was found during the middle sampling date in 2014 ($P < 0.01$), final sampling date of 2015 ($P = 0.05$), and for all three sampling dates in 2016 ($P < 0.03$). Concentrations of ADF were greater ($P < 0.01$) for BMR and PM followed by PMCG, and least for SS at the middle sampling date in 2014. At the final sampling date in 2015, BMR had greater ($P < 0.01$) ADF levels than SS, PM, and PMCG. SS and BMR had increased ($P < 0.01$) levels of ADF compared to PMCG at both the initial and middle sampling dates in 2016. By the final harvest, SS contained greater ($P < 0.01$) concentrations than either PM or PMCG, with BMR as an intermediate.

Lignin concentration increased between each harvest in 2014 ($P < 0.02$) and between the initial and middle harvests in 2015 ($P < 0.01$) and 2016 ($P < 0.01$). Although lignin concentration did not differ ($P = 0.15$) between the middle and final sampling dates in 2015, a decrease ($P < 0.01$) was observed in 2016. At the initial sampling date in both 2014 ($P < 0.01$) and 2015 ($P < 0.04$), lignin concentration was lower for BMR compared to PM and PMCG but did not differ ($P > 0.26$) in 2016. When comparing the two sorghum treatments, it was found that BMR contained lower lignin concentrations than SS at the initial sampling date in 2014 ($P = 0.01$) and 2016 ($P < 0.01$). Levels were also lower for BMR than SS at the middle sampling date in both 2015 ($P < 0.01$) and 2016 ($P < 0.01$) but were surprisingly higher in 2014 ($P < 0.01$). By the final sampling date of the grazing trail, differences in lignin content between SS and BMR treatments did not exist ($P > 0.05$). Lignin concentrations between PM and PMCG were not different ($P > 0.05$) at each sampling date within each year, with the exception of PMCG having decreased ($P = 0.03$) levels at the middle sampling date in 2016.

Variables that are indicative of overall forage quality are presented in Table 6. As forages matured in 2014, TDN levels decreased ($P < 0.01$) from the initial to the middle sampling date and were maintained ($P = 0.15$) between sampling dates thereafter. Similar results were found between the first and second sampling dates in both 2015 ($P < 0.01$) and 2016 ($P < 0.01$), however, an increase ($P < 0.01$) in TDN levels was observed between the middle and final sampling date in these years and may be attributed to irrigation practices or late seasonal rains producing new, vegetative tissue. Forage treatments exhibited similar TDN levels at each sampling date during 2015 ($P > 0.18$) and 2016 ($P > 0.08$). In 2014, SS and PMCG had a greater ($P < 0.01$) concentration of TDN at the middle sampling date than either BMR or PM. At the final sampling date, SS had greater ($P < 0.01$) TDN levels than the other three forage treatments. The results between the SS and BMR treatments found in 2014 was surprising in that the brown-midrib gene is characteristic of lower lignin levels and theoretically should have resulted in a higher concentration of TDN. Although Beck et al. (2007a) did not report TDN values, they reported that SS varieties containing the brown-midrib gene had higher effective degradability levels than non-BMR varieties. However, in a comparison of the composition of pasture species in this study, it was found that BMR pastures contained only 4% BMR at the final sampling date in 2014. Thus, undesirable species in those pastures may have been lower in quality and therefore TDN, than SS forage.

Decreases were observed in NIR-predicted RFQ, DMI, and IVTDMD48 from the initial to the middle sampling date in 2014, 2015, and 2016 ($P < 0.01$). Although RFQ and DMI did not differ ($P > 0.34$) between the middle and final sampling dates in 2014, an increase was detected for both variables in 2015 ($P < 0.01$) and 2016 ($P < 0.01$) and again, confirming the boost in nutritive value of young, green tissue produced during that time. The NIR-predicted IVTDMD48 decreased ($P < 0.01$) from the middle to final sampling

Table 6. Predictions of TDN, DMI, IVTDMD48, and RFQ, as measured by near infrared spectroscopy of SS, BMR, PM, and PMCG pastures harvested at three dates in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Forage treatment					
Item/year/harvest	SS	BMR	PM	PMCG	SEM	*P* value
TDN, g/kg[1]						
2014[2]						
Initial	606	603	616	613	4.0	0.14
Middle	602^{a}	549^{c}	574^{b}	595^{a}	7.4	<0.01
Final	599^{a}	566^{b}	573^{b}	550^{b}	8.0	0.01
2015[3]						
Initial	615.2	593	603	637	14.7	0.23
Middle	557.2	570	550	568	6.6	0.18
Final	595.6	595	604	597	5.7	0.64
2016[4]						
Initial	607.7	612	599	604	3.1	0.08
Middle	546.9	569	553	564	5.9	0.10
Final	571.5	589	577	585	5.2	0.15
DMI, %[5]						
2014[2]						
Initial	2.8^{b}	2.8^{b}	2.9^{a}	2.9^{a}	0.0	0.02
Middle	2.7^{a}	2.4^{b}	2.5^{b}	2.6^{a}	0.1	<0.01
Final	2.7^{a}	2.5^{b}	2.5^{b}	2.4^{b}	0.1	0.02
2015[3]						
Initial	2.9	2.8	2.8	3.0	0.1	0.20
Middle	2.6	2.6	2.5	2.6	0.0	0.15
Final	2.7	2.7	2.8	2.8	0.0	0.30
2016[4]						
Initial	2.8	2.8	2.8	2.8	0.0	0.26
Middle	2.4^{b}	2.6^{a}	2.5^{a}	2.6^{a}	0.0	0.01
Final	2.6	2.7	2.7	2.7	0.0	0.14
IVTDMD48, %						
2014[2]						
Initial	81.2^{b}	82.8^{a}	80.7^{b}	80.4^{b}	0.5	0.02
Middle	81.7^{a}	76.3^{c}	77.0^{bc}	79.3^{ab}	0.8	<0.01
Final	77.7	76.0	76.6	73.3	1.8	0.39
2015[3]						
Initial	82.6	83.1	81.5	83.1	1.1	0.54
Middle	69.9^{c}	73.7^{ab}	72.9^{b}	74.9^{a}	0.6	<0.01
Final	79.5	79.9	82.4	81.6	0.7	0.06
2016[4]						
Initial	76.9^{b}	78.7^{a}	78.6^{a}	78.8^{a}	0.3	<0.01
Middle	68.8^{b}	73.1^{a}	73.4^{a}	74.3^{a}	0.7	<0.01
Final	75.4^{b}	78.7^{a}	77.6^{ab}	79.9^{a}	0.8	0.02
RFQ[6]						
2014[2]						
Initial	138^{ab}	136^{b}	144^{a}	143^{a}	1.9	0.05
Middle	133^{a}	106^{b}	115^{b}	127^{a}	4.1	<0.01
Final	132^{a}	113^{b}	118^{b}	108^{b}	4.1	0.01
2015[3]						
Initial	144	133	139	156	7.6	0.20
Middle	116	122	112	119	2.9	0.19
Final	131	130	137	134	3.2	0.43
2016[4]						
Initial	139	140	134	137	1.8	0.16
Middle	105^{b}	118^{a}	112^{ab}	118^{a}	3.0	0.02
Final	121	130	126	130	2.9	0.18

^{abc}Means within a row without a common superscript differ ($P < 0.05$).

[1]TDN: Predicted total digestible nutrients = (NFC × 0.98) + (CP × 0.87) + (FA × 0.97 × 2.25) + [Neutral detergent fiber nitrogen-free × (Neutral detergent fiber digestibility÷100)] − 10.

[2]Initial = June 25, 2014; Middle = July 23, 2014; Final = August 20, 2014.

[3]Initial = June 24, 2015; Middle = July 22, 2015; Final = August 25, 2015.

[4]Initial = June 27, 2016; Middle = July 25, 2016; Final = August 30, 2016.

[5]DMI: Estimated dry matter intake = 120/NDF (% of DM).

[6]RFQ: Estimated relative forage quality = DMI (% of BW) × TDN (% of DM)/1.23.

Table 7. In situ DM degradation of SS, BMR, PM, and PMCG pastures in 2014, 2015, and 2016 at the University of Georgia, Department of Animal and Dairy Science Eatonton Beef Research Unit in Eatonton, Georgia

	Forage treatment					
Year/harvest/item[1]	SS	BMR	PM	PMCG	SEM	*P* value
2014[2]						
Initial						
Degradation fraction, % of DM						
A	17.6	18.4	24.1	21.7	1.92	0.24
B	73.6	71.4	58.3	60.5	7.16	0.10
C	11.0	10.3	17.6	17.8	6.97	0.62
Rate of degradation, %/h	2.84	3.79	3.90	4.20	0.98	0.70
Middle						
Degradation fraction, % of DM						
A	22.8[b]	26.8[a]	18.3[c]	24.1[ab]	0.70	0.01
B	48.6	35.3	69.5	46.9	6.14	0.10
C	28.6	37.9	12.2	29.2	5.85	0.11
Rate of degradation, %/h	4.43	4.55	3.03	2.65	1.12	0.20
Final						
Degradation fraction, % of DM						
A	21.2	17.8	19.0	20.6	1.14	0.16
B	66.8	54.8	52.0	54.7	10.23	0.63
C	12.0	27.4	29.0	24.7	9.58	0.53
Rate of degradation, %/h	2.32	2.93	4.10	3.11	0.83	0.51
2015[3]						
Initial						
Degradation fraction, % of DM						
A	25.9	26.4	24.5	27.3	1.70	0.36
B	41.9	39.9	49.3	37.5	5.16	0.19
C	31.7	33.8	26.1	34.3	3.21	0.17
Rate of degradation, %/h	3.84	4.14	4.87	4.61	1.23	0.78
Middle						
Degradation fraction, % of DM						
A	24.0[b]	25.6[a]	21.0[c]	25.0[ab]	0.53	<0.01
B	32.1[c]	37.7[bc]	56.6[a]	45.2[ab]	5.23	0.01
C	43.9[c]	36.8[bc]	22.4[a]	29.8[ab]	5.47	0.02
Rate of Degradation, %/h	4.08	4.73	3.51	3.55	0.62	0.11

Table 7. Continued

Year/harvest/item[1]	Forage treatment				SEM	*P* value
	SS	BMR	PM	PMCG		
Final						
Degradation fraction, % of DM						
A	18.9	22.9	22.4	23.6	1.11	0.06
B	54.6	48.0	54.4	46.4	5.39	0.40
C	26.4	29.1	23.2	30.0	4.94	0.55
Rate of degradation, %/h	4.25	3.77	4.09	4.38	0.68	0.77
2016[4]						
Initial						
Degradation fraction, % of DM						
A	21.7[b]	25.1[a]	22.7[b]	25.9[a]	0.76	0.01
B	49.2[a]	50.3[a]	51.5[a]	40.4[b]	6.81	0.04
C	29.0	25.5	25.8	33.7	6.02	0.14
Rate of degradation, %/h	4.08[b]	2.80[b]	4.39[ab]	5.75[a]	1.02	0.02
Middle						
Degradation fraction, % of DM						
A	27.8[a]	26.8[a]	23.4[b]	24.5[b]	0.75	0.01
B	28.4	29.2	36.5	33.6	5.53	0.47
C	43.9	44.0	40.1	41.9	5.16	0.85
Rate of degradation, %/h	2.66[b]	4.65[a]	4.52[a]	4.62[a]	0.66	0.04
Final						
Degradation fraction, % of DM						
A	26.6	29.0	28.7	26.5	1.11	0.08
B	29.8	33.6	29.6	33.4	4.59	0.37
C	43.6	37.4	41.7	40.1	4.04	0.15
Rate of degradation, %/h	5.04	4.01	4.88	5.50	0.66	0.38

[abc]Means within a row without a common superscript differ ($P < 0.05$).

[1]Degradation fraction: A = fraction immediately degradable; B = fraction degradable at a measurable rate; C = fraction unavailable to ruminal degradation.

[2]Initial = June 25, 2014; Middle = July 23, 2014; Final = August 20, 2014.

[3]Initial = June 24, 2015; Middle = July 22, 2015; Final = August 25, 2015.

[4]Initial = June 27, 2016; Middle = July 25, 2016; Final = August 30, 2016.

dates in 2014 and increased in 2015 (P < 0.01) and 2016 (P < 0.01). Estimated RFQ in 2014 was greater (P < 0.03) for BMR compared to PM and PMCG at the initial sampling date and was greater (P < 0.04) for PMCG and SS than BMR and PM at the middle sampling date. By the final sampling date, RFQ of SS was greater (P < 0.03) than the other forage treatments. Predicted DMI was greater (P < 0.04) for the PM forage systems than the sorghum forage systems at the initiation of the grazing trial in 2014. As forages matured that year, DMI levels for SS were greater (P < 0.01) than that for BMR and PM at the middle and greater (P < 0.04) than BMR, PM, and PMCG by the final sampling date. In contrast, NIR estimated DMI was least (P < 0.04) for SS at the middle sampling date in 2016, but no effect (P > 0.05) of forage treatment was detected in the final sampling date.

Estimates of IVTDMD48 were greatest (P < 0.03) for BMR at the initial sampling date in 2014 but were lower (P < 0.02) than SS and PMCG at the middle sampling date. At the middle sampling date in 2015, both BMR and PM had greater (P < 0.01) predicted levels of IVTDMD48 than SS. SS had a lower predicted 48-h digestibility than all other forage treatments at both the initial (P < 0.01) and middle (P < 0.01) sampling dates in 2016 and was lower (P < 0.02) than BMR and PMCG at the final sampling date, with PM as an intermediate.

Differences in nutritive value between forages that contain or do not contain the brown-midrib gene have been well documented in the literature. An increase in nutritive value of BMR containing compared to non-BMR containing forages been reported in SS hybrids (Fritz et al., 1990) as well as PM species (Cherney et al., 1990). Though the 2014 data in the current trial are inconsistent with these previous reports of improved nutritive value, the higher fiber and lignin, lower digestibility, and resulting lower predicted IVTDMD48, DMI, and RFQ of the BMR treatment in 2014 at the later sampling dates is likely the result of stand loss and aforementioned increases in undesirable species, namely broadleaf signalgrass, observed in that treatment in 2014 (Table 3).

In Situ DM Degradation

With the variability seen in rainfall as well as differences seen in forage nutritive value, forage treatment and harvest date interacted (P < 0.03) to affect all in situ variables and year, harvest date, and forage treatment interacted (P < 0.01) to affect the "A" immediately soluble fraction. Therefore, DM degradation parameters are presented in Table 7 by year and harvest. The immediately degradable fraction (A) tended to differ (P < 0.10) or was found to differ by forage treatment in all but the initial (P = 0.24) and final (P = 0.16) harvests of 2014 and the initial harvest in 2015 (P = 0.36). Each year at the middle harvest date, differences in the immediately soluble fraction were observed among treatments and may be indicative of the effect warmer temperatures in combination with rapidly growing forage has on fiber structures and quantities. In Florida, bermudagrass, bahiagrass, and stargrass were found to have reduced in vitro organic matter digestibility when harvested at later dates in summer and when forages became more lignified (Johnson et al., 2001). Similarly, Beck et al. (2007b) also reported a linear decrease in the immediately soluble fraction of DM as forage harvest interval increased. Though no forage treatment consistently exhibited a higher A fraction, the PM treatment tended to have the lowest A fraction of the forage treatments. The rate of degradation did not differ at any harvest in 2014 (P > 0.20) or 2015 (P > 0.11). However, degradation rates of the forage treatments did differ at the initial (P < 0.02) and middle (P < 0.04) sampling dates in 2016. The lowest degradation rates were exhibited by the BMR treatment in the former and the SS treatment in the later. At the midseason sampling date in 2015, the potentially degradable DM fraction (B) was greater for PM compared to SS or BMR and consequently, resulted in BMR (P = 0.03) and SS (P < 0.01) having a greater DM fraction unavailable to degradation than PM. The inconsistency of the in situ DM degradation data suggest that animal performance may be affected more by forage maturity within forage treatment rather than across forage treatments of the same maturity stage.

SUMMARY AND CONCLUSIONS

In this study, SS forage systems, with their ability to quickly establish and produce greater herbage accumulation, required an increase level of management during the first few weeks after emergence. Failure to properly graze both sorghum and PM pastures can result in mature forage that has decreased nutritive value. Under the conditions of this research, pre-grazed forage mass, overall forage distribution and stocking densities of SS forage systems was skewed toward the beginning of the growing season. This study also indicated that under grazing, PM forage systems can maintain their plant densities better than SS forage systems. Forage nutritive value among forage treatments was variable and appeared to be largely influence by environment as well as grazing management. However, there is very little available literature on using warm-season annual grasses in forage-finishing beef production systems and additional research is needed to determine the effects of using mixed pastures of warm-season annual forages on animal performance. As warm-season annual grasses of SS, BMR, PM, and PMCG performed relatively similarly across years and species, selection of forage species should be based on other factors including seasonal production goals, production costs, seed availability, and adaptability into an already established forage program.

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LITERATURE CITED

Allen, V. G., C. Batello, E. J. Berretta, J. Hodgson, M. Kothmann, X. Li, J. McIvor, J. Milne, C. Morris, and A. Peeters. 2011. An international terminology for grazing lands and grazing animals. Grass Forage Sci. 66(1):2–28. doi:10.1111/j.1365-2494.2010.00780.x

Beck, P. A., S. Hutchison, S. A. Gunter, T. C. Losi, C. B. Stewart, P. K. Capps, and J. M. Phillips. 2007a. Chemical composition and in situ dry matter and fiber disappearance of sorghum x sudangrass hybrids. J. Anim. Sci. 85:545–555. doi:10.2527/jas.2006-292

Beck, P. A., S. Hutchison, C. B. Stewart, J. D. Shockey, and S. A. Gunter. 2007b. Effect of crabgrass (digitaria ciliaris) hay harvest interval on forage quality and performance of growing calves fed mixed diets. J. Anim. Sci. 85:527–535. doi:10.2527/jas.2006-358

Cherney, D. J., J. A. Patterson, and K. D. Johnson. 1990. Digestibility and feeding value of pearl millet as influenced by the brown-midrib, low-lignin trait. J. Anim. Sci. 68:4345–4351. doi:10.2527/1990.68124345x

Dalrymple, R. L. 2001. Registration of "Red River" crabgrass. Crop Sci. 41:1998–1999. doi:10.2135/cropsci2001.1998

Daly, C.C., O.A. Young, A.E. Graafhuis, S.M. Moorehead, H.S. Eaton. 1999. Some effects of diet on beef meat and fat attributes. N.Z. J. Agric. Res. 42:279–287.

Duckett, S. K., J. P. Neel, J. P. Fontenot, and W. M. Clapham. 2009. Effects of winter stocker growth rate and finishing system on: III. Tissue proximate, fatty acid, vitamin, and cholesterol content. J. Anim. Sci. 87:2961–2970. doi:10.2527/jas.2009-1850

Fontaneli, R. S., L. E. Sollenberger, and C. R. Staples. 2001. Yield, yield distribution, and nutritive value of intensively managed warm-season annual grasses. Agron. J. 93(6):1257–1262.

Fritz, J. O., K. J. Moore, and E. H. Jaster. 1990. Digestion kinetics and cell wall composition of brown midrib sorghum× sudangrass morphological components. Crop Sci. 30(1):213–219. doi:10.2135/cropsci1990.0011183X003000010046x

Gadberry, S., and J. A. Jennings. 2016. *Nitrate poisoning in cattle*. Fayetteville (AR) Agriculture and Natural Resources, University of Arkansas.

Hill, G. M., W. W. Hanna, and R. N. Gates. 1999. Pearl millet cultivar and seeding method effects on forage quality and performance of grazing beef heifers. J. Prod. Agric. 12(4):578–580. doi:10.2134/jpa1999.0578

Hoveland, C. S., and G. A. Buchanan. 1973. Weed seed germination under simulated drought. Weed Sci. 21(4):322–324. doi:10.1017/S0043174500027090

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:10.2527/2001.7992439x

Leheska, J.M., L.D. Thompson, J.C. Howe, E. Hentges, J. Boyce, J.C. Brooks, B. Shriver, L. Hoover, M.F. Miller. 2008. Effects of conventional and grass feeding systems on the nutrient composition of beef. J. Anim. Sci. 86:3575–3585.

The Georgia Automated Environmental Monitoring Network. (T.G.A.E.M.N.). 2017. [Accessed January 15, 2017]. http://www.georgiaweather.net/?content=calculator&variable=CC&site=EATONTON.

NIRS Consortium. 2013. NIRSC calibrations. NIRS Forage and Feed Testing Consortium. [Accessed March 15, 2019]. http://nirsconsortium.org/.

NRC. 2000. *Nutrient requirements of beef cattle*. Washington (DC): National Academy Press.

Ørskov, E. R., and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agr. Sci. 92(02):499–503. doi:10.1017/S0021859600063048

Realini, C.E., S.K. Duckett, G.W. Brito, M. Dalla Rizza, and D. De Mattos. 2004. Effects of pasture v.s. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. Meat Sc. 66:567–577.

Redmon, L. A., F. T. McCollum, G. W. Horn, M. D. Cravey, S. A. Gunter, P. A. Beck, J. M. Mieres, and R. San Julian. 1995. Forage intake by beef steers grazing winter wheat with varied herbage allowances. J. Range Manage. 48:198–201. doi:10.2307/4002420

Roberts, O. T. 1970. A review of pasture species in Fiji. I. Grasses. Trop. Grassl. 4(2):129–137.

Schmidt, J. R., M. C. Miller, J. G. Andrae, S. E. Ellis, and S. K. Duckett. 2013. Effect of summer forage species grazed during finishing on animal performance, carcass quality, and meat quality. J. Anim. Sci. 91:4451–4461. doi:10.2527/jas.2012-5405

Soil Survey Staff; 2017. Natural Resources Conservation Service; United States Department of Agriculture. Web Soil Survey [Accessed August 21, 2017]. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Teutsch, C. D., J. H. Fike, and W. M. Tilson. 2005. Yield, digestibility, and nutritive value of crabgrass as impacted by nitrogen fertilization rate and source. Agron. J. 97(6):1640–1646. doi:10.2134/agronj2005.0047