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COPING WITH DROUGHT IN BEEF CATTLE PRODUCTION: INNOVATION THROUGH OPTIMAL WARM-SEASON FORAGE SYSTEMS

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I am submitting herewith a thesis written by Katelynn Elizabeth Zechiel entitled "COPING WITH DROUGHT IN BEEF CATTLE PRODUCTION: INNOVATION THROUGH OPTIMAL WARM-SEASON FORAGE SYSTEMS." 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.

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COPING WITH DROUGHT IN BEEF CATTLE PRODUCTION: INNOVATION THROUGH OPTIMAL WARM-SEASON FORAGE SYSTEMS

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ABSTRACT

Drought conditions have had detrimental effects on beef cattle production in the southeastern states where forages are the primary source of feed for livestock. Many southeastern states lie within the fescue-belt, where tall fescue is the predominant livestock forage. Tall fescue is a cool-season (CS) grass that thrives in the cooler temperatures of spring and fall, becoming semi-dormant during peak summer temperatures and again in winter. Conversely, warm-season (WS) forage species increase in production during the summer months and exhibit drought tolerant qualities, making them a viable summer forage option to complement tall fescue for beef cattle producers. The primary objective of this study is to evaluate various WS forage options and how they can help producers cope with drought. To accomplish this objective, a side-by-side comparison of five WS grasses were evaluated for production, nutrient density, and animal performance. The five WS grasses analyzed were: switchgrass (SW), eastern gamagrass (EG), big bluestem and Indiangrass mixture (BBI), bermudagrass (BG), and crabgrass (CG). This study was conducted over three years (2014, 2015, and 2016) at two locations: Ames Plantation Research and Education Center (APREC), and Highland Rim Research and Education Center (HRREC). To analyze animal performance, four heifers were placed on 1.2-ha paddocks with three replications per treatment. All test heifers were fed an equilibrium diet at the beginning and end of the grazing trial to help decrease variation in gut fill. The put-and-take method was used with additional heifers to help maintain targeted forage heights. Data was analyzed with SAS 9.4 (SAS Institute, Cary, N.C.) using the mixed model analysis of variance. When comparing the 5 species of forage, average daily gains (kg/day) were 0.62, 0.41, 0.44, 0.42, and 0.51, BBI, BG, CG, EG, and SW; respectively. Grazing days (days/ha) were 412, 459, 455, 664, and 617, BBI, BG, CG, EG, and SW; respectively. Total gain per ha (kg/ha) were 259, 186, 200, 276, and 315, BBI, BG, CG, EG,

and SW; respectively. Grazing WS grasses during the summer months can be a complementary tool to producers grazing cattle on CS grasses.

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ABBREVIATIONS AND SYMBOLS

ADF	Acid detergent fiber
ADG	Average daily gain
APREC	Ames Plantation UT AgResearch and Education Center
BCS	Body Condition Score
BBI	Big Bluestem and Indiangrass mixture
BG	Bermudagrass
Ca	Calcium
CG	Crabgrass
CP	Crude protein
CS	Cool-season grasses
DM	Dry matter
EG	Eastern Gamagrass
ha	Hectare
HRREC	Highland Rim AgResearch and Education Center
IVTDMD48h	In-vitro true dry matter digestibility 48 hour
K	Potassium
N	Nitrogen
NDF	Neutral detergent fiber
NIRS	Near-infrared spectroscopy
NWSG	Native warm-season grasses
SW	Switchgrass
P	Phosphorus
TDN	Total digestible nutrients
TLP	Tennessee Livestock Producers
WS	Warm-season grasses

CHAPTER 1.
INTRODUCTION

In 2012, over 80% of the United States experienced some level of drought (Adonizio et al., 2012). Roughly 67% of the cattle industry was affected by drought in 2012 (Countryman et al., 2016). A drought is a moisture deficit severe enough to have social, environmental, or economic effects (The National Drought Mitigation Center, 2017). Droughts are categorized into five levels based on severity (ranked 1 through 5, with 5 being most severe). Further information on drought classification can be seen at The National Drought Mitigation Center (2017). Much of the grain and forage being grown to feed cattle was also severely affected by the drought with 70-75% of corn and soybean production being raised under drought conditions, and 58% of pastures were in poor or very poor quality due to the drought (Rippey, 2015; Countryman et al., 2016). The drought-related decrease in crop yield increased the prices of feedstuffs for livestock. Increased input cost, combined with lack of available pasture, resulted in decreased profitability in the cow/calf and stocker sectors of the beef industry. Drought also impairs animal performance, depresses calving rate, results in herd reduction or liquidation, and damages pastures. This damage can result in long term negative effects for cattle producers; especially for forage-based cow/calf operations that rely primarily on pastures to support optimal reproductive efficiency.

According to USDA statistics (2012), Tennessee, Arkansas, and Kentucky (three states that rely on forage-based cattle production) had cattle inventories of 1.97, 1.72, and 2.15 million head of cattle; respectively. They were ranked 9th, 11th, and 8th in the United States for the amount of cattle produced (USDA, 2012). In 2007, the three states together produced a total of 1.6 billion dollars in income from cattle. The fescue-belt consists of 15 states, and accounted for 24% of the total beef cattle production in the United States in 2012 (USDA, 2012).

Tall fescue is a cool-season (CS) grass. Cool-season grasses become semi-dormant during summer months, which decreases both yield and quality. Cool-season grasses also tend to be poorly adapted to severe summer drought. While tall fescue is generally considered to be drought tolerant as compared to other CS forage species, it can still be damaged by severe drought during the summer grazing season. However, warm-season (WS) grasses may be a viable summer forage because their peak production is during summer months. With many summer forage options, it is important to analyze drought tolerance, productivity, and economics of these summer forage options to determine their value for integration into cattle grazing systems.

In 2012, the United States Department of Agriculture, Natural Resources Conservation Service, funded Conservation Innovation Grants to support demonstration of drought coping strategies for livestock. The work presented in this thesis was funded under those series of grants. The primary objective of this study was to evaluate the use of various WS forage options in southeastern beef cattle production to mitigate the negative effects of drought on productivity and profitability. To accomplish these objectives, a side-by-side evaluation of five WS grasses for forage production and cattle performance was conducted.

CHAPTER 2.
LITERATURE REVIEW

Approximately 14 million hectares (35 million acres) of tall fescue (*Festuca arundinacea*) are produced in the United States (Young, 2014). Most tall fescue pasture is grown in states located within the "fescue belt": the Mid-Southern region of the United States (Young, 2014). The state of Tennessee lies in the middle of the fescue belt.

Tennessee beef cattle producers predominately use forage grazing systems to feed their cattle, which can consist of CS and WS grasses. Species of grasses are deemed either CS or WS based on their growing season. Currently, the most commonly grazed grass in Tennessee is tall fescue. Tall fescue is a CS grass, exhibiting peak production between the months of March and June and again between September and November. It can be grazed during the less productive season of June through August. However, grazing tall fescue during the summer months can be problematic for cattle producers. One problem seen during the summer months while grazing cattle on tall fescue is fescue toxicosis, which is discussed later in this paper.

Drought

One issue often faced while grazing tall fescue in summer is its ability to cope with drought. Prolonged and severe droughts can cause long lasting damage to tall fescue pastures, leading to decreased revenue for the beef cattle industry. Prolonged lack of rainfall decreases the quantity and quality of forage produced, leading to limited nutrient availability for cattle. This lack of nutrients decreases cattle performance, through reduced weight gain, decreased birthweights of calves born to dams that were malnourished, and lower weaning weights because dams produce less milk (Smith et al., 2012).

Decreased calving rates are also experienced during drought. As body condition score (BCS) decreases, post-partum interval is lengthened (Smith et al., 2012). Limited nutrition, as a result of reduced forage production during drought, leads to difficulty for cows and heifers to become pregnant and maintain pregnancies that are established. Later in pregnancy, more still births are experienced for dams that were malnourished during their third trimester (Smith et al., 2012).

With the combination of decreased animal growth performance and calving rates, along with increased feed costs, cattle producers can experience impaired profitability during drought. For individual producers, this decrease in revenue can lead to liquidation of mature cows or complete exit from a cattle production enterprise.

Fescue Toxicosis

Tall fescue (*Lolium arundinaceum*) is a CS, perennial grass that is a desirable forage due to its persistence. However, animals consuming tall fescue that is infected with the endophytic fungus *Neotyphodium coenophialum* can experience fescue toxicosis. The endophytic fungus grows within the seed head and stem base of tall fescue, and produces ergot alkaloids. If consumed by cattle beyond a tolerable dose, these alkaloids cause symptoms of fescue toxicosis. As reviewed by Hemken et al. (1984), animals experiencing fescue toxicosis have shown a loss of appetite, a decrease in body weight, increased respiration rates, and tend to spend more time in the shade. In cattle, fescue toxicosis can also cause vasoconstriction, lameness, shaggy hair coat, and a decrease in reproductive efficiency. Smith (1975) reported a 72% pregnancy rate for cows grazing endophyte-infected tall fescue, whereas a 90% pregnancy rate was seen in cows grazing orchardgrass. Cows also experience a decrease in milk production (Karg and Schams, 1974), and a decrease in serum concentrations of prolactin (Schams et al., 1972) due to the ergot alkaloids.

Ergot alkaloids can also cause vasoconstriction of the arteries and veins, decreasing blood flow to the extremities. Decreased blood flow to the extremities can cause sloughing of the ear tips, tail switch, and hoof. Sloughing of the hoof is also known as “fescue foot,” and it can cause animals to become lame. Lastly, endophyte consumption can cause cattle to decrease dry matter intake (Hemken et al., 1981). Growing cattle grazing endophyte-infected tall fescue have reduced average daily gain (ADG) and decreased body weights (Drewnoski et al., 2009).

In conclusion, fescue toxicosis decreases cattle performance. Decreased cattle performance is observed as reduced ADG, decreased body weights, lameness, and/or decreased reproductive efficiency. Decreased cattle performance can result in major losses for cattle producers. Therefore, it is important for producers to watch for signs of fescue toxicosis while grazing tall fescue, or to use an alternative forage to eliminate fescue toxicosis.

Warm-Season versus Cool-Season Grasses

Relying on WS grasses (rather than CS grasses, like tall fescue) during the summer months can be beneficial to cattle producers. One benefit of WS grasses is a higher quantity of forage in the summer months as compared to tall fescue since tall fescue is a CS grass and it becomes semi-dormant during summer as temperature increases beyond its window of physiological tolerance. Tall fescue produces 60% of its total production by June 1st (Rountree et al., 1974) whereas native warm-season grass (NWSG) species produce approximately 70% of their total production from June 1st to September 1st (Rountree et al., 1974).

Warm-season forages also tend to be a better summer forage than CS because they have better coping abilities than CS when challenged with limited rainfall (Waller and Lewis, 1979). This is attributed to WS being C4 species and CS being C3 species. Warm-season and CS forages are labeled as C4 and C3 grasses to indicate the differences in their photosynthetic pathways. In order for photosynthesis to occur, the plant must take in carbon dioxide through its stomata. When the stomata are open, it allows carbon dioxide to enter the plant and water and oxygen to exit the plant. Warm-season C4 grasses have a more efficient Calvin cycle than CS grasses (Waller and Lewis, 1979). Therefore, a C4 plant does not need to consume as much carbon dioxide as C3 grasses to fuel the Calvin cycle. Requiring less carbon dioxide allows the stomata to remain closed for a longer period of time. If the stomata are closed, less water loss will occur. Warm-season grasses are more efficient in water use than CS grasses are in this process which allows them to be more competitive than CS during moisture stress (Waller and Lewis, 1979). Adding to NWSG drought tolerance is their deep root systems that can reach depths of 10 feet below ground level. This allows the plants to reach deep water sources that competing grasses might not be able to reach.

Understanding the superior performance of WS grasses, as compared to the CS grasses, during the summer months is a viable tool for cattle producers to make decisions about their best summer forage options. However, this is just one of the important variables to consider when choosing what type of WS is most ideal for summer grazing. Other important components include how well cattle perform on the forages and how well the forage species fits into the overall grazing management plan and business model. The following descriptions of WS grasses currently used in the fescue belt provide details that are important for determining their fit into various production systems.

Eastern Gamagrass

Eastern gamagrass (EG, *Tripsacum dactyloides*) is a perennial WS grass classified as a NWSG in Tennessee. It grows in a bunch formation and typically exhibits peak forage production from the middle of April to September. After seeding, it takes a year to establish before it can withstand grazing pressure. On average, EG produces between 7 to 14 megagrams per hectare (Mg/ha) dry matter (DM) (Aiken, 1997). When grazing EG, plant height should not fall lower than 20 centimeters (cm). A three-year study conducted by Backus and others (2017) reported ADG of 0.48 kg/day in steers grazing EG during the summer months.

Switchgrass

Switchgrass (SW, *Panicum virgatum*) is a perennial NWSG that grows as a bunch. Switchgrass is most productive from the end of April to September. Switchgrass also takes a year to establish before grazing and should not be grazed lower than 20 cm when used as pasture. Switchgrass produces between 9 to 11 Mg/ha of DM during its peak growing season (Barnhart et al., 2007). When grazing cattle on SG, Burns and others (1984) reported ADG from 0.96 to 1.07 kg/day. More recently, Backus et al. (2017) reported ADG of 0.85 kg/day for steers grazing Switchgrass.

Big Bluestem

Big Bluestem (*Andropogon gerardii*) is a perennial NWSG that also takes a year to withstand grazing pressure. It also grows in a bunch formation with peak production exhibited from the months of May through September. During big bluestem’s productive season it can produce on average 9 to 11 Mg/ha (Henning, 1993). When grazing big bluestem, plant height should not fall below 20 cm. A study conducted by Mitchell and others (2005) found an ADG of 1.22 kg/day when grazing cattle on big bluestem.

Indiangrass

Indiangrass (*Sorghastrum nutans*) is a bunch-forming species of grass that is most productive from mid-May to September. Indiangrass is a perennial NWSG season grass that takes a year to fully establish prior to grazing. It should not be grazed lower than 20 cm, and if managed properly, can produce between 9 to 11 Mg/ha. An ADG of 1.08 kg/day was observed when grazing beef cattle on Indiangrass (Krueger and Curtis, 1979). Indiangrass is often planted as a mixture with big bluestem in grazing pastures to mimic their natural tendency to grow together on native rangeland.

Bermudagrass

Bermudagrass (BG, *Cynodon dactylon*) is a WS perennial grass that grows as a sod, rather than the bunch formation NWSG form. Peak productivity is between the months of May and September, and takes a year after being seeded to become fully established. When managing BG pastures, it should not be grazed below 8 cm. On average, BG can produce 11 to 14 Mg/ha (Hansen et al., 2000). A six-year study in North Carolina found an ADG of 0.49 kg/day when grazing steers on BG (Burns and Fisher, 2013).

Crabgrass

Crabgrass (CG, *Digitaria sanguinalis*) is an annual WS species of grass. It grows in a creeping formation, and is most productive between the months of May through September. Since CG is an annual grass, it takes only 30-45 days from seeding until it can sustain grazing pressure. Crabgrass produces 5 to 6 Mg/ha DM during summer months (UTBFC Research Report, 2016). Crabgrass should be kept taller than 8 cm when it is being grazed. A study conducted in Northern Florida reported 0.50 to 0.86 kg/day gain for stocker cattle grazing CG (Blount et al., 2003).

Forage Quality

Animal performance on a forage-based diet is heavily dependent on forage nutritive value and abundance. Forage nutritive value and availability is defined as forage quality (Newman et al., 2015). Forage quality can be measured by nutrient density, energy, protein, digestibility, fiber, mineral, vitamins, and animal performance (Newman et al., 2015). Nutritive value is often considered synonymous to forage quality. However, nutritive value measures the total digestible nutrients (TDN) and the concentration of crude protein (CP) in the forage, but does not take into consideration forage intake.

As forages mature, quality declines. This occurs because the forage becomes more fibrous, which decreases intake (Ball et al., 2001). Forage quality declines as forages mature because the leaf-to-stem ratio shifts. Leaves are higher quality than stems, and the proportion of leaves decline as the forage matures. Grazing forages in early growth delivers the highest nutritive value but also produces the lowest yields. As a forage matures, yield increases while nutritive value decreases (Backus et al., 2017). Finding an appropriate balance between yield and nutritive value results in both ample quality and practical yields.

Since forage quality plays an important role in animal performance in a grazing program, it is beneficial in production management to conduct commercial laboratory analysis to determine forage quality for the purpose of designing supplemental feeding strategies. Common measurements in commercial forage analyses include: dry matter, CP, neutral detergent fiber (NDF), and acid detergent fiber (ADF; Ball et al., 2001). Dry matter measures the proportion of forage that is not water (Ball et al., 2001). This allows a measurement of the nutrients in the forage without the dilution effect of water (Ball et al., 2001).

Protein is an important nutrient for livestock production. It is commonly measured as CP, which is calculated by multiplying nitrogen (N) content by 6.25 (Ball et al., 2001). Forage fiber content is expressed as NDF and ADF. Neutral detergent fiber is the fibrous portion of the plant that is either slowly digested or indigestible (Ball et al., 2001). Neutral detergent fiber indicates how much forage an animal can consume; intake decreases as NDF increases in a forage. However, without an adequate level of NDF, health problems such as acidosis, displaced abomasums, and foundering occur more frequently (Ball et al., 2001). Acid detergent fiber indicates forage digestibility (Ball et al., 2001). Forages decrease in digestibility when ADF increases. Analyzing forage quality enables targeted ration formulation and supplemental feeding strategies.

Heifer Development

Replacement heifer development is one of the most costly investments in a cow-calf operation. One of the primary objectives for a successful heifer development program is the achievement of puberty prior to the first breeding season. Heifers that reach puberty early in relation to the beginning of the breeding season are more fertile (Byerley et al., 1987). Puberty is characterized as the first expression of behavioral estrus and ovulation of a fertile oocyte (Olson and Hollis, 2007). Factors affecting attainment of puberty in heifers include: genetics, age, and nutrition. Nutrition is important in heifer development as it affects rate of gain and overall body condition. Generally, heifers should reach 60% to 65% of their mature body weight before the time of breeding (Short and Bellows, 1971).

Calving heifers for the first time as two-year-olds requires breeding them at 13 to 15 months of age. If a heifer is projected to weigh 544 kg as a mature cow, the target weight approach to nutritional development requires them to reach 327 to 354 kg prior to initiation of the first breeding season. After determining target breeding weight, the number of days between weaning and breeding can be used to calculate ADG required to reach the target breeding weight.

Depending on genetic limitations, if a heifer is undernourished between weaning and breeding, puberty can be delayed. If a heifer reaches puberty and then becomes malnourished, it can cause a return to anestrus (Olson and Hollis, 2007). Reproduction can also be negatively affected when heifers greatly exceed the target weight with excessive fat deposition. Lower conception rates have been reported for heifers above body condition score 6 (Olson and Hollis, 2007). Excessive fat accumulation in mammary tissue can reduce milk production as a mature cow, decreasing lifetime productivity as measured by calf weaning weights. Feeding a forage-based diet with supplementation based on forage analysis is a viable option for achieving a target weight for developing heifers.

Conclusion

Grazing WS grasses during the summer months can help decrease effects of drought and fescue toxicosis. Knowing the forage quality of these WS grasses would be a helpful tool for producers to choose which WS grass best fits their operation. This decision would be extremely important to producers who choose to develop heifers since nutrition is a limiting factor for successful development of both fall- and spring-born heifers.

CHAPTER 3.
MATERIALS AND METHODS

This study was conducted with heifers grazing WS in two locations during the summers of 2014, 2015, and 2016. At Ames Plantation UT AgResearch and Education Center (APREC), located near Grand Junction, Tennessee (35°6’N, 89°13’W), Angus and Angus-cross fall-born heifers weighing an average of 237 kg (227, 243, and 240 kg for 2014, 2015, and 2016; respectively) at initiation of the grazing season grazed EG (*Pete*), SW (*Alamo*), big bluestem (*OZ 70*) and Indiangrass (*Rumsey*) mixture (BBI), BG (*Cheyenne II*), or CG (*Red River*). Eastern gamagrass, BBI, and SW are native to North America and are categorized as NWSG. Heifers grazed NWSG at APREC on average 94 days from May 9^{th} to August 11^{th} (May 13^{th} to August 4^{th}, May 8^{th} to August 17^{th}, and May 6^{th} to August 12^{th} for 2014, 2015, and 2016; respectively). Heifers grazed BG and CG at APREC on average 72 days from June 5^{th} to August 16th (June 6th to August 18^{th}, June 5th to August 17th, June 3rd to August 12^{th} for 2014, 2015, and 2016; respectively).

At the Highland Rim UT AgResearch and Education Center (HRREC), located near Springfield, Tennessee (36°28’N, 86°50’W). Fall-born dairy-beef cross heifers were utilized at HRREC in 2014. In 2015 and 2016, predominantly black-hided British and British-Continental cross fall born heifers (with no visible *Bos indicus* influence) grazed SW (*Alamo*), big bluestem (*OZ 70*) and Indiangrass (*Rumsey*) mixture (BBI), BG (*Cheyenne II*), or CG (*Red River*). Unlike APREC, HRREC did not include EG pastures. Grazing of the NWSG on average 101 days from May 14^{th} to August 23^{rd} (May 16^{th} to August 8^{th}, May 15th to August 31^{st}, May 12^{th} to August 29^{th} for 2014, 2015, and 2016; respectively). Bermudagrass was not grazed at HRREC in 2014 due to limited establishment from winter kill. Grazing BG and CG on average 70 days from June 14^{th} to

August 23rd (June 20th to August 8th, June 12th to August 31st, and June 9th to August 31st for 2014, 2015, and 2016; respectively). Tennessee Livestock Producers (TLP) (a service arm of the Tennessee Farm Bureau Federation; Columbia, Tennessee) provided weaned heifers grazed at HRREC. Heifers received from TLP were backgrounded for at least 45 days to mitigate shipping stress, and illness during the study. Heifer starting weights averaged 242 kg (202, 274, and 249 kg for 2014, 2015, and 2016; respectively).

Native warm-season grasses were established in 2008 at both locations as described by Backus et al., 2017. Briefly, EG, SG, BG, and CG were planted as pure stands individually into individual pastures. Big Bluestem and Indiangrass was the only blended grass mixture planted for this study. The ratio of this mixture planted into each pasture was 65% big bluestem and 35% Indiangrass seeded by weight. Each species or mixture was planted in three replicated 1.2-ha paddocks. This resulted in a total of 15 (5 species/mixture with 3 replications) test paddocks at APREC, and 12 (4 species/mixture with 3 replications) paddocks at HRREC.

Bermudagrass was seeded in May 2013 at both locations. However, due to winter-kill, BG was re-established at HRREC in 2014. Crabgrass was seeded yearly at both locations. Bermudagrass and CG were planted in a prepared seedbed at both locations. The soil was disked then cultipacked before planting the seed. Bermudagrass was planted at a rate of 10 pure live seed kilogram per hectare (kg/ha), and CG was planted at a rate of 7 pure live seed kg/ha.

All pastures received 67 kg/ha of nitrogen (N) following green-up, and phosphorus (P) and potassium (K) levels were adjusted according to soil test to maintain a medium level of nutrients. Soil test results led to addition of 67 kg/ha of P to indicated pastures at APREC (no additional K was required). Pastures at HRREC required addition of P ranging from 33 to 67 kg/ha and 67 to 135 kg/ha of K. Crabgrass pastures at HRREC received 33 kg/ha of P every year.

Nitrogen fertilization was maintained at a constant level across all grasses rather than following established best management practices for each species. This approach was taken to accurately address the mitigation of negative effects during drought by evaluating their productivity under a single management protocol that was standardized to the N requirements of WS grasses. Application of N during drought conditions does not result in effective utilization, and therefore, is not utilized in normal management situations.

Both APREC and HRREC recorded daily weather data, including air temperatures and amount of rainfall. Average temperature for the 2014 grazing season was 24°C (21, 25, 24, and 25°C, May, June, July, and August; respectively). Average temperature for the 2015 grazing season was 25°C (21, 25, 27, and 25°C, May, June, July, and August; respectively). Average temperature for the 2016 grazing season was 25°C (20, 26, 28, and 28°C, May, June, July, and August; respectively) (Figure 1). Average rainfall for the 2014 grazing season was 11 cm (6, 22, 17, and 0 cm, May, June, July, and August; respectively). Average rainfall for the 2015 grazing season was 12 cm (10, 18, 13, and 8 cm, May, June, July, and August; respectively). Average rainfall for the 2016 grazing season was 10 cm (13, 6, 18, and 5 cm, May, June, July, and August; respectively) (Figure 2). Twenty year average temperatures and rainfall for both locations are reported by Backus et al., 2017.

Data Collection

Forage samples were taken at the initiation of grazing and every 28 days following until grazing was concluded. Ten 0.25-m^2 plots were sampled randomly throughout each paddock. At each sample site, the forage height was measured and then clipped with a battery operated hedge trimmer at designated heights depending on species. Sampling heights were assigned based on the grasses growth characteristics with the intention of measuring response variables in plant tissue that would be within the actual grazing horizon. Native warm-season grasses are taller species while BG and CG are naturally shorter. In NWSG paddocks, (EG, SW, and BBI) forage samples were collected and processed in two separate sections for each sampling site; 40.64 cm and above (upper horizon) followed by a clipping at 20.32 cm (lower horizon) to collect plant tissue between there and the previous clipping height (Figure 3). These areas of sampling between different heights of growth will be referred to as sample horizons. Forage collected from the ten sample sites within a pasture were placed into a forage collection bag based on sample horizon. Multiple bags per sample horizon were often required during peak forage production. For BG and CG pastures, forage samples were collected from a single horizon (above 5.08 cm) and placed into forage bags.

Pasture samples were dried in the net forage bags at 55°C for 72 hours. After drying, sample bag weights (minus bag weight) were recorded in grams to estimate dry matter (DM) availability and forage production. Total forage DM availability was estimated using the total weight of forage collected per paddock. Grab samples were taken from each forage bag and ground through a Wiley Mill with a 1 mm screen. Ground samples were analyzed, using Near-Infrared Spectroscopy technology (FOSS 5000, FOSS NIRSystems, Inc.), for CP, NDF, ADF, and In-vitro true dry matter digestibility 48 hour (IVTDMD48h).

Animal performance data were collected from four weanling heifers (testers; described above for each location) in each pasture. Testers were randomly allotted to pastures by weight from the middle one third of the weight range of available animals. Prior to the initiation of grazing, testers were fed an equilibration ration for four consecutive days to decrease initial body weight (BW) variability from variation in gut fill as described by Backus et al., 2017. Briefly, the equilibration ration was composed of cottonseed hulls, soyhulls, citrus pulp, dried distillers grains, and molasses and contained 12.9% CP and 27.2% crude fiber. Heifers were fed the equilibration diet at 2.25% of body weight on d-4, d-3, d-2, and d-1. On the fourth day (d-1) of feeding the equilibration diet, heifers were fed and weighed in the morning. On the morning of d 0, heifers were weighed, but not fed, and turned out on their previously assigned paddocks. Starting BW is considered as the average of d-1 and d 0. Tester BW was recorded every 28 days throughout the grazing period. At termination of grazing for each species, heifers were again fed the equilibration diet and ending BW was assessed with the same protocol described for initiation of grazing. Animal-related response variables were ADG, average stocking rate, and total grazing days.

Canopy height of the forages were managed by using the put-and-take grazing method. Briefly, four testers remained on their assigned paddock throughout the grazing period. To maintain target grazing heights, additional heifers were added and removed (based on forage height) when BW measurements were taken after each sample collection. Target heights for the NWSG were 60 cm to 76 cm for SW, 40 cm to 46 cm for BBI, and 45 cm to 60 cm for EG. Bermudagrass and CG target height was 7 cm to 20 cm. Extra heifers were removed once forage height neared the lower range limit. Heifer care and management was conducted under UTK-IACUC Protocol No. 2258-0414 approved on April 14, 2014 by the Institutional Animal Care and Use Committee.

Statistical Analysis

Data were statistically analyzed using SAS 9.4 (SAS Institute, Cary, N.C.) using mixed models. Experiment was conducted as a randomized complete block design, except EG was only used at one location, resulting in an incomplete block analysis. Experimental unit was the 1.2-ha paddock. Fixed effects were species (BBI, SW, EG, BG, and CG) and period as repeated measures over May, June, July, and August, and the interactions for response variables ADG, grazing days, stocking rate, total gain, and forage nutrients (CP, NDF, ADF, and IVTDMDh). Random effects were location, year, and the pasture whole plot error term for species. Breed of animal differed at Highland Rim in 2014, but since year and location were blocking factors, breed effects were automatically accounted for due to confounding with blocks. Means were separated using Fisher's Least Significant Differences ($P < 0.05$).

CHAPTER 4.
RESULTS

Forage Performance

Season-long

Forage nutrient content of samples from upper horizons (above 40.64 cm) of NWSG were compared to single-height samples from BG and CG to evaluate forage performance when grazed at targeted heights. All forage nutritive values (CP, NDF, ADF, and IVTDMD48h) are reported on a dry matter basis. Crabgrass had greater ($P < 0.001$) CP than SW and BG (Figure 4). No differences were found in NDF content among SW, EG, and BBI, however they contained higher concentrations ($P < 0.001$) of NDF than BG and CG (Figure 4). Acid detergent fiber concentration was greater ($P < 0.001$) in EG and BBI compared to the other species (Figure 4). Crabgrass had a greater ($P < 0.001$) IVTDMD48h than BBI, SW, and EG, but was similar to BG (Figure 4).

Along with nutrient composition, forage heights, and total forage mass were measured to evaluate relative forage performance. Of the NWSG, SW had greater ($P < 0.001$) forage height than BBI and EG (Figure 5). No differences were found between BG and CG when comparing forage height (Figure 5). Switchgrass and CG produced more ($P < 0.001$) forage DM, with BBI and EG having the least forage DM (Figure 6).

Season-long for NWSG Horizons

Each paddock of SW, EG, and BBI, were sampled at two separate heights, collected at 40.64 cm and above, and between 20.32 cm and 40.64 cm. Forage nutrients were analyzed in the upper horizon (above 40.64 cm) and lower horizon (between 20.32 cm and 40.64 cm) and compared across species. Crude protein content was greater (*P* < 0.001) in the upper horizon for BBI and SW compared to the lower horizon (Table 1). No differences were seen in NDF content between horizons for BBI, SW, and EG (Table 1). Acid detergent fiber content was greater (*P* < 0.001) in the lower horizon for BBI and SW (Table 1). Switchgrass had greater (*P* < 0.05) IVTDMD48h in the upper horizon compared to the lower horizon. Big bluestem and Indiangrass showed no differences in IVTDMD48h between horizons (Table 1). No differences were seen in CP, NDF, ADF, and IVTDMD48h content amongst horizons in EG (Table 1).

Monthly Forage Performance for NWSG Horizons

Crude protein was higher (*P* < 0.05) in the upper horizon, compared to the lower horizon, in BBI for the months of May, June, and July, but no differences were detected between horizons in August (Table 2). Crude protein was also higher (*P* < 0.05) in the upper horizon compared to the lower horizon for EG in the month of May (Table 2). Switchgrass had higher (*P* < 0.05) CP content in the upper horizon for May and June. Neutral detergent fiber content was greater (*P* < 0.05) in the lower horizon for SW in the month of May and June when compared to the upper horizon (Table 2). No differences were observed over the total grazing season for NDF content in the 2 horizons for EG and BBI. No differences (P = 0.1196) were observed in ADF content between horizons for SW, EG, and BBI (Table 2). Big Bluestem and Indiangrass showed no differences in IVTDMD48h between horizons for the months of May, June, and August. However, the upper horizon had greater (*P* < 0.05) IVTDMD48h than the lower horizon in July. Eastern gamagrass showed no differences in IVTDMD48h between horizons (Table 2). Switchgrass had a greater (*P* < 0.05) IVTDMD48h in the upper horizon for May and June but showed no differences in horizons for July and August (Table 2).

Monthly Forage Performance Comparison Among Species

Forage nutrients were analyzed by month for each species. When analyzing CP for the month of May, EG had greater ($P < 0.05$) CP content than SW, and BBI was similar to EG and SW (Figure 7). Forage nutrients were not analyzed for BG and CG in May, because they were not grazed in the month of May. In June, CG had the greatest ($P < 0.05$) CP compared to the other species. Eastern gamagrass had the greatest CP ($P < 0.05$) content in July and August with CG being similar. When analyzing NDF content in the forages, no differences were seen between BBI, EG, and SW for the month of May (Figure 8). Eastern gamagrass had the highest ($P < 0.05$) amount of NDF in June (Figure 8). No differences were reported in NDF content of SW, BBI, and EG for the month of July, but they had significantly greater NDF ($P < 0.05$) content than BG and CG (Figure 8). Similar results were observed for the month of August with the exception of EG having similarities to BG and CG. In May, BBI had greater ($P < 0.05$) ADF content than SW, with EG being similar to both (Figure 9). No differences were reported in ADF content of SW, BBI, and EG for the months of June, July, and August but they had significantly greater ADF ($P < 0.05$) content than BG and CG (Figure 9). When analyzing IVTDMD48h, BBI had greater ($P < 0.05$) IVTDMD48h than EG (Figure 10). CG had the greatest ($P < 0.05$) IVTDMD48h in June, with EG having the least IVTDMD48h (Figure 10). Crabgrass and BG had similar but higher ($P < 0.05$) IVTDMD48h for the month of July. In August, CG ($P < 0.05$) had the highest IVTDMD48h with BG being similar to CG. Forage heights were analyzed monthly to monitor if target grazing heights were maintained. Comparison of monthly forage heights are reported in Figure 11. When analyzing forage mass (Mg/ha of dry matter), no differences were seen between BBI, EG, and SW for the month of May (Figure 12). Crabgrass had the greatest ($P < 0.001$) forage mass in June. Eastern gamagrass had the lowest ($P < 0.001$)

forage mass in July, but no differences were observed between SW, BG, CG, and BBI. Lastly, in August, SW had the greatest ($P < 0.001$) forage mass compared to the other species (Figure 12).

Monthly Forage Performance by Species

Crude protein content of BBI, EG, and SW was greatest ($P < 0.001$) in May compared to the other months (Figure 7). Bermudagrass and CG showed the highest ($P < 0.001$) CP content in June, followed by July and August (Figure 7). Switchgrass, BBI, BG, and CG had the highest ($P < 0.001$) NDF content in August and July (Figure 8). Eastern gamagrass had higher levels of NDF in June and July, with the least ($P < 0.001$) amount of NDF in May. Acid detergent fiber content was lowest ($P < 0.001$) in May for BBI, EG, and SW. Bermudagrass and CG had the lowest ($P < 0.001$) levels of ADF in June compared to the other months (Figure 9). Big Bluestem and Indiangrass, EG, and SW showed highest ($P < 0.001$) IVTDMD48h in May compared to the other months (Figure 10). Bermudagrass and CG showed a linear decline in IVTDMD48h with the greatest ($P < 0.001$) being in June and least in August (Figure 10). When comparing forage mass BBI, EG, and SW all showed a higher ($P < 0.001$) forage mass content in May, with June being similar to May for BBI and EG (Figure 12). Crabgrass showed a steady decline in forage mass, with June having the largest ($P < 0.001$) forage mass and August having the lowest. No differences were seen in BG forage mass over the grazing season (Figure 12).

Animal Performance

Season-Long

One variable measured for animal performance was ADG. When comparing the 5 species of forage, BBI showed the greatest ($P < 0.001$) ADG compared to the other species (Figure 13). Total amount of days that the forage was grazed by the testers and grazers were also measured and analyzed. Switchgrass and EG had the greatest ($P < 0.001$) amount of days supporting grazing of the animals (Figure 14). Total gain per ha was analyzed by calculating total ADG multiplied by total amount of grazing days then divided by total ha (1.2-ha) of the test paddock. Switchgrass had the greatest ($P < 0.001$) amount of gain per ha followed by EG (similar to both SW and BBI), then BBI (Figure 15). Bermudagrass and CG had the least ($P < 0.001$) amount of gain per ha. Lastly, the average stocking rate was similar for SW, EG, BG, and CG. However, BBI had a significantly lower ($P < 0.001$) stocking rate compared to the other species (Figure 16).

Monthly Animal Performance Comparison Among Species

Switchgrass and EG had the greatest ($P < 0.001$) amount of grazing days in May and June compared to the other species (Figure 17). Crabgrass and BG had the greatest ($P < 0.001$) amount of grazing days in July (Figure 17). Crabgrass and BG also had greater ($P < 0.001$) grazing days in August, with SW being similar to CG. When analyzing stocking rate for May, EG and SW had the greatest ($P < 0.001$) stocking rate with BBI having the lowest stocking rate (Figure 18). In June, BBI also had the lowest ($P < 0.001$) stocking rates. Bermudagrass had similar stocking rates as EG and SW in June. Crabgrass and BG had the highest ($P < 0.001$) stocking rate for July (Figure 18). Bermudagrass showed the greatest ($P < 0.001$) stocking rate for August compared to the other species (Figure 18).

Monthly Animal Performance by Species

For BBI, EG, and SW, total amount of grazing days per ha were the highest ($P < 0.001$) in May and June (Figure 17). Grazing days significantly decreased in July and in August. Bermudagrass had the greatest ($P < 0.001$) amount of grazing days in July followed by June then

August. Crabgrass had the highest ($P < 0.001$) amount of grazing days in June and July and a significant decrease was observed in August (Figure 17). No differences in stocking rate were found for BG between the 3 months. Crabgrass showed a steady decline in stocking rates from June to August, with June having the highest ($P < 0.001$) stocking rate and August having the lowest stocking rate (Figure 18). Switchgrass, BBI, and EG had the highest ($P < 0.001$) stocking rate in May, followed by June.

CHAPTER 5.
CONCLUSIONS AND DISCUSSION

Backus and others (2017) studied grazing beef steers on BBI, SW, and EG at the APREC and HRREC locations used in the current study. While the current methods resulted in ADG (kg/day) of 0.62, 0.51, and 0.42, for BBI, SW, and EG; respectively. Backus et al. (2017) reported ADG (kg/day) of 0.82 to 0.96, 0.56 to 0.79, and 0.48, for BBI, SW, and EG; respectively. Burns and Fisher (2013) reported ADG (kg/day) of 0.85, 0.70, and 0.67, for big bluestem, SW, and EG; respectively, when grazing steers. Average daily gains of the NWSG are numerically lower in the current study compared to that reported previously (Backus et al., 2017; Burns and Fisher, 2013). Variation in target grazing height management in the current study should be considered when comparing findings from previous research. Also, differences in animal type (steers vs. heifers) and natural year-to-year variation would add to variation between studies. Burns and Fisher (2013) also used greater amounts of N fertilization, which could explain apparent differences in reported ADG. In this study, ADG for BG was 0.41 kg, which was lower than, but within reasonable variation of, previously reported ADG (kg/day) of 0.49, 0.51 to 0.55, and 0.55 to 0.63 (Burns and Fisher, 2013; Scaglia and Boland, 2014; DeRouen and Ward, 2005; respectively). Average daily gain on CG has been reported to range between 0.50 and 0.86 kg/day (Blount et al., 2003; Teutsch et al., 2007). The current study reported a slightly lower overall ADG of 0.44 kg/day, likely because heifers were used in this study. Differences in forage maturity, stocking rate, total grazing days, and N application are other contributing factors that could explain differences in previously reported ADG and those reported here.

Total grazing days per ha of 412, 664, 617, 459, and 455 for BBI, EG, SW, BG, and CG, respectively, were reported here. Burns and Fisher (2013) reported similar total grazing days supported by big bluestem, EG, and SW compared to this study. However, they reported more grazing days for BG than reported here, which could have been caused by the difference in stocking rates. Backus et al. (2017) reported fewer total grazing days, which could be due to differences in stocking rates, and the amount of days cattle were grazed. Limited data has been reported for cattle grazing CG. Total gains (kg/ha) in this study were reported as 259, 276, 315, 186, and 200 for BBI, EG, SW, BG, and CG; respectively. Comparable gains per ha were reported by Backus et al. (2017), Burns and Fisher (2013), and Scaglia and Boland (2014). Differences among total gains per ha could be attributed to differences in stocking rates, total grazing days, average daily gain, and amount of N used for fertilization.

Forage nutrient and digestibility reported here was consistent with that found in previous literature. When comparing forage nutrients, NDF and ADF content tended to increase over the grazing season, while IVTDMD48h and CP content generally decreased (Backus et al., 2017). A similar trend was observed in this study for all 5 WS species. In this study, it is also noted that the NWSG species had higher NDF and ADF content than CG and BG. Crude protein (% DM; 10.66, 9.41, 11.54, 11.48, and 10.27 for BBI, BG, CG, EG, SW; respectively). Comparable CP (% DM) content was reported by Burns and Fisher (2013) of 9.0, 13.4, 11.6, and 10.3 for big bluestem, BG, EG, SW, respectively. Crabgrass CP (% DM) content has also been reported as 10.6 to 14.1 and 15.0 (Beck et al., 2007; Teutsch et al., 2007). Neutral detergent fiber (% DM) content reported here was 66.36, 61.54, 60.06, 67.92, and 68.03 for BBI, BG, CG, EG, and SW; respectively. Acid detergent fiber content (% DM) was 41.09, 37.88, 38.80, 41.68, and 39.16 for BBI, BG, CG, EG, and SW; respectively. Similar NDF and ADF content was reported previously (Backus et al., 2017; Burns and Fisher, 2013; Beck et al., 2007; Scaglia and Boland, 2014). In-vitro true dry matter digestibility 48 hour (% DM) was 66.92, 68.04, 70.79, 63.43, and 65.89 for

BBI, BG, CG, EG, and SW; respectively. Backus et al. (2017) reported IVTDMD48h (% DM) as 68.6 to 65.7, 63.7 to 60.3, and 59.8 for BBI, SW, and EG; respectively. Differences seen among forage nutrients can be due to plant maturity, levels of N applied, and plant tissue collected.

In summary, comparison of all forage species performance did not reveal a single option that was clearly the most optimal forage to graze cattle under these conditions and management. However, each species could be successfully included in pasture allocation for use during the summer months, depending on specific needs and objectives of the user. Big bluestem and Indiangrass exhibited higher ADG compared to the other species. However, BBI had the lowest season average stocking rate. Bermudagrass had a higher stocking rate than BBI, but BG had relatively low ADG. Crabgrass followed a performance pattern similar to BG. Eastern gamagrass and SW provided the most grazing days and with relatively high stocking rates. However, season-long ADG was less than BBI. It is important to recognize that the NWSG used in this study had been previously established and experience had been gained by research technicians for proper grazing management of them. When considering the most appropriate forage species for mitigating drought, and increasing productivity of summer grazing in non-drought years, differences in forage establishment should also be considered. A good example of such differences is the time required for establishing a perennial (BBI, BG, EG, and SW) verses an annual forage species (CG). Perennial species take over a year to establish before they can be grazed while an annual can be grazed the same year it is planted. On the other hand, annual species have to be planted each year, adding more long-term cost and repeated risk of stand failure.

Warm-season forages can be an effective complementary forage to CS forages during the summer months. Choosing the most appropriate summer forage depends on local environmental constraints, management style, and production goals in each grazing operation. Factors to consider include stocking rate, ADG, total gain per unit of land resource, establishment time before grazing, and management style. Since a WS species did not clearly outperform the others in all aspects in this and other trials, it is important for cattle producers to choose the most appropriate forage for their specific management and goals.

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APPENDICES

APPENDIX A

TABLES

Table 1. Average forage nutrients over the years 2014, 2015, and 2016.

Species	Horizon	CP	NDF	ADF	IVTDMD48h
BBI	**Lower**	$9.2^{BC} \pm 1.14$	$67.4^{BC} \pm 1.91$	$43.5^{A} \pm 1.72$	$65.4^{AB} \pm 1.73$
	Upper	$10.6^{A} \pm 1.15$	$66.3^{C} \pm 1.95$	$41.1^{B} \pm 1.76$	$66.8^{A} \pm 1.80$
EG	**Lower**	$10.2^{AB} \pm 1.21$	$69.2^{AB} \pm 2.07$	$42.4^{AB} \pm 1.84$	$61.8^{C} \pm 2.03$
	Upper	$11.4^{A} \pm 1.23$	$68.1^{ABC} \pm 2.10$	$41.8^{AB} \pm 1.87$	$62.9^{BC} \pm 2.08$
SW	**Lower**	$8.4^{C} \pm 1.14$	$69.9^{A} \pm 1.91$	$41.9^{AB} \pm 1.72$	$62.3^{C} \pm 1.73$
	Upper	$10.2^{AB} \pm 1.15$	$68.1^{ABC} \pm 1.94$	$39.1^{C} \pm 1.74$	$65.7^{AB} \pm 1.77$

Averages of season-long (May through August) forage quality variables (expressed on dry matter basis) by horizon for big bluestem and Indiangrass (BBI), eastern gamagrass (EG), and switchgrass (SW) across three years. Crude protein (CP); Neutral detergent fiber (NDF); Acid detergent fiber (ADF); In-vitro true dry matter digestibility 48 hour (IVTDMD48h). Lower horizon sample was taken at 20.32 cm, and upper horizon sample was taken at 40.64 cm. Means without common superscripts differ ($P < 0.05$).

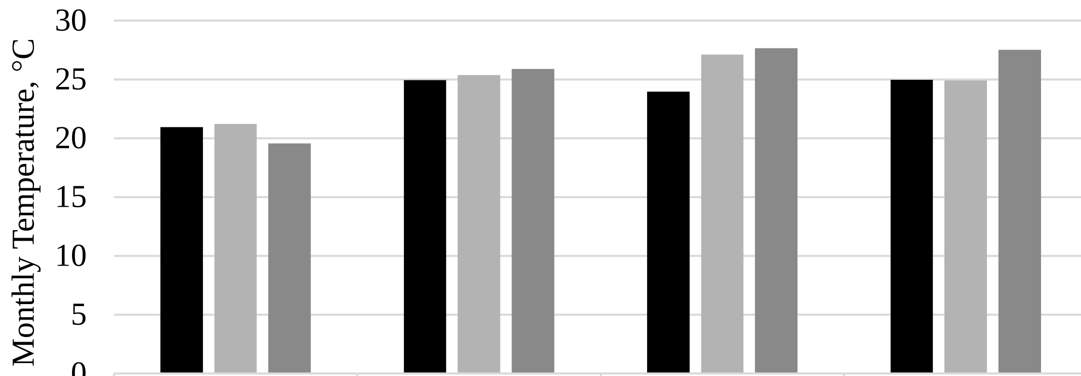
Table 2. Average forage nutrients over the years 2014, 2015, 2016 by month.

		MAY			
Species	**Horizon**	**CP**	**NDF**	**ADF**	**IVTDMD48h**
BBI	**Lower**	$12.3^{BD} \pm 0.74$	$63.5^{AB} \pm 1.24$	38.8 ± 1.03	$72.0^{ABC} \pm 1.26$
	Upper	$14.2^{AC} \pm 0.74$	$60.9^{B} \pm 1.24$	36.1 ± 1.03	$73.6^{A} \pm 1.26$
EG	**Lower**	$12.4^{CD} \pm 1.05$	$65.3^{A} \pm 1.76$	37.7 ± 1.45	$68.5^{BC} \pm 1.79$
	Upper	$14.6^{AB} \pm 1.05$	$63.1^{AB} \pm 1.76$	36.7 ± 1.45	$69.8^{ABC} \pm 1.79$
SW	**Lower**	$11.3^{D} \pm 0.74$	$65.0^{A} \pm 1.24$	37.5 ± 1.03	$68.7^{C} \pm 1.26$
	Upper	$13.8^{ABC} \pm 0.74$	$60.9^{B} \pm 1.24$	33.3 ± 1.03	$72.8^{AB} \pm 1.26$
		JUNE			
Species	**Horizon**	**CP**	**NDF**	**ADF**	**IVTDMD48h**
BBI	**Lower**	$8.7^{E} \pm 0.74$	$67.2^{BC} \pm 1.24$	43.9 ± 1.03	$64.5^{DE} \pm 1.26$
	Upper	$10.5^{CD} \pm 0.80$	$64.9^{C} \pm 1.40$	41.2 ± 1.13	$66.8^{CD} \pm 1.47$
EG	**Lower**	$9.7^{CDE} \pm 1.05$	$71.0^{AB} \pm 1.76$	45.1 ± 1.45	$61.0^{EF} \pm 1.79$
	Upper	$8.7^{DE} \pm 1.05$	$74.2^{A} \pm 1.76$	45.7 ± 1.45	$59.0^{F} \pm 1.79$
SW	**Lower**	$8.5^{DE} \pm 0.74$	$70.3^{AB} \pm 1.24$	42.7 ± 1.03	$61.7^{EF} \pm 1.26$
	Upper	$11.8^{BC} \pm 0.77$	$65.3^{C} \pm 1.31$	38.3 ± 1.07	$69.0^{BC} \pm 1.35$
		JULY			
Species	**Horizon**	**CP**	**NDF**	**ADF**	**IVTDMD48h**
BBI	**Lower**	$6.9^{C} \pm 0.74$	$71.4^{AB} \pm 1.24$	47.3 ± 1.03	$59.2^{DE} \pm 1.26$
	Upper	$8.8^{AB} \pm 0.74$	$69.1^{B} \pm 1.24$	43.6 ± 1.03	$63.2^{BC} \pm 1.26$
EG	**Lower**	$7.6^{ABC} \pm 1.05$	$74.0^{A} \pm 1.76$	47.7 ± 1.45	$56.4^{E} \pm 1.79$
	Upper	$9.4^{ABC} \pm 1.05$	$72.0^{AB} \pm 1.76$	46.2 ± 1.45	$58.5^{DE} \pm 1.79$
SW	**Lower**	$7.2^{BC} \pm 0.74$	$72.8^{A} \pm 1.24$	44.0 ± 0.81	$59.3^{DE} \pm 1.26$
	Upper	$8.3^{ABC} \pm 0.74$	$72.7^{A} \pm 1.24$	42.3 ± 0.81	$61.4^{CD} \pm 1.26$
		AUGUST			
Species	**Horizon**	**CP**	**NDF**	**ADF**	**IVTDMD48h**
BBI	**Lower**	$8.6^{AB} \pm 0.74$	$68.1^{B} \pm 1.24$	44.6 ± 1.03	$63.3^{ABC} \pm 1.26$
	Upper	$8.5^{AB} \pm 0.81$	$69.8^{AB} \pm 1.42$	44.6 ± 1.14	$61.8^{BCD} \pm 1.50$
EG	**Lower**	$8.4^{AB} \pm 1.05$	$71.6^{AB} \pm 1.76$	44.5 ± 1.45	$57.8^{D} \pm 1.79$
	Upper	$9.0^{AB} \pm 1.05$	$68.8^{AB} \pm 1.76$	44.3 ± 1.45	$59.7^{CD} \pm 1.79$
SW	**Lower**	$7.3^{B} \pm 0.74$	$71.4^{AB} \pm 1.24$	43.4 ± 1.03	$58.6^{D} \pm 1.26$
	Upper	$7.6^{AB} \pm 0.74$	$71.7^{A} \pm 1.24$	41.9 ± 1.03	$61.0^{CD} \pm 1.26$

Averages of 3 years comparing forage quality variables (expressed on dry matter basis) by horizon by month, for big bluestem and Indiangrass (BBI), eastern gamagrass (EG), and switchgrass (SW) across three years. Crude protein (CP); Neutral detergent fiber (NDF); Acid detergent fiber (ADF); In-vitro true dry matter digestibility 48 hour (IVTDMD48h). Lower horizon sample was taken at 20.32 cm, and upper horizon sample was taken at 40.64 cm. Means without common superscripts differ ($P < 0.05$).

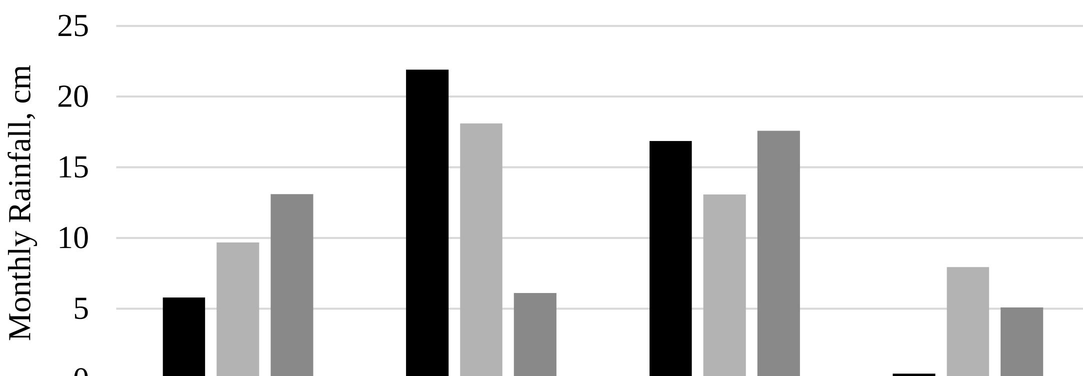
APPENDIX B

FIGURES



	May	June	July	August
2014	21	25	24	25
2015	21	25	27	25
2016	20	26	28	28

Figure 1: Monthly average temperatures (May through August) per year (2014, 2015, 2016), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years. Monthly temperature was recorded at Ames Plantation Research and Education Center, Grand Junction, TN and at Highland Rim Research and Education Center, Springfield, TN. Monthly temperature did not differ between locations. Therefore, means are reported together.



	May	June	July	August
2014	6	22	17	0
2015	10	18	13	8
2016	13	6	18	5

Figure 2: Monthly rainfall (May through August) per year (2014, 2015, 2016), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years. Monthly rainfall was recorded at Ames Plantation Research and Education Center, Grand Junction, TN and at Highland Rim Research and Education Center, Springfield, TN. Monthly temperature did not differ between locations. Therefore, means are reported together.

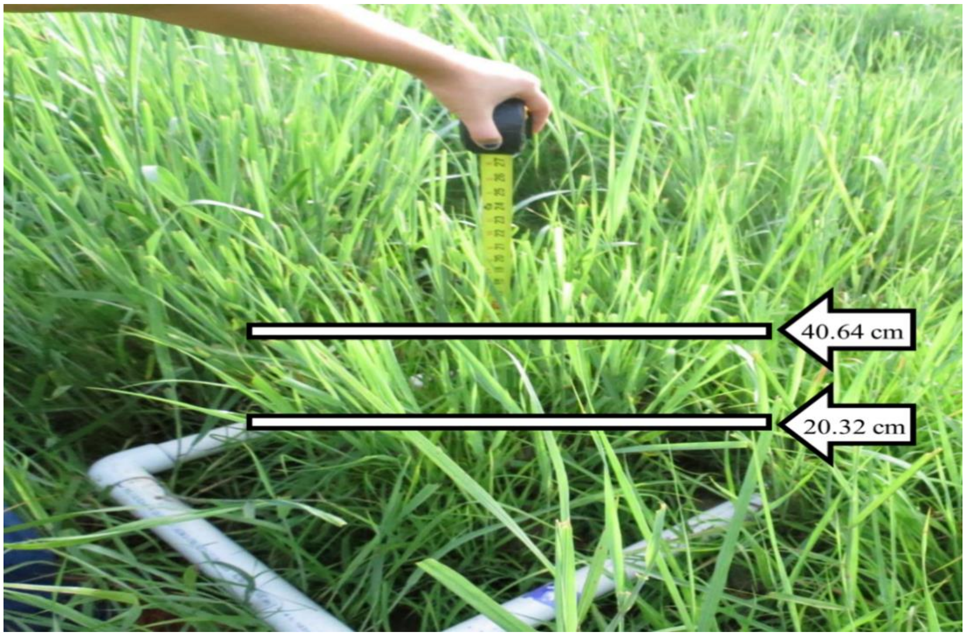
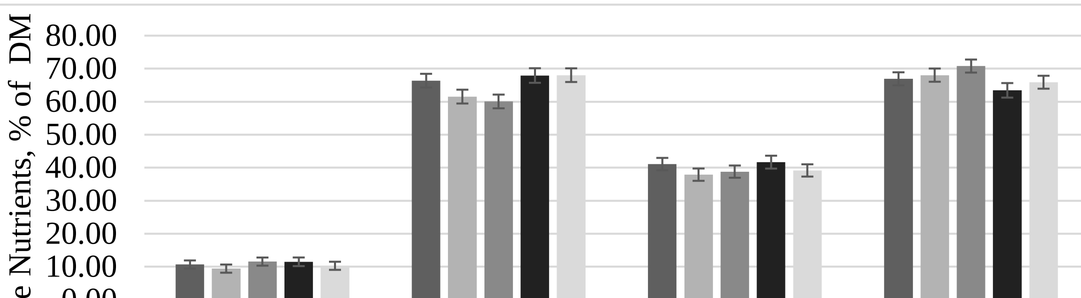


Figure 3. Native warm-season grass sampling heights. For eastern gamagrass, switchgrass, and big bluestem and Indiangrass, forage samples were collected from two horizons at each sampling site; 40.64 cm (upper horizon) followed by a clipping at 20.32 cm (lower horizon).



	CP	NDF	ADF	IVTDMD48h
BBI	10.66 ABC	66.36 C	41.09 B	66.92 B
BG	9.41CDE	61.54 D	37.88 C	68.04 AB
CG	11.54 A	60.06 D	38.80 C	70.79 A
EG	11.48 AB	67.92 ABC	41.68 AB	63.43 CDE
SW	10.27 BCD	68.03 ABC	39.16 C	65.89 BC

Figure 4: Averages of season-long (May through August) forage quality variables (expressed on dry matter (DM) basis) for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Crude protein (CP); Neutral detergent fiber (NDF); Acid detergent fiber (ADF); In-vitro true dry matter digestibility 48 hour (IVTDMD48h); Means without common superscripts differ ($P < 0.05$).

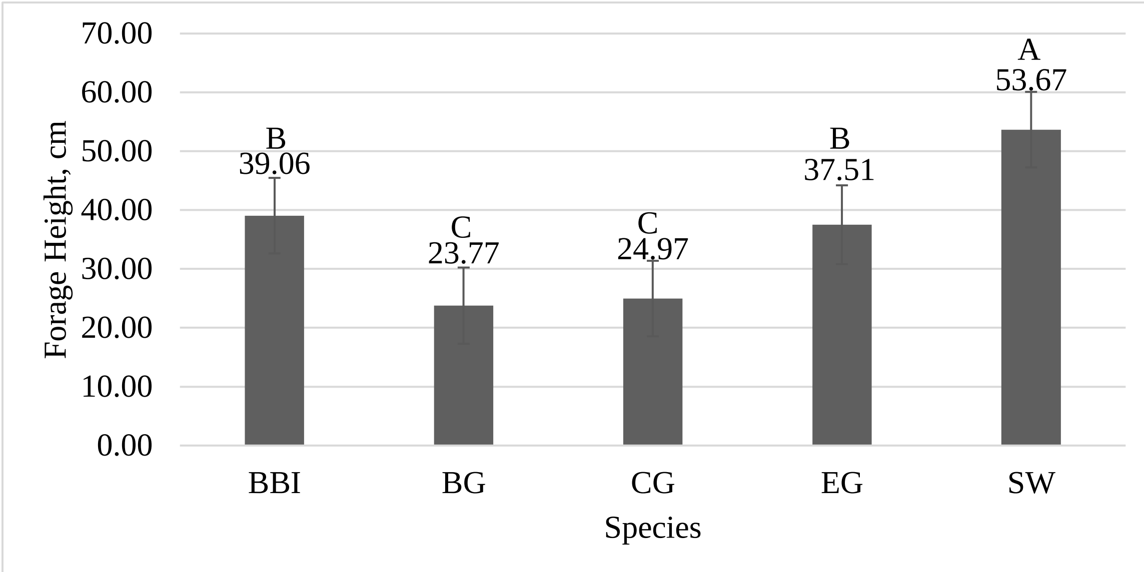


Figure 5: Average forage height per species across three years (2014, 2015, and 2016) for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) at two locations. Means without common superscripts differ (P < 0.05).

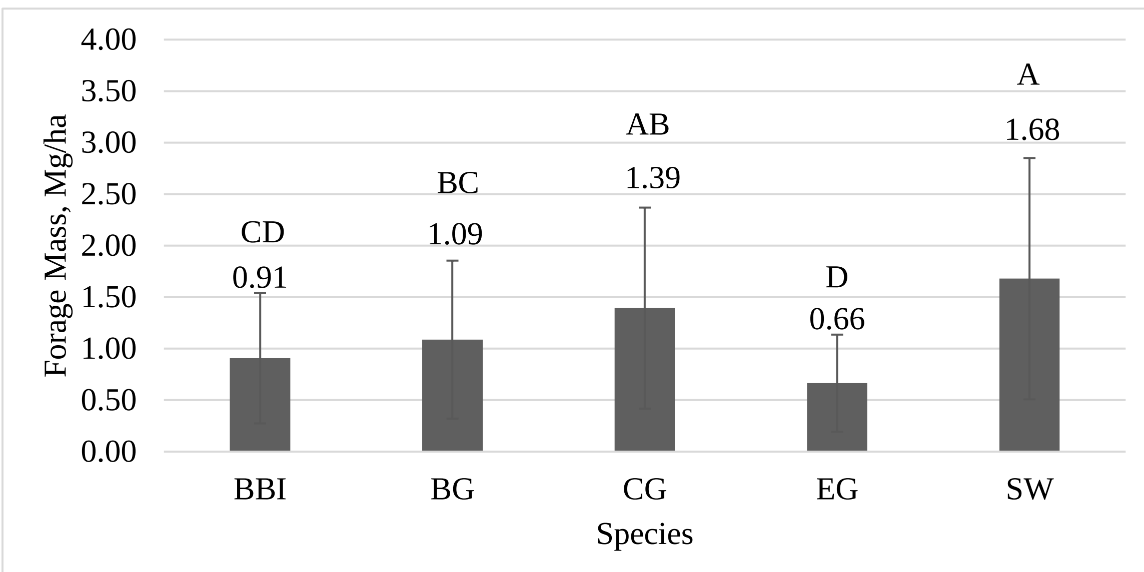
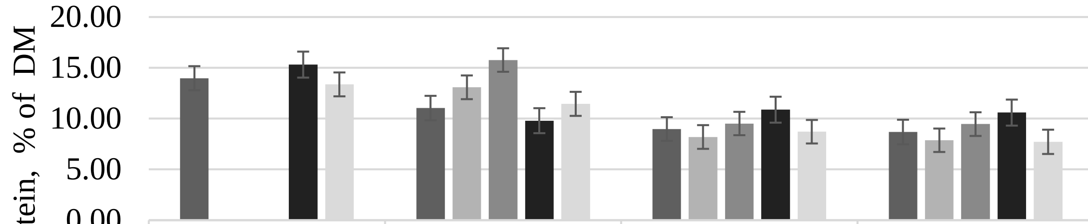
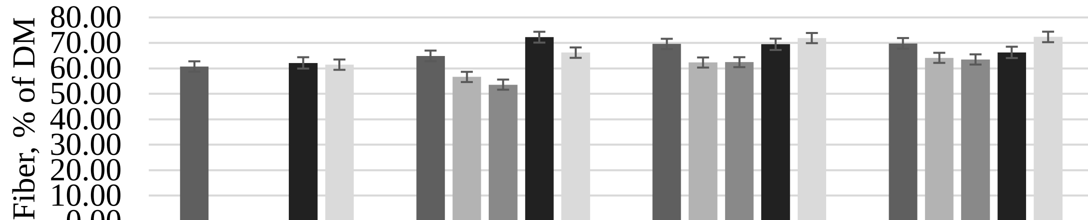


Figure 6: Average forage mass per species across three years (2014, 2015, and 2016) for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) at two locations. Means without common superscripts differ (P < 0.05).



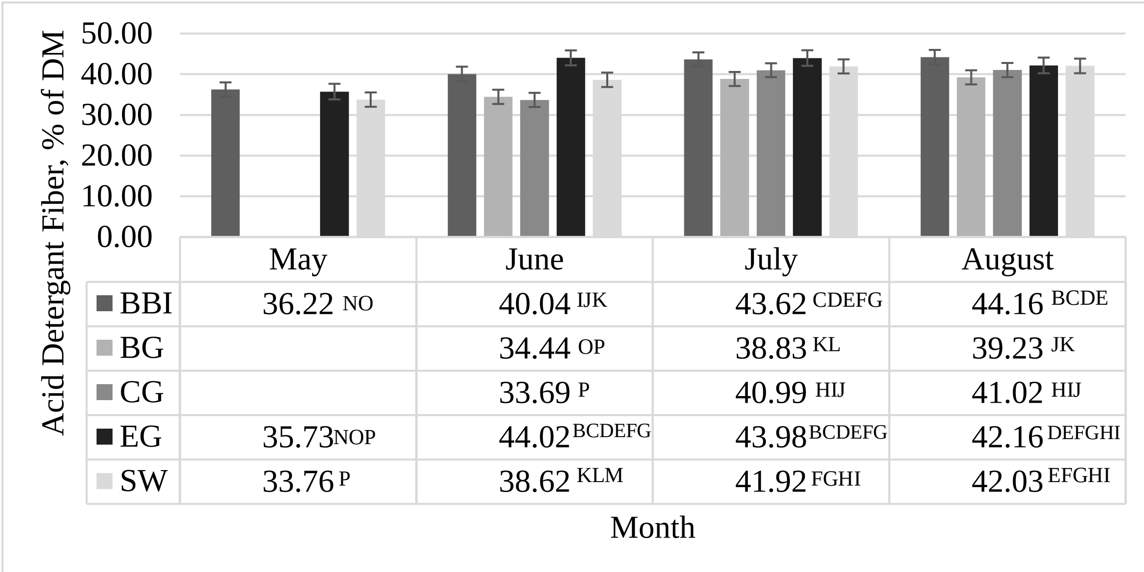
	May	June	July	August
BBI	13.98^{BC}	11.04^{EFG}	8.97^{IJKLM}	8.68^{JKLM}
BG		13.08^{CD}	8.19^{KLMNO}	7.87^{MNO}
CG		15.77^{A}	9.52^{HIJ}	9.46^{HIJK}
EG	15.32^{AB}	9.80^{GHIJ}	10.88^{EFGH}	10.59^{FGHI}
SW	13.37^{CD}	11.45^{EF}	8.71^{JKLM}	7.72^{MNO}

Figure 7: Average crude protein (CP on dry matter (DM) basis) per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ ($P < 0.05$).



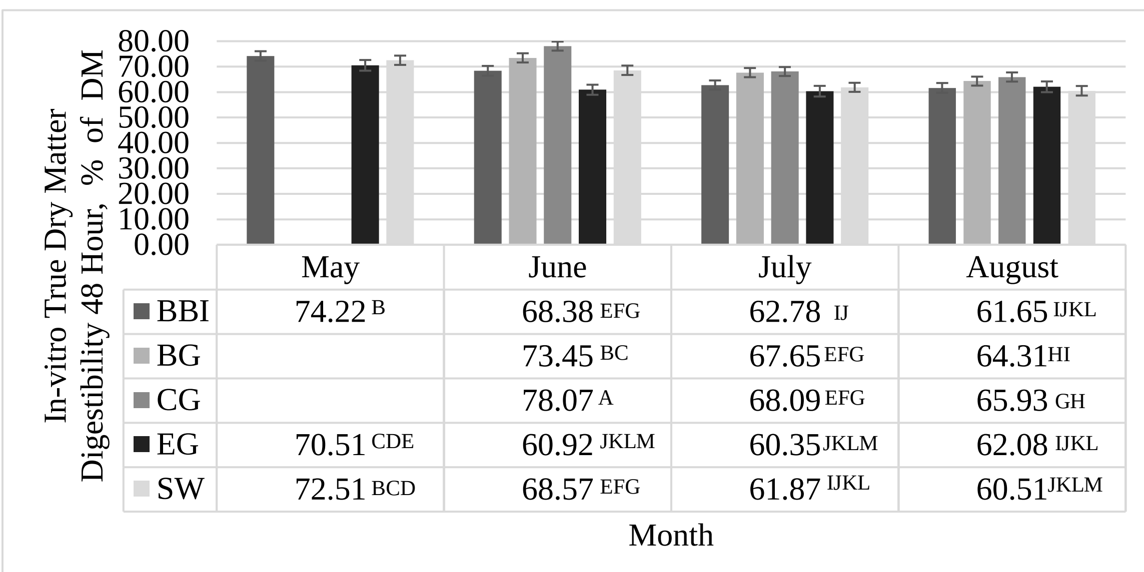
	May	June	July	August
BBI	60.73^{N}	64.90^{IJK}	69.60^{CEF}	69.81^{BCDE}
BG		56.63^{O}	62.29^{LMN}	64.13^{IJKL}
CG		53.60^{P}	62.43^{KLMN}	63.50^{JKLM}
EG	62.14^{KLMN}	72.25^{ABCD}	69.45^{BCDEG}	66.27^{GHIJ}
SW	61.46^{MN}	66.18^{HI}	71.90^{ABCD}	72.35^{ABD}

Figure 8: Average neutral detergent fiber (NDF on dry matter (DM) basis) per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ ($P < 0.05$).



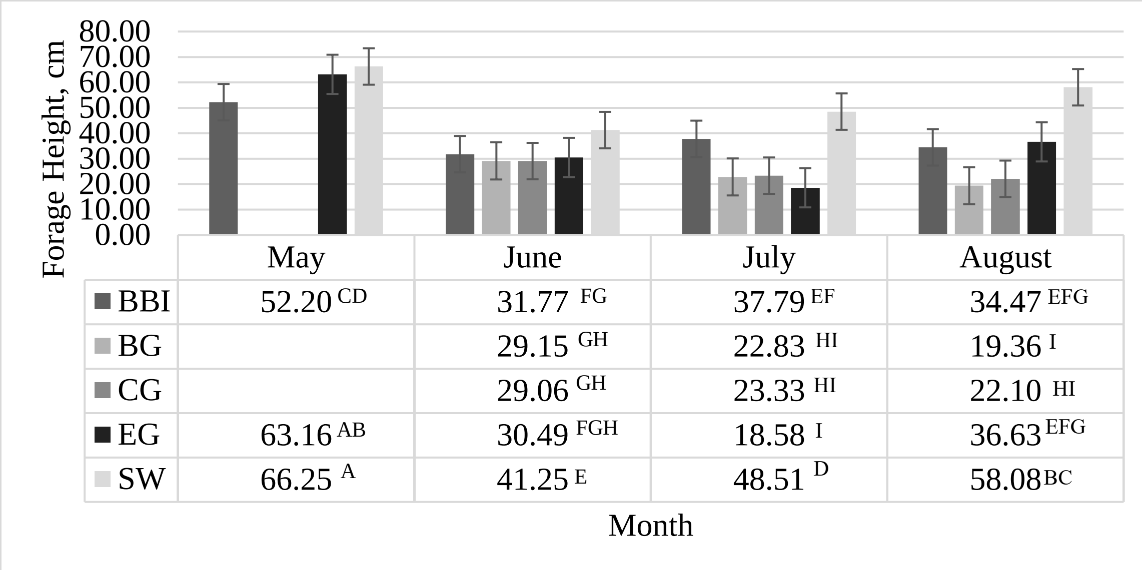
	May	June	July	August
BBI	36.22 NO	40.04 IJK	43.62 CDEFG	44.16 BCDE
BG		34.44 OP	38.83 KL	39.23 JK
CG		33.69 P	40.99 HIJ	41.02 HIJ
EG	35.73 NOP	44.02 BCDEFG	43.98 BCDEFG	42.16 DEFGHI
SW	33.76 P	38.62 KLM	41.92 FGHI	42.03 EFGHI

Figure 9: Average acid detergent fiber (ADF on dry matter (DM) basis) per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ (P < 0.05).



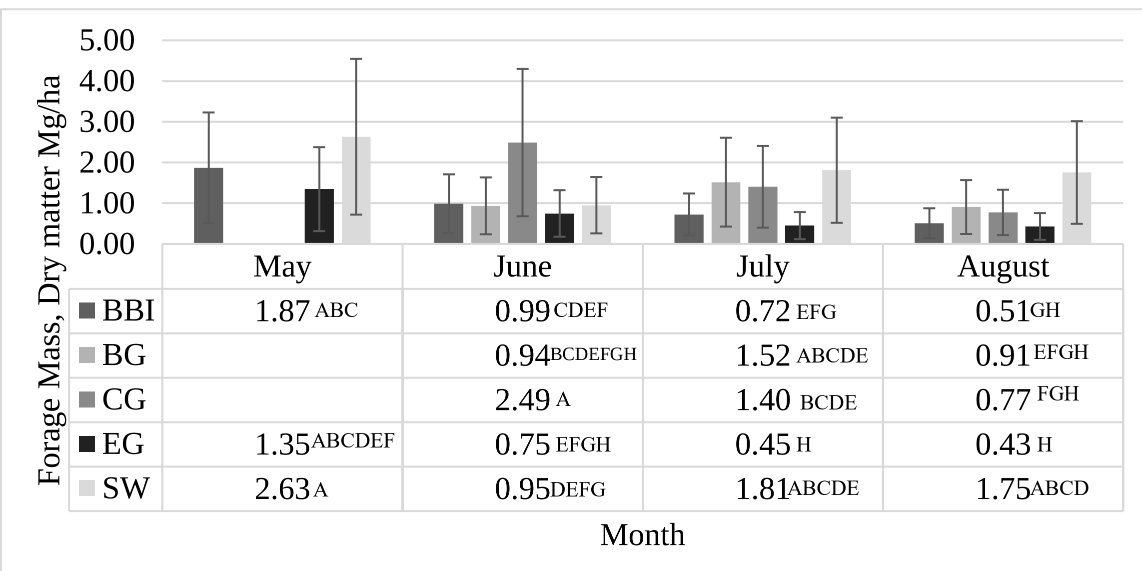
	May	June	July	August
BBI	74.22 B	68.38 EFG	62.78 IJ	61.65 IJKL
BG		73.45 BC	67.65 EFG	64.31 HI
CG		78.07 A	68.09 EFG	65.93 GH
EG	70.51 CDE	60.92 JKLM	60.35 JKLM	62.08 IJKL
SW	72.51 BCD	68.57 EFG	61.87 IJKL	60.51 JKLM

Figure 10: Average in-vitro true dry matter digestibility 48 hour (IVTDMD48h on dry matter (DM) basis) per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ (P < 0.05).



	May	June	July	August
BBI	52.20^{CD}	31.77^{FG}	37.79^{EF}	34.47^{EFG}
BG		29.15^{GH}	22.83^{HI}	19.36^{I}
CG		29.06^{GH}	23.33^{HI}	22.10^{HI}
EG	63.16^{AB}	30.49^{FGH}	18.58^{I}	36.63^{EFG}
SW	66.25^{A}	41.25^{E}	48.51^{D}	58.08^{BC}

Figure 11: Average forage height per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ ($P < 0.05$).



	May	June	July	August
BBI	1.87^{ABC}	0.99^{CDEF}	0.72^{EFG}	0.51^{GH}
BG		$0.94^{BCDEFGH}$	1.52^{ABCDE}	0.91^{EFGH}
CG		2.49^{A}	1.40^{BCDE}	0.77^{FGH}
EG	1.35^{ABCDEF}	0.75^{EFGH}	0.45^{H}	0.43^{H}
SW	2.63^{A}	0.95^{DEFG}	1.81^{ABCDE}	1.75^{ABCD}

Figure 12: Average forage mass per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ ($P < 0.05$).

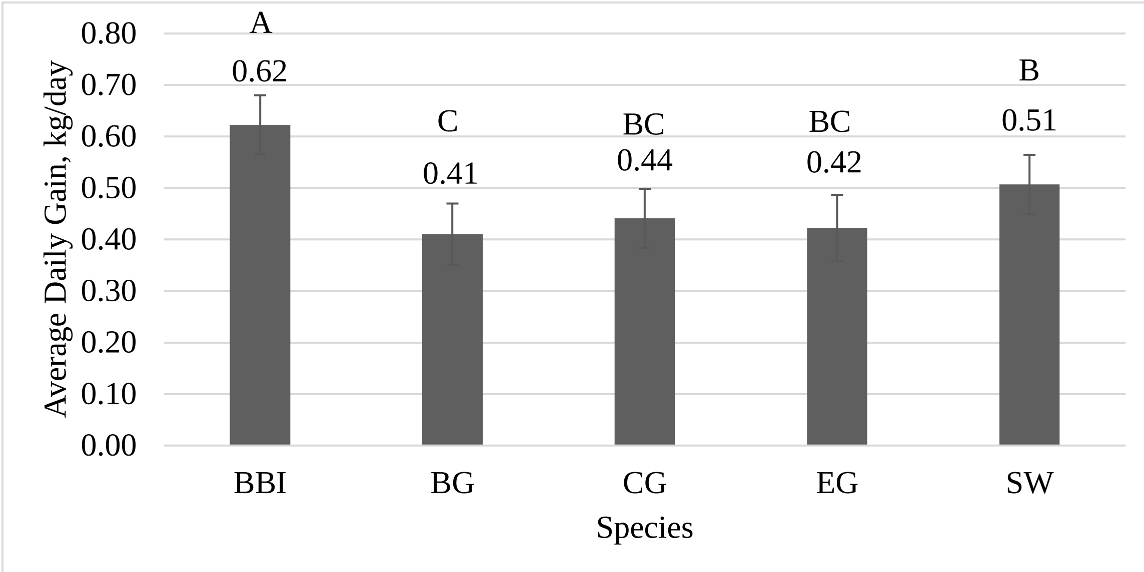


Figure 13: Average daily gain per species from the years 2014, 2015, and 2016, for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Means without common superscripts differ (P < 0.05). Average Daily Gain Calculation: tester heifer end weight – beginning weight / number of days heifers grazed on paddock

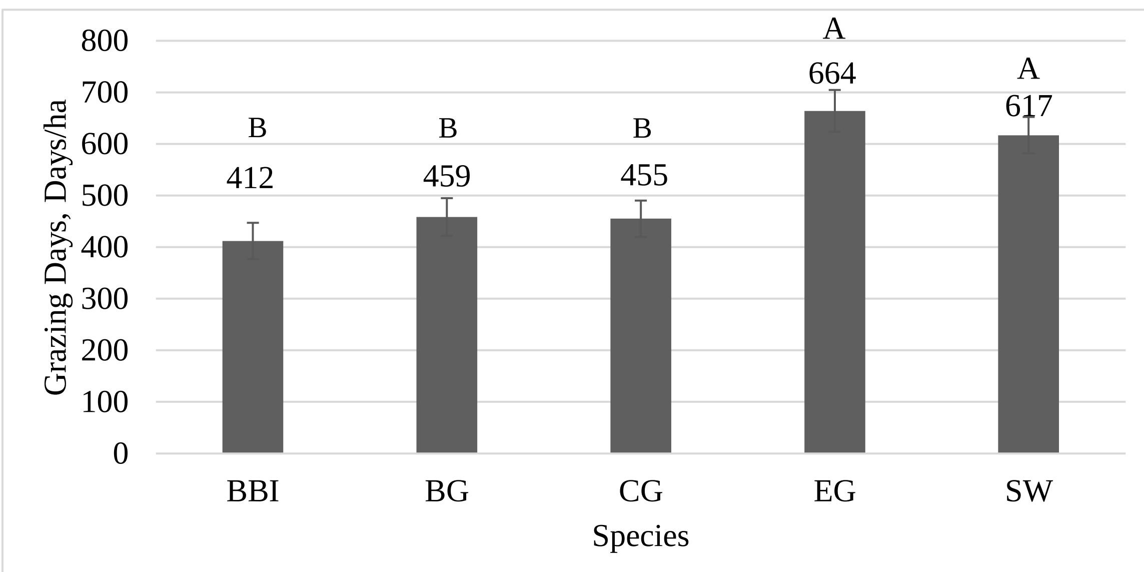


Figure 14: Average grazing days per species from the years 2014, 2015, and 2016, for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Means without common superscripts differ (P < 0.05). Grazing days calculation: sum of days that tester and grazer heifers were on paddock / 1.2-ha.

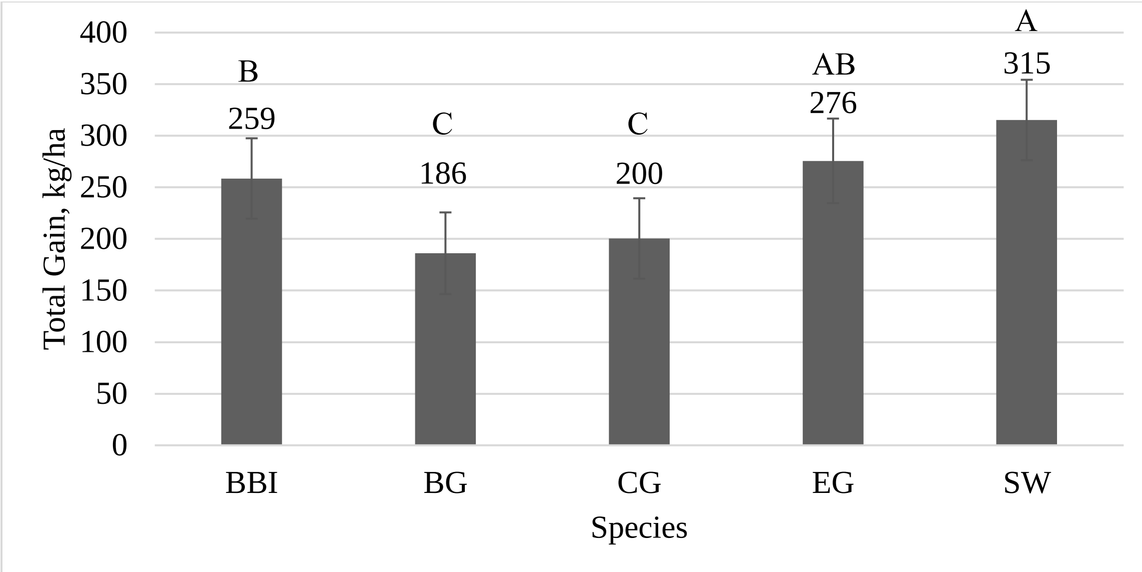


Figure 15: Average total gain per species from the years 2014, 2015, and 2016, for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Means without common superscripts differ ($P < 0.05$). Total Gain Calculation: Average daily gain (kg/day) * grazing days (days/ha).

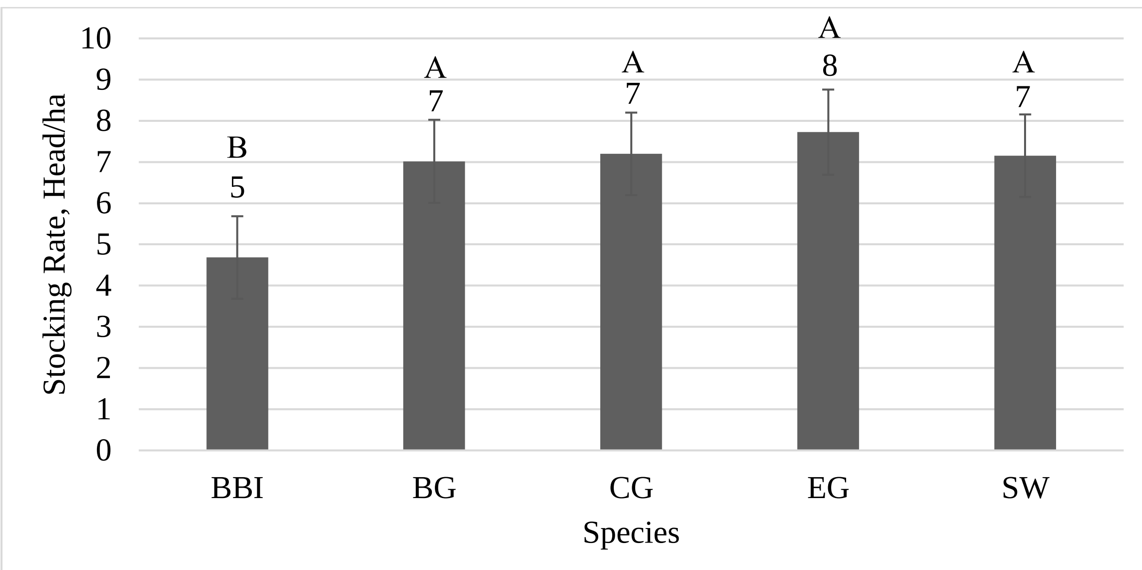
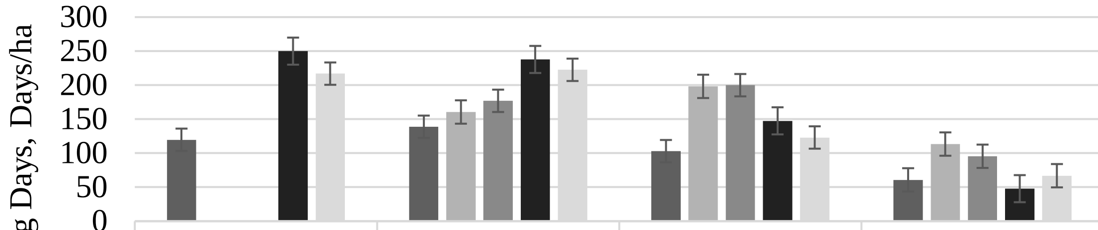


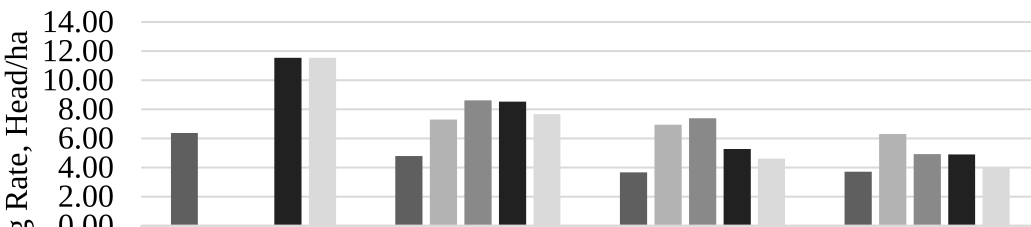
Figure 16: Average stocking rates per species from the years 2014, 2015, and 2016, for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Means without common superscripts differ ($P < 0.05$). Stocking Rate Calculation: number of heifers on paddock / 1.2-ha.



	May	June	July	August
BBI	120 FG	139 EF	103 G	61 I
BG		160 DE	198 BC	113 FG
CG		177 CD	200 BC	95 GH
EG	250 A	238 A	148 DEF	48 I
SW	217 AB	223 AB	123 FG	67 HI

Month

Figure 17: Average grazing days per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ (P < 0.05). Grazing days calculation: sum of days that tester and grazer heifers were on paddock / 1.2-ha.



	May	June	July	August
BBI	6.36 EF	4.79 G	3.67 H	3.72 H
BG		7.31 CDE	6.94 DE	6.31 EF
CG		8.61 B	7.39 CD	4.93 G
EG	11.55 A	8.53 BC	5.26 FG	4.89 GH
SW	11.54 A	7.67 BCD	4.62 GH	4.03 GH

Month

Figure 18: Average stocking rate per species by month (May through August), for big bluestem and Indiangrass (BBI), bermudagrass (BG), crabgrass (CG), eastern gamagrass (EG), and switchgrass (SW) across three years at two locations. Grazing for BG and CG was initiated in June of each year. Means without common superscripts differ (P < 0.05). Stocking Rate Calculation: number of heifers on paddock / 1.2-ha.

VITA

Katelynn Zechiel was born on November 22, 1992 to L. Dean and Tina Zechiel. She grew up and attended school in a small town called Argos, Indiana. In May of 2011, she received her high school diploma from Argos High School.

In 2011 she attended Ball State University where she majored in nursing. After a year at Ball State University she realized that she no longer wanted to pursue a degree in nursing and decided to transfer to Purdue University in the fall of 2012 to study animal science. In May 2015 she obtained her Bachelor of Science degree in Animal Sciences from Purdue University.

After graduation she started her master’s degree in Animal Sciences at the University of Tennessee, Knoxville under the direction of her mentor Dr. Justin Rhinehart. She graduated with her Master of Science degree in Animal Sciences in December 2017.