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Alternative Feeding Strategies for Growing Cattle Grazing Endophyte-Infected Tall Fescue During the Summer

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ALTERNATIVE FEEDING STRATEGIES FOR GROWING CATTLE GRAZING ENDOPHYTE-INFECTED TALL FESCUE DURING THE SUMMER

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By

Kerri A. Johnson

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ABSTRACT

Two experiments were conducted to determine animal performance of alternative feeding strategies to heifers grazing endophyte-infected tall fescue during summer months. In Experiment 1, 40 Limousin heifers (261$\pm$ 40kg initial BW) were stratified by weight and assigned to either a spring harvested tall fescue silage diet or grazing endophyte-infected tall fescue pasture with grain supplement having either natural or artificial shade for 80 days. In Experiment 2, 40 Limousin heifers (277 $\pm$ 44kg initial BW) were stratified by weight and assigned to either a traditional grain supplement or feather-meal supplement (rumen bypass arginine supplement) with natural or artificial shade while grazing endophyte-infected tall fescue pastures for 98 days. Heifers were weighed on two consecutive days at the start and end of each experiment. Cost of gain ($/kg) and returns ($/hd) were computed. In Experiment 1, weight gain of heifers was greater in grain supplement treatment than in silage treatment and was greater for natural than artificial shade. Cost of gain was higher for heifers fed silage and returns were higher for heifers fed grain supplement. In Experiment 2, there was no difference in weight gain between traditional and feather meal supplements. Cost of gain and returns were not different between supplement treatments. Heifers that were given natural shade had a greater weight gain than artificial shade in both experiments. In conclusion, feeding early-spring harvest tall fescue silage or a supplement with high rumen bypass arginine did not improve performance of growing cattle during summer.

KEYWORDS: tall fescue, ergot alkaloids, arginine, beef cattle, energy supplement

This abstract is approved as to form and content

Phillip Lancaster
Chairperson, Advisory Committee
Missouri State University

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INTRODUCTION

Justification of the Study

Tall fescue (*Festuca arundinacea)* is a cool season perennial grass consumed by various species of livestock in southeastern to lower midwestern regions of the United States. Tall fescue is a bunchgrass with short rhizomes having leaves with prominent veins and rough edges. Pasture, hay, and erosion control are some of the major uses of tall fescue. Tall fescue is adapted to clay and loam soils and is tolerant of low fertility and acidic soils but responds well to fertilization. Lime additions to an acidic soil (pH of 4.3) resulted in a 32% increase in dry matter production (Belesky and Fedders, 1995). Usual season production is September through December and March through July. Beef cattle producers utilize tall fescue for its hardy performance in inadequate environments and tolerance of low fertile soils. According to The United States Department of Agriculture Census, nearly 30,000 hectares of tall fescue are grown in Missouri (USDA, 2012).

Endophyte-infected tall fescue is easy to establish and is resistant to drought, insects, and nematodes because of the endophyte fungus (*Neotyphodium coenophialum)* present within the tillers. The endophyte fungus and tall fescue plant have a symbiotic relationship where the endophyte fungus improves tolerance of tall fescue to heat, cold, drought, and overgrazing (Ball et al., 2015). Because of the increased tolerance to environmental stressors, tall fescue is an aggressive plant that invades pastures. Even though, the endophyte fungus provides benefits for the tall fescue plant, it can cause low animal performance by producing ergot alkaloids, such as lysergic acid or ergotamine, that cause vasoconstriction of the blood vessels which disrupts thermo-regulation in beef cattle. Another fungus (*Claviceps purpurea*), is present in the seed head of tall fescue as sclerotia and produces ergot alkaloids, particularly ergotamine (Yates et al., 1985). The pathological conditions caused by the ergot alkaloids in tall fescue are known as fescue toxicosis in beef cattle (Bacon, 1995). Fescue toxicosis can occur any time of the year in various ways. Low reproductive performance, suppressed appetite, heat stress, and reduced growth occur during the summer months in beef cattle grazing tall fescue. These conditions are referred to as summer slump (Smith and Cassady, 2015). Gangrene or sloughing of the extremities, especially hooves, is referred to as fescue foot. This occurs during the fall grazing seasons on endophyte-infected tall fescue. These undesirable conditions can potentially affect profitability of cattle. Strategies to mitigate the negative effects of ergot alkaloids on cattle performance are needed (Smith and Cassady, 2015).

Problem Statement

The endophyte fungus in tall fescue produces ergot alkaloids that can be detrimental to cattle performance causing millions of dollars lost revenue in the beef cattle industry. Consumption of ergot alkaloids causes vasoconstriction of the blood vessels which disrupts thermo-regulation in cattle. Cattle grazing endophyte-infected tall fescue during summer months can have decreased daily gains because of this heat stress. However, endophyte-infected tall fescue is hardy and drought resistant, which makes it difficult to eliminate the plant. To achieve economic daily gains in cattle, energy supplements are fed to grazing cattle during the summer to increase energy intake by cattle and dilute the consumption of ergot alkaloids. Yet, costs of grain can fluctuate and be cost prohibitive at times.

Objective and Null Hypothesis

The purpose of this study is to evaluate the effect of alternative feeding strategies for cattle grazing endophyte-infected tall fescue during summer months on animal growth and economics. Animal data was collected measuring heifer ADG. Forage data was collected for forage biomass, total ergot alkaloid concentration, and nutrient content. Feed and hay samples were collected for a nutrient analysis.

Cattle consuming a high-quality, low-ergot tall fescue silage during summer months will not affect ADG. Cattle consuming a rumen by pass arginine supplement while grazing endophyte-infected tall fescue during summer months will not affect ADG.

LITERATURE REVIEW

History of Tall fescue

Tall fescue is a native plant from Europe that was introduced to the United States in the 1800s. In addition, it is the most widely grown cultivated pasture grass in the United States. but was originally introduced as a contaminant in other grass seed (Ball et al., 2015). In 1931, E.N. Fergus, a professor at the University of Kentucky, identified tall fescue growing alongside a hill in eastern Kentucky. In 1943, the University of Kentucky released a cultivar of fescue called Kentucky 31. The cultivar spread rapidly throughout the United States making it the most introduced forage species (Rogers and Locke, 2016).

The ability of fescue to adapt to different types of environment made it a popular choice for forage establishment and grazing systems. By the late 1940s and 1950s the plant was incorporated into grazing systems for livestock species. A large portion of the lower Midwest and upper South tall fescue has become the dominant forage species where other cool-season grasses are not well adapted (Ball et al., 2015). In the 1970s, an association between the endophyte fungus and fescue toxicosis was discovered. Since then, other cultivars like endophyte-free (E-) and novel endophyte (NE) tall fescue, does not hinder animal performance because these varieties do not produce toxic ergot alkaloids. Although, low endophyte tall fescue cultivars have decreased plant's hardiness, weight gain of grazing cattle can be 30 to 100% greater compared with cattle grazing high-endophyte tall fescue pastures. Each 10% gain in endophyte infestation tall fescue equates to approximately 0.045 kg/d decrease in steer ADG (Paterson et al., 1995). Novel endophyte-infected tall fescue cultivars have similar plant hardiness as the toxic endophyte-infected cultivars, and similar animal performance as the low endophyte-cultivars (Bouton et al., 2002). However, endophyte-infected tall fescue is still the predominate cultivar utilized across the lower Midwest and upper South regions of the United States.

Fungal Endophyte (*Neotyphodium coenophialum*)

The fungal endophyte (*Neotyphodium coenophialum*) lives its whole life cycle within the tall fescue plant. The fungus is endophytic, meaning the fungus grows within the tillers, culms, and inflorescence of the grass without invading the host cell, as do most pathogenic fungi producing mycotoxins (Fayrer-Hosken et al., 2008). The endophyte fungus is present in the seed at time of planting, and as the plant grows into a seedling, the endophyte starts infecting the plant at the base of the leaf. As tall fescue matures to a reproductive stage, the endophyte fungus moves into the stem, and as the tillers grow the endophyte fungus moves into the seed (Bacon, 1995). Laboratory examination is the only way the presence of the fungus can be detected in the plant because it is not visible (Ball et al., 2015). Tall fescue pastures that are free of the endophyte can remain that way if well managed. However, invasion of endophyte-infected tall fescue can occur when an infected seed from hay is introduced to the pasture or by cattle that have recently grazed infected tall fescue within the last 72 hours (Ball et al., 2015). The presence of ergot alkaloids have been found in seed heads and hay (Stuedemann, 1987). Findings of ergot alkaloid biosynthesis preserved within the family *Clavicipitaceae,* tribe *Balansia*, initiated a search of similar endophytes of toxic tall fescue within a north central Georgia pasture contaminated with the fungus (Bacon, 1995). It was discovered that a fungal endopyhte was connected with toxic tall fescue (Bacon et al., 1977).

Tall fescue and the fungal endophyte live in a symbiotic relationship. The fungus provides defensive compounds, and the grass provides the fungus with protection and nutrients (Bacon, 1995). Endophyte infected tall fescue has an advantage over non-infected varieties and species because the presence of the endophyte fungus improves the ability of the plant to adapt to abiotic stresses. Due to its greater root depth and volume, it is drought tolerant and able to absorb moisture at deeper depths over a longer period of time than other forage species (Bourguignon et al., 2015).

The presence of the endophyte fungus improves seed germination rate, seedling vigor, tiller growth rate, seed production, and mineral uptake. Infected tall fescue can also be resistant to some diseases, insects, and nematodes (Ball et al., 2015).

Ergot Alkaloids

Alkaloid Structure. Ergot alkaloids are categorized into three families: ergopeptines, ergolines, and clavines. Ergopeptines are comprised of ergovaline, ergotamine, ergosine, ergocornine, ergonine, and ergocryptine (Fayrer-Hosken et al., 2008). Ergopeptine alkaloids have a tricylic peptide component attached via a carbonyl at the 8 position in the D ring that differs at 2 locations (designated as R1and R2: Figure 1 A) resulting in different ergopeptine alkaloids that can be grouped by structural similarities at the R1 and R2 positions (Figure 1 B) (Klotz et al., 2010). Ergovaline and ergotamine structurally differ only at the R2 position, and results of Klotz et al. (2007) indicated that they generate an identical contractile response of peripheral blood vessels. Ergolines include lysergic acid, lysergol, and ergonovine. Clavines include elymoclavine and agroclavine (Fayrer-Hosken et al., 2008). Yet, ergovaline, from the ergopeptide family, is the predominant ergot alkaloid produced by the endophyte fungus (Kallenbach, 2015).

The pathophysiology of ergot alkaloids and their toxicity on animal species affects three receptors: α-2 adrenergic receptors, dopamine-2 receptors, and serotonin-2 receptors (Fayrer-Hosken et al., 2008). Ergot alkloids act as ligands at these serotinergic, dopamingeric, and adrenergic receptor sites (Pertz and Eich, 1999) stimulating similar actions as natural ligands. Enhanced blood aggregation happens through the α-2 adrenergic receptors, leading to clotting and avascular necrosis. Dopamine-2 receptors are induced by the alkaloid acting as a dopamine agonist, resulting in decreased prolactin secretion. Increased body temperature and appetite depression is influenced by the induction of the serotonin-2 receptor (Fayrer-Hosken et al., 2008).

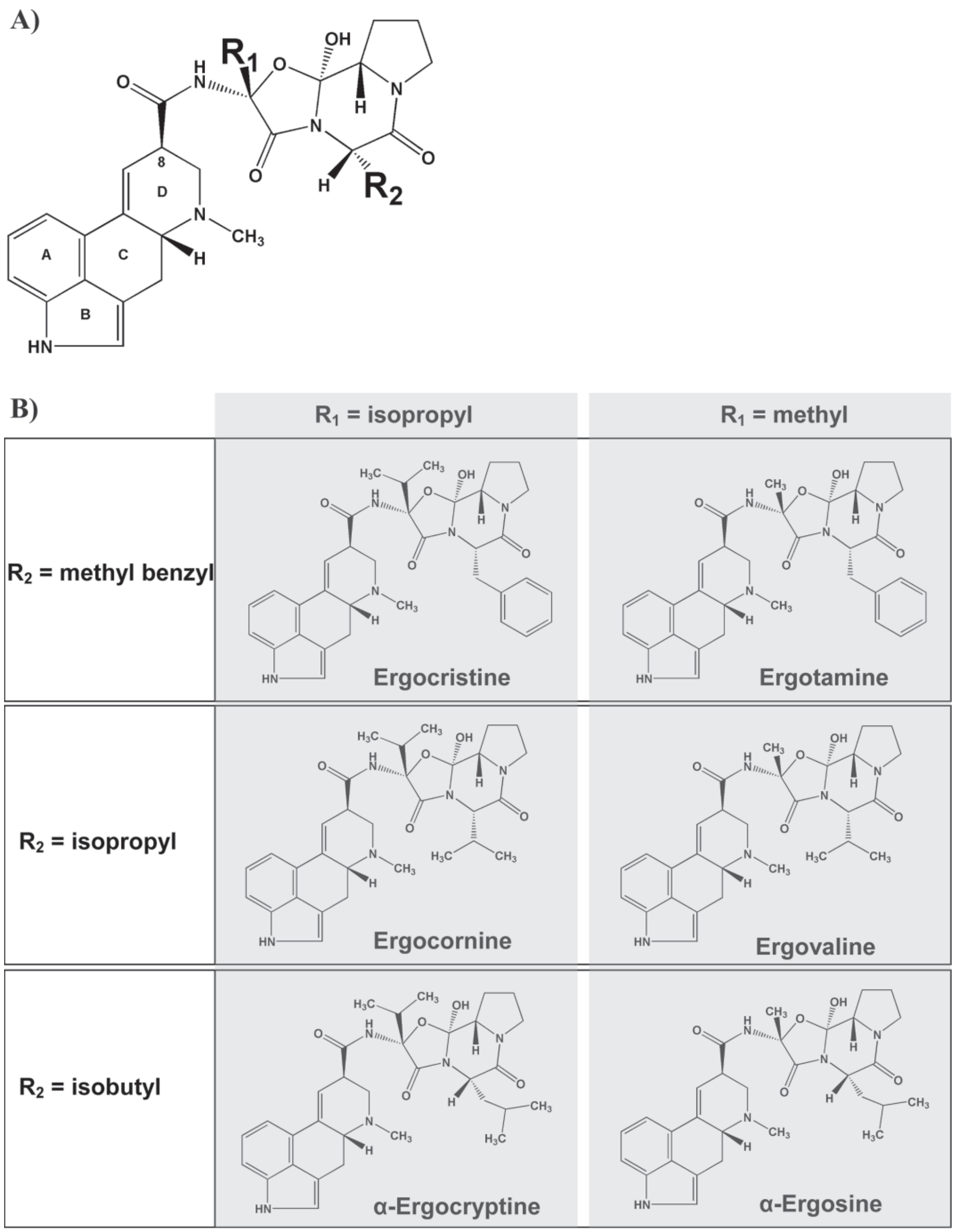

Figure 1. A) General structure of ergopeptine alkaloids that illustrates the two functional groups R1 and R2. B) Chemical structures of ergopeptine alkaloids organized be an isopropyl or methyl group in the R1 position and a methyl benzyl, isopropyl, or isobutyl group at the R2 position (Klotz et al., 2010).

Fertilization Tolerance. Ergot alkaloid concentration in tall fescue is influenced by fertilization. Nitrogen (N) fertilization is an important practice for soil nutritional health and seed establishment, and increasing herbage yield of plants (Malinowski and Belesky, 2000), however, it can affect concentrations of the alkaloids. High rates of N fertilizer increased the quantification of ergopeptine alkaloids (Lyons and Bacon, 1984). Increasing N fertilization from 134 kg/ha to 334 kg/ha increased the total ergopeptine alkaloids by 60 to 80%, depending on the year (Belesky et al., 1988). Furthermore, form of N affected ergot alkaloid concentrations where ergot concentration was greater with $NO3^{-}$ fertilization compared to $NH4^{+}$. Reported levels of ergot alkaloids in various fescue cultivars range from 488 to 2504 mg/kg of dry matter in the spring, and 219 to 986 mg/kg of dry matter in the summer (Fayrer-Hosken et al., 2008). The amount of ergot alkaloids in tall fescue is increased by high availability of phosphorus to the root system as well (Fayrer-Hosken et al., 2008).

Rumen Degradation. Once the alkaloid is freed from the fungal plant matrix, it is degraded to some extent by rumen microorganisms, and the remainder is available for absorption by the host animal (Klotz, 2015). In a study done by Moyer (1993) it was determined that degradation by rumen organisms declines linearly over 48 hours (h) for ergovaline in the soluble fraction and for ergonovine. Meyer and De Lorme (1993 and 2007) speculated that ergovaline was converted to an ergoline alkaloid by the ruminal microbes. Lysergic acid concentrations in rumen fluid increased following a 48 h in vitro ruminal fermentation of tall fescue seed containing ergovaline (Ayers et al., 2009).

Ergot alkaloids not degraded in the rumen are available for absorption. Lysergol, lysergic acid, ergonovine, ergotamine, and ergocryptine concentrations were analyzed in rumen, reticular, and omasum tissue. Ruminal tissue had the greatest transport potential, and the ergoline alkaloids were transported across the ruminal barrier in greater quantities (mean of 680ng/mL) than the ergopeptine alkaloids (mean of 329ng/mL) (Hill et al, 2001). Absorption of all ergot alkaloids increases as they escape from the rumen and enter the small intestine (Koltz, 2015). The primary absorption site of ergot alkaloids such as ergovaline and ergotamine is in the jejunum by direct transcellular or paracellular absorption across the epithelium into the bloodstream (Westendorf et al., 1993. and Schumann et al., 2009).

Ergot alkaloids absorbed directly into the bloodstream are further metabolized by the hepatic cytochrome P450 enzyme to lysergic acid (Moubarak and Rosenkrans, 2000). An alternative route of absorption is via the lymphatic system. Fat soluble ergot alkaloids are transported to the systemic circulation by the lymphatic system circumventing first-pass hepatic detoxification and metabolism (Koltz, 2015). This indicates there is another way in which ergot alkaloids reach the periphery and elicit vasoconstriction in beef cattle that suffer from fescue toxicosis.

Excretion. Ergot alkaloids are found in the bile and urine of steers that grazed ergot alkaloid-containing tall fescue pastures (Stuedenmann et al., 1998). The elimination route of ergot alkaloid compounds depends on the molecular weight of the compound with compounds below 350 Da being eliminated through the renal system and compounds above 450 Da eliminated via the biliary system (Eckert et al., 1978). Absorbed ergopeptine alkaloids could reenter the gastrointestinal tract via the biliary system and be reabsorbed across the intestinal epithelium or excreted with the feces.

Receptor binding. The structure of the ergoline ring is common to all ergot alkaloids which permits interaction with the assortment of biogenic amine receptors. Structural differences between and within the different structural classes of ergot alkaloids has a relationship with the receptor (Klotz et al., 2010). Alkaloid-receptor interactions are the result of ergopeptines' potentcy and efficacy of stimulating a vascular response. When ergovaline makes it to the peripheral blood supply, given that it binds to a receptor, there is potential to remain at that location for some time (Klotz, 2015). Ergonovine, with a simple ergoline ring, is also a potent alkaloid that generates a strong contractile response (Klotz et al., 2010).

Ergot alkaloids can act as agonists, partial agonists, and antagonists (Berdi and Sturmer, 1978). Adrenergic, dopaminergic, and serotonergic receptors are associated with the physiological effects of ergot alkaloids in various livestock species (Klotz, 2015). Diverse symptoms related to fescue toxicosis correlate with ergot alkaloids that are structurally similar to their matching endogenous neurotransmitters (Strickland et al., 2011).

Prolactin concentration in the blood is controlled by dopamine. Consumption of ergot alkaloids increases dopamine antagonist which will decrease circulating concentrations of prolactin (Schillo et a., 1988). Ergot alkaloids like ergopeptides, bind to dopamine receptors which can disrupt the release of prolactin. Yet, studies have shown that dopamine agonists inhibit activity of dopamingeric neurons in the brain (Moore, 1987). At dopamine receptor sites, ergot alkaloids act as a dopamine agonist and reduces prolactin secretion from the anterior pituitary, which lowers milk production (Frayer-Hosken et al., 2008).

Serotonin is a natural ligand for cell receptors. The serotonin receptors have a high affinity of binding to the ergoline ring in ergot alkaloids (Klotz et al., 2010). In these receptor sites, ergot alkaloids cause smooth muscle contractions, affects satiety, and vasoconstriction resulting decreased appetite and reduced feed intake (Fayrer-Hosken et al., 2008).

Binding of ergot alkaloids to the α2 adrenergic receptor in vascular smooth muscle results in a sustained, almost irreversible contractile response (Klotz, 2015). Ergovaline receptor disassociation is slow enough that neither successive serotonin administration nor rinsing of contracted vessel appears to reverse the receptor site occupation by ergovaline (Schoning et al., 2001). Vasoconstriction of bovine lateral saphenous veins was determined when exposed to various combinations of ergopeptine (ergovaline), ergoline (lysergic acid), and loline (N-acetylloline) alkaloids. Ergovaline was the most potent of the ergot alkaloids tested at constricting the bovine lateral saphenous vein (Klotz et al., 2008).

Disruption of various biological processes is caused by sustained signaling of biogenic amine receptors by ergot alkaloids. Persistent binding can result in the desensitization of affected receptors (Oliver, 1997). The ergotamine derivative pergolide has been shown to tightly bind and internalize D2 dopamine receptors (Barbier et al., 1997). The ligand-receptor complex is perhaps held either in a cell surface microenvironment or in an internalized endosomal compartment and the activated signaling receptors are effectively trapped, preventing disassociation. Six crossbred steers were grazed on Kentucky-31(> 90% infection) tall fescue pastures from April to September and then slaughtered to examine the neural tissue. Decreased dopamine concentrations were shown in the anterior pituitary glands of the steers grazing endophyte-infected tall fescue. This indicates endophyte toxins can alter the activity of dopaminergic neurons (Schillo et al., 1988).

Endophyte toxins may reduce prolactin synthesis and release, and may alter activity of dopaminergic neurons. High endophyte fescue consumption in steers was associated with decreased concentrations of prolactin in serum and the anterior pituitary. Dopamine concentrations influence its metabolites. Decreased concentrations of dopamine in the stalk median and decreased concentrations of homovanillic acid were in the preoptic area and hypothalamus. Tall fescue did not influence levels of 3, 4-dihydroxyphenyl-acetic acid. (Schillo et al., 1988).

The hypothalamic-pituitary-ovarian axis is closely related to prolactin and blood metabolites (Flores et al., 2007). Feeding of E+ diet increased rectal temperatures and decreased concentrations of prolactin in plasma in Angus heifers within 48 h after consumption of E+ (Aldrich et al., 1993) and steers that grazed endophyte infected fescue in the spring season had depressed concentrations of serum prolactin (Parish et al., 2013).

Biogenic amine receptors by ergot alkaloids can sustain cell signaling. Unett et al. (2013) reported that the serotonin receptor 5HT2B exceeded the “normal” receptor dissociation rates and hypothesized the ligand-receptor compound was either in a cell surface or an endosomal compartment that is trapping signaling receptors, preventing disassociation rates. Ergopeptine alkaloids can interact with the serotonin receptor 5HT2A (Schoning et al., 2001). Extended stimulation of 5HT2A receptors with ligands other than ergot alkaloids can lead to phosphorylation of associated G proteins and blunting of signaling or weakening of signal transduction (Millan et al., 2008).

Consumption of ergot alkaloids decreases the expression of genes that encode for 5HT2A receptors in the smooth muscle of the bovine gastrointestinal tract (Klotz et al., 2014).

Antagonism of receptor binding sites through exposure to ergot alkaloids can affect vascular tissue. Steers that were fed the endophyte infected tall fescue seed had low levels of vasoactivity in both serotonin and the ergovaline response curves. Steers that received the ergovaline had significantly lower mean contractile responses for the majority of ergot alkaloid compounds tested compared with controls (endophyte-free) in bovine mesenteric artery and vein (Ergert et al., 2014). Lower contractile responses to serotonin were from steers that grazed toxic endophyte-infected fescue compared to steers that grazed nontoxic endophyte-infected tall fescue (Klotz et al., 2013). Steers grazing toxic endophyte-infected fall fescue had a much lower mean response to the 2.,5-dimethoxy-4-iodoamphetamine, a serotonin agonist, additions compared with the low-endophtye tall fescue steers (Klotz et al., 2012).

Recovery by blood vessels and tissue from ergot alkaloid load has been evaluated. Steers grazed either an endophyte-infected or Bermuda grass pasture then were moved to a corn silage-based diet (Bussard, 2012) Lateral saphenous veins were biopsied in correspondence to the day steers were removed from pastures. Vasoactivity increased significantly with time off tall fescue, indicating some shift away from the suppressed contractile response linked with ergot alkaloid response. Contractile response to ergotamine in the tall fescue steers was significantly lower than that of the Bermuda grass steers (Bussard, 2012). It takes 10 to 15 days for recovery time of serum prolactin from toxic tall fescue to nontoxic baselines (Aiken et al., 2013). Vascular recovery appears to exceed prolactin recovery by three to four more weeks. Total alkaloid clearance may not be fully indicated by serum prolactin levels and alkaloid residues are gradually released over time (Klotz, 2015).

Ergot alkaloids causes damaging effects to the endothelial lining of blood vessels which reduces blood flow and can result in tissue necrosis (Oliver, 2005). The reasons for these negative effects are through stimulation of biogenic amine receptors. Thermoregulation and vasoconstriction is associated with the hydroxytryptamine (5HT2A) receptors and ergopeptine alkaloids interact with this receptor. Stimulation of these receptors can result in a phosphorylation of associated G-proteins and a reduction in signal transduction. Adrenergic receptors have involvement in vasoconstriction of veins as well. However, α2- adrenergic receptors have a higher affinity for ergopeptines than α1-adrenergic receptors (Pertz and Eich, 1999). Ergotamine and ergovaline act as a partial agonist and competitive antagonist on α-adrenergic receptors. Ergot alkaloid exposure negatively effects adrenergic receptors (Klotz et al., 2016). Prior research evaluated the vasoactivity in cattle grazing endophyte-infected tall fescue and found that the lateral saphenous vein was not as responsive as cattle grazing endophyte-free tall fescue (Klotz et al., 2016). Vascular thickening has been associated with a decreasing luminal diameter in studies that exposed veins to ergot alkaloids (Williams et al., 2016). Klotz et al. (2016) reported that an increasing time off of E+ pasture resulted in a decreasing wall thickness (vascular dimension).

Fescue Toxicosis

The presence of the endophyte fungus in tall fescue, although beneficial to the plant, is detrimental to cattle. Cattle that consume the endophyte fungus can develop symptoms of fescue toxicosis. Fat necrosis, fescue foot, and summer slump are some of the negative impacts of the endophyte (Ball et. al., 2015). Through extended research fescue toxicosis can occur in both summer and winter, affects most cattle in a herd, and is considered an economically important aspect of the cattle industry (Stuedemann and Hoveland, 1988). Economically, fescue toxicosis costs the U.S. beef industry nearly $2 billion annually (USDA Agricultural Marketing Service, 2015). This occurs either in decreased calving rates, decreased weaning weights of calves, or decreased total production in cattle consuming this forage (Kallenbach, 2015). Although a persistent forage, it has inhibited producers from replacing fescue with other plants species, on a wide scale, due to its socioeconomics and geographical barriers (Roberts and Andrae, 2004).

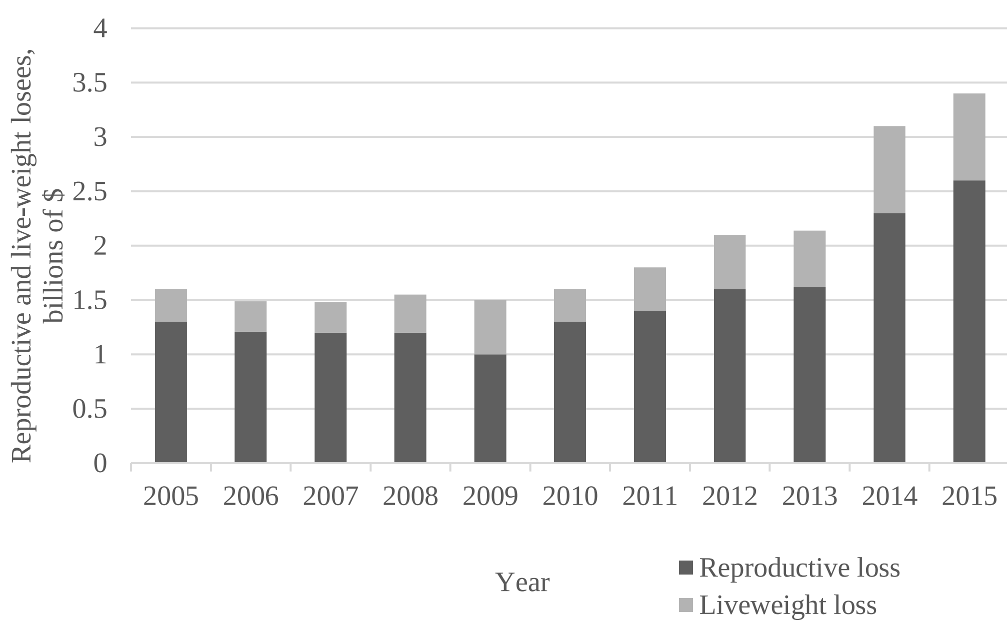

Figure 2. Economic losses attributed to tall fescue toxicosis in the “Fescue Belt” for the cow-calf sector (Kallenbach, 2015).

There may be a breed or individual link to endophyte susceptibility in cattle which may help producers in selecting animals most adapted to their environment. In a study done by Gould and Hohenboken (1993) only two Polled Hereford sires were fed endophyte infected tall fescue seed to measure variability in susceptibility to fescue toxicosis. The progeny of the two sires were measured and found no differences based on symptoms. (Smith et al., 2015).

Differences between breeds can be another genetic parameter of fescue toxicosis. *Bos inidicus* and *Bos taurus* have distinctive characteristics from one another. *Bos indicus* cattle have originated in the subtropical regions thus having a phenotype of more skin surface area, heat tolerance and tolerance of parasites and diseases. Reports had focused on incorporation of *Bos indicus* breeding into a *Bos taurus* herd because of their adaptability in subtropical regions (Smith et al., 2015). In 2000, it was determined that there were no differences in cortisol or prolactin concentrations, respiration rate, rectal temperature, skin temperature at the tail head or tip, systolic or diastolic blood pressure or heart rate between Hereford and Red Brahman steers injected with ergotamine (Browning, 2000). Senepol and Hereford steers were compared for thermal levels and growth when challenged with a diet consisting of endophyte-infected tall fescue or orchardgrass. Senepol had lower respiration rates, shade use, and skin temperatures compared to Hereford steers. Average daily gain decreased in both breeds, but Senepol had greater weight gain than Hereford (Browning, 2004).

Fescue Foot. Vasoconstriction of the extremities during cooler months results in fescue foot. Clinical signs of fescue foot are elevated respiration rate and gangrene. Loss of hooves and portion of the ears or tail, is caused by the extremities getting inadequate blood flow (Ball et al., 2015). Fescue foot can be associated with cold ambient temperatures and it occurs in the northern areas of the tall fescue growing region or in winter in the southern region (Bacon, 1995).

Previous research has evaluated effect of different varieties on incidence of fescue foot. Cornell et al. (1982) reported that there was no significant difference between KY-31, Kenhy, and Mo-96 in the incidence of fescue foot. In another study, videothermometry was used to measure surface temperatures of the steers' feet (Garner et al. 1982). The coronary band temperature of cattle increased over time as long as the cattle were exposed to tall fescue toxins.

Fat Necrosis. Bovine fat necrosis is another clinical sign of fescue toxicosis. Hard masses of adipose tissue, mainly in the abdominal cavity, can cause distressed digestion and difficulty in calving. Fat necrosis is associated with high rates of N fertilization from mineral fertilizers or poultry litter (Ball et. al., 2015). Previous research found that concentrations of calcium, magnesium, potassium, and sodium were greater in necrotic fat than normal fat of steers grazing fertilized KY-31 tall fescue. Also, molar proportions of stearic acid were greater in necrotic fat residue and the proportions of oleic and palmitoleic were less than normal fat residue (Rumsey et al., 1979).

Summer Slump. Decreased feed intake, elevated body temperatures, excessive salivation, increased respiration, and more time spent in the shade are symptoms of summer slump. These signs are associated with the inability of to regulate internal body temperature (Aldrich et al., 1992). This disturbance in thermoregulation is caused by the ergot alkaloids causing vasoconstriction, and in turn cattle have more difficulty dissipating heat. Heat stress during the summer months will potentially decrease feed intake which will decrease animal daily gains.

Beef steers grazing high endophyte (E+) tall fescue pastures during summer months had decreased weight gain from 30 to 100% compared with steers grazing endophyte free fescue. The depression in weight gain of cattle grazing toxic endophyte-infected tall fescue pastures is not limited to geographical locations or management conditions (Paterson et al., 1995). Although, concentrations of ergot alkaloids are greatest in May and signs of fescue toxicosis are apparent during July and August and reduced gains can happen at any time during the year. An interaction is suggested between the environmental temperature and feed intake of cattle (Hemken et al., 1981). Peters et al. (1992) reported that cattle grazing E+ pastures consumed less (1.6% of BW) forage than cattle grazing E- pastures (2.0%) in August. However, in June, both cattle grazing E+ or E- pastures had similar intake. This indicates that when environmental temperatures are higher, endophyte-infected tall fescue decreases intake of cattle likely due to the increased heat stress and less time spent grazing.

Cattle Performance

Profitable stocking of young, growing cattle generally requires an average daily gain of at least 0.68 kg/day for a feeding period (Ball et al., 2015). Cattle grazing toxic endophyte infected tall fescue have a low ADG compared with those grazing novel endophyte and endophyte-free tall fescue. In southern part of the United States, high daily gains, high stocking rate, and long grazing season of non-toxic tall fescue results profitable stocker enterprise (Ball et al., 2015). Cattle grazing fescue that was either endophyte-free or infected with a novel endophyte had greater ADG, gain per acre, and gain per animal compared with cattle grazing toxic endophyte-infected tall fescue (Table 1).

Table 1. Beef steer performance on pastures in the Southern United States (Ball et al., 2015)

Pasture Species	Location	Nitrogen per acre, kg	Average Daily Gain, kg	Gain per acre, kg	Gain per animal, kg	Grazing season days
Tall fescue (endophyte-free)	Alabama Black Belt	91	0.83	194	146	171
Tall fescue (endophyte-infected)	Alabama Black Belt	91	0.45	137	67	171
Tall fescue (toxic endophyte)	Central Georgia	55	0.41	97	65	158
Tall Fescue (novel endophyte)	Central Georgia	55	0.9	211	143	158

Despite negative effects of the ergot alkaloids on calving rates and weaning rates, tall fescue has been primarily utilized for cow-calf operations (Aiken et al,, 2013). Negative effects of the endophyte are an annual cost to the U.S. beef industry of $354 million in reduced calf numbers and $255 million in reduced weaning weights (Hoveland, 1993). Poor body weight (BW) gain and ill thrift of calves that graze toxic endophyte-infected tall fescue pasture have resulted in minimal use of the grass for stocker production

(Hoveland, 1993).

Two tall fescue cultivars infected with a novel endophyte (NE), Jesup infected with AR542 endophyte (Jesup AR542) or HiMag infected with Number 11 endophyte (HM11), were established and compared with toxic endophyte-infected KY31, wheat and cereal rye, and annual ryegrass (Beck et al., 2008). Each year for three years, 3 steers (3.7 steers/ha) were placed on each grazing pasture for fall and winter grazing, and 5 steers (6.2 steers/ha) on the spring pasture. Costs, net returns, and animal performance were analyzed across the forage systems. Overall, body weight gain of steers per hectare was greater on NE tall fescue than cereal rye and wheat, and KY-31, but did not differ from ryegrass. The profitability of NE was not different from cool season annuals but was greater than KY-31. At profitability net return of $219 per hectare, it would take 4 years for a new planting of NE tall fescue to break even (Beck et al., 2008)

Tall fescue has decreasing levels of crude protein as the plant matures. Vegetative stage of tall fescue has a crude protein (CP) of 17.4% and mature tall fescue has a CP of 7.8% (Fieser and Vanzant 2004). For instance, a growing steer that is gaining 0.77kg/d will have the required CP content from consumption of late matured hay (tall fescue hay, full bloom, 12% CP). However, the same growing steer will not receive the required TDN (58%) of that same forage because it is of lower quality because of the maturity. The TDN and CP requirements of a growing beef steer and the TDN and CP concentration of tall fescue at various stages of growth are represented in Table 2.

Table 2. Total digestible nutrients (TDN) and crude protein (CP) requirements of a growing beef steer and TDN and CP content of maturing tall fescue (Ball et al., 2015).

Growing beef steer (Ball et al., 2015)	TDN %	CP %
204 kg (0.68 kg/gain day)	65	11-13
294 kg (0.77 kg/day gain)	68	10-11
Nutritional Composition of Tall Fescue (NRC, 1996)		
Fresh, early vegetative	73	22.1
Fresh, early bloom	67	16.7
Fresh, mature	61	14.7
Hay, late vegetative	76	21.3
Hay, early bloom	62	20.2
Hay, mid-bloom	60	16.4
Hay, full bloom	58	12.1

Energy Supplementation. Energy supplementation of cattle can improve animal performance, forage utilization, and can extend forage resources. Endophyte infected tall fescue can decrease the availability of energy in a diet because of the detrimental effects ergot alkaloids has on cattle performance. Cool season grasses like fescue, become more mature in summer seasons which will cause low energy intake of grazing cattle. The ergot alkaloids does not affect the quality of the forage available for animal consumption, but rather the maturity of the plants affects quality (Richards et al., 2006).

Fiber is a structural carbohydrate that can be fermented by bacteria in the rumen. Soybean hulls, a highly digestible fiber feedstuff, were used to supplement cattle consuming freshly clipped, endophyte infected tall fescue. Supplementation of soybean hulls decreased forage organic matter (OM) intake from 1.64 to 1.41% of body weight but increased total OM intake from 1.64 to 2.01% of BW (Richards et al., 2006). Supplementing with high-fiber energy source increases total intake of an animal.

Cattle grazing endophyte-infected tall fescue have decreased intake due to the detrimental effects of the ergot alkaloids. Supplementing cattle with an energy source is a common management tool when grazing endophyte-infected tall fescue. A meta-analysis, (Gadberry et al., 2015) confirms energy supplementation significantly increases ADG of cattle grazing tall fescue pastures. Comparisons between different types of supplements were analyzed as well. Supplemental energy in the form of highly digestible fiber showed the greatest numerical increase in BW gain (0.13 ± 0.06 kg/d) of calves. Feed conversion ratios were also analyzed between starch and fiber energy supplements for growing calves grazing endophyte-infected tall fescue. Calves given a starch-based supplement had a feed conversion 11:1 (supplemental feed: additional BW gain), and calves given a digestible fiber-based supplement had a feed conversion of 6:1 (Gadberry et al., 2015).

Protein Supplementation. Feeding grain to cattle that graze on pasture can be a profitable way to grow and finish cattle. Increasing the number of stocker cattle grazed per hectare, lowering cost of gain associated with supplemental feed cost, and supplementing pasture during drought or times of low production are reasons for energy supplement. Regarding cool season grasses, protein supplement is provided during warmer months because grasses are mature and low in protein compared to cooler months. Feeding protein can increase the digestibility of mature grasses and increases consumption when the protein is deficient (Sewell, 1993).

Lyons et al. (2016) determined if protein supplement and/or additional forage could improve growth and reproductive performance of replacement heifers grazing KY-31 tall fescue. Heifers weighing on average 272 kg were randomized to four different feeding treatments. The treatments were as follows: normal forage allocation with mineral supplement (FM), normal forage allocation with protein tub (FT), extra forage allocation with mineral supplement (EM), and extra forage allocation with protein tub (ET). Treatments were managed for 8 wk from early November to early January and were fed tall fescue hay for 1 wk before breeding in late January. Supplement intake was greater for protein tub than mineral supplement and additional dietary protein in increased serum urea N concentration. Condition score was greater in ET than other treatments. Feeding a protein supplement or providing extra forage increased gain and increased BCS but did not have an effect on reproductive performance. Results indicate that these treatments are strategies that can increase gain and can aid heifers in reaching puberty before estrous synchronization (Lyons et al., 2016).

Supplemental protein can increase forage digestibility (Church and Santos, 1981) and there-by increase gain in growing cattle and improve maintenance of cattle weight and body condition during grazing periods. Forage dry matter intake (DMI) had indigestible ADF flow and depressed ($P<0.10$) liquid flow in low protein and high levels of supplement. High protein (41% CP) had greater forage DMI, indigestible acid detergent fiber fill values, liquid volume, and ruminal dry matter (DM) fill. Increased levels of protein supplement increased intake and utilization of forage (DelCurto et al., 1990).

Energy supplementation can interact with protein supplement. Low levels (12%

CP) and high (41% CP) levels of protein were given with low (9.2 kcal ME/kg BW) and high levels (18.4 kcal ME/kg BW) of supplemental starch energy to cannulated steers (DelCurto, 1990) were evaluated on dormant forage intake and utilization affected by different levels of protein supplement. Total DM digestibility increased for the supplemented steers; however, low protein (12% CP) depressed NDF digestibility (DelCurto et al., 1990). Cannulated steers were evaluated on dormant forage intake and utilization affected by different levels of protein supplement. Total DM digestibility increased for the supplemented steers; however, low protein (12% CP) depressed NDF digestibility (DelCurto et al., 1990). Steers that were supplemented with low protein and high energy consumed 31% less forage than steers on other supplemental treatments. Total DM digestibility was increased with increasing protein and increasing energy levels. However, NDF digestibility tended to be depressed with higher levels of energy. Increasing supplemental energy without sufficient protein availability was related to depressed intake and digestibility (DelCurto, 1990). In another study (Elizalde et al., 1998), steers that grazed endophyte-infected tall fescue were given 1.4 kg/d of cracked corn or given no supplement at all. Steers that were fed cracked corn had higher daily gains (0.74 kg/d) than steers without supplement of (0.64 kg/d).

Arginine. Arginine is one of the ten essential amino acids required by cattle. Not only is arginine a precursor for protein synthesis but also of nitric oxide, urea, polyamines, proline, glutamate, creatine, and agmatine (Wu and Morris, 1998). Arginine is a precursor to nitric oxide, which has angiogenic properties and participates in regulation of blood flow (Galyean et al., 2016). Research in 1987 reported that arginine is the precursor for mammalian nitrite/nitrate synthesis (Hibbs et al., 1987) and that nitric oxide (NO) in the endothelium of blood vessels has a relaxing effect (Palmer et al., 1987 and Ignarro et al., 1987). Cells utilize arginine to produce NO which increases blood flow by causing vasodilation and stimulating the development of blood vessels (Wu and Morris, 1998).

Nitric oxide is produced from arginine by nitric oxide synthase (Morris 1998). This enzyme has three isoforms: iNOS (type II NOS), eNOS (type III NOS), and nNOS (type I NOS), The inducible (pathological) iNOS form of the enzyme can either be turned on or off, and the constitutive (physiological) form is constantly active (Wu and Morris 1998). The three isoforms are expressed in certain tissues of the body; eNOS is endothelial tissue, nNOS is neuronal tissue, and iNOS is involved in the immune response. iNOS is calcium independent by producing NO by converting arginine and O2 to NO and citrulline (Feher, 2017). Whereas, eNOS and nNOS are calcium dependent (Fuchs, 2014). Cellular capacity of NO synthesis is determined by NOS expression levels and regulation of catalytic productivity of NOS via calcium (Morris and Billiar 1994).

Arginine supplementation could have potential to be beneficial in animals grazing toxic endophyte-infected tall fescue because of its role in nitric oxide and glutamate production (Wu and Morris 1998). Four cannulated, nonlactating, cyclic cows were used in a 2x2 factorial design, utilizing a 4x4 Latin square design. Cows were assigned one of the four treatments consisting of endophyte infected seed with rumen protected arginine, endophyte free fescue seed with rumen protected arginine, endophyte fescue seed alone, and endophyte free seed alone (Green et al., 2017). Cattle consuming toxic endophyte-infected tall fescue seed without arginine had decreased lutenizing hormone concentrations. Cattle consuming toxic endophyte infected tall fescue with arginine had serum LH concentrations similar to cattle consuming endophyte-free seed with and without arginine. However, nitric oxide concentration levels didn't show a significant difference among treatments. (Green et al., 2017).

METHODS

Research for both Experiment 1 and Experiment 2 were conducted at Missouri State University's Shealy farm west of Fair Grove, Mo. For both experiments forty head of Limousin heifers were provided by Pinegar Cattle Company. All animal handling and care was conducted by employees of the Shealy farm, MSU faculty, and students. Approval for this project was obtained prior to animal data collection from the Missouri State University Institutional Animal Care and Use Committee (16-030.0).

Animals and Treatment

Experiment 1. Limousin heifers (n = 40; mean BW = 261(40) kg) were used to evaluate the effects of diet and shade type in a 2 × 2 factorial arrangement of treatments. Heifers were stratified by BW and allotted to graze one of the four 0.40-ha endophyte-infected (90% infection) tall fescue (*Festuca arundinacea*) pastures with energy supplementation (2.27 kg as-fed/hd/d) or one of the four 0.1-ha grass traps and fed tall fescue silage ad libitum. Ingredient and nutrient composition of the grain supplement are presented in Table 3. Within each diet type, heifers were provided natural or artificial shade. Based on USDA recommendations (2012) artificial shade was provided by using 13.38m^2 of 80% shade cloth per pasture of grass trap. Natural shade was provided by allowing heifers access to shade trees. Supplement samples were collected monthly and silage samples were collected at start of the experiment using a hay probe (Colorado Hay Probe, UDY Corp., Fort Collins, CO), dried, grounded to pass a 1mm screen using a

Wiley Mill (Thomas Scientific, Sewedesboro, NJ), composited, and sent to Dairy One Forage Laboratory (Ithaca, NY) for chemical analysis.

Pastures were mowed in early June 2016 to remove tall fescue seed heads. Silage was harvested on April 25, 2016 at approximately 55% moisture, wrapped with plastic, and allowed to ferment for eight weeks until start of the study. Silage was fed by tractor and a TMR mixer (Kuhn Knight Model Vertical Max 5127) ad libitum for 80 days (d) starting on June 22, 2016. Refusal of silage was assessed by visual observation. In each paddock, cattle were supplied with fresh water and free-choice mineral tub supplement (MFA, Mineral Lick w/ Chelates, FesQ Guard, & BioMos), containing 12% Crude Protein, 3% Crude Fat, 1% Crude Fiber, 4% Calcium, 2% Magnesium, 9 ppm Cobalt, 1230 ppm Copper, 25 ppm Iodine, 1070 ppm Manganese, 8.8 ppm Selenium, 3580 ppm Zinc, 200,000 IU/lb Vitamin A, 20,000 IU/lb Vitamin D3, 30 IU/lb Vitamin E.

Heifers were vaccinated against respiratory and clostridial diseases and treated for internal and external parasites prior to arrival at the research facility. Heifers were weighed on two consecutive days following overnight withdrawal from feed at the start and end of the study. Animal ADG was computed as the difference between final and initial BW divided by the number of days.

Table 3. Ingredient and nutrient composition of energy supplement fed to heifers grazing endophyte infected tall fescue pasture in Experiment 1.

Ingredient (% as-fed)	Amount
Ground Corn	17.8
Corn Chops	26.7
Gluten Pellets	17.8
Distillers Grain	22.25
Stock Salt	1.25
Calcium Feed Grade M	3.5
Loose Cottonseed Hulls	8.9
Liquid Molasses	7.2
Nutrient Content[1]	**Value**
DM, %	93.50
CP, % DM	17.60
NDF, % DM	25.20
ADF, %DM	12.30
EE, % DM	5.30
TDN, %DM	74
NEm, Mcal/kg	1.75
Neg, Mcal/kg	1.13

[1]DM = dry matter, CP = crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, EE= ether extract, TDN= total digestible nutrients, NEm= net energy for maintenance, NEg= net energy for growth

Experiment 2. Limousin heifers (n = 40: mean BW= 277(44) kg) were used to evaluate the effects of diet and shade type in a 2 × 2 factorial arrangement of treatments. Heifers were stratified by BW and allotted to one of the four endophyte-infected tall fescue (*Festuca arundinacea*) pastures at the Shealy farm. Treatments included traditional energy supplement using dried distillers grains that provided 15.4 g/d rumen bypass arginine (Control) with natural or artificial shade and a nontraditional supplement using feather meal that provided 48.5 g/d of rumen bypass arginine (Feather Meal). Ingredient and nutrient composition of the supplements are presented in Table 4. Supplements were fed daily at 4.5 kg/hd as-fed for 98 d starting on June 22, 2017. Water was given free choice, but a mineral tub was not provided free choice because mineral was already provided within the supplement. Samples of supplements were collected every two weeks, ground to pass a 1 mm screen, composited, and sent to Dairy One Forage Laboratory for chemical analysis.

Four pastures of tall fescue had the seed head present with natural shade available while four pastures of tall fescue had been mowed to remove seed heads with artificial shade available. Artificial shade and natural shade were provided as in Experiment 1.

Heifers were vaccinated against respiratory and clostridial diseases and treated for internal and external parasites prior to arrival at the research facility. Heifers were weighed on two consecutive days following overnight withdrawal from feed at the start and end of the study. Animal ADG was computed as the difference between average final and initial BW divided by the number of days.

Table 4. Ingredient and nutrient composition of energy supplements fed to heifers grazing endophyte-infected tall fescue pasture in Experiment 2.

	Type of Supplement	
Ingredient (% as-fed)	Control	Feather-meal
Corn chops	22.7	36.0
Soybean hull pellets	25.5	25.0
Cottonseed hull, loose	10.0	10.0
Cottonseed hull, pellets	10.0	---
Corn distillers grains	26.3	---
Feather meal	---	24.0
Molasses	2.0	2.0
Calcium carbonate	1.0	0.5
Pasture mineral R1600	2.5	2.5
Nutrient content[1]		
DM%	87.20	89.10
CP %DM	17.00	34.70
NDF %DM	37.80	30.70
ADF %DM	26.00	22.20
EE %DM	5.90	3.50
TDN %DM	77	76
NEm, Mcal/kg	1.85	1.82
NEg, Mcal/kg	1.22	1.19

[1]DM= dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, EE= ether extract, TDN= total digestible nutrients, NEm= net energy for maintenance, NEg= net energy for growth

Forage Collection

Experiment 1. Prior to initiation of the experiments, endophyte infection level was determined in tall fescue pastures using an immunoblot kit (Agrinostics, Inc., Watkinsville, GA.). Forage biomass of pastures was measured monthly by collecting six samples per pasture, using a 30.48 cm x 30.48 cm or 35.56 cm x 35.56 cm forage square. Forage was clipped to a height of approximately 2.54 cm. Hand plucked forage samples were collected monthly based on visual observation of grazing behavior to determine forage nutritive value. Silage and grain samples were collected monthly. Samples were weighed placed in a forced-air oven at 50˚C and weighed in order to determine DM concentration. Samples were ground to pass a 4mm screen in a Wiley Mill, composited by weight, and ground to pass a 1mm screen. Composite samples were sent to Dairy One Forage Laboratory for chemical analysis. Grazed forage samples were collected monthly and tall fescue silage was collected at the start of the experiment using a hay probe, and sent for (Agrinostics Inc; Watkinsville, Ga) for total ergot alkaloid analysis.

Experiment 2. Forage biomass was measured using double sampling technique. The indirect measure was settling height of a disk (Rising Plate Meter, Jenquip, Feilding, NZ) and direct measurement involved hand clippings from 2 cm above soil surface to the top of the canopy. At each pasture, disk settling height was measured at 30 locations and the forage was clipped at two locations per pasture. The harvested samples were weighed dried in a forced-air oven at 50˚C for 72 h and weighed to determine dry matter percent. Forage mass of the hand clipped area was regressed on disk height to develop a calibration equation, which was used to predict forage availability ($\hat{y} = b_0 + b_1x$) in each pasture over the duration of the experiment.

Hand plucked forage samples were collected every two weeks in each pasture by observance of grazing behavior to determine total ergot alkaloid concentration and nutritive value. A subset of samples were composited by pasture and sent to Agrinositics Inc. for total ergot alkaloid analysis. The remainder of each sample was weighed, dried in a forced-air oven at 50˚C for 72 h, and weighed to determine moisture concentration. Dried samples were ground to pass a 4 mm screen, composited by pasture, ground to pass a 1 mm screen, and sent to Dairy One Forage Laboratory for chemical analysis.

Economic Analysis

Experiment 1 and 2. Net return of the stocker cattle enterprise were analyzed using the average profit potential (Beck et al., 2008) based on USDA Agricultural Marketing Service feeder cattle reports from the Springfield Livestock Marketing Center (Springfield, MO), for medium and large framed, number 1-2 heifers. Initial value of heifers was computed as the average initial BW of heifers multiplied by the price per kilogram of BW. Final value of heifers was computed as the average final BW multiplied by the price per kilogram of BW. Reports were collected based on a purchase date (beginning date of the experiment) and sell date (end date of the experiment). Costs of both experiments are represented in Table 4. Price of silage was based on USDA Agricultural Marketing Service Missouri Weekly Hay Summary reports near the beginning date of Experiment 1. Silage price was based on $0.067/kg of silage as-fed, and pasture rent was estimated at $87.50/ha across both experiments. Prices of feedstuffs for both Experiment 1 and 2 were collected from Main Street Feeds (Springfield, Mo.). The feed costs included the following: traditional grain diet in Experiment 1, $0.06/kg of

BW; traditional grain diet from Experiment 2, $0.05/kg of BW; feather meal diet from Experiment 2, $0.06/kg of BW. Feed cost of gain was computed as feed cost per day divided by ADG. Pasture cost was calculated as pasture rent multiplied by the number of hectares in each pasture. Pasture cost of gain was calculated as pasture cost divided by the product of stocking rate per pasture number of grazing days, and ADG. Total cost of gain was the sum of the pasture cost of gain and feed cost of gain. In Experiment 1, pasture cost of heifers that were fed silage was valued at zero because heifers were placed in a dry-lot. Returns to labor and management were calculated as the final value of heifers minus the sum of initial value of heifers and the total cost.

Cot of nutrition was the focus of the analysis so direct and fixed costs of tractor and equipment were not computed in Experiment 1. Vaccine and medication costs were not recorded for both Experiment 1 and Experiment 2. Cost of artificial shade for both experiments and mineral provided in Experiment 1 were not computed as well because the cost is negligible.

Table 5. Estimated costs of energy supplement, silage, and pasture rent in both Experiment 1 and Experiment 2.

	Experiment 1		Experiment 2	
	Grain	Silage	Control	Feather Meal
Supplement Cost, $/kg of BW	0.06	---	0.05	0.06
Silage cost, $/kg of BW	---	0.01	---	---
Pasture rent, $/ha	87.50	---	87.50	87.50

Statistical Analysis

Cost of gain, returns, BW data, dry matter intake, forage availability, total ergot alkaloid concentration of tall fescue pastures and silage, and nutrient composition of tall fescue pastures for both Experiment 1 and 2 were analyzed as completely randomized designs using PROC MIXED of SAS (version 9.4; SAS Inst. Inc., Cary, NC). The statistical model included fixed effects of diet, shade, and diet x shade interaction. Pasture was the experimental unit in all analyses for both experiments and heifers the sampling units (Steel and Torrie, 1980). For BW data in Experiment 2, initial BW was a significant covariate ($P<0.05$) for final BW and ADG. Forage availability and total ergot alkaloid concentration were also evaluated as covariates in the analysis of BW data and were found to be non-significant ($P>0.50$). For all data pair-wise comparisons of least square means were conducted using Tukey's W procedure if the probability of a F statistic was significant for the main effect or the interaction being tested. Probabilities discussed as significant are $P<0.05$.

RESULTS

Experiment 1

Forage Data. Nutrient composition of tall fescue silage harvested in spring 2016 (Yr. 1) and 2017 (Yr. 2) and tall fescue pastures is presented in Table 6. Tall fescue silage harvested in spring 2016 had a low TDN value. Hay fields were mowed in fall 2016 to remove residual dead material prior to harvesting tall fescue silage in spring 2017. However, TDN values for silage in 2017 were similar to 2016. Tall fescue silage in 2017 also had lower concentration of acetic and lactic acid than in 2016. Tall fescue pastures for the grain supplement treatment had lower NDF, ADF, and lignin content, and greater TDN value compared with the tall fescue silage. Total ergot alkaloid concentration was considerably greater in tall fescue pasture than the silage in 2016. Total ergot alkaloid concentration of tall fescue silage was not determined in 2017.

Table 6. Nutrient composition of tall fescue silage and pasture consumed by heifers in Experiment 1.

Nutrient[1]	Silage 2016	Silage 2017	Fescue Pasture[2]
DM, %	51.30	51.66	34.13 (3.35)
CP, %DM	14.70	11.10	15.63 (2.12)
NDF, %DM	63.55	64.00	57.83 (2.3)
ADF, %DM	43.95	47.20	35.68 (1.71)
Lignin, %DM	6.70	7.50	4.25 (0.52)
Ash, %DM	10.91	10.18	9.89 (0.36)
EE, %DM	3.00	3.10	4.05 (0.33)
TDN, %DM	52.50	51.00	61.00 (0.82)
Forage avail., kg DM/100kg BW	--	--	287 (45.12)
pH	5.40	5.60	--
Acetic acid, %DM	0.61	0.29	--
Butyric acid, %DM	0.05	0.00	--
Lactic acid, %DM	1.38	0.65	--
Total ergot alkaloid, ppb	487	--	1427.5 (294.48)

[1]DM = dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, EE= ether extract, TDN= total digestible nutrients, Ac= acetic acid, But= butyric acid.
[2]Mean (SD)

Animal Data. Least square means for animal performance and economic data are presented in Table 7. Initial BW did not differ (*P* = 0.96) among diet or shade treatments, and there was not an interaction (*P* = 0.95) between diet and shade treatments. Final BW was greater (*P* < 0.01) in the grain supplement treatment than the silage treatment, as well as in the natural versus artificial shade treatment (*P* < 0.05), but there was not an interaction (*P* = 0.15) between diet and shade treatments. Average daily gain was greater (*P* < 0.01) in heifers fed the grain supplement while grazing endophyte-infected tall fescue pasture than in heifers fed silage. Heifer ADG was greater (*P* < 0.05) when provided natural shade than heifers that were provided artificial shade. There was no interaction (*P* = 0.16) of diet and shade for heifer ADG. Cost of gain ($/kg) was lesser (*P* = 0.01) and returns ($/hd) were greater (*P*<0.01) for heifers fed the grain supplement while grazing tall fescue than heifers fed tall fescue silage. Type of shade had no effect on cost of gain (*P* = 0.40) or returns (*P* = 0.14).

Table 7. Performance of growing heifers during summer grazing endophyte-infected tall fescue with supplement or consuming early harvested tall fescue silage, and economic data in Experiment 1.

	Diet		Shade			P-value		
	Grain	Silage	Natural	Artificial	SEM (n=4)	Diet	Shade	D*S
Initial BW, kg	248.1	247.4	247.8	247.1	8.5	0.96	0.96	0.95
Final BW[2], kg	292.3	257.6	278.0	270.9	2.5	0.01	0.04	0.15
ADG, kg/d	0.55	0.13	0.39	0.29	0.03	0.01	0.04	0.16
Grain Suppl. Intake kg DM hd/d	2.12	---	1.06	1.06	---	---	---	---
Silage Intake kg DM hd/d	---	6.75	3.37	3.37	---	---	---	---
Cost of Gain, $/kg	1.43	7.26	3.91	4.78	0.65	0.01	0.40	0.64
Returns, $/hd	-25.77	-119.40	-62.69	-82.49	7.67	0.01	0.14	0.22

[1]Diet = fixed effect of diet; Shade = fixed effect of shade type; D*S = interaction of diet and shade

[2]Significant covariate of initial BW ($P < 0.01$).

Denominator df= 4

Experiment 2

Forage Data. Nutrient composition, forage availability, and total ergot alkaloid concentration tall fescue pastures for the effects of diet and shade are presented in Table 8. Dry matter and crude protein concentration of tall fescue pastures were not different between diet and shade treatments ($P > 0.30$). Neutral detergent fiber and ADF concentration of tall fescue pastures were greater ($P = 0.01$) in pastures with natural shade than in pastures with artificial shade. Lignin concentration of tall fescue pastures was not different between diet ($P = 0.46$) and shade ($P = 0.12$) treatments. There was a diet × shade interaction ($P = 0.01$) for lignin content in tall fescue pastures such that in Control pastures the natural shade had greater lignin content than artificial shade, but in Feather Meal pastures the natural shade and artificial shade were not different. Ether extract and TDN content were not significantly different between diet ($P > 0.05$) or shade ($P>0.05$) treatments. Forage availability was greater ($P = 0.04$) in pastures with natural shade than pastures with artificial shade there was no difference in forage availability among diet treatments ($P = 0.88$). Total ergot alkaloid concentration did not differ ($P > 0.10$) among diet or shade treatments.

Table 8. Nutrient composition of tall fescue pastures in a Control or Feather Meal diet in either natural or artificial shade grazed by heifers in Experiment 2.

Nutrient[2]	Artificial Shade		Natural Shade			P-value[1]		
	Control	Feather Meal	Control	Feather Meal	SEM (n=4)	Diet	Shade	D*S
DM %	37.03	35.83	35.42	36.68	0.99	0.98	0.72	0.29
CP, %DM	17.05	16.65	15.15	17.05	0.70	0.34	0.34	0.17
NDF, %DM	51.85	50.95	56.30	58.65	1.45	0.64	0.01	0.33
ADF, %DM	34.45	35.45	36.20	36.50	0.65	0.38	0.01	0.62
Lignin, %DM	4.25[a]	5.65[b]	5.90[b]	4.85[ab]	0.22	0.46	0.12	0.01
Ash, %DM	9.41	10.34	9.02	9.34	0.31	0.14	0.07	0.46
EE, %DM	4.00	4.55	4.45	4.80	0.17	0.06	0.11	0.59
TDN, %DM	61.50	60.50	59.00	60.00	0.61	1.00	0.07	0.18
Forage avail. kg DM/100 kg BW	134.20	145.41	329.62	298.44	60.18	0.88	0.04	0.74
Total ergot alkaloid, ppb	1649.00	1374.00	1300.50	935.50	191.90	0.17	0.11	0.83

[1]Diet = fixed effect of diet; Shade = fixed effect of shade type; D*S = interaction of diet and shade
[2]DM = dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, EE= ether extract, TDN= total digestible nutrients.
[a,b]Means within a row not bearing a common superscript letter differ $P<0.01$
Denominator df= 4

Animal Data. Least square means of animal performance and economic data are represented in Table 9. There was no significant difference in initial BW between diet and shade treatments ($P > 0.85$). Final BW and ADG were not different ($P = 0.18$) between Feather Meal and Control, but were significantly greater ($P = 0.02$) for heifers provided natural versus artificial shade. Cost of gain ($/kg) and returns ($/kg) were not different ($P > 0.05$) between diet and shade treatments.

Table 9. Performance of growing heifers during summer grazing of endophyte-infected tall fescue given with supplement and shade, and economic data in Experiment 2

	Diet		Shade			P-value[1]		
	Control	Feather Meal	Natural	Artificial	SEM (n=4)	Diet	Shade	D*S
Initial BW, kg	243.9	242.7	243.1	243.4	5.6	0.88	0.97	0.84
Final BW[2], kg	308.6	312.7	314.7	306.6	5.4	0.18	0.02	0.32
ADG[2], kg/d	0.67	0.72	0.74	0.65	0.02	0.18	0.02	0.32
Suppl. Intake, kg DM/hd/d	4.05	3.96	4.00	4.00	---	---	---	---
Cost of Gain, $/kg	0.38	0.37	0.41	0.33	0.03	0.84	0.08	0.30
Returns, $/hd	83.01	97.59	95.03	85.56	6.04	0.16	0.33	0.43

[1]Diet = fixed effect of diet; Shade = fixed effect of shade type; D*S = interaction of diet and shade

[2]Significant covariate of initial BW (*P*< 0.01).

Denominator df= 4

DISCUSSION

Effect of Diet

Experiment 1. The results in this study indicate that heifers grazing endophyte-infected tall fescue fed a grain supplement had greater daily BW gains than heifers that were fed silage. No previous studies have evaluated feeding of early spring harvested tall fescue silage during summer months as a means to increase nutrient intake and reduce ergot alkaloid consumption of growing cattle. As such, no previous studies have compared the effects of feeding a grain supplement with early spring harvested tall fescue silage to cattle during summer months. However, several previous studies have evaluated the effect of feed supplements for cattle grazing endophyte-infected tall fescue pastures during summer months, as well as inclusion of non-endophyte infected forage species on cattle performance.

Aiken et al., (1998) reported greater ADG when feeding corn and broiler litter to stocker calves grazing endophyte-infected tall fescue with high endophyte infection level (>75%) compared with low levels (<5%). Also, Stokes et al. (1988) found increased ADG in heifers and steers grazing endophyte-infected tall fescue while supplemented with corn at 0.65% of BW compared to endophyte-free tall fescue. In the current study, heifers were supplemented at 0.85% of initial BW. Elizalde et al. (1998) found that steers grazing endophyte-infected tall fescue with supplement (1.4 kg/d of cracked corn) had higher ADG than steers that had no supplement. Steers on the supplement gained 0.74 kg/d, whereas steers without supplement gained 0.64 kg/d. In Experiment 1, heifers fed grain supplement while grazing endophyte-infected tall fescue pastures gained 0.55 kg/d.

Inclusion of non endophyte-infected forages in an endophyte-infected tall fescue pasture, such as legumes, is also a common practice for managing ergot alkaloid consumption by cattle grazing endophyte-infected tall fescue (Kallenbach, 2015). Additional protein and energy content of legumes in these mixed species pastures can increase the nutrient intake of grazing cattle which will increase animal performance. Hoveland et al. (1981) reported that ADG of steers grazing Ladino white clover (*Trifolium refens*) mixed with tall fescue pastures was higher (0.74kg/d) than for a monoculture tall fescue pastures (0.37 kg/d). McMurphy et al. (1990) reported that red clover interseeded in a high endophyte-infected tall fescue pastures increased ADG by 0.2 kg/d compared with a high endophyte infected tall fescue pasture alone. Thompson et al. (1993) observed spring and summer ADG response to clovers; spring stand was 25% and the summer was 10% increase in daily weight gains.

Interseeding legumes and supplemental dietary nutrients are highly adopted tall fescue management strategies. Gadberry et al. (2015) summarized animal performance based on certain tall fescue management practices. Interseeding legumes increased ADG of calves by 0.11 kg/d -on average, but endophyte-free and novel endophyte-infected tall fescue pastures increased ADG of calves by 0.22 and 0.29 kg/d, respectively, compared with calves grazing toxic endophyte-infected tall fescue pastures. Application of energy supplement should be managed by offering rates no greater than 1% BW. Supplementing growing cattle at a rate up to 1% BW can be a cost-effective strategy to recover production losses from endophyte-infected tall fescue. Gadberry et al. (2015) reported that high fiber energy supplements increased ADG of calves by 0.13 kg/d, a number similar to that of interseeding legumes, but that high starch energy supplements did not significantly increase ADG of calves compared with grazing toxic endophyte-infected tall fescue alone. Costs, returns, and animal performance need to be further evaluated between energy supplementation or interseeding with legumes in tall fescue management practices.

The objective of harvesting tall fescue silage in early spring was to provide heifers with forage of higher nutritive value and lower total ergot alkaloid concentration than the summer pasture. In early May, tall fescue is primarily in a vegetative stage of growth and ergot alkaloid concentrations are relatively very low. However, the nutritive value of the tall fescue silage was less than expected and heifer growth was very poor even though the heifers consumed 2.7% of initial BW. Based on visual appraisal of the hay fields, the reason for the lower than expected nutritive value of the tall fescue silage, was likely due to residual dead material from the previous growing season. Thus, management of the hayfields was modified by mowing in late fall of 2016 to remove standing dead material from the previous growing season. Despite mowing the hay fields in late fall of the previous year, nutritive value of tall fescue silage harvested in 2017 was similar to that harvested in 2016 without mowing the hay fields in late fall of the previous year. Alternative management practices should be evaluated in order to harvest high quality tall fescue silage in early spring. Because of the low nutritive value of tall fescue silage harvested in 2017, similar results as observed in 2016 were expected which would not adequately test our hypothesis. Thus, a second experiment comparing grain supplementation with tall fescue silage was not conducted. Costs of tractor and equipment labor and any other additional cost should be considered in repeating this experiment.

Experiment 2

In this experiment, heifers fed a supplement based on feather meal formulated to provide 48.5 g/d of rumen bypass arginine had similar ADG compared with heifers fed a supplement based on dried distillers grains formulated to provide 15.4 g/d of rumen bypass arginine while grazing endophyte-infected tall fescue pasture during summer months. Few previous studies have evaluated supplementation with arginine in cattle grazing endophyte-infected tall fescue as a method to alleviate the associated heat stress from the vasoconstriction induced by ergot alkaloids. Green et al. (2017) reported that supplementing rumen-protected arginine to beef cows consuming endophyte-infected tall fescue increased arterial blood velocity indicating that arginine supplementation can reduce the vasoconstrictive action of ergot alkaloids

A commercially available mineral supplement (Fescue EMT™ Mineral Defense; Cargill Inc., Minneapolis. MN) that includes proprietary amounts of vasodilators was evaluated in an experiment with growing calves at the University of Missouri Research Center near Mt. Vernon, MO. This experiment used stocker heifers with 18 replicated tall fescue pastures given either a control mineral or Fescue EMT Mineral Defense. Heifers given Fescue EMT Mineral Defense gained 0.07 kg/d more than the control (unpublished data, Kallenbach, 2016). In Experiment 2, heifers fed the Feather Meal supplement gained 0.05 kg/d more than the Control, although not statistically different, which is similar improvement in gain as Kallenbach (2016). This suggests that additional replication of treatments in our experiment would have resulted in a statistically significant difference.

Little research has been done on supplementing a vasodilator like rumen-protected arginine, to cattle grazing endophyte infected tall fescue pastures. Further research will be needed to enumerate the results in a production setting. Any other additional costs for this experiment should be included when performing an accurate economic analysis.

Effect of Shade

Experiment 1 and 2. Heifers that were provided natural shade had greater ADG than heifers in artificial shade in both experiments. In Experiment 2, forage availability was greater for heifers under natural shade compared with those under artificial shade. Fisher et al. (2010) reported that dairy cattle given available shade had lower mean body temperatures during the day which increased animal performance when compared to cattle with no available shade. Monn et al. (2018) observed greater daily gains of grazing heifers that were permitted shade (0.48 kg/d) compared to heifers without shade (0.33 kg/d). McDaniel and Roark (1956) reported that cattle had higher daily gains in abundant (tree) shade (0.58 kg/d) than artificial (0.38 kg/d) or no shade whatsoever (0.02 kg/d). In Experiment 1, heifers given natural shade (0.39 kg/d) had higher gains than heifers given artificial shade (0.29 kg/d). In Experiment 2, heifers given natural shade (0.74 kg/d) gained more kg per BW than heifers given artificial shade (0.65 kg/d). Growing cattle grazing endophyte-infected tall fescue need adequate amount of shade to reduce heat stress. Cost of shade can be further analyzed in research with artificial or natural shade.

CONCLUSIONS AND IMPLICATIONS

Conclusions

Supplementing growing cattle with a grain supplement while grazing endophyte-infected tall fescue pasture improved gain compared with early spring harvested tall fescue silage likely due to the residual dead material in the hay fields when silage was harvested. This resulted in high cost of gain and low returns for heifers fed silage. Mowing hay fields during the previous fall did not improve the nutritive value of early spring harvested tall fescue silage

Supplementing with a feather meal based supplement to provide additional rumen bypass arginine did not affect ADG of heifers, cost of gain, or returns to labor and management compared with a traditional supplement. However, the lack of significant differences may be due to small replication as a similar study found significantly greater ADG from supplementation of vasodilators to growing heifers grazing toxic endophyte-infected tall fescue.

Natural shade enhanced ADG in heifers compared with artificial shade in both experiments. Although, the improvement in ADG for heifers under natural shade did not significantly reduce cost of gain or increase returns to labor and management.

Implications

Using early spring harvested tall fescue silage as an alternative feeding strategy for cattle grazing toxic endophyte-infected tall fescue pasture during summer months will require further research on hay field management in order to harvest silage with high nutritive value. Supplementation with vasodilators may be an effective strategy to improve growth in cattle grazing endophyte-infected tall fescue pastures. More research is necessary to evaluate types and amounts of vasodilators for their effectiveness in counteracting the vasoconstrictive effects of ergot alkaloids as well as profitability compared with a traditional energy supplement. Natural shade will provide improved animal performance and development of natural rather than artificial shade for cattle in rotational grazing systems may be beneficial. Collecting more economic information for both experiments would be beneficial for the economic analysis.

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