

Management of native warm-season grasses for beef cattle and biomass production in the Mid-South USA¹

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ABSTRACT: Native grasses, such as switchgrass (SG; *Panicum virgatum* L.), big bluestem (BB; *Andropogon gerardii* Vitman), indiangrass (IG; *Sorghastrum nutans* Nash), and eastern gamagrass (EG; *Tripsacum dactyloides* [L.] L.) may be capable of providing desirable summer forage for cattle as well as a source of biomass for renewable energy. To evaluate that potential, experiments were conducted at 2 locations in Tennessee comparing weaned beef (*Bos taurus*) steers (268 ± 25 kg initial BW) during early-season grazing (Early; 30 d, typically corresponding to May, followed by postdormancy biomass harvest) and full-season grazing (Full, mean duration = 98 d). For Exp. 1, which compared SG, a blend of BB and IG (BBIG), and EG, ADG was greater ($P < 0.05$) for BBIG (1.02 kg/d) than SG (0.85 kg/d), and both were greater ($P < 0.05$) than EG (0.66 kg/d).

Grazing days for SG and EG were similar (389 and 423 animal unit days [AUD]/ha, respectively) and exceeded ($P < 0.05$) that of BBIG (233 AUD/ha) during Full. In Exp. 2 (SG and BBIG only), rates of gain were comparable to that of Exp. 1, but AUD were 425 (SG) and 299 (BBIG) AUD/ha. Such rates of gain and grazing days indicate that these grasses can provide desirable summer forage for growing cattle. Early produced 211 to 324 kg BW gain/ha, depending on experiment and forage, followed by dormant-season harvests of 7.5 to 10.5 Mg/ha of biomass, indicating a potential for beef cattle forage and biomass production on the same land resource. Native grasses provided productive summer pasture and good rates of gain on growing cattle and could contribute to forage programs, especially where cool-season grasses currently predominate.

Key words: beef, biomass, cattle, forage, grazing, native grass

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doi:10.2527/jas2017.1488

INTRODUCTION

Beef cattle production is important throughout the Mid-South USA, an area overlapping with the distribution of tall fescue-dominated (*Lolium arundina-*

ceum [Schreb.] Darbysh.) forage production. This 14 million ha region supports approximately 12 million beef cows (*Bos taurus* and *Bos indicus*; Kallenbach, 2015) and produced 19% of U.S. calves in 2012 (USDA-NASS, 2016). The dominance of tall fescue in this region leads to a summer forage gap (Burns et al., 1984; Tracy et al., 2010; Kallenbach et al., 2012) that is compounded during hot weather by exposure to toxins from tall fescue (Thompson et al., 1993; Paterson et al., 1995; Kallenbach, 2015). Perennial, native C4 grasses may be able to fill this forage gap and avoid impacts associated with fescue toxicosis (Hudson et al., 2010; Burns and Fisher, 2013; Keyser et al., 2016).

Increased interest in renewable energy has brought attention to dedicated herbaceous crops, most notably, SG (Lynd et al., 1991; McLaughlin and Kszos, 2005; Sanderson et al., 2006). Other native

¹Directors R. Carlisle and B. Sims of Ames Plantation and Highland Rim AgResearch, and Education Centers, respectively, and their staff, especially C. Dixon, R. Wyatt, P. Pratt, and B. Fisher as well as C. Smithson are gratefully acknowledged for their hard work and dedication that made this work possible. This project was supported by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service, grant number 2007-35101-18258 and in part by NRCS 69-3A75-9-133.

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Received February 20, 2017.

Accepted April 20, 2017.

C4 grasses have also been considered as prospective renewable energy crops, including BB (Weimer and Springer, 2007; Stork et al., 2009; Zhang et al., 2015), EG (Weimer and Springer, 2007; Stork et al., 2009), and multispecies blends (Tilman et al., 2006; McIntosh et al., 2015, 2016). It has been estimated that more than 21 million ha might be needed for biomass production leading to displacement of other crops (English et al., 2006) including forages (Sanderson and Adler, 2008). An integrated forage-biomass production model may help mitigate displaced forage production within the tall fescue belt (Sanderson et al., 1999; Guretzky et al., 2011; Mosali et al., 2013). To explore this opportunity and determine its feasibility, experiments were conducted at 2 locations in Tennessee to evaluate management options for 3 native warm-season grass (NWSG) forages (SG, EG, and BBIG) under 2 grazing strategies to produce beef cattle forage and biomass.

MATERIALS AND METHODS

For Exp. 1, 3 NWSG forages, SG, BBIG, and EG, were established at the AgResearch and Education Center at Ames Plantation (Ames) located near Grand Junction, TN (35°6' N, 89°13' W) on a Memphis silt loam soil (Fine-silty, mixed, active, thermic, Typic Hapludalfs). For Exp. 2, SG and BBIG were established at the Highland Rim AgResearch and Education Center (HRREC) located near Springfield, TN (36°28' N, 86°50' W) on soils composed of Dickson and Sango silt loams (Fine- and Coarse-silty, siliceous, semiactive, thermic, Glossic Fragidults, respectively). For both experiments, 2 grazing strategies were used on each NWSG: 1) early-season and 2) full-season grazing. Early lasted for 30 d beginning when the sward was initially able to sustain grazing, typically in early May, and was designed to graze the high-quality, early growth of forage and allow the regrowth to accumulate for a postdormancy biomass harvest. Grazing initiation occurred for both treatments when mean canopy height of sward was 30 to 38 cm. Target canopy height at termination of Early was 20 cm. Full was designed to provide maximum grazing days from early May through August. Target canopy height for Full was 38 to 45 cm initially (2010), but was adjusted in 2011 and 2012 to 45 to 60 cm for SG and EG based on experience during the first year. Forage treatments were replicated 3 times per grazing strategy for a total of eighteen 1.2-ha paddocks (experimental unit) for Exp. 1 and twelve 1.2-ha paddocks for Exp. 2.

Pasture and Forage Management

Prior to establishment of NWSG, paddocks at Ames and HRREC had been dominated by tall fescue; NWSG

establishment protocols were the same at both locations. In fall 2007, paddocks were clipped with a rotary mower and, after appropriate regrowth (> 15 cm), were treated with glyphosate (*N*-(phosphonomethyl)glycine; 2.24 kg/ha a.i.) to eradicate all vegetation. A second glyphosate treatment (2.24 kg/ha a.i.) was applied in April 2008 in preparation for no-till planting. Paddocks assigned BBIG treatment were sprayed with imazapic ((\pm) -2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1Himidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid; 146 mL/ha a.i.) for pre-emergent weed control. A no-till drill (Flex II; Truax, New Hope, MN) was used to plant SG and BBIG (38-cm row spacing; May 2008), and a corn planter (Model 7000; John Deere, Moline, IL) was used to plant EG (76-cm row spacing; April 2008). Seeding rates were 6.72, 6.55:3.53, and 13.44 kg PLS (pure live seed)/ha for SG, BBIG, and EG, respectively. Cultivars of NWSG were: "Alamo" switchgrass, "OZ-70" big bluestem, "Rumsey" indiagrass and "Pete" eastern gamagrass. Big bluestem/indiagrass was planted in a blend of 65% big bluestem and 35% indiagrass based on seed mass.

Soil samples were taken from paddocks in 2010, 2011, and 2012; P and K amendments were made in April of each year based on test (Mehlich 3) results to maintain those nutrients in the medium category (University of Tennessee Soil, Plant and Pest Center, Nashville, TN). For Exp. 1, pH averaged 6.2 ± 0.05 (SE), P 32.8 ± 3.11 (SE) kg/ha, and K 154.2 ± 7.00 (SE) kg/ha and amendments for P and K averaged 32 and 21 kg/ha per year, respectively. For Exp. 2, pH averaged 6.6 ± 0.05 (SE), P 17.9 ± 1.14 (SE) kg/ha, and K 83.2 ± 6.47 (SE) kg/ha and amendments for P and K averaged 32 and 28 kg/ha per year, respectively. Paddocks did not receive N fertilization during the establishment year in an attempt to minimize growth of competitive species. Nitrogen was applied annually, 2010 to 2012 following green-up (late April) to all paddocks at the rate of 67 kg/ha in the form of ammonium nitrate (NH_4NO_3). Daily temperature and precipitation data were obtained from on-site weather stations for each month in which the experiment was conducted. In spring (March) 2010, 2011, and 2012, paddocks were burned (Ames) or clipped to a height of 20 cm with a rotary mower (HRREC) to remove residual biomass from the previous year.

Steers and Grazing Management

Tennessee Livestock Producers (Columbia, TN) provided weaned beef steers (Angus with some continental breed influence) for both experiments. For Exp. 1, mean initial BW was 269 ± 26 kg ($n = 109$), 265 ± 30 kg ($n = 145$), and 261 ± 28 kg ($n = 168$) in 2010, 2011, and 2012, respectively. Mean initial weight of

steers in Exp. 2 was 267 ± 24 kg ($n = 90$), 266 ± 23 kg ($n = 104$), and 279 ± 17 kg ($n = 108$) in 2010, 2011, and 2012, respectively. Before delivery, steers were backgrounded for 42 d on fescue-dominated pastures to alleviate symptoms of marketing and shipping stress. Steers were received at experimental sites at least 1 wk prior to initiation of grazing. For 5 d before initiating grazing, steers were placed in a dry lot and put onto a high-fiber equilibration ration to adjust gut fill, thereby improving precision of animal weight measurements (Watson et al., 2013). The equilibration ration was fed at 2.25% BW on an as-fed basis; it consisted of cottonseed hulls, soyhulls, citrus pulp, distillers dried grains, and molasses and contained 12.9% crude protein and 27.2% crude fiber.

Four steers were assigned as testers based on consistent weights and randomly assigned to each paddock. A put-and-take grazing strategy was implemented with extra steers (grazers) added to paddocks as needed to maintain target canopy heights. Grazing days for grazers were recorded for calculation of AUD. Due to abundant forage growth and limited availability of steers, yearling heifers supplemented steer grazers in 2010 and 2011. All animal care was in accordance with UT-IACUC Protocol No. 1264. Cattle were provided a general mineral supplement-free choice, and each paddock had adequate shade structures and fresh water.

At Ames, grazing began in 2010 on May 28; Early concluded on June 28 in all paddocks; and Full concluded on July 26, August 9, and August 30 for BBIG (58 d), SG (72 d), and EG (93 d), respectively. In 2011, grazing began on May 4 in all paddocks, Early concluded on June 6, and Full on August 9 (97 d) in all paddocks. In 2012, grazing began on April 17 and Early concluded on May 21; Full concluded on July 16 (90 d) in all 3 SG, 1 BBIG, and 1 EG, whereas the remaining 2 BBIG and 2 EG paddocks concluded on July 27 (101 d).

At HRREC, grazing began in 2010 on May 7. In all paddocks, Early concluded on June 7 and Full concluded on August 9 (94 d). In 2011, grazing began on May 6 in all paddocks. Early concluded on June 6 and Full concluded on August 29 (115 d) for all paddocks. In 2012, grazing began on April 27 in all paddocks. Early concluded on May 29 and Full concluded on August 20 (115 d) in all paddocks.

Steer Performance

Steers were fed the equilibration ration d-1, d-2, and d-3. On the morning of d-4, steers were fed the equilibration ration and then weighed. On the morning of d-5, steers were not fed but weighed and turned out to paddocks. The mean weights of steers on the mornings of d-4 and d-5 were used as the initial weight for each grazing treatment. Upon termination of Early

and Full each year, steers were placed in a dry lot, fed the equilibration ration, and weighed in the same manner as before grazing began. The average of d-4 and d-5 weights was used as ending weights of steers in each grazing treatment. Steers were weighed every 28 d until grazing was terminated.

Average daily gain was calculated on a per paddock basis using the 4 testers assigned to each paddock. The formula (total tester weight gain in kg/total tester grazing days = ADG) was used to calculate ADG. To calculate BW gain/ha, the formula [(paddock ADG (kg) x total paddock grazing days)/1.21] was used. Animal unit days were calculated by summing total steer grazing days per paddock and then multiplying by 0.68; heifer grazers were assigned an animal unit of 0.84 (Allen et al., 2011) and included in calculations for total AUD.

Forage Nutritive Value

At the initiation of grazing in spring and concurrent with weigh days, forage samples were taken; additionally, samples were taken in early November to determine biomass. In 2012, biomass samples were not taken due to logistical constraints; therefore, there were only 2 yr of data on biomass yield. Forage height and mass were collected to a 2.54 cm residual height at ten 0.25 m² randomly located plots in each paddock; a subsample was retained for nutrient composition analysis. Samples were dried at 55°C for 24 h to determine dry matter (DM), ground to pass through a 2-mm screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) and then subsequently ground to pass a 1-mm screen in a UDY Cyclone Mill (UDY Corporation, Fort Collins, CO) in preparation for analysis using Near-Infrared Reflectance Spectroscopy (NIRS) technology (Model 5000; FOSS NIR Systems, Inc., Laurel, MD). Equations for the forage nutritive analysis were standardized and checked for accuracy using the 2012 Mixed Hay Equation provided by the NIRSC (NIRS Forage and Feed Consortium, Hillsboro, WI). A subset of samples was selected representing each treatment and wet chemistry (Dairy One Analytical, Ithaca, NY) was used to validate the equations for harvest treatments and forage species. Using these equations allowed the samples to be run against the Global *H* statistical test in the WINSI II program for accuracy (Murray and Cowe, 2004). All forage samples fit the equation with $H < 3.0$ and were used to report results. Analyses included CP, ADF, NDF, and in vitro true DM digestibility 48 h (IVTDMD48H).

Statistical Analyses

Two experiments (sites) were conducted over 3 yr (2010, 2011, and 2012), each in a 2-factor, completely

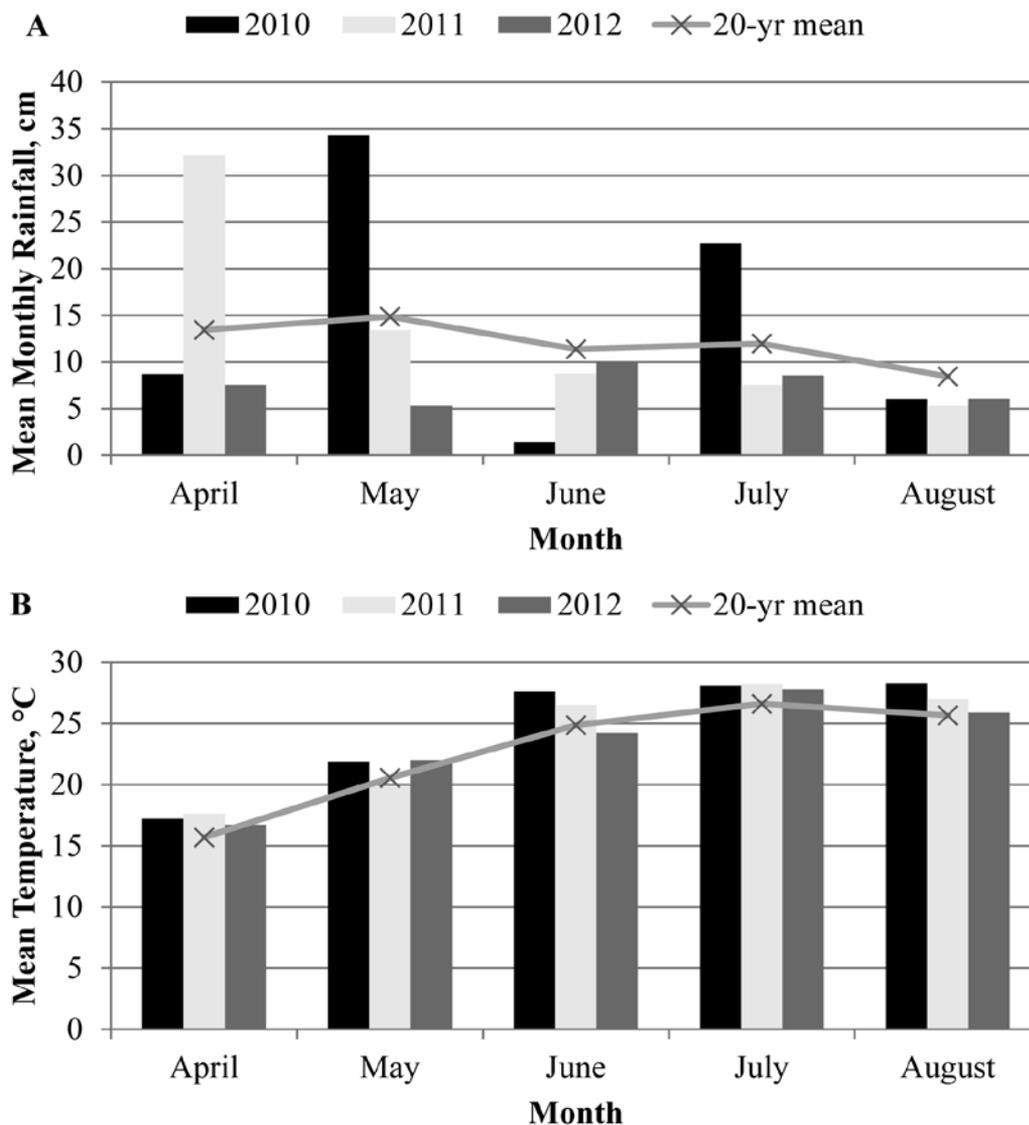


Figure 1. Mean total monthly precipitation (A) and mean monthly temperature (B) and departures from 20-yr means, April to August 2010 to 2012, AgResearch and Education Center at Ames Plantation (Experiment 1), Grand Junction, TN.

RESULTS AND DISCUSSION

randomized design with sampling and autoregressive repeated measures over periods. Data for each experiment were analyzed separately using the same mixed models in SAS 9.3 (SAS Inst. Inc., Cary, NC). Experimental unit was defined as one 1.2-ha paddock. Fixed effects were season (Early or Full), forage (SG, BBIG, EG), period, and all interactions for response variables ADG, BW gain/ha, AUD, available forage/biomass, and nutrient composition metrics. All effects were evaluated at the $P < 0.05$ level of significance and means were separated using Fisher's LSD. Quadratic regression models were developed to explore relationships between ADG (dependent variable) and forage allowance (forage mass/steer) for each experiment.

Weather

For Ames, precipitation was well above the 20-yr mean during May 2010 and April 2011 and in July of 2010 (Fig. 1). In general, 2011 and 2012 were drought years, with monthly rainfall totals below the 20-yr mean. The average monthly temperature was near or above the 20-yr mean each year and exceeded 25°C in June, July, and August (Fig. 1). At HRREC, following a dry April (except 2011) and wet May (except 2011), rainfall remained below 20-yr means all 3 yr with the exception of July 2012, which was wetter than average (Fig. 2). In general, mean monthly temperatures in 2010, 2011, and 2012 were near or above the 20-yr mean (Fig. 2). These weather conditions provided a more severe test of these summer forages than would be expected during a

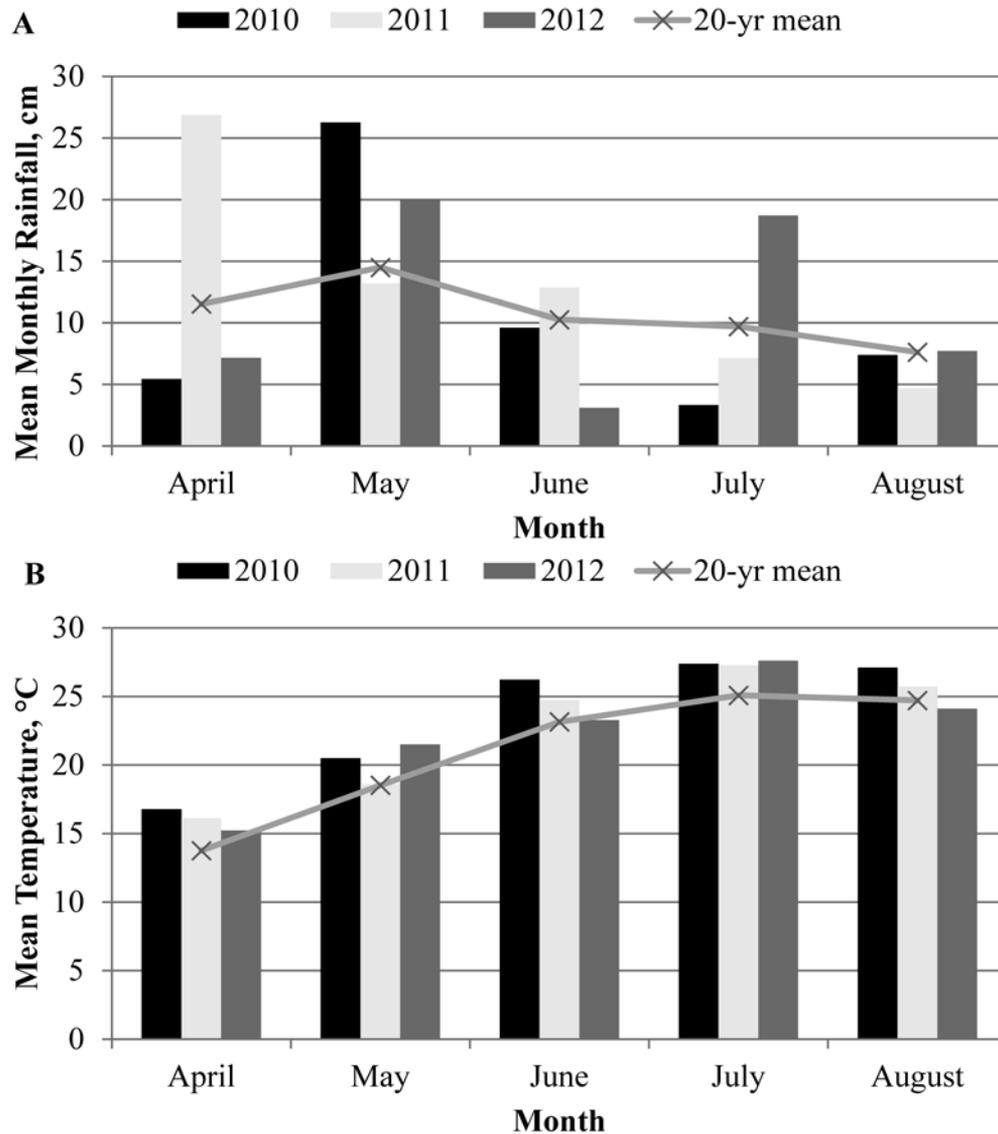


Figure 2. Mean total monthly precipitation (A) and mean monthly temperature (B) departures from 20-yr means, April to August 2010 to 2012, Highland Rim AgResearch and Education Center (Springfield, TN; Exp. 2).

typical 3-yr period in the region, suggesting producers could expect these results to be applicable in most cases.

Forage Production

During Early, forage mass did not differ among species for either Ames (6.31, SG; 5.43, EG; 4.28, BBIG Mg/ha) or HRREC (4.04, SG; 3.03, BBIG Mg/ha). The short duration, high stocking, and rapid growth of the forages during this 30-d period allowed for relatively consistent forage masses within experimental locations. On the other hand, during Full, forage mass varied by species across sample periods for both Ames ($P < 0.001$) and HRREC ($P < 0.001$). At Ames, SG had forage mass equal to or greater than the other species with the exception of the first sample period; during the first sample period, EG had nearly twice the forage

mass as the other two (Fig. 3). The lowest forage mass was most often associated with BBIG paddocks (Fig. 3). Although forage mass for SG was always numerically greater than BBIG at HRREC, that difference was only significant during the second sampling period (corresponding to June; Fig. 3). The lower (less stemmy) growth habit of BBIG, its later initiation of growth in the spring, and relatively slower growth during May and June led to shorter and more consistent canopies than what was possible for SG. Consequently, forage mass was typically lower during Full for this forage in both experiments. At Ames, initiation of grazing in 2010 was delayed 4 wk due to fence construction; during that time, forage mass almost doubled that obtained in 2011. In 2011 and 2012, grazing was initiated 3 wk and 5 wk earlier, respectively, than in 2010. Reduced forage masses observed at HRREC, especially for SG,

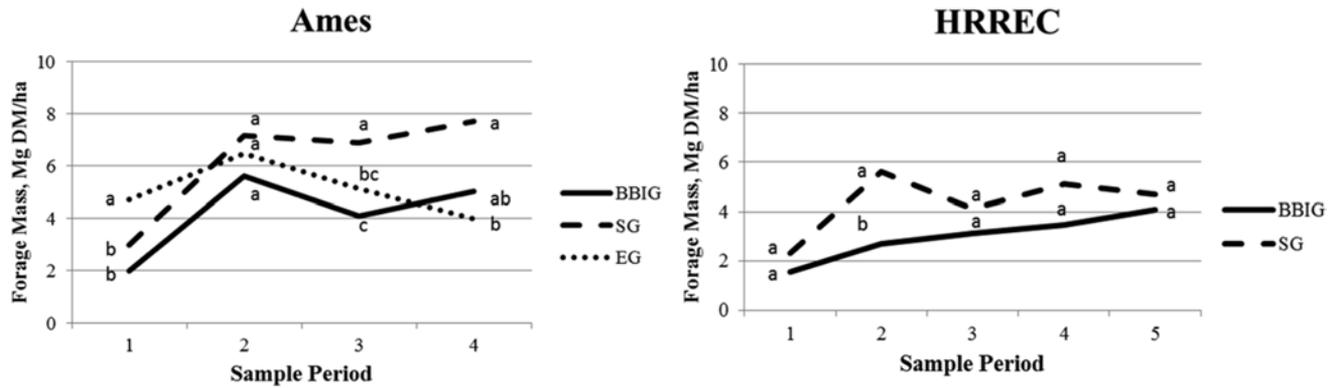


Figure 3. Forage mass for 3 native warm-season grass forages during summer sampling periods, pooled across 3 experimental years (2010 to 2012) for Ames Plantation AgResearch and Education Center, Grand Junction, TN (Ames) and Highland Rim AgResearch and Education Center (HRREC). Forages were a big bluestem/indiangrass blend (BBIG), switchgrass (SG), and eastern gamagrass (EG; Ames only). Means within sample periods with the same letter did not differ ($P < 0.05$).

could be attributed to timelier adjustments in the number of grazing animals on pasture, thus keeping forages more vegetative. Other studies have reported forage mass similar (Chamberlain et al., 2012; Burns and Fisher, 2013) to or somewhat less than (Keyser et al., 2016) those in this experiment.

Forage Nutritive Values

Forage nutritive values during Full varied by species across sample periods at Ames (CP, $P < 0.001$; ADF, $P < 0.001$; NDF, $P < 0.001$; and IVTDMD48H, $P < 0.001$) and HRREC (CP, $P < 0.001$; ADF, $P < 0.001$; NDF, $P < 0.001$; and IVTDMD48H $P < 0.001$), but in all cases, indicated decreasing nutritive values through the summer grazing period as would be expected (Fig. 4, 5). For both experiments, BBIG had the greatest overall nutritive values with consistently lower NDF and higher IVTDMD48H at Ames (Fig. 4) and greater CP and IVTDMD48H and lower NDF at HRREC (Fig. 5). Keyser et al. (2016) also reported greater CP content in a big bluestem and indiagrass blend compared to switchgrass. However, Burns and Fisher (2013) reported greater fiber contents in BB by itself vs. SG, likely a function of the greater canopy heights at which they managed BB and lower canopy heights at which they managed SG compared to this study. Perhaps because of its earlier maturity and growth, coupled with lighter initial stocking, EG was more fibrous than SG in the earlier part of the season (Fig. 4). In contrast, Burns and Fisher (2013) found lower ADF and greater CP in EG vs. SG and BB, again, likely a result of their management that produced shorter canopies than was the case in our study. Aiken (1997) reported CP levels considerably lower (i.e., 30 to 60 g/kg) than either those observed in the current study or reported by Burns and Fisher (2013; 116 g/kg), but he managed swards with much greater herbage mass (5 to 8 Mg/ha) than in the other 2 studies. In the current study,

estimates of forage quality may have been biased somewhat low (at least relative to cattle intake) as a result of including lower strata of the sward, below the grazing horizon (i.e., 2.5 cm), in the analyses.

With respect to grazing season (Early vs. Full), forage nutritive value patterns were dissimilar between experiments. For Ames, forage nutritive value did not differ between Early and Full for CP (83.2 vs. 88.8 g/kg) or IVTDMD48H (629.4 vs. 641.0 g/kg), but did for ADF ($P < 0.008$; 421.2 vs. 411.0 g/kg) and NDF ($P < 0.017$; 720.3 vs. 706.9 g/kg). Interactions between season and species were not significant for any of the nutritive value measures. The somewhat greater fiber levels in Early, which were contrary to expectations, were likely the result of the unusually late start on grazing in 2010 and associated levels of maturity in the swards. On the other hand, at HRREC there was an interaction between species and season indicating that during Early, BBIG and SG differed for CP ($P = 0.007$; 99.6 vs. 66.3 g/kg) and NDF ($P = 0.005$; 679.3 vs. 745.5 g/kg). Despite an interaction for these same terms for ADF ($P = 0.029$), BBIG (413.7 g/kg), and SG (424.2 g/kg) did not differ within Early. Although these 2 forages differed ($P < 0.001$) with respect to IVTDMD48H (BBIG = 663.6, SG = 593.5 g/kg), that difference remained consistent regardless of season. More timely initiation of grazing each spring at HRREC allowed both forages to remain less mature, thus expressing the greater nutritive value associated with BBIG at this stage of growth (McIntosh et al., 2016).

Steer Performance

For both experiments, ADG of steers differed by season and species, but these factors did not interact (Table 1). Steers grazing BBIG had greater rates of gain than those grazing SG at both locations, and at Ames, steers grazing SG had greater rates of gain than those grazing EG (Table 2). Daily performance of steers reflected nutritive

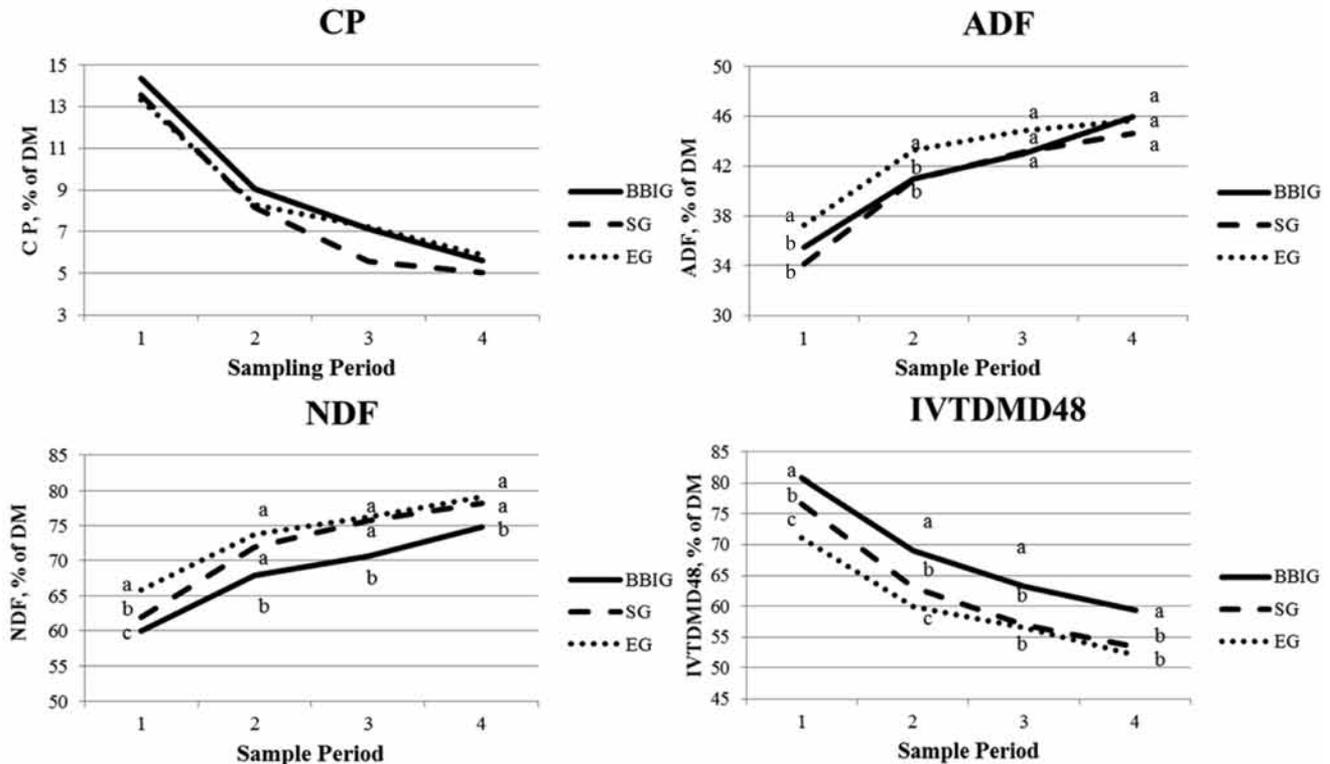


Figure 4. Forage nutritive values for 3 native warm-season grass forages for 4 summer sampling periods, pooled across 3 experimental years (2010 to 2012), Ames Plantation AgResearch and Education Center (Grand Junction, TN). Forages were a big bluestem/indiangrass blend (BBIG), switchgrass (SG), and eastern gamagrass (EG). Means within sample periods with the same letter did not differ ($P < 0.05$); CP did not differ among forages.

value of the forages. Steers grazing BBIG had higher-quality forage, resulting in higher ADG. These gains were similar to those reported for BB of 0.70 (Krueger and Curtis, 1979), 0.85 (Burns and Fisher, 2013), and 1.22 kg/d (Mitchell et al., 2005). Gains from IG by itself have not often been reported, but in one study it produced 1.08 kg/d (Krueger and Curtis, 1979). Likewise, past studies have reported gains on SG similar to ours at 0.70 (Burns and Fisher, 2013), 0.83 to 1.05 (Mosali et al., 2013), and 0.93 kg/d (Krueger and Curtis, 1979). For EG, gains were somewhat lower than those reported previously, 0.67 (Burns and Fisher, 2013), 0.75 (Aiken, 1997), and 0.76 kg/d (Burns and Fisher, 2010).

Lower rates of gain at Ames than at HRREC during Full may have been the result of several factors: delayed grazing initiation in 2010, greater forage mass and associated plant maturity in 2010 and 2011, a pinkeye outbreak in 2011, and high temperatures and drought during 2011. Conversely, the higher rates of gain during Early at Ames for both BBIG and SG were likely the result of increased selectivity associated with greater forage mass and, at least in 2010 and 2011, lighter stocking. For both experiments across all species, rates of gain during Full were lower than those during Early (Table 2). This was expected given declining forage nutritive values across the full grazing season and agreed with results reported by Keyser et al. (2016) for a compa-

rable BBIG blend and SG and by Aiken (1997) for EG. It should be noted, though, that gains for Early were based on a short time interval, and thus the potential for variability must be recognized. Use of 2 consecutive weights and standardized handling and diet allowed for increased precision and, at least, direct comparison within the study itself (Watson et al., 2013).

Relationships between ADG and forage allowance did not produce significant (SG, $P = 0.051$; BBIG, $P = 0.316$; EG, $P = 0.901$) models for Ames, although the SG model suggested a trend. Similarly, at HRREC, relationships between ADG and forage allowance did not produce significant (SG, $P = 0.239$; BBIG, $P = 0.255$) second-order regression models. When data from both experiments were combined, the relationship for SG was not significant ($P = 0.092$). This lack of a relationship suggests these forages, at the range of forage allowance animals were exposed to during this study, may be resilient to variability in management, at least as it relates to ADG. Thus, producers could expect comparable outcomes within the range of forage allowances we experienced.

Animal Unit Days and Stocking Rates

For AUD, season, species, and the interaction of these 2 factors were significant for both experiments (Table 1). As expected, the greatest AUD in both

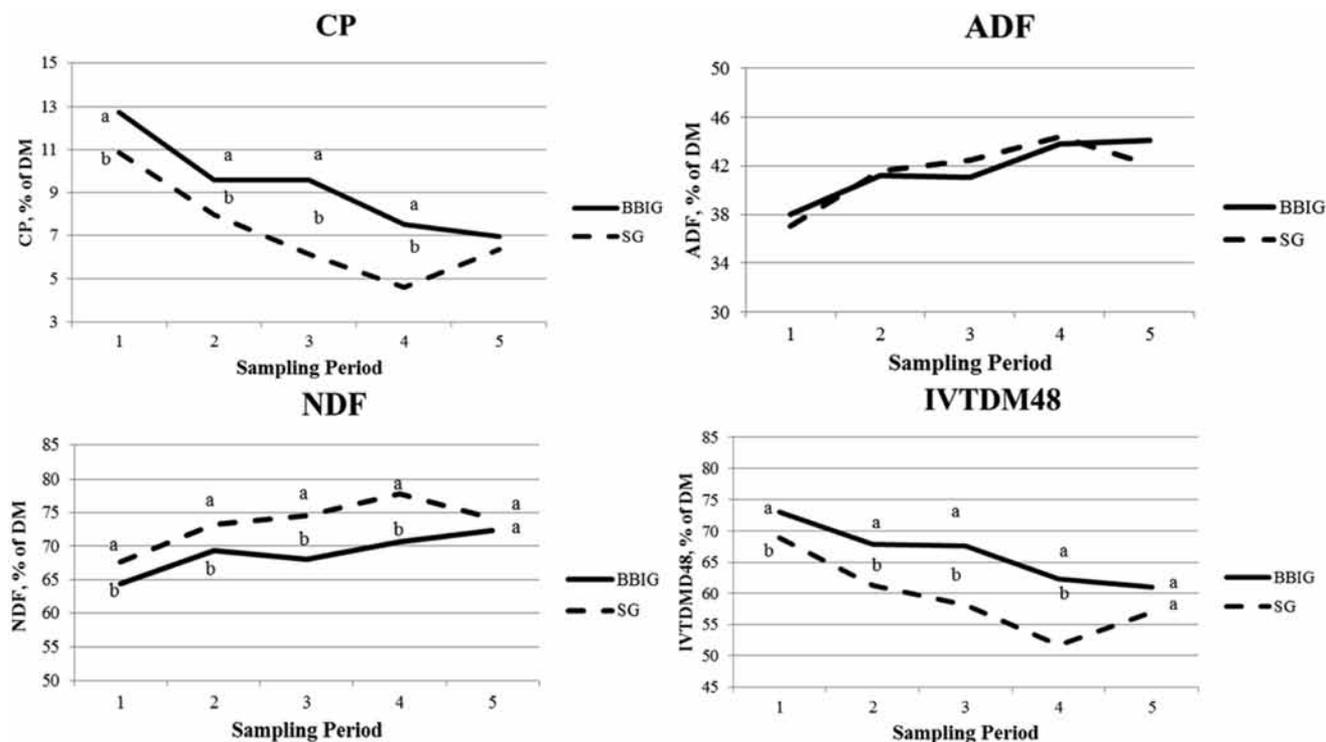


Figure 5. Forage nutritive value measures for 2 native warm-season grass forages for 5 summer sampling periods, pooled across 3 experimental years (2010 to 2012), Highland Rim AgResearch and Education Center (Springfield, TN). Forages were a big bluestem/indiangrass blend (BBIG) and switchgrass (SG). Means within sample periods with the same letter did not differ ($P < 0.05$); ADF did not differ among forages.

experiments was associated with Full (Table 2). At Ames, EG and SG did not differ within seasons and provided considerably more grazing than BBIG in both Early and Full (Table 2). In fact, during the 30-d Early, EG and SG had as many grazing days as BBIG Full (Table 2). Similarly, at HRREC, SG produced greater AUD than BBIG both in Early and Full (Table 2). Burns and Fisher (2013) reported comparable grazing days for BB (292 on an AUD basis) as observed in the current study for BBIG during Full at HRREC. Their stocking for SG (373 on an AUD basis), on the other hand, was more similar to the level at Ames for Full. For EG during Full, grazing days exceeded the 331 reported by Burns and Fisher (2013), but were well below (517 on an AUD basis) that observed by Burns and Fisher (2010). With respect to Early, there were considerably greater grazing days than Mosali et al. (2013), who never exceeded 58 AUD/ha during a similar study evaluating dual-use biomass and forage production with SG in Oklahoma. Keyser et al. (2016) reported somewhat higher AUD for the same 2 forages (221 and 165 AUD for SG and BBIG, respectively) for a comparable period at the initiation of the grazing season.

At Ames, stocking for SG and EG remained near or above 2,000 kg/ha through July, then declined to approximately 1,000 kg/ha for the balance of the grazing season (Fig. 6). On the other hand, stocking for BBIG remained consistent at about 1,000 kg/ha until mid-June,

then increased through the balance of the season to about 1,500 kg/ha (Fig. 6). At HRREC, stocking for SG remained above that for BBIG as was observed at Ames, but showed a pronounced peak that exceeded 2,500 kg/ha during May and June, followed by a decline that leveled off at approximately 1,400 kg/ha for the balance of the summer. By contrast, BBIG remained relatively level all summer (1,200 to 1,500 kg/ha) with only a modest peak at about 1,500 kg/ha during June (Fig. 6).

At Ames, there were no main effects differences for forage treatment or grazing season for total BW gain/ha, but these 2 factors interacted (Table 1). Means for Early and Full-season forage treatments ranged from 253 to 324 kg/ha (Table 2). Production from SG Early exceeded that produced by either BBIG Early or EG Early, as well as that produced by BBIG Full. The lack of differences in total BW gain for any of the three forages between Early and Full was likely due to the issues associated with optimizing stocking in a timely manner; rates of gain during Full often suffered due to excessive forage maturity coupled with tardy stocking adjustments. Rate of gain for SG Full was well below what it was at HRREC and has been reported elsewhere in the literature. Indeed, at Ames, forage mass for SG remained almost 50% greater than at HRREC for much of the summer. Total BW gain for EG also was handicapped by inordinately low ADG, also a function of excessive maturity associated with stocking level and timing. At

Table 1. ANOVA model results for grazing and biomass experiments for native warm-season grass forages across 3 experimental years (2010 to 2012) for Ames Plantation AgResearch and Education Center (Grand Junction, TN; Ames) and Highland Rim AgResearch and Education Center (Springfield, TN; HRREC)¹

	Effect	Num df	Den df	ADG		AUD ²		Total BW gain/ha		Biomass			
				F	Pr > F	F	Pr > F	F ³	Pr > F	Num df	Den df	F	Pr > F
Ames	grass	2	46	18.59	< 0.001	32.89	< 0.001	0.81	0.449	2	14	0.82	0.461
	season	1	46	87.22	< 0.001	143.95	< 0.001	0.00	0.964				
	grass*season	2	46	1.84	0.170	8.06	0.001	4.33	0.019				
HRREC	grass	1	30	19.77	< 0.001	48.51	< 0.001	1.95	0.184	1	9	7.23	0.025
	season	1	30	6.27	0.018	295.72	< 0.001	135.17	< 0.001				
	grass*season	1	30	0.25	0.622	12.09	0.002	4.52	0.049				

¹Forages were a big bluestem/indiangrass blend (BBIG), switchgrass (SG), and eastern gamagrass (EG; Ames only). Forages were grazed (season) for either 31 d (Early) at the beginning of the summer or 88 (mean, Ames) or 108 (mean, HRREC) d (Full) across years. Biomass harvests were taken post-dormancy from Early experimental pastures that had been grazed for 31 d during early summer and then rested for the balance of the growing season.

²AUD = animal unit days.

³Denominator df for HRREC for grass = 14 and for season and grass*season interaction = 16.

HRREC, there was no main effect difference between forages for total BW gain, but there was 1 for grazing season and the interaction of these 2 factors (Table 1). Early beef production did not differ between BBIG and SG. Full beef production for SG exceeded that of BBIG, and both were greater than that produced during Early for either forage (Table 2). The greatest total BW gain was associated with SG, a reflection of a lower ADG (0.79 vs. 0.96 kg/d), but a considerably higher AUD (425 vs. 299 AUD/ha) for this species vs. BBIG. Total BW gain for SG exceeded that reported by Burns and Fisher (2013) for Alamo SG, more as a result of greater stocking at HRREC (425 vs. 373 AUD/ha) than rate of gain (0.79 vs. 0.70 kg/ha). For BBIG and SG, HRREC outproduced Ames during Full. Although other factors contributed, closer stocking adjustments played a key role in the greater productivity at HRREC during Full. Working with these same 2 study sites, Lowe et al. (2015) documented the greatest net returns were from SG Full at HRREC (\$852/ha) followed by BBIG at that same location (\$636/ha) and at Ames returns were \$336, \$256, and \$245/ha for BBIG, SG, and EG, respectively.

Biomass Production

One of the objectives of this study was to collect biomass yield data on paddocks that had been subjected to early grazing to provide livestock and/or biofuel producers with alternatives for marketing native warm-season grasses. At Ames, yields of 9.9, 9.0, and 9.0 Mg/ha for EG, BBIG, and SG, respectively, did not differ among species (Table 1) and were slightly more than those reported by Mosali et al. (2013) using similar grazing strategies. In Exp. 2, biomass yields for SG (10.50 Mg/ha) and BBIG (7.48 Mg/ha) differed ($P < 0.025$). The variation in management for beef production (i.e., grazing) directly influenced the profitability of biomass

production options. For instance, net returns for beef production influenced break-even prices for biomass with targets more than doubled at HRREC over Ames (Lowe et al., 2015). Where beef production is high during the first 30 grazing days (e.g., HRREC), biomass

Table 2. Animal performance for native warm-season grass grazing experiment at Ames Plantation AgResearch and Education Center (Grand Junction, TN; Ames) and Highland Rim AgResearch and Education Centers (Springfield, TN; HRREC), 2010 to 2012¹

Site	Effect	Treatment	ADG	AUD ²	Total BW gain/ha
			(kg/d)	(AU/ha)	(kg)
Ames	grass	BBIG	1.02 a	189 b	278.6
		SG	0.85 b	318 a	265.1
		EG	0.66 c	293 a	290.3
	season	Early	1.07 a	184 b	278.3
		Full	0.62 b	348 a	277.6
	grass*season	BBIG Early	1.23	146 c	258.4b
		BBIG Full	0.82	233 b	256.7b
		EG Early	0.84	212 b	252.7b
		EG Full	0.48	423 a	277.5 ab
		SG Early	1.14	195 b	323.9 a
HRREC	grass	BBIG	1.03 a	217 b	349.9
		SG	0.84 b	300 a	318.7
	season	Early	0.98 a	155 b	216.8b
		Full	0.88 b	362 a	451.8 a
	grass*season	BBIG Early	1.09	134 d	210.9c
		BBIG Full	0.96	299 b	414.7b
		SG Early	0.88	176 c	222.7c
		SG Full	0.79	425 a	488.8 a

¹Native grass forages were a big bluestem/indiangrass blend (BBIG), switchgrass (SG), and eastern gamagrass (EG; Ames only). Forages were grazed (season) for either 31 d (Early) at the beginning of the summer or 88 (mean; Ames) or 108 (mean; HRREC) d (Full) across years. Means within a site, effect (grass, season, grass*season), and column with the same letter did not differ ($P < 0.05$). Means without letters are not different ($P > 0.05$).

²AUD = animal unit days.

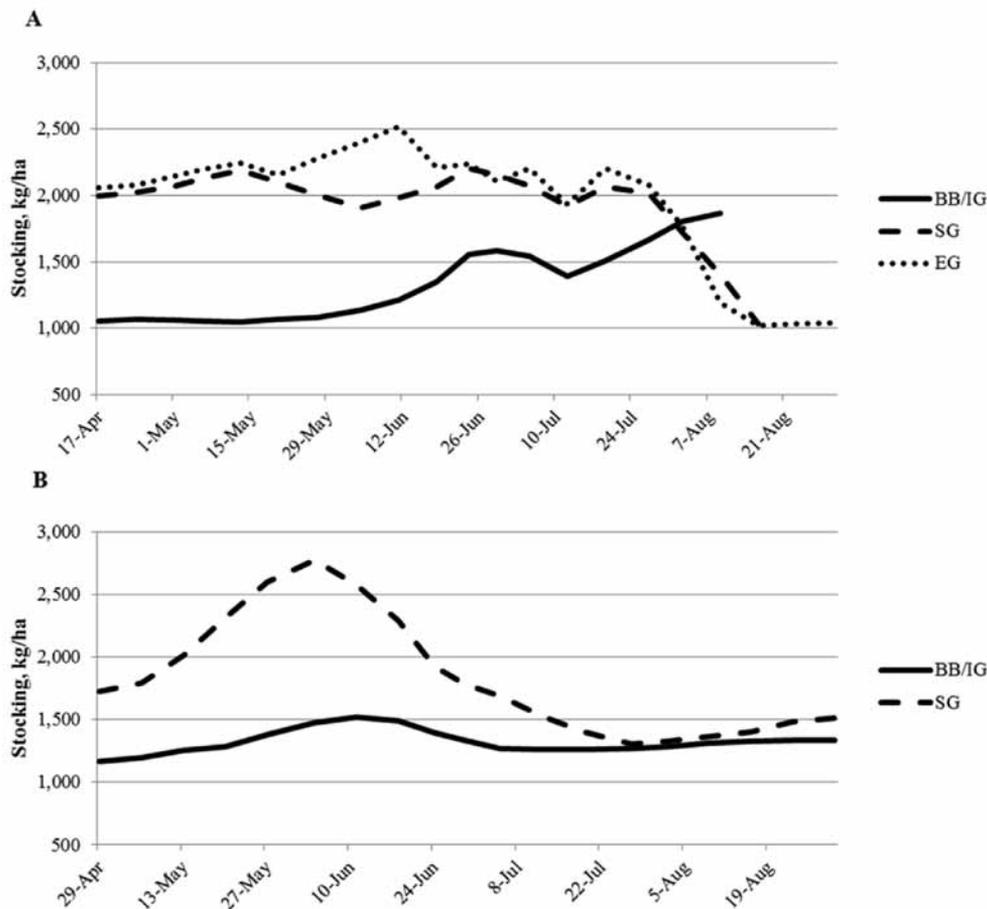


Figure 6. Stocking (kg/ha) for native warm-season grass forages averaged across 3 experimental years (2010 to 2012) for Ames Plantation AgResearch and Education Center (Grand Junction, TN) (A) and Highland Rim AgResearch and Education Center (B). Stocking based on 3-wk running average of weekly adjustments in animal numbers under a put-and-take stocking system. Forages were a big bluestem/indiangrass blend (BB/IG), switchgrass (SG), and eastern gamagrass (EG; Ames only).

would have to be >\$90/ha to justify a shift into biomass production. On the other hand, even at the lowest levels of beef production, the early 30-d grazing period always produced positive returns (Lowe et al., 2015). Absence of an ungrazed control limited the ability to calculate the reduction in biomass yield postgrazing as was reported by Mosali et al. (2013). Although BBIG and EG have not received as much attention as prospective biofuel feedstock, these findings are promising for developing management programs that combine animal production and biomass on the same land resource for these species as well as for SG.

IMPLICATIONS

Stocker cattle successfully grazed NWSG in the summer over 3 yr. Cattle grazing BBIG exhibited the highest ADG, which was related to higher forage nutritive values over the course of the study. Switchgrass had greater forage production; therefore, it supported a larger number of steers for a longer period over the course of the summer. For all NWSG, grazing manage-

ment was important to optimizing production. Growth of SG in early spring was rapid, and thus more aggressive management was required to maintain nutritive values and beef cattle performance at an optimal level. Full season grazing on these forages provided substantial nutrition during a period when pasture quality may be reduced in cool-season grass dominated systems. The Early stocking approach provided substantial gain in a short period and, when combined with the quantity of biomass produced subsequently, demonstrated the potential of combining grazing and biomass for biomass production in the same land resource.

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