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PERFORMANCE OF BEEF CATTLE GRAZING NATIVE WARM-SEASON GRASSES IN AN INTEGRATED FORAGE/ BIOFUELS SYSTEM IN THE MID-SOUTH

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I am submitting herewith a thesis written by William Matthew Backus entitled "PERFORMANCE OF BEEF CATTLE GRAZING NATIVE WARM-SEASON GRASSES IN AN INTEGRATED FORAGE/ BIOFUELS SYSTEM IN THE MID-SOUTH." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

John C. Waller, Major Professor

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ABSTRACT

Early season (ES) and full season (FS) grazing strategies were used to evaluate performance of stocker steers grazing native warm-season grasses (NWSG) in 2010, 2011 and 2012 in two experiments. Experiment one was conducted at the Research and Education Center (REC) at Ames Plantation near Grand Junction and experiment two was conducted at Highland Rim REC near Springfield in which Angus and Angus cross steers (268±25kg) were used in completely randomized design with three forage treatments: 1) switchgrass (*Panicum virgatum* L.); 2) a combination of big bluestem (*Andropogon gerardii* Vitman) and indiangrass (*Sorghastrum nutans*); and 3) eastern gamagrass (*Tripsacum dactyloides*). Stands of switchgrass (SG), big bluestem and indiangrass (BB/IG) and eastern gamagrass (EG) were 3 yr old (28%) or 4 yr old. Before and after grazing NWSG pastures all steers were fed a high fiber filler diet for 4 d with individual BW taken in the early AM each day and the average BW for the last 2 d was used for initial and final BW for the grazing period. Four steers (testers) were allotted to 1.2-ha paddocks with three replications per treatment. Additional steers were used in a put-and-take manner to keep forage in a vegetative state. Steers had free choice access to pasture, water, mineral, and shade. Data were analyzed using the MIXED procedure of SAS. Experiment one least square means for ADG of ES steers grazing BB/IG and SG differed from EG ($P < 0.05$) with ADG of 1.23, 1.14 and 0.84 kg/d respectively. Least square means for ADG of FS steers grazing BB/IG differed from SG and EG ($P < 0.05$) with ADG of 0.82, 0.56 and 0.48 kg/d respectively. Experiment two least square means for ADG of ES steers grazing BB/IG differed from SG ($P < 0.05$) with ADG of 1.09 and

0.88 kg/d respectively. Least square means for ADG of FS steers grazing BB/IG differed from SG ($P < 0.05$) with ADG of 0.96 and 0.79 kg/d respectively. The results of these two grazing experiments demonstrate the ability of NWSG to provide adequate summer performance for cattle grazing in the mid-south.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Tennessee ranks 9th nationally in beef cattle numbers and 15th nationally in total cattle numbers. Of the 79,000 farms in Tennessee, beef cattle are found on 42,000 or 53% of all farms. The receipts from sales of cattle in 2007 totaled nearly $582 million dollars, making cattle the state's top agricultural commodity (Neel, 2013). Tennessee is known as a cow/calf state that produces quality cows and calves. Producers must have a means of a readily available cheap feedstuff for their cattle to consume. Historically the feedstuff of choice has been tall fescue, either on pasture as forage, stockpiled for winter or baled into hay. The growth patterns associated with cool-season forages leave producers with limited options for feeding their cattle in the summer. The cool-season forages decrease in both yield and quality during the dormant summer months. In addition to decreased yield and quality in tall fescue, an endophyte associated with the tall fescue causes cattle to experience decreased weight gain and reproductive performance.

Recently the Tennessee Biofuels Initiative selected switchgrass, a native warm season grass, as a feedstuff for cellulosic ethanol production. Switchgrass, like many native warm-season grasses, is a C4 grass and can grow on marginal ground with minimal agricultural inputs required. Unlike cool-season grasses, warm-season grasses have peak production of nutrients in the warmer months of the summer. To meet the proposed production of ethanol, many acres currently used for grazing and forage production will need to be converted to switchgrass. If producers in Tennessee could shift their grazing lands to switchgrass in the summer and then harvest the crop for biofuels in the fall, the impact of making this major shift in grazing lands would be reduced. Cattle grazing warm-season grasses in the summer should have a greater weight gain than those grazing cool-season grasses in the summer. Results from the studies conducted in the mid-south indicate that native-warm season grasses show potential to provide adequate summer forage for producers looking to fill the summer forage gap. Burns and co-workers (2010) reported that Eastern Gamagrass produced higher ADG than a traditional grazing system in the summer. Kirch et al. (2007) reported that steers grazing native-warm season grasses were able to selectively graze individual plants and consume a diet more nutritious than one that could be sampled.

The objectives of these experiments were to: 1) Evaluate three species of native warm-season grasses and two grazing strategies to determine production parameters for both livestock forage and biofuels. 2) Document grazing strategies for native warm-season grasses conducive to Mid-South beef cattle operations. 3) Determine feasibility of combining grazing strategies and biomass production for biofuels.

CHAPTER II

LITERATURE REVIEW

Tall fescue (*Lolium arundinaceum* Schreb.) grows on approximately 14 million hectares throughout the United States (Beck et al., 2008). Of these 14 million hectares, approximately 75 percent of all pastures are infected with an endophytic fungus (*Neotyphodium coenophialum*) which causes cattle to exhibit symptoms of tall fescue toxicosis (Oliver et al., 2000). Symptoms of this toxicosis include decreased weight gain and reproductive performance. Economic losses of $600 million annually due to tall fescue toxicosis are probably underestimated (Allen and Segarra, 2001).

Tall fescue and other cool-season forages are high quality during the early spring and fall (Beck et al., 2006). During the summer months most of these grasses are unproductive (Anderson and Matches, 1983). Studies have shown that native warm-season grasses in pure stands can provide large amounts of high quality forage during the summer when cool-season forages are essentially dormant (Rountree et al., 1974). Tall fescue makes nearly 60 percent of its production before June 1. This leaves very little forage to be produced during the warmer summer months. In contrast, native warm-season grasses make nearly 70 percent of their growth between June 1 and September 1. The production of forage by native warm-season grasses fills the gap during the heat of summer left by tall fescue and other cool-season grasses (Rountree et al., 1974).

Switchgrass

Switchgrass (*Panicum virgatum* L.) is an erect, warm-season perennial whose native range originally included the prairies, open woods, brackish marshes and pinewoods of most of North America except areas west of the Rocky mountains and north of 55°N lat (Moser et al., 2004). There are both upland and lowland types of switchgrass. Beef cattle graze switchgrass from the top of the canopy, defoliating the plants as they go. Switchgrass stands can be damaged by overgrazing. The plant needs time to replenish carbohydrate reserves in tissues or there is a risk of losing the stand if it is grazed too closely (Moser et al., 2004). Beef cattle gains in switchgrass range from 1.1 kg/day in the spring to 0.9 kg/day in the summer (Burns et al., 1984) Switchgrass is a viable and high performing forage when managed correctly.

Big Bluestem

Big bluestem (*Andropogon gerardii* Vitman) is found throughout the tallgrass prairie region of the plains grassland of North America. It is distributed from New Brunswick and Quebec, west to Alberta and south to Florida, Arizona and northern Mexico (Moser et al., 2004). Big bluestem is an erect perennial. Development is rapid and by the first of June, leaves are 20 to 40 centimeters high. By late summer, foliage reaches a height of 0.6 to 0.9 meters (Weaver, 1954). Big bluestem is the best native warm-season grass for pasture and hay. It is highly palatable, nutritious and preferred by cattle. Unless it is managed properly, it will be replaced by invasive species (Weaver, 1954). When properly managed, big bluestem pastures deliver adequate gain to grazing cattle. A 3 year study by Mitchell and coworkers (2005) revealed that average daily gain by cattle ranged from 1.02 to 1.28 kg/day.

Indiangrass

Indiangrass (*Sorghastrum nutans* L.) is a tall coarse grass with water requirements and growth patterns very similar to big bluestem (Weaver, 1954). Indiangrass may form sod patches or grow in bunches. It is indigenous to the Americas, with a range from southern Mexico to east-central Canada (Stubbendieck et al., 1997). It is found in clumps within patches of big bluestem sod. This results from tillering under severe competition (Weaver, 1954). It is almost always seeded in a mixture with other native warm-season grasses, most often big bluestem. An advantage of combining big bluestem and indiangrass is that indiangrass matures later in the season. Grazing cattle will have a higher quality forage to graze for a longer period of time (Moser et al., 2004). Indiangrass is suitable for grazing or making hay and it ranks almost as high as big bluestem in palatability. When cut before flowering, it is readily eaten by livestock (Weaver, 1954). In one of the few studies reporting animal performance of cattle grazing indiangrass, Krueger and Curtis (1979) reported that beef cattle gained 1.08 kg/day when grazing indiangrass.

Eastern Gamagrass

Eastern Gamagrass (*Tripsacum dactyloides* L.) is a bunch type perennial grass with potential for efficient dry matter production (Burns et al., 1992). Eastern gamagrass occurs from Massachusetts to Nebraska through Kansas, Oklahoma and Texas into northeastern Mexico and Eastward to the Atlantic and Gulf coasts (Moser et al., 2004). It is a widely adapted species, with strains occurring in prairies, coastal plains, semi-arid regions, deep sandy soils, rocky soils, river banks and open forests (Moser et al., 2004). Eastern gamagrass is has been recognized as highly productive and palatable (Bidlack et al., 1999). Eastern gamagrass initiates growth in the spring before most other warm-season grasses. It can be grazed when other grasses are at a critical growth stage (Moser et al., 2004). Cattle grazing eastern gamagrass during a summer season gained 0.82 kg/day (Burns et al., 1992). When used in a rotation with other warm-season grasses, grazing eastern gamagrass early and then rotating to another warm-season grass, producers should see more production and sustained growth in their cattle.

Nutritive Value

The nutritive value of a forage largely determines ruminant animal performance through digestible energy, crude protein, vitamins and minerals (Burns, 2009). The term forage quality is sometimes considered the same as with nutritive value, as they are both applied to the relationship between nutritional characteristics of forage and the animal's production (Burns, 2009). Forage quality is sometimes used to explain the relationship between forage characteristics and how an animal responds. Nutritive value describes the relationship between the chemical features of the plant to nutrient utilization without regards to factors such as intake and quality. Both forage quality and nutritive value should be considered to evaluate animal performance (Burns, 2009). In early growth, forage has low yield but high nutritive value, conversely as the forage matures the yield increases while nutritive value decreases. Dry matter intake, dry matter digestion and digestible dry matter intake have negative non-linear relationships with maturity As the forage plant matures, cellulose, hemicelluloses, NDF, ADF and crude protein digestibility increase (Burns et al., 1997). (Ademosum et al., 1968; Burns et al., 1997). Prediction of forage quality has long relied on voluntary intake to estimate a measure of quality. New evaluation procedures using near infrared reflectance spectroscopy and in vitro digestion in forage testing have led to the development of a new way to predict forage quality.

Relative feed quality uses voluntary intake and TDN to estimate overall forage quality in an index (Moore and Undersander, 2002). To be successful in grazing forages, especially native warm season grasses, whose fiber contents increase as they mature, proper management should be utilized to keep it in a vegetative state. If successful, grazing such forages can be beneficial and provide adequate gains during summer months.

Biofuels

Renewable biofuels have been projected as the future of the bioenergy industry; a pathway to reduce fossil fuel dependency and reduce greenhouse gas emissions (Sanderson and Adler, 2008; Schmer et al., 2008). Previous generation biofuels have centered on annual grain crops; a transition towards renewable bioenergy crops has led to perennial biomass crops as a producer of biofuels (Sanderson and Adler, 2008; Sanderson et al., 2006). Perennial biomass crops have replaced annual grains because they require fewer inputs, produce more energy and result in less environmental side effects than annual grain crops. Intensive research funded by the U.S. Department of Energy in the 1990s established the groundwork for the development of dedicated biofuels systems based on switchgrass (Sanderson et al., 2006). Relying on switchgrass as a monoculture to lead the biofuels industry could be risky because of insect, disease and marginal performance on differing soil types. Developing paddock mixes with switchgrass and other highly productive C4 grasses such as big bluestem, indiangrass and eastern gamagrass could prove to be beneficial. Planting a mix of perennial biomass crops, specifically NWSG, may help in disease and insect control (Grabowski et al., 2004; Samson and Omielan, 1992). Furthermore, mixtures of NWSG could lead to higher yields, less year to year variability of yields and increased production throughout the growing period (Trenbath, 1974). Pasture mixes of NWSG are especially suited to a cattle producer grazing these forages and then trying to harvest them as a biofuels crop, a modified two cut system. Instead of mechanically harvesting the forage early in the summer cattle would graze a short period of time and then the forage would rest until the first killing frost before being harvested for biomass. In Iowa, traditional two cut biomass systems yield ranged from 5.51-6.57, 5.91-6.77 and 5.49-5.73 MG/ha for switchgrass, big bluestem and indiangrass respectively (Hall et al., 1982). Lee and co-workers (2009) reported that biomass yields from switchgrass and big bluestem grown in South Dakota ranged from 4.1-6.2 and 2.6-4.8 MG/ha respectively. A multi-state switchgrass study reported that two cut biomass total yields for switchgrass ranged from 13.4 to 21.3 MG/ha (Fike et al., 2006). A three year, three cut system reported that eastern gamagrass yields range from 3.7-12.7 MG/ha (Brejda et al., 1996). The variability in yield data in studies reported can likely be accounted for in differing temperate and physiogeographical zones. Soil fertility and management as well as species selected are also factors.

Animal Unit

The term animal unit (AU) is commonly used in grazing management strategies, particularly in the plains regions of the United States. Before animal units there were “cow-days,” precursors to the AU mentioned as early as 1907 (Scarnecchia, 1985). There are many current definitions of AU, but they all have one underlying factor; the defined forage intake of a standard animal. Associated terminologies of AU include animal unit days (AUD), animal unit months (AUM) and animal unit years (AUY). An AUD refers to the amount of dry forage consumed by one animal unit per 24 hour period (Allen et al., 2011). An AUM is the monthly dry forage intake of a standard animal unit and an AUY is the yearly dry forage intake of a standard animal unit. Much discussion of a standard livestock unit has been reported (Allen et al., 2011; Scarnecchia, 1985; Scarnecchia and Kothmann, 1982; Vallentine, 1965), Allen and co-workers (2011) define a standard animal unit as "one mature, non-lactating bovine (middle third of pregnancy) weighing 500 kg and fed at a maintenance level for zero gain (8.8 kg dry matter/ d) : NRC (1984) or the equivalent expressed as [$(\text{weight})^{0.75}$kg]. There are many variations of animal units and how they are expressed, however they all require the intake of a standard animal unit.

CHAPTER III

GRAZING NATIVE WARM-SEASON GRASSES IN TWO PHYSIOGEOGRAPHIC REGIONS OF TENNESSEE

ABSTRACT

Two grazing experiments were conducted in different physiographic regions of Tennessee to evaluate the potential of native grasses to fill a late spring through summer forage gap usually associated with grazing systems based on tall fescue. Two grazing strategies used were (1) early grazing of spring growth for approximately 30 d followed by biomass harvest postdormancy and (2) grazing full season to determine the potential for these grasses to supply forage throughout the summer. Three forage treatments were: 1) switchgrass (*Panicum virgatum* L.); 2) a combination of big bluestem (*Andropogon gerardii Vitman*) and indiangrass (*Sorghastrum nutans*); and 3) eastern gamagrass (*Tripsacum dactyloides*). Weaned beef steers (268±25kg) were used to graze 1.2 ha paddocks of three replications in a put-and- take system. Steers received a special diet before and after grazing to aid in reducing gut fill variation in animal weights. Experiment 1 compared SG, BB/IG and EG in using both early and full season grazing strategy. Steers grazing BB/IG had higher daily gains ($P < 0.05$) early season, SG provided more animal unit grazing days in both early and full season. Experiment 2 compared SG and BB/IG. The BB/IG produced higher ($P < 0.05$) ADG in early season and resulted in higher beef/ha in full season. Biomass harvest resulted in sufficient yield following early grazing indicating a potential for beef and biofuel biomass production on the same land resource.

INTRODUCTION

Tennessee ranks 9th nationally in beef cattle numbers and 15th nationally in total cattle numbers. Of the 79,000 farms in Tennessee, beef cattle are found on 42,000 or 53% of all farms. The receipts from sales of cattle in 2007 totaled nearly $582 million dollars, making cattle the state's top agricultural commodity (Neel, 2013). Tennessee is known as a cow/calf state that produces quality cows and calves. Producers must have a means of a readily available cheap feedstuff for their cattle to consume. Historically the feedstuff of choice has been tall fescue, either on pasture as forage, stockpiled for winter or baled into hay. The growth patterns associated with cool-season forages leave producers with limited options for feeding their cattle in the summer. The cool-season forages decrease in both yield and quality during the dormant summer months. In addition to decreased yield and quality in tall fescue, an endophyte associated with the tall fescue causes cattle to experience decreased weight gain and reproductive performance. Recently the Tennessee Biofuels Initiative selected switchgrass, a native warm season grass, as a feedstuff for cellulosic ethanol production. Switchgrass, like many native warm season grasses, is a C4 grass and can grow on marginal ground with minimal agricultural inputs required. Unlike cool-season grasses, warm-season grasses have peak production of nutrients in the warmer months of the summer. To meet the proposed production of ethanol, many acres currently used for grazing and forage production will need to be converted to switchgrass. If producers in Tennessee could shift their grazing lands to switchgrass in the summer and then harvest the crop for biofuels in the fall, the impact of making this major shift in grazing lands would be reduced. Cattle grazing warm-season grasses in the summer should have a greater weight gain than those grazing cool-season grasses in the summer. Results from the studies conducted in the mid-south indicate that native-warm season grasses show potential to provide adequate summer forage for producers looking to fill the summer forage gap. Burns and co-workers (Burns and Fisher, 2010) reported that eastern gamagrass produced higher ADG than a traditional grazing system in the summer. Kirch et al. (2007) reported that steers grazing native-warm season grasses were able to selectively graze individual plants and consume a diet more nutritious than one that could be sampled. The objectives of these experiments were to: 1) evaluate three species of native warm-season grasses and two grazing strategies to determine production parameters for both livestock forage and biofuels. 2) document grazing strategies for native warm-season grasses conducive to Mid-South beef cattle operations. 3) determine the impact of early season grazing strategies on biomass yield.

MATERIALS AND METHODS

Experiment 1

Three native warm-season grass (NWSG) combinations; 1) switchgrass (SG), 2) big bluestem/indiangrass combination (BB/IG) and 3) eastern gamagrass (EG) were established on predominantly tall fescue pastures at the Research and Education Center at Ames Plantation located near Grand Junction, TN (35°6'N, 89°13'W). Forage treatments were replicated three times per grazing strategy for a total of 18 (1.2-ha) paddocks. Additionally, there were two grazing strategies used on each NWSG; 1) early season grazing and 2) full season grazing. Early season grazing lasted 30 days beginning each late spring and was designed to graze the high quality early growth of forage and allow the regrowth to accumulate for a biomass harvest in the fall. Full season grazing was designed to provide the maximum grazing days from early may through the summer. In the fall of 2007, paddock sites were clipped with a rotary mower and after appropriate regrowth (> 15 cm), were treated with Roundup (*N*-(phosphonomethyl)glycine) (4.7 L/ha) to control cool-season grass and weed competition. A final Roundup (*N*-(phosphonomethyl)glycine) treatment (2.3 L/ha) was applied in April 2008 in preparation for planting. Paddocks receiving BB/IG treatment were sprayed with Plateau ((±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid) (585 mL/ha) to control competition in the establishment year. A no-till drill was used to plant each SG and BB/IG paddock and a corn planter was used to plant EG in 2008. Seeding rates were 6.72 kg PLS (pure live seed)/ha, 6.55/3.53 kg PLS/ha and 13.44 kg PLS/ha for SG, BB/IG and EG respectively. Cultivars of NWSG used were; 'Alamo' switchgrass, 'OZ-70' big bluestem/'Rumsey' indiangrass and 'Pete' eastern gamagrass. Big bluestem/indiangrass combinations were planted in a blend of 65% big bluestem and 35% indiangrass seed by weight. 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 results to maintain the soils in the medium category for these two nutrients. Paddocks did not receive N fertilization during the establishment year in the attempt minimize growth of competitive species. Application of 67 kg/ha of N in the form of ammonia nitrate was done annually following green up (late April) to all paddocks. Daily weather data information was obtained from the weather station located at the Research and Education Center at Ames Plantation. Maximum and minimum daily air temperatures as well as cumulative rainfall were recorded for each month in which the experiment was conducted. In the spring of 2010, 2011 and 2012 paddocks were burned to remove residual biomass from the previous year.

In 2010, grazing began on May 28. Early season grazing concluded on June 28 in all paddocks and full season grazing concluded on August 9, July 26, and August 30 for SG, BB/IG and EG paddocks, respectively. In 2011 grazing began on May 4 in all paddocks. Early season grazing concluded on June 6 and full season grazing concluded on August 9 in all paddocks. In 2012 grazing began on April 17 in all paddocks. Early season grazing concluded on May 21 in all paddocks. Full season grazing concluded on July 16 in all 3 SG, 1 BB/IG and 1 EG and grazing concluded on July 27 for the remaining 2 BB/IG and 2 EG paddocks.

Tennessee Livestock Producers (Columbia, TN) provided 109, 145 and 168 weaned beef steers in 2010, 2011 and 2012, respectively. Mean initial weight of steers was 269±26 kg, 265±30 kg and 261±28 kg in 2010, 2011 and 2012, respectively. Before arriving at research and education centers, the steers were backgrounded for 42 days at the Tennessee Livestock Producers cattle facility to alleviate symptoms of marketing and shipping stress. The animals that were used in this study were m1 and m2 feeder cattle grade beef steers, predominantly all black hided with some continental breed influenced steers being present. Steers were received at Ames Plantation at least one week prior to the initiation of grazing. Five days before turning steers into grazing paddocks, steers were put onto a high fiber equilibration ration. The purpose of the equilibration ration was to adjust for individual animal gut fill and to reduce the affects of variation in gut fill on animal weight. 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. 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 average weights of steers on the mornings of d-4 and d-5 was used as the initial weight for each grazing treatment. Upon termination of early season and full season grazing each year, steers were 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. In each paddock a core group of four tester steers was assigned. Steers were sorted from lightest to heaviest and the most uniform group of steers in the middle of the group were considered as tester animals and randomly assigned to each paddock. Performance of testers was the basis of calculating pasture performance (ADG, beef/ha, AUD), steers were weighed every 28d until grazing was terminated. A put-and-take grazing strategy was implemented; the core group of four testers grazed the paddock. When forage growth was over target height (20 cm for early season and 38 cm for full season), extra steers were added to paddocks. Once forage had been grazed down, extra steers were taken off. Number of days grazed for extra cattle was recorded for the calculation of animal unit days (AUD). All animal care was in accordance with UT-IACUC Protocol No. 1264 approved on March 30, 2006 by the Institutional Animal Care and Use Committee. All grazing animals were provided a general cattle mineral free choice and each paddock had adequate shade structures and fresh clean water.

At the initiation of grazing and every 28 d until grazing was terminated, forage samples were taken. In addition to the samples taken during the grazing season a set of samples were taken in early November of each year to determine biomass availability. Ten 0.25 m^2 sample sites were randomly assigned in each paddock. At each sample site overall forage height was measured in centimeters and forage clipped with gasoline powered hedge trimmers at 2.54 cm and weighed in grams. One sample site was randomly selected in each paddock to be used to determine nutrient composition of the forage. Samples were dried at 55°C for 24 hours, ground to pass through a 2 mm screen in a Wiley Mill and then subsequently ground to pass a 1 mm screen in a UDY Cyclone Mill in preparation for analysis by Near-Infrared Reflectance Spectroscopy (NIR) on (FOSS NIR Systems, Model 5000). Analyses included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), In-Vitro True Dry Matter Digestibility 48 hour (IVTDMD48H) and relative feed quality (RFQ). Dry Matter of each paddock was calculated using the dried sample (% DM = dry sample weight (g)/wet sample weight (g)). Mean dry weight (g/0.25 m^2) was calculated by taking averaging the ten wet sample weights from each paddock and multiplying them by the calculated DM of the paddock. Upon calculating mean dry weight of the paddock, values were then multiplied by 40 to transform from g/0.25m^2 to kg/ha of available dry matter forage.

Early season steers were weighed at the onset and conclusion of grazing as described above. Additionally, steers on full season grazing treatments were weighed in the early a.m. every 28-d throughout the grazing season. Average daily gain was calculated on a per paddock basis using the four testers assigned to each paddock. The formula (total tester weight gain in kg/total tester grazing days = ADG) was used to calculate ADG for both early and full season grazing paddocks. To calculate beef/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 multiplied by 0.68 to adjust standard animal unit for smaller animals.

Experiment 2

Two NWSG combinations; 1) switchgrass (SG) and 2) big bluestem/indiangrass combination (BB/IG) were established on predominantly tall fescue pastures at the Highland Rim Research and Education Center located near Springfield, TN (36°28'N, 86°50'W). There were two grazing strategy used on each NWSG; 1) early season grazing and 2) full season grazing. Forage treatments were replicated three times per grazing strategy for a total of 12 (1.2-ha) paddocks. Early season grazing lasted 30 days beginning each late spring and was designed to graze the high quality early growth of forage and allow the regrowth to accumulate for a biomass harvest in the fall. Full season grazing was designed to provide the maximum grazing days from early may through the summer. In the fall of 2007, paddock sites were clipped with a rotary mower and after appropriate regrowth (> 15 cm), were treated with Roundup (*N*-(phosphonomethyl)glycine) (4.7 L/ha) to control cool-season grass and weed competition. A final Roundup (*N*-(phosphonomethyl)glycine) treatment (2.3 L/ha) was applied in April 2008 in preparation for planting. Paddocks receiving BB/IG treatment were sprayed with Plateau ((±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid) (585 mL/ha) to control competition in the establishment year. A no-till drill was used to plant each SG and BB/IG paddocks, seeding rates were 6.72 kg PLS (pure live seed)/ha and 6.55/3.53 kg PLS/ha for SG and BB/IG, respectively. Cultivars of NWSG used were; 'Alamo' switchgrass and 'OZ-70' big bluestem/'Rumsey' indiangrass. Big bluestem/indiangrass combinations were planted in a blend of 65% big bluestem and 35% indiangrass by weight. Soil samples were taken from paddocks in 2010, 2011 and 2012; P and K amendments were made in April of each based on test results to maintain the soils in the medium category for these two nutrients. Application of 67 kg of N in the form of ammonia nitrate was done annually following green up (late April) to all paddocks. Paddocks were not fertilized during establishment in the attempt minimize growth of competitive species. Daily weather data information was obtained from the weather station located on the Highland Rim Research and Education Center. Maximum and minimum daily air temperatures as well as cumulative rainfall were recorded for each month in which the experiment was conducted.

In the springs of 2010, 2011 and 2012 paddocks were clipped to a height of 20 cm with a rotary mower to remove residual biomass from the previous year. In 2010, grazing began on May 7. On all paddocks early season grazing concluded on June 7 and full season grazing concluded on August 9. In 2011, grazing began on May 6 on all paddocks. Early season grazing concluded on June 6 and full season grazing concluded on August 29 for all paddocks. In 2012, grazing began on April 27 on all paddocks. Early season grazing concluded on May 29 and full season grazing concluded on August 20 on all paddocks.

Source of animals, animal management, grazing strategy, data collection, nutrient composition, animal performance calculations, and animal care protocol were the same as in Exp. 1. Mean initial weight of steers in Exp. 2 was 267±24 kg, 266±23 kg and 279±17 kg in 2010, 2011 and 2012 respectively. Steer numbers provided were 90, 104 and 108 in 2010, 2011 and 2012, respectively.

Experimental Design and Statistical Analysis

The experiments were conducted over three years (2010, 2011, 2012) in a two factor completely randomized design with sampling and repeated measures. Data were analyzed using mixed models in SAS 9.3 (SAS Institute, Cary, N.C.) Experimental unit was defined as one 1.2 ha paddock. Fixed effects were grazing strategy (early or full) and forage species (SG, BB/IG, EG) treatment for ADG, beef/ha, AUD, available forage/biomass and nutrient composition.

RESULTS AND DISCUSSION

Experiment 1

Several factors influenced the quantity and quality of nutrients available to steers grazing native warm-season grasses at this location during 2010, 2011, and 2012. Weather influenced the growth of forage, the starting dates for grazing and animal grazing behavior. Participation was well above the 20-year mean during April 2010 and May 2011 and in July of 2010 (Figure 1.) In general 2011 and 2012 were drought years, with monthly rainfall totals below the 20-yr mean. The average monthly temperature near the 20-year mean each year and exceeded 25°C in June, July and August. Generally below average participation, except July 2010, and high temperatures reduced the growth potential for the paddocks grazed for the full season.

In 2010 grazing was delayed due to fencing being constructed around the paddocks. The delay allowed forages to mature before grazing was initiated and resulted in reduced forage quality for both grazing strategies. In 2011 and 2012 grazing was initiated 3 weeks and 5 weeks earlier than in 2010, respectively. Earlier initiation was an attempt to accommodate the exponential growth that the NWSG forages exhibit in the early summer. Earlier stocking in each year also resulted in forage samples taken at different stages of growth of the plants and contributed to variation in nutrient quality. Additionally, stage of growth of the plant resulted in different initial stocking rates each year to achieve our planned grazing heights. Due to abundant forage growth and no available extra grazers, yearling replacement heifers were put in with steers in 2010 and 2011 to aid in controlling the growth of the paddocks. Animal unit days were corrected to reflect a different size animal grazing during that time period. Heifers were assigned an animal unit of 0.84 for the duration they grazed. In 2011 every steer on the grazing experiment was treated for pinkeye. This problem coupled with the high temperatures and drought resulted in impaired animal performance. Adjusting the number of animals grazing each paddock to follow the forage growth pattern during the full season was difficult and not as timely as planned for the experiment.

In early season grazing, SG produced more forage than BB/IG and EG (Table 1). Early season forage production ranged from 4.1 to 6.3 MG/ha. In full season grazing forage production from SG was greater than (P = 0.002) forage produced by BB/IG and EG. Forage availability in full season ranged from 3.9 to 6.0 MG/ha. There was a year difference (P < 0.001) between 2010 and 2011, 2012. Initiation of grazing in 2010 was delayed 4 weeks, during that time the forage quantity almost doubled that obtained in 2011. A two year study (Chamberlain et al., 2012) reported forage quantities similar to those collected in both early and full season in our experiment. One of the objectives of this experiment 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. Yield of about 9 MG/ha in our experiment was slightly more than reported by (Mosali et al., 2013) using similar grazing strategies. Absence of an ungrazed control limited our ability to calculate the reduction in biomass yield post grazing as was reported by Mosali et al. (2013). Although BB/IG and EG are not usually considered biofuel feedstock , our findings are promising for developing management programs that combine animal production and biomass on the same land resource.

Comparing forage quality parameters indicated there were no main effect differences for forage treatment (P = 0.157) and grazing season (P = 0.148) for CP (Table 2). However there was a year interaction (P = 0.035). Concentrations of CP in 2012 were higher than 2010 and

2011. Earlier initiation of grazing in 2012, when the forage was still vegetative, led to an increased CP concentration. Percent CP ranged from 7.6% in early season SG to a high of 9.0% in full season BB/IG. Our results are similar to those reported in a Texas study where CP values for SG ranging from 5.1 to 7.8% (Sanderson et al., 1999). Means for ADF concentration ranged from 40.1 to 43.2% in both grazing seasons. In early and full season BB/IG maintained a lower ADF concentration than did EG, with SG having intermediate values. As ADF increases animal performance would be expected to decrease because ADF is associated with digestibility. Main effect differences of ADF for forage treatment and grazing season were significant, ($P = 0.0002$) and ($P = 0.008$) for forage treatment and grazing season, respectively. As expected, there was a year and a sampling time x forage species interaction. In 2010 ADF was higher than in 2011 and 2012. Each sampling time shows an upward progression of ADF concentration between all species (data not shown). These changes were expected because as the forage species matures ADF concentrations increase. Main effect differences for forage treatment and grazing season of NDF were significant,($P < 0.0001$) and ($P = 0.012$), respectively. Year and sampling time x forage species interactions were significant ($P < 0.0001$). Means ranged from 69.3 to 73.3% across early season and full season. Intake is inversely related to NDF, a NDF percent is associated with bulkier feedstuffs. Across early and full season, BB/IG had a lower value and EG had a higher value, with SG landing in the middle. The year interaction indicated decreasing NDF from 2010 to 2012 ($P < 0.001$), suggesting that earlier initiation of grazing captured higher quality forage.

The main effect differences for forage treatment ($P < 0.0001$) and grazing season ($P < 0.008$) of TDN were significant, as were sampling time x forage species, and year interactions

($P < 0.0001$). The TDN of EG was lower than BB/IG and SG in early and full season. The TDN of BB/IG and SG did not differ in the two grazing seasons. Higher TDN was observed at the initiation of grazing when compared to subsequent sampling times because TDN declines as plants mature. Mean separation for IVTDMD48H revealed that BB/IG was the most digestible of the three forages ($P < 0.0001$). In early season means ranged from 60.2 to 67.2% and full season means ranged from 68.6 to 59.8%. A higher IVTDMD48H value should relate to higher digestibility, increased intake and lower rumen retention time which should lead to increased animal performance when grazing higher quality forages. The forage with the highest RFQ in both early and full season was BB/IG ($P < 0.0001$). A 20% increase in RFQ was found when comparing full season BB/IG to full season EG. Sampling time x forage species, and year interactions were significant ($P < 0.0001$). Values for RFQ decreased as the grazing season progressed. Mean values for RFQ in 2011 and 2012 were higher than those values in 2010. A later initiation of grazing in 2010 allowed the forage to become more mature before it was sampled.

Average daily gain of steers grazing BB/IG and SG in early season was higher than those grazing EG (Table 3). The Main effect differences for forage treatment ($P < 0.0001$) and grazing season ($P < 0.0001$) of ADG were significant, as were year x grazing season ($P < 0.0007$), and year interactions ($P < 0.0004$). Steers Grazing BB/IG in full season had higher ADG than those steers grazing SG or EG. Daily performance of steers was reflective of nutritive value of the forages. Steers grazing BB/IG had higher quality pasture provided to them, resulting in higher average daily gains. There were no main effect differences between forage treatment and grazing season for beef/ha. Means for early and full season forage treatments ranged from 253 to 324 kg/ha. A year interaction ($P < 0.0001$) showed that beef production differed in all 3 years with 2012 having the highest beef production. This does not define which forage was best, but does show that management of the forage through grazing pressure increased as the study progressed. For animal unit days the main effect differences between forage treatment and grazing season were significant ($P < 0.0001$). The stocking rates of paddocks increased each year due to the amount of forage that was being produced and the cattle's inability to keep it in a vegetative state. By 2012, steer numbers were such that they could maintain forages in a more optimal stage of growth. Early season paddocks produced lower AUD than full season paddocks because they were only grazed for 30d. Full season grazing treatment figures were all different. Eastern gamagrass had the highest AUD, followed by SG and then BB/IG. Based on these results EG would provide longer grazing season at a higher stocking rate even though the animals ADG would be lower.

Experiment 2

Weather information was collected from the weather station at Highland Rim Research and Education Center. Rainfall in 2010 and 2011 occurred in April and May and aided in the growth of the forage (Figure 3). In general, 2010 and 2011 were drought years, with monthly rainfall totals falling short of the 20-yr mean, while 2012 had variable rain throughout the grazing season. In general mean monthly temperatures in 2010, 2011 and 2012 were near or slightly above the 20-yr departure (Figure 4).

During the early grazing season, SG and BB/IG produced similar quantities of forage dry matter (Table 1). In full season SG produced significantly more forage than BB/IG ($P < 0.05$). The inability to burn at this location may have led to increased yield in both forages due to the residual stubble left over. Additionally, the lack of differences in forage quantity could be attributed to timelier adjustments in the number of grazing animals on pasture to keep the forage more vegetative at this location. Biomass yields for SG and BB/IG differed (P = 0.014), in 2010 and 2011. Yields were 10.50 and 7.48 MG/ha for SG and BB/IG, respectively. Due to inadequate sampling in 2012 only two years of biomass data are reported. Yields of this magnitude were similar to those reported by Mosali et al. (2013). The lack of an ungrazed control prohibits our calculating the potential loss in biomass associated with grazing for 30 d each year.

Means for crude protein concentration ranged from 6.6 to 9.9% in both grazing seasons (Table 2). Early season BB/IG crude protein concentration differed from switchgrass (P = 0.0002). A sampling time x forage species interaction (P < 0.0001) occurred because forage protein generally was higher in the earlier portion of the grazing period and SG was grazed for longer than BB/IG in some years. As would be expected extending the grazing season resulted in decreased CP concentrations. There were no main effect differences for forage treatment (P = 0.785) and grazing season (P = 0.239) of ADF. As ADF increases, the potential for digestibility and subsequently animal performance would be expected to decrease. Means for NDF forage treatment differences (P < 0.001).Year (P < 0.001) and sampling time x forage species interactions were significant (P < 0.0001). Across grazing seasons BB/IG was lower in NDF than SG. In 2011 NDF concentrations were higher than in 2010 and 2012. Changes in NDF as the grazing season progressed were similar to those of ADF as the plants were becoming more mature.

There were no main effect differences for forage treatment (P = 0.769) and grazing season (P = 0.261) of TDN. Since TDN is directly related to digestible energy it is often calculated by using ADF values, lack of differences in TDN should be expected if ADF values were similar. Forage treatment differences for IVTDMD48H ($P < 0.001$) revealed BB/IG to be of higher digestibility in both early and full season grazing strategies. Means ranged from 58.1 to 66.6% for IVTDMD48H across grazing season and forage treatments. Year interactions showed 2010 and 2012 different than 2011 ($P < 0.0001$). Additionally sampling time x forage species ($P < 0.0001$), and year interactions ($P = 0.012$) were significant. As grazing season progressed, RFQ values decreased. Year interactions indicate that 2010 and 2012 were different than 2011. These findings could be attributed to changes in weather and altering of nutritive values. Mean temperatures rising above the 20-yr departure and limited rainfall stunted growth of forage.

Main effect differences for forage treatment ($P = 0.0004$) and grazing season ($P = 0.029$) of ADG were significant. Steers grazing BB/IG in early season gained more per day on average than steers grazing SG in both early and full season. Means for early season BB/IG and SG average daily gain were 1.09 and 0.88 kg/d while full season BB/IG and SG were 0.96 and 0.79 kg/d, respectively. These gains were similar to gains reported on SG by Mosali et al. and gains reported for sudangrass [*Sorghum bicolor* (L.)] by.(Mosali et al., 2013; Parish et al., 2013). Means for beef/ha differed between seasons ($P < 0.001$). Early season BB/IG and SG beef production was 211 and 223 kg and FS beef production was 489 and 415 kg of beef, respectively. Main effect differences for forage treatment and grazing season were significant ($P < 0.001$) for AUD. Early season grazing treatment means differed between BB/IG and SG with means of 161 and 211, respectively. Full season grazing treatment means differed between BB/IG and SG with means of 359 and 510 kg respectively.

The management of both forage and animals in experiment 2 was more intensive than in experiment 1. The result was more beef production in the full season due to allotting extra grazers to a pasture and removing them in a timely manner. Inability to burn pastures left a stubble height that did not allow cattle to graze all the way to the ground. It also may have negatively affected forage composition because the remaining thatch was observed in the forage samples cut on these pastures. The practice of mowing native grass pastures rather than burning may aid in grazing management by preventing animals from potentially overgrazing and the residue may help reduce competition from other undesirable plants in the pastures. The drought of 2011 impacted both animal performance and forage quality. Animal performance in experiment 2 can be summarized as follows: BB/IG provided higher gain per day in the early and full season. There was no difference in early season beef production between BB/IG and SG. During full season BB/IG provided more beef/ha. This was the result of a combination of both higher ADG and adequate stocking rate. Switchgrass excels in AUD because of higher carrying capacity and longer grazing season than BB/IG. However if more beef per unit of land is the goal then BB/IG is the preferred choice.

IMPLICATIONS

Stocker cattle successfully grazed native warm-season grasses in the summer over three years. Cattle grazing BB/IG exhibited the highest ADG which was related to higher average forage quality over the course of th grazing seasons. Switchgrass had greater forage production, therefore it provided more nutrients to a larger number of steers for a longer period over the course of the summer. In all native warm-season grass species management was more critical than is associated with most perennial plants. Growth characteristics in early spring are more like that of summer annuals and thus require more intense management to maintain nutritive value and animal performance at an acceptable level. Quantity of biomass produced after early season grazing demonstrated the potential of combining grazing and biomass for biomass production.

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APPENDICES

APPENDIX A

TABLES

Table 1. Average quantity of forage during early and full grazing season and quantity of biomass in fall following early season grazing.

Experiment [1]	Forage Treatments[2]	Grazing Season[3] Early	Full	Fall Biomass[4]
		------ Mg/ha ------		
1	BB/IG	4.11 [b]	3.90 [b]	9.01 [a]
	SG	6.31 [a]	6.08 [a]	8.97 [a]
	EG	5.37 [ab]	4.65 [b]	9.14 [a]
	LSD [c]	1.52	1.52	2.05
2	BB/IG	2.99 [b]	2.90 [b]	7.48 [a]
	SG	4.11 [ab]	4.77 [a]	10.50 [b]
	LSD	1.52	1.52	2.05

[1]Experiment 1 conducted at Research and Education Center at Ames Plantation; Experiment 2 conducted at Highland Rim Research and Education Center.
[2]BB/IG = big bluestem/indiangrass combination; SG = switchgrass; EG = eastern gamagrass.
[3]Early season = 30d of grazing from May - June; full season = around 100d of grazing from May - August.
[4]Forage regrowth on early grazing season paddocks until harvested as biomass in early November.
[a-b]Means within experiment within columns and rows for grazing season and means within column for fall biomass with no common letter differ ($P < 0.05$).
[c]LSD = average least significant differences of means within a column.

Table 2. Average forage nutrient composition on a dry matter basis and relative forage quality index of samples taken during grazing native warm season grasses in 2010, 2011, and 2012.

Forage Treatment[2]	CP		ADF		NDF		TDN		IVTDMD48H[3]		RFQ[4]	
	Early[5]	Full	Early	Full	Early	Full	Early	Full	Early	Full	Early	Full
Experiment 1[1]												
BB/IG	9.0[a]	9.0[a]	41.9[abc]	41.0[cd]	69.3[cd]	67.8[d]	51.8[bcd]	52.8[ab]	67.2[a]	68.6[a]	85.2[ab]	90.3[a]
SG	7.6[a]	8.6[a]	41.3[bcd]	40.1[d]	72.9[ab]	71.1[bc]	52.5[abc]	53.8[a]	61.4[c]	63.7[b]	77.2[c]	83.7[b]
EG	8.5[a]	9.0[a]	43.2[a]	42.3[ab]	74.0[a]	73.3[a]	50.4[d]	51.4[cd]	60.2[c]	59.8[c]	74.2[c]	74.6[c]
LSD[6]	1.3	1.3	1.3	1.3	1.9	1.9	1.4	1.4	2.3	2.3	5.7	5.7
Experiment 2												
BB/IG	9.9[a]	8.6[b]	41.4[a]	41.9[a]	68.0[c]	70.0[c]	52.4[a]	51.8[a]	66.6[a]	65.7[a]	89.2[a]	85.6[a]
SG	6.6[c]	7.7[bc]	42.4[a]	40.6[a]	74.5[a]	72.4[b]	51.3[a]	53.3[a]	58.1[b]	60.3[b]	69.2[c]	78.1[b]
LSD	1.3	1.3	1.6	1.6	2.2	2.2	1.8	1.8	3.1	3.1	8.4	8.4

[1]Experiment 1 conducted at Research and Education Center at Ames Plantation; Experiment 2 conducted at Highland Rim Research and Education Center.
[2]BB/IG = big bluestem/indiangrass combination; SG = switchgrass; EG = eastern gamagrass.
[3]IVTDMD48H = in vitro total dry matter digestibility in 48 hours.
[4]RFQ = relative forage quality index.
[5]Early season = 30d of grazing from May - June; full season = around 100d of grazing from May - Aug.
[a-d] Means within experiment within columns and rows for CP, ADF, NDF, TDN, IVTDMD48H and RFQ with no common letter differ ($P < 0.05$).
[6]LSD = average least significant differences of means within a column.

Table 3. Average daily gain (kg), beef production (kg) and animal unit days during early and full grazing seasons in 2010, 2011, and 2012.

Experiment 1[1]

Forage	ADG		Beef/ha[3]		AUD[4]	
Treatment[2]	Early[5]	Full	Early	Full	Early	Full
BB/IG	1.23[a]	0.82[b]	258[a]	299[a]	175[c]	279[c]
SG	1.14[a]	0.56[c]	324[a]	257[a]	234[d]	467[b]
EG	0.84[b]	0.48[c]	253[a]	277[a]	254[cd]	508[a]
LSD[6]	0.15	0.15	46	46	25	25
Experiment 2						
BB/IG	1.09[a]	0.96[ab]	211[c]	489[a]	161[d]	359[b]
SG	0.88[bc]	0.79[c]	223[c]	415[b]	211[c]	510[a]
LSD	0.13	0.13	63	63	37	37

[1]Experiment 1 conducted at Research and Education Center at Ames Plantation; Experiment 2 conducted at Highland Rim Research and Education Center.
[2]BB/IG = big bluestem/indiangrass combination; SG = switchgrass; EG = eastern gamagrass.
[3]Beef/ha = Beef production /ha calculated as (PADG*total grazing days per paddock); where PADG = pasture ADG; and grazing days per paddock = sum of tester and extra grazing days.
[4]AUD = Animal Unit Days calculated as (total steer grazing days*0.68) + (total heifer grazing days*0.84) + cow grazing days.
[5]Early season = 30d of grazing from May - June; full season = around 100d of grazing from May - Aug.
[a-c]Means within experiment within columns and rows for ADG, Beef/ha and AUD with no common letter differ ($P < 0.05$).
[6]LSD = average least significant differences of means within a column.

APPENDIX B

FIGURES

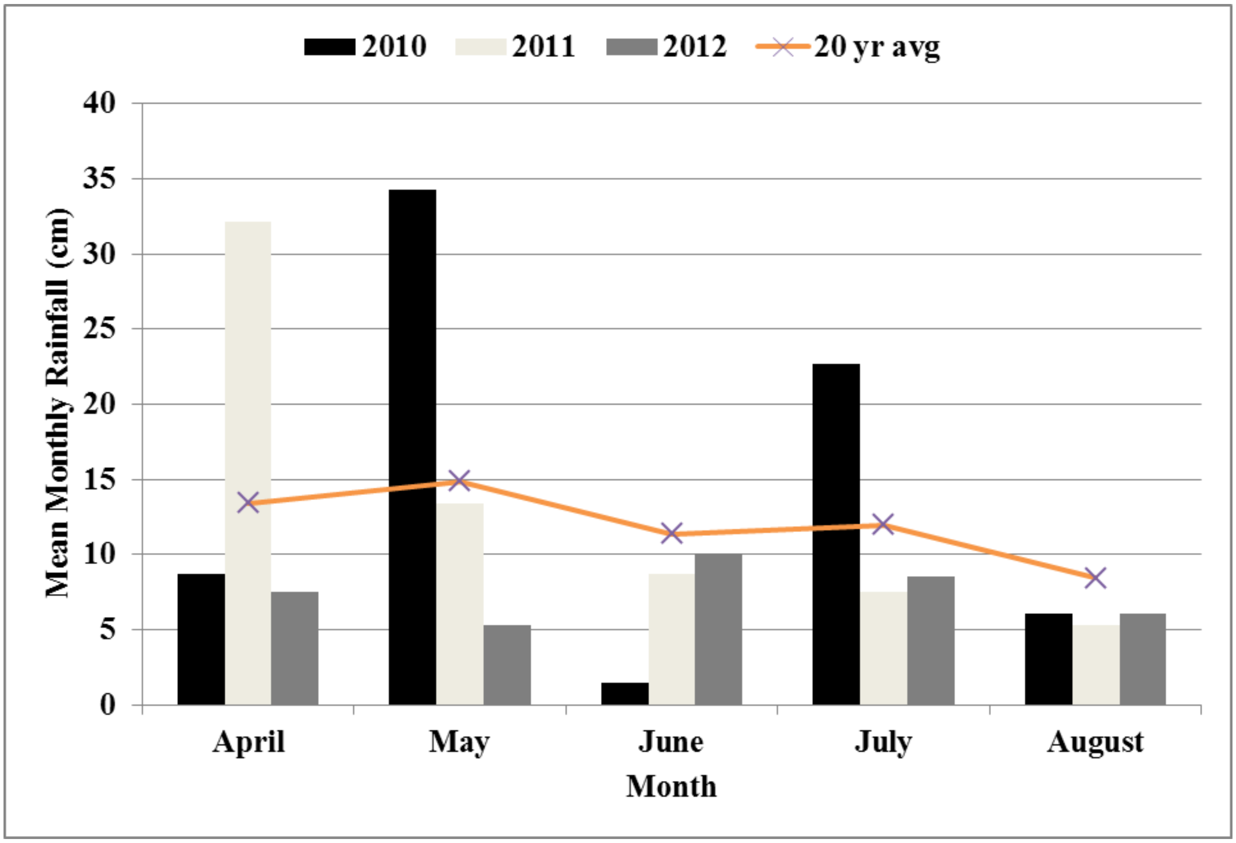

Figure 1. Average total monthly precipitation departure from 20-year mean for April-August of 2010, 2011, and 2012 at Research and Education Center at Ames plantation for Experiment 1. Recorded at Ames Plantation, Grand Junction, TN.

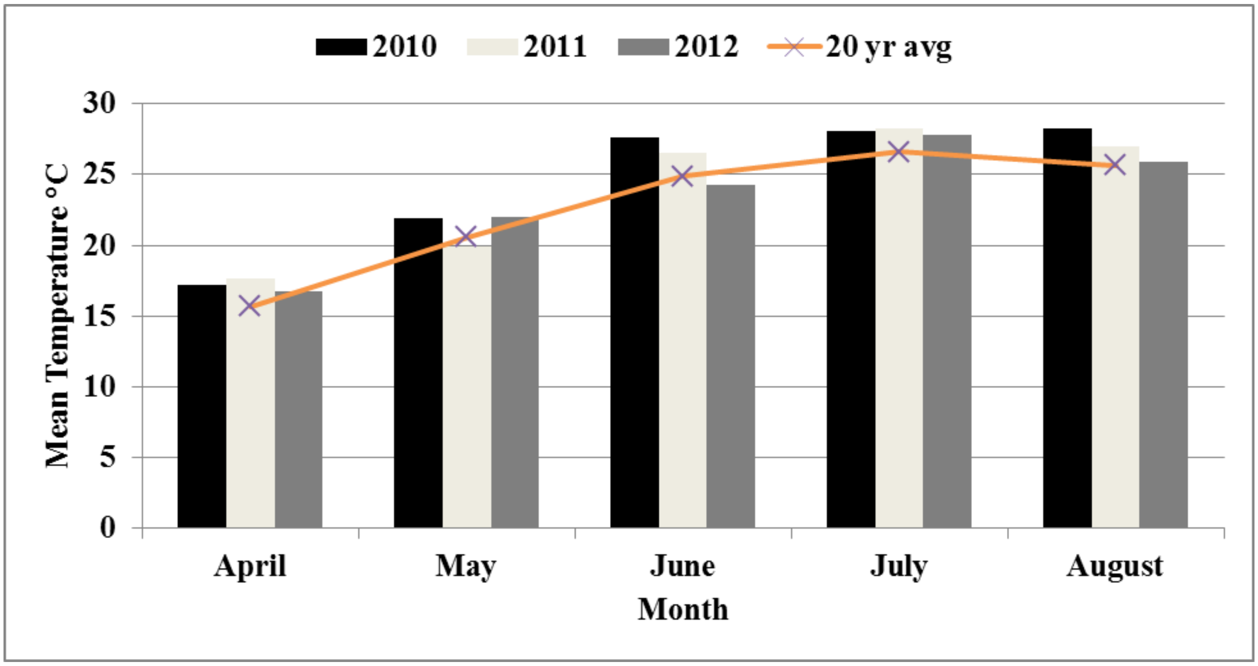

Figure 2. Average monthly temperature departure from 20-year mean for April-August of 2010, 2011, and 2012 at Research and Education Center at Ames plantation for Experiment 1. Recorded at Ames Plantation, Grand Junction, TN.

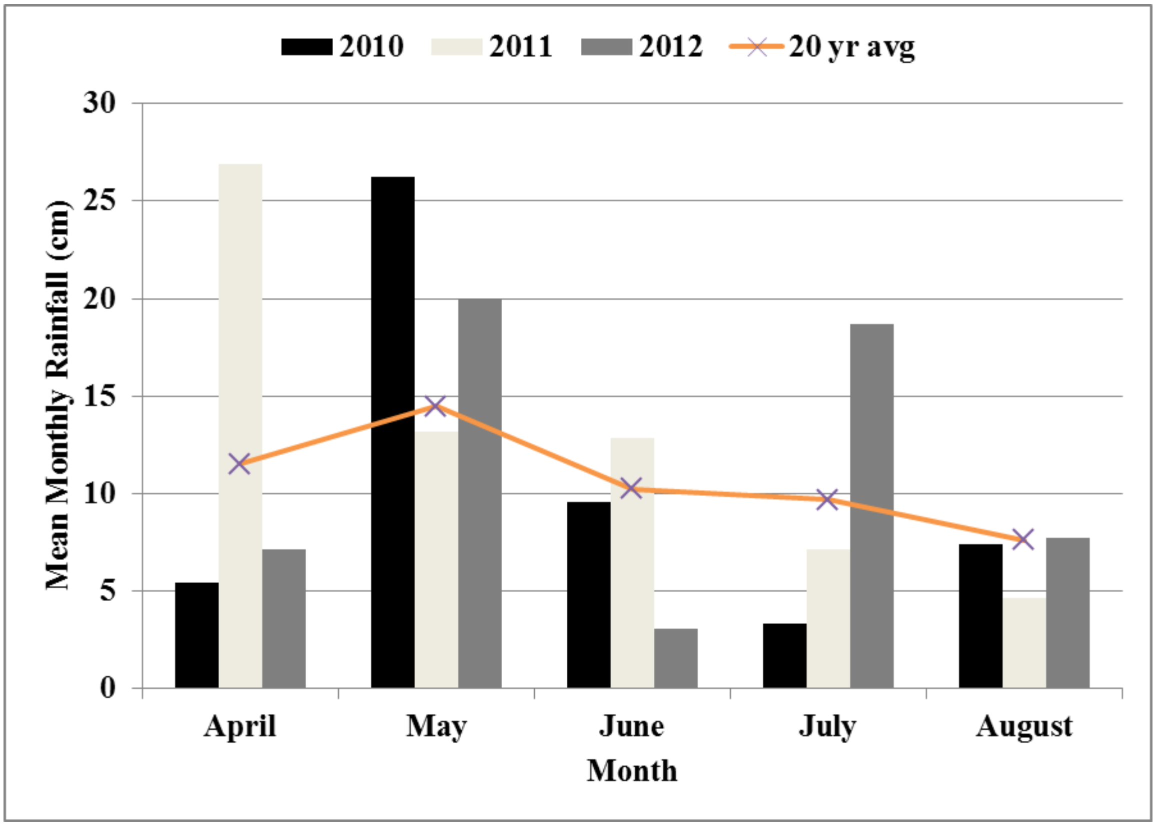

Figure 3. Average total monthly precipitation departure from 20-year mean for April-August of 2010, 2011, and 2012 at Highland Rim Research and Education Center for Experiment 2. Recorded at Springfield, TN.

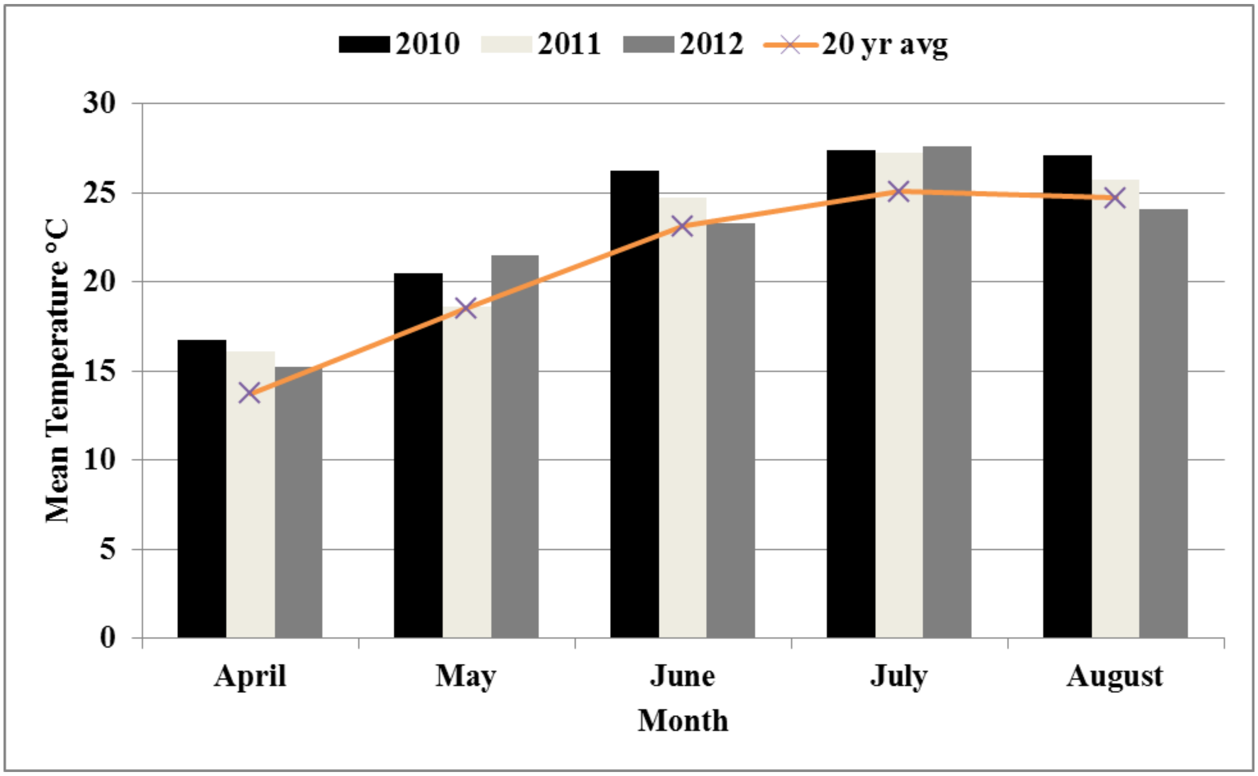

Figure 4. Average monthly temperature departure from 20-year mean for April-August of 2010, 2011, and 2012 at Highland Rim Research and Education Center for Experiment 2. Recorded at Springfield, TN.

VITA

Matt Backus was born in Maryville, Tennessee on May 20, 1985 to Mr. Landon and Dr. Cindy Backus. He earned his high school diploma from Alcoa High School in Alcoa, Tennessee in 2003. He then attended the University of Tennessee at Knoxville where he played football for the Volunteers for two years and earned his Bachelor of Science in Animal Science in 2007.

Following a year off, he started his master's degree in the spring of 2009. Dr. John Waller was his major professor. He received his Master of Science in Animal Science in December 2014.