8-2013

Steer Performance and Forage Productivity from Tall Fescue Pastures Grazed at Two Stocking Rates

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I am submitting herewith a thesis written by Autumn Nicole Stewart entitled "Steer Performance and Forage Productivity from Tall Fescue Pastures Grazed at Two Stocking Rates." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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STEER PERFORMANCE AND FORAGE PRODUCTIVITY FROM TALL FESCUE PASTURES GRAZED AT TWO STOCKING RATES

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Autumn Nicole Stewart
August 2013

ABSTRACT

Tall fescue, *Lolium arundinaceum* (Schreb.) Darbysh., is the predominate pasture grass in the mid-south region of the United States. The most dominant cultivar of tall fescue in the region is Kentucky-31. Kentucky-31 is infected with an endophytic fungus *Neotyphodium coenophialum* (Morgan-Jones and Gams), which is responsible for the cultivar's drought tolerance, persistence under stressful conditions, and adaptation to multiple soil types. However, the endophyte is also responsible for producing toxic alkaloids that cause tall fescue toxicosis. Symptoms of fescue toxicosis are retention of winter hair coat, elevated body temperature, increased respiratory rate, reduced average daily gain (**ADG**), lower serum prolactin levels, and reduced reproductive performance. Four approaches proposed to reduce or eliminate tall fescue toxicosis are to use endophyte-free cultivars, dilute the toxins, dietary supplementation, or switch to novel endophyte cultivars. In this study, Jesup MaxQ, a novel endophyte-infected tall fescue, was investigated at two stocking rates at Blount Livestock Unit of the East Tennessee Research and Education Center. Tall fescue was renovated with white clovers to evaluate the persistence of the clover cultivars and to investigate the interactions of clovers with Kentucky-31 and Jesup MaxQ. Both fescue cultivars were grazed at different stocking rates to provide information needed by beef producers desiring to optimize animal performance. In addition, animal performance was measured for beef steers grazing tall fescue cultivars with and without toxic endophytes. Differences in stocking rate were not found in this study. Patriot clover was more persistent that Regal clover in Ky-31 E+ tall fescue. Animal performance was similar when steers grazed Jesup MaxQ and endophyte-free tall fescue and superior to those grazing endophyte-infected tall fescue. Steers grazing E+ tall fescue exhibited the typical performance, hair scores, and prolactin levels found when cattle are experiencing tall fescue toxicosis.

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INTRODUCTION

Tall fescue, *Lolium arundinaceum* (Schreb.) Darbysh., is the predominate cool-season pasture grass in the mid-south region of the United States. Approximately 14.2 million hectares exist in the United States (Yates and Powell, 1988; Bates, 1997). The dominant cultivar of tall fescue in the region is ‘Kentucky-31’ (Hoveland et al., 1980). Bacon et al. (1997) discovered that the Kentucky-31 cultivar was infected with an endophyte fungus, [*Neotyphodium coenophialum* (Morgan-Jones and Gams, 1982)]. The fungus allows the Kentucky-31 cultivar to express drought tolerance, persistence under stressful conditions, adaptation to multiple soil types, and ability to be grazed throughout the majority of the year (West and Waller, 2007; Arachevaleta et al., 1989). The Kentucky-31 cultivar follows a cool-season growth pattern such that increased growth occurs in the spring and fall months and reduced growth in the summer (Roberts et al., 2009).

The endophyte fungus in Kentucky-31 tall fescue cultivar infected with the wild type endophyte is responsible for the expression of tall fescue toxicosis (Hoveland et al., 1983a). Ergovaline produced by the fungus is currently believed to be the causative agent in tall fescue toxicosis (Klotz et al., 2008). The syndrome encompasses a multitude of issues that, are most severe in the extreme temperatures of summer. These symptoms include retention of winter coat, elevated internal body temperature, increased respiratory rate, reduced average daily gain (ADG), lower serum prolactin levels, increased salivation, and reduced reproductive performance (Hemken, 1984; Stuedemann and Hoveland, 1988; Paterson et al., 1995).

Several advances have been made in strategies to reduce or alleviate tall fescue toxicosis. One approach to the toxic endophyte issue is to remove the fungus from the plant (Stuedemann and Hoveland, 1988). The resulting endophyte-free tall fescue cultivar was originally an encouraging solution to the tall fescue toxicosis problem. However, while the toxicity problem was absent in the livestock, the endophyte-free plants did not persist. Another approach is to dilute the cultivars with clovers to diminish the effects of the toxin (Ball, 1997). The most successful approach has been to utilize non-ergovaline producing strains of the endophyte fungus. Ergovaline has been identified as the most potent alkaloid (Klotz et al., 2008). Jesup tall fescue containing the wild type endophyte was a cultivar selected for the southern region of the fescue belt (Bouton et al., 2002). The wild type endophyte was removed and AR542 endophyte fungus strain was inserted into Jesup. The AR542 endophyte, originating from New Zealand, produces negligible amounts of ergovaline (Johnson et al., 2012). The cultivar was developed at the University of Georgia and patented as Jesup MaxQ by Pennington Seed, Inc. (Gunter and Beck, 2004; Hancock, 2009). This forage has the characteristics of endophyte-infected tall fescue but animal performance similar to that on endophyte-free tall fescue.

Previous research indicates that endophyte-free cultivars do not persist under grazing conditions. Endophyte-infected pastures persist under grazing conditions, but consumption of the cultivar result in tall fescue toxicosis. Jesup MaxQ has not been studied under Tennessee conditions for tolerances to different stocking rates. Eight pastures were interseeded with white clovers to examine the persistence of the legumes. Beef producers require this information to optimize animal and pasture performance.

The objectives of this study were: 1) To evaluate performance and physiological characteristics of steers grazing pastures containing Kentucky-31 endophyte-infected tall fescue (**Ky-31 E+**), Kentucky-31 endophyte-free tall fescue (**Ky-31 E-**), Jesup endophyte-free tall fescue (**Jesup E-**), and Jesup novel endophyte-infected tall fescue (**Jesup MaxQ**) cultivars at low or medium stocking rates; 2) To evaluate forage productivity and longevity of Ky-31 E+, Ky-31 E-, Jesup E-, and Jesup MaxQ tall fescue cultivars at low or medium stocking rates; and

3) To compare Regal and GC-89 white clovers grown in Jesup MaxQ and Ky-31 E+ tall fescue pastures.

CHAPTER 1: LITERATURE REVIEW

Tall fescue, *Lolium arundinaceum* (Schreb.), is the predominate pasture grass with 10% of the approximately 14.2 million hectares existing in the United States are in Tennessee (Yates and Powell, 1988; Bates, 1997). The predominant cultivar of tall fescue in the mid-south region is Kentucky-31 (Hoveland et al., 1980). Approximately 20% of the beef cows in the United States are raised on Ky-31 pastures (West and Waller, 2007).

Origin, Transition Zone, and Plant Characteristics

The Kentucky-31 tall fescue cultivar was discovered growing in a pasture on a Menifee County farm located in northeastern Kentucky in 1931. The seed collected from this pasture was tested for eleven years prior to release for commercial availability under the Kentucky-31 label (Fergus and Buckner, 1972). The use of the cultivar was widespread by farmers and the general population because of its adaptability in the transition zone. This zone tends to be a problematic area to manage warm-season and cool-season grasses. Tennessee is located in the center of the transition zone. The Kentucky-31 cultivar is preferred in this zone due to a deep root system, adaptability to varying soil pH, drought tolerance, and sun/shade tolerance (West and Waller, 2007). These characteristics allow for this particular cultivars adaptation to multiple soil types, persistence under stressful conditions, and the ability to be grazed throughout the majority of the year (Arachevaleta et al., 1989).

Nutritive Value

The Kentucky-31 tall fescue cultivar is comparable in nutritional value to other cool-season, perennial cultivars. The crude protein (**CP**) content in the Kentucky-31 cultivar was 213 g/kg, while Kentucky Bluegrass (*Poa pratensis*) was 192 g/kg and Orchardgrass (*Dactylis glomerata L.*) cultivars were 226 g/kg. The means did not differ between the three cultivars ($P < 0.05$) and the data was an average of three experimental years (Lassiter et al., 1956).

The digestibility of a forage is inversely correlated to the stage of maturity. Lignin is a complex chemical compound, considered indigestible to ruminants, that accumulates as forage matures. Thus, as forage matures, lignin increases, and the digestibility of the forage declines. There is an increased retention time for the animal to digest the forage, which results in declined in feed intake. The animal shows a decline in performance due to the consumption of less digestible forage. This result is a decrease in ADG (Ball et al., 2002).

Total digestible nutrients (**TDN**) is a measure of the energy in a forage. Acid detergent fiber (**ADF**) is a used in the estimation of the TDN. Neutral detergent fiber (**NDF**) includes lignin, cellulose, and hemicellulose, whereas, the ADF only contains cellulose and lignin. The NDF is used to estimate forage intake and ADF is associated with forage digestibility. There is an inverse correlation between plant maturity and NDF and ADF values (Ball et al., 2002).

Problems Associated with Tall Fescue

Despite all of the encouraging aspects about Kentucky-31 tall fescue in terms of plant characteristics and nutritional value, livestock consumption of the forage results in chronic deleterious effects. The endophytic fungus discovered in the plant is the source of the toxin responsible for tall fescue toxicosis (Hoveland et al., 1983a). Multiple chemicals are produced by the fungus; each one has a specific purpose in the mutualistic symbiotic relationship between the plant and fungus. However, not all the chemicals produced by the fungus are beneficial to the animal. Ergovaline is an ergopeptine alkaloid currently believed to be the causative agent in tall fescue toxicosis (Klotz et al., 2008). In recent years, research has resulted in speculation that lysergic acid amide could also be a chemical factoring into the expression of the disease (Bush and Fannin, 2009).

The Endophyte. The endophyte has been classified under several different scientific name designations: [*Epichloë typhina* Pers., Fr.] (Tulasne and Tulasne, 1865), [*Sphacelia typhina* Pers.] (Saccardo, 1881), and [*Acremonium coenophialum* Morgan-Jones and Gams] (Morgan-Jones and Gams, 1982). Glenn et al. (1996) proposed that fungus be reclassified into the genus known as *Neotyphodium*. The endophyte is currently as *Neotyphodium coenophialum* (Glenn et al., 1996).

The fungus in question, *N. coenophialum*, thrives in the intercellular spaces of the tall fescue plant with no evidence of hyphae in the intracellular regions (Bacon et al., 1977). Intracellular hyphae only appear during the reproductive phase (Sampson, 1933). Both the fungus and plant flourish together in a mutualistic symbiotic (Latch, 1993). The energy requirements to maintain the endophyte are minimal (Breen, 1994). The mutualism enables the fungus to protect the plant from biotic and abiotic environmental stressors. The biotic stressors include insect, nematode, and herbivory resistance, while the abiotic stressor would be drought tolerance. This protection increases the vigor of the tall fescue plant, which results in increased persistence. The plant provides the appropriate conditions for the endophyte to conveniently propagate during the inflorescence phase to disseminate in seed. The plant also provides necessary nutrients to the fungus (Bacon et al., 1977; Clay, 1987; Clay, 1988; Siegel, 1993).

Alkaloids Produced by Neotyphodium Coenophialum

Multiple alkaloids are produced by the fungus, each one has a specific purpose in the mutualistic symbiotic relationship between the plant and fungus. According to Porter (1995), ergovaline is the most concentrated ergopeptine found in E+ tall fescue, also lysergic acid amide can also be found at similar concentration to ergovaline. The term "ergot alkaloids" includes several different compounds, which can be grouped into classes of: clavine class of ergot alkaloids, pyrridiazonal alkaloids, loline alkaloids, peramine alkaloids, and ergopeptine alkaloids. Ergotamine, ergovaline, and ergonovine are example of ergopeptines, which are believed to be causative agents in tall fescue toxicosis (Foote et al., 2011).

Ergovaline. Ergovaline is an ergot alkaloid compound with ergoline comprising its basic structural component (Lane, 1999). The inactive isomer form to ergovaline is ergovalinine, which have been combined in some studies resulting in elevated values (Lane, 1999). In a mass spectrometry analysis conducted by Porter et al. (1981), ergovaline and its isomer were the most abundant compounds in *N. coenophialum* culture. A similar study utilizing Kentucky-31 pasture samples infected with *N. coenophialum* also confirmed ergovaline was the dominant chemical component (Yates et al., 1985).

The level of ergovaline in the leaf blade, leaf sheath, and seedhead varies throughout the tall fescue growing season (Rottinghaus et al., 1991). Rottinghaus et al. (1991) sampled three replicates of E+ tall fescue weekly between May 1988 and June 1988. The ergovaline levels for the leaf blades remained steady from 177 µg/kg to 425 µg/kg. A decline in the ergovaline concentration was observed across the sampling dates with the peak of 1083 µg/kg (sample date: May 10) and lowest level at 399 µg/kg (sample date: June 21). The opposite trend was observed in the seedheads with an increase in ergovaline concentration from 806 µg/kg (sample date: May 17) to 1648 µg/kg (sample date: June 21). The elevated temperatures and excessive dry conditions of summer also factored into increased the ergovaline concentrations (Barker et al., 2009). The symptoms of fescue toxicosis are typically higher during the summer due to elevated temperatures resulting in heat stress and increased consumption of seedheads containing increased ergovaline levels. A method to control the level of ingested ergovaline was to adjust the stocking rate to keep reproductive growth of the plant to a minimum (Barker et al., 2009). In a vasoconstriction study utilizing Doppler ultrasonography, horses consuming grounded endophyte-infected tall fescue seed showed reduced blood flow to the digital palmar artery (McDowell et al., 2013). Thus, this confirms that cattle should not be allowed to consume endophyte-infected tall fescue seedheads, which could result in the same vasoconstriction issue.

Most research studies implicate ergovaline as a primary compound in tall fescue toxicosis. However, Piper et al. (1997) using rats as models to suggest that ergovaline was not the major compound associated with the toxicosis. The following studies reveal the potency and the possible accumulation of ergovaline. Lateral saphenous veins and dorsal metatarsal arteries from post-harvested cattle were subjected to various toxins produced by endophyte-infected tall fescue. The elicited response, in terms of constriction, was observed in both the veins and arteries. The amount of ergovaline required to elicit a response was minimal at 1×10^{-8} M (Klotz et al., 2007; Klotz et al., 2008). Another experiment revealed that it required a slightly higher concentration at 1×10^{-6} M (Foote et al., 2011). This level was low compared to other chemicals tested in the experiments. (Klotz et al., 2007; Klotz et al., 2008; Foote et al., 2011) A lateral saphenous vein exposed to ergovaline did not return to zero tension when washed with an ergovaline-free buffer for 15 min seven times over 105 min, but norepinephrine required only four buffer washes to normalize (Klotz et al., 2007).

Lysergic Acid Amide. A reasonable question to consider is whether ergovaline is the only compound or could multiple toxins be involved in tall fescue toxicosis. Lysergic acid amide may have as much importance in causing tall fescue toxicosis as ergovaline (Hill, 2005). Porter et al. (1995) reported near equivalent concentrations of the ergovaline and lysergic acid amide in the endophyte-infected tall fescue cultivar. In comparison to other ergot alkaloids, lysergic acid was more soluble in the rumen and had the greatest potential for crossing the ruminal tissues (Hill, 2005). When tested with ergovaline in the vasoconstriction study, lysergic acid amide required only a 1 x 10^{-5} M concentration to elicit a response (Klotz et al., 2008). Although this concentration is higher than ergovaline, the transportation characteristics of lysergic acid render it possible to find lysergic acid at the reported 1 x 10^{-5} M concentration.

Insect and Nematode Resistance. Insect, nematode, and herbivore resistances are due to the alkaloids produced by the endophyte (Clay, 1988). Different compounds are produced by the endophyte, which result in varying degrees of resistance for the host plant. Each endophyte and plant interaction is complex resulting in the production of variable types and levels of alkaloids (Qawasmeth et al., 2011). If herbivorous animals are experiencing symptoms of toxicosis, then it is logical to examine the invertebrate populations for possible issues associated with the fungus. The effects of the endophyte are obviously widespread throughout the entire ecosystem.

Avoidance of the endophyte-infected plant by the insect is dependent upon several factors. Not all insects are impacted in the same manner (Bultman and Bell, 2003). The species and age of an insect can confer preference in addition to fungus-plant combinations and plant maturity (Johnson et al., 1985; Hardy et al., 1986). Alkaloids may collect in areas of high infestation to deter insects (Hardy et al., 1986; Patchett et al., 2008). Exposure to endophyte-infected tall fescue conditions alone has been shown to impact insects negatively. Two aphid species, *Rhopalosiphum padi* (L.) and *Schizaphis graminum* (Rondani), placed in endophyte-infected tall fescue conditions resulted in 100% mortality (Johnson et al., 1985). In a ground seed storage experiment, the vials containing *A. coenophialum* (or *N. coenophialum*) infected tall fescue impacted survivability and population growth negatively in the common flour beetle, *Tribolium castaneum* (Herbst). The endophyte-free conditions marked an increase in both survival and population size (Cheplick and Clay, 1988).

In E+ tall fescue, the fungus resulted in nearly non-existent or zero population levels of nematodes (Pedersen et al., 1988; West et al., 1988; Elmi et al., 2000). Some nematodes species were not deterred by the endophyte (Kimmons et al., 1988). The fungus protects the plant's root system from the destructive consequences of nematodes. This protection results with the establishment of a more elaborate and deeper root system, which will assist the plant during drought conditions (West et al., 1988; Elmi et al., 2000).

Effects of Neotyphodium on Grazing Animals

Antiherbivory is best described as the undesirable interactions of the alkaloids with grazing livestock. This affects the performance and production of the grazing animal resulting in loss of profit. Four syndromes are associated with antiherbivory, which has continued to impact the livestock industry for over half a century. These syndromes include fescue foot, fat necrosis, agalactia, and fescue toxicosis (Hemken et al., 1984).

Fescue Foot. Fescue foot is a condition that begins with lameness and can advance to loss in the affected appendages (Cunningham, 1949). Lameness of the hindquarters occurred as early as eight days after grazing on the endophyte-infected pasture (Jacobson et al., 1963). Symptoms can take up to six months to appear, which is thought to be dependent on endophyte level in the pasture (Jacobson and Miller, 1961; Yates, 1962). Rough hair coat, weight loss, and drying of skin near the hoof are symptoms associated with fescue foot (Yates, 1962). Eruptions and lesions on the legs, coronary band erythema, and reduced hoof growth are outer manifestations of the disease observed and reported by Jacobson et al. (1963). Fescue foot is the form of tall fescue toxicosis that is typically observed in the winter months. The progression of disease is caused by poor blood flow resulting in decreased warmth to the extremities and further transitions into the expression of the latter symptoms (Jacobson et al., 1963). Treatment of fescue foot is achieved by removing the cattle promptly from the toxic field as these symptoms start to manifest. Prompt removal from the field has been known to reverse the effects of fescue foot. However, if the symptoms have been allowed to progress into a more serious situation, such as severe lameness, then it may be too late for the animal to recover (Yates, 1962; Cornell and Garner, 1983).

***Fat Necrosis*.** Fat necrosis, or bovine fat necrosis, is a syndrome associated with the accumulation of hard fat masses around the digestive tract (Wilkinson et al., 1983; Bush et al., 1979). Abdominal fat necrosis was commonly known as lipomatosis in earlier literature, but the term misrepresents the syndrome (Smith et al., 2004). Necrotic lesions were found mainly in abomasal fat deposits, but also located in the perirenal, abdominal, and pelvic fat. The size of the necrotic fat lesions ranged from small nodules in normal fat tissue to large masses of irregular shape that can constrict; surrounding the intestines, urinary tract, and reproductive organs (Rumsey et al., 1979; Smith et al., 2004). The syndrome appears to be more widespread in beef cattle grazed on high nitrogen fertilized E+ tall fescue (Stuedemann et al., 1975; Stuedemann et al., 1985). Species diagnosed thus far are cattle, pigs, horses, and Eld's deer. The most recent case has been a pygmy goat grazing a stand of endophyte-infected tall fescue with greater than 74% infection (Smith et al., 2004). The issues that arise from the syndrome are digestive tract disturbances and dystocia (Bush et al., 1979; Smith et al., 2004).

***Agalactia*.** Agalactia defined as the complete absence of milk production, tends to occur in horses, while cattle only experience a decline in milk production (Hemken et al., 1984; Cross et al., 1995). Serum prolactin is the major hormone involved in horse milk production. In cattle, placental lactogen is produced in addition to serum prolactin (Forsyth, 1986). Serum prolactin levels are lowered in horses and cattle consuming endophyte-infected tall fescue (Goetsch et al., 1987). Therefore, Cross et al. (1995) speculated that horse milk production is affected more significantly, since cattle have the placental lactogen hormone to compensate. Horses also experience decreased udder development (Putnam et al., 1991).

Summer Syndrome. Summer syndrome is known specifically in relation to the tall fescue cultivar as summer toxicosis, summer fescue toxicosis, or tall fescue toxicosis (Hoveland et al, 1983a; Hemken, 1984; Stuedemann and Hoveland, 1988). The syndrome encompasses a multitude of issues, which are most severe in the extreme temperatures of summer. Tall fescue toxicosis signs include retention of winter coat, elevated internal body temperature, increased respiratory rates, reduced ADG, lower serum prolactin levels, increased salivation, and reduced reproduction performance (Hemken, 1984; Stuedemann and Hoveland, 1988).

The physiological effects of fescue toxicosis have been documented by numerous researchers (Schmidt et al., 1982; Hoveland et al., 1983b; Garner et al., 1984; Aldrich et al., 1993; McMurphy et al., 1990). Respiration rate increased in cattle consuming endophyte-infected tall fescue from 54.1 to 77.9 breaths per minute (Koontz et al., 2012). Average daily gains were depressed 0.045 kg/d for each 10% increase in endophyte level (Garner et al., 1984). The reduced average daily gain is directly related to decrease feed intake (Stuedemann and Hoveland, 1988).

Approaches to Alleviate Tall Fescue Toxicosis

Endophyte-free Cultivars. Removal of the endophyte was one approach to the toxic endophyte issue. Certified endophyte-free cultivars were considered to have a percent infection of less than 5% (Stuedemann and Hoveland, 1988). The techniques used to produce endophyte-free cultivars were fungicide application, length of time in storage, and temperature treatments (Siegel et al., 1984). In the study conducted by Siegel et al. (1984), the endophyte perished after

11 months in storage at 21°C. The germination of the seed was comparable to the endophyte-infected cultivar (Siegel et al., 1984). When the seed were stored at 13% or higher moisture content, the endophyte viability declined from 84% to 0-14% (Rolston et al., 1986). The endophyte-infected seed has an increased survival rate in cooler and drier environments (Siegel et al., 1984; Rolston et al., 1986).

The performance of livestock on E- tall fescue was significantly better in comparison to E+ tall fescue. Average daily gain for steer increased on E- tall fescue regardless of consuming pasture, seed, or hay. Hoveland et al. (1983b) reported a four-year ADG average of 0.50 kg/d for steers grazing E+ Kentucky-31 pastures and 0.83 kg/d for steers on E- Kentucky-31 pastures. According to Schmidt et al. (1982), the ADG of steers consuming E+ Kentucky-31 seed versus E- was 0.20 kg/d and 0.96 kg/d, respectively. A similar ADG observation of 0.41 kg/d and 0.84 kg/d with steers consuming E+ and E- Kentucky-31 tall fescue cultivars, respectively (Parish et al., 2003).

The E- tall fescue cultivar was an encouraging solution to the tall fescue toxicosis problem. The toxicity problem was absent in the livestock. However, E- tall fescue cultivars did not persist unless certain management strategies are implemented. The inability of the endophyte-free stand to remain viable is probably due to overgrazing, since the toxic component affecting the cattle is absent from the forage. Typical management of tall fescue involved brief periods of overgrazing. However, E- managed in this manner usually results in a limited life stand. In hay harvesting and grazing conditions, the recommendations were to cut or graze at a stubble height of 0.0762 m to 0.1016 m (Hoveland et al., 1990).

Toxin Dilution. A common tall fescue toxicosis management protocol implemented by producers was to interseed with clovers to diminish the effects of the toxin (Ball, 1997). The addition of clovers to any forage system results in increased nutritive value and produces improved ADG. A clover amount comprising 10% to 25% of the pasture is considered to be sufficient to dilute the effects of tall fescue toxicosis (Fribourg et al., 1991). However, the effect of the dilution can be questionable in high E+ pastures, since the animals could still be consuming high amounts of the alkaloids (Thompson et al., 1993). Steer gains on high E+ tall fescue/clover mixture was intermediate in comparison to high E+ and low E+ tall fescue pastures (McMurphy et al., 1990). The decreasing levels of endophyte infection appeared to be more consistent for increasing ADG than the clovers (Thompson et al., 1993). Similar to the addition of clovers, dilution of the endophyte toxin can be achieved by supplementing soybean hulls to the diet of cattle.

Addition of Clovers. The purpose of clovers in livestock grazing systems is to improve the forage quality. Some of the benefits of adding legumes in endophyte-infected pastures are increased weight gain, higher reproduction rates, and dilution of intake of endophyte toxin. In addition, there is a reduction in pasture input costs for nitrogen with the inclusion of clovers to the system (Lomas et al., 1999; Taylor, 2008). Regal, a ladino clover, also known by its test name as "Alabama Synthetic," was registered in 1970. This was a cultivar derived from five parent clones and tested from 1952 until its release in 1962 (Johnson et al., 1970). Patriot, or GC-89, is a ladino cross clover recently developed in a joint research effort between University of Georgia and AgResearch Ltd. of New Zealand and registered in 2005. The cultivar is a cross between the GA-ETN germplasm and southern regional virus resistant (SRVR) germplasm (Bouton et al., 2005a). Persistence, yield, and adaptability were criteria selected for in the parent clovers comprising the genetic composition of the Regal and Patriot clovers (Johnson et al., 1970; Taylor, 2008).

Clovers tend to be difficult to maintain in livestock grazing systems and generally do not persist. Basal coverage is an indicator of the survivability of the clover stand. In Georgia, two years of continuous grazing revealed that Patriot had 75% basal coverage, whereas, Regal was only 6%. The basal coverage of Patriot and Regal was initially 85% and 77%, respectively (Andrae, 2009). Another study conducted in Georgia produced similar results on basal coverage of Regal and Patriot (Bouton et al., 2005b).

A higher average daily gain was observed for Patriot clover in a three-year study conducted by Georgia. The ADG in the spring season for Georgia 5 E+/Patriot clover, Georgia 5 E+/Regal clover, and Georgia 5 E+/N fertilizer was 1.02, 0.86, and 0.85 kg/d ($P < 0.05$), respectively (Bouton et al., 2005b).

Supplementation and Direct Treatment of Animals. A method to treat fescue toxicosis is to administer certain compounds that reduce the symptoms. One such compound was to supplement thiamine into the diet. After exposure to E+ tall fescue, cattle recovered faster with thiamine supplementation (Smith et al., 1986).

Glucomannans, a yeast cell wall component, has absorptive capabilities and has produced inconsistent results in reducing the signs of tall fescue toxicosis. A modified glucomannan, MTB-100 (Alltech, Inc., Nicholasville, KY), has produced both positive and neutral results in improving beef cattle. Mills (2007) reported no increased performance when MTB-100 was fed to grazing steers and heifers in a two-year study. However, a similar study conducted by Merrill et al. (2007) revealed serum prolactin levels were maintained and animal performance was increased.

Extract from [*Ascophyllum Nodosum* (L.) Le Jolis], a brown seaweed, has been shown to reduce the elevated core body temperature in cattle during heat stress caused by grazing E+ tall fescue. The reduction in core body temperature may help improve animal performance. The actual benefit to cattle from the extract is unknown, but the vitamins and minerals are implicated as a factor (Fike et al., 2001). Another compound investigated was Endo-Fighter (ADM Alliance Nutrition Inc., Quincy, IL), which contains compounds that have been shown to bind ergovaline, improve rumen function, and support immune function. In a study by Norman et al. (2010), no improvement to cattle was observed in two trials. Lastly, cattle consuming endophyte-infected tall fescue plus domperidone injection showed no suppressed weight gain and lower rectal temperature (Jones et al, 2012).

***Non-toxic Endophyte-infected Cultivars*.** The most successful approach has been to utilize non-ergot alkaloid producing strains of the endophyte fungus. These strains do not cause the expression of tall fescue toxicosis in livestock species. The term used to reference these strains is "novel endophyte". Multiple combinations of tall fescue cultivars and novel endophyte fungal strains were screened to evaluate the most desirable relationship in terms of percent infection, ergot alkaloid levels, and viability (Bouton et al., 2002). Pennington Seed, Inc. has patented the combination of tall fescue cultivar and novel endophyte marketed as MaxQ (Gunter and Beck, 2004; Hancock, 2009). The plant is a combination of the AR542 fungal strain isolated by researchers from New Zealand and Jesup endophyte-free tall fescue (Gunter and Beck, 2004). The AR542 endophyte produces negligible amounts of ergovaline (Johnson et al., 2012). This forage exhibits a behavior that is a cross between the toxic endophyte-infected and endophyte-free tall fescue cultivars. It is similar to toxic cultivar in persistence and productivity while diminishing the toxic component and results in improved animal performance similar to that observed in endophyte-free tall fescue (Bransby et al., 2002).

Jesup MaxQ underwent several trials before being produced commercially by Pennington

Seed. These trials were conducted to evaluate the plant and animal performances of the cultivars. Jesup MaxQ has similar dry matter yield, CP, NDF, and ADF as with both endophyte-infected Ky-31 (KY-31 E+) and endophyte-free tall fescue (Burns et al., 2006). Stand persistence of Jesup MaxQ is similar to Ky-31 E+, which is greater than endophyte-free tall fescue. In a two year study by Lang, the stand performance for Ky-31 E+ and AR542 was 25-50% and for endophyte-free tall fescue less than 25% (Lang et al., 2001).

When comparisons are made for growth and persistence of Jesup MaxQ to endophyte-free and Ky-31 E+ cultivars, Jesup MaxQ performs similar to Ky-31 E+. However, when comparing the animal performance while grazing the respective cultivars Jesup MaxQ behaves similarly to Ky-31 E-. Parish et al. (2003) reported ADG for AR542, E- and E+ of 0.82, 0.84, and 0.41 kg ($P < 0.10$), respectively. In the same study, serum prolactin levels were severely diminished for Ky-31 E+ cultivars but not for Jesup MaxQ. Serum prolactin is a hormone correlated with hair growth that is reduced when animals consume E+ tall fescue. Seasonal shed of the hair coat is observed in cattle grazing Jesup MaxQ (Schuenemann et al., 2005).

Jesup MaxQ tall fescue cultivars currently appear to be the most probable solution to the tall fescue toxicosis. However, the reestablishment of pastures can be a lengthy and costly process for producers. The procedure required to change a pasture from endophyte-infected tall fescue to the nontoxic endophyte will take about 2 years. Pastures would have to be taken out of production and the stocking rates would have to be reduced if cattle could not be accommodated on extra pastures. After the establishment of the pastures, the length of time to recover costs from the renovation is estimated to be 4 years (Beck et al., 2008). The most economical time to replace toxic endophyte pastures with nontoxic endophyte cultivars is when the infection status of the pasture is above 74%. With higher stocking rates (4 steers/ha), it will be more beneficial to replace pastures with novel endophyte cultivars at > 25% infection level (Zhuang et al., 2005).

Other novel endophyte combinations include: 'Texoma' MaxQ II, Estancia with ArkShield, Duramax Armor, and BarOptima Plus E34. Estancia/ArkShield, a rebranding of Ark-Plus, was marketed to the public by Mountain View Seeds in 2011. 'Texoma' MaxQ II is Pennington Seed, Inc. second novel endophyte-infected tall fescue, registered in 2010 (Hopkins et al., 2010). MaxQ II was developed for south-central USA, with equal or increased performance than Jesup MaxQ in this region. Available in 2011, DuraMax Armor is being marketed by DLF International Seeds and BarOptima Plus E34 is being marketed by Barenbrug.

Summary

The Ky-31 E+ cultivar was selected for drought tolerance, persistence, adaptation to multiple soil types, and ability to graze throughout the majority of the year. The documented performance of this forage resulted establishment of millions of hectares by producers. However, the tall fescue toxicosis problem was not discovered until years later. An endophyte was discovered in the plant that produces ergovaline. Ergovaline has been implicated as the cause of tall fescue toxicosis. Practices that have been implemented as probable solutions to the issue: endophyte-free cultivars, toxin dilution, supplementation, and novel endophyte-infected cultivars. Jesup MaxQ is the novel endophyte cultivar of interest in this experiment that produces negligible amounts of ergovaline. The cultivar needs to be tested from a production standpoint to evaluate the positive and negative aspects for producers. White clover cultivars also may be beneficial in reducing tall fescue toxicosis, if they persist.

CHAPTER 2: PERFORMANCE OF STEERS GRAZING TALL FESCUE AT DIFFERENT STOCKING RATES

ABSTRACT

In fall/winter and spring for 4 years, weaned steers were grazed on twenty-four 1.2-ha tall fescue, *Lolium arundinaceum* (Schreb.) Darbysh., pastures. Forage evaluated were Kentucky-31 endophyte-infected (Ky-31 E+), Jesup non-toxic endophyte-infected (Jesup MaxQ), and endophyte-free (Ky-31 E- and Jesup E-) cultivars. Experiment one, a two year grazing study, compared the performance of Ky-31 E+ and Jesup MaxQ pastures interseeded with 'Regal' or 'Patriot' white clover. Experiment two compared Ky-31 E+, Ky-31 E+ (a six year old stand), Jesup MaxQ, Jesup E-, and Ky-31 E- at different stocking rates for four years. Regal white clover was not as persistent as Patriot white clover in Ky-31 E+. Steers grazing Ky-31 E+ with Patriot clovers had ADG values similar to Jesup MaxQ pastures (P < 0.05) during the spring grazing season. Jesup MaxQ seeded with Patriot clover (Ky-31 E+/Patriot) had the highest ADG of 1.27 kg/d in the spring grazing season. While steers grazing Ky-31 E+/Patriot experienced higher ADG they still had depressed serum prolactin levels and higher haircoat scores similar to steers grazing Ky-31 E+. There were no performance differences between cultivars during the fall/winter grazing season. Stocking rates per pasture were low, 2 to 4 steers, and medium, 4 to 6 steers. Steers grazing at different stocking rates had similar animal performance (P < 0.05). Steers grazing newly established Ky-31 E+ and Ky-31 E+ (old) performed similarly (P < 0.05). Steers grazing Jesup MaxQ, Ky-31 E-, and Jesup E- cultivars performed similar to each other and better than Ky-31 E+ cultivars (P < 0.05).

INTRODUCTION

In 1931, the Kentucky-31 tall fescue cultivar was discovered growing on a pasture in northeastern Kentucky (Fergus and Buckner, 1972). The use of the cultivar was widespread by farmers due to it adaptability in the transition zone (West and Waller, 2007). However, the plant contains an endophytic fungus that produces a toxin implicated as the causative agent in tall fescue toxicosis (Hoveland et al., 1983a; Klotz et al., 2008). Symptoms of fescue toxicosis include poor weight gain, reduced reproductive performance, and elevated body temperature (Hemken et al., 1984).

The development of novel endophyte cultivars has been the most successful approach because there is no expression of tall fescue toxicosis. Jesup MaxQ is the non-toxic endophyte-infected cultivar patented by Pennington Seed, Inc. used in this study (Gunter and Beck, 2004). Multiple combinations of tall fescue cultivars and novel endophytes were tested to find the best interaction. Jesup MaxQ is a combination of the Jesup E- tall fescue cultivar and AR542 fungal strain (Gunter and Beck, 2004). The AR542 produces negligible amounts of ergovaline (Johnson et al., 2012).

Approaches to alleviate tall fescue toxicosis include the use of E- cultivars, adding clovers to E+, supplementation/direct treatment, and replaced E+ fescue with new nontoxic endophyte-infected cultivars, such as Jesup MaxQ. Research and producer experience indicated that E- cultivars could not persist under heavy grazing pressure (Hoveland et al., 1990). Animal performance on E- pastures was substantially better than E+ pastures (Parish et al., 2003). Another approach has been to use legumes to offset some of the toxicosis, which also increased the nutritive value of the forage system (Fribourg et al., 1991). When adding a clover to any forage system, producers want a cultivar that will persist. In trials, GC-89 showed more persistence in a stand under heavy grazing pressure than Regal clover (Andrae, 2009; Bouton et al., 2005b).

The objectives of this study were: 1) To evaluate performance and physiological characteristics of steers grazing pastures containing Ky-31 E+, Ky-31 E-, Jesup E-, and Jesup MaxQ tall fescue cultivars at low or medium stocking rates; 2) To evaluate forage productivity and longevity of Ky-31 E+, Ky-31 E-, Jesup E-, and Jesup MaxQ tall fescue cultivars at low or medium stocking rates; and 3) To compare Regal and GC-89 white clovers grown in Jesup MaxQ and Ky-31 E+ tall fescue pastures.

MATERIALS AND METHODS

This study was conducted at the East Tennessee Research and Education Center (ETREC), Blount Livestock Unit, near Louisville, Tennessee (35°50' N, 83°57' W) from December 2002 through July 2006. Twenty-four 1.2-hectare (ha) pastures were utilized with the following treatments: 1) Kentucky-31 endophyte-infected tall fescue (Ky-31 E+); 2) Kentucky-31 endophyte-infected tall fescue plus Regal clover (Ky-31 E+/Regal); 3) Kentucky-31 endophyte-infected tall fescue plus GC-89 clover (Ky-31 E+/GC-89); 4) Kentucky-31 endophyte-free (Ky-31 E-); 5) Jesup nontoxic endophyte-infected tall fescue (Jesup MaxQ); 6) Jesup nontoxic endophyte-infected tall fescue plus Regal, *Trifolium repens L*, clover (Jesup MaxQ/Regal); 7) Jesup nontoxic endophyte-infected tall fescue plus GC-89 clover (Jesup MaxQ/GC-89); 8) Jesup endophyte-free (Jesup E-); and 9) Kentucky-31 endophyte-infected tall fescue pastures (Ky-31 E+ (old)) established in October 1995. Each treatment consisted of two 1.2-hectare pastures. Refer to Figure 1 for a layout of the experimental pastures.

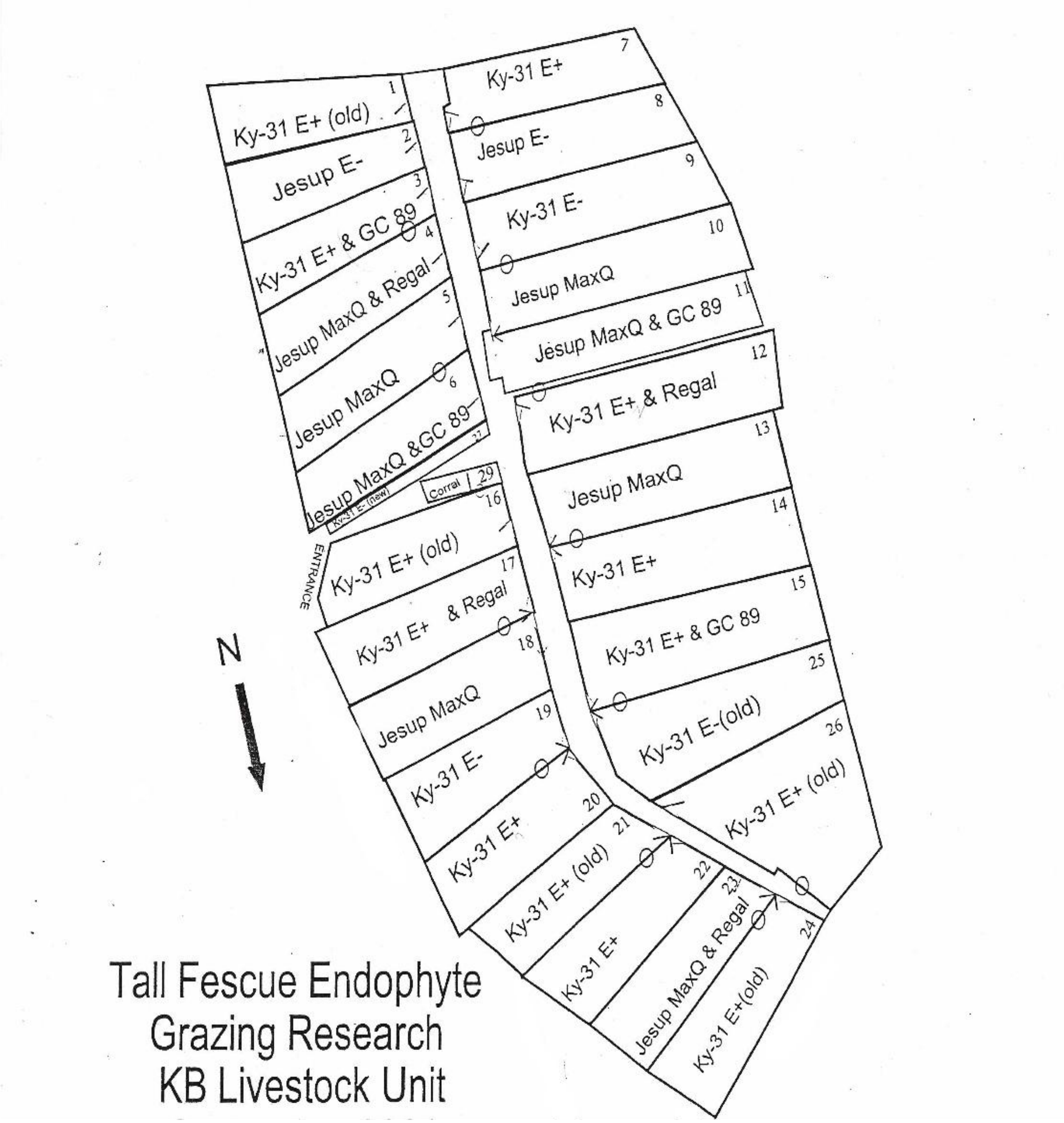

Figure 1. Map of research pastures on the Blount Livestock Unit of the East Tennessee Research and Education Center near Louisville, TN. Jesup E- = Jesup tall fescue without endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E- = Kentucky-31 tall fescue without endophyte; Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Ky-31 E+ (Old) = Kentucky-31 tall fescue with endophyte planted in October 1995. Regal = ladino white clover; GC-89 = ladino cross white clover; None = no clover established in these pastures.

Pasture Establishment

The pastures had been utilized in previous grazing research and had to be reestablished for this study. The pasture establishment period was from April 2001 to September 2001. The tall fescue (Ky-31 E+ (old)) that remained in four pastures were included in this study.

Previously used cultivars were killed in April by applying an herbicide on 20 of the 24 pastures. Pastured were limed and fertilized according to soil test recommendation. In late April 2001, the pastures were overgrazed to a short height to prevent seedhead production. Once the tall fescue cultivars had grown to a 5 to 7-cm height, N,N´-dimethyl-4,4´-bipyridinium dichloride, paraquat was at a rate of 1375 mL ha^{-1}. A second paraquat application plus non-ionic surfactant at the same rate was performed following a 10 to 15-d regrowth period. Glyphosate was applied at a 2.75 mL ha^{-1} rate with 2 to 4-L surfactant/378-L of spray to control the weed population. Roundup-Ready® soybeans were planted on the pastures in late May 2001 and harvested with a forage silage harvester in September 2001. The chopped plant residue was blow out the back of the harvester on the plots to provide cover for the seedbed and minimize soil erosion (Mitchell et al., 2005). In September 2001, Ky-31 E+, Ky-31 E-, Jesup E-, and Jesup MaxQ tall fescue cultivars were seeded at a rate of 15.72 kg/ha according to their respective treatment assignments on the 20 renovated pastures. Regal and GC-89 clovers were broadcasted in February 2002 on select Ky-31 E+ and Jesup MaxQ pastures at 2.25 kg/ha. During the fall 2001/winter 2002 season, the pastures were not grazed to allow the tall fescue stands to become established. The pastures were grazed at a moderate stocking rate from late spring through summer 2002. Beginning in early September 2002, the steers were removed to stockpile tall fescue. All pastures were fertilized with nitrogen at a rate of 56 kg/ha and allowed to grow in the fall. The steers remained off the pastures until the beginning of December 2002.

On pastures designated not to contain clovers, nitrogen was applied at 56 kg/ha and herbicides were utilized to keep the legume population below 5%. If clover designated pastures contained less than 30% legumes in April-May, or less than 10% in September, they were overseeded in February 2003 at half the establishment rate.

Grazing Seasons

Four fall/winter and four spring/summer grazing seasons were used from November 2002 through July 2006. The fall/winter grazing season initiated about November 1 and terminated in mid-March. The spring grazing season started on mid-March 15 and finished approximately on June 30.

Stocking Rate

The stocking rate (SR) on the pastures was varied each year with growing season and weather conditions (i.e. drought). A low stocking rate consisted of two to four steers per 1.2-ha pasture. A medium stocking rate consisted of four to six steers per 1.2-ha pasture. The stocking rate was kept lower in summer than in the spring at two (low SR) to four (moderate SR) steers per 1.2-ha pasture. At all times, there was at least two steers separating the low and medium stocking rates.

Animal Management

The cattle in this experiment were managed under the protocol TN-176-KB3 approved by the University of Tennessee Institute for Animal Care and Use Committee. Approximately 136 weaned steer calves weighing from 205 kg to 325 kg were acquired each year at fall weaning. The steer calves utilized in this study were from the ETREC Blount Livestock Unit beef cattle herd. Other steer calves were purchased, as needed, from other individually owned herds. Steers were allotted based on breed, age, and weight. The steers were observed daily to: 1) Ensure that the steers were in their assigned pastures; 2) Monitor the health status of each steer; and 3) Monitor the availability of water, salt, and minerals. During fall/winter grazing season, a windbreak was provided to the steers and removed no later than April 15. Adequate shade was available throughout the study in each pasture.

When forage was unavailable due to adverse weather conditions. During the fall/winter grazing season, the steers were fed 1.82 kg/steer/d of CO-OP 18% Beef Supplement Cubes, or range cubes. The range cubes had an 18% protein, 3% fat, and 8% fiber plus vitamins/minerals on an as-fed basis (Tennessee Farmer's Cooperative, LaVergne, Tennessee, 37086). This level of supplementation was selected to be the energy and protein needed for maintenance of these steers. Fall/winter grazing was terminated when pasture growth was insufficient at a height of 5 cm to 7.5 cm. These steers were maintained off the experimental pastures and returned to their respective pastures at the initiation of the spring grazing season. Surplus steers not utilized in the fall/winter season were managed similarly to steers on experimental pastures. In late June of each year, the grazing season concluded when there was insufficient pasture growth.

Sample and Data Collection Frequency

Steers were weighed at the beginning and end of the fall/winter and spring/summer grazing seasons, and at 21-d intervals during the season. Strip sample collection and pasture scoring coincided with the weighing of the steers. Clover percentage was estimated in June 2003 and June 2004. Haircoat scores were recorded in the late spring and early summer. Blood samples were collected at the beginning and end of the fall/winter and spring/summer grazing seasons, and at 21-d intervals during the season from pre-selected steers. Ergovaline was quantified in the last year of the study in late June 2006. Weather information was obtained from a weather station located approximately 6 km from the pastures.

Available Forage and Nutrient Composition

Strip sample collection of forages occurred at the beginning and end of the fall/winter and spring/summer grazing seasons, and at 21-d intervals during the season. Six strip samples (304.8 cm X 50.8 cm from a height of 3.81 cm above ground) were harvested at random locations in the pastures. Each forage sample was collected in pre-weighed bags and samples were combined after drying at 55°C for 48 hours and weighing. Forage availability was estimated by extrapolating sampling area to obtain a per ha basis.

Clover Percentage

Clover percentage was measured in June 2003 and June 2004. The pastures in this experiment are arranged in a rectangular shape. An x-sampling pattern was utilized across the pasture to collect measurements. A technician crossed the paddock diagonally and every five steps placed the left edge of 1 m^2 grid at the end of his right foot. The 1 m^2 grid was divided into 100 ten by ten cm quadrants. If clover was inside a 100 cm^2 quadrant, this was considered to be one clover percent. The values obtained in the x-sampling pattern were averaged to obtain the clover percentage for each pasture.

Hair Coat Scores

Hair coat scores were estimated in the chute in late spring and summer of each year. The hair coat scoring scale ranged from 1 (slick, healthy appearance) to 5 (brittle, dull appearance) (Saker et al., 2001).

Blood Collection

Whole blood samples were collected at the beginning and end of the fall/winter and spring/summer grazing seasons, and at 21-d intervals during the season from pre-selected steers. The jugular vein was punctured with a BD Vacutainer® System (needle, holder, blood collection tube). Blood tubes were placed on ice and allowed to clot. At the nutrition laboratory blood samples were centrifuged at 2000g at 4˚C for 20 minutes. After centrifugation samples were removed and serum was decanted and placed in the glass vials for storage at 4˚C until analyzed for serum prolactin. The blood serum was analyzed for prolactin hormone using the radioimmunoassay procedure (Bernard et al., 1993).

Ergovaline Concentration

Ergovaline concentration was measured in late June 2006 using high performance liquid chromatography (Rottinghaus et al., 1991). Forage samples were took from each pasture every 3 m following a diagonal pattern. The samples were clipped 3 to 4 cm above the ground and placed in an 18L bucket. The plants were then clipped into 2.5 to 3.8 cm segments, mixed, and sampled to obtain a composite sample. The sample was then frozen before shipping for analysis. The samples were shipped frozen to the Veterinary Medicine Diagnostic Laboratory in Columbia, Missouri. The samples were freeze-dried and ground to pass a 1-mm screen in a cyclone-type grinder. The samples were stored at 5˚C until ergovaline analysis by HPLC.

Weather Information

The weather conditions for Louisville, Tennessee were obtained from recorded daily by the National Climatic Data Center at the Knoxville McGhee Tyson Airport weather station. The weather station was located approximately six km from the ETREC Blount Livestock Unit. Weather information used was the monthly precipitation and lowest/highest atmospheric temperatures and the 30-year averages for each.

NIR Analysis

Forage samples were ground using a Wiley Mill containing a 1-mm screen. These samples were further ground down to a 0.5-mm size using a Cyclone Sample Mill (UDY

Corporations, Fort Collins, Colorado, 80524) to obtain more uniform particles size for near infrared reflectance (NIR) analysis (FOSS NIRSystems, Model 5000, Silver Springs, Maryland, 20904). The FOSS NIRSystem lamp was set to remain on at all times. A series of diagnostic tests were conducted prior to instrument utilization to ensure data reliability. Diagnostic information obtained from the tests was entered into Sentinel Software (Caltest, LLC, Clifton Park, New York, 12065). If the information did not meet reference standards, then the diagnostic tests were conducted again. The samples were loaded in quarter cup holders; packing the sample firmly between the quartz lens and foam pad. The holders were inserted in the sample loader. The software package for the FOSS NIRSystem that collected the nutrient data was WinISI II (Version 1.5, Infrasoft International, LLC, Port Matilda, Pennsylvania, 16870). Dry Matter (DM), Crude Protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF), and ash concentrations were obtained from the forage samples via NIR.

NIR Calibration

The ground forage samples collected at the ETREC Blount Livestock Unit were referenced against standards. Nutritional data for the standards were obtained using wet chemistry. The NIR was calibrated by taking the complete reflectance spectrum of these standards. The reflectance data obtained from the NIR was between 1100 nm and 2500 nm. This range was used to do the background that is above and below these wavelengths (Locher et al., 2005). A program using stepwise multiple least squares test was performed on the data to evaluate the best wavelengths to analyze for specific nutritional values. The wavelengths were chosen for each nutritional value by the calibration curve having a good R^2 and data reliability. The equations for the calibration were developed using data that took into consideration one to several different wavelengths. Selection was dependent on how it improved the reliability of the data (Corson et al., 1999).

Statistical Analysis

The experiment was a randomized block design blocked with factorial treatments. Pastures were blocked according to soil test and topography. Each pasture treatment was replicated twice. Data were analyzed using the mixed model analysis of variance procedure in SAS Version 9.3 (Cary, NC).

RESULTS AND DISCUSSION

Experiment 1

Carolina Horsenettle/White Clover. Between spring 2004 and fall/winter 2004, Carolina Horsenettle (*Solanum carolinese*) invaded the pastures and we concluded the level of infestation was at a level that would interfere with grazing by the cattle. To remove the horsenettle, Grazon ® P+D (*picloram + 2,4-D*), a herbicide, was applied to the pastures at a rate 0.94 to 1.42 L/ha. The result of the treatment was the eradication of the horsenettle and all white clovers. The white clover from the pastures was not reestablished for grazing in 2005-2006 of this study because chemical residue from the herbicide prevented clover growth. The removal of the clovers along with the Carolina Horsenettle resulted in splitting this study into two experiments. Experiment one contains two years of data in which comparisons of Regal and Patriot clovers in Jesup MaxQ and Ky-31 E+ pastures were possible. Steers grazed all pastures using a medium stocking rate

Grazing Seasons. Two grazing seasons were used in this two-year clover study. The fall/winter season initiated around November 1 of and continued determined end dates. Ending dates for 2003 and 2004 fall/winter grazing season were February 20 and February 19, respectively. The spring grazing season started in mid-March and continued until late June. Ending dates for the two years were June 26, 2003 and June 23, 2004. The 2002-2003 and 2003-2004 grazing seasons were designated as year one and year two, respectively.

Statistical Analysis. The experimental design used for experiment one was a completely randomized design with factorial treatments. Data were analyzed using the mixed model analysis of variance procedure in SAS Version 9.3 (Cary, NC). The fixed effects were the tall fescue/clover combinations. Plant data analyzed using this experimental design was ergovaline, forage availability, and nutrient composition. Animal data was analyzed for average daily gain (kg/d), beef production per pasture (kg/ha), hair coat scores, and serum prolactin. Least squares means were obtained and differences were determined at $P < 0.05$.

Ergovaline. The level of ergovaline required to induce the effects of tall fescue toxicosis has been reported as 50 ppb (Cornell et al., 1990). Ergovaline levels were tested in June 2006 for all pastures. The ergovaline levels should have remained relatively consistent between pastures over time. Therefore, data obtained in June 2006 could be applicable to the first two years of the study (Table 1). Negligible levels of ergovaline was reported for all Jesup MaxQ pastures. According to levels reported by Cornell et al. (1990), steers grazing Jesup MaxQ in the experimental pastures should not exhibited signs of fescue toxicosis. A range of 310-560 pbb was found on Ky-31 E+ tall fescue pastures. The level of ergovaline ingested by the steers on Ky-31 E+ pastures was six to ten times above the minimal level that has been reported to illicit fescue toxicosis.

Available Forage. Weather data was normal for each growing season and comparable to the 30-year average. Fall/winter grazing seasons showed a decline in the available forage as the season progressed through the winter. There were no differences ($P < 0.05$) noted between different forage combinations (Table 2). Spring grazing season for 2003 had the most available forage in May and in 2004 the most available forage was in April. However, there were no differences between the forage treatments noted. Available forage data was missing from 2002 fall/winter, early part of 2003 spring, and late part of 2004 spring grazing seasons due to construction.

When the two years of the fall/winter grazing season were combined, available forage was the same ($P > 0.05$) for the tall fescue cultivars for all two experimental years combined (Table 3). In pastures containing Ky-31 E+, Regal or no clovers produced higher ($P > 0.05$) available forage than those containing Patriot clover. Pastures planted with Jesup MaxQ cultivars produced more ($P > 0.05$) available forage when grown alone or with Patriot. According to Parish et al. (2003), the amount of available forage in this experiment was considered adequate for evaluating tall fescue and clover combinations. No significant differences ($P < 0.05$) were found between Patriot grown in Ky-31 E+ and Jesup MaxQ pastures. Regal clovers produced more available forage ($P < 0.05$) in Ky-31 E+ than Jesup MaxQ.

Nutrient Composition. No significant differences ($P > 0.05$) were observed in NDF, ADF, and CP in the fall/winter and spring grazing seasons for all tall fescue pastures (Table 4, Table 5). The nutrient composition between all pastures appears to be very comparable to that reported by Parish et al. (2003). Therefore, the presence of the toxic endophyte can be attributed to the tall fescue toxicosis syndrome observed in livestock. Any differences in animal performance must be due to other factors than NDF, ADF, and CP such as endophyte infection, ergot alkaloids, and grazing behavior.

Animal Performance. In fall/winter 2002, no significant differences ($P > 0.05$) were observed between the fescue/clover combinations (Table 6). A similar observation occurred in fall/winter 2003 except the only significant difference ($P < 0.05$) was between Ky-31E+/None and Jesup MaxQ/Patriot. The Jesup MaxQ/Patriot combination resulted in a higher ADG. When the experimental data was averaged over 2 years, no significant difference ($P > 0.05$) was found between the treatments. White clover growth is most active in the spring with little regrowth in the fall/winter. Thus, Patriot and Regal clovers should result in similar performance in fescue/clover combinations and to Ky-31 E+/None in the fall/winter months.

In spring 2003 and spring 2004, Jesup MaxQ had higher ADG ($P < 0.05$) than Ky-31 E+ in the absence of clovers (Table 7). Ky-31 E+/Patriot resulted in higher ADG ($P > 0.05$) than Ky-31 E+/Regal and Ky-31 E+/None. A similar observation was reported for spring 2004 when Ky-31 E+/Patriot had higher ADG than Ky-31 E+/Regal and Ky-31 E+/None ($P > 0.05$) (Table 7). This increase in gain was attributed to more Patriot clover compared to Regal clover (Andrae, 2009, Bouton et al., 2005a).

In spring 2003, Jesup MaxQ cultivars with and without clover had similar ADG values and there was no difference ($P > 0.05$) when compared to Ky-31 E+/Patriot (Table 7). In spring 2004, the Jesup MaxQ/Regal combination resulted in higher ADG ($P < 0.05$) than Jesup MaxQ/None. When comparing ADG of steers grazing tall fescue with Patriot and Regal clovers, those grazing pastures with Patriot performed better than those grazing pastures with Regal in the Jesup MaxQ combination ($P < 0.05$). The increased performance of steers grazing Patriot over those grazing Regal could be due to the greater quantity of Patriot compared to Regal in the pasture. In the two study years, there was a higher percentage of Patriot than Regal. However, the percentages Regal and Patriot percentage (Table 8) remained higher in Jesup MaxQ than Ky-31 E+ (Andrae, 2009; Bouton et al., 2005b). A possible clover/endophyte interaction could be occurring with Jesup MaxQ resulting in increased clover persistence.

When the two years of experimental data were combined, Ky-31 E+/Patriot resulted in higher ADG (*P* < 0.05) than any Ky-31 E+ combination (Table 7). Jesup MaxQ/Regal was intermediate in performance with the highest ADG reported on Jesup MaxQ/Patriot and lowest on Jesup MaxQ/None (*P* > 0.05). Pastures containing Patriot white clover produce the highest ADG (*P* < 0.05) within each individual fescue combination.

Beef Production. In fall/winter 2002, the amount of beef produced per hectare was the same (*P* > 0.05) between Ky-31 E+/None and Jesup MaxQ/None (Table 9). The amount of beef produced on Ky-31 E+ and Jesup MaxQ pastures with Patriot and Regal clovers was not different (*P* > 0.05). A difference of 59 kg/ha (P < 0.05) was found between Jesup MaxQ/Patriot and Ky-31 E+ in the fall/winter 2003 grazing season. When both fall/winter grazing seasons were combined no significant differences (*P* > 0.05) were found between the cultivar/clover combinations (Table 9). Therefore, steers will produce the same amount of beef per hectare regardless of whether the pastures contain novel or wild-type endophyte with or without of clover due to minimal effect from the endophyte in the fall grazing season.

In general, novel endophyte MaxQ pastures produced more beef per hectare than the wild-type stands (Table 10). In spring 2003 the Ky-31 E+/Patriot (*P* > 0.05) performed the same as all Jesup MaxQ combinations. The presence of clovers resulted in producing more beef per hectare because of toxin dilution and improved nutritive value in the pastures (Ball, 1997; Fribourg et al., 1991). The amount of beef produced on Ky-31 E+/Patriot was higher than (*P* < 0.05) Ky-31 E+/None and Ky-31 E+/Regal. In spring 2004, Jesup MaxQ/None and Ky-31 E+/Patriot produced more beef per hectare (*P* < 0.05) than Ky-31 E+/None and Ky-31 E+/Regal. Jesup MaxQ/Patriot produced the most kilograms of beef (*P* < 0.05) for the grazing period. The results of combining the two spring grazing seasons were similar to those observed in spring

2004 alone (Table 10) between Ky-31 E+/None and Ky-31 E+/Regal versus Jesup MaxQ/None and Ky-31 E+/Patriot ($P < 0.05$). The Jesup MaxQ/Patriot combination produced the most kilograms of beef per hectare ($P < 0.05$) in both experimental years combined. The improved animal performance can be attributed to the higher percentage of Patriot clovers in the Jesup MaxQ stand.

Hair Coat Scores/Serum Prolactin. Hair coat scores differed between steers grazing on ergovaline producing tall fescue and non-ergovaline producing tall fescue. Scores for the non-toxic pastures ranged from 1.1-1.4 and 1.8-2.0 for the toxic pastures (Table 11). These results show that clover treatments in endophyte-infected tall fescue pastures did not effect the hair coat scores. In non-toxic pastures, steers are not experiencing the effects of the toxin shed seasonal hair coat (Schuenemann et al., 2005).

Serum prolactin levels measured in steers grazing Ky-31 E+ with and without clovers were below normal and were not different (Table 12). The addition of clover did not negate the effects of ergovaline adequately to increase serum prolactin levels. Steers grazing pastures containing Jesup MaxQ with and without clovers showed normal serum prolactin levels for the spring grazing season (Table 12).

Experiment 2

Carolina Horsenettle invaded the pastures early summer 2004. The eradication of the horsenettle also resulted in the removal of Patriot and Regal white clovers. Chemical residue did not allow for the replanting of the white clovers. Steers grazed the pastures at low and medium stocking rates. Experiment two consists of four years of data comparing Ky-31 E+ (old and new stands), Ky-31 E-, Jesup E-, and Jesup MaxQ.

Grazing seasons. Two grazing seasons were used in each of the four years. The fall/winter season initiated November 1 of each year and continued a determined end date. Ending dates for 2003, 2004, 2005, and 2006 fall/winter grazing season were February 20, February 19, February 15, and January 09, respectively. The spring grazing season started in mid-March and continued until late June. Ending dates for 2003, 2004, 2005, and 2006 for spring grazing season were June 26, June 23, June 30, and June 21, respectively. Grazing periods presented as 2002-2003, 2003-2004, 2004-2005, and 2005-2006 grazing seasons are designated as year 1, 2, 3 and year 4, respectively.

Statistical Analysis. A completely randomized design was used for experiment two. Plant data analyzed were ergovaline, forage availability, and nutrient composition. Animal performance data included average daily gain (kg/d), beef production (kg/ha), hair coat scores, and serum prolactin. The fixed effects were tall fescue cultivars. Analysis by least square means of forage and animal data indicated that there were no differences between different stocking rates within the same forages ($P > 0.05$). Additionally, both endophyte-free fescues, Ky-31 E- and Jesup E-, showed no differences. Therefore, data was combined for statistical analysis.

Ergovaline. All pastures with Jesup E-, Ky-31 E-, and Jesup MaxQ cultivars had negligible levels of ergovaline (Table 1). Pastures with the Ky-31 E+ cultivar had ergovaline levels between 335-530 pbb and Ky-31 E+ (old) 390-500 ppb as determined by HPLC. The level of ergovaline was six to ten times above the minimal level shown to produce fescue toxicosis. It was reasonable to suspect the steers grazing Ky-31 E+ in this experiment were suffering from fescue toxicosis.

Available Forage. Weather data was normal for each growing season and comparable to the 30-year average. In fall/winter and spring grazing seasons (Table 13), the same amount ($P >$

0.05) of forage was produced by all pastures. The available forage at initiation of grazing in the fall was greater than at initiation of spring grazing (Table 13). These results were comparable to the study conducted in Eatonton, GA and met adequate forage requirements (Parish et al., 2003). Available forage data was missing from 2002 fall/winter, early part of 2003 spring, and 2006 spring grazing seasons due to construction.

Nutrient Composition. There were, no significant differences ($P > 0.05$) between CP, ADF, and NDF observed between the tall fescue cultivars. These results (Table 14, 15, 16) are consistent with Parish et al. (2003) in which they reported no difference in nutrition composition between tall fescue cultivars. Therefore the ingestion and metabolism of the ergot alkaloid and changes in grazing behavior explains the differences seen in animal performance not the nutrient composition of the forage.

Animal Performance. In fall/winter 2002-2005 fall grazing seasons (Table 17), steer gains ($P > 0.05$) were similar across all forage treatments. In fall/winter 2005, a significant difference ($P < 0.05$) of 0.23 kg/d was found between Ky-31 E+ (old) and E- tall fescue tall fescue cultivars. No significant differences ($P > 0.05$) were found between ADG of steers grazing Ky-31 E+, Jesup MaxQ, and Ky-31 E+ (old) in the same experimental year.

For each spring grazing season (Table 18) Ky-31 E+ and Ky-31 E+ (old) steer ADG were not significantly different ($P > 0.05$). A similar comparison can be no difference (P <0.05) between the Jesup MaxQ and E- cultivars ($P > 0.05$). Higher steer ADG ($P < 0.05$) were observed on Jesup MaxQ and E- cultivars than Ky-31 E+ and Ky-31 E+ (old). When the four years of this study were combined, steer ADG were higher ($P < 0.05$) on Jesup MaxQ and E- than Ky-31 E+ pastures. These results are similar to those reported by Parrish et al 1993.

Beef Production. In fall/winter 2002, 2004, and 2005 no significant differences (P > 0.05) were found between the Ky-31 E+ (old and new), Jesup MaxQ, and endophyte-free cultivars (Table 19). In fall/winter 2003, Jesup MaxQ produced more (P < 0.05) beef per hectare than the endophyte-free cultivars. The Ky-31 E+ (old and new) produced less beef/ha but were not different (P > 0.05). The results differed from Parish et al. (2003) who reported higher gain per hectare on Jesup MaxQ and E- cultivars than Ky-31 E+ cultivars. However, the grazing seasons in the Parish et al. (2003) study initiated/terminated earlier than this study. Steers were able to graze on the fall/winter regrowth of the cool-season forage.

In spring 2003-2006 Ky-31 E+ (old and new) cultivars produced the same (P > 0.05) amount of beef per hectare (Table 20). No significant differences (P > 0.05) were found between Jesup MaxQ and endophyte-free pastures during the spring 2003-2006 grazing seasons. When all four experimental years were combined, the same effect was observed as previously discussed. However, no significant differences (P > 0.05) were found between Ky-31 E+ (old), Jesup MaxQ, and endophyte-free cultivars in spring 2006. The Jesup MaxQ and endophyte-free pastures produced more (P < 0.05) kilograms of beef per hectare than Ky-31 E+ (old and new) cultivars. These findings were similar to the Parish et al. (2003) discussion on gain per hectare.

Hair Coat Scores/Serum Prolactin. Hair coat scores for steers grazing endophyte-free and Jesup MaxQ cultivars were lower than Ky-31 E+ and Ky-31 E+ (old). Scores ranged from 1.2-1.6 on non-toxic pastures and 1.9-2.3 on toxic pastures (Table 21). The lower hair coat scores were the result of the steers not consuming the toxic Ky-31 E+ cultivars (Schuenemann et al., 2005). Hair coat score data was lost for 2005 due to construction.

Steers grazing Ky-31 E+ and Ky-31 E+ (old) did not differ in serum prolactin levels (Table 22). The steers consuming forage on these pastures showed depressed serum prolactin levels. Normal serum prolactin levels were observed in cattle grazing Jesup MaxQ, Ky-31 E-, and Jesup E- (Parish et al., 2003). Depressed serum prolactin levels were probably the most consistent indicator of fescue toxicosis (Hemken, 1984; Stuedemann and Hoveland, 1988; Aldrich et al., 1993, Paterson et al., 1995; Parish et al., 2003).

IMPLICATIONS

Experiment 1 revealed differences between Jesup MaxQ and Ky-31E + with and without white clover. Regal white clovers did not persist as well as Patriot in Ky-31 E+. However, Patriot white clover did persist in Ky-31 E+ and increased the forage quality such that beef production was comparable to Jesup MaxQ without clover. Hair coat scores and prolactin levels in cattle grazing Ky-31 pastures were not changed by the presence of legumes. Therefore, legumes do not alter the two indicators of tall fescue toxicosis.

In experiment 2, animal performance was not effected by stocking rate. Jesup MaxQ and endophyte-free cultivars performed similarly and better than Ky-31 E+ cultivars in Spring, but no differences were noted in fall/winter. When comparing newly established Ky-31 E+ with older established Ky-31 no differences were found in animal performance.

In these two experiments the available forage and nutrient composition of forage were similar. The cattle grazing E+ had reduce daily gain and beef production because they were suffering from tall fescue toxicosis.

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CONCLUSIONS

According to West and Waller (2007), more than 20% of the beef cows in the US graze E+ tall fescue. Tall fescue toxicosis is the most limiting factor for the use of Ky-31 E+. The nutritional value of tall fescue is similar to other forages that do not have the toxic endophyte, drought persistence, and adaptability. These characteristics make Ky-31 E+ a forage of choice for many beef production systems. Endophyte-free cultivars can be used in a grazing system, but careful management is required to prevent overgrazing because animals will consume more of the endophyte-free forage. In addition, E- forages will not tolerate drought. These two factors result in increased pasture management. Other methods of reducing the toxic behavior of Ky-31 E+ are needed for the cultivar to be used more widely.

When clovers were added to Ky-31 E+ pastures, the need for nitrogen fertilization was diminished for the pasture and gains of the cattle were increased. However, Regal white clover was not persistent from year to year resulting in the need to reseed. Patriot white clover was persistent throughout our study. When added to Ky-31 E+ cultivars, Patriot increased the nutritive value and reduced the amount of toxic forage consumed resulting in increased cattle gains. Patriot also increased the gains in steers grazing non-toxic endophyte-infected tall fescue.

Novel endophyte-infected tall fescue has been promising as another option in retaining the desired properties of Ky-31 E +, while also eliminating the negative effects cause by the ergot alkaloid ergovaline. Jesup MaxQ was developed and tested at medium and low stocking rates in this study. Animals performed the same on Jesup MaxQ at both stocking rates. Perhaps stocking rates in this study were not differed enough to result in difference in animal performance. Animal performance data including ADG, hair coat scores, and serum prolactin levels showed that steers grazing Jesup MaxQ were gaining the same as steers grazing endophyte-free cultivars. When Patriot clovers were interseeded with Jesup MaxQ, increased steer gains were observed.

Both Jesup MaxQ and Patriot clovers are solutions to tall fescue toxicosis. Jesup MaxQ had similar properties as Ky-31 E- on animal performance and Ky-31 E+ on forage quality basis. Patriot clovers reduced the toxins enough to cause increased gains, but do not eliminate all the symptoms of tall fescue toxicosis such as higher hair coat scores and reduced serum prolactin associated with grazing E+ tall fescue.

In a stocker operation, Jesup MaxQ, Jesup E-, Ky-31 E-, Ky-31 E+/Patriot, and Jesup MaxQ/Patriot would be combinations to consider in the spring grazing season because higher ADG were observed. The same combinations would be applicable to a cow/calf operation, because adequate forage was consistently available for producers following either a fall or spring calving season. A fall calving producer would have adequate forage available to maintain the calf at weaning time in the spring. The spring calving producer would be more concerned about maintaining a lactating cow and rebreeding the animal. In the fall/winter grazing season, the ADG were the same among all tall fescue forage combinations because temperatures are lower and cattle do not show signs of fescue toxicosis.

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APPENDIX

Table 1. Ergovaline levels (ppb) measured in tall fescue cultivars in pastures containing clover

Cultivar[1]	Clover[2]	Ergovaline[3]
Jesup MaxQ	None	ND
Jesup MaxQ	Regal	ND
Jesup MaxQ	Patriot	ND
Ky-31 E+	None	430-530
Ky-31 E+	Regal	310-410
Ky-31 E+	Patriot	435-560

[1]Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ = Kentucky-31 tall fescue with endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.
[3]ND = not detected.

Table 2. Least squares means of available forage (kg/ha) from years 1 and 2 fall/winter and spring grazing season on tall fescue[1] pastures with and without clover[2]

Clipping Date	Ky-31 E+ None	Ky-31 E+ Regal	Ky-31 E+ Patriot	Jesup MaxQ None	Jesup MaxQ Regal	Jesup MaxQ Patriot	SE
5/13/03	2993^{a}	2789^{ab}	2630^{ab}	2906^{a}	1983^{b}	2580^{ab}	237.6
6/02/03	2527^{a}	2332^{a}	2172^{ab}	2134^{ab}	1622^{b}	1967^{ab}	183.7
6/23/03	2852^{a}	2694^{a}	2337^{a}	2345^{a}	1729^{a}	1974^{a}	404.4
11/03/03	3055^{a}	2876^{a}	3108^{a}	2851^{a}	2904^{a}	3304^{a}	227.7
1/07/04	2600^{a}	2742^{a}	2396^{a}	2302^{a}	2467^{a}	2544^{a}	523.7
2/20/04	2292^{a}	2215^{a}	2135^{a}	2041^{a}	2197^{a}	2245^{a}	449.6
3/29/04	2747^{a}	2400^{a}	2494^{a}	2124^{a}	2037^{a}	2037^{a}	231.2
4/20/04	2492^{a}	2496^{a}	2257^{a}	2321^{a}	2255^{a}	2732^{a}	249.4

[a-b]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 3. Least squares means of available forage (kg/ha) for years 1 and 2 fall/winter and spring grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	**Clover[2]**	**Fall/Winter[3]**	**SE**	**Spring[4]**	**SE**
Ky-31 E+	None	2650^{a}	246	2728^{a}	112
Ky-31 E+	Regal	2611^{a}	246	2549^{ab}	112
Ky-31 E+	Patriot	2547^{a}	246	2379^{b}	122
Jesup MaxQ	None	2398^{a}	246	2449^{ab}	112
Jesup MaxQ	Regal	2523^{a}	246	1939^{c}	122
Jesup MaxQ	Patriot	2710^{a}	246	2386^{b}	112

[a-c]Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.

[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

[3]Fall/winter grazing seasons combined from 2002-2003.

[4]Spring grazing seasons combined from 2003-2004.

Table 4. Least squares means of nutrient composition data for years 1 and 2 fall/winter grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	Clover[2]	NDF	SE	ADF	SE	CP	SE
Ky-31 E+	None	57.1[a]	2.65	28.6[a]	1.79	16.6[a]	1.11
Ky-31 E+	Regal	57.5[a]	2.83	28.7[a]	1.91	16.1[a]	1.19
Ky-31 E+	Patriot	57.0[a]	2.65	28.7[a]	1.79	16.7[a]	1.11
Jesup MaxQ	None	57.2[a]	2.65	28.6[a]	1.79	17.2[a]	1.11
Jesup MaxQ	Regal	58.4[a]	2.65	30.1[a]	1.79	17.0[a]	1.11
Jesup MaxQ	Patriot	57.6[a]	2.65	29.9[a]	1.79	17.5[a]	1.11

[a]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 5. Least squares means of nutrient composition data for years 1 and 2 spring grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	Clover[2]	NDF	SE	ADF	SE	CP	SE
Ky-31 E+	None	59.9[a]	2.25	28.7[a]	1.22	18.4[a]	1.22
Ky-31 E+	Regal	59.4[a]	2.17	28.8[a]	1.18	17.3[a]	1.18
Ky-31 E+	Patriot	56.5[a]	2.33	27.3[a]	1.26	19.3[a]	1.26
Jesup MaxQ	None	59.3[a]	2.17	28.3[a]	1.18	18.2[a]	1.17
Jesup MaxQ	Regal	56.3[a]	2.25	26.9[a]	1.22	20.1[a]	1.22
Jesup MaxQ	Patriot	57.7[a]	2.25	27.7[a]	1.22	20.0[a]	1.22

[a]Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.

[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 6. Least squares means of average daily gains (kg/d) for years 1 and 2 fall/winter grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	Clover[2]	2002	SE	2003	SE	2002-2003	SE
Ky-31 E+	None	0.36^{a}	0.05	0.31^{b}	0.04	0.33^{a}	0.03
Ky-31 E+	Regal	0.31^{a}	0.05	0.34^{ab}	0.04	0.33^{a}	0.03
Ky-31 E+	Patriot	0.26^{a}	0.05	0.39^{ab}	0.04	0.33^{a}	0.03
Jesup MaxQ	None	0.40^{a}	0.05	0.35^{ab}	0.04	0.37^{a}	0.03
Jesup MaxQ	Regal	0.39^{a}	0.05	0.41^{ab}	0.04	0.40^{a}	0.03
Jesup MaxQ	Patriot	0.35^{a}	0.05	0.43^{a}	0.04	0.40^{a}	0.03

[a-b]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 7. Least squares means of average daily gains (kg/d) for years 1 and 2 spring grazing seasons on tall fescue pastures at with and without clovers

Cultivar[1]	Clover[2]	2003	SE	2004	SE	2003-2004	SE
Ky-31 E+	None	0.53[b]	0.10	0.50[d]	0.06	0.51[d]	0.06
Ky-31 E+	Regal	0.49[b]	0.10	0.55[d]	0.07	0.52[d]	0.06
Ky-31 E+	Patriot	0.86[a]	0.10	0.86[c]	0.06	0.86[c]	0.06
Jesup MaxQ	None	1.05[a]	0.10	0.89[c]	0.06	0.96[bc]	0.06
Jesup MaxQ	Regal	1.03[a]	0.10	1.18[b]	0.06	1.12[ab]	0.06
Jesup MaxQ	Patriot	1.07[a]	0.10	1.43[a]	0.06	1.27[a]	0.06

[a-d]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 8. Clover sword percentages in June

Cultivar[1]	Clover[2]	2003	2004
Ky-31 E+	Regal	17.7	5.0
Ky-31 E+	Patriot	37.4	32.5
Jesup MaxQ	Regal	37.4	32.5
Jesup MaxQ	Patriot	37.3	45.0

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]Regal = ladino white clover; Patriot = ladino cross white clover.

Table 9. Least squares means of beef per hectare (kg/ha) for year 1 and year 2 fall/winter grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	Clover[2]	2002	SE	2003	SE	2002-2003	SE
Ky-31 E+	None	265[a]	37.0	155[b]	20.2	202[a]	21.7
Ky-31 E+	Regal	232[a]	37.0	189[ab]	20.2	207[a]	21.7
Ky-31 E+	Patriot	191[a]	37.0	193[ab]	20.2	192[a]	21.7
Jesup MaxQ	None	297[a]	37.0	175[ab]	20.2	227[a]	21.7
Jesup MaxQ	Regal	291[a]	37.0	203[ab]	20.2	241[a]	21.7
Jesup MaxQ	Patriot	256[a]	37.0	214[a]	20.2	232[a]	21.7

[a-b]Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.

[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 10. Least squares means of beef per hectare (kg/ha) for years 1 and 2 spring grazing seasons on tall fescue pastures with and without clovers

Cultivar[1]	Clover[2]	2003	SE	2004	SE	2003-2004	SE
Ky-31 E+	None	226^{b}	42.6	210^{d}	26.9	217^{d}	24.8
Ky-31 E+	Regal	209^{b}	42.6	242^{d}	26.9	229^{d}	24.8
Ky-31 E+	Patriot	367^{a}	42.6	361^{c}	26.9	363^{c}	24.8
Jesup MaxQ	None	452^{a}	42.6	373^{c}	26.9	407^{bc}	24.8
Jesup MaxQ	Regal	441^{a}	42.6	496^{b}	26.9	472^{ab}	24.8
Jesup MaxQ	Patriot	458^{a}	42.6	600^{a}	26.9	539^{a}	24.8

[a-d]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 11. Hair coat scores measured in June from 2003-2004 on tall fescue pastures with and without clover

Cultivar[1]	Clover[2]	2003	SE	2004	SE	2003-2004	SE
Ky-31E+	None	2.0[a]	0.12	2.0[a]	0.11	2.0[a]	0.08
Ky-31E+	Regal	1.9[a]	0.12	1.9[a]	0.11	1.9[ab]	0.08
Ky-31E+	Patriot	1.8[ab]	0.12	1.8[a]	0.11	1.8[b]	0.08
Jesup MaxQ	None	1.2[c]	0.12	1.2[b]	0.11	1.2[c]	0.08
Jesup MaxQ	Regal	1.3[c]	0.12	1.1[b]	0.11	1.2[c]	0.08
Jesup MaxQ	Patriot	1.4[bc]	0.12	1.2[b]	0.11	1.3[c]	0.08

[a-c]Within a column, means without a common superscript letter differ (*P* < 0.05).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte.
[2]None = no clover established in these pastures; Regal = ladino white clover; Patriot = ladino cross white clover.

Table 12. Steer serum prolactin levels measured in June 2003 and June 2004 on tall fescue pastures at medium stocking density with and without clovers

		2003		2004		2003-2004	
Cultivar[1]	**Clover**[2]	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**
Ky-31E+	None	11[c]	28.4	11[d]	38.8	12[c]	23.7
Ky-31E+	Regal	14[c]	28.4	25[d]	38.8	19[c]	27.4
Ky-31E+	GC-89	20[c]	28.4	30[cd]	38.8	25[c]	27.4
Jesup MaxQ	None	250[a]	28.4	244[a]	38.8	235[a]	23.3
Jesup MaxQ	Regal	170[b]	28.4	153[ab]	38.8	162[b]	27.4
Jesup MaxQ	GC-89	178[ab]	28.4	134[bc]	38.8	156[b]	27.4

[a-c]Within a column, means without a common superscript letter differ ($P < 0.05$)

[1]Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ = Kentucky-31 tall fescue with endophyte.

[2]Regal = ladino white clover; GC-89 = ladino cross white clover; None = no clover established

Table 13. Least squares means of available forage (kg/ha) from years 1 to 4 grazing season on tall fescue[1] pastures

Clipping Date	Ky-31 E+ Medium[2]	Ky-31 E+ Low	Jesup MaxQ Medium	Jesup MaxQ Low	Ky-31E+ (old) Medium	Ky-31E+ (old) Low	Jesup E- Low	Ky-31 E- Low	SE
3/31/03	1879^{ab}	2041^{ab}	1753^{ab}	2087^{ab}	1563^{b}	2226^{a}	1795^{ab}	2014^{a}	180
5/13/03	2851^{ab}	2750^{ab}	2767^{ab}	3338^{a}	2607^{ab}	2656^{ab}	2410^{b}	2841^{ab}	245
6/2/03	2407^{b}	2436^{b}	2033^{c}	2823^{a}	2389^{b}	2279^{bc}	2405^{b}	2577^{ab}	109
6/23/03	2717^{a}	2580^{a}	2233^{a}	2495^{a}	2756^{a}	2548^{a}	2507^{a}	2514^{a}	384
11/3/03	2910^{a}	2862^{a}	2716^{a}	2578^{a}	3449^{a}	3325^{a}	2764^{a}	3047^{a}	275
1/7/04	2477^{a}	2193^{a}	2193^{a}	2796^{a}	2420^{a}	2321^{a}	2236^{a}	2151^{a}	415
2/20/04	2184^{a}	1943^{a}	1944^{a}	2623^{a}	2275^{a}	2274^{a}	2235^{a}	2547^{a}	383
3/29/04	2617^{a}	2282^{ab}	2024^{ab}	2320^{ab}	1812^{b}	2200^{ab}	2205^{ab}	2389^{ab}	223
4/20/04	2469^{a}	2541^{a}	2211^{a}	2799^{a}	2244^{a}	2372^{a}	2055^{a}	2558^{a}	246
6/29/04	2530^{c}	3174^{abc}	2727^{bc}	2929^{abc}	2539^{c}	3047^{abc}	3211^{ab}	3436^{a}	199
11/8/04	2957^{a}	2766^{a}	2836^{a}	2619^{a}	2954^{a}	2987^{a}	2602^{a}	2829^{a}	208
1/3/05	2399^{c}	2987^{a}	2422^{c}	2603^{c}	2496^{c}	2958^{ab}	2542^{c}	2680^{bc}	88
2/15/05	1610^{cd}	1809^{a}	1626^{bcd}	1725^{abc}	1539^{d}	1747^{ab}	1584^{d}	1791^{a}	38
3/29/05	1488^{a}	1510^{a}	1523^{a}	1461^{a}	1287^{a}	1506^{a}	1508^{a}	1626^{a}	112
4/18/05	2139^{b}	2300^{ab}	2602^{a}	2348^{ab}	2439^{ab}	2208^{ab}	2312^{ab}	2623^{a}	136
5/9/05	2692^{a}	2739^{a}	2538^{a}	3002^{a}	2672^{a}	2808^{a}	2775^{a}	2936^{a}	165
6/27/05	2037^{a}	2751^{a}	1934^{a}	2370^{a}	1946^{a}	2364^{a}	2217^{a}	2601^{a}	254
11/7/05	2998^{a}	3286^{a}	2739^{a}	3322^{a}	3219^{a}	3286^{a}	2844^{a}	3152^{a}	315
11/29/05	2441^{ab}	3599^{a}	2474^{ab}	2658^{ab}	2305^{b}	2760^{ab}	2818^{ab}	2792^{ab}	390
12/19/05	2473^{a}	2658^{a}	2355^{a}	2446^{a}	2536^{a}	2720^{a}	2355^{a}	2729^{a}	135

$^{a\text{-}d}$Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.

[2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture

Table 14. Least squares means of CP from years 1 to 4 on tall fescue[1] pastures

Grazing Year	Clipping Date	Ky-31E+ Medium[2]	Ky-31E+ Low	MaxQ Medium	MaxQ Low	Ky-31E+(Old) Medium	Ky-31E+(Old) Low	Jesup E- Low	Ky-31E- Low	SE
1	5/13/03	17.2[a]	16.4[a]	16.5[a]	16.0[a]	17.5[a]	16.3[a]	15.9[a]	16.3[a]	0.51
1	6/2/03	16.8[a]	15.7[a]	16.8[a]	15.7[a]	16.6[a]	16.4[a]	15.8[a]	15.6[a]	0.55
1	6/23/03	16.4[a]	15.1[b]	14.8[b]	15.4[ab]	15.6[ab]	15.2[b]	15.7[ab]	15.4[b]	0.33
2	11/3/03	19.9[ab]	19.4[ab]	20.8[a]	19.7[ab]	19.3[ab]	19.5[ab]	18.1[b]	18.1[b]	0.77
2	1/7/04	14.1[a]	14.5[a]	14.7[a]	14.9[a]	14.7[a]	15.1[a]	13.9[a]	14.1[a]	0.42
2	2/20/04	12.8[b]	12.6[b]	13.5[ab]	14.4[a]	14.7[a]	12.9[b]	12.8[b]	12.6[b]	0.45
2	3/29/04	24.9[b]	24.9[b]	25.7[ab]	23.9[b]	28.8[a]	24.7[b]	23.8[b]	23.8[b]	0.95
2	4/20/04	22.5[a]	22.0[a]	20.7[a]	20.0[a]	23.0[a]	22.0[a]	19.8[a]	21.2[a]	1.00
2	6/4/04	14.5[ab]	17.2[a]	13.3[b]	14.2[ab]	14.8[ab]	13.9[b]	13.7[b]	13.2[b]	0.94
3	11/8/04	19.5[a]	17.8[a]	18.5[a]	18.4[a]	18.1[a]	18.4[a]	17.7[a]	18.7[a]	0.77
3	1/3/05	15.1[a]	13.8[ab]	14.4[a]	14.2[ab]	14.7[a]	14.8[a]	12.8[b]	13.7[ab]	0.47
3	2/15/05	13.9[ab]	12.6[b]	14.3[a]	14.1[a]	14.5[a]	13.7[ab]	13.8[ab]	14.1[a]	0.45
3	3/29/05	29.7[a]	29.0[a]	29.3[a]	28.5[ab]	28.3[ab]	28.1[ab]	26.8[b]	28.7[ab]	0.62
3	5/9/05	17.9[abc]	17.1[bc]	18.3[ab]	17.7[abc]	19.2[a]	18.1[ab]	16.5[c]	16.9[bc]	0.48
4	11/7/05	17.5[a]	17.0[a]	17.1[a]	16.6[a]	17.6[a]	17.0[a]	17.0[a]	17.3[a]	0.59
3	11/29/05	18.3[a]	16.8[c]	17.1[bc]	17.6[abc]	17.2[bc]	17.9[ab]	16.9[c]	17.0[c]	0.26
4	12/19/05	17.1[ab]	16.8[ab]	15.2[c]	17.5[a]	16.7[ab]	16.8[ab]	16.1[bc]	17.0[ab]	0.39
4	1/9/06	17.3[a]	15.9[abc]	15.5[bc]	14.9[c]	16.5[ab]	16.4[abc]	15.0[bc]	15.1[bc]	0.48
4	3/27/06	22.0[a]	20.1[ab]	21.7[a]	21.1[ab]	21.5[a]	19.1[b]	21.3[ab]	21.5[ab]	0.75
4	4/18/06	22.6[a]	18.4[a]	21.7[a]	20.7[a]	22.0[a]	21.4[a]	19.4[a]	21.5[a]	1.41
4	5/9/06	17.1[ab]	15.9[ab]	18.4[a]	16.5[ab]	16.3[ab]	16.9[ab]	14.4[b]	16.4[ab]	0.96
4	5/30/06	16.6[a]	17.7[a]	16.0[a]	15.7[a]	15.6[a]	17.6[a]	14.7[a]	14.3[a]	1.08
4	6/20/06	12.4[a]	12.4[a]	11.8[a]	12.8[a]	12.3[a]	11.6[a]	12.3[a]	11.9[a]	0.47

[a-c]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte. [2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture

Table 15 . Least squares means of ADF from years 1 to 4 on tall fescue[1] pastures

Grazing Year	Clipping Date	Ky-31E+ Medium[2]	Ky-31E+ Low	MaxQ Medium	MaxQ Low	Ky-31E+(Old) Medium	Ky-31E+(Old) Low	Jesup E- Low	Ky-31E- Low	SE
1	5/13/03	28.6^{bc}	29.0^{bc}	28.4^{c}	30.5^{a}	28.2^{c}	29.3^{bc}	29.6^{ab}	28.7^{bc}	0.36
1	6/2/03	29.9^{a}	31.6^{a}	29.9^{a}	31.6^{a}	30.4^{a}	32.0^{a}	31.8^{a}	30.7^{a}	0.97
1	6/23/03	30.6^{a}	31.4^{a}	32.5^{a}	32.4^{a}	31.3^{a}	30.3^{a}	31.9^{a}	31.0^{a}	0.84
2	11/3/03	21.9^{a}	23.1^{a}	21.3^{a}	21.8^{a}	24.0^{a}	23.7^{a}	22.3^{a}	22.2^{a}	1.17
2	1/7/04	29.7^{ab}	27.7^{c}	29.8^{ab}	28.6^{bc}	31.1^{a}	28.3^{bc}	28.9^{bc}	29.2^{bc}	0.52
2	2/20/04	35.4^{ab}	33.9^{bc}	36.0^{a}	33.1^{c}	35.2^{ab}	35.2^{ab}	33.9^{bc}	33.9^{bc}	0.57
2	3/29/04	24.3^{abc}	24.9^{ab}	21.5^{bc}	25.2^{ab}	20.6^{c}	25.2^{ab}	25.4^{a}	23.9^{abc}	1.17
2	4/20/04	23.8^{a}	25.8^{a}	24.7^{a}	25.7^{a}	24.1^{a}	25.0^{a}	26.6^{a}	23.9^{a}	1.53
2	6/4/04	32.8^{a}	32.9^{a}	34.1^{a}	33.3^{a}	33.8^{a}	33.6^{a}	34.1^{a}	32.7^{a}	0.70
3	11/8/04	24.5^{b}	27.3^{a}	25.5^{ab}	25.6^{ab}	26.5^{ab}	25.9^{ab}	25.9^{ab}	25.6^{ab}	0.81
3	1/3/05	32.0^{a}	32.8^{a}	32.3^{a}	31.6^{a}	32.5^{a}	32.8^{a}	32.7^{a}	32.2^{a}	0.67
3	2/15/05	36.1^{ab}	36.9^{a}	35.8^{ab}	36.3^{ab}	36.3^{ab}	35.7^{b}	36.6^{ab}	35.7^{b}	0.35
3	3/29/05	20.3^{a}	21.6^{a}	22.7^{a}	21.0^{a}	22.7^{a}	22.3^{a}	22.6^{a}	20.4^{a}	1.61
3	5/9/05	29.3^{a}	26.4^{b}	26.4^{b}	25.7^{b}	27.3^{ab}	27.0^{ab}	28.1^{ab}	27.5^{ab}	0.86
4	11/7/05	25.9^{a}	27.7^{a}	28.7^{a}	27.5^{a}	26.8^{a}	28.1^{a}	25.7^{a}	25.8^{a}	1.49
3	11/29/05	25.9^{b}	28.1^{ab}	29.4^{a}	27.0^{ab}	29.5^{a}	27.3^{ab}	27.7^{ab}	27.7^{ab}	0.76
4	12/19/05	26.2^{bc}	24.5^{c}	31.4^{a}	26.0^{bc}	28.6^{ab}	25.7^{bc}	25.3^{c}	24.5^{c}	0.91
4	1/9/06	30.6^{c}	31.5^{c}	35.0^{a}	34.0^{ab}	31.6^{c}	32.4^{bc}	32.4^{bc}	32.9^{abc}	0.71
4	3/27/06	20.9^{c}	25.0^{ab}	21.7^{bc}	21.6^{bc}	24.0^{abc}	25.7^{a}	21.9^{abc}	21.0^{c}	1.17
4	4/18/06	24.1^{ab}	29.0^{a}	24.4^{ab}	24.8^{ab}	24.7^{ab}	26.0^{ab}	26.6^{ab}	23.4^{b}	1.50
4	5/9/06	30.3^{a}	31.7^{a}	28.1^{a}	30.6^{a}	30.7^{a}	29.9^{a}	31.8^{a}	29.1^{a}	1.55
4	5/30/06	31.9^{a}	30.3^{a}	30.9^{a}	32.4^{a}	32.4^{a}	29.7^{a}	32.4^{a}	32.4^{a}	1.09
4	6/20/06	34.2^{b}	34.0^{b}	34.4^{ab}	36.1^{a}	35.5^{ab}	35.0^{ab}	35.7^{ab}	35.5^{ab}	0.56

$^{a\text{-}c}$Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte. [2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture

Table 16. Least squares means of NDF from years 1 to 4 on tall fescue[1] pastures

Grazing Year	Clipping Date	Ky-31E+ Medium[2]	Ky-31E+ Low	MaxQ Medium	MaxQ Low	Ky-31E+(Old) Medium	Ky-31E+(Old) Low	JesupE- Low	Ky-31E- Low	SE
1	5/13/03	60.5[bc]	61.0[bc]	60.8[bc]	64.1[a]	60.1[c]	62.1[abc]	62.6[ab]	60.5[bc]	0.67
1	6/2/03	62.0[a]	65.1[a]	62.5[a]	65.0[a]	62.5[a]	64.2[a]	65.4[a]	63.8[a]	1.26
1	6/23/03	63.6[a]	64.9[a]	65.7[a]	65.9[a]	63.5[a]	63.5[a]	65.3[a]	64.5[a]	1.05
2	11/3/03	50.2[a]	51.3[a]	49.6[a]	50.6[a]	52.3[a]	52.3[a]	51.7[a]	51.4[a]	1.42
2	1/7/04	60.2[ab]	57.1[c]	60.3[ab]	59.3[abc]	61.3[a]	57.3[bc]	59.8[abc]	60.1[abc]	0.93
2	2/20/04	67.1[ab]	65.2[ab]	68.0[a]	64.4[b]	66.0[ab]	66.5[ab]	66.1[ab]	66.2[ab]	0.92
2	3/29/04	50.5[ab]	51.2[ab]	47.9[ab]	52.5[a]	46.8[b]	51.7[ab]	52.9_a	50.4[ab]	1.65
2	4/20/04	51.9[a]	53.6[a]	54.2[a]	54.9[a]	52.4[a]	53.5[a]	55.8[a]	52.1[a]	1.68
2	6/4/04	67.8[ab]	65.3[b]	69.0[ab]	68.1[ab]	67.2[ab]	67.6[ab]	69.7[a]	67.7[ab]	1.15
3	11/8/04	53.8[a]	57.6[a]	56.0[a]	55.4[a]	57.1[a]	56.4[a]	57.2[a]	55.9[a]	1.26
3	1/3/05	62.9[a]	64.6[a]	64.3[a]	63.5[a]	63.7[a]	63.6[a]	64.8[a]	64.2[a]	0.70
3	2/15/05	68.9[ab]	70.2[a]	68.1[b]	69.3[ab]	68.3[ab]	68.3[ab]	69.1[ab]	67.9[b]	0.58
3	3/29/05	46.0[a]	47.7[a]	47.6[a]	47.3[a]	49.3[a]	48.4[a]	49.1[a]	45.8[a]	1.42
3	5/9/05	59.0[a]	56.8[abc]	56.5[abc]	55.9[bc]	55.3[c]	56.6[abc]	59.1[a]	58.3[ab]	0.88
4	11/7/05	51.6[a]	53.9[a]	55.4[a]	55.3[a]	51.9[a]	55.1[a]	52.6[a]	52.3[a]	1.98
3	11/29/05	51.9[c]	54.8[ab]	57.3[a]	53.7[bc]	55.9[ab]	53.6[bc]	55.1[ab]	55.1[ab]	0.85
4	12/19/05	52.7[b]	50.6[b]	61.8[a]	52.1[b]	54.6[b]	51.0[b]	52.9[b]	51.4[b]	1.39
4	1/9/06	56.8[e]	58.3[de]	65.3[a]	62.4[b]	57.9[de]	59.4[cd]	61.6[bc]	62.1[b]	0.76
4	3/27/06	46.0[c]	51.0[ab]	47.2[bc]	47.5[bc]	49.5_{abc}	52.2[a]	47.9[abc]	45.6[c]	1.33
4	4/18/06	52.5[a]	57.0[a]	53.4[a]	54.2[a]	52.4[a]	54.1[a]	56.1[a]	52.0[a]	1.62
4	5/9/06	62.5[a]	63.2[a]	59.3[a]	63.4[a]	61.8[a]	61.2[a]	65.0[a]	61.8[a]	1.88
4	5/30/06	63.4[a]	60.4[a]	62.7[a]	65.1[a]	63.5[a]	60.3[a]	65.6[a]	65.1[a]	1.76
4	6/20/06	67.6[a]	67.6[a]	67.7[a]	69.5[a]	67.4[a]	68.7[a]	69.4[a]	70.2[a]	0.99

[a-c]Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte. [2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture

Table 17. Least square means of average daily gains (kg/d) from 2002-2005 fall/winter grazing season on tall fescue pastures

Cultivar[1]	Stocking Rate[2]	2002	SE	2003	SE	2004	SE	2005	SE	2002-2005	SE
Ky-31 E+	Medium	0.79^{b}	0.15	0.69^{c}	0.07	0.49^{ab}	0.12	1.04^{bc}	0.14	0.76^{bc}	0.10
Ky-31 E+	Low	0.88^{b}	0.18	0.88^{abc}	0.10	0.21^{ab}	0.16	0.81^{c}	0.19	0.70^{bc}	0.14
MaxQ	Medium	0.88^{b}	0.15	0.78^{bc}	0.07	0.45^{ab}	0.11	0.91^{bc}	0.14	0.74^{bc}	0.10
MaxQ	Low	0.96^{b}	0.21	1.11^{a}	0.10	0.53^{ab}	0.16	1.63^{a}	0.19	1.02^{b}	0.15
Ky-31E+(Old)	Medium	0.57^{b}	0.15	0.65^{c}	0.07	0.26^{b}	0.11	0.84^{c}	0.14	0.58^{c}	0.10
Ky-31E+(Old)	Low	0.92^{b}	0.21	1.05^{a}	0.10	0.61^{ab}	0.16	0.73^{c}	0.19	0.82^{bc}	0.15
Ky-31 E-	Low	4.90^{a}	0.26	1.02^{ab}	0.10	0.75^{a}	0.16	1.21^{abc}	0.19	1.55^{a}	0.15
Jesup E-	Low	1.06^{b}	0.21	0.88^{abc}	0.10	0.62^{ab}	0.16	1.38^{ab}	0.19	0.98^{b}	0.15

[a-c]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.
[2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture.

Table 18. Least square means of average daily gains (kg/d) from 2003-2006 spring grazing season on tall fescue pastures

Cultivar[1]	Stocking Rate[2]	2003	SE	2004	SE	2005	SE	2006	SE	2003-2006	SE
Ky-31E+	Medium	1.16^{b}	0.14	1.10^{b}	0.15	1.20^{e}	0.15	1.39^{de}	0.17	1.20^{d}	0.08
Ky-31E+	Low	1.00^{b}	0.18	1.07^{b}	0.21	1.81^{cd}	0.19	1.71^{cde}	0.17	1.41^{cd}	0.10
MaxQ	Medium	2.31^{a}	0.14	1.96^{a}	0.15	2.22^{bc}	0.15	2.36^{ab}	0.13	2.21^{b}	0.08
MaxQ	Low	2.68^{a}	0.20	2.14^{a}	0.21	2.56^{ab}	0.19	2.36^{ab}	0.15	2.41^{ab}	0.10
Ky-31E+(Old)	Medium	1.38^{b}	0.14	1.08^{b}	0.15	1.69^{d}	0.15	1.78^{cd}	0.13	1.49^{c}	0.08
Ky-31E+(Old)	Low	1.23^{b}	0.20	0.76^{b}	0.21	1.39^{de}	0.19	1.31^{e}	0.17	1.18^{d}	0.11
Ky-31E-	Low	2.45^{a}	0.25	2.31^{a}	0.21	`2.52^{ab}	0.19	2.14^{bc}	0.15	2.32^{ab}	0.11
Jesup E-	Low	2.71^{a}	0.20	1.95^{a}	0.21	2.86^{a}	0.19	2.66^{a}	0.19	2.54^{a}	0.11

[a-b]Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.

[2]Stocking Rate where: Low = 2 – 4 steers per pasture, Medium = 4 – 6 steers per pasture.

Table 19. Least squares means of beef per hectare (kg/ha) from 2002-2005 fall/winter grazing season on tall fescue pastures

Cultivar[1]	2002	SE	2003	SE	2004	SE	2005	SE	2002-2005	SE
Ky-31 E+	238^{a}	35.4	137^{ab}	12.1	77^{a}	18.6	176^{a}	23.5	153^{ab}	13.4
Jesup MaxQ	270^{a}	37.3	158^{a}	12.6	82^{a}	19.4	188^{a}	24.5	170^{a}	14.0
Ky-31 E+ (old)	197^{a}	37.3	136^{ab}	12.6	60^{a}	18.6	145^{a}	23.5	130^{b}	13.7
E-	210^{a}	50.1	106^{b}	15.4	74^{a}	22.8	138^{a}	28.8	124^{b}	17.1

$^{a\text{-}c}$Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.

Table 20. Least squares means of beef per hectare (kg/ha) from 2003-2006 spring grazing season on tall fescue pastures

Cultivar[1]	2003	SE	2004	SE	2005	SE	2006	SE	2003-2006	SE
Ky-31 E+	188^{b}	22.7	189^{b}	23.0	282^{b}	25.5	242^{b}	25.5	221^{b}	13.7
Jesup MaxQ	426^{a}	23.9	340^{a}	24.0	419^{a}	28.8	330^{a}	21.6	373^{a}	13.6
Ky-31 E+ (old)	225^{b}	23.9	169^{b}	24.0	296^{b}	27.6	284^{ab}	22.4	244^{b}	13.7
E-	388^{a}	32.1	271^{a}	29.4	402^{a}	39.0	340^{a}	25.5	344^{a}	16.5

[a-b]Within a column, means without a common superscript letter differ ($P < 0.05$).
[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.

Table 21. Hair coat scores measured in June 2003, June 2004, and June 2006 on tall fescue pastures.

Cultivar[1]	2003	SE	2004	SE	2006	SE	2003-2006	SE
Ky-31 E+	1.9[a]	0.10	1.9[a]	0.08	2.3[a]	0.13	2.0[a]	0.07
Jesup MaxQ	1.2[b]	0.11	1.2[b]	0.08	1.6[b]	0.13	1.4[b]	0.07
Ky-31 E+ (old)	2.2[a]	0.10	1.9[a]	0.08	2.2[a]	0.13	2.1[a]	0.07
E-	1.4[b]	0.15	1.3[b]	0.09	1.5[b]	0.14	1.4[b]	0.08

[a-b]Within a column, means without a common superscript letter differ ($P < 0.05$).

[1]Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E+ (old) = Kentucky-31 tall fescue with endophyte planted in October 1995; E- = Kentucky-31 tall fescue without endophyte and Jesup tall fescue without endophyte.

Table 22. Steer serum prolactin levels measured in June for 2003-2006 on tall fescue.

	2003		2004		2005		2006		2003-2006	
Cultivar[1]	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**	**(ng/mL)**	**SE**
Ky-31E+	9^{b}	28.4	9^{b}	37.0	8.3^{b}	46.1	32^{c}	61.6	12^{b}	21.0
MaxQ	225^{a}	28.4	296^{a}	37.0	148^{a}	46.1	285^{b}	71.1	249^{a}	21.6
Ky-31E+ (Old)	12^{b}	26.3	16^{b}	39.1	9^{b}	43.2	56^{c}	61.6	19^{b}	21.0
E-	156^{a}	49.2	219^{bc}	41.4	218^{a}	46.1	506^{a}	58.0	264^{a}	23.5

[a-e]Within a column, means without a common superscript letter differ ($P < 0.05$)

[1]Jesup E- = Jesup tall fescue without endophyte; Jesup MaxQ = Jesup tall fescue with AR542 endophyte; Ky-31 E- = Kentucky-31 tall fescue without endophyte; Ky-31 E+ = Kentucky-31 tall fescue with endophyte; Ky-31 E+ (Old) = Kentucky-31 tall fescue with endophyte planted in October

VITA

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