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Preservation of Nutrients in Cool- and Warm-Season Forages At Different Stages of Maturity and Management

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To the Graduate Council:

I am submitting herewith a thesis written by Jason Allen Shultz entitled "Preservation of Nutrients in Cool- and Warm-Season Forages At Different Stages of Maturity and Management." 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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Preservation of Nutrients in Cool- and Warm-Season Forages At Different Stages of Maturity and Management

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ABSTRACT

The overall goals of the studies described in this thesis were to investigate management practices of tall fescue and native warm-season grasses (**NWSG**) and find the best time to harvest and method to preserve forage quality. Study one investigated the effects of maturity on tall fescue and switchgrass and the effects of preservation method on forage quality. This study confirmed that maturity reduced forage quality in both tall fescue and switchgrass. Both tall fescue and switchgrass were successfully preserved as haylage or hay and did not differ in forage quality. Forages harvested before mid-May met the TDN and CP requirements for winter feeding in both spring- and fall-calving herds. Feeding tall fescue from mid-May harvest to stocker cattle would result in a gain 0.45 kg/day based on TDN provided. However, switchgrass from the same harvests would result in stockers gaining 0.63 kg/day. Study two investigated the effects of multiple harvests, N fertilization, forage species, and preservation methods on NWSG quality and biomass production. Neither fertilization nor species had an effect on forage quality or biomass production. June harvested NWSG had similar forage quality regardless of preservation methods. Biomass production from switchgrass was reduced by a summer forage harvest, but a big bluestem/indiangrass mix stand was not. However, a June forage harvest paired with a biomass harvest resulted in greater yearly yields. Study three investigated the effects of treating and ensiling mature switchgrass with alkali on forage harvested in October and November. The October harvest had decreased NDF content when treated with alkali. Concentrations of at least three g of alkali treatment per 100 g of forage DM reduced NDF content, which could potentially improve forage intake. The results of these studies are promising and provide forage and livestock producers needed information on timing of harvest and preservation methods. However, more research needs to be completed to determine the ideal preservation method of

cool- and warm-season grasses based on a cost benefit analysis in regards to the preservation of nutrients in forages and the ability to meet cattle requirements.

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INTRODUCTION

In the Southeast United States forage production is vital for beef producers, especially in areas where crops are not easily grown. These available forages feed and maintain the beef cattle industry, which is predominantly made up of cow-calf operations. In the 2010 USDA census, Tennessee was ranked 15th in the nation for number of cattle and calves, with nearly two million head (USDA, 2011). The same census ranked the state 20th in the nation and list total cattle sales at over 633 million dollars (USDA, 2011). With the rising cost of both fuel and grain, it is vital to increase the productivity of the forage base to feed cattle grown for beef consumption. Better management of forages can lead to higher quality livestock feed, increased feed efficiency, and new opportunities for increased profits for beef producers.

If a cattle producer were to implement both a cool- and warm-season grasses in their forage-system grazing cattle cannot consume enough to manage forage growth during late spring to early summer. This may result in excess available forage. If a producer has both of these forages in their production system they need to best utilize the resources they have available to them. This can be achieved through proper management of forages to ensure that the best yields and quality are preserved. The evaluation of both cool- and native warm-season grasses (**NWSG**) is needed for forage and biomass management systems through harvest, preservation, and fertilization to develop management systems for forage and livestock producers to best utilize current and potential forage systems and to potentially improve the quality of these forages.

Tennessee lies within the fescue belt; with roughly 1.5 million hectares of pasture consisting of tall fescue (*Lolium arundinaceum (schreb.*) Darbyshire) as the primary forage for the state's beef industry. Tall fescue is a hardy grass that is widely adapted to various soil types and produces an abundance of good quality forage throughout the majority of the year. Much of the plant's hardiness comes from a symbiotic endophytic fungus (*Neotyphodium coenophialum)* that lives between the plant's cell walls. Unfortunately, the same endophyte that provides the ability for tall fescue to grow well in less favorable conditions also produces alkaloid toxins that reduce animal performance and cause symptoms of tall fescue toxicosis. This issue may lead producers to find substitutes for tall fescue, which often don't perform nearly as well, or to find ways to reduce the effects of the alkaloids. Until effective and affordable alternatives are found, most producers will stick with what they have available to them, tall fescue.

Cool-season forages such as tall fescue mature and decrease in quality rapidly during the late spring. This drop in forage quality can lead to reduced animal performance as a whole. The quality of harvested forage can be improved if it is harvested during earlier stages of growth when the plant contains more available nutrients. However, cool-season forages are in these early stages usually around the time when seasonal spring rains are frequent. These rains make hay drying difficult and often result in delayed cuttings and poor quality hay preservation. Available carbohydrates are vulnerable to rain damage and account for 70% of cell contents lost to rain leaching (Fonnesbeck et al., 1986). As a result of the seasonal weather, many producers wait until spring rains have ended and hay drying conditions become more favorable; however by this time forage and nutrient quality have declined.

Hay production under this management style tends to lead to poor quality forage that is low in nutrient content. The production of hay from cool-season forages that have matured or been compromised by unfavorable weather conditions lead to a need for cattle producers to feed more expensive supplements. Preserving forage as haylage instead of hay would increase forage quality, decrease the need of expensive supplementation, and improve animal performance.

The production of round bale haylage could be a solution to the problem of timing cool-season forage harvest and preservation. Grass haylage production is not as weather dependent and allows for the harvest of forages earlier in the spring when quality is high and weather is questionable. This method could also provide a way to reduce tall fescue toxicosis by altering or degrading alkaloid toxins during the fermentation process needed in haylage production.

Another option to meet the need for quality forage that is less weather dependent is the use of NWSG, such as switchgrass (*Pancium virgatum* L.), big bluestem (*Andropogon gerardi* Vitman), and indiangrass (*Sorgastum nutans* L. Nash). These warm-season grasses begin their growth stages in late spring to early summer and mature more rapidly compared to cool-season forages. Harvest and preservation of these warm-season forages could help offset the effects that unfavorable spring rains can have on the feeding quality of preserved forages that mature earlier. These forages also do not contain the toxins seen in tall fescue and could be used to help offset decreased animal performance.

Biofuel production from biomass producing forages and crops is currently being evaluated across the United States. Therefore, production of switchgrass and other high yielding warm-season forages could be a potential secondary source of income for beef and forage producers. Under proper stand management the rapid growth and maturity of these forages could provide the opportunity for multiple harvests throughout the growing season. Excess forage produced could be preserved either as hay or haylage depending on weather conditions. However, the management of warm-season grasses primarily for biomass production typically uses a single late fall cutting. Developing techniques for stand management and harvest of these warm-season grasses as hay and haylage needs to be evaluated in order to determine their effects on the quality that these forages may have for feeding livestock.

The objectives of this study were 1) to determine how management based on maturity at harvest and method of preservation of tall fescue affects yields, forage quality, and ergovaline concentrations in hopes of reducing effects of tall fescue toxicosis in beef cattle; 2) to determine how management based on maturity at harvest, method of preservation, and nitrogen fertilization of native warm-season grasses affects yields, forage quality, and biomass production; 3) to determine the effects of alkali treatment on ensiled late maturity stage switchgrass on nutritive quality and nutrients available for livestock feeding.

CHAPTER 1: LITERATURE REVIEW

Tall Fescue

Tall Fescue (*Lolium arundinaceum (*schreb.) Darbyshire) is a predominant forage that covers over 14 million hectares of the humid transition zone of the United States, also called the fescue belt (Paterson et al., 1995). Tall fescue is not only plentiful; it is also easily established and provides two periods of forage production. Tall fescue provides both a spring growing period, which begins in early March and ends in late June, and a fall growth period that begins in mid-September and ends in early December (Ball et al., 2007).

Prevalence of tall fescues and its ability to endure unfavorable conditions is a result of the plant's relationship with an endophytic fungus (*Neotyphodium coenophialum*). Bacon (1995) reported that the endophyte lives between the cell walls of the plant, is found in all plant tissues, and is concentrated in the seedheads. Endophyte infected tall fescue (**E+**) is shown to have a greater ability to survive drought stress when compared to tall fescue that is not infected (**E-**) with the endophyte (Arechavaleta et al., 1989). However, the presence of the endophyte is also associated with a syndrome called tall fescue toxicosis when animals consume E+ tall fescue.

Tall Fescue Toxicosis

Tall fescue toxicosis often leads to reduced animal performance and leads to a loss of income for beef producers. Bacon et al., (1977) first reported about the endophyte/toxicity relation and states that the entophytic fungus in tall fescue was correlated to have a relationship to tall fescue toxicosis in cattle. Paterson et al., (1995) reported that tall fescue toxicosis in cattle have reduced daily feed intake and reduced weight gain. Tall fescue toxicosis is also linked to reproduction issues, with decreases in reproduction rates and delayed puberty (Jones et al., 2003). It has been estimated that the economic loss in livestock due to the toxins produced by the endophyte, in the form of lost production, leads to fewer calves being born and reduced weaning weights; these two losses combined have a value at around $609 million per year (Hoveland, 1993). Taking this dated figure in mind, the use of an inflation calculator provided by the US Department of Labor Statistics this value is calculated to be around $969 million per year in today's dollars.

The toxic compounds produced by the endophyte that are responsible for tall fescue toxicosis are ergot alkaloids. Belesky et al., (1988) and Porter, (1994) reported that the ergopeptide alkaloid ergovaline represents the majority of alkaloids isolated from toxin producing E+ tall fescue. Fribourg et al., (1991) reported that as the level of endophyte infection is reduced from 80% to 3% signs of fescue toxicosis are reduced and average daily gains are increased in cattle. These findings indicate that level of infestation and quantity of toxin consumed affect animal performance.

Reducing Tall Fescue Toxicosis

The options for producers wanting to alleviate tall fescue toxicosis include either replacing current E+ stands with E- (novel or endophyte-free) non-toxic tall fescue (Waller, 2009) or other species of forage, or employing some form of management strategy. Nihsen et al., (2004) reported that steers had higher average daily gain (**ADG**), normal rectal temperatures and respiratory rates, and normal prolactin levels when grazing tall fescue pastures either inoculated with a novel (non-ergovaline producing) endophyte or endophyte-free tall fescue. In the same trial steers grazing KY-31 E+ tall fescue had lower ADG, elevated rectal temperatures and respiratory rates, and suppressed prolactin levels (Nihsen et al., 2004).

Management options in tall fescue stands to reduce tall fescue toxicosis include limiting N fertilization in that N application can increase alkaloid production, diluting the pasture by interseeding E+ stands with legumes and other forages, harvesting the stand for hay, and not grazing E+ stands during late spring or summer (Roberts et al., 2009b). These options are proven ways to reduce tall fescue toxicosis, but a few can be costly for producers and may not be economically feasible. Therefore, it is only recommended to replace stands of E+ fescue when the endophyte infection level is considered high.

Animals perform well on tall fescue at low level endophyte levels and periods when alkaloid production is low. For instance, Holstein cows fed a first-cut, early boot, May harvested tall fescue in total mix ration (**TMR**) silage from a low level endophyte infected stand had higher milk production than cows fed orchardgrass TMR silage, and performed equally to cows fed an alfalfa TMR silage (Cherney et al., 2004). Stockpiling Ky-31 E+ tall fescue for winter grazing from December to March showed a decline of nearly 85% of total alkaloids by the end of the winter, and rapid losses after mid-December (Kallenbach et al., 2003).

The harvest and preservation of tall fescue is one of the more economical options for producers to help reduce the effects of alkaloids causing tall fescue toxicosis. Harvesting tall fescue and preserving it as hay can result in a significant decline in the total ergovaline concentration, and longer curing times result in lower ergovaline levels. Nearly 75% of total ergovaline decline that occurred was in the first days directly after clipping during the curing stage in the field, once baled ergovaline continues to degrade but much more slowly and at a continuous rate during an 18 month storage period (Roberts et al., 2009b). Norman et al., (2007) found similar results with 27.3% and 79.4% reduction in ergovaline concentrations at two separate locations directly after mowing and no effect during covered or outdoor storage. Tall fescue in the form of fresh-chop and as silage, wilted to 55% moisture, was found to be higher in ergot alkaloid concentration than hay sun-cured to 16% moisture or sun-cured and ammoniated hay; however, in all treatments alkaloid concentrations were still considered to be toxic (Roberts et al., 2002). It was suggested that ergopeptide alkaloids such as ergovaline are sensitive to acids, bases, light, and air (Garner et al., 1993). The same study also reported a list containing both lactic and acetic acids as solvents of ergot alkaloids. Both of these acids are produced during anaerobic fermentation, such as the ensiling of forages. However, the production and concentration of these acids vary due to factors such as available carbohydrates and moisture level at the time of ensiling.

Replacing tall fescue or providing other forage species can help reduce the effects of tall fescue toxicosis. The use of native warm-season grasses (**NWSG**) may provide an option for both alleviating tall fescue toxicosis and/or fill the forage gap seen in tall fescue during the summer months.

Native Warm-Season Grasses

Native warm-season grasses are forages that are classified as tropical (**C_4**) plants based on their photosynthetic pathway. The term C_4 comes from the fixation of CO_2 forming a four carbon acid (Nelson, 1995). Switchgrass (*Pancium virgatum* L.), big bluestem (*Andropogon gerardi* Vitman), and indiangrass (*Sorgastum nutans* L. Nash) are three species that are currently being investigated for their forage quality and high yielding ability for potential biofuel production. Burns and Fisher, (2012) declared that NWSG's can be pastured during their mid-summer growing season or be harvested and fed in periods of drought or for winter feeding as a ration or ration component. Reid et al., (1988) compared data from 428 forage species fed to cattle and sheep and reported that, when compared to cool-season (**C_3**) grasses, C_4 grass intake levels were higher than would be expected based on their dry matter digestibility.

Switchgrass has historically been associated with the North American tallgrass prairie, and ranges from southern Canada to northern Mexico and from the Atlantic coast to the Rocky

Mountains (Wullschleger et al., 2010). With a variety of lowland and upland cultivars available switchgrass has a great potential for biomass production; however, this depended on proper cultivar selection for geographic location (Parrish and Fike, 2005).

Big bluestem is another native grass found in the tallgrass prairie with better nutritive value than switchgrass (Moser and Vogel, 1995). Big bluestem has much potential as a source of preserved forage (Burns and Fisher, 2012). Big bluestem is often inter-seeded with indiangrass and matures later than switchgrass (Mitchell and Anderson, 2008). Indiangrass is a tallgrass and commonly found in hay meadows, rangelands, and pastures of the Eastern Great Plains (Hitchcock and Chase, 1950). Indiangrass matures later than both switchgrass and big bluestem, and typically has a higher quality if harvested at the same level of maturity (Mitchell and Anderson, 2008).

Native warm-season grasses can also be used as a feed source for ruminants. Burns et al., (1984) reported that out of three warm-season grasses (switchgrass, ‘coastal’ bermudagrass, and flaccidgrass) grazed by beef steers, switchgrass provided the most available forage, allowed for a more consistent stocking rate, and had the highest daily gains.

Another grazing trial reported that steers grazing indiangrass had higher ADG than steers on big bluestem and switchgrass. Indiangrass, however, had fewer days of available forage, which resulted in switchgrass and big bluestem having the highest beef gains per hectare. This is likely because of their longer periods of available forage due to indiangrass reaching later stages of maturity sooner (Krueger and Curtis, 1979).

Forage Growth and Photosynthesis

Plant growth is achieved through the formation and processing of sugars produced from a carbon source, carbon dioxide (**CO_2**), during photosynthesis. These sugars, particularly glucose, are used and stored either as an energy source in the form of starches or are used to form structural components, such as the plant's cell walls, by forming cellulose and hemicellulose. Grasses can undergo one of two major biochemical pathways that reduce CO_2, and these pathways are closely related to differences in leaf anatomy (Waller and Lewis, 1979). Both warm-season and cool-season grasses are classified according to their fixation of CO_2.

The process of photosynthesis in both C_4 and C_3 plants was described by Nelson, (1995) as follows: Photosynthesis in C_4 plants starts with the fixation of CO_2 to phosphoenolpyruvate, a 3-carbon acid, within the mesophyll cells using the enzyme phosphoenolpyruvate carboxylase (**PEPc**) into oxaloacetate, a 4-carbon acid. This 4-carbon acid is then transported to the inner bundle sheath cells where CO_2 is removed and fixed by the enzyme ribulose bisphosphate carboxylase (**RuBisCO**) to ribulose bisphosphate, a 5-carbon phosphorylated sugar, into two molecules of a 3-carbon acid called 3-phosphoglyceric acid (**3-PGA**). 3-PGA then moves out of the chloroplast into the cytoplasm of the cell, and is metabolized into sugar compounds such as hexose and sucrose. Phosphoenolpyruvate is then recycled into the mesophyll to react with CO_2 and continues to repeat the process. Photosynthesis in C_3 plants is similar to the steps that occur in the bundle sheath cells of C_4 plants; however, C_3 photosynthesis only occurs in the mesophyll cells. Here RuBisCO fixes CO_2 directly to ribulose bisphosphate and forms two molecules of 3-PGA, which are transported to the cytoplasm where they are metabolized into sugars that then pass through the bundle sheath cells and to the rest of the plant.

Maturity Effects on Forage Quality

The quality of forages is affected more by maturity than by any other factor, including management, forage species, dry matter (**DM**), or harvest system (Harrison et al., 1994). This makes the proper timing of harvest one of the largest effectors that lead to either a good or poor nutrient quality in preserved forages. Plant maturity occurs as a plant grows and develops into the advancing growth stages: germination, vegetative, elongation, reproductive, and seed development and ripening (Nelson and Moser, 1995). Understanding how maturity affects a plant's nutrient composition and an animal's ability to extract these nutrients from that plant is vital for forage and livestock producers.

The effects of forage maturity and the association with the decline in forage quality have been researched for many decades. Ball et al., (2001) defined forage quality as the ability that a forage has to produce a desired animal response. Another definition of forage quality is animal performance, especially when comparing forages fed to growing and lactating animals (Coleman and Moore, 2003). Factors that influence forage quality include palatability, intake, nutrient content, animal performance, and anti-quality factors that reduce animal performance (Ball et al., 2001).

The effect of forage maturity on forage quality has been reported in all types of forage, both cool- and warm-season grasses and legumes. Crude protein (**CP**) levels of tall fescue have been found to drop by 50% when forage was harvested at heading rather than at the vegetative or boot stage (Fieser and Vanzant, 2004). Similar changes were found in a one-week delay in alfalfa harvest, resulting in lower digestibility and a decreased amount of CP by about 20 g/kg, as well as an increase in cell wall concentration of nearly 30 g/kg (Buxton, 1996). Burns et al., (1997) reported that switchgrass harvested on June 9th was 2.5 times higher in CP intake than forage harvested 14 days later and 3.8 times greater than forage harvested 28 days later. Another study involving tropical forages found a 37.8% decrease in the average of CP between two stages of maturity, four and ten weeks of regrowth, for all forages tested (Arthington and Brown, 2005).

Much of the influence on forage quality is placed on cell wall components and cell contents. As plants mature, cell wall components within the stems and leaves increase as cell solubles decreased (Buxton, 1996). Cell walls are broken down into the fiber fraction containing hemicellulose, cellulose, lignin, and lignin nitrogenous compounds (Van Soest, 1965). In the detergent system, neutral detergent fiber (**NDF**) is the concentration of total cell walls and is negatively related to forage intake; where acid detergent fiber (**ADF**) is negatively associated with digestion (Buxton, 1996). The ADF fraction represents the less digestible elements including: cellulose, lignin, and ash (Ball et al., 2001). As plants mature, cell wall components within the stems and leaves increase as cell solubles decrease (Buxton, 1996). The decline in forage quality is largely due to increases in cell wall thickness in stems and leaves and the rapid increase in lignin concentration with advancing maturity (Buxton, 1990). Jung and Allen, (1995) reported that as plant cells develop, phenolitic acids and lignin were deposited in the maturing cell wall and that lignin was the key element that limits digestibility. It was also reported that as total cell wall components of forages increased with maturity, lignin concentrations were found to increase exponentially (Jung and Vogel, 1986). The continuous increase of fiber with forage maturity ultimately leads to a less favorable forage for livestock feeding to meet animal requirements and reach ideal animal performance.

Forage Maturity and Animal Performance

As forages mature and quality declines, there are direct effects on animal performance, such as decreased digestibility, reduced ADG, and lower levels of milk production. Coleman and Moore, (2003) stated that animals have the genetic potential to produce meat, milk, and fiber and that the goal of animal production is to express this potential. The outputs of ruminants on forages are associated with DM intake, digestible energy, digestible protein, and adequate vitamins and minerals (Blaser, 1964). In a study by Burns et al., (1997) steers fed a diet of switchgrass hay harvested on June 9 as compared to that harvested 14 days later had an ADG of 1.0 kg/day to 0.2 kg/day, respectively.

Possible explanations for reduced gains were found in serum samples from steers grazing more mature intermediate wheatgrass. These animals were found to have higher levels of nonesterified fatty acid concentrations indicating that; these animals were mobilizing body fat to meet energy demands. The same steers also had reduced insulin-like growth factor I, a sign that the animals were in a slowed state of growth (Park et al., 1994).

Buxton and Marten, (1989) reported that the digestibility of cool-season forages decreased linearly with time during the spring. Ball et al., (2001) stated that as forages mature their digestibility will decreased 1/3 to 1/2 percentage units each day until digestibility was below 50%. Cool-season grasses can decline in digestible DM concentration by three to five g/kg from early spring to the development of flowers and the production of seeds (Collins, 1991). The low digestibility and high cell wall content in forages limit the available energy to animals, and the reduction of cell wall materials may improve both intake and available energy (Jung and Allen, 1995). Increases in fiber fractions and lignin lead to declines of in vitro dry matter digestibility and protein (Cogswell and Kamstra, 1976).

Cell wall components found within forages negatively affect intake and digestibility in the animal, these components are divided into intake (affected by hemicellulose and NDF) and digestibility (affected by lignin and ADF) (Van Soest et al., 1978). Allen and Mertens, (1988) stated that NDF digestibility is an action of a forage's potential digestible fraction, the rate it is digested, and the rate of passage through the digestive tract. Buxton and Mertens, (1995) stated that intake was a physical element of the animal and is reduced when forages are high in NDF and low in available energy. Park et al., (1994) reported that, as intermediate wheatgrass pastures matured, both intake and NDF digestibility by steers decreased on each sampling date. Pond et al., (1987) reported that voluntary dry matter intake was around 26% greater in immature versus matured ‘coastal’ bermudagrass.

The rumen environment and products of rumen fermentation are also altered when forages mature. Rinne et al., (1997b) reported increases in NDF with maturation of timothy-meadow fescue harvested as silages, along with increases in rumen pH from early to the later harvested forage. In a grazing study, steers on range type forages were shown to have an increase in rumen fluid volume and decreases in volatile fatty acid (**VFA**) and ammonia-N concentrations with advancing forage maturity (Adams et al., 1987). Similar results were found in a study reported by Park et al., (1994), who reported that steers grazing intermediate wheatgrass had higher levels of VFA and ammonia-N in May and June samplings than in September and November samplings. A reduction in dry matter intake (**DMI**) was also found in steers fed switchgrass with increasing maturity. This was associated with increases in mean retention time and a reduction in rate of passage (Burns et al., 1997). Rinne et al., (1997a) reported that both rate of passage and mean retention time of ingested forage were increased as steers grazed timothy-meadow fescue pastures.

Preservation Effects on Forage Quality

The seasonal growth of cool- and warm-season grasses predominantly occurs during the spring and early-fall and summer, respectively. This leaves the winter months with little to no forage for livestock. In order to feed cattle in these periods of little forage production either supplemental feeds are needed or quality forages need to be preserved and fed. Hay production, the most widely used method of forage preservation requires extended drying periods. This is due to the high stem to leaf ratio of some grass species which extends drying time in the field and increase DM losses to unfavorable weather (Taliaferro et al., 2004). Weather is a major factor in hay production, rains can either prevent harvest due to fields being too wet and often reduce forage quality if rain falls on harvested material during the drying process. Fonnesbeck et al., (1986) stated that rain leaching of harvested drying forages can account to up to 70% of nutrient losses during harvest.

Preserving forages as haylage will help reduce the total time required for harvest, lower DM losses, improve forage quality, and could lead to increased animal performance. Haylage production is the process of ensiling forages, at higher moisture than hay, in an oxygen free environment to undergo bacterial fermentation to produce acidic products that preserve the forage and prevent spoilage (Lemus, 2010). Good quality grass haylage, when fermentation is completed, will reach a pH between 3.5 and 4.5 (Dairy One, 2012). A pH below five is reached when lactic acid producing bacteria are predominant, lactic acid should make up 60% of silage organic acids (Lemus, 2010). The oxygen free environment of the ensiling process prevents mold growth and yeast that in the presence of oxygen will metabolize lactic acid and cause spoilage (Kung, 2010).

Animals perform well on haylage diets. Ensiled forages had the highest nitrogen (N) solubility when compared to fresh forage and hay, and also had greater CP digestibility when compared to hay (Lopez et al., 1991). The moisture level of forage when ensiled can also affect its feeding quality and animal response. Kung (2010) reported that less acidic pH levels in haylages are seen when DM was above 50% and in very wet silages, DM less than 25-30%, tended to have prolonged fermentation phases and were of lower quality. Wilting of haylage, when compared to direct cut haylage, results in higher DMI and improved ADG in growing and lactating animals (Zimmer and Wilkins, 1984). When comparing the intakes of steers fed switchgrass haylage or hay, it was found that DMI and NDF intake was higher for haylage than hay by 0.9 and 0.6 kg/day, respectively (Luginbuhl et al., 2000). Increases in DMI can result from haylage fermentation which also increased palatability, lowered structural fiber, increased DM and cell wall digestibility, and increased digestion rates (Harrison et al., 1994).

The economics of haylage production is an important area to cover. Many associate the need of extra equipment, such as bale wrappers, to driving up the cost of haylage production. Hersom et al., (2011) conducted a study comparing the production of hay and round bale silage (**RBS**) from Tifton-85 Bermudagrass and reported that haylage had a greater initial cost per bale. However, the same study also produced results over a growing season, with three hay harvest and five RBS harvest, producing a total of 259 bales of hay in 10.12 hectares and 479 RBS in 10.12 hectares, these harvest provided a total of 66,270 kg of DM in hay and 131,679 kg of DM in RBS. Spoilage loss during storage was also calculated and found that 28% hay production was lost and only 5% loss in RBS. When taking the cost of production, yields, and spoilage into account hay had higher cost of production than RBS. Hay cost were, DM = \$0.12/kg, TDN = \$0.21/kg, CP = \$1.16/kg, and RBS cost were, DM = \$0.09/kg, TDN = \$0.16/kg, CP = \$0.71/kg.

Comparing traditional harvest and preservation methods in both cool- and warm-season grasses will allow us to determine if higher quality forage can be preserved as either haylage or hay. Also, taking the management factors discussed into account and combining them with different preservation techniques will lead to the best possible combination of management and preservation for livestock feeding. Haylage production can produce an equal if not higher quality and more cost effective forage. The effects of moisture level at ensiling on the feeding quality of haylage produced from both cool- and warm-season grasses and comparing haylage to hay produced from forage on the same harvest date needs to be evaluated to improve preservation techniques by producers and in turn determine the best form of preservation based on level of maturity.

Fertilizer Effects on Native Warm-Season Grass

Another potential to increase forage quality and quantity of warm-season grasses is the use of N fertilizer. McLaughlin and Kszos, (2005) stated that N management is especially important in bioenergy crops because of the cost associated with adding N. Nitrogen fertilization at levels of 45 to 90 kg N/ha resulted in increases in leaf yield and CP (Perry and Baltensperger, 1979). Switchgrass and big bluestem hay CP levels were found to increase by 21 and 30%, respectively, when comparing forages fertilized with urea at 0 and 75 kg N/ha (Puoli et al., 1990). The same study also found that N fertilization increases DM intake in steers that were fed switchgrass and big bluestem hays by 11 and 16%, respectively, and increased NDF intake by 12 and 14%, respectively.

The amount of N needed in warm-season grasses production depends on the management style and intended use of the stand, differing between forage use and biomass production. McLaughlin and Kszos, (2005) stated that the amount of N needed for a one-cut harvest system uses a third to a half of what a two-cut system needs to maintain the stand and not affect yields. Perry and Baltensperger, (1979) reported that big bluestem responds to N fertilization with nearly double the rate of DM production than switchgrass and indiangrass, however indiangrass had higher levels of digestibility at any rate of N-fertilization. For biomass production N levels can be reduced if forages are harvested late in the growing season due to translocation of nutrients in the plant from above ground to the root system (McLaughlin and Kszos, 2005). Translocation is also associated with improved biofuel quality, in that reduced nutrient content in the above ground biomass reduced the amount of slagging in the fuel making process (McLaughlin and Kszos, 2005) and (Alder et al., 2006).

Alkali Treatment to Alter Forage Quality

Alkali chemicals have been shown to increase digestibility of crop residues by breaking the bonds between lignin and hemicellulose or cellulose (Klopfenstein, 1978). A study of treated wheat straw reported that sodium hydroxide (**NaOH**) treatment resulted in higher DM in vitro digestibility than the control at 24 hours and higher NDF in vitro digestion at 48 hours (Lewis et al., 1988). Wanapat et al., (1984) reported that alkali treatment of barley straw increased digestibility and energy utilization, and rank their effectiveness from greatest to least starting with wet NaOH, dry NaOH, and control.

The level of pH reached during ensiling is an indication the level of fermentation that the forage underwent, lower pH is best. Tetlow and Mason (1987) reported that whole crop wheat treated with NaOH had an increase in pH compared to the control treatment. An increase in pH is typically not desired in the ensiling process. However, in a similar study, it was reported that NaOH treatments enhance the anaerobic stability of alkali treated whole crop cereal silages (Tetlow et al., 1987). The level of pH is also related to the concentration of volatile fatty acids produced during fermentation. A laboratory study ensiling ‘coastal’ bermudagrass both untreated control and pretreated with NaOH and neutralized prior to ensiling, suggested that NaOH improved silage quality through an increased acetic and lactic acid production (McHan, 1985). The production of these acids is an indication that the silage was of good quality and had been properly preserved.

Increases in digestibility, intake, and weight gain by animals have been observed when fed forages that were treated with alkali chemicals. Whole-crop wheat at 600 g of DM/kg of material treated with 50-70 g NaOH/kg DM; increased both digestibility and intake when fed to sheep (Tetlow et al., 1987). Deschard et al., (1987a) reported that in a feeding trial using multiple alkali treatments of wheat silage, NaOH treatments resulted in increased intake and had higher daily gains in steers when comparing the control and the NaOH treatment (0.68 and 1.15 kg/day, respectively). Garrett et al., (1979) reported that both sheep and steers consuming diets containing NaOH treated rice straw at 72% of the total diet consumed higher amounts of the ration, and less feed was needed per unit of gain when compared to the untreated rice straw diet. It was suggested that this was due to an increase in digestibility of cellulose in treated straw, along with a greater intake level. Dairy cows fed alkaline hydrogen peroxide treated wheat straw had increased NDF and ADF digestibility (9.4 and 3.0% units, respectively), increased milk fat percentage (3.07 to 3.32%), decreased milk protein (2.61 to 2.56%), and had an increase in total volatile fatty acid production (Cameron et al., 1990).

By removing the lingo-cellulosic bonds through alkali treatment a source of nutrients that are inaccessible prior to treatment become available to the animal, leading to a potential increase in animal performance. Kerley et al., (1985) used an electron scanning microscope and observed that alkali hydrogen peroxide had removed a significant barrier to ruminal bacterial attachment. Untreated wheat straw collected from rumen fluid only had ruminal bacteria attached to edges where the plant's tissues were broken, whereas, treated straw particles were nearly covered by a dense population of bacteria. Garrett et al., (1979) reported that diets fed to sheep or steers of rice straw treated with NaOH or ammonia did not affect the rumen pH or the volatile fatty acid percentages when compared to the control diet; the rumen bacterial population was not affected and remained productive.

Not all stages of maturity can be improved with alkali treatment; the greatest improvements were seen in the more mature material. Brown (1988) reported that stargrass hay quality was increased with both NaOH and ammoniation, but the more mature hays had a greater response to treatment. A study of immature whole crop wheat treated with NaOH and ensiled reported that the silage underwent excessive primary and secondary fermentation, and it was recommended that immature crops should not be preserved with alkali chemicals due to improper preservation (Deschard et al., 1987b). The use of thermo-ammoniation on immature and mature switchgrass and mature indiangrass led to increases in digestibility, intake, rate of disappearance, and rate of NDF digestion, with the greater results for the mature grasses (Gates et al., 1987).

Summary

Tall fescue is the main forage base for cattle producers in the southeastern United States. Its spring and fall growing season provides forage for a good portion of the year. However, its association with an endophytic fungus results in the syndrome tall fescue toxicosis when E+ (endophyte infected) tall fescue is consumed. Tall fescue toxicosis can lead to loss of income for cattle producers through reduced animal performance and/or reduced calf crops in breeding herds grazing of fed E+ tall fescue. For producers wanting to alleviate tall fescue toxicosis the options are to replace their E+ tall fescue stands with E- or novel endophyte tall fescue or another forage species, inter-seed with legumes, or to employ some other form management strategy.

The growth pattern of tall fescue over the year leaves a forage gap during the summer months. This gap can be filled utilizing NWSG's such as switchgrass, big bluestem, and indiangrass. The growth of NWSG in the summer is highest when tall fescue growth is limited. Filling the fescue gap in the summer with NWSG may reduce the need for expensive supplemental feeds and improve profitability for cattle producers. Native warm-season grasses also have the potential to be harvested after the growing season as a biomass crop for ethanol production. Determining if NWSG can be used as forage and then harvested as a biomass crop for an additional source of income for producers is of great interest.

As both cool- and warm-season forages mature their feeding quality declines for all quality measures. The use of forage management through both harvest and preservation has been researched but minimal research has been conducted on determining the best preservation method of forages based on maturity changes. Determining the best preservation method for tall fescue and NWSG forages as they mature during the growing season may help develop harvest management techniques to improve available forage.

Our study examined the effects of maturity at harvest and the use of preservation methods to improve forage quality and reduce the need of expensive supplements. Objective one was to determine how maturity at harvest and preservation method of tall fescue and switchgrass affects yield, forage quality, the ability to meet nutrient requirements of livestock, and alter ergovaline content of tall fescue. Objective two was to determine how maturity at harvest, method of preservation, and nitrogen fertilization of native warm-season grasses affects yields, forage quality, and biomass production. Objective three was to determine the effects of alkali treatment of ensiled mature switchgrass to improve nutritive quality and nutrients available for livestock feeding.

CHAPTER 2: CHANGES IN QUALITY OF TALL FESCUE AND SWITCHGRASS HARVESTED AT DIFFERENT MATURITIES AND PRESERVED AS HAYLAGE OR HAY

ABSTRACT

During late spring and early summer, forage growth is rapid and excess forage is often available. This excess needs to be harvested and preserved so it can be used as feed during periods when forages are limited. Determining how maturity and preservation method affect tall fescue (*Lolium arundinaceum (*schreb.) Darbyshire) and switchgrass (*Pancium virgatum* L.) quality will help cattle producers better manage these forages. Two years of data were collected from endophyte-infected (**E+**) 'Kentucky' 31 (**Ky-31)** tall fescue and 'Alamo' switchgrass stands. Harvest began by mid-May with subsequent initial harvests at two-week increments and regrowth harvests four-weeks after each initial harvest. On each harvest date, forage was clipped and preserved as: 1) 60% high moisture haylage, 2) 40% low moisture haylage, or 3) hay. Forage nutritive values were compared to CP and TDN requirements for winter feeding of spring and fall cow-calving herds and stocker cattle. Tall fescue decreased in TDN and CP with maturity. Switchgrass increased in DM yield and NDF and decreased CP and TDN with maturity. Preservation method did not affect CP and TDN of forages. Both forages harvested by mid-May met TDN and CP requirements during the winter for spring- and fall-calving beef cows. Stockers fed tall fescue from mid-May harvests without supplementation would have an ADG of 0.45 kg when TDN is the first limiting nutrient. However, stockers feed switchgrass from the same harvest would have an ADG of 0.63 kg.

INTRODUCTION

Tall fescue (*Lolium arundinaceum (*schreb.) Darbyshire) is the primary forage in Tennessee and is used to feed and maintain the state's beef herds, as well as many of the other forage-based livestock systems. Tall fescue provides optimum forage both in quality and quantity to support livestock in the spring and mid- to late-fall. However, there is a gap in available forages in the summer and early fall in tall fescue-based forage systems. This gap can be filled by using native warm-season grasses (**NWSG**) such as switchgrass (*Pancium virgatum* L.). Switchgrass can provide good quality forage for livestock feeding and is also a high yielding forage. If producers use both of these forages on their farm there will be excess growth overlap during the late-spring and early summer. This excess needs to be harvested and fed in the winter months or when grazing is unavailable for cattle.

Tennessee is largely a cow-calf producing state and meeting nutrient requirements of cow herds are important for the state's cattle producers. Most cow-calf producers implement either a spring or fall controlled caving season. However, these herds will have different requirements throughout the year due to differences in stage of production. Typically pasture grazing will maintain herds during the spring and summer months, but harvested forage and at times additional supplementation may be needed to meet animal requirements during the late-fall and winter months. Another beef cattle production system in Tennessee is the growing of stocker cattle. Stockers are fed throughout the year to meet nutrient requirements to reach a targeted ADG and finishing weight in a timely and cost effective manner. Evaluating tall fescue and switchgrass forage harvest and preservation based on available nutrients in forage and the ability of these forages to meet these animal's nutrient requirements will prove very beneficial for livestock producers. The objective of this study was to determine how tall fescue and switchgrass maturity at harvest and method of forage preservation, affected forage yield and quality, and ability to meet the requirements for cow-calf and stocker production.

MATERIALS AND METHODS

Tall Fescue

This study used an established stand of Ky-31 endophyte infected tall fescue with a 90% endophyte infestation level at the Blount Farm Unit at the East Tennessee Research and Education Center (**ETREC**) in Knoxville Tennessee (35.53°N 83.57°W). Soil at the Blount Farm Unit is classified as a Cumberland silt loam (fine, mixed, semi active, thermic Rhodic Paleudalfs).

In this two-year, 2010 and 2011, study treatments consisted of five initial cuttings at two-week intervals and five four-week regrowth cuttings, preserved using three methods at each cutting. Each cutting date was replicated three times. Harvest treatments were a series of harvest dates with an initial cutting followed by a four-week regrowth cutting. The three preservation treatments were 1) ensiled at 60% moisture, 2) ensiled at 40% moisture, and 3) hay at 15% or less moisture. All plots were fertilized at a rate 67 kg of N/ha after each initial cutting in addition to 67 kg N/ha at green up prior to the growing season each year of the study and P, K, and lime were applied according to soil test to achieve medium fertility levels. One experimental unit consisted of a single 1.5 m x 6.1 m plot. There were 15 total units at the ETREC, with treatments randomly assigned to eliminate bias.

Forage was harvested using a flail type harvester (Swift Machines and Welding Ltd.) with a 0.76 m cutting head along the entire 6.1 m length individual plots. Cutting height on the harvester was set at 7.6 cm. All material harvested from this area was weighed for yield determination. After total plot weight was measured, fresh samples were collected, weighed, sealed in a Ziploc® freezer bag, and immediately placed on dry ice and later stored in a freezer at -4° C. Samples were lyophilised (Freeze Dryer 5, Labconco Corp., Kansas City, MO). Dry matter (DM) content of freeze-dried samples was determined and was used for calculation of DM yield. Freeze-dried samples were then ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

Remaining forage was spread on black poly-blend landscape fabric placed on top of plant stubble. Forage was allowed to wilt to the desired moisture content for haylage and hay. Forage was turned once daily at noon to simulate the use of a hay tedder. During periods of inclement weather a hoop tent with clear plastic sheeting was placed over the drying forage to prevent nutrient leaching by rain.

Moisture levels were measured in the field using a Koster Tester (Koster Crop Tester Inc., Strongsville, OH). Once the desired range of moisture (60±3%) was reached for haylages forage was packed into 0.95 L glass miniature silos, labeled, and stored in a dark room for at least 60 days before opening for analysis. This procedure was repeated for 40% moisture haylage.

When the desired moisture was reached for hay (15%), samples were placed into a cloth bag. Hay samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

After at least 60 days of fermentation, haylage samples were opened. A mold score of 0 to 100% expressed in 5% increments was given to each silo. At this time haylage fluid was extracted using the methods described by Dairy One (2012). The pH of haylage fluid was measured using a pH meter (Acument Basic AB15 pH meter, Fisher Scientific, Pittsburg, PA).

The remaining haylage was stored in a freezer at -4°C until samples could be lyophilised (Freeze Dryer 5, Labconco Corp., Kansas City, MO). Freeze-dried haylage samples were weighed and DM calculated. Haylage samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

All dried, ground, forage samples from the three preservation treatments then underwent forage quality analysis for: NDF, ADF, and N content for calculating crude protein (CP = N x 6.25). The NDF and ADF concentrations were determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY) using the procedures described by Ankom Technology, (1998). Nitrogen content was measured using a LECO TruMac N Nitrogen Determinator (LECO Corp., St, Joseph, MI) using the procedures described in the LECO manual (2011), and CP was calculated as N x 6.25. Total digestible nutrients (TDN) were estimated using the formula: TDN = 4.898 + 89.796 x NEl, Net energy of lactation (NEl) = 1.044 – 0.0119 x ADF (Pennsylvania State University, 1995).

Due to cost of analysis, a single harvest sample for each year was used to determine the effects of preservation on ergovaline concentration in tall fescue. Samples from all preservation treatments from a mid-May harvest were analyzed for ergovaline concentration at the University of Missouri Veterinary Medical Diagnostic Lab, 1600 E. Rollins, Columbia, MO 65211 using the high pressure liquid chromatography method reported by Rottinghaus et al., (1991).

The results from DM yield calculation, pH, mold scores, forage quality analysis, and ergovaline concentrations were used as the dependent variables and were statistically analyzed using a mixed model ANOVA, in SAS version 9.3 (Cary, NC). The fixed effects were all interactions between harvest date, cuttings, and preservation methods where the random effects were the interactions between year, harvest date, cuttings, and preservation methods. Because variation was expected to occur between years, initial and regrowth cuttings, harvest dates, and preservation type, a randomized block with split-split plot design was used. The whole plot was year; blocking occurred on year, with the first split on the cutting (initial and regrowth) within each year, the second split on the five harvest dates within each cutting, and three preservation methods occurring in three replications within cuttings. The level of significance was set at $P \leq 0.05$.

The nutrient content of preserved forage was compared to the requirement for winter feeding of spring- and fall-calving cows and to feeding stocker cattle. Cows were assumed to be 544 kg mature size and producing an average of 9.1 kg of milk. The controlled calving seasons used by producers in Tennessee are either a spring (Feb. or Mar.) or fall (Oct. or Nov.) calving season. Typical winter feeding occurs in Tennessee from Mid-November to Mid-March. The requirements for TDN and CP for these cows were obtained from tables published by Gadberry, (2004). Nutrient requirement for cows were based on the months since the cow calved. Spring-calving cows fed during winter have requirements for months 9, 10, 11, 12, 1, and 2 since calving and fall-calving cows have requirements for months 1, 2, 3, 4, 5, and 6 since calving. Average monthly % TDN requirement for spring-calving cows and fall-calving cows for Oct., Nov., Dec., Jan., Feb., and Mar. are 48.5, 50.6, 54.2, 57.4, 59.3 and 59.3, 58.8, 56.9, 55.4, 54.0, respectively. Average monthly % CP requirement for spring-calving cows and fall-calving cows for Oct., Nov., Dec., Jan., Feb., and Mar. are 6.8, 7.3, 8.2, 9.4, 10.4 and 10.4, 10.3, 9.6, 8.9, 8.2, respectively. The TDN and CP content of the preserved forage were compared to these requirements to determine how well preserved forages meet the cow's requirement for winter feeding.

Switchgrass

This study used stands of ‘Alamo’ switchgrass at the East Tennessee Research and Education Center in Knoxville Tennessee (35.53°N 83.57°W). Switchgrass in the first year of this study (2010) was a five-year old stand located at the Holston Unit. The second year (2011) used a four-year old switchgrass stand located at Plant Science Unit of the ETREC. Sites were comparable in weather conditions and management procedures and were located only 16 km apart. Change in location between years was due to lack of switchgrass availability at the Holston unit for the second year of the study. Both locations were managed the same with 67 kg of N/ha applied at green up and P and K were applied based on soil test to achieve medium fertility levels. Soil at the Holston Unit is classified as a Huntington silt loam (fine-silty, mixed, active, mesic Fluventic Hapludolls). Soil at the Plant Sciences Unit is classified as a Sequatchie loam (fine loamy, siliceous, semi-active, thermic Humic Hapludults). Other research conducted on switchgrass yield indicated that these two locations were similar (Lane, 2011).

During year one, forage was harvested using a flail type harvester (Swift Machines and Welding Ltd., Swift Current, SK, Canada) with a 0.76 m cutting head along the 3.5 m length individual plots. Cutting height on the harvester was set at 20.3 cm of stubble. During year two of this study all forage was harvested with the larger flail type harvester (Carter Mfg. Co., Brookston, IN) with a 0.81 m cutting head along the 2.7 m length of individual plots. After harvest switchgrass materials were processed and analyzed using the same methods as in the tall fescue, excluding testing for ergovaline content. The switchgrass study used the same harvest and preservation methods as were used in the tall fescue study. Harvest dates and stage of growth at harvest for 15 plots of switchgrass from 2010 and 2011 are presented in table 1.2. Statistical analysis was performed using the same procedure and statistical design as used in the tall fescue study. The nutrient content of preserved forage was compared to the requirement for winter feeding of spring and fall-calving cows and to feeding stocker cattle.

RESULTS AND DISCUSSION

Tall Fescue

Year in the statistical model was found to have no effect ($P \geq 0.1$) on the dependent variables tested in this study. Therefore, years were combined and data were pooled for tall fescue. Regrowth harvests did not differ with maturity, most likely because each harvest had 28 days of regrowth and were in the same stage of regrowth. Regrowth harvests also did not differ between preservation methods. Weather was monitored one month prior to the first harvest and daily during harvest and periods of wilting forage. Monthly average maximum and minimum temperatures and total monthly rainfall had very little variation between years (NOAA, 2012).

The DM yields of tall fescue initial and regrowth cuttings were not affected by harvest date, but initial cuttings were different from regrowth (table 4.1). The lack of change with maturity was most likely due to the stands being in similar stages of growth at harvest having reached seed head by the beginning of the study. Regrowth yield varied and was weather dependent.

In this study, tall fescue was successfully preserved as haylage. This conclusion is supported by pH of the haylage produced and lack of mold present (table 4.1). Moisture level at ensiling affected the pH in both initial and regrowth harvests. High moisture haylage had a lower pH ($P \leq 0.05$) when compared to low moisture haylage in all initial and regrowth harvest. Han et al., (2004) reported similar results in alfalfa haylage of higher moisture content and lower pH. Dairy One, (2012) proposed a pH of five for haylage. Packing density is important in making high quality haylage. Tightly packed haylage will have increased air exclusion, lower pH, and less spoilage loss (Lemus, 2010). Kung, (2010) recommended that the packing density of at least 240 kg/m^3 for round bale haylage, 192 kg/m^3 for bag haylage, and 224 to 256 kg/m^3 for bunker silos. High moisture haylage in miniature silos in our study were found to have at an average density of 301 ± 56 kg/m^3. Low moisture haylage had an average packing density of 246 ± 31 kg/m^3. The packing density of high moisture haylage would indicate that silos were packed at a level that was well above minimal requirements for haylage production. The high packing density reached in this study is not likely to be reached in a full scale production system. Therefore, haylage produced in normal production systems may have higher pH and more mold than we found in our laboratory silos.

The CP of tall fescue was not affected be maturity ($P > 0.1$). Preservation method did not affect CP content of tall fescue based on mean separation (table 1.3). This is in agreement with Lopez et al., (1991) who reported that preservation type (fresh, silage, and hay) did not affect crude protein concentration in mixed cool-season forage pastures tested in either an initial late June cut or September (after summer regrowth) cut.

Harvest date had a significant effect on the TDN of the initial cuttings of tall fescue (table 4.1). Fresh-chop tall fescue at harvest one had the highest ($P \leq 0.05$) TDN with a value of 63.5% and decreased across harvests to the lowest ($P \leq 0.05$) TDN in harvest five with a value of 53.8% (figure 1.1). These results agree with Newman et al., (2012) who reported that the TDN content of Ky-31 E+ tall fescue harvested in May had a 37% probability of meeting cow requirement while the probability of June/July harvest was only 26%. In the first three harvests, preservation methods did not differ but in harvests four and five hay had greater ($P \leq 0.05$) TDN content than haylages. The TDN content of harvests four high and low moisture haylages were 52.6 and 51.1%, respectively. Harvest five high and low moisture haylages TDN content were 52.8 and

52.0%, respectively. Preservation method of initial harvest of tall fescue did not greatly affected TDN content in the earlier harvests (table 1.4). The results from this study disagreed with Rayburn and Wallbrown (2008), who reported that wrapped haylage tended to have a greater TDN content than dry hay.

Maturity had no affect ($P > 0.1$) on tall fescue NDF content of initial cutting harvests (table 4.1). However, there were differences in NDF due to preservation methods (table 4.1). In harvest one high moisture haylage had a lower ($P \leq 0.05$) NDF than hay (table 1.5). These results agree with Lopez et al., (1991), who reported small differences between NDF of haylage and hay. He noted the differences were most likely due to the loss of cell contents as forages dried. However in our study, low moisture haylage had higher ($P \leq 0.05$) NDF when compared to the other preservation methods. These results agree with Burns et al., (1993) who reported higher ADF and NDF in haylages compared to hay and stated that the increase was due to cell solubles being converted into fermentation products in haylages.

Preservation method did not affect ($P \geq 0.1$) ergovaline levels of the mid-May (harvest two) initial cutting of tall fescue (table 4.2). Fresh-chop tall fescue ergovaline level had the highest value at 194.0 µg/kg on a DM basis and declined consistently as the forage was wilted, with hay having the lowest ergovaline levels at 133.5 µg/kg DM. Roberts et al., (2002) reported similar results with non-significant reduction in total ergot alkaloids from fresh forage to haylage, but did find a significant reduction when preserved as hay. Stamm et al., (1994) reported the threshold of ergovaline to induce symptoms of tall fescue toxicosis to be a concentration of about 150.0 µg/kg DM. Preservation method in our study was not an effective method in alleviating tall fescue toxicosis even though below toxic levels were reached.

Tall fescue preserved in our study was evaluated as winter feed for meeting requirements of spring- and fall-calving cows. Tall fescue from harvest one met the TDN requirements for both spring- and fall-calving cows in winter feeding. Harvests two and three met TDN requirements of spring-calving cows for Oct., Nov., and Dec. and fall-calving cows for Feb. and Mar. while harvest four and five met spring-calving cows TDN requirements in Oct and Nov but did not meet TDN requirements for fall-calving cows. In any month when tall fescue did not meet the TDN requirement for cows and energy supplement must be provided. Tall fescue from harvest one meets CP requirement for both spring- and fall-calving cows for the entire winter feeding period. For spring-calving cows preserved tall fescue from harvest two met requirements for all months of the winter feeding except Mar. and fall-calving cows CP requirements were met by harvest two for all months except Oct. and Nov. Harvests three tall fescue met the CP requirements of spring-calving cows for Oct., Nov., and Dec. and fall-calving cows for Feb. Preserved tall fescue from harvest four and five will meet CP requirements for spring-calving in all months except Feb. and Mar. and will only meet Mar. requirements for fall-calving cows. Tall fescue harvested by mid to late May met the majority of spring- and fall-calving cow's energy and protein requirements during winter feeding. This agrees with Newman et al, (2012) who reported that the TDN content of KY-31 E+ tall fescue harvested in May had a higher, 37%, probability of meeting the cow requirements in cow-calf herds where the probability of June/July harvest was only 26%.

Tall fescue was also evaluated in its ability to meet the TDN and CP requirements of stocker cattle. Based on TDN stocker cattle fed tall fescue from harvest one and regrowth one would gain about 0.45 kg/day. In other harvests the TDN provided by tall fescue would result less than 0.45 kg of ADG. The CP of harvest one with an average of 12.2% would support up to

0.93 kg of ADG when adequate energy is supplied. Tall fescue from harvest two would support 0.6 kg of ADG based of CP supplied and if adequate energy is supplied. The remaining harvests would support gains of about 0.2 – 0.36 kg of ADG when adequate energy is supplied.

Switchgrass

Year in the statistical model was found to have no effect ($P \geq 0.1$) on the dependent variables tested for switchgrass. Therefore, years were combined and data were pooled for this study. Regrowth harvests did not differ with maturity, most likely because each harvest had 28 days of regrowth and were in the same stage of regrowth. Regrowth harvests also did not differ between preservation methods.

Switchgrass initial cuttings have increased DM yields ($P \leq 0.1$) with maturity (figure 1.2) of the forage stands, but were not at the level of significance chosen for this study (table 4.3). These increased yields were expected because of the rapid growth of switchgrass. Switchgrass regrowth was not affected by the time of initial cutting and did not differ between harvests.

Switchgrass in our study was successfully preserved as haylage. This conclusion is supported by the pH reached and the low presence of mold in switchgrass haylage (table 4.3). Haylage pH values were affected by the maturity of switchgrass at harvest. High moisture haylage had the lowest ($P \leq 0.05$) pH at harvest one (5.03) and steadily increased to the highest pH at harvest five (6.43). Low moisture haylage was less or not, affected by maturity. Haylage pH was also affected by moisture level at preservation within a harvest date. High moisture haylages had lower ($P \leq 0.05$) pH values when compared to low moisture haylage. Mold scores were not affected ($P \geq 0.05$) by maturity or moisture at preservation. Packing density of haylage in miniature silos may have affected quality results. Tightly packed haylage will have increased air exclusion, lower pH, and less spoilage loss (Lemus, 2010). Kung, (2010) recommended that the packing density of at least 240 kg/m^3 for round bale haylage, 192 kg/m^3 for bag haylage, and 224 to 256kg/m^3 for bunker silos. High moisture haylage in miniature silos were packed to an average density of 356 ± 29 kg/m^3. Low moisture haylage had an average packing density of 283 ± 54 kg/m^3. Silos were packed at a density that would be greater than could be reached in normal production systems; therefore, pH and mold scores may be higher in normal production systems than were reached in our study.

The CP concentrations of switchgrass were affected by maturity and have a steady decline in CP as the forage matures (table 4.3). Harvest one had the highest ($P \leq 0.05$) CP with a value of 10.1% and decreases in each harvest until harvest four and five with a value of 5.2% CP (figure 1.3). This agrees with previous research when CP was highest in a May harvest of switchgrass and decreased significantly when switchgrass was harvested in July (Sanderson et al., 1999). This also agrees with Burns et al., (1997), who found that in switchgrass harvested in early June had 2.5 times greater ($P \leq 0.05$) CP levels than forage harvested 14 days later. Preservation method effected ($P \leq 0.05$) CP content of switchgrass forage (table 4.3). However, based on mean separation CP values did not differ between hay and haylage preservations in any harvest of our study (table 1.6). These results agree with Burns et al., (1993), who found that switchgrass in the form of direct cut silage, wilted silage, or hay were not different in crude protein levels as a result of preservation method.

Percent TDN was significantly affected by maturity at initial harvest (table 4.3). The fresh-chop initial cutting switchgrass harvest one having the highest ($P \leq 0.05$) TDN with a value of 65.8% (figure 1.4). Harvests four and five had the lowest ($P \leq 0.05$) TDN content for fresh-chop switchgrass with values of 55.6 and 56.7% TDN, respectively. The overall switchgrass

TDN declined with maturity agrees with Coblentz et al., (2010) who reported that eastern gamagrass TDN content was highest in earliest harvest date (June 1) were lowest at the latest harvest date (August 15). Method of preservation also affected the TDN content of switchgrass forage (table 4.3). The TDN content of switchgrass did not differ in harvests one through three with preservation method. In harvest four, hay had a higher ($P \leq 0.05$) TDN than high and low moisture haylages (table 1.7). In harvest five low moisture haylages had the lowest ($P \leq 0.05$) TDN and high moisture haylage and hay were similar. Our results for harvest one through three are in agreement with those of Hersom et al., (2011) who reported that with bermudagrass round bale haylage had a higher TDN than hay.

Maturity effected the NDF content of switchgrass, but was did not reach the level of significant chosen for this study (table 4.3) The NDF content of switchgrass increased ($P \leq 0.1$) as stands mature (figure 1.5). Preservation method was found to effect NDF content in switchgrass at some but not all harvest dates (table 4.3). In earlier harvest haylages had the lowest ($P \leq 0.05$) NDF when compared to hay, whereas in later harvest haylages and hay were similar for NDF content (table 1.8). These results disagree with Burns et al., (1993) who reported that both direct and wilted switchgrass silage had higher NDF than switchgrass hay, and stated that the increase was due to the conversion of cell solubles into the products of fermentation.

Switchgrass from harvest one meets TDN requirements for both spring- and fall-calving cows during the entire winter feeding period. For spring-calving cows preserved switchgrass from harvest two met all months of the winter feeding except Mar. and fall-calving cows TDN requirements will be met for all months except Oct. and Nov. Harvests three, four, and five of preserved switchgrass met the TDN requirements in all months except Feb. and Mar. of spring-calving cows and only Feb. and Mar. for fall-calving cows. Regrowth harvest one and two was of high enough quality to meet the TDN requirements of both spring- and fall-calving cows throughout the winter. Switchgrass from harvest one met all CP requirement of both herds during the winter with a value of 10.6%. Harvest two average 8.5% CP and met the requirement of spring-calving cows in Oct., Nov., and Dec. and fall-calving herds for Mar. Harvest three had a CP of 7.2% and meets the requirement only for spring-calving cows only for Oct. and Nov. and none of the winter months requirement for fall-calving cows. Harvest four and five do not meet requirements for either herd for any of the winter feeding months. However switchgrass regrowth form harvest one and two will meet CP requirement for all months for all cows. Switchgrass harvested by mid to late May will meet the majority of spring- and fall-calving cow's energy and protein requirements during winter feeding.

Switchgrass was also evaluated for meeting the TDN and CP requirements of stocker cattle. The TDN of switchgrass from harvest one would result in 0.63 kg of ADG, when adequate CP is supplied. Switchgrass from harvest two would provide enough TDN to reach an ADG of 0.4 kg, if supplied with adequate CP. Harvest three, four, and five switchgrass provided TDN would result in an ADG of 0.28 kg/day. Switchgrass from harvest one supplied enough CP to reach an ADG of 0.68 kg/day, if energy needs are met. Harvest two provided 8.4% CP and would result in gains of 0.28 kg/day, if adequate TDN is supplied. Switchgrass from harvest three, four, and five will result in gains below 0.23 kg/day.

CONCLUSIONS

Tall fescue and switchgrass should be harvested early for the best quality. Preservation methods used with these forages did not differ in quality. Forages should be preserved according to weather conditions at the time of harvest, if rain is expected haylage is less weather dependent, and would be the preservation method of choice. The TDN and CP requirements for winter feeding of either spring- or fall-calving cows could be met without the need for supplementation with tall fescue and switchgrass if harvested by mid-May. Stocker cattle weighing 272 kg fed tall fescue from a mid-May harvest will gain about 0.45 kg/day with TDN being the first limiting nutrient. Whereas switchgrass harvested by mid-May will result in stockers having gains of about 0.63 kg/day.

APPENDIX 1: Tables and Figures

Table 1.1. Dates and stages of growth of initial and regrowth cuttings of tall fescue in 2010 and 2011.

	Initial Cutting[1] Harvest					Regrowth Cutting[2] Harvest				
	1	2	3	4	5	R1	R2	R3	R4	R5
2010	May 3	May 17	Jun 1	Jun 14	Jun 28	Jun 1	Jun 14	Jun 28	Jul 12	Jul 26
Julian Date	123	137	152	165	179	152	165	179	193	207
Stage of Growth	Heading[4]	Anthesis[5]	Seed Filling[6]	Ripe Seed[7]	Ripe Seed	Veg[8]	Veg	Veg	X[3]	X
2011	May 9	May 23	Jun 6	Jun 20	Jul 5	Jun 6	Jun 20	Jul 5	Jul 18	Aug 1
Julian Date	129	143	157	171	186	157	171	186	199	213
Stage of Growth	Heading	Anthesis	Seed Filling	Ripe Seed	Ripe Seed	Veg	Veg	Veg	Veg	X

[1]Initial = The first cutting of forage.
[2]Regrowth = The cutting of forage allowed to regrow four-weeks after the initial cutting.
[3]X = No regrowth in either year one or two.
[4]Heading = inflorescence emergence.
[5]Anthesis = pollination.
[6]Seed filling = water, milky, dough, hard.
[7]Ripe Seed = seed is dry, shatter.
[8]Veg = Vegetative.

Table 1.2. Dates and stages of growth of initial and regrowth cuttings of switchgrass in 2010 and 2011.

	Initial Cutting[1] Harvest					Regrowth Cutting[2] Harvest				
	1	2	3	4	5	R1	R2	R3	R4	R5
2010	May 17	Jun 1	Jun 14	Jun 28	X[3]	Jun 14	Jun 28	Jul 12	Jul 26	X
Julian Date	137	152	165	179	X	165	179	193	207	X
Stage of Growth	Veg[4]	Boot[5]	Heading[6]	Anthesis[7]	X	Veg	Veg	Veg	Veg	X
2011	May 9	May 23	Jun 6	Jun 20	Jul 5	Jun 6	Jun 20	Jul 5	Jul 18	Aug 1
Julian date	129	143	157	171	186	157	172	286	199	213
Stage of Growth	Veg	Stem Elongation[8]	Boot	Heading	Anthesis	Veg	Veg	Veg	Veg	Veg

[1]Initial = The first cutting of forage.
[2]Regrowth = The cutting of forage allowed to regrow four-weeks after the initial cutting.
[3]X = Harvest five did not occur in 2010.
[4]Veg = Vegetative, leaves only.
[5]Boot = Inflorescence is enclosed.
[6]Heading = Inflorescence is enclosed.
[7]Anthesis = Pollination.
[8]Stem elongation = Stems elongated.

Table 1.3. Least square means for CP of initial cuttings of tall fescue over a series of five harvests with two-week intervals and preserved in three methods beginning in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh-chop[2]	11.3[b]	9.9[a]	8.3[a]	8.0[a]	7.1[b]	1.2
High Moisture Haylage[3]	12.1[ab]	10.6[a]	9.3[a]	8.6[a]	10.0[a]	1.2
Low Moisture Haylage[4]	12.8[a]	10.3[a]	9.3[a]	8.4[a]	8.8[a]	1.2
Hay[5]	11.6[ab]	9.4[a]	8.2[a]	7.6[a]	7.5[b]	1.2

[1]Initial = The first cutting of forage.
[ab]Means within a column with no common letter differ ($P \leq 0.05$).
[2]Fresh-chop = Fresh forage collected directly after harvest.
[3]High Moisture Haylage = Forage wilted to 60% moisture before ensiled.
[4]Low Moisture Haylage = Forage wilted to 40% moisture before ensiled.
[5]Hay = Forage dried to ≤ 15% moisture.

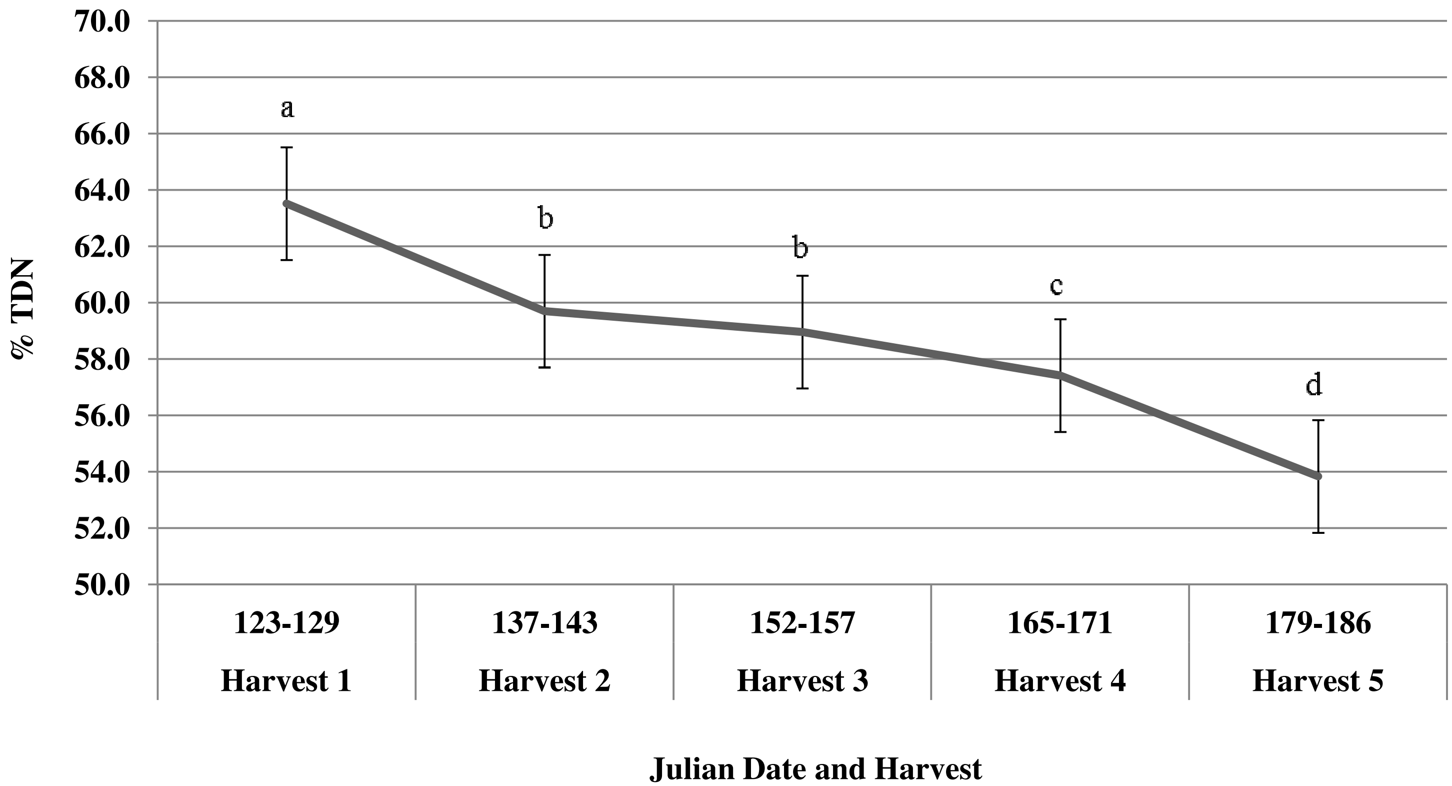

Figure 1.1. Effect of maturity on the TDN of tall fescue over five harvest dates for initial cuttings averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between harvests ($P \leq 0.05$).

Table 1.4. Least square means for TDN of initial[1] cuttings of tall fescue over a series of five harvests with two-week intervals and preserved in three methods beginning in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh-chop[2]	63.5[a]	59.7[a]	59.0[a]	57.4[a]	53.8[a]	2.1
High Moisture Haylage[3]	60.2[b]	56.1[b]	55.2[b]	52.6[c]	52.8[b]	2.1
Low Moisture Haylage[4]	60.6[b]	56.3[b]	54.5[b]	51.1[c]	52.0[b]	2.1
Hay[5]	61.3[b]	58.1[ab]	56.1[b]	55.1[b]	55.1[a]	2.1

[1]Initial = The first cutting of forage.
[a-c]Means within a column with no common letter to differ ($P \leq 0.05$).
[2]Fresh-chop = Fresh forage collected directly after harvest.
[3]High Moisture Haylage = forage wilted to 60% moisture before ensiled.
[4]Low Moisture Haylage = forage wilted to 40% moisture before ensiled.
[5]Hay = forage dried to ≤ 15% moisture.

Table 1.5. Least square means for NDF of initial[1] cuttings of tall fescue over a series of five harvests with two-week intervals and preserved in three methods beginning in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh-chop[2]	58.7[c]	63.9[b]	64.5[c]	66.3[c]	70.7[ab]	2.8
High Moisture Haylage[3]	61.6[b]	66.4[ab]	68.5[b]	70.0[b]	70.4[ab]	2.8
Low Moisture Haylage[4]	63.9[ab]	68.9[a]	71.8[a]	75.2[a]	72.1[a]	2.8
Hay[5]	65.8[a]	68.5[a]	70.1[ab]	70.2[b]	69.1[b]	2.8

[1]Initial = The first cutting of forage.
[a-c]Means within a column with no common letter differ ($P \leq 0.05$).
[2]Fresh-chop = Fresh forage collected directly after harvest.
[3]High Moisture Haylage = Forage wilted to 60% moisture before ensiled.
[4]Low Moisture Haylage = Forage wilted to 40% moisture before ensiled.
[5]Hay = Forage dried to ≤ 15% moisture.

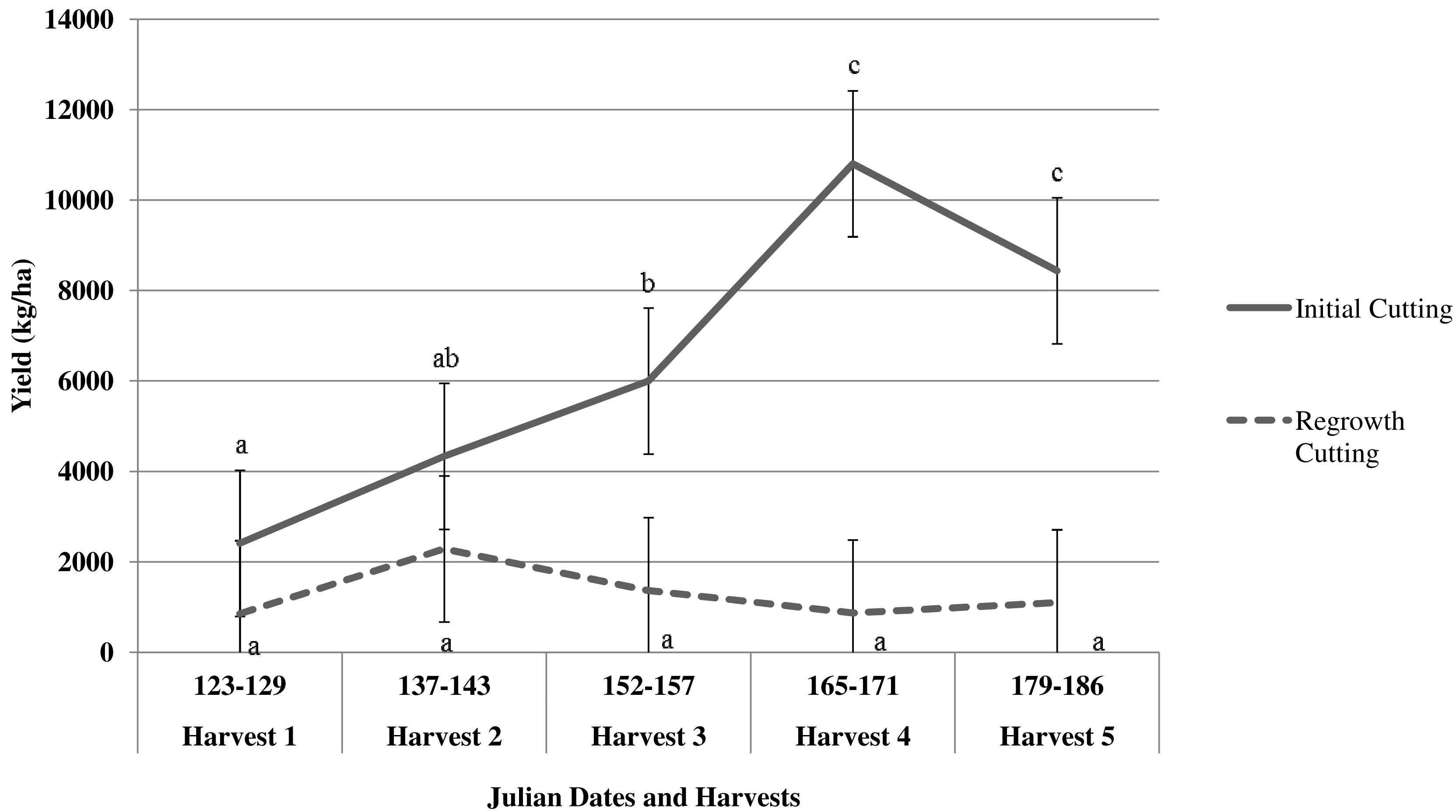

Figure 1.2. Effect of maturity on the DM yield of switchgrass over five harvest dates for initial and regrowth cuttings averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between harvests and within a cutting ($P \leq 0.1$) but are not at a level of significance selected for this study.

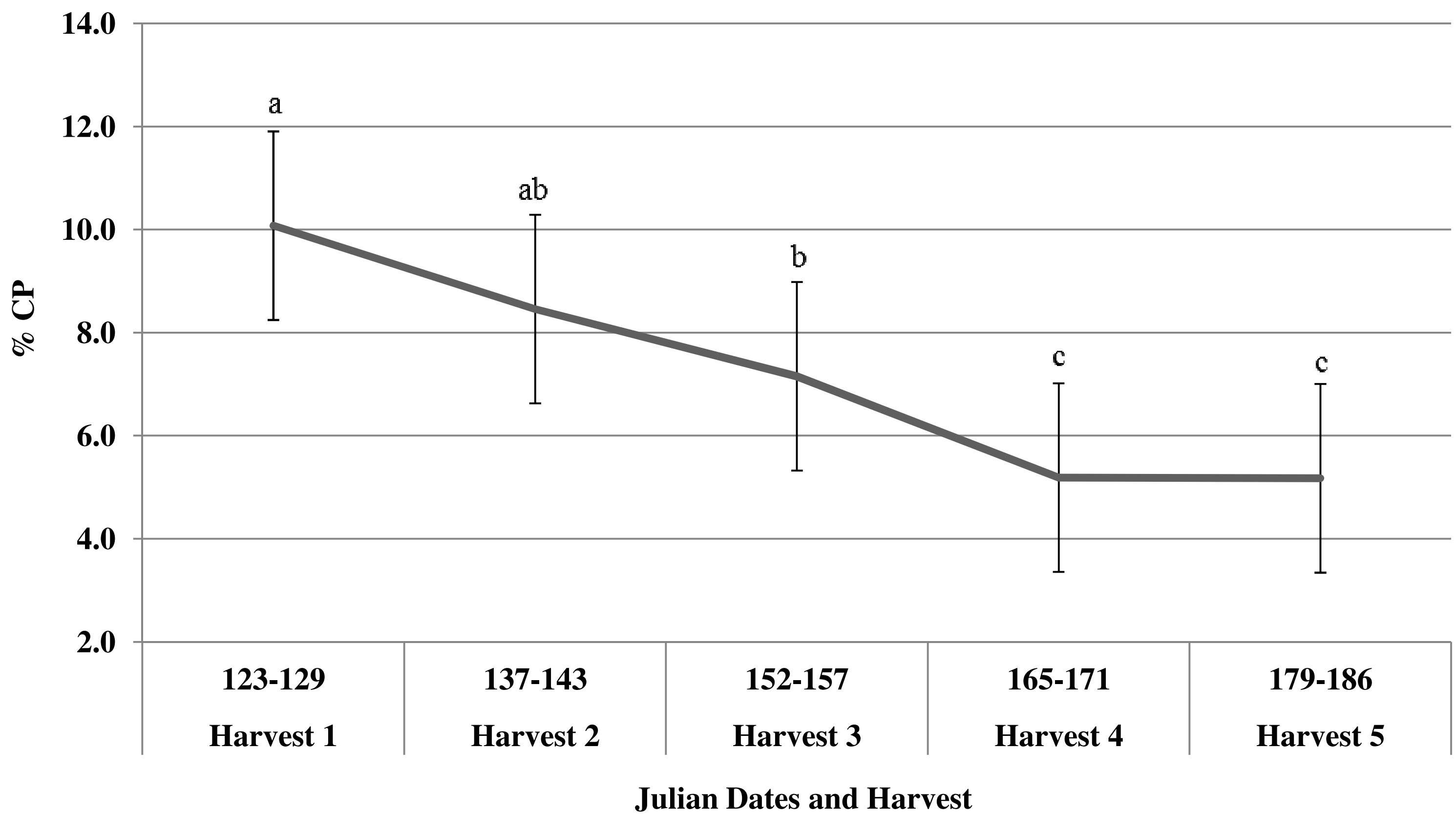

Figure 1.3. Effect of maturity on CP on a DM basis of switchgrass over five initial harvest dates averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between preservation methods ($P \leq 0.05$).

Table 1.6. Least square means for CP of initial[1] cuttings of switchgrass over a series of five harvests with two-week intervals and preserved in three methods beginning in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh Cut[2]	10.1[a]	8.5[a]	7.2[a]	5.2[a]	5.2[a]	1.8
High Moisture Haylage[3]	10.5[a]	8.2[a]	7.3[a]	5.8[a]	6.6[a]	1.8
Low Moisture Haylage[4]	11.2[a]	8.6[a]	7.6[a]	6.1[a]	6.1[a]	1.8
Hay[5]	10.3[a]	8.6[a]	7.1[a]	6.1[a]	6.2[a]	1.8

[1]Initial = The first cutting of forage.
[a]Means within a column with no common letter differ ($P \leq 0.05$).
[3]Fresh-chop = Forage at the time of cutting.
[4]High Moisture Haylage = Forage wilted to 60% moisture before ensiled.
[5]Low Moisture Haylage = Forage wilted to 40% moisture before ensiled.
[6]Hay = Forage dried to ≤ 15% moisture.

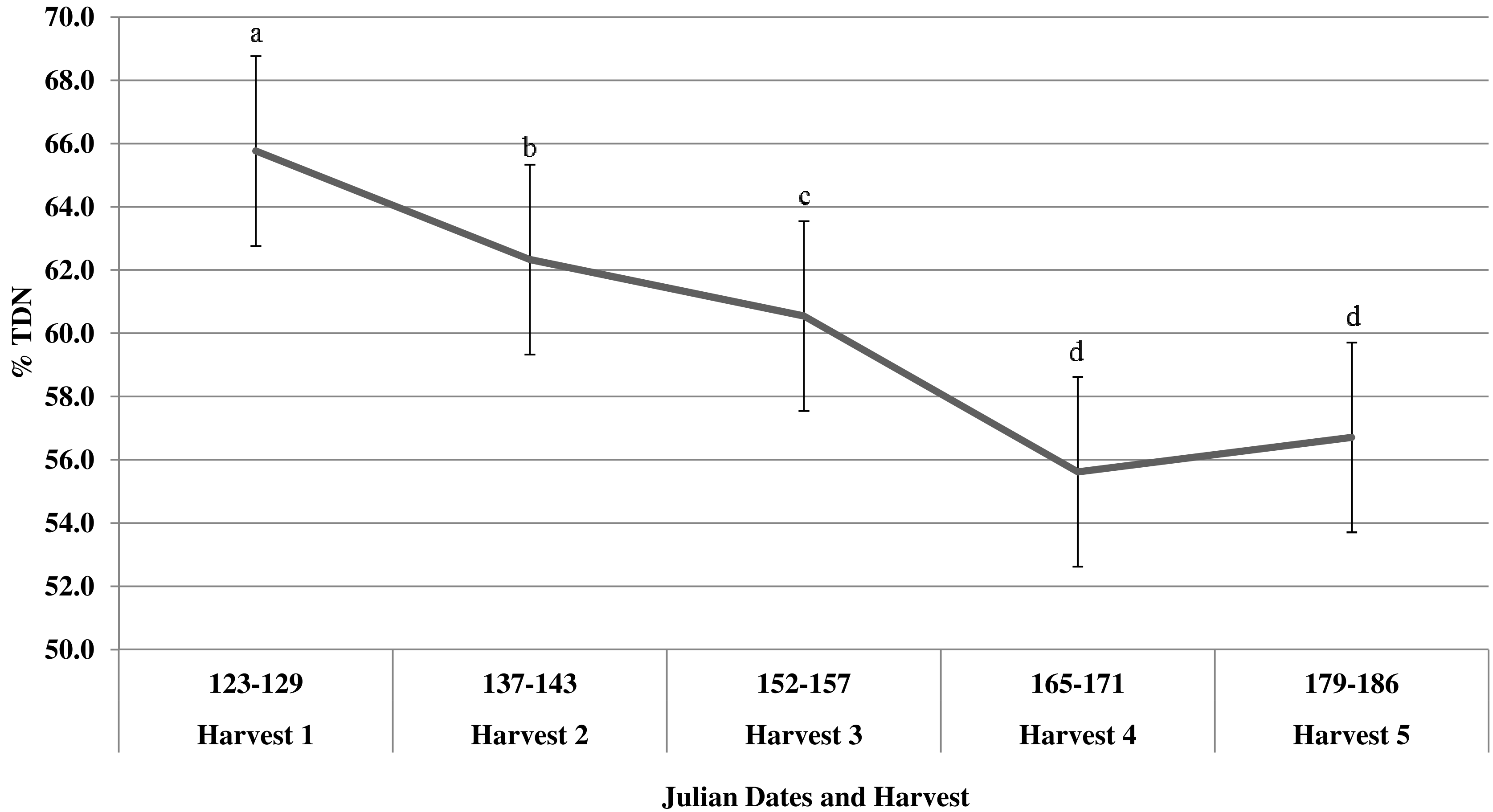

Figure 1.4. Effect of maturity on TDN on a DM basis of switchgrass over five initial harvest dates averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between preservation methods ($P \leq 0.05$).

Table 1.7. Least square means for TDN of initial[1] cuttings of switchgrass over a series of five harvests with two-week intervals and preserved in three methods beginning in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh-chop[2]	65.8^{a}	62.3^{a}	60.5^{a}	55.6^{ab}	56.7^{a}	3.0
High Moisture Haylage[3]	62.0^{b}	57.5^{b}	55.1^{b}	52.7^{b}	56.9^{a}	3.0
Low Moisture Haylage[4]	61.6^{b}	56.3^{b}	55.0^{b}	52.4^{b}	53.5^{b}	3.0
Hay[5]	63.2^{ab}	58.0^{b}	57.7^{ab}	57.0^{a}	57.4^{a}	3.0

[1]Initial = The first cutting of forage.
[a-c]Means within a column with no common letter differ ($P \leq 0.05$).
[2]Fresh-chop = Fresh forage collected directly after harvest.
[3]High Moisture Haylage = Forage wilted to 60% moisture before ensiled.
[4]Low Moisture Haylage = Forage wilted to 40% moisture before ensiled.
[5]Hay = forage dried to ≤ 15% moisture.

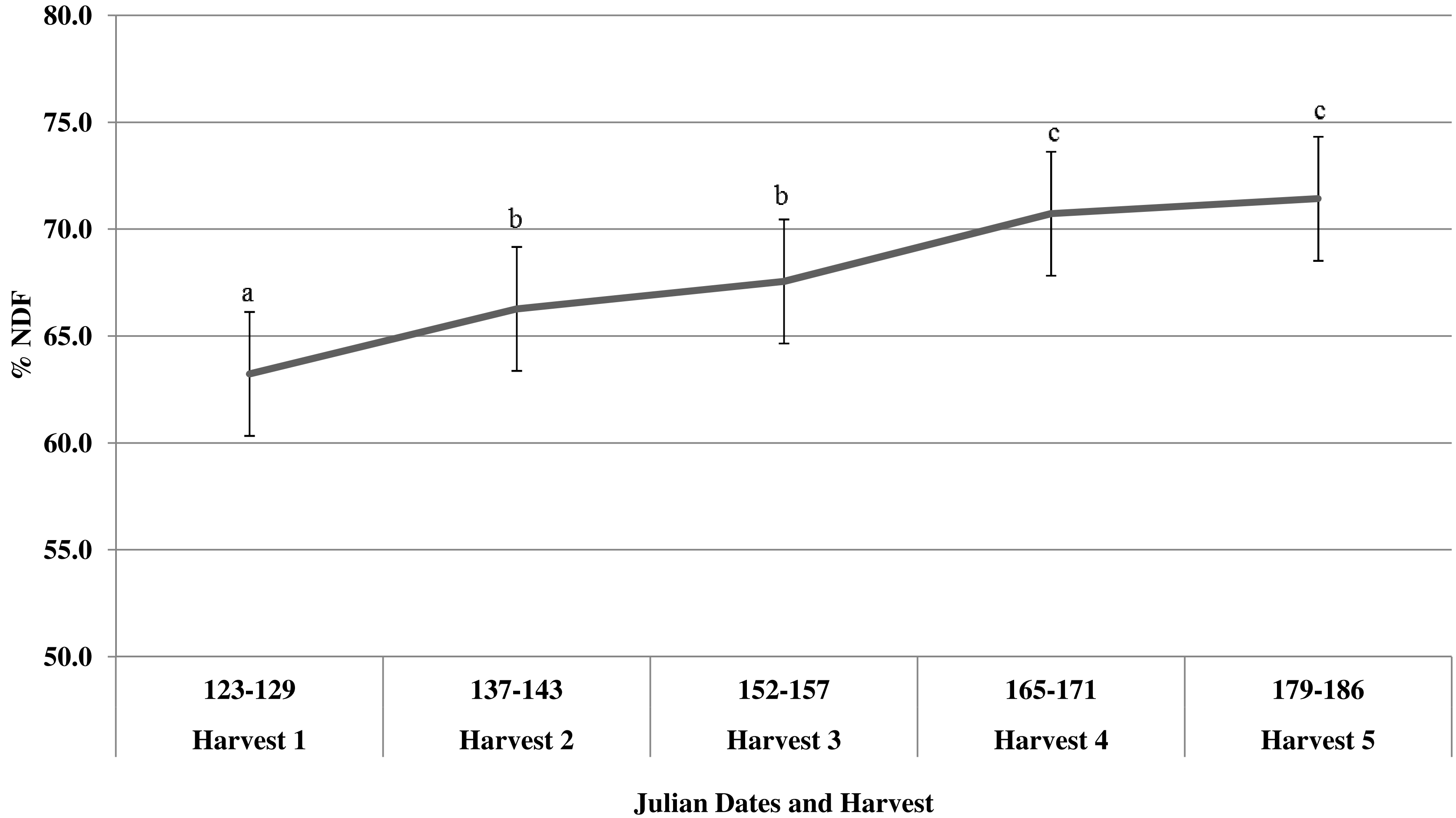

Figure 1.5. Effect of maturity on NDF on a DM basis of switchgrass over five initial harvest dates averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between preservation methods ($P \leq 0.1$).

Table 1.8. Least square means for % NDF of initial[1] cuttings of switchgrass over a series of five harvests with two-week intervals and preserved in three methods beginning the in May averaged for 2010 and 2011.

	Harvest					
Treatment	**1**	**2**	**3**	**4**	**5**	**Std. Error**
Fresh Cut[4]	63.2[b]	66.3[b]	67.6[b]	70.7[b]	71.4[b]	2.9
High Moisture Haylage[5]	63.6[b]	68.4[ab]	71.6[ab]	72.8[b]	69.0[b]	2.9
Low Moisture Haylage[6]	66.3[ab]	71.2[a]	73.8[a]	76.1[a]	76.4[a]	2.9
Hay[7]	68.8[a]	70.9[a]	69.1[b]	70.6[b]	71.3[b]	2.9

[1]Initial = The first cutting of forage harvests.
[ab]Means within a column with no common letter differ ($P \leq 0.05$).
[4]Fresh-chop = Forage at the time of cutting.
[5]High Moisture Haylage = Forage wilted to 60% moisture before ensiled.
[6]Low Moisture Haylage = Forage wilted to 40% moisture before ensiled.
[7]Hay = Forage dried to ≤ 15% moisture.

CHAPTER 3: EFFECTS OF MANAGEMENT OF NATIVE WARM-SEASON GRASSES ON FORAGE QUALITY

ABSTRACT

Determining if nitrogen fertilization, multiple harvest systems, and preservation method affects the yield and forage quality of native warm-season grasses (**NWSG**), will potentially lead to better utilization of available forage. Double cropping (forage and biofuel) NWSG could result in more potential profit for producers. Two years of forage data were collected from established stands of switchgrass (*Pancium virgatum* L.) and a big bluestem (*Andropogon gerardi* Vitman)/indiangrass (*Sorgastum nutans* L. Nash) mix. Plots were assigned one of three harvest system treatments: 1) mid-June, 2) mid-June/post-frost (biofuel), or 3) post-frost (biofuel). Within harvest systems, 67 kg of N/ha was applied at green-up with plus additional nitrogen fertilization (0 or 67 kg N/ha) was applied after June harvests. June harvests were preserved as haylage or hay and compared to fresh frozen samples collected at each harvest. All samples were analyzed for CP, TDN, and NDF. Yield was calculated from total plot yield and the DM of the fresh-chopped forage. Data were analyzed using a mixed model analysis of variance with a randomized block split-split-split plot design. Harvest system affected ($P \leq 0.05$) the DM yield of NWSG forages. Harvesting NWSG in mid-June reduced total DM yield compared to single post-frost (biofuel) harvest of switchgrass, but increased ($P \leq 0.05$) the total yield of the big bluestem/indiangrass mix. Nitrogen fertilization less than 134 kg/ha did not affect ($P \geq 0.05$) yield or quality. Preservation methods did not differ in CP, TDN, or NDF content of June harvested forages.

INTRODUCTION

Switchgrass (*Pancium virgatum* L.), big bluestem (*Andropogon gerardi* Vitman), and indiangrass (*Sorgastum nutans* L. Nash) are native warm-season grasses (**NWSG**) that have great potential for incorporation into a livestock feeding system. Proper management of NWSG is essential for maintaining forage quality, stand persistence, and biomass production. Understanding the effects that multiple harvests, fertilization, and preservation method have on DM yield and forage quality will improve utilization of NWSG.

Seasonal growth of NWSG is predominantly during the late-spring and summer; thus, preserving these forages for later feeding to livestock is valuable. Due to a high stem-to-leaf ratio, warm-season grasses often require an extended drying time in the field leading to increased DM losses to unfavorable weather (Taliaferro et al., 2004). Because of the shorter drying times required for haylage production, haylages may provide a solution to DM and forage quality losses at harvest and possibly increase animal performance for animals fed conserved NWSG.

Many studies on the management of NWSG have been performed in regard to biomass for ethanol production. Obtaining the greatest yield of cellulose is the main goal when harvesting for biomass. However, the ability of NWSG to produce both forage and biomass with multiple harvests may prove the most profitable for producers. Sanderson et al., (1999) reported that NDF was lowest (640 g/kg) and CP was highest (110 g/kg) during a mid-May harvest of switchgrass and that a spring-autumn harvest would allow a farmer to feed the spring harvest and use the autumn harvest for biomass. Thus producers may have the option for double cropping their NWSG as both forage (in the early growing season) and a biomass harvest (in the fall). The objective of this study was to determine how management based on multiple harvests, preservation method, and nitrogen fertilization of NWSG affected DM yield, forage quality, and biomass production in second and third year stands of NWSG.

MATERIALS AND METHODS

This study utilized two-year old stands in 2010 and three-year old stands in 2011 of NWSG at the Plateau Research and Education Center (PREC) in Crossville Tennessee (35.95N 85.03W). Soil at PREC is classified as a Ramsey loam (lomey, siliceous, mesic Lithic Dystrudepts).

In this two-year study, treatments were two forage systems, three harvest strategies, two preservation methods, and two rates of nitrogen fertilization. One experimental unit consisted of a 1.83 m x 7.62 m area plot in which one harvest system treatment, one N treatment, and two preservation treatments were applied. The study was replicated four times and had a total of 48 total experimental units.

Forage systems were a monoculture of ‘Kanlow’ switchgrass and a combination of 65% ‘OZ-70’ big bluestem/35% ‘Rumsey’ indiangrass (on a pure live seed basis). Harvest strategies were: 1) mid-June cutting, 2) mid-June/post-frost cutting, and 3) post-frost cutting. Preservation methods for mid-June harvest were: 1) 60-50% moisture haylage and 2) ≤ 15% moisture hay. Preservation methods were compared to fresh-chop forage collected at each harvest. The preservation method for post-frost harvest cutting was in the form of a biofuel harvest. Nitrogen treatments were: 1) 0 kg N/ha and 2) 67 kg N/ha in the form of ammonia nitrate applied following June harvests.

Forage was harvested using a flail type harvester (Carter Mfg. Co., Brookston, IN) with a 0.81 m cutting head along the 6.1 m length of individual plots. Cutting height on the harvester was set to leave 20.3 cm of stubble. Following the June cuttings all plots selected to receive N application at the 67 kg/ha application rate were fertilized by hand application of pre-weighed fertilizer this is in addition to the 67 kg N/ha that stands received at green up prior to the growing season each year of the study and with P, K, and lime applied based on soil test to achieve medium fertility levels. Harvested forage was subsampled for DM determination. Samples were sealed in a Ziploc® freezer bag labeled and immediately placed on dry ice, and later stored in a freezer at -4° C. Samples were lyophilised (Freeze Dryer 5, Labconco Corp., Kansas City, MO). Samples were weighed for DM determination, and then ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

Forage harvested from plots was spread on black poly-blend landscape fabric placed on top of plant stubble. Forage was wilted to 55% haylage and 15% hay. Moisture levels were measured every few hours in the field using a Koster Tester (Koster Crop Tester Inc., Strongsville, OH). Forage was turned once daily at noon to simulate the use of a hay tedder.

For haylage, forage was packed into miniature silos (0.95 L glass jars) sealed with a lid to keep silo air tight and stored in a dark room. When the desired moisture was reached for hay, samples were placed into a cloth bag and labeled. Hay samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

After at least 60 days of fermentation, haylage samples were opened. A mold score of 0 to 100% expressed in 5% increments was given to each haylage silo. Haylage fluid was extracted using the methods described by Dairy One (2012). The pH of haylage fluid was measured using a pH meter (Acument Basic AB15 pH meter, Fisher Scientific, Pittsburg, PA). The remaining haylage was stored in a freezer at -4°C until samples could be lyophilised (Freeze Dryer 5, Labconco Corp., Kansas City, MO). Freeze-dried haylage samples were weighed and DM calculated. Haylage samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

Post-frost harvest occurred after the first killing frost at the end of the fall growing season as a biofuel harvest. Forage was harvested and samples were taken weighed then dried in a walkin forced air oven at 46°C for 72 hours. Sub samples were used for DM calculation. Samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

All dried, ground, forage samples from the preservation treatments were then analyzed for NDF and ADF using an Ankom 200 Fiber Analyzer (Ankom Technol., Macedon, NY) using the procedures described by Ankom Technol., (1998). Nitrogen content was measured using a LECO TruMac N Nitrogen Determinator (LECO Corp., St, Joseph, MI) using the procedures described in the LECO manual (2011), and CP was calculated as N x 6.25. Total digestible nutrients (TDN) were estimated using the formula: TDN = 4.898 + 89.796 x NEl, Net energy of lactation (NEl) = 1.044 – 0.0119 x ADF, (Pennsylvania State Univ., 1995).

The results from DM yield calculation, pH, mold scores, and forage quality analysis were used as the dependent variables and were statistically analyzed using a mixed model analysis of variance procedure, in SAS version 9.3 (Cary, NC). Because variation was expected to occur between years, harvest strategies, forage systems, and preservation type, a randomized block with split-split plot design was used. Year was the whole plot and blocking occurred on year, with species applied to the two years, the first split was on harvest strategies within forage systems, the second split was applied to nitrogen fertilization within harvest, and the third split was applied to the three preservation methods occurring in four replications. The fixed effects were all interactions between forage system, harvest strategies, N fertilization, and preservation methods where the random effects were the interactions between year, forage systems, harvest strategies, N fertilization, and preservation methods. Level of significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Year and N fertilization had no effect based on statistical analysis ($P > 0.1$, respectively) on the dependent variables tested in this study, therefore, years and N rates were combined and data were pooled for this study. Weather was monitored one month prior to the first harvest and daily during harvest and periods of wilting forage. Monthly average maximum and minimum temperatures and total monthly rainfall had very little variation between years (NOAA, 2012).

The DM yield of both specie systems was affected by the harvest strategies used in this study (table 4.4). Harvest strategy one (June only) had the lowest ($P \leq 0.05$) DM yields in both species (figure 2.1). Harvest strategy two (June and October harvests) had higher yields than harvest strategy one for switchgrass. The highest ($P \leq 0.05$) switchgrass yields came from harvest strategy three (October only) with a yield of 11,656 kg/ha. This agrees with Sanderson et al., (1999) who reported decreased DM yields in switchgrass harvested in a two-cut (spring – autumn) system versus a single late-fall cutting. This was different with big bluestem/indiangrass stands. Both June harvests of big bluestem/indiangrass had similar yields. Biomass yields of big bluestem/indiangrass were also similar.

The CP content of these forages was not affected by harvest strategy but was affected by preservation method (table 4.4). The CP content of switchgrass did not differ when comparing haylage to hay in harvest strategy one. This agrees with Burns et al., (1993) who found that CP of switchgrass hay did not decline as forage was dried. In harvest strategy one, the big bluestem/indiangrass mix haylage and hay had similar CP content with a values of 13.1 and 12.1%, respectively. In harvest strategy two, haylage and hay had similar CP content (12.3 and 11.7%, respectively). These results agree with Burns and Fisher (2012) who reported that CP levels of big bluestem haylage at 55% moisture was similar to hay. Biofuel in both forage systems in this study had the lowest ($P \leq 0.05$) CP but this was expected because of the maturity effect when comparing forages harvested in June and October. Perry and Baltensperger (1979) report that switchgrass, big bluestem, and indiangrass all show rapid declines in leaf CP at a constant rate throughout the growing season.

The TDN of these forages was not affected by harvest strategy but was affected by preservation method (table 4.4).The TDN content of switchgrass in harvest strategy one haylage and hay were similar at 57%. In harvest strategy two, haylage was lower ($P \leq 0.05$) than hay with values of 55.7 and 57.7, respectively. This disagrees with Hersom et al., (2011) who reported that the TDN of bermudagrass round bale haylage was higher than the TDN of hay. Big bluestem/indiangrass in both harvest strategies one and two hay and haylage were similar to each other. Haylages averaged 56.8% TDN and hay had an average value of 56.2% TDN in harvest strategies one and two, respectively. Percent TDN was also affected by the maturation of the forage into a biofuel harvest. Biofuel in harvest strategy two for both switchgrass and the big bluestem/indiangrass mix had the lowest ($P \leq 0.05$) TDN when compared to the forage in the June harvest. These results are expected due to the effects of maturity on the stands between June and October harvest.

The NDF content of these forages was not affected by harvest strategy but was affected by preservation method (table 4.4). In harvest strategy one, preserved switchgrass hay had the highest ($P \leq 0.05$) NDF content when compared to haylage with values of 66.6 and 71.0 %, respectively. This agrees with Luginbuhl et al., (2000) who reported that the NDF of switchgrass was higher in hay than in haylage. This does not agree with results from harvest strategy two, where hay and haylage had similar NDF content with values of 69.3 and 71.53 %, respectively.

The NDF of big bluestem/indiangrass also differed between preservation methods. In harvest one, haylage had a lower ($P \leq 0.05$) NDF than hay of 64.7 and 69.8%, respectively. The same results occurred in the harvest strategy two June cutting forage preservations with NDF values of 66.0% for haylage and 69.8% for hay. The results disagree with Burns and Fisher (2012) who reported that NDF did not differ between big bluestem hay and haylage. The NDF content of forages is related to forage intake, a lower NDF content may result in an increase in potential intake by cattle compared to hay. Biofuel produced from both switchgrass and the big bluestem/indiangrass mix had the highest ($P \leq 0.05$) overall NDF in harvest strategy two with a value of 78.0 and 77.6%, respectively. The increase in NDF between June and October harvest was expected due to maturity.

CONCLUSIONS

In managing NWSG stands of switchgrass and big bluestem/indiangrass a fertilization rate lower than 134 kg of N/hectare had no effect on yield or forage quality. To obtain higher biomass yields it is best to use a single harvest in the fall for switchgrass. However, in the big bluestem/indiangrass mix, a June forage and October biofuel harvest resulted in greater total DM yields when compared to the single cutting harvests. The forage quality of switchgrass and the big bluestem/indiangrass mix were not affected by preservation method. Haylage preservation of June harvested NWSG is recommended when weather conditions storage of hay are unfavorable to potentially prevent spoilage loss, otherwise hay is the preferred method.

APPENDIX 2: Tables

Table 2.1. Least square means for DM yield[1] of switchgrass and an indiangrass and big bluestem mix harvested in one of three harvest strategies.

Treatment	Switchgrass	Big Bluestem and Indiangrass	Std. Error
Harvest strategy 1[2]	2959[a]	2313[a]	1290
Harvest strategy 2[3] - June	5066[b]	2587[a]	1290
Harvest strategy 2 - October	4650[b]	7079[b]	1290
Harvest strategy 2 - Total	9716[c]	9666[c]	1290
Harvest strategy 3[4]	11656[d]	8282[b]	1290

[1]DM yield = Dry matter yield in kilograms per hectare.
[a-d]Means within a column with no common letter differ ($P \leq 0.05$).
[2]Harvestd in early June.
[3]Harvestd in early June with regrowth harvested in October as biofuel.
[4]Harvestd in October as Biofuel.

CHAPTER 4: EFFECT OF ALKALI TREATMENT OF MATURE SWITCHGRASS PRODUCED FOR BIOFUEL FEEDSTOCK

ABSTRACT

Mature switchgrass (*Pancium virgatum* L.) was treated with alkali and potentially resulted in a new feedstuff for cattle. Two years of forage data were collected from an established stand of 'Alamo' switchgrass located at the Plant Science Unit of the East Tennessee Research and Education Center in Knoxville Tennessee. Forage was harvested either in mid-October or mid-November each year. Harvested forage was passed through a chipper to obtain a length of 7.6 to 12.7 cm. Forages were treated with one of 12 alkali treatments consisting of increasing concentrations and varying combinations of NaOH and/or CaO based on a percentage of forage DM and ensiled in laboratory silos. After ensiling haylages were analyzed for quality of fermentation using mold scores and pH. Forage quality analysis was performed to determine CP and NDF and estimate TDN. Data were analyzed using a randomized block, split-plot design. Harvest date did not affect mold score, CP, TDN, or NDF. October harvest had the lowest and most stable pH ($P \leq 0.05$). Alkali treatment at concentrations of three g/100 g of forage DM reduced NDF. Alkali treatment did not affect mold score, CP or TDN. Switchgrass harvested in October had decreased NDF content when treated with alkali. It is recommended that fall harvest switchgrass be harvested in October rather than November and treated with at least three g alkali per 100 g of forage DM to maximize forage quality of mature switchgrass.

INTRODUCTION

Once warm-season grasses like switchgrass (*Pancium virgatum* L.), reach senescence quality is drastically reduced. The use of alkali chemicals to treat mature forages could be a feasible option to increase the nutritive value of these forages. Klopfenstein, (1978) concluded that crop residues treated with alkali chemicals have increased digestibility by breaking the bonds between lignin and hemicellulose or cellulose. By removing the lingo-cellulosic bonds through alkali treatment, a source of nutrients that are inaccessible prior to treatment become available to the animal, leading to a potential increase in animal performance. This was supported by Kerley et al., (1985) who found that alkali hydrogen peroxide treatment of mature wheatgrass removed a significant physical barrier to ruminal bacterial attachment.

Warm-season grasses have been shown to increase digestibility when treated with alkali chemicals. 'Coastal' bermudagrass haylage pretreated with both neutralized and non-neutralized NaOH had increased digestibility (McHan, 1985). Another study in the use of thermo-ammoniation on immature and mature switchgrass and mature indiangrass led to increases in digestibility, intake, rate of disappearance, and rate of NDF digestion, with the largest increases occurring in the more mature grasses (Gates et al., 1987). These findings make the treatment of NWSG with alkali a potential source for producing quality forage from forage that has matured beyond a point of a useful feed source for livestock. The objective of this study was to determine the effects of alkali treatment on ensiled late maturity switchgrass on nutritive quality and nutrients available for livestock feeding.

MATERIALS AND METHODS

Mature 'Alamo' switchgrass was harvested, treated with alkali, and ensiled. Switchgrass was located at the Plant Science Unit of the East Tennessee Research and Education Center

(ETREC) in Knoxville Tennessee (35.53°N 83.57°W). Soil at the Plant Science unit is classified as a Sequatchie loam (fine loamy, siliceous, semiactive, thermic Humic Hapludults). Stands received 67 kg N/ha at green up prior to the growing season each year of the study and P and K applied based on soil test to achieve medium fertility levels.

Harvest treatments were separated by 28 days and were mid-October and mid-November. Forage was harvested using a flail type harvester (Carter Mfg. Co., Brookston, IN) with a 0.81 m cutting head along the 6.1 m length of individual plots. Cutting height on the harvester was set at 20 cm of stubble. Harvested forages were passed through a McCulloch MCS 2001 electric chipper/shredder (McCulloch, Charlotte, NC) to reach 7.6 – 12.7 cm length prior to treating. Moisture of forage was found using a Koster Crop Tester (Koster Crop Tester Inc., Strongsville, OH) prior to treatment and ensiling. A moisture content of at least 60% was desired. If moisture content was below 60%, samples were standardized to a moisture level of 60% by adding distilled water.

Alkali treatments were: 1) Control/no alkali added; 2) 1% NaOH; 3) 2% NaOH; 4) 3% NaOH; 5) 4% NaOH; 6) 1% CaO; 7) 2% CaO; 8) 3% CaO; 9) 4% CaO; 10) 1% NaOH:3% CaO; 11) 2% NaOH:2% CaO; and 12) 3% NaOH:1% CaO. Percent alkali was based on grams of chemical per 100 g of forage DM. Alkali treatments were mixed with the forage prior to ensiling. Sodium hydroxide was dissolved in the water supplied to standardize the moisture content of forage using a glass beaker and magnetic stir plate before being added to the forage material. Calcium oxide was top dressed on the forage material and water was added to standardize moisture content of forage to 60%. Treated forage was packed into miniature silos (0.57 L glass jars) and capped and sealed to keep silo air tight. Silos were labeled with alkali treatment, replication, and date of ensiling.

After at least 40 days of fermentation, haylage samples were opened. A mold score of 0 to 100% expressed in 5% increments was given to each haylage silo. At this time haylage fluid was extracted using the methods described by Dairy One (2012). The pH of haylage fluid was measured using a pH meter (Acument Basic AB15 pH meter, Fisher Scientific, Pittsburg, PA). The remaining haylage was stored in a freezer at -4°C until samples can be lyophilised (Freeze Dryer 5, Labconco Corp., Kansas City, MO). Freeze-dried haylage samples were weighed and DM calculated. Haylage samples were ground using a Wiley Laboratory Mill Model 4 (Thomas Technol. Service, Swedesboro, NJ) to pass a 1-mm screen.

All dried, ground, forage samples were then analyzed for NDF, ADF, and N content for calculating CP (CP = N x 6.25). The NDF and ADF concentrations were determined using an Ankom 200 Fiber Analyzer (Ankom Technol., Macedon, NY) using the procedures described by Ankom Technol., (1998). Nitrogen content was measured using a LECO TruMac N Nitrogen Determinator (LECO Corp., St, Joseph, MI) using the procedures described in the LECO manual (2011). Total digestible nutrients (TDN) were estimated using the formula: TDN = 4.898 + 89.796 x NEl, Net energy of lactation (NEl) = 1.044 – 0.0119 x ADF, (Pennsylvania State Univ., 1995).

This experiment was a two year study beginning in the fall of 2010 and repeated in the fall of 2011. Treatments applied to mature switchgrass were two harvest dates and 12 chemical treatments with three miniature silo replications for each date and chemical combination. One experimental unit consisted of a single replication of chemically treated switchgrass haylage on a harvest date (one miniature silo) leading to a total of 72 units for quality analysis. The results from pH, mold scores, and forage quality were used as the dependent variables and were statistically analyzed using mixed model analysis ANOVA in SAS version 9.3 (Cary, NC). The fixed effects were all interactions between harvest date and alkali treatment where the random effects were the interactions between year, harvest date, and alkali treatment. Because it was expected that differences would occur between years within the study, a randomized block with split plot design was used. The whole plot was year and blocking occurred on year, the split was on date of harvest, and treated with 12 chemical treatments applied within each chemical harvest and replicated three times. The level of significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

The effect of year in the statistical model was found to have no effect ($P \geq 0.1$) on the dependent variable tested in this study. Therefore, years were combined and data were pooled for this study. Harvest date and alkali treatment did not affect ($P \geq 0.1$) CP or TDN content of switchgrass. Weather was monitored one month prior to the first harvest and daily during harvest and periods of wilting forage. Monthly average maximum and minimum temperatures and total monthly rainfall had very little variation between years (NOAA, 2012).

Date of harvest affected ($P \leq 0.05$) the pH values of alkali treated mature switchgrass (table 4.5). October harvested switchgrass had lower ($P \leq 0.05$) pH values than November harvested switchgrass with alkali treatments. This was most evident in the control groups, where October harvested switchgrass had a pH of 4.52 and November harvested switchgrass had a pH of 6.75. The higher pH values of November harvests compared to the October harvests may be due to the presence of lower levels water soluble carbohydrate that undergo fermentation. This agrees research reported by Orians et al., (2011) indicating that mature plants favored sequestration of nutrients to storage tissues, roots, due to environmental stressors such as lack of nutrients, herbivory/defoliation, and weather conditions such as drought, cool weather, and/or frost.

The addition of alkali affected pH levels of ensiled switchgrass ($P \leq 0.05$) (table 4.5). The greater the concentration of alkali added the more pH increased from the control. In October harvests the highest ($P \leq 0.05$) pH values were found at concentrations of 2% and higher regardless of the alkali used or combinations. However, the pH of November harvested switchgrass haylage was not affected by alkali treatment. In later harvest pH is not affected as others (Tetlow and Mason, 1987) have reported no change in pH when lower concentrations of alkali were used to treat whole cereal crops.

Switchgrass was successfully treated with alkali and preserved as haylage. Packing density of haylage in miniature silos may have affected quality results. Tightly packed haylage will have increased air exclusion, lower pH, and less spoilage loss (Lemus, 2010). Kung, (2010) recommended that the packing density of at least 240 kg/m^3 for round bale haylage, 192 kg/m^{3}for bag haylage, and 224 to 256 kg/m^3 for bunker silos. Haylages were found to be packed at an average density of 328 ± 25 kg/m^3. Silos were packed at a level that was well above recommended density for haylage. In a normal production system haylage will most likely not be at the same packing density as in this study and may result in higher pH and mold scores.

Date of harvest did not affect TDN of mature switchgrass, but alkali treatment did to effect switchgrass TDN ($P \leq 0.1$) (table 4.5). However, only November harvest was changed with alkali treatment. October harvests TDN content was not affected with alkali treatment.

Level of alkali treatment affected ($P \leq 0.05$) the NDF content of treated mature switchgrass (table 4.5). In October harvest the treatment of switchgrass with higher levels alkali decreased the NDF content of mature switchgrass haylage (figure 3.1). October harvest had the lowest ($P \leq 0.05$) NDF values at treatment levels of at least 3% alkali regardless of alkali type or combination. In the November harvests the treatment of switchgrass haylage with alkali compounds did not significantly affect NDF content of treated haylage. The results for October harvests were similar to those found by Haddad et al., (1994), who reported that treatment of wheat straw with 3% and 5% NaOH and CaO and a 2.5% NaOH + 2.5% CaO mix, had decreased NDF levels when compare to untreated wheat straw silage. The decrease in NDF could potentially lead to an increase in forage intake.

CONCLUSIONS

Switchgrass should be harvested as soon as possible after a killing frost and treated with at least three g of alkali per 100 g of DM. Harvesting and ensiling switchgrass in October resulted in a lower and potentially more stable pH. October harvested switchgrass had decreased NDF content when treated with alkali. This reduction in NDF could potentially result in improved intake of the treated forage. Perhaps levels of alkali used in this study were not sufficient to result in a large change in nutritive value. Treating mature switchgrass at higher concentrations of alkali than used in this study needs further investigation.

APPENDIX 3: Figures

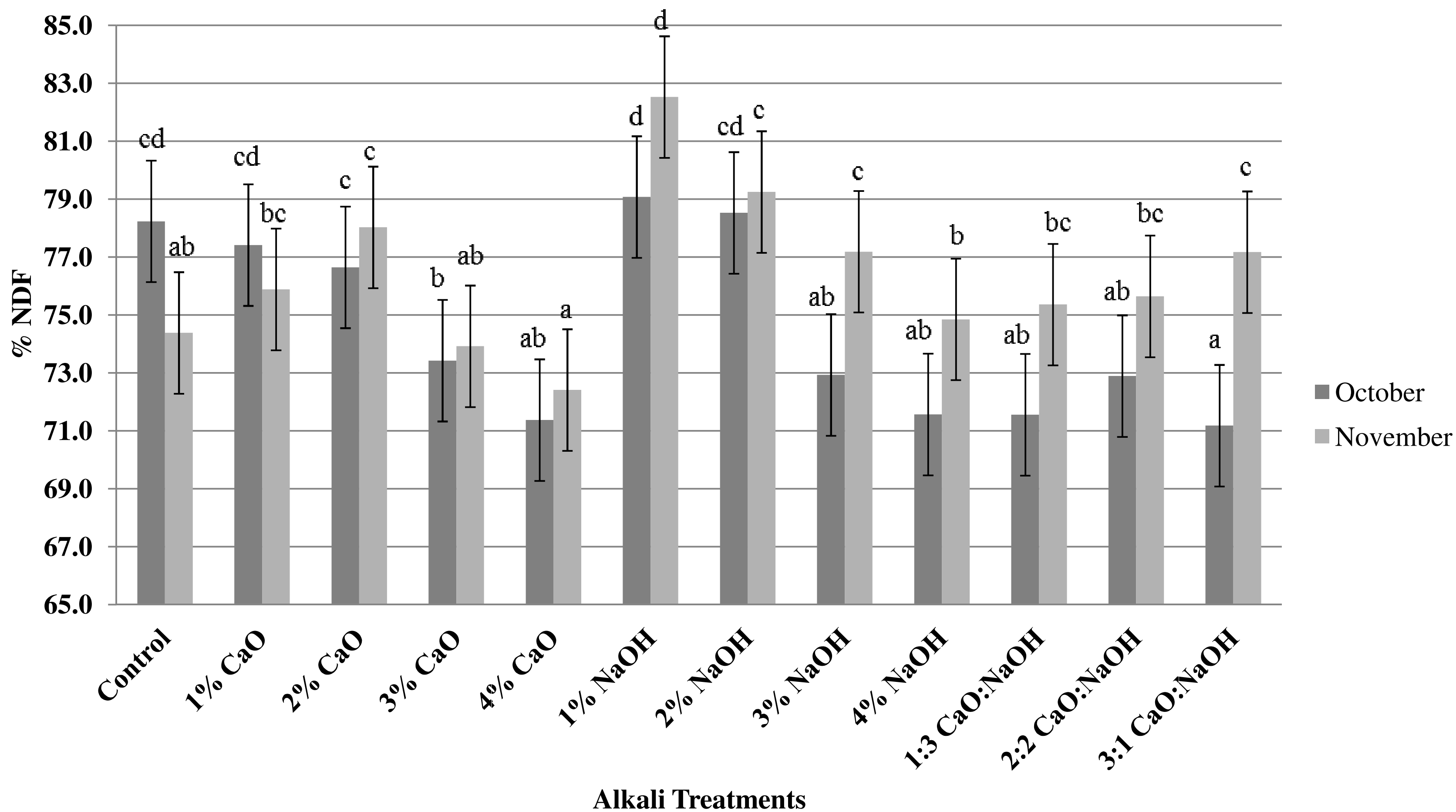

Figure 3.1. Effect of alkali treatment of NDF on a DM basis on mature switchgrass from an October and November harvest averaged for 2010 and 2011. Raw means with SE are shown; means with different letters differ between preservation methods ($P \leq 0.05$). Alkali treatment are on a % or g of alkali treatment per 100 g of forage DM. Alkali treatments consist of CaO = calcium oxide, NaOH = sodium hydroxide, and combinations of CaO and NaOH.

CONCLUSIONS

The use of forages as a feed source for livestock production is necessary for producers to maintain a profitable operation and provide a quality product for consumers. Tennessee is predominantly a cow-calf production state and utilizes tall fescue as its base forage. The use of preservation methods are necessary to provide quality forage for livestock during periods when forage production is lacking. These methods need to be evaluated to determine which method can provide the highest quality forage.

The growth cycle of tall fescue and other cool-season grasses often leaves a gap in forage production during summer months. This may be alleviated through the addition of native warm-season grasses such as switchgrass for grazing or as conserved forage. Switchgrass may provide suitable forage if managed properly with respect to maturity and if a preservation method that maximizes forage quality during its growth stages is implemented.

Management of tall fescue and switchgrass through proper timing of harvest and the use of preservation methods may lead to an increase of forage quality and potentially reduce tall fescue toxicosis. The first study investigated the effect that maturity at harvest and compared preservation methods of high and low moisture haylage and traditional hay. Findings indicated that both tall fescue and switchgrass had the highest forage quality when harvested earlier in the growing season and that preserving in the form of high or low moisture haylage had similar forage quality when compared to hay. It was also found that preservation method used did not affect ergovaline levels in tall fescue, but conserved tall fescue hay was below the toxic threshold. Therefore, production of haylage is not a recommended method in reducing the potential of tall fescue toxicosis. With the benefits of haylage being similar to hay production, haylage is only recommended to lower the potential of losses in quality due to unfavorable weather during curing or when covered hay storage is unavailable. Tall fescue and switchgrass from early to mid-May harvests met CP and TDN requirements of mature cows in a spring- and fall-calving season. Tall fescue from mid-May harvests allowed stocker cattle, fed to reach a finishing weight of 544 kg, to gain 0.45 kg/day with TDN as the limiting nutrient. However, switchgrass from the same harvests would allow stockers to reach an ADG of 0.63 kg.

Native warm-season grasses are currently being studied extensively for their potential as a biofuel source. Switchgrass, big bluestem, and indiangrass have potential to provide both a high biomass for biofuel ethanol production when harvested late in their growing season and a potential quality feed source for beef producers if harvested early in the season. The potential for multiple harvest of NWSG would provide forage early in their growth cycle and regrowth would be harvested as biomass for ethanol production. However, proper management and preservation methods need to be implemented to maintain yields and quality. In study two NWSG yields and quality were not affected by nitrogen fertilization at rates of 134 kg/ha or less. Initial harvest in June was found to decrease biomass yields of switchgrass and not change potential yields of big bluestem/indiangrass. June harvest in both single and multiple harvest were unaffected by harvest system used and had similar yields and forage quality. Hay and haylage produced from NWSG did not differ in forage quality. This lack of difference supports hay as the preservation method of choice due to reduced input in cost of production. Haylage from June harvested NWSG would only be recommended when weather conditions do not support hay production and proper storage hay is not available to prevent spoilage.

Another area of interest is the potential use of NWSG that have matured past a point of quality grazing or hay harvest and are reduced in forage quality through maturity. In study three, mature switchgrass harvested two months apart after a killing frost, treated with alkali compounds, and ensiled with the intent of breaking indigestible fiber bonds and freeing nutrients that can be used by cattle. In this study, it was found that an October harvest was better than November harvest in silage stability and had greater increases in forage quality. Mature switchgrass that has experienced a killing frost should be harvested in October and treated at levels of at least three g NaOH and/or CaO per 100 g of dry forage in order to improve NDF and potential intake of mature switchgrass for feeding cattle.

These studies have helped identify management practices that can be used by beef producers who use tall fescue in their forage system to help improve forage quality and extend the use of available forages. Harvesting tall fescue early in the growing season and preservation method did not improve forage quality. However, haylage production may reduce the need of supplemental feeds due to forage loss during hay harvest or spoilage during hay storage. If producers use switchgrass as forage in the spring and summer early harvest is recommended for highest forage quality. Haylage preservation of switchgrass is recommended for switchgrass harvested in May, but hay production is recommended to reduce potential cost input if harvest of switchgrass is later that May. Native warm-season grasses can be harvested in a multi-harvest system, but final yields of potential biomass harvest will be affected by a single forage harvest in June. Switchgrass harvested in the fall has reduced quality due to maturity and alkali treatment and ensiling may increase NDF and potential if harvested early after a killing frost.

In conclusion, this research provides insight into management practices that can be implemented by producers to increase feeding quality of tall fescue and native warm-season grasses. First a tall fescue timeline was identified for best forage quality and compared preservation methods of harvested tall fescue for quality. Then switchgrass was examined for its use as summer forage, identifying a harvest timeline and best preservation methods. Also multiple harvest and fertilization of NWSG was studied to determine their effects on biomass yield and forage quality. Finally improvements in forage quality of mature switchgrass through the treatment of increasing concentrations of alkali compounds were evaluated at two harvest dates. This study revealed management strategies that can improve forage quality through techniques that will maximize forage quality.

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APPENDIX 4: Tables

Table 4.1. ANOVA results for yield[1], CP[2], TDN[3], and NDF[4] for tall fescue from 2010 and 2011.

	Yield[1]			CP[2]			TDN[3]			NDF[4]			pH		
Source	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	***DF***	**F value**	***P* > F**
Preservation Method[5]	0	X[8]	X	3	5.62	0.005	3	12.41	< 0.0001	3	10.96	0.0002	1	31.68	0.001
Harvest[6]	4	0.70	0.608	4	0.79	0.118	4	4.53	0.048	4	3.35	0.116	4	0.63	0.656
Cut[7]	1	112.88	< 0.0001	1	21.42	0.118	1	24.24	0.003	1	8.80	0.203	1	2.32	0.170

[1]Yield = forage yield on a dry matter basis.
[2]CP = crude protein on a dry matter basis.
[3]TDN = total digestible nutrients on a dry matter basis.
[4]NDF = neutral detergent fiber on a dry matter basis.
[5]Preservation method = 60% moisture haylage, 40% Moisture, and Hay at least 15% moisture.
[6]Harvest = five harvest date at two-week increments beginning in May.
[7]Cut = initial or first cutting and regrowth cutting (four-weeks after initial cuttings)
[8]X = No value.

Table 4.2. ANOVA results ergovaline concentration in tall fescue from 2010 and 2011.

Source	**DF**	**F value**	***P* > F**
Preservation Method[1]	3	0.68	0.0002

[1]Preservation method = 60% moisture haylage, 40% Moisture, and Hay at least 15% moisture.

Table 4.3. ANOVA results for yield[1], CP[2], TDN[3], and NDF[4] for switchgrass from 2010 and 2011.

	Yield[1]			CP[2]			TDN[3]			NDF[4]			pH		
Source	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**
Preservation Method[5]	0	X[8]	X	3	13.63	< 0.0001	3	24.29	< 0.0001	3	15.58	< 0.0001	1	32.74	0.001
Harvest[6]	4	3.77	0.072	4	4.44	0.052	4	6.19	0.025	4	3.73	0.074	4	3.64	0.656
Cut[7]	1	11.31	X	1	3.11	0.220	1	0.54	0.595	1	1.23	0.468	1	2.52	0.170

[1]Yield = forage yield on a dry matter basis.
[2]CP = crude protein on a dry matter basis.
[3]TDN = total digestible nutrients on a dry matter basis.
[4]NDF = neutral detergent fiber on a dry matter basis.
[5]Preservation method = 60% moisture haylage, 40% Moisture, and Hay at least 15% moisture.
[6]Harvest = five harvest date at two-week increments beginning in May.
[7]Cut = initial or first cutting and regrowth cutting (four-weeks after initial cuttings)
[8]X = No value.

Table 4.4. ANOVA results for yield[1], CP[2], TDN[3], and NDF[4] for NWSG from 2010 and 2011.

	Yield[1]			CP[2]			TDN[3]			NDF[4]		
Source	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**	**DF**	**F value**	***P* > F**
Preservation Method[5]	X	X	X	2	250.70	< 0.0001	2	51.63	< 0.0001	2	25.85	0.0003
Harvest Strategy[6]	2	7.48	0.0234	2	4.67	0.0604	2	2.02	0.1637	2	1.35	0.4746
Forage Systems[7]	1	1.16	0.3854	1	0.30	0.6313	1	0.87	0.3643	1	1.03	0.4362

[1]Yield = forage yield on a dry matter basis.
[2]CP = crude protein on a dry matter basis.
[3]TDN = total digestible nutrients on a dry matter basis.
[4]NDF = neutral detergent fiber on a dry matter basis.
[5]Preservation Method = haylage ensiled at 50% moisture or hay at 15% moisture.
[6]Harvest Strategy = June forage only harvest, June forage with post-frost biofuel harvest, and post-frost biofuel only harvest.
[7]Forage Systems = Switchgrass and Big Bluestem Mix stands.
[8]X = No value.

Table 4.5. ANOVA results for pH, CP, TDN, and NDF in alkali treated switchgrass from 2010 and 2011.

	pH			CP[1]			TDN[2]			NDF[3]		
Source	**DF**	**F value**	**P > F**	**DF**	**F value**	**P > F**	**DF**	**F value**	**P > F**	**DF**	**F value**	**P > F**
Date[4]	1	83.69	< 0.0001	1	0	0.980	1	31.26	0.113	1	1.12	0.401
Treatment[5]	11	4.68	0.001	11	1.39	0.244	11	2.13	0.063	11	3.94	0.003
Date*Treatment[6]	11	1.75	0.124	11	1.00	0.475	11	1.02	0.459	11	1.06	0.430

[1]CP = crude protein on a dry matter basis.
[2]TDN = total digestible nutrients on a dry matter basis.
[3]NDF = neutral detergent fiber on a dry matter basis.
[4]Date = the date of harvest; October and November.
[5]Treatment = 12 treatments: Control, 1, 2, 3, and 4 g CaO, 1, 2, 3, and 4 g NaOH, and 1:3. 2:2 and 3:1 g CaO:NaOH.
[6]Date*Treatment = the effect of date and treatment combinations.

VITA

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