SCRUGGS, JESSICA MARIE. Performance of Growing Beef Heifers Grazing Stockpiled Tall Fescue and Being Fed Differing Amounts of Corn gluten feed and Soyhulls. (Under the direction of Matthew H. Poore).

Producers often feed supplements to increase performance of heifers grazing stockpiled fescue (SF). Corn gluten feed (CGF) and soybean hulls (SH) are common supplements (SUPS), but are not widely compared for cattle grazing SF. The objective of these studies was to evaluate the performance of beef heifers grazing SF, either unsupplemented (US) or supplemented (SUP) with differing amounts and variations of CGF and SH, and to determine how supplementation influences SF utilization. Pastures in both years had an endophyte infection rate of 15-33%. A randomized complete block design with 4 land replicates and 16 individual pastures (0.85 ha) was used. Angus and Angus X heifers were blocked by weight and breed into 16 groups of 4 and randomly assigned to treatments (TRT). In year 1, heifers were fed 0.5% BW/d of CGF, SH or a 50:50 mix of CGF:SH. Nitrogen was applied at 84 kg/ha in early Sept, and forage accumulated until early Nov. Forage mass at the start of the trial was 4670 kg/ha. Heifers (initial BW 293 kg) grazed SF from Nov 12 to Jan 7. Average daily gains (ADG) were greater for SUPS (P<0.01) than US (0.33, 0.73, 0.64, and 0.68 kg/d for US, CGF, SH, Mix, respectively). Forage DMI did not differ between TRT (5.29, 4.95, 5.26, and 4.56 kg/d for US, CGF, SH, Mix, respectively). Total DMI was greater for SUP (P<0.05) compared to US (5.29, 6.32, 6.64, and 5.90 kg/d for US, CGF, SH, Mix, respectively). Feed efficiency (gain:feed) was greater for SUP (P<0.01) compared to US (0.062, 0.117, 0.096, and 0.115 for US, CGF, SH, Mix, respectively). Gain/ha was greater for SUP (P<0.01) compared to US (181, 412, 335, and 398 kg/ha for US, CGF, SH, Mix, respectively). Animal grazing d/ha (566, 570, 534, and 588 d/ha for US, CGF, SH, Mix, respectively) and serum urea nitrogen (SUN) (9.9, 10.4, 10.5, and 10.4 mg/dL for US, CGF, SH, Mix, respectively) did not differ between TRT. Performance was improved by SUPS, but there was little difference between SUPS. In year 2, heifers were fed a 50:50 mix of CGF:SH at rates of 0%, 0.5%, 1.0%, or 1.5% BW/d. Nitrogen was applied at 56.2 kg/ha in early
Sept, and forage accumulated until early Nov. Forage mass at the start of the trial was 4574 kg/ha. Heifers (initial BW 275 kg) grazed SF from Nov 10 to Jan 5. ADG increased linearly as level of SUP increased (P<0.01; 0.23, 0.47, 0.71, and 0.85 kg/d for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively). Forage DMI decreased linearly (P<0.05) as SUP level increased (8.94, 7.64, 7.96, and 6.81 kg/d for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively). Total DMI increased linearly as SUP level increased (P<0.05; 8.94, 9.04, 10.76, and 11.02 kg/d for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively). Gain:feed increased linearly as SUP level increased (0.025, 0.051, 0.067, and 0.078 for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively). Gain/ha (358, 449, 454, and 612 kg/ha for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively), animal grazing d/ha (340, 357, 374, and 412 d/ha for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively), and SUN (6.8, 7.6, 7.3, and 9.0 mg/dL for US, 0.5% BW, 1.0% BW, 1.5% BW, respectively) all increased linearly (P < 0.05) as SUP level increased. Animal performance was improved by SUPS and the level of feed provided to grazing cattle has a large effect on animal performance.
Performance of Growing Beef Heifers Grazing Stockpiled Tall Fescue and Being Fed Differing Amounts of Corn gluten feed and Soyhulls

by
Jessica Marie Scruggs

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APPROVED BY:

______________________________     ______________________________
Dr. Jerry Spears                  Dr. Mark Alley

______________________________
Dr. Matthew Poore
Chair of Advisory Committee
DEDICATION

This thesis is dedicated to my family, primarily my momma, unck, nanny, and granny lou lou for their love, endless support, and never-ending encouragement.
BIOGRAPHY

Jessica Marie Scruggs was raised in the mountains of Western North Carolina in the rural community of Cowee. After graduating with honors from Franklin High School in 2004, she moved to the small town of Berea, Kentucky to obtain further education. While attending Berea College she was employed at the college farm where she managed the cattle operation and in 2008, she received a Bachelor of Science degree in Agriculture and Natural Resources. Jessica was given the opportunity to pursue a Masters degree in Animal Science at North Carolina State University, in Raleigh. Upon completion of her Masters degree, she will begin pursuit of her Doctor of Veterinary Medicine at North Carolina State University.
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My deepest gratitude goes to my family for their love and support throughout everything for my entire life. I am forever indebted to my momma for her compassion, patience, and love. She worked to support me and spared no effort to provide me with the best possible environment for me to grow up and attend school. She never complained, even through all the hardships that life brought her way. There are not enough words in the world to describe the love that she has shown me through the years. Momma, I love you. I could not have asked for a better uncle, Unck, as he is like a father to me. Through late night calls and early morning questions, he was always there to lend a helping hand and some good
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CHAPTER 1
LITERATURE REVIEW

Introduction

Tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh), which dominates approximately 35 million acres in the mid-Atlantic region of the United States, is one of the most abundant and important perennial forage grasses in the United States. It is dominant primarily due to its ease of establishment, pest resistance, range of adaptation, and tolerance to poor management practices (Thompson and Stuedemann, 1993). However, this forage has also been associated with poor animal performance due to the presence of an endophytic fungus (*Neotyphodium coenophialum*), which is linked to both the desirable and undesirable traits that are seen with this forage type (Joost, 1995). Due to the poor performance, supplementation may be necessary to support the demands of production by improving the weight and/or performance of grazing cattle (Poore et al., 2000). There are many different classes of supplements available to beef producers; however, the majority of them are placed into two categories, protein and energy supplements. Protein supplements are added to the diet primarily to increase protein supply, while energy supplements are added primarily to increase energy supply.

Energy supplements vary in their CH$_2$O type and degradability. When cattle consume low quality forages and are supplemented with non-structural carbohydrates, like cereal grains, their forage intake and digestibility can be depressed. However, there has been an increase in intake and utilization when cattle are fed structural carbohydrates. It has been
shown that, “energy supplemented cattle lost less body condition before calving than protein supplemented cattle” (Winger et al., 2006). Energy supplementation has also been shown to improve reproductive performance. A protein supplement has been shown to increase total intake and digestibility of low quality forages, which is known as a positive associative effect. However, when the supplement decreases the intake and digestibility of the forage, which leads to lower intake of nutrients from both the forage and the supplement, it is termed a negative associative effect (Bowman and Sanson, 1996). This can arise through the supplementation of large amounts of energy that contain a particularly high level of non-structural carbohydrates, such as starch.

Protein supplements have been shown to increase cattle weights, as have some energy supplements. Liquid supplements, of both protein and energy sources, have been lacking on increasing or maintaining the body weight of cattle. However, cows that are supplemented with protein sometimes are better able to maintain their body condition when compared to non-supplemented cows. Increased protein supplementation has been associated with increased forage intake and digestibility, while increased energy supplementation has been associated with a decrease in forage intake and digestibility (DelCurto et al., 1990).

It is known that adding supplement to a diet for growing cattle will increase the cattle’s weight gain, but what is not understood clearly is which causes a better increase in weight gain, a protein or an energy source. The consumption of tall fescue (Lolium arundinaceum) by cattle in a stockpiling system during the winter in the piedmont of North Carolina gives adequate nutrition to meet the requirements of growing cattle due to its ability
to produce good quality forage in higher yields compared to other forages. Fescue contains
an endophyte that is known to be toxic to animals during the summer months, but is a much
less common problem during the winter (Poore et al., 2000). Stockpiling assists in lowering
winter feed bills, due to a decrease in the need for hay. However, animal weight gains will
be lower than desired, so supplementation may be preferred. Adding supplements can
increase the average daily gains for the cattle and may be an advantage to the producer and/or
the owner.

By feeding a large amount of energy based supplements, asynchrony of available
energy and nitrogen in the rumen can lead to microbial growth and digestion becoming less
efficient. Nitrogen can be rapidly degraded in the rumen and is not incorporated into
microbial protein, thus it is lost as ammonia-N (Beck et al., 2006). If the amount of nitrogen
entering the rumen exceeds a ratio of 3:1 for TDN:CP, large losses of nitrogen occur, and the
excess is excreted in the urine (Beck et al., 2006). With this, the protein flow to the small
intestines can limit the growth of cattle grazing forages (Beck et al., 2006). The amount of
protein entering the small intestines is related to ruminally-available energy (Beck et al.,
2006).

Commonly soybean hulls, corn gluten feed, and other supplements have been studied
on hay diets, but rarely with grazing stockpiled fescue. Soybean hulls can be used as a low
protein energy source (~12% crude protein), corn gluten feed can be used as a moderate
protein energy source (~20% crude protein), and a 50:50 mix of the two feeds (low in non-
structural carbohydrates) can be used as a high energy, moderate protein source. The
following research was focused on the impact of supplementation of soybean hulls, corn gluten feed, and a 50:50 blend of soybean hulls and corn gluten feed on the performance of beef heifers on stockpiled fescue.

**Soybean Hulls**

Soybean hulls are a byproduct of soybean processing, and are used to replace either grain or forage in animal diets. Soybean hulls (also known as soyhulls), like the name implies, is composed of the seed coat of the soybean which comes apart from the bean during processing (Ipharraguerre and Clark, 2003). These hulls are small and light weight. The hulls are normally found either ground or in pelleted form, in order to reduce transportation costs. Soyhulls are an effective energy supplement for forage based diets. Due to their high fiber content and the avoidance of any negative associative effects on the digestion of forages, the net effect when feeding low to moderate quality forages, is that the total energy intake is similar to supplementing the same amount of corn (Boggs et al., 1997).

Soyhulls are starch-free, low in lignin (1.8 to 2.0% ADL), and high in fiber (57 to 71% NDF) (Garleb et al., 1988; DePeters et al., 2000; Ipharraguerre and Clark, 2003). The crude protein content of soyhulls is variable, but usually ranges between 11 – 14% on a dry matter basis (DePeters et al., 2000; Ipharraguerre and Clark, 2003). The nutritional value of soyhulls is dependent upon the rate at which the feed is digested in the rumen and the rate at which the feed is moved from the rumen to the lower digestive tract. Due to the low lignin content and the relatively large particle size of the cell walls, soyhulls have a rapid and extensive fermentation of the fiber fraction (Ipharraguerre and Clark, 2003). However, even
though the fermentation rate by rumen microbes is rapid and mostly complete, differences were seen in in-vitro, in-situ, and in-vivo procedures, with greater differences seen in diets that contained soyhulls alone or in diets where soyhulls were the primary ingredient (Ipharraguerre and Clark, 2003). The rate of passage is also dependent on other factors that can affect intake and rumen environment. The lack of starch in soyhulls results in little effect on fibrolytic activity by rumen fiber-digesting microbes (Hoover, 1986). Soyhulls appear to be equivalent to corn in terms of energy supplementation on forage based diets, regardless of their difference in energy content (Anderson et al., 1988).

Garces-Yepez et al. (1997) evaluated the effects of two levels of energy containing different types of carbohydrates on 1) voluntary intake of forage and performance by growing steers fed bermudagrass hay and 2) total diet digestibility by sheep fed bermudagrass hay. In one experiment, 63 crossbred yearling cattle were given ad libitum access to chopped bermudagrass hay with no supplementation or with 25 or 50% of projected total TDN intake from corn-soybean meal (CSBM), wheat middlings (WM), and soybean hulls (SBH). In another experiment, the digestibility of organic matter and neutral detergent fiber was determined with sheep fed levels of hay and concentrate similar to those used in the growth trials. The treatments included CSBM, WM, or SBH, at either a high (50% of TDN intake) or low (25% of TDN intake) level or a control group. At the high level of concentrate supplementation, hay intake was depressed to a similar extent in steers supplemented with CSBM, WM, or SBH. At the low level of concentrate supplementation, shrunk ADG was similar among supplements (0.63 kg/d), but at the high concentrate level steers fed SBH had
higher shrunk ADG (0.95 kg/d) than steers fed CSBM (0.76 kg/d). Body condition score increased more for CSBM and SBH than for WM supplemented steers. Total tract OMD was lower in sheep fed WM than in sheep fed SBH or CSBM. Total tract NDFD was higher for SBH diets than for CSBM or WM diets. Supplements containing highly digestible fiber (SBH) produced less negative associative effects than high-starch supplements when fed with bermudagrass hay at the high level (0.8 – 1.0% of BW), but no differences were found at the low feeding level (0.4 – 0.5% of BW).

**Corn Gluten Feed**

Corn gluten feed (CGF) is a byproduct of the wet-corn milling process that provides starch, sweeteners, syrup, oil, protein, and bran from the corn kernel. The corn is soaked in a dilute sulfurous dioxide solution (Stock et al., 2000). The steep liquor that results contains proteins, carbohydrates, minerals, and vitamins. From the swollen kernel, the endosperm (containing a high percentage of starch) and the germ (containing most of the oil) are extracted, and the remaining bran (containing most of the fiber) is mixed with the condensed liquor to produce corn gluten feed. Nutrient compositions vary widely from plant to plant depending on the processors and how they handle the bran and the steep liquor (Stock et al., 2000). Corn gluten feed is sold either wet or dry; however, drying reduces the energy value of the feed, but increases its ability to be transported over longer distances and makes storage of the product much easier (Ham et al., 1995).
Corn gluten feed is 23% CP and 80% TDN (NRC, 1996). The crude protein is rapidly degraded in the rumen with a rate of nitrogen disappearance similar to that of soybean meal (Firkins et al., 1984). Corn gluten feed is an effective protein and energy supplement for forage based diets. The byproduct is low in calcium (0.07%) and has a high amount of phosphorus (0.95%); which leaves a Ca:P ratio of 1:10. Considering this, one should add dietary calcium to diets where CGF is being fed. Corn gluten feed contains a high amount of sulfur that when fed in high amounts can go above the maximum tolerable level of 0.4%, which can reduce feed intake and/or induce a copper deficiency or polioencephalomalacia; diets high in non-protein nitrogen or high in rumen undegradable intake protein often reduces the amount of sulfur available to rumen microorganisms and increase the need for supplemental nitrogen (Poore et al., 2002; Wagner, 2008).

When compared to CGF, corn has higher negative associative effects on digestion. Corn gluten feed has also been shown to increase the digestibility of hay and increase its intake, when compared to a nitrogen equivalent corn and urea supplement (Cordes et al., 1988). However, the feed value of CGF seems to be similar to or lower than corn, when fed at moderate levels, only when the CP content of the forage is not limiting gains.

**Introduction to Supplementation**

One approach for supplementing cattle on a forage based diet is to provide adequate protein, minerals, and vitamins in order to correct any deficiencies in the forage (Kunkle et al. 2000). Soyhulls are a by-product of soybean processing and provide 12-14% protein,
0.63% calcium, and 0.23% phosphorus. Corn gluten feed is offered in two forms, both wet and dry corn gluten feed and is a by-product of corn processing. It provides 18-24% protein on a dry matter basis, 0.10-0.35% calcium, and 1.0% phosphorus (Hoffman, 2002). Corn gluten feed needs to be fed with a mineral supplement in order to keep the calcium to phosphorus ratio in 2:1. The use of alternate-day grazing of small-grain forages has worked to improve gains in cattle grazing low quality hay (Kunkle et al., 2000). The frequency of supplementation led to cows spending less time grazing and more time around feeding areas; however, the time of feeding may play a role in the affect of performance on grazing animals (Kunkle et al., 2000). This may be due to the disruption of their normal grazing times and behaviors.

Many supplements may have intake limiters. Salt is the primary limiter because it is readily available in the environment. Monensin tends to reduce the level of salt that limits supplement intake. Gypsum in small amounts can limit the amount of cottonseed meal consumed by growing cattle. Calcium chloride has been reported to limit supplement intake by up to 1% of body weight and can cause more problems with high-calcium forages. Fats and oils, supply energy that can lead to increased gains, but also have an increased cost associated with them. Phosphoric acid is used to limit the consumption of liquid supplements and phosphorus to cattle. However, there is an increased cost and necessary handling expenses associated with this product. Other limiting compounds include dehydrated potatoes, cornstarch, animal fat, sodium tripolyphosphate, dicalcium chloride, magnesium sulfate, and calcium carbonate (Kunkle et al., 2000). There are many potential
intake limiters and more research is being done to determine how these substances limit intake.

Krysl and Hess (1993) reviewed pertinent literature on supplementation and grazing behavior. Research results indicated that grazing activities are sensitive to some environmental variables and vegetative (sward) characteristics; however, minimal information is available on the influence of supplementation regimens on cattle grazing activities. Protein supplementation affected the time spent grazing; unsupplemented cattle grazed approximately 1.5 hours/day more than did supplemented cattle. The type of supplemental protein and time of daily feeding did not affect this response. Different types and timing of starched-based supplements produced variable results; however, increasing the level of supplemental starch decreased daily grazing time. Protein supplementation increased harvest efficiency; however, high-starch supplements either did not alter or decreased HE compared with unsupplemented cattle. Progressive defoliation can influence grazing behavior in both sheep and cattle grazing actively growing forage; however, evaluation of vegetative characteristics of dormant forage and the corresponding effect on grazing behavior are not known. The effects of various grazing management strategies on cattle behavior are inconclusive and deserve additional attention. Methods and/or management practices that modify behaviors to control feed intake, improve efficiency, or reduce stress could provide major contributions to the livestock industry.

Schauer et al. (2005) evaluated whether infrequent protein supplementation to cows grazing low quality forage affected cow performance, grazing time, distance traveled,
maximum distance from water, cow distribution, DMI, DM digestibility, harvest efficiency, percentage of supplementation events frequented, and the CV for supplement intake. A control group was compared with either group given a supplement every day or a group given supplement every 6 days. Cattle were on pasture for 84 days from August to November each year of the trial. Pastures were dispersed western juniper with an overstory and shrub layer of sagebrush, Wyoming big sagebrush, or mountain big sagebrush. Cows were stratified by age within treatment and four cows from each treatment were fitted with a global positioning system (GPS) collar in order to obtain data related to animal distribution and behavior. Cow BW and BCS change were greater in the supplemented treatments compared to the control group, with no change in BW and BCS seen between daily or every 6 days of treatments. Grazing time was greater for the control group as compared to the supplemented groups, with no difference due to supplementation frequency. Distance traveled, maximum distance from water, cow distribution, DMI, DM digestibility, and harvest efficiency were not affected by protein supplementation or supplementation frequency. The percentage of supplementation events frequented and CV for supplement intake were not affected by supplementation frequency. The author concluded that by providing protein daily or once every 6 days to cows grazing low quality forage increased BW and BCS gain, while decreasing grazing time. Also, protein supplementation and supplementation frequency may have little to no effect on cow distribution, DMI, and harvest efficiency in the northern Great Basin.
Guthrie and Wagner (1988) investigated the effects of 1) feeding a grain supplement or two levels of a high-protein supplement on forage intake, utilization and ruminal pH and NH$_3$-N in steers consuming medium-quality prairie hay (PH) and 2) feeding graded levels of a high-protein supplement on intake, digestibility and rate of passage of PH. In one experiment, 16 Hereford steers were used in four replications. Steers had ad libitum access to PH. Treatments consisted of a control, a low level of protein supplement (0.32 kg of 32% CP (LL)), a high level of protein supplement (0.67 kg of 34% CP (HL)), and a grain-based supplement (1.41 kg of 13% CP (GR)) fed daily. Soybean meal was fed at 0, 121, 241, 362, and 603 g DM/day to 15 Angus-Hereford heifers with ad libitum access to early-cut PH. In experiment 1, supplementation increased PH intake, digestibilities of DM, organic matter, CP, ADF, and cellulose and ruminal NH$_3$ concentrations. Compared with LL, HL increased forage intake, digestibilities of DM, OM, CP, and cellulose (CSE), ruminal NH$_3$ concentrations and ADF digestibility. Forage intake, ruminal NH$_3$, and digestibilities of DM, OM, CP, and ADF were similar between LL and GR, but higher than the control groups. Ruminal pH was not altered during the trial. In experiment 2, SBM resulted in a quadratic increase in forage intake, CP digestibility, ruminal NH$_3$ concentrations and in OM digestibility, whereas linear increases were noted in digestibilities of DM, ADF, and CSE and in particulate passage rate of forage. Rate of particulate passage and intake were highly correlated. Added SBM consistently increased observed diet digestibility’s above calculated digestibilities.
Beck et al. (1992) evaluated the performance and forage utilization characteristics of beef cattle fed ammoniated wheat straw unsupplemented except for minerals or supplemented with energy and protein. In experiment 1, 194 crossbred beef cows in late gestation were allotted by weight, breed type, and age during two consecutive winters to 12 drylot pens (3 pens/trt) for a 60 day feeding trial. In experiment 2, 16 ruminally fistualated Angus-Hereford steers randomized to treatments in a 35 day intake-digestion trial. Daily supplementation treatments in both experiments were control, no supplemental energy or protein; LSG, 1.36 kg of sorghum grain (SG); HSG, 2.72 kg of SG, and; SG+SBM, 1.02 kg of SG+0.34 kg of SBM. In experiment 1, all supplements increased gains vs. control and cows fed SG+SBM had higher gains than those fed LSG. The SG+SBM showed a greater change in cow BCS than LSG. Birth weights of calves, ADG, percentage of cows cycling at the start of breeding, and percentage of cows pregnant after a 60 day breeding season were similar for all treatments. In experiment 2, intake of AWS tended to be greater for SG+SBM than for LSG. NDF digestibility was decreased by both energy and protein supplementation, and a large decrease was evident for HSG compared with SG+SBM. Indigestible ADF fill and passage rate were not affected, liquid dilution rate was slightly increased with energy supplementation and decreased with protein supplementation. The ability of the supplements to enhance performance was probably due to increased total intake, moderate changes in digestion, and subsequent increase in the input of total digestible nutrients. The response to additional natural protein seemed to be greater than the response to energy, even though AWS alone exceeded requirements for CP.
When forages do not provide enough protein and energy to meet production needs, then supplements of energy and protein can be added to the diets to improve rate of gain. However, feeding supplements sometimes decreases the consumption of forages enough to decrease the availability of dietary energy.

**Growing Cattle on Stockpiled Tall Fescue with Supplementation**

Hay or silage has been the traditional winter feed source for many cattle operations, when little forage is available. However, removing all grazing animals from the pasture at some point during the growing season and allowing the forage to accumulate for later grazing, can be used to extend the grazing season and reduce production costs. Tall fescue is a commonly used cool-season forage because it provides sufficient forage growth during late summer and autumn and reduces winter feed costs as compared to some other supplementation programs (Looper et al., 2005). As the growing season progresses, the yield of the forage usually declines (Cuomo et al., 2000). Adding nitrogen to the pasture can increase the forage yield and lead to a larger amount of forage and a further extended grazing season. Tall fescue is able to retain its green and productive characteristics, as well as its high digestibility and palatability (Hancock et al., 2008). In one study, differences in body weight (BW), body condition scores (BCS), average daily gain (ADG), and pregnancy rates were observed. More cows became pregnant from the groups that were supplemented with SH or CSB, when compared to those cows that were not supplemented, which in turn, increased the selling price due to the increase in body weight at market time (Looper et al., 2005).
Protein Supplementation. Paterson et al. (1983) compared two sources of supplemental protein with a high or low ruminal extent of N degradation with or without lasalocid addition on lamb or steer gain. A soybean meal supplement included escape protein with a combination of dehydrated alfalfa and distillers dried grains. Steers were placed on fescue pasture for 105 days from December to March either supplemented or unsupplemented. Treatments included a high extent of N degradation (SBM) or a low extent of N degradation (EP; dehydrated alfalfa and distillers dried grains); both treatments were supplemented with or without lasalocid (L) and a control group. Supplementation with SBM increased N digestibility by 8% compared with EP supplements and L added a 6% increase in N digestibility to both SBM and EP supplements. Supplemented steers gained more weight than unsupplemented steers with no significant effects on gain due to either protein source or L addition. Steers fed EP supplements gained numerically faster than SBM supplement fed steers and those steers fed supplement with L gained 13% faster than steers fed supplements without L. The author concluded that EP supplements may promote faster gains than SBM supplements and that the addition of L may further increase gains although the data was somewhat inconsistent.

Driskill et al. (2007) evaluated the effects of stocking rate and corn gluten feed supplementation on forage mass and composition and the BW and BCS of bred 2 year old cows strip-grazing stockpiled forage, at two stocking rates, during the winter. In October, twenty-four, 30 month old Angus-Simmental and Angus cows were allotted by BW and BCS to strip-graze for 147 days at 0.84 and 1.19 cows/hectare. Eight similar cows were allotted to
2 dry lots and fed tall fescue-red clover hay ad libitum. Corn gluten feed was fed at a high and low level of supplementation to cows in 2 pastures to maintain a mean BCS of 5 at each stocking rate (high and low) and in the dry lots or when weather prevented grazing in the remaining 2 pastures at each stocking rate. Mean concentrations of CP in year 1 and 2 and IVDMD in year 2 were greater in hay than in stockpiled forage over the winter. At the end of grazing, cows fed hay in dry lots had a greater BCS in year 1 and greater BW in year 2 than grazing cows. Grazing cows in the high supplementation treatment had greater BW than cows grazing at the low supplementation level in year 1. Cows in the dry lots were fed 2565 and 2158 kg of hay DM/cow. Amounts of corn gluten feed supplemented to cows in year 1 and 2 were 46 and 60 kg/cow, respectively, and did not differ between cows fed hay or grazing stockpiled forage in either year. The authors concluded that estimated production costs were greater for cows in the dry lots because of hay feeding when compared to the stockpiled fescue feeding systems (whether the cattle were in a high or low stocking rate or a high or low supplementation level), even though the cattle on the dry lots performed better.

Strauch et al. (2001) evaluated the effects of undegradable intake protein supplementation (UIP) on primiparous beef heifers grazing endophyte-free stockpiled fescue pastures. Heifers were maintained on endophyte-infected tall fescue and individually fed supplement daily beginning 60 days prepartum (in December). Supplement was adjusted depending on the expected need of the gestating or lactating heifers. Increasing the amount of UIP in the supplement tended to increase the DMI (using a daily dose of Cr₂O₃ to determine fecal output coupled with forage in-vitro digestibility analysis). Additional UIP
increased BCS at several points during the study, and increased serum IGF-1, but there was no difference seen in calf birth weight or weaning weight, cow milk production, or postpartum interval. Metabolizable protein levels in the forage/supplement combinations appeared to be adequate for both treatments, reducing the magnitude of response to UIP. However, there were no treatment effects on postpartum interval, but the authors showed an inverse relationship between IGF-1 and postpartum interval.

**Energy Supplementation.** Richards et al. (2006) evaluated the influence of supplemental pelleted SH on fresh forage intake, rumen fermentation, site and extent of nutrient disappearance, and microbial N production in beef steers consuming freshly clipped, endophyte-infected KY-31 tall fescue. Six Angus and Angus-Hereford steers were provided with free choice access to fresh forage, water, and a vitamin/mineral supplement. Supplement was fed at 0700 with ~65% of the estimated daily forage. Chromic oxide was used as a marker of duodenal digesta flow. Periods were 21 days with 14 days of adaptation and 7 days of digesta sample collection. Soyhulls were fed at a rate of 0.60% of BW. Supplementation of SH decreased forage OM intake from 1.64 to 1.41% of BW but increased total OM intake from 1.64 to 2.01% of BW. Apparent percentages and quantities of rumen OM disappearance were not affected by supplementation. Percent disappearance of total tract OM was not different. Percentages of apparent rumen NDF disappearance also were not different. Percentages of N disappearance were not different. Supplementation of SH resulted in increased total N and microbial N flowing to the duodenum. Ruminal Ph was not affected, and ruminal ammonia concentrations exhibited a time x treatment interaction in
which SH decreased ammonia for 12 hours after supplementation. Total VFA concentrations were unaffected. Liquid dilution rate and rumen OM fill were not different between treatments. Supplementation of SH at a rate of 0.60% of BW (OM basis) to calves consuming fresh E+ tall fescue decreased forage consumption but resulted in greater total intake, greater flow of N to the duodenum, and increased total tract OM disappearance.

**Energy and Protein Supplementation.** Beck et al. (2006) tested the effects of supplementation with either energy or two levels of bypass protein on performance of growing cattle grazing stockpiled fescue from January through April. Cattle were grazed using frontal strip grazing during January, and then continuously grazed once spring growth began in early February. Supplements were fed at 0.91 kg/d (~0.25% of initial BW) and provided with 200 mg lasalocid/hd/d. Supplementation treatments included 1) no supplemental feed offered (control), 2) supplemental corn (corn), 3) a 22% CP supplement designed to supply 100g/day of escape protein, a low level of escape protein supplementation (LEP), or 4) a 42% CP supplement designed to supply 200 g/day of escape protein, higher level of escape protein (HEP). Each pasture was assigned to one of four supplemental treatments to test the ability of either supplemental energy or two levels of supplemental escape protein to correct a possible ruminal imbalance of protein and energy found in high quality forages. The performance of calves grazing fescue was increased by supplementation (combined gender analysis), but gains were not improved with the addition of escape protein to energy supplements. Performance of steers was increased by supplementation, while supplementation did not statistically increase gains in heifers. The authors concluded that the
different responses due to gender indicate energy supplementation is required in steers grazing stockpiled fescue in the winter and spring, but is unnecessary in heifers.

Research in North Carolina (Poore et al., 2006) evaluated the composition of stockpiled fescue from December through February over 2 years and determined the performance of heifers grazing stockpiled fescue with or without supplemental whole cottonseed. In December, 36 heifers were assigned randomly to 6 groups with each being assigned randomly to a 2.4 hectare tall fescue pasture. The cattle were strip-grazed for 83 days with daily forage allocation, with three groups being fed 0.33% of BW whole cottonseed and a small amount of corn-based concentrate. Forage intake estimations were made every 2 weeks from pre- and post-graze forage mass. Supplemented heifers showed a higher shrunk ADG and change in BCS. Heifers that were supplemented had greater serum urea nitrogen in year 1 and year 2. Forage disappearance was similar between supplemented and unsupplemented heifers. The authors concluded that heifers responded to supplementation, but that their performance was lower than expected based on forage nutrient content.

Research in Arkansas (Looper et al., 2005) evaluated the effects of supplementation on performance, reproduction, and economics of market cows grazing a stockpiled, endophyte-infected fescue system. Non-pregnant cull cows (BCS 4.3) were allotted to one of six stockpiled fescue pastures near December 1 (fertilized with 40 kg N/ha near October 1), and were exposed to bulls for 105 days. Cows remained on these pastures through the spring grazing season (160 days at a constant stocking rate of one cow/2 acres), and then were
palpated for pregnancy determination and marketed. Treatments included an unsupplemented control, and two supplement treatments; soyhulls (SH), or an 80:20 mix of corn:SBM (CSB), each at a rate of 0.91 kg/d prorated to be fed 3 days/week. Feeding either supplement increased the selling weight by 27 kg. BCS change was higher for soyhulls than for the control and intermediate of corn:soybean meal, while breeding rate was highest for the CSBM (96%), lowest for the control (74%) and intermediate (87%) for the soyhulls. The authors concluded that supplementation of market cows grazing stockpiled tall fescue can increase performance but may not increase farm profitability. Supplementation can enhance performance and may increase value of market cows. However, if availability of stockpiled fescue is adequate, supplementation of cows may not be cost-effective.

Hannah et al. (1989) compared whole corn vs. ground-pelleted corn and ground-pelleted corn vs. dry corn gluten feed as sources of supplemental energy for steers grazing tall fescue. In experiment 1, twelve steers and six heifers grazed three 0.8 hectare pastures on Kenhy tall fescue during the last week of June, 1987. Supplements were fed at 1.0% of BW either as whole grain or ground-pelleted grain. Treatments were 1) no supplement, 2) ground-pelleted corn grain, and 3) whole corn grain. Animals were grazed for 14 days after adjustment period. Starting on day 9 of the trial animals were individually fed 20 g of chromic oxide. Starting on day 15 and continuing through day 21, fecal grab samples were collected at time of supplementation (0600) and again at 1600. Experiment 2, was conducted during the last week of July and first two weeks of August, 1987. With treatments of either no supplement or supplemented at 1.0% of BW with either ground-pelleted corn or CGF.
Forage OM intakes by grazing steers were not decreased by either corn or corn gluten feed supplements and resulted in increased total OM intakes. Forage OM digestibility was decreased with corn supplement but not CGF supplement. Starch digestibility was greater when ground and pelleted corn was fed compared with whole corn. Supplementation decreased total grazing time for the supplemented cattle as compared to unsupplemented cattle.

**Overall Supplementation.** Meyer et al. (2009) compared the performance of spring-calving beef cows fed hay, hay plus a grain supplement, or stockpiled tall fescue pasture during the winter feeding period and also to determine if residual effects of winter feeding treatments could be detected when cows were managed similarly until calves were weaned in autumn. Three wintering systems for spring-calving cows in Missouri, including hay feeding with or without supplementation, or strip-grazing stockpiled tall fescue. The tall fescue pastures were E-, and cows were managed using frontal strip-grazing with new strips allocated twice weekly. Mean pasture utilization efficiency was 82% in year 1 and 61% in year 2. During year 1, supplemented cows received 0.4 kg/hd/d corn during gestation and 2.7 kg/hd/d of a mix of corn and dried distiller’s grain with soluble (46% corn) during calving and early lactation. During year 2, supplemented cows received 2 kg/hd/d of a corn and dried distiller’s grains with soluble mix (54% corn) during gestation, early calving and lactation. After the wintering period, cows were managed together to determine residual effects on spring cow performance and calf weaning weight. In year 1, the nutritive value of the stockpiled fescue was similar to that reported in earlier work from Missouri, but in year 2.
forage quality fell to lower levels by late winter than earlier reported. This was attributed to snow and ice during year 2. Hay was similar in quality both years and was near 8% CP and ranged in ADF from 40.3 to 46.7%. Cows started the study near BCS 5.5 in year 1 and 5.0 in year 2. During year 1 cows grazing stockpile gained 21.3 kg, while hay-fed cows lost 5.4 and 17.4 kg for the hay only and supplemented treatments, respectively. During year 2, cows on hay lost more BCS than supplemented or grazing cows. There was no significant difference in post treatment weight gain in either year. BCS showed a similar pattern to BW, except that in year 2 cows on the hay only treatment increased in body condition post-treatment more than the other treatments. There were no differences in breeding rate or calf weaning weight in either year. Authors concluded that the stockpiled tall fescue and the hay plus supplement treatments gave similar performances, and that both clearly resulted in better cow performance than hay only. However, differences in winter performance was not so great as to have residual effects on breeding rate or calf weaning weight. The authors’ final conclusion was that strip-grazing stockpiled tall fescue is a viable alternative winter system for cows in MO.

**Supplementation Frequency.** Beaty et al. (1994) evaluated the effects of supplementation frequency by CP concentration or grain type in supplements fed to beef cattle consuming low-quality forages. All experiments included supplementation frequency (daily=7X and three times weekly=3X) as one factor in a factorialized arrangement of treatments. In experiments 1 and 2, the second factor was supplemental CP concentration, altered by changing the ratio of SBM to SG in supplements. Supplements were fed at 13.9
and 14.1 kg of DM/week for experiments 1 and 2, respectively. In experiment 3, the second factor was supplement grain type and supplements containing 21% CP were fed at 14.8 kg of DM/week. In experiment 1, eight ruminally-fistulated steers consumed wheat straw ad libitum. Pregnant beef cows grazing dormant tallgrass prairie were used in experiments 2 and 3. In experiment 1, reducing the supplementation frequency decreased straw intake but increased DM and NDF digestion. As CP concentration in supplements increased, straw DMI increased quadratically, whereas DM and NDF digestion increased linearly. In experiment 2, increasing CP concentration in supplements enhanced a cows’ ability to maintain BW and condition up to calving, with decreasing magnitude of difference between treatments at higher CP concentrations. Increasing CP in supplements fed to the dams linearly increased calf weaning weight in experiment 2. In experiment 2 and 3, reducing supplementation frequency increased winter weight loss through calving. Grain type did not significantly affect most performance variables. In summary, response to supplementation frequency was not dependent on supplementation CP concentration or grain type. Daily supplementation maximized forage intake and cow performance, although the magnitude of performance differences was not large.

In summary, strip-grazing stockpiled tall fescue is a viable alternative winter feeding system for cows. Overall, supplementation decreased forage consumption and grazing time, but increased total DMI, with only moderate changes seen in digestion, and a subsequent increase in the input of total digestible nutrients. Supplementation frequency had little impact on animal performance; however, daily supplementation maximized forage intake and
cow performance. Forage nutrient content plays a large role in the level of response seen in animal performance with supplementation. Estimated production costs are lower in stockpiled fescue feeding systems with supplementation, compared to cattle on dry lots. Supplementation can enhance animal performance and may increase the market value of cows. However, if the availability of stockpiled fescue is adequate, supplementation may not be cost-effective. Methods and/or management practices that modify behaviors to control feed intake, improve efficiency, or reduce stress could provide major contributions to the livestock industry.

**Stockpiled Tall Fescue**

Stockpiling is termed as the process of, “allowing late summer and fall growth of forages to accumulate with the intentions of deferring it for controlled winter grazing” (Poore et al., 2006). In a study performed in North Carolina, crude protein levels of stockpiled tall fescue fertilized in September ranged from 16.8 to 12.6 % and ADF levels ranged from 25.9 to 30.7 % during the winter (early December to late February) (Poore et al., 2006). In a three year study conducted by Burns and Chamblee (2000b) similar crude protein levels were seen during the winter. Crude protein averaged 15.7, 9.8, and 10.2% from December to early March in years 1, 2, and 3, respectively (Burns and Chamblee, 2000b).

The accumulation and fertilization of stockpiled fescue early in the summer causes an increase in dry matter yield (Burns and Chamblee, 2000a). However, with early accumulation the quality of the forage decreases (Burns and Chamblee, 2000b). By delaying the forage accumulation until September, there was a linear IVDMD increase. The in-vitro
dry matter disappearance in December was 59.5% and 69.9% for June and September accumulation dates, respectively (Burns and Chamblee, 2000b).

With stockpiled infected tall fescue there is a potential loss of nutrients during the winter that can occur with age and weather. Indicators of forage quality decline slightly as the winter progresses (Ocumpaugh and Matches, 1977; Burns and Chamblee, 2000b; Poore et al., 2006). The decline in nutritive value of the forage is caused by leaf senescence and leaching of digestible fractions due to cell rupture caused by freezing during the winter months (Ocumpaugh and Matches, 1977).

Differences in herbage mass may be due to a cultivar effect. One study showed that KY-31 produces more fall growth than most other cultivars (Joost and Mattas, 1996). Endophyte status did not affect the ability of fescue to maintain its nutrient content during the winter. Nutritive value decreased throughout the winter, but did not differ among treatments (Kallenbach et al., 2003).

**Stockpiled Forages.** Hitz and Russell (1998) compared the nutritive value of stockpiled forages from different perennial forage species or corn crop residues during winter and quantified the amounts of stored forages required to maintain equivalent body condition in pregnant cows grazing these forages or maintained in a dry lot. Mid-gestation mature, medium-framed crossbred beef cows were strip-grazed on replicated fields containing stockpiled tall fescue-alfalfa, strip-grazed stockpiled smooth bromegrass without and with red clover, and strip-grazed corn crop residues at 1.2 cows/ha, or they were confined in a dry lot for 129 to 141 days. All the cows were offered grass-legume hay as large round bales to
maintain a condition score of 5 on a 9 point scale. Cows grazing the stockpiled forage systems required an average of 1050 kg/cow less hay than cows fed hay in the dry lot, while cows grazing corn residues required 627 kg/cow less hay. Cows grazing stockpiled fescue-alfalfa had greater BW gain than the other systems, and greater body condition score (BCS) gain than cows grazing corn residue. While this study showed advantages for fescue-alfalfa over the other forage systems, it also demonstrated that stockpiling forages could extend the grazing season even outside of the typical “fescue belt.”

Research in Ohio (Penrose et al., 1996) compared animal preference, stockpile, yield and quality of tall fescue (TF) and orchardgrass. Tall fescue for grazing livestock is commonly considered a versatile and persistent perennial forage. During the autumn, TF produces higher yields of stockpiled forages of superior quality compared to other cool season grasses. The fall-saved forage is very palatable and high in digestibility and maintains quality longer into the winter. The plots were established in 1995 and fertilized at planting (June), and again in October and April. Two plots were endophyte-free fescue, two were endophyte-infected fescue and two were orchardgrass. Forage yield and quality was collected in each year in late May, early July and mid-August. The plots were stockpiled and harvested in mid-December and on February 20\textsuperscript{th} of each year on one of each of the plots. The plots were harvested for hay in early June of each year and grazed in late July and early August for two weeks to determine preference. There were no significant differences in crude protein (CP) among the varieties in the late May harvests except Barcel Fescue which was significantly higher than the other varieties in the May 1995 harvest. During the winter,
the two orchardgrass varieties had higher CP than the fescue varieties in each of the three years.

Cattle grazing stockpiled forages require, on average, less hay than cattle fed in a dry lot system. Cattle grazing stockpiled fescue-legume forage had higher BW gains and BCS than cattle in feeding systems. There are advantages to feeding stockpiled fescue-legume forages, including extending the grazing season even outside the normal fescue region. During the fall, fescue gives higher yields of greater quality compared to other cool season forages; it can also maintain its higher quality for longer periods in the winter.

**Stockpile Initiation.** Burns and Chamblee (2000a) evaluated the yield potential and associated nutritive value differences by mid-November of tall fescue accumulated for different periods during the summer. Five treatments consisted of four periods of forage accumulation beginning June 1st, July 1st, August 1st, and September 1st. The fifth treatment was a N rate variable with an additional 67 kg N/ha applid on July 1st (J+N), giving a seasonal total of 269 kg N/ha. The experiment was initiated the year following seeding by uniformly cutting the entire experimental area from about 18 cm to a 5 cm stubble until June 1st. Applying additional N at the July 1st starting date (J+N) compared with delaying N application until August resulted in more DMY in all three years. Delaying the starting date of accumulation from June 1st to September 1st resulted in a linear increase in IVDMD for each delay in accumulation. Applying N at the July 1st starting date resulted in the lowest IVDMD, but similar ADF, NDF, and other fiber constituents. Tall fescue can be accumulated in the Piedmont of NC during the summer for fall and winter grazing. Overall,
there is no effect of the date stockpiling started during the summer on subsequent
spring/summer growth. It was speculated that the farther south, and the lower the elevation,
in the fescue belt, the quicker the sward will decline in quality because freezing and thawing
conditions occur more frequently.

Burns and Chamblee (2000b) evaluated the changes in the nutritive value of tall
fescue accumulated for different periods in the summer when sampled from October to
March. Treatments consisted of four periods of forage accumulation starting June 1st, July
1st, August 1st, and September 1st. The fifth treatment was a N rate variable with 67 kg N/ha
applied at the July 1st (J+N) starting date, giving a seasonal total of 202 kg N/ha as
ammonium nitrate. Contradictory to the previous study, some of the data show the highest
late winter nutrient concentrations in the literature. There was no difference in forage CP
content for differing stockpile initiation dates during a 3 year study in NC, but in that study N
was applied near August 25th on all treatments. The authors concluded that summer
accumulation of tall fescue at the lower elevations in the Piedmont region of the tall fescue
transition zone has as much, if not more, potential as a fall-winter feed than in more
temperate environments further north and west.

Cuomo et al. (2000) evaluated pasture management options and animal performance
for fall stockpiled forages. On the date of stockpile initiation, the experimental area was
mowed to leave a stubble height of 3 inches and N treatments were applied. Electric fence
was used to exclude cattle from the area and the stockpiled forage was harvested in mid-
October. Total yield declined as stockpile initiation date progressed later into the growing season. Initiating stockpiling after July 1\textsuperscript{st} reduced total and leaf yield.

Overall, the date of stockpiling started during the summer has no effect on subsequent spring/summer growth. However, as the stockpile initiation date advanced later into the growing season, total forage yield declined. It is speculated that the farther south, and the lower the elevation, within the fescue belt, the faster the sward will decrease in quality due to freezing and thawing conditions that occur more often in this area. However, it appears that forage nutritive value of stockpiled fescue in the south and eastern parts of the fescue belt are some of the highest in the literature.

\textit{Nitrogen Application.} Singer et al. (2003) determined the N response and optimum harvest date for yield and quality of stockpiled tall fescue. Nitrogen was applied to the main plots as ammonium nitrate at rates of 0, 28, 56, and 112 lbs N/ac in August of 1999 and 2000. Authors concluded that increased N application rate increased CP and in-vitro digestibility, and decreased NDF. Dry matter yield increased in a linear fashion with increasing nitrogen rate in both years. Nitrogen use efficiency (kg DM/kg N) was 15 in the first year and 19 in the second year.

Archer and Decker. (1976b) studied the effects of temperature and nitrogen fertilization on the growth and quality of autumn-accumulated forages. Forage samples were collected from randomly-selected, previously unharvested areas. These samples were separated into green, dead, and miscellaneous fractions for yield and quality evaluation. The treatments were three levels of N (0, 50, and 100 kg N/ha) and two grass species (KY-31 tall
fescue-TF and Potomac orchardgrass-OG). Digestibility and protein percentages decreased only slightly during autumn. Nitrogen fertilization stimulated growth of the autumn-saved pastures and also tended to increase crude protein percentages. An application of 100 kg N/ha in late summer produced up to 50% more dry matter by early winter than zero N. IVDMD of the forage was not affected by N fertilization. Growth of the grasses during the fall was stimulated by increasing the soil temperature. The effect was greater for tall fescue than orchardgrass. Plant quality was only slightly affected. However, the relative effects of the soil temperature treatments in relation to air temperatures and light parameters were not determined.

Teutsch et al. (2005) evaluated the effects of N rate and source on yield and nutritive value of stockpiled tall fescue. The study was conducted in two locations in southeastern Virginia which compared nitrogen rate and source. Nitrogen was applied to predominantly tall fescue swards from late August to early September at rates of 0, 45, 90, or 135 kg plant available N/ha. Nitrogen sources evaluated included ammonium nitrate, ammonium sulfate, urea-ammonium nitrate (liquid N), urea, complete fertilizer, or broiler litter. There was a linear increase in yield for each of the N sources, but nitrogen response varied by N source. Nitrogen response was highest for ammonium nitrate, ammonium sulfate and complete fertilizer, intermediate for broiler litter and urea, and lowest for urea-ammonium nitrate, with N use efficiency of 13.3, 11.1, 10.0, 9.3, 7.1, and 5.0, respectively. While both rainfall and temperature deviated from the 30-year mean in all 3 years, authors indicated that there were precipitation events shortly after N application and that soil moisture and temperature were
adequate for growth during the trial. Despite differences between sources, nitrogen use efficiency for all the sources were at the lower end of the range seen in the literature. Dry matter yield was near 2800 kg/ha at the 0 application rate; the authors suggested that residual soil nitrogen may have contributed to the N use efficiency being lower than values typically seen in studies. Nitrogen sources used to grow stockpiled fescue vary, and availability and relative prices of different sources has fluctuated in recent years. The scarcity of research comparing different sources hampers recommendations on optimal rate and source of N. Because of the importance of nitrogen response efficiency to the economics of the system (Poore et al., 2000) more research clarifying response to various nitrogen sources is warranted.

Poore et al. (2000) reviewed information on the 1) agronomic aspects of stockpiling fescue, including optimal initiation dates, timing and level of nitrogen fertilization, and nutrient concentrations of stockpiled fescue, especially in late winter, and 2) animal performance and supplementation responses while grazing stockpiled fescue. Nitrogen was applied in late summer and autumn. By applying 50-100 kg N/ha to pastures in late summer yielded a response of 7-33 kg DM/kg N, but a range of 10-20 kg DM/kg N can be expected in most situations. It seems that quality and use are improved by controlled grazing and are maximized by the use of daily strip-grazing. Economic stimulation for a yearling wintering system showed that strip-grazing stockpiled fescue could reduce feeding costs by about 40%, compared with harvesting and feeding autumn growth as hay. Use of stockpiled fescue could
be expanded and with controlled grazing management and efficient supplementation could lead to improved economics of winter feeding in the fescue belt.

In summary, N application rate increases CP and in-vitro digestibility, and decreases NDF. Nitrogen response is highest for ammonium nitrate, ammonium sulfate, and complete fertilizer, intermediate for broiler litter and urea, and lowest for urea-ammonium nitrate, with N use efficiency falling in the same order. Applying 50-100 kg N/ha to pastures in late summer yields a response of 7-33 kg DM/kg N, with a range of 10-20 kg DM/kg N expected, depending on the situation. Dry matter yield increases with increasing nitrogen application rate. Forage growth during the fall is stimulated by soil temperature increases. Nitrogen application and source is extremely important for forage growth in a stockpiled production system.

**Plant Separations.** Archer and Decker (1977) evaluated the relationship between dead leaf content and whole plant digestibility of autumn-saved tall fescue and orchardgrass. Nitrogen was applied at either 0, 50 or 100 kg N/ha in late September. Forage samples were collected from randomly-selected, previously unharvested areas and were separated into green and dead leaf fractions. These separations were analyzed for fiber components and quality parameters. Forage species, N application, nor soil temperature greatly affected NDF, ADF, lignin, or silica contents of autumn-saved forages. However, there were trends for high fiber and lignin contents in plants grown on high soil temperature plots and for increased fiber content with time during autumn and early winter. Green leaves had lower levels of NDF and ADF, lignin, and silica than dead leaves. During autumn and early winter,
the proportion of dead leaves in the pastures increased from approximately 20-46% in both years. Autumn-growth of orchardgrass was about 75% that of tall fescue and they initially had 75% green tissue, but this declined to 60% by December 24th.

Archer and Decker (1976a) investigated the relationship developed by Van Soest and Van Soest and Jones for evaluating digestibility of autumn-saved forages. Autumn-saved forage samples of KY-31 tall fescue and Potomac orchardgrass were obtained from two separate field experiments. Three samples of accumulated, previously unharvested forage were collected from each experiment; these samples were sorted into green, dead, and miscellaneous weed fractions. Fiber, lignin, and silica contents of autumn-saved forage samples were all highly correlated with IVDMD, and equations were developed to predict IVDMD from these chemical constituents. The equation, \( \text{IVDMD} = 0.98 \times (100 - \text{NDF}) + \text{NDF} \times [91.1 - 1.43(\text{LIG+SIL})/\text{ADF}] \), can be used to predict digestibility of forages, especially those with similar species composition growth under similar environmental conditions to those used in these studies.

In summary, as the winter progresses the proportion of dead leaves within the sward increased from 20 to 46%. Dead leaf fractions have higher levels of NDF, ADF, lignin, and silica when compared to green leaf fractions. Green tissue declines by approximately 60% by late-December, replaced by an increasing concentration of dead tissue.

**Ergovaline Affects.** Burns et al. (2006) evaluated the adaptation and production potential of Jesup tall fescue with the presence or absence of a novel endophyte for the mid-Atlantic region when used in either a repeated grazing system or accumulated and grazed as
autumn stockpile. Jesup tall fescue was also evaluated to determine if the presence of a novel or a wild-type endophyte would alter the nutritive value of the forage and affect stand persistence as compared with an endophyte-free control. Finally, the forage was observed for any changes in grazed forage production and nutritive value during the autumn and winter when allowed to stockpile at different periods before grazing. Treatments consisted of grazing autumn growth to about 7 cm each time it accumulated to approximately 10 to 15 cm, and grazing stockpiled forage on the 15th of every month, from November to February. Animals on the stockpiled forage were removed when the forage was defoliated to approximately 7 to 10 cm. Yield and nutritive value of the stockpiled E+, E-, and EN (AR542 endophyte) Jesup tall fescue were similar. However, stand loss after three years of grazing was 29, 75, and 42% for E+, E-, and EN, respectively. Authors concluded that EN would not perform as well as E+ in a long-term stockpiling system. It was also found that ergovaline concentrations declined from October through February (as the winter progressed).

Curtis and Kallenbach (2007) evaluated the effects of endophyte infection level in tall fescue stockpiled for winter grazing on forage yield, nutritive value, total ergot alkaloid concentrations, and subsequent animal performance. Treatments included infection rates of low (20%), medium (51%), or high (89%). Cow/calf pairs were grazed on the stockpiled pastures starting in early December for 84 days. After the trial cows and calves were grazed together on the medium infection rate pasture until the calves were weaned. Intake was estimated using the mass disappearance method. Dry matter yield was higher for the high
infection rate than for the low or medium infection rate in both years of the study. Total ergot alkaloid content of the sward declined as the winter progressed, and nutritive value of the forage was adequate for lactating cows (13% CP and 75% true in-vitro dry matter digestibility). Cows lost less BW and BCS in the low treatment, but remained at or above 5.2 on all three treatments. ADG in both the stockpiled phase and the commingled phase, and weaning weight of calves was not influence by endophyte infection rate. Authors concluded that the lack of a difference in calf performance was in part due to the decline in ergot alkaloids. They also concluded that if targeted for a winter stockpiling system, that wild-type endophyte fescue could be suitable for wintering fall calving cows.

Research in Missouri (Kallenbach et al., 2002) evaluated yield, forage quality, and ergovaline content of tall fescue infected with a native endophyte (K31 E+), a non-toxic endophyte (HiMag NTE), and with no endophyte (HiMag E-) through the entire winter. Each of these three treatments was replicated three times in a randomized complete block design. Forage yield did not change from mid-December through mid-March for any entry. All entries had similar levels of ADF on comparable dates. Neither HiMag E- nor HiMag NTE contained any ergovaline, but K31 E+ had substantial levels of ergovaline in both years. The ergovaline content in K31 E+ declined approximately 6 fold from December to March each year. The stable yield, slowly declining forage quality, and rapidly falling ergovaline levels in K31 E+, suggest that livestock producers could minimize winter toxicosis by delaying the use of stockpiled K31 E+ until mid or late winter. So, stockpiled tall fescue
after mid-December shows no yield loss, has a slow decline in forage quality, and that ergovaline in K31 E+ declines rapidly.

Research in Missouri (Kallenbach et al., 2003) evaluated the herbage mass, nutritive value, and ergovaline concentration of tall fescue infected with a toxic, native endophyte (K31 E+), a nontoxic endophyte (HiMag NTE), and no endophyte (HiMag E-) through the winter. From early April until early August of each year, four, 250 kg steers were continuously stocked on each of the 3 pastures (0.8 ha each of tall fescue). Herbage mass from the three tall fescue entries was measured monthly from mid-December through mid-March in 1999-2000 and 2000-2001. Dry matter yield was greater for KY-31 than for either of the Hi-Mag treatments, and was not influenced by the endophyte status of Hi-Mag, while there was little effect on nutritive value. Studies have shown that ergovaline or total ergot alkaloid measured over the winter has shown large decreases in alkaloid concentrations, especially during late winter. In this 2 year study, ergovaline concentrations declined 85% from December to March during both years.

Matthews et al. (2005) compared and evaluated the effects of toxic endophyte-infected (E+), endophyte-free (E-), and non-toxic endophyte-infected (NE) Jesup tall fescue hay consumption on ad libitum intake, water intake, diet digestibility, N metabolism, plasma prolactin (PRL) concentrations, and rectal temperatures under thermoneutral conditions in growing beef steers. Eight polled Hereford steers were used during the study. Steers were fed ad libitum for 14 days, followed by a 9 day adaptation to restricted intake and urine collection. Results indicated that E+ tall fescue hay was lower in ad libitum DMI, DM
digestibility, and N retention than NE or E- hays with similar chemical composition. Hay from NE and E- fescue had nearly identical composition, and did not differ for any variable measured. Steers fed toxic endophyte-infected hay had lower dry matter and crude protein digestibility, lower plasma prolactin concentration, and lower nitrogen retention than steers fed endophyte-free fescue hay. These results show that Max Q, nontoxic endophyte-infected fescue hay is equal to endophyte-free fescue hay, and that both are superior to toxic endophyte-infected fescue hay as feed sources for beef cattle.

During a 5-year study conducted in Butner, NC, Drewnoski et al. (2009a) evaluated the effects of endophyte-free (E-), endophyte-infected (E+), and novel endophyte-infected (EN) tall fescue on the performance of beef cattle intensively grazing the stockpiled fescue during the winter and spring. Treatments consisted of Jesup tall fescue that was either infected with wild-type toxic endophyte (E+), infected with a novel (AR542) endophyte (EN) or endophyte-free (E-). The study used 48 Angus-cross heifers that were strip-grazed on 12 fescue pastures after being blocked by weight and assigned to 1 of 4 treatments. The heifers grazed for three months (December through February). In this 5-year study, the growth rate of cattle grazing stockpiled E+, E-, or EN from December to February was not influenced by endophyte status. Average daily gains were 0.51, 0.59, and 0.56 kg/d for E+, E-, and EN, respectively. Pasture mass before and after grazing was used to estimate DMI which did not differ (4.7, 4.7, and 5.0 kg/hd daily, for E+, E-, and EN, respectively). Despite the lack of difference in ADG and forage DMI, cattle were being affected by endophyte as evidenced by decreased prolactin levels in the E+ cattle (7, 90, and 92 ng/mL for E+, E-, and EN,
respectively). Animal grazing days and BW gain/ha favored E+ fescue over the other treatments, and breeding rate the following spring was not affected by endophyte status supporting the suggestion of Curtis and Kallenbach (2007) that E+ fescue has a viable role when used in a winter stockpiling system. Because ergot alkaloid levels decline in early winter, it is suggested that producers feed hay or graze non-toxic fescue during autumn and early winter and defer grazing of stockpiled E+ until later in the winter.

Research in North Carolina (Drewnoski et al., 2009b) evaluated the effects of endophyte status on the composition and nutritive value of endophyte-infected, endophyte-free, and novel endophyte-infected tall fescue stands when stockpiled and intensively grazed over five consecutive winters. Changes in total ergot alkaloid concentration in endophyte-infected tall fescue over the winter were also evaluated. Jesup tall fescue that was E-, E+, or EN (Max Q, AR542) was compared using stockpiled grazing from December through February. Fertilization (65 kg N/ha) was done in early March, grazing from April through June (in year 2, 3, and 4, with spring hay in year 1 and 5), and hay was cut in late August prior to fertilization (average 84 kg N/ha plus other nutrients to soil test). Cattle were not removed from pasture during wet periods during winter grazing and severe treading of pasture occurred during several years. Stockpiled mass of E- was less than E+ or EN (3979, 3508, and 3829 kg/ha for E+, E-, and EN, respectively). There were significant differences in forage nutritive value for the different endophyte treatments; however, the differences were small. Crude protein was higher for E- than for E+ or EN (10.9, 11.8, 11.1 for E+, E-, and EN, respectively); and ADF was slightly higher for E- than E+ with EN being
intermediate (28.8, 29.3, and 29.1 for E+, E-, and EN, respectively). Stands persisted well in all treatments over the 5 years study, despite the expectation that E- stands would be greatly reduced because of severe winter trampling. Final stand counts (measured using a modified point step method) in September following the last year of grazing showed that fescue comprised 32.8, 45.2, and 57.3% of the sward for E-, EN, and E+, respectively, with all three treatments differing from each other (Vibart et al., 2008). This observation is consistent with the stand loss reported by Burns et al. (2006).

Smith et al. (1989) summarized some of the problems with stockpiled fescue. Stockpiled fescue may serve to minimize the negative effects of fescue on the grazing of stocker cattle and their subsequent finishing in the feedlot phase. Steers had been grazed from November to May on KY-31 fescue (76% endophyte-infected), KY-31 (74% infected) interseeded with a mixture of clovers, or low endophyte KY-31 fescue (0.7% infected). Steers from the high endophyte-infected fescue pastures weighed 101 lbs less than steers from the low endophyte-infected pastures at the end of the grazing period; however, steers fed high endophyte gained 68 lbs more during the feedlot phase (on high concentrate). This study showed that steers with clinical signs of fescue toxicosis can compensate for up to 67% of the reduced gains resulting from grazing infected fescue.

In summary, yield of E+, E-, and EN are similar. Stockpiled fescue after mid-December shows a decline in both yield and quality. Stand loss associated with endophyte-infected (E+) fescue pasture is less as compared to endophyte-free (E-) and novel endophyte-infected (EN) pastures, with endophyte-free being the least likely to survive repeated
grazings. Animal performance can be affected by endophyte infection rate in the summer; however, throughout the winter ergovaline (ergot alkaloid) concentrations decrease, leading to no differences in animal performance between E+, E-, and EN forages. Due to the rapid decline in ergot alkaloid concentrations in late winter, it has been suggested that producers feed non-toxic fescue, endophyte-free fescue, or fescue hay during autumn and early winter. Producers should, when possible, use stockpiled E+ fescue later in the winter, when ergovaline concentrations are low. When cattle are taken off of endophyte-infected pasture and show signs of fescue toxicosis, the cattle are able to compensate for the reduced gains on pasture when placed.

**Forage Intake.** Bagley et al. (1983) evaluated the chemical composition, digestibility and relative forage intake of tall fescue (TF) harvested at four different times during the year when fed to sheep. Treatments included four dried TF forages harvested on May 23, Aug. 1, Nov. 16, and Mar. 4th, with a fifth treatment of alfalfa hay used as a reference. Differences did exist between TF for digestibility and voluntary intake when harvested at different times during the year. There was no selective grazing by the animals, but selectivity is low where pastures are fully utilized. Fall stockpiling of TF appears to be an excellent method of managing TF to increase quality and consumption while extending the grazing season. Stockpiling produces a forage that combines good nutritive value with a relatively high voluntary intake. In February, stockpiled TF has deteriorated due to winter burn and was of poor quality and lead to low voluntary intake.
Davis et al. (1993) compared tall fescue forage intake, forage availability and animal performance indices. Two grazing systems were evaluated, high and low. The high treatment had 10 paddocks and the low treatment had 6 paddocks. Around 25 non-lactating, mature, mid-gestation Hereford x Gelbvieh cows were used in each system. Weaned calves were allowed to graze paddocks for 2-3 days to remove top growth. The cows grazing season began Nov. 11th and continued until late December. In the first grazing system (high) pastures were fertilized with 60 lb N as urea/acre and subdivided into 2.17 acre paddocks to make forage available for 7 day grazing periods. In the second grazing system (low), pastures were fertilized with 30 lbs N as urea/acre and subdivided into 5.33 acre paddocks to make forage available for 14 day grazing periods. The use of NE as an estimate of intake for the high system underestimated performance. This may be explained by the increase in fiber of the forage later in the grazing period. Late in the grazing period, fiber concentration increased due to animal selectivity and a reduction of high quality forage. This increase in fiber resulted in forage that was lower in calculated NE. It was also possible that the equation for the estimation of NE underestimated the energy value of the forage.

In summary, stockpiled tall fescue decreases in quality as the winter progresses, which leads to lower than normal voluntary forage intake. High quality forage is consumed at a higher rate, which can lead to animals being selective when fiber concentration increases over the winter. This can lead to lower intake and therefore, lower performance by late winter.
Stocking Rate. Kuykendall et al. (1999) evaluated the effects of continuous stocking (CS) and rotational stocking (RS) of steers on endophyte-infected (E+) tall fescue-common bermudagrass pastures fertilized with broiler litter on pasture species composition, forage availability, and forage quality and animal performance. Broiler litter was broadcast annually at approximately 6 tons (dry weight)/acre in split applications during late winter and early autumn of each treatment year. Four broiler litter applications were made during the 2 years of this study. Actual nutrients applied varied between applications based on nutrient and moisture content of the litter. Six 2.0 acre common bermudagrass pastures were treated to kill existing E- tall fescue prior to no-till planting of Georgia 5 E+ tall fescue at 20 lbs/ac in drill rows. Grazing method had no effect on tall fescue or other species basal cover or frequency of other species. Grazing methods also had no effect on monthly harvested forage samples measured for CP, NDF, or ADF content. Rotational stocking resulted in increased forage available of tall fescue in January and November. It had no effect on stocking rate the first year, but increased by 24% in the second year. Animal performance was unaffected by grazing method and were in the expected range for steers grazing E+ tall fescue pastures. Rotational stocking maintained bermudagrass better than CS in the aggressive heavily fertilized E+ tall fescue of the mixed pastures. However, it was similar to CS in utilizing nutrients from broiler litter.

Cattle continuously grazing pastures consume only 30-40 percent of the forage produced. Rotating animals between four or more subdivided areas, or paddocks, within a pasture (rotational grazing) can improve forage use efficiency to 50-60 percent. Rationing
out small strips of pasture (strip grazing) every 1-3 days can improve grazing efficiency to a point where 65-75 percent of the forage produced will be consumed.

**Management Methods.** Research in Arkansas, (Caldwell et al.,2009) evaluated how autumn-stockpiling of different proportions of the total tall fescue grazing area affects forage nutritive value, ergot alkaloid concentration, and the overall performance of fall-calving beef cows. Fescue-based grazing systems where 0, 33, or 50% of the total allotted area (1 ha/cow) were stockpiled for deferred grazing. Pastures were divided into 6 paddocks and stocked with cows in mid-August. Cows in the 0% treatment were rotated weekly through the paddocks, while cows in the stockpiled treatments were grazed in the paddocks to be stockpiled until mid-September when they were fertilized with N at 54 kg/ha. Forage was allowed to accumulate in the stockpiled paddocks until available forage was depleted in the non-stockpiled paddocks, which was mid- to late-November. Hay was offered to cows when forage mass was measured to be below 1120 kg/ha. Cow performance, including BW gain and BCS were similar across the three systems. Hay offered tended to be lower for the stockpiled treatments, while calf weight and ADG tended to favor the 33% treatment over the 50% treatment. The authors concluded that there were benefits to stockpiling 33% of the fescue pasture for deferred grazing.

Research in Ohio (Owens and Shipitalo, 2009) evaluated two different systems for over-wintering beef cows in terms of vegetative cover, surface runoff, sediment loss, and N losses in surface runoff. This study was conducted from November 1974 through October 1986. Two rotationally grazed pasture management systems, at high and medium fertility
levels, were used. A spring calving beef herd grazed four pastures during the summer in each system. The cattle were on each pasture for 5-7 days before being moved to the next pasture. During the dormant, wintering period, cattle were rotated through paddocks in the high fertility system and kept continuously in one paddock in the medium fertility system. The authors concluded that using stockpile and grazing as a wintering system might improve the environmental impact of winter feeding as compared to a hay feeding system.

A study conducted in Missouri (Curtis et al., 2008) evaluated how different levels of stockpiled tall fescue would influence pasture utilization as well as animal performance using lactating beef cows and their calves. Over a two-year period, cow/calf pairs were allocated stockpiled tall fescue twice weekly at a rate of 2.25, 3.00, 3.75, or 4.5% of BW/d. Also included in this comparison was a conventional hay feeding system. Cows were placed on treatments in early December and remained there until mid-February when they were commingled until the calves were weaned. Allocations of forage were based on availability in the ungrazed area ahead of the cows, and intake and forage utilization was determined by measuring residual forage after a two week grazing period. In the first year of the study, cows lost less BCS over the winter period as forage allowance increased and cows grazing fescue lost more BCS than cows fed hay. However, in the second year, there was no difference in BCS loss between the grazing and the hay treatments. Despite BCS loss in year one, there was no effect on overall breeding rate. Estimated forage DMI increased with increasing forage allowance from 13.4 kg/d at 2.25% of BW to 19.4 kg/d at 4.5% of BW. However, utilization rate declined from near 85% at 2.25% BW to near 60% at 4.5% BW.
Calf ADG was increased from 0.65 kg/d at 2.25% BW to near 0.80 kg/d at 4.5% BW, with calves from hay being intermediate (0.73 kg/d). However, calf gain/acre increased as forage allowance decreased, and weaning weight of calves was not influenced by treatments. The results of this study led authors to conclude that a low forage allowance would result in a high utilization efficiency and would be optimal for a stockpiled fescue system while maintaining critical BCS on cows.

Dierking et al. (2008) studied whether or not pasture-based dairies in the lower Midwest could use stockpiled festulolium as an acceptable alternative to Jesup tall fescue for winter pasture. Yield and nutritive value of the two forages were evaluated from November to March over a three year period. In general festulolium had higher CP and energy levels than tall fescue, but the yield of the tall fescue was higher than festulolium, especially in year one of the study. The authors concluded that either forage had sufficient quality to support non-lactating cows through the winter, but that the lower yield seen in festulolium made it questionable as a forage for autumn stockpiling.

In summary, there are benefits to stockpiling 33% of fescue pastures for deferred grazing. Using stockpiled fescue and grazing for a winter feeding system has the potential to improve the environmental impact compared to hay feeding systems. A low forage allowance can result in a high utilization efficiency and is optimal for a stockpiled forage system, while maintaining BCS of cattle. Fescue has sufficient quality to support beef cattle at different stages of development through the winter, depending on whether or not good management practices are used.
Alkaloids

The primary mechanism for improving tolerance to biotic stress is through the anti-herbivore attributes of the alkaloids present in the forage, produced in response to the fungus or by the fungus itself (Malinowski and Belesky, 2000). Diazaphenanthalene alkaloids, ergot alkaloids, lolitrem alkaloids, pyrrolizidine alkaloids, and pyrrolopyrazine alkaloids, along with several other alkaloids are five compounds that have been identified in endophyte-infected tall fescue (Porter, 1995; Drewnoski et al., 2007). The class of ergot alkaloids has been known to effect performance of mammalian herbivores and is thought to be the primary cause of toxicosis symptoms seen in livestock grazing endophyte infected tall fescue (Porter, 1994). The pyrrolizidine and pyrrolopyrazine alkaloid classes have been known to have insect deterring properties (Dahlman et al., 1997).

Ergot alkaloids. The vasoconstrictive ergot alkaloids have been implicated in the similarities between fescue foot and chronic ergotism. However, it is unknown as to what combinations of alkaloids are responsible for fescue toxicosis in livestock, being that the alkaloids bioavailability and metabolism is not well understood (Hill et al., 2001). Three ergot alkaloid classes have been identified from \textit{N. coenophialum}: ergopeptines, simple lysergic acid amides, and clavines (Porter, 1994).

Ergot alkaloids have been known to affect lipid metabolism by lowering fat stores and blood concentrations of cholesterol and triglycerides (Barnett et al., 1991; Nihsen et al., 2004). These alkaloids stimulate dopamine receptors, which are provoked by α adrenergic and serotonin receptors and altered thermoregulatory and vasoregulatory mechanisms (Floss
et al., 1973). Physiological effects of ergot alkaloids are linked with the monoamine-affected systems (Muller-Schweiniter and Weidmann, 1978).

Phosphorus appears to be involved in ergot alkaloid biosynthesis and accumulation in endophyte-infected fescue. A greenhouse study of four different tall fescue clones showed that the concentration of ergot alkaloids increased with increasing levels of phosphorus availability in the soil with levels between 17 to 50 mg per kg; however, when levels increased above 96 mg per kg, ergot alkaloid concentrations decreased (Malinowski et al., 1998). One in-vitro study showed that the activity of the first enzyme in the biosynthesis pathway of ergot alkaloids, dimethylallyl tryptophan synthase, has been shown to be restricted as a response to high phosphorus concentrations (Robbers, 1984; Flieger et al., 1991; Malinowski and Belesky, 2000). This may be able to explain the reduced alkaloid concentration noticed at the 96 mg per kg seen in the study by Malinowski et al. (1998).

It has been shown that by making the grass into hay that the ergot alkaloid concentrations have been lowered (Roberts et al., 2002). This may be explained by the several cycles of drying and rehydration that happen when the forage is sun-cured. The alkaloids are thought to be unstable when rehydration, photolysis, and air oxidation of the plant tissue happens repeatedly (Gardner et al., 1993; Porter, 1995; Kallenbach et al., 2003).

Ergot alkaloids have been associated with vasoconstriction in livestock grazing tall fescue. Ergovaline has been noticed to have a sustained contractile response, while lysergic acid has not been noticed (Klotz et al., 2009). Klotz et al. (2009) determined if repetitive in-vitro exposure of bovine lateral saphenous vein to lysergic acid or ergovaline would result in
an increasing contractile response. Sixteen Angus x Brangus cross-bred, fescue-naïve heifers had sections of veins biopsied immediately after slaughter. Veins were trimmed and cross-sections were suspended in a myograph chamber that contained 5 ML of oxygenated Krebs-Henseleit buffer (Klotz et al., 2009). Contractile responses were evaluated with additions of ergovaline and lysergic acid. The data shows that ergovaline and not lysergic acid bioaccumulates with the repetitive exposure in-vitro (Klotz et al., 2009). Authors concluded that ergovaline may have a higher possibility for inducing fescue toxicosis in grazing livestock than lysergic acid due to its potential for bioaccumulation at the cellular site of action.

**Ergopeptines.** Physiological responses associated with endophyte-infected fescue have been attributed to ergopeptines. Belesky et al. (1988) measured Kentucky-31 during late February until mid-December for the ergopeptine concentrations in the forage. Beginning in early April, the alkaloid levels began to increase with a peak around middle to late May at 550 mg/kg. The concentrations were lowest during the summer (around 400 mg/kg) when the fescue was dormant. Concentrations began to rise in early September and continued until early November, peaking at 1150 mg/kg (Belesky et al., 1988).

Ergovaline is an ergopeptine alkaloid produced by *N. coenophialum*. Of the total ergopeptine alkaloid concentration, ergovaline is known to make up 80 to 90% (Belesky et al., 1988; Rottinghaus et al., 1991). Due to its high content of ergovaline, it has been used as an indicator of total ergot alkaloid content (Rottinghaus et al., 1991; Vibart, R.E., 2003). Total ergovaline concentrations in the leaf blade, sheath, stem, and the seedhead of infected
tall fescue plants was measured during a two year study conducted between April and July (Rottinghaus et al., 1991).

Ergovaline concentrations increased from late April until early May in the leaf blade and stem. In late April, the leaf blade concentration was less than 250 ug/kg, but in May the concentrations increased from 450 to 500 ug/kg. The concentrations in the stem increased from 500 ug/kg to between 800 and 1300 ug/kg (Belesky et al., 1988; Rottinghaus et al., 1991). However, once the seedhead started to develop in mid-May, the concentrations in the leaf and stem declined. Ergovaline concentrations increased in the seedhead as it matured and peaked in mid-June. Concentrations at the peak were variable, ranging from 5000 ug/kg in year one to 1700 ug/kg in year two (Belesky et al., 1988; Rottinghaus et al., 1991). Once the seedhead is matured, the concentration in the leaf and stem remained between 200 to 400 ug/kg (Rottinghaus et al., 1991). These data suggest that the matured seedhead is the most toxic part of the plant and that the reduction of seedheads would reduce the toxicity of the forage.

Stockpiled Kentucky-31 ergovaline content was measured from mid-December until mid-March for two years by Kallenbach et al. (2003). By mid-March, in both years of the study, the ergovaline concentrations were decreased by 85%. The concentrations by mid-December were approximately 450 to 190 ug/kg in year 1 and 2, respectively.

**Lysergic acid amide.** Lysergic acid amide (LAA) can exist in high quantities in endophyte infected tall fescue and is reported to approach 45% of the concentration of ergovaline (Oliver et al., 1993). LAA (ergine, ergonovine, eronovine) have been reported to
bind and agonize with the D₂ dopamine receptors; however, they were 1/100th as potent as ergovaline (Larson et al., 1999). Eronovine has been shown to have vasoconstrictive effects (Oliver et al., 1992).

It has been shown to produce vasoconstriction of veins in-vitro at concentrations that seem to be within the range that animals grazing endophyte-infected tall fescue would consume (Oliver et al., 1993). It is possible for lysergic acid amides to play a role in fescue toxicosis but to what extent is unknown; although, they seem to be less potent than ergopeptides, ergovaline, or ergotamine (Hill et al., 2001). Lysergic acid amides are thought to have a higher potency when compared to ergovaline, because of its potential to be transported in the omasum and rumen at higher rates, when compared to lysergol and ergonovine (two lysergic acid amides) and ergotamine and ergocryptine (two ergopeptines).

A study was conducted to investigate the digestion of ergovaline and the production of lysergic acid in sheep consuming Neotyphodium coenophialum-infected tall fescue, containing straw and seed, and approximately 0.50 mg of ergovaline/kg (De Lorme et al., 2007). Six crossbred wethers were used on two treatments with six observations per treatment. The treatments consisted of tall fescue straw containing <0.010 mg of ergovaline/kg (E-) and tall fescue straw containing 0.610 mg of ergovaline/kg (E+). Ruminal fluid was sampled 3 times during each 28 day feeding period to determine the level of ergovaline, lysergic acid, ammonia, and Ph. Over the course of the trial a total of 35% of dietary ergovaline and 248% of dietary lysergic acid was recovered in the feces and urine collected from the wethers used. The appearance of lysergic acid in the feces, urine, and
ruminal fluid is more than likely due to microbial degradation of ergovaline in the rumen and the further breakdown in the lower digestive tract (De Lorme et al., 2007).

Ergot alkaloids can cause fescue toxicosis when cattle graze endophyte-infected tall fescue. It is acknowledged that ergovaline is the toxic component of endophyte-infected tall fescue, but there is no direct evidence to support that case (Hill et al., 2001). Research conducted in Georgia (Hill et al., 2001) examined the relative and potential transport of ergoline and ergopeptine alkaloids across isolated gastric tissues in-vitro. Sheep rumenal and omasal tissue were collected and placed in parabiotic chambers. Lysergic acid, lysergol, ergonovine, ergotamine, and ergocryptine were added to a Kreb’s Ringer phosphate (KRP) solution on the mucosal side of the tissue (Hill et al., 2001). The alkaloids with the greatest potential for transport were lysergic acid and lysergol. Ergopeptine alkaloids tended to pass across omasal tissues in larger quantities than ruminal tissues, but their transport was minimal compared to lysergic acid and lysergol. Authors concluded that the reticulum, rumen, and omasum are absorptive sites for alkaloids that are associated with fescue toxicosis.

**Clavine alkaloids.** Four types of 50ersiste alkaloids have been isolated from *N. coenophialum* infected tall fescue: Chanoclavine(s), penniclavine, elymoclavine, and agroclavine (Lyons et al., 1986). These alkaloids are precursors in the biosynthesis of the simple lysergic acid amides and the ergopeptines (Floss, 1976; Gardner et al., 1993; Porter, 1994).
**Pyrrolopyrazine alkaloids.** Peramine is a product produced by endophyte-infected tall fescue (Siegel et al., 1990) and has been shown to have insect deterrent properties (Breen, 1994). Even though it has these properties, it does not seem to have any effect on mammalian herbivores (Bush et al., 1997).

**Pyrrolizidine (loline) alkaloids.** N-formal and N-acetyl (loline alkaloids) are synthesized by endophyte infected tall fescue (Siegel et al., 1990; Porter, 1994). Loline is found in the plant, in the leaves and roots, where the fungus is known to exist. Therefore, the synthesis of this compound is translocated in the leaf blade and in the roots of the plant. A 2 to 3 fold increase in loline alkaloid concentration has been seen in plants that are subjected to water stress, but no change was seen with nitrogen application (Kennedy and Bush, 1983). These loline alkaloids have been shown to have insect deterrent properties (Dahlman et al., 1997) and do not appear to have insignificant effects on livestock (Strickland et al., 1996; Fletcher et al., 2000). Loline alkaloids have been shown to be detrimental to other plants grown in tall fescue, when they are produced at high concentrations.

**Diazaphenanthrene alkaloids.** A diazaphenathrene alkaloid, such as perloline, was thought to be the cause of fescue toxicosis, initially (Gentry et al., 1968). However, this theory has been dismissed by Hemken et al. (1979). This dismissal was supported by findings that showed that the concentrations of perloline of fescue stands of a high endophyte infection rate were similar to fescue stands of a low endophyte infection rate (Strahan et al., 1987).
**Lolitrem (indole diterpene) alkaloids.** Compounds in endophyte infected ryegrass, lolitrems and paxilline, were first identified and associated with livestock neurotoxicities of ryegrass staggers. Lolitrems and paxilline can be produced in-vitro in cultures of *N. coenophialum* (Penn et al., 1993), along with in-vivo in endophyte-infected tall fescue (Garthwaite, 1997). However, it is unlikely that lolitrem contributes to fescue toxicosis in livestock.

**Other alkaloids.** Endophyte-infected tall fescue has numerous other alkaloids, including: ergosterol, ergostatetraeneone, ergosterol-peroxide, 52ersis, norharman, and halostachine (Latch, 1993). These alkaloids may also play a role in insect deterrence and/or animal toxicities.

**Pasture and Grazing Management**

Animal performance can be hindered by endophyte-infected tall fescue, but with different management techniques, a producer can decrease these negative effects. It has been shown that by interseeding fescue pastures with clover, the effects of the infected tall fescue can be minimized. This has shown increased performance in steers (McMurphy et al., 1990; Chestnut et al., 1991) and in cow-calf pairs (Stricker et al., 1979). By adding legumes to a pasture at a rate of 10 to 25 %, the symptoms of fescue toxicosis are reduced (Fribourg et al., 1991).

Removing cattle from the endophyte-infected tall fescue is another technique used during the summer when temperatures are increased. The cattle can be grazed on a warm
season forage. This practice has shown that by switching steers from endophyte-infected tall fescue to Caucasian bluestem in the early summer has increased the steers’ average daily gain when compared to other steers left on the forage (Forcherio et al., 1992).

It was suggested that by delaying the use of stockpiled fescue until mid- to late-winter, the negative effects of the endophyte can be minimized. Alkaloid content decreases over the winter, while the nutritional content of the forage remains above the requirements for a gestating beef cow (Kallenbach et al., 2003). The alkaloid content is highest and more concentrated in the seedhead (Rottinghaus et al., 1991). Two ways of reducing the seedhead formation are by increasing the stocking rate (Ball et al., 1993; Bransby et al., 1988) or by mowing the forage before the seedhead matures in order to keep cattle from consuming the seedheads with high alkaloid content; early flash grazing can also be done.

**Tall Fescue Responses to Endophyte Infection**

Many changes in morphology and growth of tall fescue are dependent on plant and/or endophyte genotypes (Hill et al., 1990). Forage yield and tillering characteristics have been shown to be highly dependent on the plant genotype and therefore, the responses to endophyte infection have been highly variable (Wilhelm and Nelson, 1978; Hill et al., 1990). Other effects include, higher DM production per year and a lower crown depth to be more consistent among differing plant genotypes (Hill et al., 1990).

**Plant vigor and growth.** In the field, endophyte-infected tall fescue plants have been shown to have greater tiller survival and growth rates and to be larger than their endophyte
free counterparts (Clay, 1987; Read and Camp, 1986). When the two types of fescue are grown in a mixture (endophyte infected and endoppye free), the endophyte-infected plants were larger and more competitive than the endophyte-free plants (Hill et al., 1991). Under ideal conditions, endophyte-infected tall fescue seed germinates at an approximately 10% higher rate than endophyte-free seed (Clay, 1987).

It has been shown that adding nitrogen to a pasture of KY-31 plants will produce more biomass at each applied N nutrient level (Cheplick et al., 1989). Endophyte-infected tall fescue has higher glutamine synthetase activity, which may be responsible for the ability of the forage to better utilize available nitrogen (Lyons et al., 1989). The glutamine synthetase is responsible for the reassimilation of ammonia inside plants (Lyons et al., 1989).

**Insect and nematode resistance.** Insect herbivory is decreased in endophyte-infected fescue due to the accumulation of deterrents, toxins, and their synergists. During the growing season, endophyte-infected fescue had less total number of leaf hoppers (Cercopidae) than endophyte-free fescue (Muegge et al., 1991).

Root feeding nematodes are primarily located in the soil and on the roots of endophyte-infected and endophyte-free tall fescue 7 weeks after inoculation with nematodes (Pedersen et al., 1988). The reason for endophyte-infected fescues apparent resistance to nematodes is not clear. However, it has been suggested that while the fungus itself is not found in the roots, allelochemicals synthesized by the endophyte may be translocated to the roots to deter nematodes (Pedersen et al., 1988). Malinowski et al. (1999) has shown that lolines are present in the roots of endophyte-infected fescue and it supports the theory of the
endophyte being translocated to the roots. The resistance to nematodes may be due to the endophyte stimulating a thickening of the roots’ inner endodermal cell walls, which makes it difficult for juvenile nematodes to establish feeding sites (Gwinn and Bernard, 1993).

**Drought tolerance.** Drought stress has been found to be one of the most limiting factors to the adaptation and persistence of tall fescue, particularly in the southern portion of its range (Bates et al., 1990; Bacon, 1993; Bouton et al., 1993; Malinowski and Belesky, 2000). Advantages to endophyte infection are seen during times of severe water deficiencies. *Neotyphodium coenophialum* induces the adaptations that help the plant reduce transpiration losses (Elmi and West, 1995), improve water uptake, and maintain critical growing points during droughts (Elmi et al., 1989).

Endophyte-infected tall fescue populations are more stable than endophyte-free populations during drought stress (West et al., 1993; Read and Camp, 1986). When irrigating endophyte-infected fescue, at low and medium rates, there was a higher stand density and forage yield over endophyte-free fescue. However, at high irrigation rates, endophyte-infected fescue did not differ from endophyte-free (West et al., 1988).

By closing their stomata, plants can conserve water. This reduces the amount of water lost through transpiration. Endophyte-infected tall fescue, in response to drought stress, produces more phytomhormone abscisic acid than endophyte-free fescue (Bunyard and McInnis, 1990). Abscisic acid is thought to play a role in regulating the stomatal function and might be a messenger that stimulates closure of stomates when in moisture deficit for the root zone (Lachno and Baker, 1986). Endophyte-infected tall fescue’s stomatal
conductance of water-stress declines earlier and faster than endophyte-free (Elmi and West, 1995). However, other research has shown that there are variable responses of stomatal function to drought stress in respect to plant endophyte status (Malinowski and Belesky, 2000). It has been said that the plants genetic makeup controls the stomatal conductance in response to drought and a high degree of genotypic variability exists.

Morphological changes in endophyte-infected plants have been shown to reduce water loss and therefore, enhance plant survival during drought stress. Endophyte infection has been shown to affect plant morphology in many genotypes by causing an increase in leaf rolling due to drought stress compared to uninfected tall fescue (Arachevaleta et al., 1989; Belesky et al., 1989; Hill et al., 1990). Under conditions of drought, endophyte-infected tall fescue has shown a greater leaf senescence and a reduction in leaf expansion rate (Belesky et al., 1989).

During drought stress, cell turgor is maintained in critical growing points. This maintenance protects these growing points from desiccation and therefore, allows re-growth to occur when adequate moisture returns. Cell turgor is maintained with the accumulation of solutes leading to a reduction of osmotic potential (Hellebust, 1976). Infected tall fescue has been shown to have a greater degree of osmotic adjustment than uninfected tall fescue leaf blades and tiller bases (Elmi et al., 1989). Within an infected tall fescue plant, the greatest adjustment is occurring in the basal meristem (West et al., 1990). Young meristematic and elongating leaf tissue has shown greater osmotic adjustment than matured leaf tissue (West et al., 1990).
Endophyte-infected tall fescue under drought stress has shown an increased re-growth rate when compared to endophyte-free tall fescue (Arechavaleta et al., 1989; West et al., 1990; Malinowski and Belesky, 2000) and this may be due to increased turgor which allows for rapid elongation (Meyer and Boyer, 1972). Another possibility for this increased growth rate may be due to an increased amount of indole acetic acid in the plant (Debattista et al., 1990).

**Nutrient stress resistance.** Endophyte infection seems to benefit the plant when the bioavailability of phosphorus is low. Endophyte infection helps the plant by altering root morphology due to phosphorus deficiency. With low levels of available phosphorus in the soil, concentrations of phosphorus, magnesium, and calcium in the roots and shoots were higher in infected tall fescue than uninfected tall fescue (Malinowski et al., 1998). This can be due in part to infected tall fescue having a greater specific root length than uninfected tall fescue at low and medium phosphorus levels in the soil (Malinowski et al., 1998). Endophyte infection increased root dry matter, relative growth rate, and phosphorus uptake rate of two tall fescue clones (DN2 and DN4) at low phosphorus soil levels (Malinowski and Belesky, 1999). Another mechanism for increased mineral uptake due to phosphorus deficiency can be due to alterations in activity of root exudates (Malinowski and Belesky, 2000). One clone (DN2), endophyte infection increased root exudates activity by 100 % in dissolving phosphorus from the phosphate rock. While the other clone (DN4), the endophyte infection had no effect on root exudates activity (Malinowski and Belesky, 2000).
Fescue Toxicosis

Bovine fat necrosis, summer slump, and fescue foot are three conditions related to the tall fescue endophyte associated with animals grazing endophyte-infected fescue. Fescue foot occurs during the winter and is usually determined by a red line at the coronary band of the hoof (Bush et al., 1979). Vasoconstriction can lead to death of the soft tissue and lead to partial or complete loss of the extremities (hooves, ears, and tail) (Bush et al., 1979; Ball et al., 2002). Bovine fat necrosis is distinguished by the presence of hard, necrotic masses of fat in the adipose tissue of the abdominal cavity. This can lead to many disorders like: kidney failure, difficult births, and gastrointestinal disorders. Summer fescue toxicosis is the most common and costly disease associated with endophyte-infected fescue (Hoveland, 1993; Vibart, 2003). Cattle that display signs of summer fescue toxicosis exhibit increased respiratory rates, increased rectal temperatures, rough hair coats, and excessive salivation (Paterson et al., 1995).

Weight Gain. It has been seen that cattle consuming endophyte-infected tall fescue have reduced average daily gains (Hoveland et al., 1983; Chestnut et al., 1991; Gerrish et al., 1994), even though, the amount of the reduction in gains is variable. However, it has been shown by Paterson et al. (1995) that the average daily gain for steers grazing uninfected fescue had gains increased by 30 to 100 % when compared to the gains of steers grazing infected fescue. It has also been seen that beef cows grazing endophyte-infected fescue have lower milk production, lose more weight, and wean lighter calves than those cows grazing endophyte-free fescue (Peters et al., 1992; Keltner et al., 1988; Drewnoski et al., 2007).
Many factors affect the extent to which performance is affected in cattle. Those factors include infection rate, ergot alkaloid content of the grass (Chestnut et al., 1991; Crawford et al., 1989), ambient temperature (Aldrich et al., 1993b), and the species composition of the stand (Fribourg et al., 1991).

**Intake.** The ergot alkaloid content and elevated temperatures (31°C or above) interact and cause negative feedback on animal intake of the forage. In one study, steers were fed less toxic tall fescue, more toxic tall fescue or orchardgrass soilage (green chop) (Hemken et al., 1981). The more toxic strain only reduced the steers’ intake when the environmental temperatures were above 32°C and the less toxic strain of the fescue did not reduce intake when compared with the orchardgrass. In another study performed by Peters et al. (1992) the forage intake of cows grazing infected tall fescue were not decreased when the temperatures were constantly below 32°C, but their intake did decrease when the temperatures were constantly above 32°C.

In one study, a seed based diet that contained 381 ug/kg of ergovaline was fed; the intake of beef heifers was not affected by the treatment when the environmental temperature was varied diurnally between 22°C and 32°C (Aldrich et al., 1993b). When the steers were fed a diet that contained 285 ug/kg of ergovaline temperatures were maintained at 22°C, their intake was reduced by 10% when compared to steers being fed uninfected fescue. The steers’ intake was further reduced when temperatures were increased and maintained at 32°C (Aldrich et al., 1993b). Overall, under heat stressed conditions, DMI, while consuming infected tall fescue, was reduced by 22 % as compared to cattle on uninfected tall fescue.
**Diet Digestibility.** Chemical measures of forage quality are usually what is reported and found to be similar between infected and uninfected fescue stands (Bush and Burrus, 1988; Arachevaleta et al., 1989; Ball et al., 2002; Vibart, 2003; Drewnoski et al., 2007). Studies of the digestibility of the forage have had mixed results (Aldrich et al., 1993a, b; Hannah et al., 1990; Goetsch et al., 1987; Westendorf et al., 1993). In a study, steers were fed a diet of ad libitum tall fescue hay which contained 100, 75, 50, 25 or 0% infected hay with the balance in uninfected hay. The total tract dry matter, neutral detergent fiber, and nitrogen digestibility increased with increased infected tall fescue levels (Goetsh et al., 1987). With increasing levels of infected fescue in the diet, the dry matter and passage rate decreased. With the increased feed intake which can elevate the outflow of fermentable substrates from the rumen; lower digestibility can be seen with uninfected fescue diets.

In one study, sheep were fed a seed-based diet where dry matter intake was equalized between infected and uninfected tall fescue treatments (Hannah et al., 1990). Decreased ruminal and total tract organic matter, neutral detergent fiber, and cellulose digestibility in the infected tall fescue diets contained 0.19 mg/kg BW\(^{0.75}\) of ergovaline. Fiorito et al. (1991) reported similar results, when a study was performed on lambs being fed equal amounts of high endophyte (>95%) or low endophyte (<1%) KY-31. In the high endophyte treatment, the total tract dry matter, neutral detergent fiber, and acid detergent fiber digestibility was reduced. Sheep were fed 1200 g/d of a seed based diet (Westendorf et al., 1993). The infected tall fescue contained 1400 ug/kg of ergot alkaloid. Total tract DM, ADF, and CP, along with ruminal NDF, ADF, and CP digestibility were all reduced by the endophyte.
Aldrich et al. (1993a) conducted a study that reported dry matter digestibility did not differ between infected and uninfected tall fescue when the sheep intake was equalized to 1.5% BW and the infected tall fescue diet contained 0.9 mg/kg BW$^{0.75}$ of ergovaline. Aldrich et al. (1993b) conducted another study in which it was reported that steers had lower dry matter and organic matter digestibilities on the endophyte-infected fescue diet which contained 0.04 mg/kg BW$^{0.75}$, but the NDF digestibility was similar.

**Temperature Regulation.** Rectal temperatures have been shown to increase by 0.4°C to 1.2°C, in animals consuming endophyte-infected diets during heat stress conditions (Hannah et al., 1990; Schmidt et al., 1982). Increased respiration rates and excessive salivation have also been noticed in cattle and sheep being fed diets of endophyte-infected fescue (Hemken et al., 1981; Burke et al., 2001a,b; Schmidt et al., 1982).

Animals consuming endophyte-infected tall fescue showed signs of reduced intake, higher rectal temperatures, and higher respiration rates, probably due to their decreased ability to dissipate heat through their skin. There was a decrease in the animals’ ability to regulate their body temperature through surface vaporization with elevated temperatures (Aldrich et al., 1993a; Aldrich et al., 1993b). The ability of an animal to dissipate body heat was impaired by elevated environmental temperatures for animals consuming infected fescue (Aldrich et al., 1993a,b). Elevated temperatures are needed in order for an animal to be physiologically primed for fescue toxicosis.

**Temperature and Reproduction.** Burke et al. (2001a) evaluated the interaction between endophyte-infected tall fescue and environmental temperature on follicular and
luteal development and function in beef heifers. Twenty-four Angus and Angus x Hereford heifers between the age of 10-18 months of age, received either endophyte-free (EF) seed or endophyte-infected (EI) seed in a mixed feed ration and thermoneutral (TN) or heat stress (HS) temperatures resulting in four treatment combinations (EF-TN, EF-HS, EI-TN, and EI-HS). Four heifers were assigned to each treatment. Treatments were started 28 days before synchronized ovulation. During chronic or acute heat stress, follicular or serum estradiol production was reduced relative to thermoneutral conditions. There was a lack of a negative response of endophyte-infected fescue-fed heifers under thermoneutral conditions, with the exception of decreased circulating estradiol. This indicates that signs of fescue toxicosis are certainly less severe when heifers are not heat stressed. The authors concluded that the level of heat stress that induces signs of fescue toxicosis leading to decreased fertility warrants further investigation.

Burke et al. (2001b) evaluated the pregnancy rate and stage of embryonic loss in response to grazing endophyte-free or infected tall fescue in postpartum beef cows with calves. Mature beef cow-calf pairs were randomly assigned to graze endophyte-free tall fescue (E-) or endophyte-infected tall fescue (E+) for 45 days before synchronized estrus until the weaning of the current calf. Before this, all but nine cows had been exposed to bermudagrass. Cows were fed melengestrol acetate (MGA) grain carrier (0.91 kg/cow/d) without MGA for 14 days followed by carrier with MGA. The cows were monitored for standing estrus using an electronic heat detection system. Beginning 30 to 36 days after breeding, the uterus of pregnant cows was monitored and then every 7-14 day afterwards by
transrectal ultrasound scanning to examine embryo viability. The cows and calves that grazed endophyte-infected tall fescue exhibited signs of fescue toxicosis, but despite this, pregnancy rates were not reduced in those cows. A greater proportion of cows grazing E+ fescue responded to estrus synchronization 3 days after treatment with PGF\(_2\alpha\) compared with 4 days for cows grazing E- pasture. This could indicate a change in luteal dynamics due to consumption of E+ fescue. The authors concluded that under good management conditions, pregnancy rate was not reduced for cows grazing endophyte-infected tall fescue.

In summary, the occurrence of fescue toxicosis is reduced when animals are not heat stressed. However, the level of heat stress is not well understood and deserves to be investigated further. Endophyte-infected tall fescue has the potential to cause reproductive problems. With good management conditions, pregnancy rates and reproductive performance may not be adversely affected.

**Reproduction**

With endophyte-infected tall fescue, studies have shown variable results when observing pregnancy rates in cattle. Some studies have shown that cattle have reduced pregnancy rates when consuming endophyte-infected fescue (Beer and Piper, 1987; Gay et al., 1988; Schmidt et al., 1986; Aldrich et al., 1993a,b), although, other studies have shown no difference in pregnancy rates (Burke et al., 2001b; Burke and Rorie, 2002; Fanning et al., 1992). Experimental conditions may lead to discrepancies in the affect of endophyte-infected tall fescue on pregnancy rates and hormonal balances. Some of these conditions
may have included the amount of ergot alkaloid to which the animal consumed, environmental temperature, and the animal’s stage of maturity.

**Cows.** It has been shown that heifers are more susceptible to alkaloids in endophyte-infected fescue than cows. When looking at early post-partum cows, there is little difference in follicle dynamics and estradiol production between cows grazing endophyte-free fescue and cows grazing endophyte-infected fescue (Burke and Rorie, 2002). The diameter of the corpus luteum (CL) and serum progesterone concentrations did not differ between the treatments. Serum estradiol concentrations over the entire estrous cycle were not different between the treatments. However, cows grazing endophyte-infected fescue were observed to have a small, larger follicle present on the ovary when compared to cows grazing non-endophyte-infected fescue. The estradiol concentrations were lower in cattle grazing endophyte-infected fescue between days 5 and 8 of the estrus cycle. Pregnancy rates and calving intervals did not differ between the treatments. Another study was performed that had post-partum beef cows grazing endophyte-infected tall fescue pastures starting in April and being bred in May and June. The study monitored fetal development weekly until 60 days of pregnancy. There was no detected difference in pregnancy rate or embryonic losses between the treatments.

In post-partum primiparous Angus cows being fed endophyte-infected or non-endophyte-infected fescue seed from May to mid-July, their luteinizing hormone (LH) concentration and luteinizing hormone pulse amplitude and frequency did not differ (Mizinga et al., 1992). By the end of the trial however, the prolactin levels were lower for the cattle
consuming endophyte-infected seed then for those consuming non-endophyte-infected seed. Cows on endophyte-infected fescue seed received 677ug/d during the first 42 days and then 2788 ug/d of ergovaline during the last 28 days of the trial. A fescue toxicosis response may have not been elicited in the first 42 days because the intake of ergovaline may have been too low during that time.

Reproductive performance may be impaired through increased body temperature and/or decreased energy consumption while consuming ergot alkaloids. Reproduction may be impaired during breeding season due to increased environmental temperatures. Reduced conception is associated with the animal being unable to regulate body temperature while grazing endophyte-infected tall fescue. Small follicles can be damaged by heat stress (Wolfenson et al., 1995). In one study, heat stress led to reduced diameter in the corpus luteum and progesterone levels when compared to thermoneutral conditions (Burke et al., 2001b). Also, under heat stress conditions, feed consumption has been shown to be reduced (Burke et al., 2001b). This reduction in feed may also impair reproduction by decreasing energy consumption. In post partum beef cows it has been shown that an inadequate energy intake can lead to a lowered serum luteinizing hormone concentration (Lishman et al., 1979; Echternkamp et al., 1982).

**Heifers.** Numerous studies have been conducted to look at the effect of endophyte-infected tall fescue on the estrous cycle and ovarian function in growing heifers. However, when observing the effects on the estrous cycle and ovarian function, it was found that the age and reproductive status of the heifer played a key role in the heifers’ response to
consuming endophyte-infected tall fescue. Heifers exposed to endophyte-infected fescue at an early age, seemed to have more detrimental effects when compared to older heifers. Beef heifers had lower conception rates when raised on high levels of endophyte infection as compared to heifers raised on lower levels of endophyte infection, 55% versus 96% conception rates for high and low endophyte infection levels, respectively (Schmidt et al., 1986). It was reported that a 23% reduction was noticed in basal luteinizing hormone (LH) and reduced estradiol-stimulated LH, prolactin (PRL), follicle stimulating hormone (FSH), and folliculogenesis of 3 month old heifers fed endophyte-infected hay (McKenzie and Erickson, 1991). Washburn and Green (1991) showed that puberty of heifers raised on endophyte-infected fescue was delayed. However, the rates of puberty in those heifers may have been due to the lower gains that they maintained while grazing the endophyte-infected fescue. It was reported that heifers had altered luteal function while grazing endophyte-infected fescue (Estienne et al., 1990). Of the heifers that produced a corpus luteum (CL), 62% of the endophyte-infected treatment heifers showed reduced circulating progesterone concentrations. It was shown that heifers grazing the endophyte-infected tall fescue exhibited alterations in the development and cellularity of the CL (Ahmed et al., 1990). The CL showed fewer nuclei and a greater number of large luteal cells with increased diameter for heifers that consumed the endophyte-infected tall fescue (McKenzie and Erickson, 1991). These luteal cells showed increased cellularity with a larger number of mitochondria, lipid droplets and secretory granules. The effects of endophyte-infected fescue on heifers may lead to a reduced ability of the heifers to maintain pregnancy.
A two year study was conducted on grazing heifers to observe the growth and ovarian function of weanling (n=40) and yearling (n=40) beef heifers (Mahmood et al., 1994). The heifers were placed on endophyte-infected or endophyte-free pastures in April and grazed through mid-July. The heifers on the endophyte-infected pasture were noticed to have reduced average daily gains for both the weanling and the yearling heifers when compared with the endophyte free grazing heifers. The ovarian function for the yearling heifers did not differ due to treatment. However, ovarian activity and luteal function were drastically altered in weanling heifers, along with a decreased response to estrous synchronization (Mahmood et al., 1994). This decrease in estrous response after synchronization may be due to the induction of hormonal imbalances. Throughout the entire study, the weanlings grazing the endophyte-infected tall fescue showed lower progesterone concentrations than the endophyte-free heifers. These results suggest that weanling heifers are more sensitive to the effects of endophyte-infected fescue than yearling heifers. However, the ovarian effect noticed in the weanlings was probably due to a delay in the onset of puberty.

Rahe et al. (1991) showed that beef heifers grazing endophyte-infected fescue had decreased embryo survival. The lower fertility seen in the heifers grazing the endophyte-infected fescue may be due to the decreased luteal function resulting in early embryonic loss. It has also been observed that there are changes in follicular and luteal function of 350 kg beef heifers being fed endophyte-infected fescue seed (Burke et al., 2001a). Serum progesterone concentrations were not affected by the diet under thermoneutral conditions, but under heat stress, the heifers on the endophyte-infected diet had lower serum progesterone
concentrations than those on the endophyte-free diet (Burke et al., 2001a). The lack of consistent results reported in literature may be explained by the lack of negative responses of the heifers fed the endophyte-infected fescue under thermoneutral conditions. During the thermoneutral and heat stress conditions, heifers that were consuming the endophyte-infected diet showed a decrease in the number of large follicles (>10mm) during the estrous cycle. Likewise, the pre-ovulatory serum estradiol concentrations were lower in heifers consuming the endophyte-infected fescue forage.

Suppressed serum PRL levels and decreased average daily gains (ADG) were observed, but no effect of grazing endophyte-infected fescue pastures were seen on ovarian function, synchronized estrous response or pregnancy rate of heifers exposed to endophyte-infected fescue for 100 days prior to insemination (Fanning et al., 1992). The only problem with this study, was that there was a limited number of animals (n=32) and it was conducted during the winter (November to March) when the alkaloid concentrations are usually low and the ambient temperatures are cool (Belesky et al., 1988).

When exposed to endophyte-infected tall fescue, cyclic heifers seemed to be less susceptible to the negative effects of the forage than the pre-pubertal heifers. Heifers that were placed on endophyte-infected pastures showed no disruption in their estrous cycle (Bond and Bolt, 1986). During a 40 day trial (April to May) two year old cycling Angus heifers (n=8) and four year old Angus cows (n=8) were pair fed endophyte-infected or endophyte-free seed (Mizinga et al., 1992). The results of the treatments were similar between the LH concentrations, LH pulse amplitude, and frequency. Cattle being fed the
endophyte-free seed had higher ADG (0.70 versus 0.32 kg/day) than cattle being fed endophyte-infected seed. However, PRL levels did not differ among the treatments. Cattle, during the trial, consumed between 1100 and 1800 ug/d of ergovaline for the first 15 days and between 2600 and 3200 ug/d of ergovaline for the remainder of the trial (25 days). The heifers were receiving the fescue seed as 10-20% of their diet. The high energy intake of the heifers may have dispelled some of the negative effects of the endophyte that has been observed in grazing animals.

**Bulls.** There has been little research performed on the effects on bull fertility while consuming endophyte-infected tall fescue. A group of Holstein bulls being fed endophyte-infected hay and grain from the age of 2 months to 13 months had a lower prolactin levels than did bulls fed non-endophyte-infected hay and grain, but the bulls in both treatments did not differ in body weight, testicular and seminal vesicle weight, daily sperm production potential, sperm maturity, and blood testosterone levels (Evans et al., 1988).
Literature Cited


CHAPTER 2

Performance of growing beef heifers strip-grazing stockpiled tall fescue and being fed 0.5% body weight per day of corn gluten feed, soyhulls, or 50:50 mix of the two

J.M. Scruggs, M.E. Drewnoski, A.D. Shaeffer, M.H. Poore

Department of Animal Science, North Carolina State University
Raleigh, NC 27695-7621
Introduction

Tall fescue’s [Lolium arundinaceum (Schreb.) Darbusy] autumn growth can be accumulated to extend the grazing season into the winter (Matches, 1979) and reduce winter feed costs (Kallenbach et al., 2003; Poore and Drewnoski, 2010). Tall fescue is the dominant forage found in production systems stretching from central Oklahoma to central North Carolina and from northern Alabama to Kentucky, covering more than 15 million hectares (Bouton and Hopkins, 2003). Tall fescue is also grown in the Northwest USA, primarily for seed production, and is adapted to numerous temperate regions throughout the world (Hannaway et al., 2009). In a stockpiling system, nitrogen is applied in late summer and forage is allowed to accumulate until it is needed, with grazing generally initiated in late autumn to early winter (late November or early January). Frontal strip-grazing management is advised in order to achieve a high level of utilization efficiency. This results in a winter feed source that is more economical than a common hay feeding system or stockpiled tall fescue with extensive grazing management (Poore et al., 2000). Using a stockpiling and grazing wintering system can improve the environmental impact of winter feeding as compared to a hay feeding system (Owens and Shipitalo, 2009), and also might improve calf health by providing a cleaner environment (Meyer et al., 2009). Growing cattle grazing endophyte-infected fescue during the winter have low gains despite the apparently good nutritive value of the forage (Poore et al., 2000). Due to this, supplementation may be necessary in order to reach production goals. Supplementation has been shown to increase animal performance while grazing stockpiled fescue (Poore et al., 2006). Soybean hulls and
corn gluten feed are two common byproduct supplements used for cattle consuming other forages; however, they have not been widely compared for cattle grazing stockpiled fescue. Animal response to supplementation while grazing stockpiled fescue depends largely on the nutrient content of the forage (Poore et al., 2006). The objectives of this study was to 1) determine how supplements influence stockpile utilization and 2) evaluate the performance of beef heifers grazing stockpiled fescue either unsupplemented or supplemented with 0.5% BW/d of corn gluten feed (CGF), soybean hulls (SH), or a 50:50 mix (Mix).

**Materials and Methods**

The experiment was conducted during the winter of 2008-2009 in a randomized complete block design with four field replications of four treatments (trt). Treatments consisted of endophyte-infected KY-31 tall fescue with corn gluten feed, soybean hulls, 50:50 mix of the two byproducts, or forage alone (control).

*Pasture establishment and management*

The plots were planted in October, 2007 at the Butner Research Field Laboratory in Butner, NC. Plots were arranged as four land replicates, each with four individual plots of 0.8 ha. The soil was a Georgeville silt loam (clayey, kaolinitic, thermic Typic Hapludults). Plots were cut for hay in August and then allowed to accumulate for winter grazing. In early September, plots were fertilized with 84.2 kg/ha of nitrogen from liquid nitrogen (urea-ammonium nitrate). Grazing of the plots was initiated in mid-November and lasted for 56 d.
Tiller samples (50 per plot) were taken in September, 2008 to determine infection levels and percent of infected tillers producing ergot alkaloids. Tiller infection was detected by the North Carolina Department of Agriculture (Raleigh, NC) using the plant tissue stain test (AOSA, 1996). The infection rate for the pasture was found to be 23.8%. This infection rate is low; however this is a newly established stand of infected fescue which may cause the lower infection rates.

*Animals*

The protocol for this study was approved by the Institutional Animal Care and Use Committee at North Carolina State University. Sixty-four Angus-cross beef heifers were used.

Animals were given free choice access to a mineral supplement (Ru-Min 1600®, Southern States Cooperative, Inc., Richmond, VA) containing 1760 mg/kg monensin; 17.5-21% Ca; 3% P; 18.5-22% Salt; 2,500 ppm zinc; 1,250 ppm copper (from sulfate); 2,200 ppm Mn; and 26 ppm Se. The mineral was labeled to contain at least 440,000 IU/kg, 66,000 IU/kg and 330 IU/kg of Vitamin A, D, and E, respectively.

Prior to the initiation of the study, animals were treated for internal and external parasites using Cydectin (Fort Dodge Animal Health, Overland Park, KS).

Prior to the start of grazing all animals were given ad libitum orchardgrass hay and water for 7 d and then weighed on two consecutive d to determine initial full barn weights. Animals were divided into four weight blocks, and then each weight block was randomly
assigned to one of four land replicates. Within each land replicate, the animals were randomly allotted into four groups and each group was randomly assigned to one of four treatments. After being assigned to pastures, animals were sorted and placed on the plots and after 7 d animals were weighed on two consecutive d to determine pasture-adjusted start weights. Animals were given a new allotment of grass on Monday, Wednesday, and Friday of every week through strip-grazing management. The target residue grazing height was 5 cm.

Interim weights were taken every 28 d during the grazing period. At the end of the grazing period animals were weighed on two consecutive d to determine pasture end weights. Animals were then commingled and given ad libitum orchardgrass hay for 7 d. Prior to the initiation and at the conclusion of the grazing period an independent evaluator that was blind to treatment assigned body condition scores. Body condition score (BCS) was based on a 9 point scale (1=emaciated; 9=extremely obese) (NRC, 1996).

**Blood Samples**

Blood samples were collected via jugular venipuncture 7 d prior to placement on plots to determine a baseline level of serum urea nitrogen (SUN) and were collected every 28 d during the grazing period. Blood was collected in vacuum tubes without additive (Becton Dickinson, Franklin Lakes, NJ) and put on ice for no more than 6 h before transport to the laboratory, centrifugation at approximately 1,900 g for 20 min and extraction of serum. Serum samples were then stored at -15°C until assayed. Serum urea nitrogen was analyzed in
duplicate by colorimetry using an auto-analyzer (Technicon Industrial Systems, Tarrytown, NY) and the diacytl monoxime method (Marsh et al., 1965).

**Forage Samples**

At the start of the grazing period and every two weeks thereafter, forage samples were clipped within the area that was estimated to be grazed in the next two weeks at 5 cm from ground level using hand-held battery operated grass shears (American Gardener, Duluth, GA), at 10 randomly selected areas (0.25m²) per pasture. Forage samples taken for nutrient content were placed in cloth bags and dried in a 60°C forced air oven for 48 h and air equilibrated. Once during the trial samples from each land replication were taken and used to determine species composition by hand separation. This sample was separated into 5 fractions consisting of green fescue, brown fescue, green non-fescue, brown non-fescue and orchardgrass species. Following hand separation, samples were dried in a forced air oven at 60°C for 48 h and weighed hot to determine the percent of each fraction in the sward on a DM basis.

**Forage Measurements**

Initial forage mass was determined in late-October. Indirect estimates of forage mass were taken using a 0.25m² falling plate meter (Vartha and Matches, 1977; Mueller et al., 1990) at 15 to 25 randomly selected sites in each pasture. Ten sample sites (0.25m²) were clipped at ground level using battery-operated electric clippers (American Gardener, Duluth, GA). The ten sample sites represented the range of forage mass present that was available.
for animal consumption. Forage harvested from the sites was dried at 60°C for 72 h and weighed hot to determine the DM per ha. Regression was used to develop an equation relating the harvested forage from the ten sample sites with falling plate meter readings taken at each of the sites (Macoon et al., 2003). This equation was used to predict the mass available in each pasture using the 15 to 25 plate meter readings.

Measurements for pre-grazing and post-grazing forage mass were taken every two weeks during the study. To determine pre-grazing mass, falling plate meter readings were taken at 15 to 25 random sites within the area that was to be grazed within the subsequent two d interval. Regressions were calibrated using 10 harvested sites cut to ground level and 10 harvested sites cut to 5 cm from within the pre-graze area. The regression for the ten harvested sites cut to ground level was used to predict the total mass available in each pasture. The regression for the ten harvested sites cut to 5 cm was used to predict the grazable forage mass on each pasture. To determine post-graze mass, falling plate meter readings were taken at 15 to 25 sites within the area that had been grazed in the previous two d. Regression was calibrated using 14 harvested sites cut to ground level within the post-graze area. A 200 ft. tape measure was used to measure the area grazed during the two d interval.

**Forage Offered and Forage Disappearance**

Forage offered (kg·hd⁻¹·d⁻¹) during each two week period was determined using the following formula [pre-grazing mass (DM/ha) x area offered during period (ha)] / [number of animals grazing (hd) x length of grazing period (d)]. Pasture disappearance (kg·hd⁻¹·d⁻¹)
during each two week period was determined using the following formula: \[
\frac{[\text{pre-graze forage mass (DM/ha)} - \text{post-graze forage mass (DM/ha)}] \times \text{area offered (ha)} / \text{number of animals grazing (hd)} \times \text{length of grazing period (d)}}.
\]

**Percent Forage Utilization**

Percent utilization to ground (total efficiency) during each two week period was determined using the following formula \((\frac{[\text{pre-grazing mass (ground) (DM/ha)} - \text{post-grazing mass (ground) (DM/ha)}]}{\text{pre-grazing mass (ground) (DM/ha)}})\times 100\). Percent utilization to 5 cm (grazable efficiency) during each two week period was determined using the following formula \((\frac{[\text{pre-grazing mass (5 cm) (DM/ha)} - (\text{post-grazing mass (ground) (DM/ha)} - \text{pre-grazing mass (5 cm) (DM/ha)})]}{\text{pre-grazing mass (5 cm) (DM/ha)}})\times 100\).

**Supplement Samples**

Over the course of the trial, supplement was weighed out into individual bags by plot. The amount of supplement in each bag was based on the average animal weight for all heifers on each individual plot at 0.5% BW. The amount of feed was adjusted when animal weights were taken every 28 d from the initiation of the trial. With each weighing of feed, a grab sample was taken of each feed to be analyzed for nutrient content.
**Forage and Supplement Nutrient Analysis**

Samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) to pass through a 1-mm screen and stored at room temperature in whirl-pack bags (NASCO, Modesto, CA). Dry Matter, ash and CP (Kjeldahl N*6.25) were analyzed by methods outlined by AOAC (1999). Total N was determined by auto-analyzer (Technicon Industrial Systems, Tarrytown, NY). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were determined sequentially according to procedures outlined by Van Soest et al. (1991), using a batch processor (Ankom Corp., Fairpark, NY). Hemicellulose was determined as the difference between NDF and ADF, and cellulose was determined as the difference between ADF and the 72% sulfuric acid residue.

In-situ true dry matter digestibility (ISTDMD) of forage samples was determined by a 48 hour in-situ fermentation using a mature Angus cross, rumen cannulated steer fed alfalfa hay (*Medicago sativa* L). Forage samples were weighed into labeled fiber bags (Ankom Corp., Fairpark, NY), placed in a large cloth bag with a weight and placed in the rumen (a string was attached to one end of the bag and left on the outside of the cannula). After 48 hours, the in-situ samples were removed from the rumen and placed in ice water for no more than 30 minutes before transport to the laboratory. The fiber bags were removed from the large sample bag, rinsed, and digestion was terminated with NDF extraction.
Gain per Hectare and Animal Grazing Days

During the study the gain per ha and the number of animal grazing d per ha was calculated for each plot. Gain per ha (kg/d) was calculated using the following formula: [pasture ADG (kg·hd\(^{-1}·d^{-1}\)) x animals grazing (hd) x length of grazing period (d)] / [total area grazed (ha)]. Animal grazing days (d/ha) was calculated using the following formula: [animals grazing (hd) x length of grazing period (d)] / [total area grazed (ha)].

Statistical Analysis

Data were analyzed using the PROC GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Nutritive composition of total sward was analyzed using repeated measures. The model included rep and trt. The effect of time on the nutritive composition of the forage was evaluated by testing for linear and quadratic effects of sample date as well as associated interactions. Mean separations were performed when the overall F test showed \(P<0.05\). The experimental unit for all animal data was group within trt and replication. The error term for all data was replication by trt. Significant differences were defined as \(P \leq 0.05\) and tendencies at \(P \leq 0.10\).

Results and Discussion

Climatological data

Rainfall and temperature (Table 1.1) during the forage accumulating phase (August through October) influences the growth of tall fescue and can therefore have a large impact...
on the dry matter yield. During the forage accumulating phase, rainfall averaged 12.4 cm per month from August to October. During the study, from November to January, rainfall averaged 6.5 cm per month. The higher rainfall during the forage accumulating phase allowed for increased growth and a greater amount of forage for animal consumption. The rainfall during the trial allowed for consistent grazing conditions without excessive tredding and pugging.

Temperature during the forage accumulating phase (August through October) ranged from a minimum of 14.6˚C to a maximum of 25.4˚C. Temperature while the cattle were on pasture (November through January) ranged from a minimum of 0.7˚C to a maximum of 11.4˚C (Table 1.1). These temperatures were normal for the area.

**Stand Composition**

The total sward was composed of green and brown fescue, green and brown other (crabgrass, Johnson grass, and clover) and orchardgrass. The total percent of fescue was 76.4; specifically, 42.8 percent green fescue and 33.6 percent brown fescue. The percentage of orchardgrass was 9.1.

**Forage Nutrient Composition**

**Total Sward.** Nutrient composition (ISTDMD, CP, ADF, NDF, cellulose, and lignin) of the total sward is shown in Table 2.1. Composition did not differ by trt ($P > 0.05$) but were within the range observed in other studies conducted in North Carolina (Burns and Chamblee, 2000ab; Burns et al., 2006; Poore et al., 2006).
The crude protein content of the total sward was 11.7 % and did not differ by trt \((P = 0.6762; \text{Table 2.1})\). However, the crude protein content of the forage stayed unchanged over the course of the trial. Poore et al. (2006) reported initial CP concentrations of 17.7% (yr 1) and 12.8% (yr 2) and final CP concentrations of 18.5% (yr 1) and 12.1% (yr 2) by the end of the study. They reported that in year 1 CP levels declined till midwinter and then recovered by late winter, but in yr 2, CP levels remained stable throughout the winter, which was more similar to results observed in our study. Collins and Balasko (1981) found similar results in that their CP levels remained stable throughout the winter.

Acid detergent fiber content of the total sward was 30.8 % and did not differ by trt \((P = 0.5622; \text{Table 2.1})\). However, the ADF content of the forage increased over the course of the trial, from 28.2 % in the beginning to 33.4 % by the end \((P < 0.01)\). Poore et al. (2006) showed that ADF values increased over the course of the trial from December to February (ranging from an initial level of 23.5% (yr 1) and 28.9% (yr 2) to a final level of 26.6% (yr 1) and 31.5% (yr 2)), similar to the levels observed in our study. Burns and Chamblee (2000) observed a similar trend for ADF levels from December to February.

Burns et al. (2006) reported that higher IVTDMD is associated with delayed accumulation. The ISTDMD of the total sward in our study was 72.4 % and did not differ by trt \((P = 0.1410; \text{Table 2.1})\). However, the ISTDMD of the sward decreased as the winter progressed, starting at 77.2 % and ending at 68.2 % \((P < 0.01)\). These values are consistent with Curtis and Kallenbach (2007) who observed that IVTDMD values started out in
December at 77.4% (yr 1) and 80.9% (yr 2) and by late February declined by 8.8 and 4.7 percentage units.

**Supplement Nutrient Composition**

Nutrient composition (CP, ADF, NDF, cellulose, and lignin) of the supplements is shown in Table 2.1. Composition differed by trt ($P < 0.05$). Levels observed were similar to those observed in other studies; however, SH CP levels were higher than those normally observed and may have been the reason why gains were similar between supplement types.

The crude protein content for CGF was 24.3%. The crude protein content for SH was 17.7%. Moore et al. (2002) reported that CP content of the CGF mixture (CGF and limestone) was 21.2% and the CP content for the SH mixture (SH, SBM, and di-calcium phosphate) was 15.7%. These values are comparable to those observed in our study, but SH still had a higher CP than normally observed.

Acid detergent fiber content for CGF was 11.2%. The ADF content for SH was 36.5%. Moore et al. (2002) reported that ADF content of the CGF mixture was 10.1% and the ADF content for the SH mixture was 41.2%. These values are similar to those observed in our study.

**Animal Performance**

*Weight gain.* Initial body weights were 293 kg and did not differ among trt ($P = 0.5047$). Pasture ADG differed among trt ($P = 0.0006$; Table 3.1), as did barn ADG ($P <$
Supplemented groups had higher ADG’s than non-supplemented groups; however, there was no difference between supplemented groups. Nutrient composition of stockpiled fescue often over predicts gains observed for grazing heifers (Poore et al., 2000). However, though nutrient composition of the stockpiled fescue was adequate to meet growing heifer nutritional requirements, added supplementation significantly increased final body weights of the grazing heifers. Final body weights differed among trts \( P = 0.0420 \) with supplemented treatments having a higher body weight at the end of the trial than the control groups. Barn ADG showed a similar trend as the pasture ADG, with supplemented heifers having higher ADG’s than unsupplemented heifers, with no difference between supplemented groups (Table 3.1).

**Body Condition Score.** Initial body condition score (BCS) averaged 5.15 and did not differ across treatments \( P = 0.0619 \). Change in body condition score (CBCS) over the course of the study differed among treatment \( P < 0.01; \) Table 3.1. Final BCS averaged 5.67 and differed among treatments \( P < 0.01 \), with supplemented groups having higher body condition scores over the control groups, but there was no difference among supplemented treatments \( P > 0.05 \). Body condition scores were within the range observed in other studies conducted in North Carolina (Drewnoski et al., 2009; Poore et al., 2006).

Poore et al. (2006) reported pasture ADG of unsupplemented heifers grazing stockpiled E+ from late December to late February of 0.56 kg/d (yr 1) and 0.41 kg/d (yr 2) and a CBCS of -0.03 (yr 1) and 0.13 (yr 2). The ADG reported by Poore et al. (2006) are higher than those that were observed in our study for unsupplemented heifers (0.33 kg/d).
The CBCS reported by Poore et al. (2006) was lower than the CBCS observed for the unsupplemented heifers (0.25) in our study. The ADG and CBCS for the supplemented heifers agrees with findings of Beck et al. (2006), Hess et al. (1996), Judkins et al. (1997), and Elizalde et al. (1998). Paterson et al. (1983) showed that ADG of steers grazing tall fescue from December to February increased an average of 0.48 kg/d with protein supplementation, but there was no difference observed in ADG between protein sources. This is similar to our study in that the unsupplemented heifers gained 0.33 kg/d on average, while supplemented heifers gained 0.35 kg/d more on average than the unsupplemented heifers (Table 3.1).

**Gain per Hectare.** Gain per hectare differed among trt ($P = 0.0008$; Table 4.1). The gain per hectare on the supplemented treatments was higher than on the control treatment, but did not differ for supplemented treatments ($P > 0.05$; Table 4.1).

**Animal Grazing Days.** Animal grazing d was 564.5 d/ha and did not differ by trt ($P = 0.5842$; Table 4.1). Drewnoski et al. (2009) reported BW gain per hectare of unsupplemented heifers grazing stockpiled E+ from December to February of 199 (yr 1), 176 (yr 2), 274 (yr 3), 297 (yr 4), and 229 (yr 5) and animal grazing d per hectare of unsupplemented heifers grazing stockpiled E+ from December to February of 591 (yr 1), 492 (yr 2), 686 (yr 3), 494 (yr 4), and 292 (yr 5). The BW gain per hectare and animal grazing d per hectare was similar to those in our study (181 and 566, respectively). The supplemented heifers had higher BW gains per hectare and animal grazing d per hectare as compared to the unsupplemented heifers. Poore et al. (2006) reported similar results for BW gain per hectare.
of 294 (yr 1) and 319 (yr 2) for supplemented heifers and 223 (yr 1) and 147 (yr 2) for unsupplemented heifers.

**Serum Urea Nitrogen.** Serum urea nitrogen (SUN) of animals grazing during the winter averaged 10.3 and did not differ by treatment ($P=0.6798$; Table 3.1). Hammond et al. (1994) indicated that blood urea nitrogen levels of cows on an all forage diet that are below 9.0 mg/dL indicate protein deficiency. Irregardless, SUN concentrations during the trial were 9.9 mg/dL or higher, suggesting that protein intake was not limiting ADG.

Drewnoski et al. (2009) reported SUN levels of 6.1 mg/dL (yr 1), 6.4 mg/dL (yr 2), 6.6 mg/dL (yr 3), 7.2 mg/dL (yr 4), and 9.8 mg/dL (yr 5). Poore et al. (2006) reported SUN levels for unsupplemented of 9.4 mg/dL (yr 1) and 7.8 mg/dL (yr 2). These values are lower than those observed in our study of 9.9 mg/dL which indicated, according to Hammond et al. (1994), that protein is not a limiting factor in our diets, but might have possibly been in some of the yrs in the other two mentioned studies. This may help to explain the higher ADG and CBCS observed in our study as compared to those observed in Drewnoski et al. (2009) and Poore et al. (2006).

**Pregnancy Rates**

Pregnancy rate to AI of heifers grazing during the winter averaged 37.5% and did not differ by treatment ($P=0.6979$; Table 3.1). The average pregnancy rates were 50.0% for CGF, 31.3% for SH, and 31.3% for MIX, as compared to the unsupplemented heifers, which had a pregnancy rate to AI of 37.5%. Overall pregnancy rate (AI and bull bred) of heifers
grazing during the winter averaged 92.2% and did not differ by treatment \((P=0.4363;\) Table 3.2). The average pregnancy rates were 100% for CGF, 75.0% for SH, and 93.8% for MIX, as compared to the unsupplemented heifers, which had an overall pregnancy rate of 100%. Hall (2007) observed pregnancy rates to AI of 45.8% to 54.1% and overall pregnancy rates of 75.0% to 83.3% with no effect of supplement type on the pregnancy rates. Heifers in this study were being fed SH, cottonseed, and corn/soybean meal and the authors found no difference with these supplements fed at levels <1.0% BW compared to CGF and wheat midds (WM) on pregnancy rates. However, supplementation of feedstuffs containing 15 to 20% CP at levels between 0.25 and 0.5% BW improved reproductive performance of cows grazing E+ fescue (Hall, 2007).

**Estimated Supplement Intake**

*Supplement Offered.* The supplement offered to the heifers did not differ by trt \((P = 0.4472;\) Table 4.1). The average amount of supplement offered was 1.4 kg·hd\(^{-1}\)·d\(^{-1}\).

**Estimated Forage Intake**

*Forage offered.* The forage offered to the heifers did not differ by trt \((P = 0.2652;\) Table 4.1). Initial forage mass for all trt averaged 5729 kg/ha every two weeks and did not differ by trt \((P = 0.5407;\) Table 4.1). Drewnoski et al. (2009) reported a forage offered amount of 8.5 kg·hd\(^{-1}\)·d\(^{-1}\) for unsupplemented heifers. This amount was similar to the amount of forage offered to all treatments in our study (9.1 kg·hd\(^{-1}\)·d\(^{-1}\) on average).
**Residual forage mass.** Residual forage mass differed by trt \((P = 0.0045; \text{Table } 4.1)\). Final forage mass for non-supplemented groups was 2404 kg/ha and for supplemented trts was 2574 kg/ha on average every two weeks. Residual forage mass for all trt averaged 2532 kg/ha on average every two weeks and differed by trt \((P = 0.0045; \text{Table } 4.1)\). Supplemented trts had higher forage residual than the unsupplemented trt, with no difference between supplemented trts; however, the mix trt was similar to both the unsupplemented trt and the other supplemented trts. Drewnoski et al. (2009) reported a residual forage mass of 1614 kg/ha for unsupplemented heifers. This amount was lower than the residual forage mass observed in our study (2532 kg/ha). However, the forage mass was also slightly lower for the trial as well. Overall, the results of our study are within the range of residual forage mass observed in other studies conducted in North Carolina, and, while unsupplemented heifers had slightly less residual forage it is unlikely that it reduced ADG.

**Forage disappearance.** Forage disappearance (DM basis) did not differ by trt \((P = 0.1613; \text{Table } 4.1)\). Forage disappearance was 5.29, 4.95, 5.26, and 4.56 kg·hd\(^{-1}\)·d\(^{-1}\) (SE ± 0.25) for control, CGF, SH, and Mix, respectively. The forage disappearance observed in this study was higher than the forage organic matter disappearance reported in a two year study by Poore et al. (2006), which observed forage disappearance of 3.29 (yr 1) and 4.16 (yr 2) kg·hd\(^{-1}\)·d\(^{-1}\). However, the forage disappearance observed in this study was similar to the forage disappearance reported in a five year study by Drewnoski et al. (2009).
**Percent Forage Utilization**

**Percent forage utilization to ground.** Percent forage utilization to ground level did not differ by trt \((P=0.8147; \text{Table 4.1})\). Percent forage utilization to ground was 58.3, 55.0, 54.5, and 55.7\% (SE ± 3.04) for control, CGF, SH, and Mix, respectively. The percent forage utilization to ground observed in this study is similar to the forage utilization observed in other studies conducted in North Carolina (Poore et al., 2006, Drewnoski et al., 2009).

**Percent forage utilization to 5 cm.** Percent forage utilization to 5 cm did not differ by trt \((P=0.8464; \text{Table 4.1})\). Percent forage utilization to 5 cm was 80.5, 76.2, 76.5, and 75.2\% (SE ± 4.52) for control, CGF, SH, and Mix, respectively. The percent forage utilization to 5 cm observed in this study is similar to the highest grazable forage utilization reported for cow/calf pairs grazing stockpiled fescue in Missouri (Curtis et al., 2008).

**Summary**

Stockpiling fescue has been shown to extend the grazing season for cattle grazing fescue. Fescue responds to late summer fertilization with urea-ammonium nitrogen to produce relatively high forage nutrient concentrations. Strip-grazing cattle on stockpiled fescue has shown to be more efficient in forage utilization over continuous grazing. In our study, supplement increased animal performance and did not affect forage intake. The ISTDMD, NDF, ADF, cellulose, and lignin of the total sward increased as the winter progressed for all trts. These differences were mainly caused by the increasing maturity of the forage as the winter progressed. A large difference was seen in weight gain for the
supplemented heifers as compared to the non-supplemented heifers, having an approximately 0.35 kg/d increase in average daily gain. Forage offered and forage disappearance did not differ among trts. Total forage mass of the supplemented trts did not differ when compared to the non-supplemented trts. Animal grazing d per ha of supplemented trts did not differ from non-supplemented trts. Animal gain per ha was double for supplemented trts than it was for non-supplemented trts. Pregnancy rates were not increased with additional supplementation over the course of this study.

**Implications**

Nutritive value of stockpiled fescue has the potential to meet the requirements of replacement beef heifers; however, heifer performance may be lower than expected due to low forage intake. Feeding corn gluten feed, soyhulls, and a 50:50 mix of the two byproducts at 0.5% of body weight will allow producers to graze heifers through the winter on stockpiled fescue and approach gains necessary to reach acceptable body weight and condition in time for breeding. However, supplementation did not enhance either AI or overall pregnancy rates. Corn gluten feed, soyhulls, and a 50:50 mix of the two byproducts will increase heifer performance, but no difference was observed between the supplements.
References Cited


Table 1.1. Precipitation and Minimum and Maximum Temperatures

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Table 2.1. Nutrient Composition (DM basis) of feedstuffs

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<td>ISTDMD (% DM)</td>
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¹ CGF-corn gluten feed, SH-soyhulls
Table 3.1. Performance of growing cattle strip-grazing stockpiled fescue with varying supplements from early-November through early-January

<table>
<thead>
<tr>
<th>Items</th>
<th>Control</th>
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<td>Pasture ADG (kg/d)</td>
<td>0.33</td>
<td>0.73</td>
<td>0.64</td>
<td>0.68</td>
<td>0.05</td>
<td>0.0006</td>
</tr>
<tr>
<td>Barn ADG (kg/d)</td>
<td>0.14</td>
<td>0.45</td>
<td>0.47</td>
<td>0.46</td>
<td>0.03</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CBCS−</td>
<td>0.25</td>
<td>0.65</td>
<td>0.63</td>
<td>0.56</td>
<td>0.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Serum Urea Nitrogen (mg/dL)</td>
<td>9.9</td>
<td>10.4</td>
<td>10.5</td>
<td>10.4</td>
<td>0.39</td>
<td>0.6798</td>
</tr>
<tr>
<td>% AI Pregnancy rate</td>
<td>37.5</td>
<td>50.0</td>
<td>31.3</td>
<td>31.3</td>
<td>11.02</td>
<td>0.6979</td>
</tr>
<tr>
<td>% Overall Pregnancy rate</td>
<td>100</td>
<td>100</td>
<td>75.0</td>
<td>93.8</td>
<td>11.83</td>
<td>0.4363</td>
</tr>
</tbody>
</table>

*Means with differing superscripts differ (P<0.05)

*CGF-corn gluten feed, SH-soyhulls, 50:50 CGF:SH Mix

*P-value of treatment effect

~CBCS-change in body condition score
Table 4.1. Forage mass, total DMI, gain per hectare, animal grazing days, estimated intake, supplement intake, gain:feed, and forage utilization of heifers strip-grazing stockpiled fescue with varying supplements

<table>
<thead>
<tr>
<th>Items</th>
<th>Control</th>
<th>CGF</th>
<th>SH</th>
<th>Mixed</th>
<th>SEM</th>
<th>P-value&lt;sup&gt;*&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-grazing mass (to ground) (kg/ha)</td>
<td>5760</td>
<td>5737</td>
<td>5753</td>
<td>5667</td>
<td>49.7</td>
<td>0.5407</td>
</tr>
<tr>
<td>Pre-grazing mass (5 cm) (kg/ha)</td>
<td>4176</td>
<td>4144</td>
<td>4174</td>
<td>4129</td>
<td>66.1</td>
<td>0.9466</td>
</tr>
<tr>
<td>Total DMI (kg/d)</td>
<td>5.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.244</td>
<td>0.0175</td>
</tr>
<tr>
<td>Gain/hectare (kg/ha)</td>
<td>181&lt;sup&gt;a&lt;/sup&gt;</td>
<td>412&lt;sup&gt;b&lt;/sup&gt;</td>
<td>335&lt;sup&gt;b&lt;/sup&gt;</td>
<td>398&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.5</td>
<td>0.0008</td>
</tr>
<tr>
<td>Animal grazing days (d/ha)</td>
<td>566</td>
<td>570</td>
<td>534</td>
<td>588</td>
<td>27.1</td>
<td>0.5842</td>
</tr>
<tr>
<td>Forage offered (kg/hd/d)</td>
<td>9.68</td>
<td>9.12</td>
<td>9.43</td>
<td>8.26</td>
<td>0.53</td>
<td>0.2652</td>
</tr>
<tr>
<td>Forage disappearance (kg/hd/d)</td>
<td>5.29</td>
<td>4.95</td>
<td>5.26</td>
<td>4.56</td>
<td>0.25</td>
<td>0.1613</td>
</tr>
<tr>
<td>Forage residual (kg/ha)</td>
<td>2404&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2586&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2624&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2513&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>43.0</td>
<td>0.0045</td>
</tr>
<tr>
<td>Supplement Intake (kg/hd/d)</td>
<td>------</td>
<td>1.38</td>
<td>1.36</td>
<td>1.37</td>
<td>0.0108</td>
<td>0.4472</td>
</tr>
<tr>
<td>Gain:Feed (g/kg)</td>
<td>62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>117&lt;sup&gt;b&lt;/sup&gt;</td>
<td>96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>115&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.008</td>
<td>0.003</td>
</tr>
<tr>
<td>% utilization to ground</td>
<td>58.3</td>
<td>55.0</td>
<td>55.7</td>
<td>54.5</td>
<td>3.04</td>
<td>0.8141</td>
</tr>
<tr>
<td>% utilization to 5 cm</td>
<td>80.5</td>
<td>76.2</td>
<td>76.5</td>
<td>75.2</td>
<td>4.52</td>
<td>0.8464</td>
</tr>
</tbody>
</table>

<sup>a-b</sup> Means with differing superscripts differ (P<0.05)

<sup>1</sup> CGF-corn gluten feed, SH-soy hulls, 50:50 CGF:SH Mix

<sup>*</sup>P-value of treatment effect
CHAPTER 3

Performance of growing beef heifers strip-grazing stockpiled tall fescue and being fed 0.5%, 1.0%, and 1.5% body weight per day of a 50:50 mix of corn gluten feed and soyhulls

J.M. Scruggs, M.E. Drewnoski, A.D. Shaeffer, M.H. Poore

Department of Animal Science, North Carolina State University
Raleigh, NC 27695-7621

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Introduction

Tall fescue’s [*Lolium arundinaceum* (Schreb.) Darbus] autumn growth can be accumulated to extend the grazing season into the winter (Matches, 1979) and reduce winter feed costs (Kallenbach et al., 2003; Poore and Drewnoski, 2010). Tall fescue is the dominant forage found in production systems stretching from central Oklahoma to central North Carolina and from northern Alabama to Kentucky, covering more than 15 million hectares (Bouton and Hopkins, 2003). Tall fescue is also grown in the Northwest USA, primarily for seed production, and is adapted to numerous temperate regions throughout the world (Hannaway et al., 2009). In a stockpiling system, nitrogen is applied in late summer and forage is allowed to accumulate until it is needed, with grazing generally initiated in early winter (late November or early December). Frontal strip-grazing management is advised in order to achieve a high level of utilization efficiency. This results in a winter feed source that is more economical than a common hay feeding system or stockpiled tall fescue with extensive grazing management (Poore et al., 2000). Using stockpiling and grazing a wintering system can improve the environmental impact of winter feeding as compared to a hay feeding system (Owens and Shipitalo, 2009), and also might improve calf health by providing a cleaner environment (Meyer et al., 2009). Growing cattle grazing endophyte-infected fescue during the winter have low gains despite the good nutritive value of the forage (Poore et al., 2000). Due to this, supplementation may be necessary in order to reach production goals for the cattle. Supplementation has been shown to increase animal performance while grazing stockpiled fescue. Supplementation with corn gluten feed,
soyhulls, and a 50:50 mix of the two byproducts has been studied at 0.5% BW, and there was found to be no difference between supplement type (Scruggs et al., unpublished); however, little is known about the level of supplementation and response to the level of feeding in growing beef heifers on stockpiled fescue.

The objectives of this study were to 1) determine how supplement levels influence stockpile utilization and 2) evaluate the performance of beef heifers grazing stockpiled fescue either unsupplemented or supplemented with 0.5%, 1.0%, or 1.5% BW/d of a 50:50 corn gluten feed (CGF); soybean hulls (SH) mix.

**Materials and Methods**

The experiment was conducted during the winter of 2009-2010 in a randomized complete block design with four field replications of four treatments (trt). Treatments consisted of endophyte-infected KY-31 tall fescue with 0.5%, 1.0%, or 1.5% of a 50:50 mix of corn gluten feed and soyhulls, or forage alone (control).

**Pasture establishment and management**

The plots were planted in October, 2007 at the Butner Research Field Laboratory in Butner, NC. Plots were arranged as four land replicates, each with four individual plots of 0.8 ha. The soil was a Georgeville silt loam (clayey, kaolinitic, thermic Typic Hapludults). Plots were cut for hay in August and then allowed to accumulate for winter grazing. In early September, plots were fertilized with 56.2 kg/ha of nitrogen from a 10-20-20 commercial
fertilizer containing nitrogen from di-ammonium phosphate and ammonium sulfate. Grazing of the plots was initiated in mid-November and lasted for 56 d.

Tiller samples (50 per plot) were taken in September, 2008 to determine infection levels and percent of infected tillers producing ergot alkaloids. Tiller infection was detected by the NCDA (Raleigh, NC) using the plant tissue stain test (AOSA, 1996). The infection rate for the pasture was found to be 23.8%. This infection rate was low; however this is a newly established stand of infected fescue which may cause the lower infection rates.

**Animals**

The protocol for this study was approved by the Institutional Animal Care and Use Committee at North Carolina State University. Fifty-six Angus-cross beef heifers and eight steers were used.

Animals were given free choice access to a mineral supplement (Performance All Purpose Mineral, Performance Livestock Company, Lawsonville, NC) containing 20.5-24.5% Ca; 1% P (min); 19.75-23.7% Salt; 2,600 ppm zinc; 1,300 ppm copper ((min) from sulfate and chloride); 550 ppm Mn (min); and 26 ppm Se (min). The mineral was labeled to contain at least 220,000 IU/kg, 26,400 IU/kg and 110 IU/kg of Vitamin A, D, and E, respectively.

Prior to the initiation of the study, animals were treated for internal and external parasites using Privermectin (First Priority, Inc., Elgin, IL) using a dose based on their respective weights on that date.
Prior to the start of grazing all animals were given ad libitum orchardgrass hay and water for 7 d and then weighed on two consecutive d to determine initial full barn weights. Animals were divided into four weight blocks, and then each weight block was randomly assigned to one of four land replicates. Within each land replicate, the animals were randomly allotted into four groups and each group was randomly assigned to one of four treatments. After being assigned to pastures, animals were sorted and placed on the plots and after 7 d animals were weighed on two consecutive d to determine pasture-adjusted start weights. Animals were given a new allotment of grass every two d through frontal strip-grazing management. The target residue grazing height was 5 cm

Interim weights were taken every 28 d during the grazing period. At the end of the grazing period animals were weighed on two consecutive d to determine pasture end weights. Animals were then given ad libitum orchardgrass hay for 7 d followed by weights on 2 consecutive mornings. Prior to the initiation and at the conclusion of the grazing period an independent evaluator that was blind to treatment assigned body condition scores. Body condition score (BCS) was based on a 9 point scale (1=emaciated; 9=extremely obese) (NRC, 1996).

Heifers were bred at the end of the trial and pregnancy rates were determined based on a pregnancy check on April 27, 2010, after breeding AI followed by a cleanup bull.
**Blood Samples**

Blood samples were collected via jugular venipuncture 7 d prior to placement on plots to determine a baseline level of serum urea nitrogen (SUN) and were collected every 28 d during the grazing period. Blood samples were also collected to analyze heifer progesterone levels. Samples were collected on two consecutive weeks at the beginning and end of the trial. Blood was collected in vacuum tubes without additive (Becton Dickinson, Franklin Lakes, NJ) and put on ice for no more than 6 hours before transport to the laboratory, centrifugation at approximately 1,900 g for 20 minutes and extraction of serum. Serum samples were then stored at -15˚C until assayed. Serum urea nitrogen was analyzed in duplicate by colorimetry using an auto-analyzer (Technicon Industrial Systems, Tarrytown, NY) using the diacytI monoxime method (Marsh et al., 1965).

**Progesterone Concentration Analysis**

Serum samples for progesterone analysis were first thawed to room temperature. Analysis of progesterone consisted of a Coat-A-Count solid-phase radioimmunoassay (Siemens Medical Solutions Diagnostics, Los Angeles, CA). The standard curve was determined from seven points (0, 0.08, 0.49, 1.88, 9.8, 18.7, and 40.0 ng/ml) in duplicate. A 100-μl serum sample was pipetted into a provided Progesterone Antibody-Coated tube. A 1 ml sample of \(^{125}\text{I}\) Progesterone was then added to each tube and vortexed. After adding the progesterone, all samples were allowed to incubate at room temperature for 3 h. Samples were then decanted and allowed to sit and dry overnight. Afterwards, samples were counted
for one minute in a gamma counter. Samples were then analyzed for heifer cyclicity in each treatment.

**Forage Samples**

At the start of the grazing period and every two weeks thereafter, forage samples were clipped within the area that was estimated to be grazed in the next two weeks at 5 cm from ground level using hand-held battery operated grass shears (American Gardener, Duluth, GA), at 10 randomly selected areas (0.25m²) per pasture. Forage was sub-sampled and analyzed for nutrient content of the total sward. Forage samples were placed in cloth bags and dried in a 60°C forced air oven for 48 h and air equilibrated. Once during the trial a sample from each plot was taken and used to determine species composition. Samples collected for separations were separated into four fractions consisting of green fescue, brown fescue, green non-fescue, and brown non-fescue species. Following hand separation, samples were dried in a forced air oven at 60°C for 48 hr and weighed hot to determine the percent of each fraction in the sward on a DM basis.

**Forage Measurements**

Initial forage mass was determined in mid-November. Indirect estimates of forage mass were taken using a 0.25m² falling plate meter (Vartha and Matches, 1977; Mueller et al., 1990) at 15 to 25 randomly selected sites in each pasture. Ten sample sites (0.25m²) were clipped at ground level using battery-operated electric clippers (American Gardener, Duluth, GA). The ten sample sites represented the range of forage mass present that was

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available for animal consumption. Forage harvested from the sites was dried at 60°C for 72 h and weighed hot to determine the DM per ha. Regression was used to develop an equation relating the harvested forage from the ten sample sites with falling plate meter readings taken at each of the sites (Macoon et al., 2003). This equation was used to predict the mass available in each pasture using the 15 to 25 plate meter readings. Measurements for pre-grazing and post-grazing forage mass were taken every two weeks during the study. To determine pre-grazing mass, falling plate meter readings were taken at 15 to 25 random sites within the area that was to be grazed within the subsequent two d interval. Regressions were calibrated using 10 harvested sites cut to ground level and 10 harvested sites cut to 5 cm from within the pre-graze area. The regression for the ten harvested sites cut to ground level was used to predict the total mass available in each pasture. The regression for the ten harvested sites cut to 5 cm was used to predict the grazable forage mass on each pasture. To determine post-graze mass, falling plate meter readings were taken at 15 to 25 sites within the area that had been grazed in the previous two d. Regression was calibrated using 14 harvested sites within the post-graze area. A 200 ft. tape measure was used to measure the area grazed during the two d interval.

**Forage Offered and Forage Disappearance**

Forage offered (kg·hd⁻¹·d⁻¹) during each two week period was determined using the following formula: [pre-grazing mass (DM/ha) x area offered during period (ha)] / [number of animals grazing (hd) x length of grazing period (d)]. Pasture disappearance (kg·hd⁻¹·d⁻¹) during each two week period was determined using the following formula: [[pre-graze forage.
mass (DM/ha) – post-graze forage mass (DM/ha)] x area offered (ha)] / [number of animals grazing (hd) x length of grazing period (d)].

**Percent Forage Utilization**

Percent utilization to ground (total efficiency) during each two week period was determined using the following formula \[((pre-grazing mass (ground) (DM/ha) – post-grazing mass (ground) (DM/ha))/[pre-grazing mass (ground) (DM/ha))]\*100. Percent utilization to 5 cm (grazable efficiency) during each two week period was determined using the following formula \[((pre-grazing mass (5 cm) (DM/ha) – (post-grazing mass (ground) (DM/ha) – (pre-grazing mass (ground) (DM/ha) – pre-grazing mass (5 cm) (DM/ha))))/[pre-grazing mass (5 cm) (DM/ha))]\*100). For the remainder of the trial. With each weighing of feed, a grab sample was taken to be analyzed for nutrient content.

**Supplement Samples**

Over the course of the trial, supplement was weighed out into individual bags by plot. The amount of supplement in each bag was based on the average animal weight for all cattle on each individual plot at 0.5%, 1.0%, or 1.5% BW. The amount of feed was adjusted starting at 0.5% BW on November 10th for all groups and increasing per group to the desired levels of 1.0% and 1.5% BW for the week after the adaptation week when pasture adjusted weights were taken. After three d with 0.5% BW to all twelve supplemented groups, eight groups on d 4 (November 14th) were increased to 1.0% BW, and on d 7 (November 17th) four groups were increased to 1.5% BW for the remainder of the trial. With each weighing of feed, a grab sample was taken to be analyzed for nutrient content.
Forage and Supplement Nutrient Analysis

Samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) to pass through a 1-mm screen and stored at room temperature in whirl-pack bags (NASCO, Modesto, CA). Dry Matter, ash and CP (Kjeldahl N*6.25) were analyzed by methods outlined by AOAC (1999). Total N was determined by auto-analyzer (Technicon Industrial Systems, Tarrytown, NY). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were determined sequentially according to procedures outlined by Van Soest et al. (1991), using a batch processor (Ankom Corp., Fairpark, NY). Hemicellulose was determined as the difference between NDF and ADF, and cellulose was determined as the difference between ADF and the 72% sulfuric acid residue.

Gain per Hectare and Animal Grazing Days

During the study the gain per ha and the number of animal grazing d per ha was calculated for each plot. Gain per ha (kg/d) was calculated using the following formula: [pasture ADG (kg·hd⁻¹·d⁻¹) x animals grazing (hd) x length of grazing period (d)] / [total area grazed (ha)]. Animal grazing d (d/ha) was calculated using the following formula: [animals grazing (hd) x length of grazing period (d)] / [total area grazed (ha)].

Statistical Analysis

Data were analyzed using the PROC GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Nutritive composition of total sward was analyzed using repeated measures. The model included the rep and trt. The effect of time on the nutritive composition of the forage
was evaluated by testing for linear and quadratic effects of sample date as well as associated interactions. Mean separations were performed when the overall F test show \( P<0.10 \). The experimental unit for all animal data was group within trt and replication. The error term for all data was replication by trt. Significant differences were defined as \( P \leq 0.05 \) and tendencies at \( P \leq 0.10 \). A linear and quadratic contrast of treatment response was defined as \( P \leq 0.10 \).

**Results and Discussion**

*Climatological data*

Rainfall and temperature (Table 1.2) during the forage accumulating phase (August through October) influences the growth of tall fescue and can therefore have a large impact on the dry matter yield. During the forage accumulating phase, rainfall averaged 8.6 cm per month from August to October. During the study, from November to January, rainfall averaged 19.4 cm per month. The rainfall during the trial resulted in very wet conditions and a high degree of pugging and forage trampling.

Temperature during the forage accumulating phase (August through October) ranged from a minimum of 15.3°C to a maximum of 25.3°C. Temperature while the cattle were on pasture (November through January) ranged from a minimum of 0.9°C to a maximum of 10.7°C (Table 1.2). These temperatures were normal for the area.
**Stand Composition**

The total sward was composed of green and brown fescue, green and brown other (crabgrass, Johnson grass, clover, and orchardgrass). The total percent of fescue was 90.3; specifically 57.7 percent green fescue and 32.6 percent brown fescue. The percentage of green and brown non-fescue fractions was 9.7.

**Forage Nutrient Composition**

**Total Sward.** Nutrient composition (CP, ADF, NDF, cellulose, and lignin) of the total sward is shown in Table 2.2. Composition did not differ by trt ($P > 0.05$) but were within the range observed in other studies conducted in North Carolina (Burns and Chamblee, 2000ab; Burns et al., 2006; Poore et al., 2006).

The crude protein content of the total sward was 10.1 % and did not differ by trt ($P = 0.2432$; Table 2.2). However, the crude protein content of the forage decreased over the course of the trial, from 11.1% in the beginning to 8.9% by the end ($P > 0.05$). Poore et al. (2006) reported initial CP concentrations of 17.7% (yr 1) and 12.8% (yr 2) and final CP concentrations of 18.5% (yr 1) and 12.1% (yr 2). They reported that in year 1 CP levels declined till midwinter and then recovered by late winter, but in year 2, they reported that CP levels remained stable throughout the winter, which was more similar to results observed in our study. Collins and Balasko (1981) found similar results in that their CP levels remained stable throughout the winter. Scruggs et al. (unpublished), working at this same site the previous year, reported no change in CP levels over the course of the trial, which is similar to
other studies conducted in North Carolina. However, Drewnoski et al. (2009) showed that CP concentrations on E+ tall fescue vary year to year. In a five year study, CP values ranged from 13.3% to 9.8%, which is within the range observed in our study. It can be observed that CP percentages of stockpiled tall fescue decline as the winter progresses from December through February (Looper et al., 2005; Kallenbach et al., 2003; Fribourg and Bell, 1984; Collins and Balasko, 1981). The results of our study are within the range observed in these studies as it shows that CP percentages decreased as the winter progressed.

Acid detergent fiber content of the total sward was 30.5 % and did not differ by trt ($P = 0.8077$; Table 2.2). There was no linear or quadratic effect for rep and trt ($P > 0.50$). Poore et al. (2006) showed that ADF values increased over the course of the trial from December to February (ranging from an initial level of 23.5% (yr 1) and 28.9% (yr 2) to a final level of 26.6% (yr 1) and 31.5% (yr 2)). Burns and Chamblee (2000) observed a similar trend for ADF levels from December to February. Scruggs et al. (unpublished), working at this same site the previous year, found ADF values that ranged from 28.2% to 33.4% from the beginning to the end of the trial. These values are similar to those observed in our study.

**Supplement Nutrient Composition**

Nutrient composition (CP, ADF, NDF, cellulose, and lignin) of the total sward is shown in Table 2.2. Composition was within the range observed in other studies conducted in North Carolina (Scruggs et al., unpublished).
The crude protein content for the CGF:SH mix was 16.6% (Table 2.2). Scruggs et al. (unpublished) observed a CP content for CGF of 24.3% and for SH of 17.7%.

Acid detergent fiber content for the CGF:SH mix was 22.6% (Table 2.2). Scruggs et al. (unpublished) observed an ADF content for CGF of 11.2% and for SH of 36.5%.

**Animal Performance**

**Weight gain.** Initial body weights were 275 kg and did not differ among supplemented trt. Pasture ADG showed a linear effect of supplement level ($P < 0.10$; Table 3.2). Increasing the percentage of feed fed to grazing cattle, resulted in higher ADGs. Nutrient composition of stockpiled fescue often over predicts gains observed for grazing heifers (Poore et al, 2000). However, though nutrient composition of the stockpiled fescue was adequate to meet growing heifer nutritional requirements, unsupplemented heifers had low gains and supplementation significantly increased final body weights of the grazing heifers. Final body weights differed among trts ($P = 0.0023$) with a linear effect of trt ($P < 0.10$).

**Body Condition Score.** Initial body condition score (BCS) averaged 5.12 and differed across treatments ($P = 0.0008$; Table 3.2) with only the control and 0.5% BW trts being similar. Change in body condition score (CBCS) over the course of the study differed among treatment ($P = 0.0002$) with only the control and 0.5% BW trts being similar. There was a linear and quadratic effect of trt ($P < 0.05$; Table 3.2). Final BCS averaged 5.87 and differed among treatments ($P < 0.0001$), with the control, 0.5% and 1.0% BW groups having similar
body condition scores as compared to the 1.5% BW, which had the highest final BCS that was different from the other three treatments. Body condition scores were within the range observed in other studies conducted in North Carolina (Drewnoski et al., 2009; Poore et al., 2000).

Poore et al. (2006) reported pasture ADG of unsupplemented heifers intensively grazing stockpiled E+ from late December to late February of 0.56 kg/d (yr 1) and 0.41 kg/d (yr 2) and a CBCS of -0.03 (yr 1) and 0.13 (yr 2). The ADG reported by Poore et al. (2006) are higher than those that were observed in this study for unsupplemented heifers (0.23 kg/d). The CBCS reported by Poore et al. (2006) was lower than the CBCS observed for the unsupplemented heifers (0.53) in our study, suggesting that ADG is not a very reliable measure of animal performance due to the variations in environmental conditions that can affect the weight of animals. This leads us to conclude that BCS measures may be more reliable due to less variance or error due to environmental conditions. Another finding that supports the previous statement is the fact that ADG was shown to increase 0.24 kg/d for 0.5% BW over the control; however, the BCS did not change for the 0.5% BW as compared to the control. Poore et al. (2006) reported pasture ADG of supplemented heifers from late December to late February of 0.68 kg/d (yr 1) and 0.63 kg/d (yr 2) and a CBCS of 0.33 (yr 1) and 0.50 (yr 2). The ADG and CBCS for the supplemented heifers agrees with findings of Beck et al. (2006), Hess et al. (1996), Judkins et al. (1997), and Elizalde et al. (1998). Paterson et al. (1983) showed that ADG of steers grazing tall fescue from December to February increased an average of 0.48 kg/d with protein supplementation, but there was no
difference observed in ADG between the protein sources. This is similar to our study in that the unsupplemented heifers gained 0.23 kg/d on average, while supplemented heifers on 1.0% BW trt gained 0.48 kg/d more on average than the unsupplemented heifers (Table 3.2). The results of this study are dependent on the amount of supplement being offered to the heifers. Those heifers on the 1.5% BW trt gained 0.62 kg/d more on average than the unsupplemented heifers. These results are lower than those observed in a study conducted by Scruggs et al. (unpublished) in which unsupplemented heifers gained 0.33 kg/d on average, while supplemented heifers gained 0.35 kg/d more on average than the unsupplemented heifers fed 0.5% BW. However, Drewnoski et al. (2009) showed similar results to those in our study with values ranging from 0.35 kg/d to 0.83 kg/d in a five year study conducted in North Carolina with cattle grazing E+ tall fescue. Poore et al. (2006) showed higher ADG for supplemented heifers, but similar CBCS as compared to our study. The results observed in earlier studies helps us to realize that ADG are variable and depend on several factors, including nutrient composition of the forage, rainfall, and temperature. However, the results observed in our study are similar to those observed in other studies conducted in North Carolina.

**Gain per Hectare.** Gain per hectare averaged 468.2 kg/ha and increased linearly ($P=0.0162$; Table 4.2) with increased supplementation.

**Animal Grazing Days.** Animal grazing d averaged 370.8 d/ha and differed by trt ($P>0.0558$). There was a linear effect of trt ($P=0.0113$; Table 4.2). The animal grazing d
per hectare on the supplemented treatments were higher than on the unsupplemented treatment, with a linear response of treatment seen with increasing levels of supplementation.

Drewnoski et al. (2009) reported BW gain per hectare of unsupplemented heifers grazing stockpiled E+ from December to February of 199 (yr 1), 176 (yr 2), 274 (yr 3), 297 (yr 4), and 229 (yr 5) and animal grazing d per hectare of unsupplemented heifers grazing stockpiled E+ from December to February of 591 (yr 1), 492 (yr 2), 686 (yr 3), 494 (yr 4), and 292 (yr 5). Scruggs et al. (unpublished) observed a BW gain per hectare for unsupplemented heifers of 181 kg/ha and for supplemented heifers of 382 kg/ha and an animal grazing d per hectare for unsupplemented heifers of 566 d/ha and for supplemented heifers of 564 d/ha. The BW gain per hectare and animal grazing d per hectare of previous studies was similar to those in our study for the unsupplemented treatment (358 and 340, respectively). The supplemented heifers had higher BW gains per hectare and animal grazing d per hectare as compared to the unsupplemented heifers (gain per hectare: 449 (0.5% BW), 454 (1.0% BW), and 612 (1.5% BW); grazing d per hectare: 357 (0.5% BW), 374 (1.0% BW), and 412 (1.5% BW)). These results are similar to those observed in other studies conducted in North Carolina. Poore et al. (2006) reported similar results for BW gain per hectare of 294 (yr 1) and 319 (yr 2) for supplemented heifers and 223 (yr 1) and 147 (yr 2) for unsupplemented heifers.

**Serum Urea Nitrogen.** Serum urea nitrogen (SUN) of animals grazing during the winter averaged 7.67 and differed by treatment (P=0.0177). There was a linear effect of trt (P=0.003; Table 3.2). The SUN concentration of cattle grazing the 1.5% BW treatment was
the highest and differed from the other treatments, though there was no difference found between the other treatments. Also, the supplemented treatments were slightly higher than the unsupplemented treatments. Hammond et al. (1994) indicated that blood urea nitrogen levels of cows on an all forage diet that are below 9.0 mg/dL indicate protein deficiency. Therefore, the SUN concentrations during the trial were around 7.67 mg/dL, suggesting that protein intake may have been a limiting factor for ADG of the heifers. When supplemented with 0.5%, 1.0%, or 1.5% BW of a 50:50 CGF:SH mix, heifers had increased SUN and gains in response to increased supplementation. The response was higher when CP in the forage was lower. The lower the CP in the forage, the lower the animal blood CP because the animal is consuming less CP, so with added supplementation with additional CP, the higher the SUN and gains from those animals receiving the supplementation and additional CP.

Drewnoski et al. (2009) reported SUN levels of 6.1 ng/mL (yr 1), 6.4 ng/mL (yr 2), 6.6 ng/mL (yr 3), 7.2 ng/mL (yr 4), and 9.8 ng/mL (yr 5). Poore et al. (2006) reported SUN levels of 9.4 mg/dL (yr 1) and 7.8 mg/dL (yr 2). Scruggs et al. (unpublished) reported SUN levels of 10.3 mg/dL. These values are similar to those observed in our study of 7.7 mg/dL which indicated, according to Hammond et al. (1994), that protein may have been a limiting factor in our diets, as well as in the diets from the other two mentioned studies. This may help to explain the similar ADG and CBCS observed in our study as compared to those observed in Drewnoski et al. (2009) and Poore et al. (2006).
**Progesterone Concentration**

Serum progesterone (SPG) levels of animals grazing during the winter averaged 0.78 ng/ml and did not differ by treatment ($P=0.5773$). The average SPG concentration of cattle grazing the control trt was 0.60 ng/ml. The average SPG concentration of cattle grazing the 0.5% BW trt was 1.07 ng/ml, 1.0% BW trt was 0.96 ng/ml, and 1.5% BW trt was 0.70 ng/ml. There was no linear or quadratic effect of trt ($P>0.10$). Heifers were considered to be cycling if their progesterone concentration was greater than 1 ng/ml for at least one of the two samples collected 7 days apart (blood samples were taken on Nov. 3, 2009, Nov. 10, 2009, Dec. 29, 2009, and Jan. 5, 2010). At the beginning of the study 6.3% of the control group heifers were cycling as compared to 16.7% for 0.5% BW, 16.7% for 1.0% BW, and 6.3% for 1.5% BW heifers. At the end of the study 20.8% of the control group heifers were cycling as compared to 25% of 0.5% BW, 20.9% of 1.0% BW, and 20.8% of 1.5% BW heifers. Drewnoski et al. (2009) reported that E+ tall fescue trt had lower circulating progesterone concentrations during the course of the trial with more heifers having serum progesterone concentrations below 1 ng/ml, when compared to E- and EN trt. Burke et al. (2001) reported similar findings with heifers being fed endophyte infected seed.

Pregnancy rate to AI of heifers grazing during the winter averaged 51.0% and did not differ by treatment ($P=0.4813$). The average pregnancy rates were 52.1% for 0.5% BW, 56.3% for 1.0% BW, and 64.6% for 1.5% BW, as compared to the unsupplemented heifers, which had a pregnancy rate to AI of 31.3%. There was no linear or quadratic effect of treatment ($P>0.10$; Table 3.2). Overall pregnancy rate (AI and bull bred) of heifers grazing
during the winter averaged 94.8% and differed by treatment ($P=0.0058$). Supplemented groups had higher pregnancy rates than non-supplemented groups; however, there was no difference between supplemented groups. The average pregnancy rates were 79.2% for the unsupplemented heifers and 100% for all supplemented treatments. There was a linear and quadratic effect of treatment ($P<0.10$; Table 3.2). Scruggs et al. (unpublished), working at this same site, reported pregnancy rates to AI of 31.3% to 50.0% and overall pregnancy rates of 75.0% to 100.0%, with no effect of supplement type on the pregnancy rate. Heifers in this study were being fed CGF, SH, and a 50:50 mix of the two supplements and the authors found no difference with these supplements fed at 0.5% BW. Hall (2007) observed pregnancy rates to AI of 45.8% to 54.1% and overall pregnancy rates of 75.0% to 83.3% with no effect of supplement type on the pregnancy rates. Heifers in that study were being fed SH, cottonseed, and corn/soybean meal and the authors found no difference with these supplements fed at levels <1.0% BW compared to CGF and wheat midds (WM) on pregnancy rates. However, supplementation of feedstuffs containing 15 to 20% CP at levels between 0.25 and 0.5% BW improved reproductive performance of cows grazing E+ fescue (Hall, 2007).

**Estimated Supplement Intake**

**Supplement Offered.** The supplement offered to the heifers differed by trt ($P < 0.0001$; Table 4.2). The average amount of supplement offered for 0.5% BW was 1.4 kg·hd$^{-1}$·d$^{-1}$. The average amount of supplement offered for 1.0% BW was 2.8 kg·hd$^{-1}$·d$^{-1}$. The
average amount of supplement offered for 1.5 % BW was 4.1 kg·hd^{-1}·d^{-1}. There was a linear effect of trt \( (P < 0.0001; \text{Table 4.2}) \).

**Estimated Forage Intake**

*Forage offered.* The forage offered (DM basis) to the heifers differed by trt \( (P = 0.0158) \). There was a linear effect of trt \( (P < 0.10; \text{Table 4.2}) \). Pre-grazing forage mass for all trt averaged 5194 kg/ha every two weeks and did not differ by trt \( (P = 0.3873) \). Drewnoski et al. (2009) reported a forage offered amount of 8.5 kg·hd^{-1}·d^{-1} for unsupplemented heifers. Scruggs et al. (unpublished) observed a forage offered amount of 9.1 kg·hd^{-1}·d^{-1} for all treatments in the study. The amount of forage offered in these studies was lower than the amount of forage offered to all treatments in our study (12.4 kg·hd^{-1}·d^{-1} on average). This could be explained by the lower quality of the forage, with the heifers in our study needing to eat more forage in order to meet their nutritional requirements. Another explanation for the increased forage offered in our study compared to other studies could possibly be due to the wet conditions of the pastures during the trial leading to higher waste of forage, as reported by Kallenbach et al. (2003).

*Residual forage mass.* Residual forage mass did not differ by trt \( (P = 0.7863) \). Final forage mass for non-supplemented groups was 1901 kg/ha and for supplemented trts was 1928 kg/ha on average every two weeks. Final forage mass for all trt averaged 1922 kg/ha every two weeks and did not differ by trt \( (P = 0.7863) \). Drewnoski et al. (2009) reported a residual forage mass of 1614 kg/ha for unsupplemented heifers. Scruggs et al. (unpublished) observed a residual forage mass of 2532 kg/ha. The amount of residual forage mass in these
studies was lower than the residual forage mass observed in our study (1922 kg/ha). However, the forage mass was also slightly lower for the trial as well.

**Forage disappearance.** Forage disappearance (DM basis) differed by trt ($P=0.0129$). Forage disappearance was 8.94, 7.64, 7.96, and 6.81 kg·hd⁻¹·d⁻¹ (SE ± 0.35) for control, 0.5% BW, 1.0% BW, and 1.5% BW, respectively. There was a linear effect of trt ($P<0.10$; Table 4.2). The forage disappearance observed in our study was higher than the forage organic matter disappearance reported in a two year study by Poore et al. (2006), which observed forage disappearance of 3.29 (yr 1) and 4.16 (yr 2) kg·hd⁻¹·d⁻¹. Likewise, the forage disappearance observed in our study was higher than the forage disappearance reported in a five year study by Drewnoski et al. (2009). Scruggs et al. (unpublished) observed forage disappearance of 5.29, 4.95, 5.26, and 4.56 kg·hd⁻¹·d⁻¹, which is also lower than the forage disappearance observed in our study. The higher forage disappearance observed in our study may be explained by the lower quality of the forage, with the heifers in our study needing to eat more forage in order to meet their nutritional requirements. It may also be explained by the higher percent forage utilization at 5 cm, discussed below.

**Percent Forage Utilization**

**Percent forage utilization to ground.** Percent forage utilization to ground level did not differ by trt ($P=0.3438$; Table 4.2). Percent forage utilization to ground was 64.4, 63.6, 62.5, and 62.8% (SE ± 0.76) for control, 0.5%, 1.0%, and 1.5% BW, respectively. The percent forage utilization to ground observed in this study is similar to the forage utilization observed in other studies conducted in North Carolina (Poore et al., 2006; Drewnoski et al.,
Scruggs et al. (unpublished) observed a percent forage utilization to ground of 54.5% to 58.3% across treatments with the mix (50:50 CGF:SH) having the lowest percent utilization and the unsupplemented groups having the highest percent utilization.

**Percent forage utilization to 5 cm.** Percent forage utilization to 5 cm did not differ by trt ($P=0.7511$; Table 4.2). Percent forage utilization to 5 cm was 99.6, 99.9, 97.8, and 98.6% (SE ± 1.52) for control, 0.5%, 1.9%, and 1.5% BW, respectively. These high percentages in forage utilization cut to 5 cm are an indication that all of the residual forage above 5 cm, and likely some of the forage below 5 cm could not be collected due to wet and muddy environmental conditions at the times of sampling. These percentages also help to explain the higher forage disappearance values previously mentioned as compared to other studies conducted in North Carolina. Scruggs et al. (unpublished) observed a percent forage utilization to 5 cm of 75.2% to 80.5% across treatments which is consistent with the highest grazable forage utilization reported for cow/calf pairs grazing stockpiled fescue in Missouri (Curtis et al., 2008).

**Summary**

Stockpiling fescue has been shown to extend the grazing season for cattle grazing fescue. Fescue responds to late summer fertilization with urea-ammonium nitrogen to produce relatively high forage nutrient concentrations. Strip-grazing cattle on stockpiled fescue has shown to be more efficient in forage utilization. Under the conditions of this study, the supplemented treatments had higher ADG for pasture weights of growing cattle. As the level of supplementation increased, the average daily gains of the growing cattle
increased in a linear fashion accordingly (0.24, 0.48, and 0.62 kg/d increase in gains over the control for 0.5%, 1.0%, and 1.5% BW, respectively). Nevertheless, the 1.5% BW feeding level seemed to have the highest results in average daily gains as compared to the other treatments. The NDF, ADF, cellulose, and lignin of the total sward increased as the winter progressed for all trts. These differences were mainly caused by the increasing senescence of the forage as the winter progressed. Forage offered and forage disappearance differed among trts. Total forage mass of the supplemented trts did not differ when compared to the non-supplemented trts. Animal grazing d per ha and animal gain per ha increased with increasing level of supplementation. There were linear effects of trt for forage intake, final pasture weights, pasture ADG, animal grazing d per hectare, gain per hectare, SUN, total DMI, feed efficiency, forage offered, and a linear and quadratic effect for CBCS. Supplementation increased pregnancy rates, with 1.5% BW having the highest pregnancy rate to AI, so heifers did not gain too much fat that would prevent conception at the higher feeding level. However, there was no difference in overall pregnancy rates observed between supplemented groups.

**Implications**

Nutritive value of stockpiled fescue has the potential to meet the requirements of replacement beef heifers; however, heifer performance may be lower than expected due to low forage intake. Feeding a 50:50 mix of corn gluten feed and soyhulls at 0.5%, 1.0%, and 1.5% BW will allow producers to graze heifers through the winter on stockpiled fescue and reach gains necessary to reach an acceptable body weight and condition in time for breeding.
Increasing levels of supplementation leads to increased ADG and BCS, in accordance with increasing the amount of supplementation provided to grazing heifers. Increasing BCS is probably too much for replacement heifers at 1.5% BW, but is about right for 0.5% and 1.0% BW. However, for stocker cattle, the higher supplementation level would be fine for BCS and ADG. Keeping that in mind, pregnancy rates for this study were enhanced by increased supplementation; even at the higher feeding level there were no negative effects of increased supplementation on pregnancy rates for 1.5% BW.
References Cited


Scruggs, J.M., M.E. Drewnoski, A.D. Shaeffer, and M.H. Poore. Unpublished. Performance of growing beef heifers strip-grazing stockpiled tall fescue and being fed 0.5% body weight of corn gluten feed, soyhulls, or 50:50 mix of the two.


Table 1.2. Precipitation and Minimum and Maximum Temperatures

<table>
<thead>
<tr>
<th>Month</th>
<th>Precip. (cm)</th>
<th>Max Temp (C)</th>
<th>Min Temp (C)</th>
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<td>31.0</td>
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<td>9.8</td>
<td>25.2</td>
<td>15.7</td>
</tr>
<tr>
<td>Oct. 2009</td>
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<td>19.7</td>
<td>9.0</td>
</tr>
<tr>
<td>Nov. 2009</td>
<td>23.0</td>
<td>16.0</td>
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</tr>
<tr>
<td>Dec. 2009</td>
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<td>8.7</td>
<td>-0.8</td>
</tr>
<tr>
<td>Jan. 2010</td>
<td>9.0</td>
<td>7.3</td>
<td>-2.9</td>
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Table 2.2. Nutritive Composition (DM basis) of feedstuffs

<table>
<thead>
<tr>
<th>Nutrient Composition</th>
<th>Mean</th>
<th>CGF:SH</th>
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<tr>
<td>DM</td>
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</tr>
<tr>
<td>CP (%DM)</td>
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<tr>
<td>NDF (%DM)</td>
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<td>43.61</td>
</tr>
<tr>
<td>ADF (%DM)</td>
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<td>22.56</td>
</tr>
<tr>
<td>Cellulose (%DM)</td>
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<td>20.63</td>
</tr>
<tr>
<td>Lignin (%DM)</td>
<td>3.4</td>
<td>1.50</td>
</tr>
</tbody>
</table>
Table 3.2. Performance of growing cattle strip-grazing stockpiled fescue with varying supplements from early-November through early-January

<table>
<thead>
<tr>
<th>Items</th>
<th>Treatment(^1)</th>
<th>SEM</th>
<th>P-value(^*)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Pasture ADG (kg/d)</td>
<td>0.23</td>
<td>0.47</td>
<td>0.71</td>
</tr>
<tr>
<td>Initial BCS</td>
<td>5.13</td>
<td>5.13</td>
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<tr>
<td>CBCS(^~)</td>
<td>0.53</td>
<td>0.53</td>
<td>0.78</td>
</tr>
<tr>
<td>Serum Urea Nitrogen (mg/dL)</td>
<td>6.75</td>
<td>7.57</td>
<td>7.34</td>
</tr>
<tr>
<td>% Heifers Cycling</td>
<td>20.83</td>
<td>25.00</td>
<td>20.92</td>
</tr>
<tr>
<td>% AI pregnancy rate</td>
<td>31.3</td>
<td>52.1</td>
<td>56.3</td>
</tr>
<tr>
<td>% Overall pregnancy rate</td>
<td>79.2</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^1\) 0.5% BW, 1.0% BW, 1.5% BW  
\(^*\)P-value of linear and quadratic effects  
\(^~\)CBCS-change in body condition score
Table 4.2. Forage mass, total DMI, gain per hectare, animal grazing days, estimated intake, supplement intake, gain:feed, and forage utilization of heifers strip-grazing stockpiled fescue with varying amounts of supplement

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<th>Items</th>
<th>Treatment¹</th>
<th>SEM</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
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<td>Pre-grazing forage mass (5 cm) (kg/ha)</td>
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<td>0.5956</td>
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<tr>
<td>Total DMI (kg/d)</td>
<td>Control</td>
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<td>0.0019</td>
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<td>1.50</td>
<td>11.02</td>
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<tr>
<td>Gain/hectare (kg/ha)</td>
<td>Control</td>
<td>358</td>
<td>0.161</td>
<td>0.5435</td>
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<td></td>
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<td>Forage offered (kg/hd/d)</td>
<td>Control</td>
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<td>0.0019</td>
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<td>Forage disappearance (kg/hd/d)</td>
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<td>1.50</td>
<td>1936</td>
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<tr>
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<td>Control</td>
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<td>Control</td>
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¹Means with differing superscripts differ (P<0.05)

¹0.5% BW, 1.0% BW, 1.5% BW

*P-value of linear and quadratic effects