Nutritional profile of native warm-season grass grown as a mono- or multi-species pasture

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The objective of this study was to evaluate the nutritional profile of mono- or multi-species pastures of native warm season grasses. One of four treatments were randomly assigned to Twelve pastures: 1) BG; 2) IG; 3) Mix G; 4) Mix NG. Growing steers (n = 225) were randomly assigned to one of nine pastures. Grass samples were taken from all pastures every 28 days during a four-month period and were analyzed for nutrient composition. Bermudagrass pastures had greater crude protein and ADF, but less NDF concentrations compared with the native warm-season grasses. Crude protein, IVDMD, and NDF IVDMD concentration decreased while NDF, ADF, and Hemicellulose concentration increased as grasses matured. Steers grazing IG and Mix G pastures gained more weight and consumed more forage than those on BG pastures. It appears that native warm-season grasses may offer a viable alternative to BG for grazing cattle during the summer.

DEDICATION

This research is dedicated to God, and my parents Adekunle and Olubunmi Oloyede.

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CHAPTER I

INTRODUCTION

Native warm-season grass pastures are promising for improving forage production in the Southeast with its nutritive quality being compared to bermudagrass, a common “traditional” warm-season grass. However, the unfamiliarity of early settlers with these native grasses may have led to their replacement with exotic species such as bermudagrass. The ability to combine the productiveness of perennial native warm-season grasses during the summer with the production from cool-season grasses during the spring and fall seasons has efficiently improved livestock production by providing a uniform supply of forage during the entire production season. Native warm-season grasses are not limited to use as livestock feed, but have potential for use as an alternative energy source due to their increased productivity under periods of elevated environmental temperature and wildlife conservation. These are, in part, some reasons for the recent interest in the restoration of these grasses.

Native grasses provide superior habitat for a variety of grassland birds compared to exotic grass species and increasing the amount of these grasses in the landscape supports diverse communities of pollinators while providing optimum wildlife habitat conditions and ideal nesting cover for many wildlife species (NRCS, 2005). Despite the advantages, increasing population decline of grassland birds has been largely attributed to the extensive loss and degradation of these native grasslands. In addition, native warm-season grasses have emerged as a potential alternative herbaceous energy crop to current petroleum-based products. This may minimize national dependency on wood products such as chips and sawdust; hence, developing the nation's agricultural potential for rural economic growth, and improving environmental quality (Waramit, 2010). While the production of native warm-season grasses for livestock forage, wildlife habitat, and alternative energy source have been mostly established as mono-species pasture, there is limited information regarding the quality and production of these grasses established as multi-species pastures. Therefore, the objective of this study was to evaluate the nutritional profile of selected native warm-season grasses that have been established as a mono- or multi-species pasture while being grazed by beef cattle.

CHAPTER II

LITERATURE REVIEW

Description of common native warm-season grass species

Indiangrass *(Sorghastrum nutans)*

Indiangrass is a tall upright, bunch-type, perennial, native warm-season grass that spreads by seed and short knobby rhizomes. It is classified into Kingdom: Plantae (plants), Subkingdom: Tracheobionta (vascular plants), Superdivision: Spermatophyta (seed plants), Division: Magnoliophyta (flowering plants), Class: Liliopsida (monocotyledons), Subclass: Commelinidae, Order: Cyperates, Family: Poaceae (grass family), and Genus: Sorghastrum nash. The genus *Sorghastrum* originated from "sorghum" and the Latin suffix "astrum", indicating its resemblance to sorghum (Waramit, 2010). Indiangrass is native to the Americas and distributed from East-central Canada to Southern Mexico. Additionally, it was one of the primary components of the Tallgrass Prairie in the central USA, being a companion with little bluestem, big bluestem, and switchgrass (Waramit, 2010). Its growth begins in April, and depending on environment, will reach a height of 1 to 2 m. Leaves are flat and narrow at base, growing 0.25 to 0.6 m long (Harper et al., 2007). Moderately well-drained soils are preferred, but indiangrass can withstand occasional flooding (USDA-NCRS, 2008). Indiangrass produces a deep root system, thus making it drought tolerant. Furthermore, indiangrass is a heavy seed producer. The seed is chaffy and can remain dormant for a long period of time (USDA-NRCS, 2008). However, seed dormancy decreases with time of storage. There are various varieties of indiangrass including Osage, Newberry, and Rumsey.

Big bluestem *(Andropogon gerardii)*

Like indiangrass, big bluestem is one of the major grasses of the Tallgrass Praire. It is a perennial, native warm-season grass with short rhizomes, and similar plant classification with indiangrass with the exception of the "Genus". It begins growth in April, but majority of its growth occurs after the first day of June (Harper et al., 2007). Additionally, a common feature used to identify this grass before flowering is the fine silky "hairs" on the sheath, which are widely dispersed near the base of the upper leaf surface (Harper et al., 2007). Big bluestem is a bunch-type grass that typically grows from 1 to 3 m tall with an attractive reddish-purple color at maturity. Its deep roots make it more tolerant to drought. It can be used on well-drained soils, fertile loamy soils, even on soils with pH as low as 4 (USDA-NCRS, 2008). Seeds are dark and "hairy", and grow slowly into seedling. However, it can also be propagated with crown divisions (Waramit, 2010). The seedhead has two or three distinct racemes on the top of the stem, looking like a turkey's foot (Harper et al., 2007). Although, big bluestem is one of the most palatable native warm-season grasses used for forage production, it is however, less tolerant to heavy grazing by animals. Cultivars of big bluestem include Rountree, Niagara, Kaw, Earl, and Oz-70.

Little bluestem *(Schizachyrium scoparium)*

Little bluestem is a perennial native, warm-season bunch-type grass that grows to about 0.6 to 1.5 m tall. It has plant classification similar to both indiangrass and big bluestem, except the “genus”. Growth of little bluestem starts from mid spring through the summer, and reaches maximum height in July (Harper et al., 2007). Plants are slender with flat leaves that are often folded along the midrib and purplish at the base. Additionally, the stem is flattened at the base and often red or purplish during early growth. However, plants are reddish-brown at maturity (Harper et al., 2007). Its seed heads are “hairy” appendages that are held in racemes along each stem (USDA-NCRS, 2008). Seeds are produced early during the fall, and are found in singles, pairs, or groups (Harper et al., 2007). Due to its exceptional tolerance to drought, it survives on dry sites that have thin or coarse soils. However, full stands get clumpy on drier sites (USDA-NCRS, 2008). In addition, its shorter growth period makes it compatible with forbs. Most common cultivar of little bluestem best adapted to the Mid-South region is Aldous; others include Camper, Cimmaron, Pastura, and Blaze.

Native warm-season grass and wildlife

In the Tallgrass Prairie region of the North America, including the Midwest and Great Plains states, native warm-season grasses were once quite widespread before the arrival and establishment of European settlers. They supplied three of the basic habitat requirements (food, shelter, and space) of grassland wildlife species (such as whitetail deer, elk, American bison, small mammals, and numerous bird species) in these regions (Waramit, 2010). However, there has been a rapid decline of grass species during the past few decades because of changing agricultural practices, including early and frequent grazing as well as increased use of pesticides and introduction of exotic cool- and warm-season grasses such as tall fescue, orchardgrass, and bermudagrass (Giuliano and Daves, 2002). Many of the exotic grasses were hardy and aggressive because they grew in dense mats that are almost not penetrable by wildlife, and consequently provide poor nesting and escape cover for many wildlife species (NRCS, 2005). Furthermore, cool-season grasses typically produce about 60 to 70 % of their biomass prior to the first day of June. Thus, fields are grazed or mowed during early April to late June; a period when most grassland birds are nesting. This results with nest disturbance and destruction. Because native warm-season grass produce 70 % of their biomass after the first day of June, grazing and mowing are typically delayed until July to August after the peak nesting season of most birds (Giuliano and Daves, 2002). Therefore, incorporating native warm-season grasses such as switchgrass or big bluestem into pasture and hayfield systems is an alternative to using only cool-season grasses in farmlands as this will substantially enhance abundance, richness, and reproductive success of birds, including many declining species while providing more suitable, less disturbed grassland habitat (Belding et al., 2000).

Native warm-season grass and biofuel

The large-scale production of ethanol from corn grain, which is a primary feedstock for ethanol production in the U. S. has raised concerns due to its other commitment for food and feed manufacturing. Although, bio-refineries can use crop residues like corn stover, wood products like chip and sawdust, research has shown that many species and varieties of native warm-season grasses have the potential as biomass feedstock. Tremendous yielding native warm-season grasses such as switchgrass, big bluestem, and indiangrass may be used as renewable bio-energy feedstock. While switchgrass have been extensively studied for its value as forage, wildlife conservation, and bio-energy crop, big bluestem and indiangrass have been evaluated primarily for forage (Waramit, 2010). However, there has been interest in evaluating their potential as bio-energy crop. Harvest management for biomass production is different from hay production because the goal is to produce great amount of lignocellulose. Because perennial warm-season grasses generally require less fertilizer input to achieve full biomass production, appropriate harvest management and timing is important for the biofuel refinery system. A single late season harvest may be most suitable for biomass fuel cropping (Waramit, 2010). Switchgrass has been reported to achieve biomass yields ranging from 9.9 to 23.0 Mg per hectare, while big bluestem achieved biomass yield similar to or slightly less than those of switchgrass with minimal energy inputs (Propheter et al., 2010).

Native warm-season grasses as livestock forage

Native warm-season grasses have been shown to be beneficial to livestock production because they thrive, produce good quality forage, and permit the maintenance of increased stocking rates during the summer months. Although, a number of factors affect the quality of these grasses including species, soil moisture, time of harvest, environmental condition, and soil fertility. Several species of native warm-season grasses such as indiangrass, big bluestem, switchgrass, and little bluestem are widely recommended for pasture and forage production across the Midwest. In Pennsylvania, native warm-season grass pastures were reported to provide approximately 212 cow-grazing days per hectare (Jung et al., 1978) with the additional advantage of producing greater dry matter yield on soils with less fertility (Vona et al., 1984). However, these grasses accumulate increased concentrations of cell wall components late in the growing season and become relatively less digestible (Moore et al., 1980), which may affect animal performance (Waramit et al., 2012). Moreover, the efficiency of ruminant production systems based on forage as the main protein and energy source are greatly affected by forage maturity, and this is often considered the primary factor that determines nutritional quality of the grasses (Nelson and Moser, 1994). Therefore, delaying harvest considerably decreased forage quality of these grasses, hence, resulted with poor performance of animals consuming them (Griffin and Jung, 1983). Forage quality encompasses nutritive value, and it includes a function of voluntary intake and the effects of any anti-quality constituents (Collins and Fritz, 2003). In addition, leaf material generally has much greater digestibility, reduced fiber, and twice as much crude protein as the stem tissue from the same plant (Collins and Fritz, 2003). Hence, the major determinant of whole plant nutritive value is the increase in the proportion of less quality stems as maturity advanced combined with more rapid decrease in nutritive value of stems compared to leaves (Waramit et al., 2012). Combining intake and digestibility with utilization of the digested nutrients provide a means of evaluating the feeding value of forages more effectively than evaluating both alone (Mott and Moore, 1970). Therefore, digestibility of forages is an important part of nutritive value alongside crude protein and fiber concentration. The amount of digestible energy in the forage primarily determines the nutritive value of warm-season grasses (Moore, 1980). Forages with greater digestibility provide more energy to animals consuming them than less digestible forages. Additionally, warm-season grasses contain more cell wall constituents and less cell contents. Hence, the relatively increased concentration of cell wall constituents and less digestibility of fiber may restrict digestible energy intake (Mertens, 1987).

Furthermore, analysis of some warm-season grasses in the Northeast showed a mean crude protein concentration of 7.6%, an amount that may be inadequate for maximal feed intake (Puoli et al., 1991). Likewise, these grasses are reported to contain marginal amount of phosphorus, sulfur, and zinc, but adequate concentrations of magnesium and calcium (Vona et al., 1984). In addition, the digestive utilization of these grasses by ruminants may be limited by nitrogen, which has shown to influence dry matter intake by animals. Nitrogen (N) is an essential macro element required by warm-season grasses and grazing ruminants. It is a constituent of amino acids, and therefore proteins, as well as nucleic acids that are important in both plant and animal nutrition (McDowell, 1992). Therefore, warm-season grasses require proper N fertilization in order to improve forage production and quality for livestock. Puoli et al. (1991) reported that application of 78 kg nitrogen per hectare to switchgrass and big bluestem only increased crude protein concentration by 1.1 % and 1.7 % units respectively, while digestibility was not affected. In addition, Waramit et al. (2012) reported that neutral detergent fiber concentrations were increased with nitrogen fertilization. The increase in these nutrient components may be attributed to a positive effect of nitrogen fertilization on stem development (i.e. less leaf to stem ratio; Wilson, 1982). Meanwhile, Minson (1990) recorded a varied response for *in vitro* dry matter disappearance of warm-season grasses to nitrogen fertilization, and the reason for this variation was not clearly understood.

Grazing behavior of ruminants at pasture

Grazing animals are faced with the daily task of searching for, harvesting, and ingesting feed; therefore, pasture utilization by these animals remains a complex biological process that is not completely understood (Burns and Sollenberger, 2002). In the development of grazing behavior research, the reductionist approach, in which small segments of the soil-plant-animal complex i.e. the plant-animal interface, have been examined in intensive, short-term experiments (Ungar, 1998). These short-term studies have identified the important ingestive behavioral components of animal intake and the influential interacting components of pasture canopy, which has led to considerable knowledge and understanding about how animals graze. In addition, grazing behavior research on both tropical and temperate pastures has resulted in data that are unique to specific plant species-animal type within each experiment. However, a complication is that ingestive behavior data from different experiments are frequently intermingled without regard for plant type (tropical or temperate) or animal type (cattle, sheep, or goats), and occasionally the specific identity of data are lost (Burns and Sollenberger, 2002).

Furthermore, it is important to be able to measure or predict daily dry matter intake and nutritive value of consumed forage, which animal graze. Therefore, maintenance of dry matter intake is the limiting factor for sustained daily animal responses in grazing systems (Hodgson, 1982). Changes in daily animal response are more influenced by changes in daily dry matter intake than changes in forage digestibility (Noller, 1997). Under unrestricted grazing conditions, animals can exhibit their full range of grazing behavior including resting, walking, socializing, and ruminating, as these behaviors can alter grazing time and dry matter intake. However, direct measurement of dry matter intake of the grazing animal is not as easy to achieve as it is with animals in confinement, but may be measured by indirect measurements such as inert markers or ingestive behavioral methods.

Intake rate is determined from the integration of a number of ingestive behavior components such bite weight/size, bite rate, and grazing time; however, the degree to which these components relate to animal daily performance from warm-season grasses is not well documented (Burns and Sollenberger, 2002). Bite size is reported to have the greatest influence on intake (Forbes, 1988). Furthermore, sward structure may influence bite size to varying degree. Leaf surface height is the dominant influence on bite size in temperate grass swards, but in tropical swards, leaf density and leaf to stem ratio have greater influence on bite size and herbage intake than leaf surface height (Forbes, 1988). In addition, in warm-season grasses, green herbage mass have more influence on bite size and herbage intake than sward height.

Ingestive behavior may be affected by boundaries in the pasture. Grazing animals will select a diet from within the physical boundaries allocated regardless of the total area available. The boundary takes the form of a perimeter fence, which restricts the animal to some part of a larger grazing system; examples include strip grazing, rotational stocking, or tethering. Additionally, animal-induced and canopy-constraint boundaries are two other boundaries that operate within the grazing paddock, and may influence ingestive behavior. Animal-induced boundaries are animal specific and may vary among spcies. On the contrary, canopy-constraint boundaries are more stable, and may be due to some characteristics of pasture canopy such as heavy stems. Burns and Sollenberger (2002) identified five grazing situations associated with management-animal imposed boundaries and pasture canopy constraints, which interact with animal grazing behavior.

These include uniform, surf, block, random, and spot grazing. Uniform grazing usually occur at the onset of grazing, where the perimeter fence is the functional boundary. Animals uniformly graze without animal-induced nor plant-constraint boundaries. As grazing progress, the canopy surface may take on a wave-like form referred to as surf grazing. When this occurs, plant-constraint boundaries emerge between waves. Additionally, in some pastures, animals may graze in blocks, where they allow portions of the canopy to mature before grazing. This may result in a plant-constraint boundary. Furthermore, animals may exhibit random grazing behavior where they graze both mature and immature plant tissues by taking series of bites from tall and short canopy areas. Lastly, the typical spot grazing may occur where animals graze mainly the immature re-growth of plants. This is an animal-induced boundary that may result from an increased stocking rate.

Native warm-season grass pastures with legumes

While some producers may be willing to adopt native warm-season grasses for pasture, others may be reluctant. Native warm-season grasses begin growth in early to mid-April and provide excellent forage until the end of June. Generally, by July or August forage becomes less palatable and nutritious, resulting with decreased animal gains (Springer et al., 2001). Hence, dietary supplements become important to prevent animal weight loss. One of the ways to enhance pasture forage production and maintain quality is to over-seed grass pastures with one or more forage legume species (Springer et al., 2001). Including forage legumes in pastures had positive effects on both pasture output and the environment (Solomon et al., 2011). Major advantages of forage legumes include providing a renewable source of nitrogen for plant growth as well as quality forage for animal production (Nelson and Burns, 2006). While warm-season grasses may extend the production season of cool-season grass pastures, legumes may also extend the production season of both cool- and warm-season grass pastures (Springer et al., 2001). Grazing animals that utilize forage legumes have been reported to grow faster (Mouriño et al., 2003).

Pastures with legumes had greater crude protein content, digestibility, and mineral content for livestock diets; these resulted in greater forage intake and better animal performance (Marten, 1985). Legumes provide substantial amount of nitrogen to the pasture system, therefore reducing the amount of N fertilizer required to the soil (Mouriño et al., 2003). For example, birdsfoot trefoil (*Lotus corniculatus*) and alfalfa (*Medicago sativa*) annually produce 115 and 200 kg N per hectare, respectively (Kroth et al., 1982). Legumes and grasses grown in mixtures can either be compatible (avoid competition with each other), competitive (make demands on the same resources), or allelopathic (interact with each other; Haper, 1977). However, these relationships are difficult to determine for grazing experiments because the dominant species in mixtures may have competitive advantages during the time when compatibility and interactive relationships are evaluated. In addition, combining abilities for species and for specific species mixture can be estimated by a combining ability analysis (Springer et al., 2001). Springer et al. (2001) suggested that Illinois bundleflower was compatible with both switchgrass and indiangrass, but plant population in stands might differ depending on method of seeding. Furthermore, grass-legume mixtures may have equal plant populations (50% legume, 50% grass) if plots are planted directly by hand, however, unequal plant populations may arise if plots were seeded indirectly. Additionally, an increased contribution of legumes to dry matter yield could account for greater crude protein content found in grass-legume mixture (Springer et al., 2001).

Measuring forage mass

There is the need for accurate budgeting of forage in grazing systems in order not to fall short during the grazing season, and this requires frequent assessment of forage mass avalable in the pasture. The standard method of assessing forage mass is to clip and weigh the forage (Sanderson et al., 2001). However, this method requires great effort and expense to collect enough samples that will accurately represent the pasture. Most researchers commonly use the double-sampling techniques to increase the precision of pasture sampling, thus reduce labor and cost (Frame, 1993). Methods for estimating forage mass are classified as direct (destructive) sampling or indirect (nondestructive) estimates (Burns et al., 1989). For direct sampling, subsampling directly ranges from the use of a quadrat of a specific frame size hand-harvested at the soil surface to harvesting long narrow strips mechanically at a specific stubble height (Burns et al., 1989). However, the number, type, size, and location of the quadrats depend on the accuracy of the estimates needed (Carter, 1962). This method is recommended when studying sward characteristics, herbage production, and animal responses to forage mass (Frame, 1981), as well as when dry matter intake is to be estimated (Meijs et al., 1982). Meanwhile, indirect estimates of forage mass can be justified and are more likely to be used in demonstrations or by producers than direct estimates (Burns et al., 1989). These methods have been classified as visual, height and density, and assessment of non-vegetative attributes (’t Mannetje, 1978). The recommended use of indirect estimates as reported by Frame (1981) and ’t Mannetje (1978) depend on several factors including: reducing the cost of sampling through reduced labor, time, and equipment, obtaining multiple measurements on large areas or in remote sites, minimizing the disturbance of canopy, negating the stubble problem associated with cutting height, ranking treatments in trial where large comparative differences exist, acquiring only a relative index of forage mass, and increasing precision of direct measures where large variation exists and a large number of estimates are needed. Furthermore, height or density can be estimated alone, by ruler for height, or by some score for density (Burns et al., 1989), but a device like the weighted disc (Powell, 1974) or any of the rising or falling disc meter methods (Bransby et al., 1977) give an integrated reading of both height and density. The non-vegetative methods include capacitance meters, radioisotope attenuation, and spectral analyses. All indirect methods require calibration when quantification (kg/ha) is desired. Calibration employs a double-sampling method in which indirect readings are associated with actual herbage mass obtained by direct sampling, and the relationship between the two (regression equation) are used as basis for predicting direct values (Frame, 1981). Indirect estimates have greater error and are more likely to cause bias than direct methods (Meijs et al., 1982). However, the error problem with indirect sampling can be offset by increasing number of readings per unit area, and bias can be reduced by more frequent calibration (Burns et al., 1989).

CHAPTER III

MATERIALS AND METHOD

Site preparation and pasture establishment

The study was conducted at the Prairie experiment station at Prairie, MS during the summer grazing seasons of 2011 and 2012. Site preparation began in October 2007 with application of glyphospate (roundup™) to all pastures intended for native warm-season grass (big bluestem, little bluestem, and indiangrass) planting. Prescribed burning of all pastures took place in March, and May 2008; bermudagrass was eradicated from all pastures intended for native warm-season grass pasture establishment using 26.7% Isopropylamine salt of imazapyr (Chopper™ Generation II). First bermudagrass release was done on bermudagrass pastures with the application of 75% Sulfosulfuron (Outrider™) at 0.14 kg per hectare in October 2008; this was repeated in June 2009. Twelve pastures (nine grazed, three not grazed) averaging 9.2 hectare each were used for this study. Nitrogen fertilizer was applied to bermudagrass and native warm-season grass pastures at a rate of 60 and 34 kg per hectare respectively, and phosphorus and potassium were applied based on soil test results. In June 2008, pre-plant application of a combination of Glyphosphate and Imazapic (Journey™) was done on all native warm-season grass pastures, which was followed by establishment of native warm-season grass species in these pastures.

Varieties used were “Kaw” big bluestem, “Aldous” little bluestem, and “Kentucky ecotype” indiangrass. Herbicide, 2, 4-dichlorophenoxyacetic acid was applied in April 2010, followed by spot replanting in June 2010. Another prescribed burn was done on all pastures in March 2011. First year grazing commenced on May 19, 2011 and ended on September 20, 2011 on nine of twelve pastures, while grazing commenced on May 15, 2012 and ended on July 28, 2012 (two months earlier than planned) due to severe drought experienced during the second year. The three ungrazed pastures were evaluated for nutrient quality, and were used for a congruent wildlife research project.

Experimental treatments

Four treatments were used for this study: 1) Bermudagrass, a “traditional” summer forage that served as control; 2) a mono-species pasture of indiangrass established at 9 kg/ha; 3) a multi-species pasture of native warm-season grasses [big bluestem (*Andropogon gerardii),* little bluestem (*Schizachyrium soparium*), indiangrass (*Sorghastrum nutans*), and some selected native forbs] established at 9 kg/ha; 4) the same multi-species pasture as treatment 3. However, they were seeded at 4.5 kg/ha, a wildlife recommendation.

Animals

Two hundred and twenty-five (Initial BW = 237 ± 1.5 kg) and 230 growing British crossbred (Angus x Hereford) beef steers were used during the first and second year respectively. They were randomly assigned to each of twelve pastures with a stocking rate of 2.7 steers per hectare. Each steer had an electronic tag that was used for identification during weighing. Body weight was measured at initiation of the study by weighing un-fasted steers on two consecutive days. Un-fasted steers were re-weighed on a single day, every 28 days during the study, and on two consecutive days at termination of the study. The study lasted 112 and 62 days during the first and second year respectively. Steers had access to a continuous supply of grasses and fresh water in each pasture. No supplement or medications were provided during the period of study.

Forage yield and dry matter intake

Grass height was measured every 28 d using a rising plate disk meter with twenty contacts per pasture. In each pasture, the first disk contact site was selected by walking a randomly selected number of steps into the pasture from the gate. Thereafter, twenty-five steps, estimated to cover five diagonal transects (a "zigzag" pattern) in each pasture was used to determine the rest of the contact sites in order to cover the entire pasture. After taking disk meter measurements in each pasture, herbage from three $1m^2$ quadrants was harvested at 7.62cm above the soil surface. The three harvest sites were selected to represent the shortest, average, and tallest grass height in the pasture in order to calibrate the disk meter (indirect estimates) with harvested samples (direct estimates). The harvested herbage was weighed and dried in a forced-air oven at 65˚C for 48 hours. Air-dry herbage was re-weighed, ground to pass a 2mm diameter screen in a Thomas Wiley Mill™, and stored in a plastic bag at room temperature until analysis. A regression equation was developed with weights of clipped samples (direct estimates) and disk meter readings (indirect estimates) for each of the four pasture treatments.

Herbage accumulation, which is a measure of pasture growth rate, was estimated every 28 days using three $1m^2$ square enclosure cages in each grazed pasture. Cages were placed at the beginning of grazing at random locations in the pasture. At 28 d intervals, cages were placed at new locations measured to represent the “un-grazed” average mass for each 28 d period. Disk meter measurements were taken from the previously enclosed areas.

Forage sample collection

Herbage samples were randomly hand-plucked in a zigzag pattern from all pastures. Herbage samples from each pasture were placed in a plastic bag, labeled, and stored in a -5˚C freezer until prepared for nutrient analysis. Frozen samples were allowed to thaw, weighed, and dried in a forced-air oven at 65˚C for 48 hours. Dry samples were re-weighed and ground to pass a 2mm diameter screen in a Thomas Wiley Mill™. Nutrient analysis of grasses was used to compare bermudagrass and native warm-season grass species that were grown as a mono- or multi-species pasture.

Laboratory analysis

Ground herbage samples from the 1m² quadrants were analyzed for dry matter content using the procedures of AOAC (2003). Likewise, hand-plucked samples were analyzed for dry matter, ash, crude protein, neutral detergent fiber, acid detergent fiber, and ether extract according to the procedures of AOAC (2003). *In vitro* dry matter disappearance and *in vitro* neutral detergent fiber digestibility were also analyzed using the procedure modified from Cherney et al. (1997). Organic matter content was calculated from the analyzed ash content, while hemicellose was the difference between analyzed neutral and acid detergent fibers.

Statistical analysis

Experimental design was a completely randomized design, and all data were analyzed as a using the general linear model procedures of SAS (SAS Institute, Inc., Cary, N.C). When significant ($P < 0.05$), means were separated using Fischer's protected least significant difference. Means were tested for the effects of treatment, month, and year, as well as treatment x year and treatment by month interactions. When there were no significant interactions, means were pooled across treatments and months.

CHAPTER IV

RESULTS AND DISCUSSION

There were differences ($P < 0.05$) among treatments for organic matter, dry matter, crude protein, neutral detergent fiber, *in vitro* dry matter disappearance, and *in vitro* neutral detergent fiber disappearance. In addition, there were no treatment x year interactions. Therefore, the values presented in Tables 1 through 4 represent the mean of values from years 2011 and 2012 of the study. However, values for the last two months (August and September) represent data from 2011 only.

Nutrient composition of the four pastures is shown in Table 1. The multi-species pastures had more organic matter than bermudagrass pastures while indiangrass pastures was intermediate.

Crude protein concentrations were greater ($P < 0.05$) for bermudagrass pastures than the native warm-season grass pastures. Bermudagrass pastures received greater amount (60 kg/ha) of N fertilizer than the native grass pastures (34 kg/ha), which may account for the increase crude protein concentration of bermudagrass pastures compared with the native warm-season grass pastures. Crude protein concentration observed for all treatments from this study were greater than the average crude protein concentration (7.6 %) reported by Reid et al. (1988) for a wide range of native warm-season grasses, which included big bluestem, little bluestem, and indiangrass. The decreased average crude protein concentration reported by Reid et al. (1988) may be attributed to the fact that their samples were obtained from different locations in several states of the country, some of which may have different soil type as well as management practices. In addition, crude protein concentration for all treatments were above 7% reported to limit forage consumption (Minson, 1982). Diet crude protein concentrations below 7% do not meet the nitrogen needs of microbial populations in the rumen (Allison, 1985), and rumen microbes cannot maintain their growth due to less N concentration. Therefore, less feed would have been digested, and may have resulted in decreased feed intake.

Neutral detergent fiber was greater ($P < 0.05$) for indiangrass and grazed multi-species pastures compared to bermudagrass while un-grazed multi-species pastures were intermediate. Acid detergent fiber was greater ($P < 0.05$) for indiangrass and grazed multi-species pastures compared to bermudagrass and un-grazed multi-species pasture. The decrease in acid detergent fiber concentration of un-grazed multi-species pastures compared to the grazed pasture may be a result of the difference in seeding rates for both pastures, as the grazed multi-species pastures were seeded at twice the rate of the un-grazed multi-species pastures. Neutral and acid detergent fiber contents of grasses for this study were similar to concentrations reported by Vona et al. (1984) and Reid et al. (1988). Neutral and acid detergent fiber concentrations reported by Vona et al. (1984) and Reid et al. (1988) were more variable, but were the result of grasses collected from six and seven states respectively, which may have accounted for this variability. Because neutral and acid detergent fiber concentrations account for potential intake and digestibility of forages respectively (Reid et al., 1988), this result implies that native warm-season grass pastures have less intake (NDF concentration). On the other hand, forages from bermudagrass and un-grazed multi-species pastures were more digestible

(ADF concentration). Hemicellulose and ether extract were similar ($P = 0.4479$ and $P = 0.9674$ respectively) for all pastures.

In vitro dry matter disappearance and *in vitro* neutral detergent fiber digestibility were greatest ($P < 0.05$) for un-grazed multi-species and bermudagrass pastures. Grazed multi-species pastures were less digestible, with indiangrass pastures being intermediate. The *in vitro* dry matter disappearance results may be related to the acid detergent fiber concentration of the grasses because a decrease in acid detergent fiber concentration would result in an increased *in vitro* dry matter disappearance of grasses from the rumen. Values from this study with the exception of the grazed multi-species pastures (48.41 %) exceeded the range reported by Morris et al. (1982) and Reid et al. (1988) who evaluated the nutritive quality of warm-season grasses on less available phosphorus soil and in the Northeastern U. S. respectively.

Table 2 shows the mean nutrient composition of treatments presented by month. Organic matter content was not different overtime except for the month of August. However, this may not have any biological significance as the difference was only by about 1.5 % units. The similarities in organic matter content over time may be because all pastures received recommended management practices, had the same soil texture, climate, landscape position, and vegetation, as these are regarded as the major factors influencing organic matter composition of the soil. Furthermore, the vegetation was prairie type vegetation, which accounts for the increased organic matter concentration for all treatments. Dry matter concentration and ether extract were inconsistent across months. The inconsistency observed for dry matter concentration may be related to the amount of rainfall recorded at the site of study, as rainfall was inconsistent across the months of this study. As expected, crude protein, *in vitro* dry matter disappearance, and *in vitro* neutral detergent fiber digestibility decreased, while neutral detergent fiber, acid detergent fiber, and hemicellulose increased as study progressed. The results from this present study agree with findings of Vona et al. (1984), who reported that both neutral detergent fiber and acid detergent concentrations increased between late vegetative and early heading stages while concentration of crude protein declined with advancing grass maturity. A probable explanation for the increase in neutral detergent fiber, acid detergent fiber, and hemicelluloses may be due to the increased concentration of cell wall components (Vona et al., 1984). The decrease in crude protein concentration may be attributed to an increase in the proportion of stem or a decrease in crude protein concentration of leaf, stem, or both (Owens et al., 2008). Another possible reason for the decreased crude protein concentration may be because all pastures were only fertilized at the beginning of the study and not during the study. Crude protein concentration for June and August observed for this study were different from those reported by Gillen and William (1998) during the same period. However, they are similar to the present trial in that crude protein concentration decreased with advanced maturity. This implies that plant maturity at harvest may be a major factor affecting forage quality including decreased *in vitro* dry matter disappearance and crude protein, and increased neutral and acid detergent fiber concentration (Waramit et al., 2012).

Estimated pasture dry matter yield was different ($P < 0.05$) for all treatments during the second month (July), but tended to be different during the first month (June; Table 3). However, they were similar during the last two months (August and September). The average dry matter yield for indiangrass pastures was 4495.4 kg/ha, which is less than 5,590 kg/ha reported by Hall et al. (1982), but average bermudagrass pasture dry matter yield was greater than that reported by Johnson et al. (2001). However, there is no literature regarding dry matter yield for multi-species pastures. Steers grazing indiangrass pastures consumed more forage than steers grazing other pastures during the first two months (Table 4), while steers grazing bermudagrass pastures consumed the least amount of dry matter during June and July. The increased forage dry matter intake by steers grazing indiangrass pastures may be because they had more forage available to them compared with the other two pastures (Table 3). Forage availability is an important factor that influences forage intake and may be dependent on physical presentation of the available forage to the grazing animals (Allison, 1985). Therefore, the less forage intake that was recorded for steers grazing bermudagrass pastures may be attributed to the unavailability of forage in these pastures, and not as a result of rumen fill, hence, influencing the average daily gain of steers grazing these pastures.

In addition, the average daily gain of steers were similar among treatments between days 1 to 28 (June), 56 to 84 (August), and 84 to 110 (September). During the peak of grass production (days 28 to 56; July), average daily gain was greater ($P < 0.02$) by steers grazing indiangrass pastures (1.1 kg) and grazed multi-species pasture (0.9 kg) than bermudagrass (0.4 kg). Average daily gains of steers grazing indiangrass pastures was similar to that reported by Krueger and Curtis (1979), but were greater than that reported by Galloway et al. (1992) for steers grazing bermudagrass pastures. The differences observed for average daily gain for this study may be attributed to the availability of more forage on indiangrass pastures compared with other pastures. However, steers grazing indiangrass and grazed multi-species pastures had similar feed conversion ratio (5.86 and 5.74 feed/gain respectively), which was less than those grazing bermudagrass pastures (9.24 feed/gain). This implies that steers grazing bermudagrass pastures were least efficient while those consuming grazed multi-species pastures had the best feed efficiency.

CHAPTER V

SUMMARY/CONCLUSIONS

The results from this study suggest that establishing a mono- (indiangrass) or multi-species (Mix G: big bluestem, indiangrass, and little bluestem) pasture did not result with different nutrient content of forages. Additionally, rate of seed establishment had no impact on the nutritional quality of these grasses. However, the mono-species native warm-season grass pastures produced greater amount of forage during peak production period (July) than the multi-species pastures. Furthermore, steers grazing the mono-species pastures gained more average daily weight than those grazing multi-species pastures. Therefore, producers without the need to grow multi-species pasture may establish mono-species pastures of native warm-season grasses for livestock production. Similarly, native warm-season grasses offer viable alternative to bermudagrass for grazing cattle during the summer, as more forage was available, and therefore, consumed by steers. Additionally, because indiangrass is one of native-warm season grasses that support wildlife production, producers willing to incorporate these species (wildlife) into livestock production systems may do so without adversely impacting production. Further studies should be done on smaller pastures focusing only on livestock production, because these will ensure a more uniform pasture growth, hence resulting in data that are more accurate.

Table 1 Nutrient composition (% dry matter basis) of native warm-season grasses established as mono- or multi-species pasture pooled across all months for each treatment during 2011 and 2012 summer grazing

Treatment	**[a]DM**	**[a]OM**	**[a]CP**	**[a]NDF**	**[a]ADF**	**[a]HC**	**[a]EE**	**[a]IVDMD**	**[a]IVNDFD**
[b]BG	28.86^{c}	91.45^{c}	10.32^{d}	66.38^{c}	34.04^{c}	32.35	12.07	55.14^{d}	65.90^{d}
[b]IG	29.43^{c}	91.90^{cd}	8.96^{c}	68.74^{d}	35.51^{d}	33.23	12.01	56.61^{de}	67.75^{de}
[b]Mix G	34.52^{d}	92.67^{d}	8.05^{c}	68.93^{d}	35.41^{d}	33.52	11.88	48.41^{c}	60.54^{c}
[b]Mix NG	28.45^{c}	92.56^{d}	8.98^{c}	67.29^{cd}	33.92^{c}	33.37	11.99	60.35^{e}	71.24^{e}
SEM	1.327	0.339	0.38	0.684	0.401	0.557	0.261	1.504	1.302
P-Value	0.0056	0.0467	0.0012	0.0298	0.0054	0.4479	0.9674	0.0001	0.0001

[a]OM = Organic matter; DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; HC = Hemicellulose; EE = Ether extract; IVDMD = *in vitro* DM disappearance; IVNDFD = *in vitro* NDF disappearance
[b]BG = Grazed bermudagrass; IG = Grazed indiangrass; Mix G = Grazed multi-species grasses; Mix NG = Un-grazed multi-species grasses
[c,d,e]Means within column lacking common superscript(s) differ *($P < 0.05$)*

Table 2 Monthly nutrient composition (% dry matter basis) of native warm-season grasses established as a mono- or multi-species pasture pooled across all treatments for each month during 2011 and 2012 summer grazing

Month	**[a]DM**	**[a]OM**	**[a]CP**	**[a]NDF**	**[a]ADF**	**[a]HC**	**[a]EE**	**[a]IVDMD**	**[a]IVNDFD**
[b*]May	23.36^{d}	92.68^{e}	13.41^{g}	62.20^{d}	31.45^{d}	30.76^{d}	11.64^{d}	70.75^{f}	79.96^{g}
[c*]June	32.79^{f}	92.97^{e}	9.29^{f}	66.12^{e}	33.29^{e}	32.83^{e}	12.45^{ef}	61.07^{e}	71.58^{f}
[c*]July	35.33^{f}	92.70^{e}	8.11^{e}	67.73^{e}	34.48^{f}	33.25^{ef}	11.66^{de}	57.69^{e}	68.27^{e}
[c#]August	27.79^{e}	90.48^{d}	8.01^{e}	71.34^{f}	37.31^{g}	34.03^{eg}	11.66^{de}	45.17^{d}	57.70^{d}
[c#]Sept.	33.79^{f}	91.98^{e}	6.61^{d}	71.78^{f}	37.06^{g}	34.73^{fg}	13.17^{f}	40.97^{d}	54.27^{d}
SEM	1.756	0.448	0.503	0.904	0.53	0.737	0.345	1.99	1.723
P-Value	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[a]OM = Organic matter; DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; HC = Hemicellulose; EE = Ether extract; IVDMD = *In vitro* DM disappearance; IVNDFD = *In vitro* NDF disappearance
[b]May = values represent pooled nutrient composition of all treatments at initiation of experiment
[c]July to Sept. = values represent pooled nutrient composition of all treatments after 28 days
*May to July = values represent average values from 2011 and 2012 summer grazing
[#]August and Sept = represent average values from 2011 only
[d,e,f,g]Means within column lacking common superscript(s) differ *($P < 0.05$)*

Table 3 Estimated monthly pasture dry matter yield (kg/ha) of grazed native warm-season grass pastures established as a mono- or multi-species pasture during 2011 and 2012 summer grazing

Treatment	a*June	a*July	a#August	a#September
bBG	3535.40c	2718.59c	2252.97	2063.79
bIG	5225.14d	6494.48e	4257.57	2004.47
bMix G	3961.21cd	4328.95d	2584.07	3193.10
SEM	507.56	529.08	780.48	566.98
P-Value	0.0879	0.0010	0.2301	0.3179

aJune to Sept. = estimated pasture DM yield during every 28-day period
*June and July = values represent average values from 2011 and 2012 summer grazing
#August and Sept = represent average values from 2011 only
bBG- Grazed bermudagrass; IG- Grazed indiangrass; Mix G- Grazed multi-species grasses
c,d,eMeans within column lacking common superscript(s) differ *($P < 0.05$)*

Table 4 Estimated monthly dry matter intake (kg/2.7steers/ha) of steers grazing native warm-season grass pastures established as a mono- or multi-species pasture during 2011 and 2012 summer grazing

Treatment	a*June	a*July	a#August	a#Sept.
bBG	358.44c	290.25c	314.92	153.09
bIG	610.06d	760.04e	386.94	192.59
bMix G	446.48cd	490.53d	368.96	255.66
SEM	62.76	52.38	83.99	84.44
P-Value	0.043	0.0001	0.8246	0.7021

aJune to Sept. = estimated steer DM intake during every 28-day period
bBG- Grazed bermudagrass; IG- Grazed indiangrass; Mix G- Grazed multi-species grasses
*June and July = values represent average values from 2011 and 2012 summer grazing
#August and Sept = represent average values from 2011 only
c,d,eMeans within column lacking common superscript(s) differ *($P < 0.05$)*

REFERENCES

Allison, C. D. 1985. Factors affecting forage intake by range ruminants: a review. J. Range Mgt. 38(4).

Belding, R., W. M. Giuliano, D. Putnam, and J. Taracido. 2000. Integrating wildlife management and agriculture: conserving biodiversity through long –term partnerships. In: Therres, G. D. (Ed.), conservation of biological biodiversity: A key to the restoration of the Chesapeake Bay ecosystem and beyond. Maryland department of natural resources, Annapolis, pp. 48-51.

Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disk meter for rapid estimation of herbage yield in grazing trials. Agron. J. 69: 393-396.

Burns, J. C., H. Lippke, and D.S. Fisher. 1989. The relationship of herbage mass and characteristics to animal responses in grazing experiments.

Burns, J. C. and L. E. Sollenberger. 2002.Grazing behavior of ruminants and daily performance form warm-season grasses. Crop Sci. 42: 873-881.

Carter, J. F. 1962. Herbage sampling for yield. Tame pastures. p. 90-101. In G. O. Mott et al. (ed.) Pasture and range research techniques. Comstock Publ. Assoc. Ithaca, NY.

Collins, M. and J. O. Fritz. 2003. Forage quality. In: Barnes, R. F., C. J. Nelson, M. Collins, K. J. Moore (eds.), Forages. Vol 1. An introduction to grassland agriculture, 6th ed. Iowa State Press, Ames, IA, pp. 363-390.

Frame, J. 1981. Herbage mass. p. 39-69. In J. Hodgson et al. (ed.) sward measurement handbook. British Grassl. Soc., Grassl. Res. Inst., Hurley, Maidenhead, Berkshire. UK.

Frame, J. 1993. Herbage mass. p. 59-63. In A. Davies et al. (ed.) sward measurement handbook. The Br. Grassl. Soc., Reading, UK.

Forbes, T. D. A. 1988. Researching the plant-animal interface: the investigation of ingestive behavior in grazing animals. J. Anim. Sci. 66: 2369-2379.

Galloway, D. L., Sr, A. L. Goestsch, W. Sun, L. A. Forster, Jr, G. E. Murphy, E. W. Grant, and Z. B. Johnson. 1992. Digestion, feed intake, and live weight gain by cattle consuming bermudagrass hay supplemented with whey. J. Anim. Sci. 70: 2533-2541.

Gillen, R. L. and W. A. Berg. 1998. Nitrogen fertilization of native grass planting in western Oklahoma. J. Range Mgt. Abstr.

Giuliano, W. M. and S. E. Daves. 2002. Avian response to warm-season grass use in pasture and hayfield management. J. Biol. Cons. 106:1-9.

Griffin, J. L. and G. A. Jung. 1983. Leaf and stem forage quality of big bluestem and switchgrass. Agron. J. 75:723-726.

Hall, K. E., J. R. George, and R. R. Riedl. 1982. Herbage dry matter yields of switchgrass, big bluestem, and indiangrass with N fertilization. Agron. J. 74: 47-51.

Harper, J. L. 1977. Population biology of plants. Academic Press Ltd., London, England.

Haper, C. A., G. E. Bates, M. P. Hansbrough, M. J. Gudlin, J. P. Gruchy, and P. D. Keyser. 2007. Native warm-season grasses: Identification, establishment, and management for wildlife and forage production in the Mid-South. A manual for natural resource professionals and other land managers. Uni. of Tenn. Ext., PB 1752.

Hodgson, J. 1982. Influence of sward characteristics on diet selection and herbage intake by the grazing animal. p. 153-166. In J. B. Hacker (ed.) Nutritional limits to animal production from pastures. CAB Int., Farnham Royal, UK.

Johnson, C. R., B. A. Reiling, P. Mislevy, and M. B. hall. 2001. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. J. Anim. Sci. Abstr.

Jung, G. A., C. F. Gross, R. E. Kocher, L. A. Burdette, and W. C. Sharp. 1978. Warm-season grasses extend beef cattle forage. Sci. Agr. 25(2): 6.

Jung, G. A., J. L. Griffin, R. E. Kocher, J. A. Shaffer, and C. F. Gross. 1985. Performance of switchgrass and big bluestem curtivars mixed with cool-season species. Agronomy Journal 77: 846-850.

Kroth, E. M., L. Meinke, and R. Matlas. 1982. Effect of nitrogen fixation by legumes in cool season grass mixtures. Univ. of Missouri Agric. Exp. Stn. Res. Bull. No. 1047, Columbia, MO.

Krueger, C. R. and D. C. Curtis. 1979. Evaluation of big bluestem, indiangrass, sideoats grama, and switchgrass pastures with yearling steers. Agron. J. 71: 480-482.

Marten, G. C. 1985. Nutritional value of legumes in temperate pastures of the U. S. p. 201-212. In R. F. Barnes et al. (ed.) Forage legumes for energy-efficient animal production. Proc. Trilateral Workshop, Palmerston North, NZ, USDA, Washington, DC.

McDowell, L. R. 1992. Minerals in animal and human nutrition. Academic Press, San Diego, CA.

Meijs, J. A. C., R. J. K. Walters, and A. Keen. 1982. Sward methods. p. 11-36. In J. D. Leaver (ed.) Herbage intake handbook. The British Grassl. Soc., Grassl. Res. Inst., Hurley, Maidenhead, Berkshire, UK.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical model of ruminal function. J. Anim. Sci. 64: 1548-1558.

Minson, D. J. 1990. Forage in ruminant nutrition. Academic Press, San Diego, CA.

Moore, J. E. 1980. Forage crops p. 61-91, *In* Hoveland, C. S. (ed.) crop, quality, storage, and utilization. ASA, CSSA, and SSSA, Madison, WI.

Moore, J. E., J. C. Burns, A. C. Linnerud and R. J. Moore. 1980. Relationships between the properties of southern forages and animal response. Proc. 37th Southern Pasture and Forage Crop Improvement Conf., Nashville, TN.

Morris, R. J., R. H. Fox, and G. A. Jung. 1982. Growth, P uptake, and quality of warm and cool-season grasses on a low available P soil. Agron. J. Abstr.

Mouriño, F., K. A. Albrecht, D. M. Schaefer, and P. Berzaghi. 2003. Steer performance on kura clover-grass and red clover-grass mixed pastures. Agron. J. 95: 652-659.

Natural Resources conservation Service. 2005. Native warm-season grasses and wildlife. May 2005. Fish and wildlife habitat management leaflet. Number 25.

Nelson, C. J. and L.E. Moser. 1994. Plant environment and quality. pp. 115-154. *In* G. C. Fahey Jr. et al. (ed.) Forage quality, evaluation, and utilization. ASA, CSSA, and SSSA, Madison, WI.

Nelson, C. J. and J. C. Burns. 2006. Fifty years of grassland science leading to change. Crop Sci. 46: 2204-2217.

Noller, C. H. 1997. Nutritional requirements of grazing animals. p. 145-172. In J. A. Gomide (ed.) Int. Symp. on Aniaml production under grazing, Vicosa, Brazil. 4-6 Nov. 1997. Dep. de zootec,. Univ. Federal de Vicosa,Vicosa, Brazil.

Owens, D., M. McGee, and T. Boland. 2008. Effects of grass regrowth interval on intake, rumen digestion, and nutrient flow to the omasun in beef cattle. Anim. Feed Sci. and Tech. J. 146: 21-41.

Powell, T. L. 1974. Evaluation of weighted disc meter for pasture yield estimation on intensively stocked dairy pasture. N.Z. J. Exp. Agric. 2: 237-241.

Propheter, J. L., S. A. Straggernborg, X. Wu, and D. Wang. 2010. Performance of annual and perennial biofuel crops: yield during the first two years. Agron. J. 102: (2) 806-814.

Puoli, J. R., G. A. Jung, and R. L. Reid. 1991. Effects of nitrogen and sulfur on digestion and nutritive quality of warm-season grass hays for cattle and sheep. J.Anim. Sci. 69:843-852.

Reid, R. L., G. A. Jung, and D. W. Allinson. 1988. Nutritive quality of warm season grasses in the northeast. p 1-57. West Virginia Agric. and For. Exp. Sta. Bull. 699, Morgantown.

Reid, R. L., G. A. Jung, and W. V. Thayne. 1988. Relationships between nutritive quality and fiber components of cool season and warm season forages: a retrospective study. J. Anim. Sci. 66: 1275-1291.

Sanderson, M. A., C. A. Rotz, S. W. Fultz, and E. B. Rayburn. 2001. Estimating forage mass with commercial capacitance meter, rising plate meter, and pasture ruler. Agron. J. 93: 1281-128.

Solomon, J. K. Q., B. Macoon, D. J. Lang, J. A. Parish, and R. C. Vann, 2001. A novel approach to grass-legume management. Crop Sci. Vol. 51. July-August 2011.

Springer, T. L., G. E. Aiken, and R. W. McNew. 2001. Combining ability of binary mixtures of native, warm-season grasses and legumes. Crop Sci. 41: 818-823.

‘t Mannetje, L. (ed.). 1978. Measuring quality of grassland vegetation. p. 63-95. In measurement of grassland vegetation and animal production. Bull. 52. Commonw. Agric. Bureaux., Farnham Royal, Bucks, England.Marten, G. C. 1985. Nutritional value of legume in temperate pastures of the U. S. p. 209-212. In R. F. Barnes et al. (ed.) Forage legumes for energy-efficient animal production. Proc. Trilateral workshop, Palmerston North, NZ, USDA, Washington, DC.

Ungar, E. D. 1998. Ingestive behavior. p. 185-218. In J. Hodgson and A.W. Illius (ed.) the ecology and management of grazing systems. CAB Int., New York.

Vona, L. C., G. A. Jung, R. L. Reid, and W. C. Sharp. 1984. Nutritive value of warm-season grass hays for beef cattle and sheep; Digestibilty, Intake and Mineral utilization. J. Anim.Sci. 59: 1582-1593.

Waramit, N. 2010. Native warm-season grasses: species, nitrogen fertilization, and harvest dates on biomass yield and composition. Iowa State Uni. Ames, Iowa. Dissertation.

Waramit, N., K. J. Moore, and S. L. Fales. 2012. Forage quality of native warm-season grasses in response to nitrogen fertilization and harvest date. J. Anim. Feed Sci. and Tech. 174: 46-59.

Wilson, J. R. 1982. Environmental and nutritional factors affecting herbage quality. In: Hacker, J. B. (Ed.), Nutritional Limits to Animal Production from Pastures. Commonwealth Agricultural Bureaux, Farnham Royal, UK, pp. 111-131.