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Forage Quality and Performance of Tall Fescue Hay Amended with Broiler Litter and Commercial Fertilizer

Stacy L. Clark

University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Stacy L. Clark entitled "Forage Quality and Performance of Tall Fescue Hay Amended with Broiler Litter and Commercial Fertilizer." 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 Environmental and Soil Sciences.

Forbes R. Walker, Major Professor

We have read this thesis and recommend its acceptance:

Mark Radosevich, Warren Gill

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor and Dean of
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Stacy L. Clark
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Abstract

Broiler chickens are a leading agricultural commodity in Tennessee. Many broiler operations are located in eastern and middle Tennessee where a common land use is tall fescue (Festuca arundinacea Schreb.) hay and pasture, for cow-calf and dairy operations. Litter from broiler operations is land applied on fescue at rates that often exceed the recommended phosphorus (P) and potassium (K) rates. Surveys of forage quality conducted by the University of Tennessee Extension in 2001 found that many forages across the state had higher than recommended K and sulfur levels and were deficient in copper (Cu) and other nutrients. In spring 2004 a two-year study initiated at the Research and Education Center at Greeneville, TN evaluated the performance and forage quality of tall fescue hay amended annually with 3 rates of broiler litter (2.3, 6.8, and 11.3 Mg/ha) and 2 commercial fertilizer rates (a recommended rate, 114-30-28 kg/ha of NPK; and a commonly used rate 65-29-54 kg/ha of NPK). The study was conducted on a Dewey silt clay loam (fine, kaolinitic, thermic, Typic Paleudult), severely eroded soil (12 to 25 percent slope). Mehlich I soil analysis indicated increased phosphorus (P) and increased zinc (Zn) levels after application and harvest. All plots were harvested in May 2004, September 2004, and May 2005. Forage analysis was conducted to determine the nutrient content in the fescue. Dry matter yields of higher quality forage were obtained using high litter rates (11.3 Mg/ha) and the recommended fertilizer rate. In 2004 and 2005, Cu, Na, and Zn levels were below and (S) sulfur levels above National Resource Council (NRC) recommendations for beef cattle, while Ca and Mg were above recommendations. Using high litter applications (11.3 Mg/ha) resulted in K levels at or above maximum tolerable concentration (30 g/kg) critical for beef cattle in May 2004 and 2005.

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Chapter 1. Introduction

Broiler Litter Production in Tennessee and Southeastern United States

The broiler industry generates over $322 million dollars in Tennessee, making it one of the largest sectors of Tennessee's agricultural economy (USDA, 2004). Many of the state's broiler operations are located in eastern and middle Tennessee, where a common land use is tall fescue (Festuca arundinacea Schreb) hay and pasture, for cow-calf and dairy operations. Broiler operations in the southeastern United States vary in size and land access.   Most broiler operations are independently owned and operated under contract with poultry companies for growing broilers.

In Tennessee, the estimated broiler population for 2004 was approximately 196 million birds (USDA, 2005) resulting in the production of large quantities of litter. Associated within these high bird densities are large quantities of litter produced. Kpomblekou-A et al., 2002 estimated that United States broiler farms alone produce 10 million metric tons of litter annually or 1.5 kg litter excreted per year for every bird. Litter is composed of bird droppings and bedding material such as wood chips mixed with feathers, drug residues, and unconsumed feed. The increasing cost of replacing bedding material affects the frequency of litter removal from Tennessee poultry houses.

Disposal and handling of the mass litter produced is a primary concern for the industry since it is concentrated in only a few Tennessee counties. Other concerns are that many producers have limited land area for litter disposal, transportation costs are increasing, and urban growth within many Tennessee poultry counties. Management concerns include storage, method of litter disposal, and in-house ammonia emissions.   A common practice among producers is to broadcast litter onto adjacent fescue pastures as a fertilizer source. Broiler litter contains many important plant nutrients including nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), zinc (Zn), copper, iron (Fe), manganese (Mn), and sulfur (S). The nutrient content of broiler litter varies from state to state depending feed, and litter type (Table 1).

Nutrient concentrations from broiler litter vary with different bedding materials, feedstuffs, pharmaceuticals, and water used in poultry houses. The overapplication of broiler litter and commercial fertilizer will over apply important nutrients such as P and K as well as many micronutrients (Cu, Zn, Mg, Fe, and Mo). The overapplication of K and S onto fescue pastures leads to forage imbalances and animal health problems (Gill et al., 2004). The overapplication of broiler litter also affects forage quality of tall fescue by decreasing its nutritive value. By definition, nutritive value includes protein, nutrient concentrations, energy consumption, energy availability, and efficiency of energy utilization.

Table 1. Comparison of Typical Litter Nutrient Contents in North Carolina and Georgia.

	North Carolina	Georgia
Nitrogen	36 g/kg total N (71 lbs/ton total N)	32 g/kg total N (64 lbs/ton total N)
Phosphorus	15 g/kg total P (30 lbs/ton total P or 68 lbs/ton P2O5)	12 g/kg total P (24 lbs/ton total P or 55 lbs/ton P2O5)
Potassium	19 g/kg total K (38 lbs/ton total K or 46 lbs/ton K2O)	20 g/kg total K (38 lbs/ton total K or 46 lbs/ton K2O)

(NRAES, 1999; Barker, 1994), (Harris et al., 2001)

Factors reducing forage quality include K luxury uptake from increased soil test levels, dilution of nutrients from excess growth, and seasonal changes affecting plant maturity. Potassium luxury uptake from excessive fertilizer use leads to Mg and Cu deficiencies. Some forage grasses will readily use more K than is needed for maximum yields. Potassium concentrations in excess of the maximum tolerable concentration of 30 g/kg will affect the uptake of other essential nutrients for cattle health (Whitehead, 2000; NRC, 1996). Dilution effects occur when excess plant growth may be attributed to fertilizer use. Seasonal changes may affect plant growth by translocating nutrients to different plant tissues during plant growth stages.

In 1999, NAHMS (National Animal Health Monitoring Network System) described many nutrition deficiencies and imbalances among southeastern cattle populations (Mortimer et al., 1999). Symptoms of these imbalances included rough hair coats, decreased reproduction, and reduced immune system functions within local cattle herds. Increased awareness among animal scientists and producers has prompted further investigation of nutrient deficiencies in Tennessee.

Forage surveys of tall fescue samples taken from 72 Tennessee counties in 2001 and 2002 revealed nutrient deficiencies of Mg, Cu, and Zn along with increased antagonistic levels of S and K (Gill et al. 2005). Surveys from 2003 and 2004 gave results similar to 2001 and 2002. Research predating the 2001-2004 Tennessee surveys correlates Cu deficiencies with the fungal endophyte, Neotyphidium coenophilum, in tall fescue pastures (Dennis et al., 1998). Cattle grazing in sampled pastures showed abnormal hair coats, enlarged hardened joints, bad eyes, and low serum blood levels of copper (Fisher et al., 2003).

Concerns and Objectives

Overpplication of P on fescue pastures can impact surface water quality. Phosphorus is a threat to environmental quality when in particulate form sorbed to sediment or in soluble form in storm water runoff. Phosphorus in runoff can result in eutrophication in nearby water ways (Sharpley, 1997). Alum (aluminum sulfate) is often applied as an in-house litter treatment to reduce ammonia emissions and will reduce P solubility (Smith et al., 2004) reducing P in stormwater runoff. Detrimental effects of alum occur only when soil pH is less than 5.5 increasing solubility (Sims and Luka-McCafferty, 2002). When in a soluble form, increased aluminum (Al) toxicity to crops and livestock may occur (Sims and Luka-McCafferty, 2002; NRC, 1996).

The objectives of this research were to quantify the effects of broiler litter and commercial fertilizer applications on forage yield and quality, and soil nutrient concentrations.

Specific objectives were to:

Objective 1) Compare the use of alum-treated litter and untreated broiler litter on yield, forage quality, and K/(Mg +Ca) ratios.

Objective 2) Compare the use of a typical producer fertilizer rate compared to the recommended rate of University of Tennessee Extension and their effects on yield, forage quality, and K/(Mg +Ca) ratios.

Objective 3) Compare the effects of both broiler litter and fertilizer applications on soil pH, P, K, Ca, Cu, and Zn.

Chapter 2. Literature Review

Tall Fescue and the Fungal Endophyte, Neotyphidium coenophialum

Pastures and hayfields in Tennessee are dominated with endophyte infected tall fescue (Festuca arundinacea Schreb). Tall fescue is an important cool-season grass for the turf and forage industry (Thompson and Kennington, 2001). Tall fescue grows during the cooler portions of spring and undergoes semi-dormancy later in summer. Growth resumes in the fall (Burns et al., 1979). An optimum growing temperature for tall fescue is between 15°C and 24°C (60°F and 75°F). Fescue will typically grow to heights of 60 to 122 cm (2 to 4 feet).

Tall fescue often forms associations with the fungal endophyte, Neotyphidium coenophialum that resides in the tall fescue plants. This mutualistic association improves insect resistance and drought tolerance in tall fescue (Bacon, 1994). Other benefits to the plants include the sequestering of Al with root exudates, and increasing root hair surface area for greater P acquisition in P deficient soils (Malinowski and Belesky, 1999a; Malinowski and Belesky, 1999b; Zaurov et al. 2001). The endophyte produces alkaloid compounds as defensive metabolites that prove toxic to cattle. Toxicity effects in cattle include lowered milk yields, increased body temperature, and decreased average daily gain. In the Nashville Basin area of Tennessee, steers fed a summer diet of endophyte infected tall fescue had reduced growth rates with elevated respiration from increased thermal status (Browning, 2004). Research in Arkansas and Oklahoma showed reduced milk yields and milk quality for cows grazed on tall fescue compared to cows grazed on bermudagrass (Cyndon dactylon) (Brown et al., 2002). Some cattle breeds are more tolerant of endophyte infected tall fescue for example Angus and Brahman reciprocal-cross breeds performed better than purebred Angus and Brahman (Brown and Brown, Jr., 2002).

Nutrient Availability

Tall fescue is tolerant of low soil fertility and acidity, but will have a yield response when appropriate fertilizer amendments are applied (Ball et al. 2002.). Amendments from either broiler litter or commercial fertilizer used on tall fescue pasture the increase nutrient availability of N, P, K, Ca, S, and Mg. Micronutrient availability decreased below pH 6. Most commercial grades of nitrogen fertilizers will increase soil acidity, and thus reduce micronutrient availability.

Fertilizer rates should be based on current nutrient status in pasture soils based on soil testing. When applying animal manures, it is important to know the soil nutrient (P and K) status to prevent nutrition imbalances and minimize the loss of nutrient runoff or leaching. Soil and manure analyses are typically performed by private testing laboratories or through the University of Tennessee Extension. Results from these services will then recommend rates suitable for individual pastures or fields. Recommended rates are developed with the conception of high yields, improved forage quality, maintaining healthy stands of tall fescue; withstand weed encroachment, and providing an economic return (Ball et al., 1996). The recommended rate in this study uses was based on the University of Tennessee Extension recommended rate (114-30-28 kg NPK / ha or 100-60-30 lbs NPK / acre) for tall fescue hay and pasture (Savoy and Joines, 2001). A commonly used rate favored by producers is 341 kg of 65-28-54 kg NPK / ha (300 lbs of 19-19-19 or 57-57-57 lbs NPK / acre). This rate is adequate when soil P and K availability is low and medium, but for high soil P and K soils will overapply P and K increasing the risk of P loss, nutrition imbalances, and luxury uptake of K.

Fescue yields vary with the amounts of NPK applied and geographic location. In Missouri, stockpiling of tall fescue for winter growth promoted yields greater than 2,500 kg/ha with 56 kg N/ha applied as ammonium nitrate (Kallenbach et al., 2003). One Tennessee fertilizer study observed yields between 700 to 1,600 kg/ha when using a complete rate of NPK (67-29-56 kg/ha) and yields greater than 2,200 kg/ha when the NPK fertilizer was increased to (134-58-112 kg/ha) (Reynolds and Wall, 1982). The complete rates provide needed N, P, and K when applied. Yield responses from Georgia and Virginia were different when applying N, P, and K. The rates used in Virginia promote tall fescue growth exceeding 3,000kg/ha using 112 kg N/ha, while the same rate in Georgia had tall fescue growth over 2,700 kg/ha (Hallaock et al. 1965,1966; Dobson and Beaty, 1977).

Land Application of Poultry Litter: Environmental Concerns

The over-application of poultry litter on fescue pastures can result in the excessive transfer of nutrients, especially N and P, to surface water negatively impacting water quality (Sharpley, 1997). Excess phosphorus can result in eutrophication of nearby water bodies reducing dissolved oxygen and killing aquatic organisms. Another water quality impact is transport of fecal pathogens from stormwater runoff (Dai and Boll, 2003.) These impacts from stormwater runoff are increased when poor pasture production and grazing conditions exist. Factors promoting the impacts are soil compaction, reduced vegetative cover, and increased weed populations. When good pasture and grazing management is practiced by low stocking density, grazing pressure is reduced allowing available forage to increase from reduced soil compaction (Ball et al, 1996).

Concerns Regarding Animal Health and Nutrition

The overapplication of commercial fertilizers, animal manures, and poultry litter can influence nutrient composition of forage grasses. High concentrations of S and K in shoots and leaves can suppress the uptake of nutrients such as Ca, Mg, Cu, and Zn. The end result can be forage deficient in some nutrients (Cu, Mg), or forage with an imbalance of nutrients. Nutrient deficiencies and imbalances include grass tetany when excess K interferes with Mg concentrations or when forage Cu is suppressed by S, as observed in a survey of Tennessee fescue (Fisher et al., 2003).

Table 2 shows required nutrients and trace elements required to maintain healthy beef cattle and the major roles each element plays. Table 3 shows typical ranges of the elements considered to be adequate, deficient, and antagonistic for beef cattle nutrition. These ranges of nutrients will vary with pasture conditions depending on soil types. Different soils vary in their fertility, which can affect plant uptake and overall forage nutrient composition. Distribution of nutrients within plant tissues varies with the stage of plant growth and the season. Such distributions are often small or inconsistent with the effects of later plant growth during the growing season. These distribution changes are no doubt related to we factors such as temperature, precipitation, and light intensity (Whitehead, 2000). Forages with deficiencies or nutrient imbalances can decrease

Table 2. Nutrients and trace elements and significant body functions for improved cattle health.

Nutrient	Significant Functions
Ca	Bone and Teeth Formation, nerve and muscle function
P	Reproduction, health of bones and teeth
Mg	Growth, reproduction, metabolic functions
K	Metabolic functions
S	Metabolic functions, amino acid formation in rumen
Cu	Immune response, glucose tolerance factor
Mn	Reproduction enzyme formation
Se	Antioxidant, glutothione peroxidase
Zn	Enzyme activity

Gill et. al, 2004.

Table 3. Nutrients, trace elements, and antagonist classification within forages.

Trace minerals	Deficient	Marginally Deficient	Adequate	MTCb
Aluminum, mg/kg				1000
Copper, mg/kg	<4	4-9	>9	100
Zinc, mg/kg	<20	20-29	>29	500
Manganese, mg/kg	<20	20-29	>39	1000
Selenium, mg/kg	<0.1	0.10-0.20	>0.20	2

		Antagonistic level			
Antagonists	Deficient	Ideal	Marginal	High	MTCb
Sulfur, g/kg	<1	1-2	2.1-3.0	3.1-3.9	>3.9
Potassium, g/kg					>30

Mortimer et al., 1999; NRC, 1996; Gill et al., 2004.
Maximum Tolerable Concentration for Beef Cattle.

production of cattle. Animal physiological factors affecting nutrient requirements include genetics, age, sex, type of production (maintenance, growth, reproduction, and lactation), and level of production (Spears, 2002).

Table 4 summarizes the National Research Council's (NRC) nutrient recommendations for sustained beef nutrition (NRC, 1996). Recent investigations have observed the effects of these nutrition imbalances observed in Tennessee beef grown on tall fescue. A two-year mineral survey conducted by Fisher et al. (2003) observed suppressed Mg concentrations in fescue with K levels greater than 30 g/kg in almost one third of the spring samples taken. Sulfur levels in both years and seasons were marginally antagonistic. Copper levels were below dietary requirements (Fisher et al., 2003). The survey results from Fisher demonstrate that forage nutrient imbalances in grazed tall fescue in Tennessee could be resulting in a lowered immunity for calves on Tennessee farms, resulting in a lower performance compared with farms with better forage quality.

Nutrition imbalances and whole plant nutrient deficiencies on Tennessee farms can be corrected through a herd supplementation program, injections, and improved pasture management. The best corrective measure for mineral nutrient deficiencies within the beef herd is monitoring cattle health effects, forage, and pasture soils. If individual cattle show related health effects then it is recommended that producers blood test for deficient nutrients (Gill et al., 2004). Forage and soils can be monitored with annual lab analyses.

Table 4. Nation Research Council nutrients & trace element requirements for beef cattle.

Requirements				
Nutrients and trace elements	**Growing & Finishing Cattle**	**Cows (544 kg)**		**Maximum Tolerable Concentration**
		Gestating	**Early Lactation**	
Ca, g/kg	3.6	1.5	2.5	*N.A.
Mg, g/kg	1.0	1.2	2.0	4.0
P, g/kg	1.9	0.12	0.17	*N.A.
K, g/kg	6.0	6.0	7.0	3.0
S, g/kg	1.5	1.5	1.5	4.0
Cu, mg/kg	10.0	10.0	10.0	100.0
Se, mg/kg	0.10	0.10	0.10	2.0
Zn, mg/kg	30.0	30.0	30.0	500.0

NRC, 1996, *N.A. =No applicable maximum tolerable concentration

Factors Affecting Nutrient Concentrations of Forage

Soils and forages from different geographic regions across the United States have different concentrations of nutrients or trace elements. These concentrations are often sufficient, but may not have sufficient amounts of Cu, Mg, S, Se, or Zn to meet animal requirements (Mayland and Hankins, 2001). Forage nutrient concentrations are affected by many geographical factors brought on by environment, plant physiology, and management practices. There are several pathways by which nitrogen are lost to the environment from the pastures cattle graze. These loss pathways include: (i) leaching into subsoil or into a field drainage system; (ii) soil erosion by wind or water; and (iii) atmospheric volatilization (Whitehead, 2000). Soil effects include: (i) soil moisture that uses mass flow to carry soluble nutrients towards roots that draw water from soil pores; (ii) diffusion of nutrients from higher concentrated areas to depleted areas near root surfaces; or (iii) root interception of nutrients with continued growth in nutrient deficient soils (Brady and Weil, 1999). Additional factors may include dilution effects from fertilizers reducing nutrient concentrations within plant tissue or removal of large nutrient quantities from harvesting plant biomass at frequent rates (McDowell, 1997).

Influence of Fertilizer N on Forage Nutrient Concentration

Tall fescue has great potential for increased for productivity with the appropriate soil fertility management. In the southeastern states, where summer rainfall is common, N fertilizer application timing will vary during the early part of the season. Increased productivity maybe observed in the early part of the season with increased dry-matter using single or split nitrogen fertilizer applications (Mayland, 1977). Nitrogen may affect concentrations of other nutrients depending on soil availability relative to total plant need of N and other plant nutrients. Ammonium or nitrate ions in soil solution may deplete other nutrient concentrations from increased plant growth. Insufficient N or other plant nutrients used for maximum growth may affect existing tissue concentrations (Wilkinson and Mays, 1979). For example, three N fertilizer rates (0, 56, 168, and 504 kg N/ha) affected nine nutrient concentrations (K, P, Ca, Mg, Mn, Cu, Zn, Mo, and Co) on tall fescue in West Virginia (Reid and Jung, 1965). Investigations found K concentrations increased by 50 percent or more with N fertilization, while P, Ca, and Mg increased slightly or not all during the first cutting. The applied N had little influence on Mn and Zn with inconsistent effects on Cu. Other investigations found that ammonium nitrate alone lowered K concentrations and increased when a complete fertilizer was used (Duell, 1965).

Fertilizer Effects on Phosphorus Composition

Applications of P when applied during the growing season will affect P tissue concentrations. Addition of P on low P soils increased tall fescue leaf concentrations in the early spring growing season and increased total forage production when stockpiled at 28 kg/ha in southwest Missouri. Forage P concentrations declined below 2 g/kg at the beginning of the growing season, and remained above the 2 g/kg recommended for lactating beef cattle in early fall. Tissue P concentrations decreased late in the fall. The researchers hypothesized that tall fescue leaves may translocate P to roots in late fall or winter (Blevins et al. 2004). In another study, soil P increased when 28 kg/ha of P were applied every March during the experiment. Leaf concentrations of tall fescue were easily maintained over 3 g/kg and suitable for lactating beef cattle in early spring. Leaf tissues sampled in the fall also maintained P concentrations over 2 g/kg when P fertilization increased soil P concentrations (Reinbott and Blevins, 1997). Reinbott and Blevins (1997) found that K, Mg, and Ca leaf tissue concentrations increased in early spring with P fertilization (28 kg P/ha) and maintained critical levels throughout early spring. A P rate of 28 kg P/ha maintained leaf Mg, Ca, and K concentrations dietary levels in late fall and early spring, but declines were observed for all three during early winter (Blevins et al., 2004).

Fertilizer Effects on K, Mg, S, and Ca Forage Concentrations

Forage concentrations will increase or decrease in response to fertilizer rates and seasonal changes. In Tennessee different rates of NPK and applied at different times of the year affected forage K, Mg, and Ca concentrations differently. The application of a commercial fertilizer applied every August (134-58-112 kg/ha) increased forage yield and K concentrations in several months with little effect on Ca and Mg (Reynolds and Wall, 1982). Reynolds and Wall used a lower commercial fertilizer rate (67-29-56 NPK kg/ha) where Mg and Ca concentrations were similar, but with slightly lower K concentrations. Ammonium nitrate (67 kg/ha) applied in December stimulated winter fescue growth. Compared to using only a complete rate of NPK, ammonium nitrate increased the yield as well as the Mg and Ca concentrations at several sampling dates. With two cold winters and a drier winter than normal, lush forage growth was minimized that kept nutrient concentrations adequate (Reynolds and Wall, 1982). Using Mg fertilizers applied in the fall (112 kg Mg /ha and 181 kg K /ha). Forage Mg concentrations were not affected by Mg fertilization (West and Reynolds, 1984). Magnesium concentrations were suppressed by K concentrations when K fertilizers were used on tall fescue growth. West and Reynolds (1984) investigated the impacts of Al on the incidence of tetany in tall fescue grown in soils with pH of 6.0. Al concentrations in tall fescue tissue were not significant and drastically dropped within a three-month period (1.35 g/kg to 0.25 g/kg). Magnesium fertilization had no antagonistic effect on K uptake, but K fertilization produced high K concentrations (greater than 20 g/kg in early spring) keeping Mg below 2 g/kg. Potassium most likely competed with Mg ions during uptake. Fertilizer treatments had no affect on plant tissue Ca concentration (West and Reynolds, 1984).

Sulfur concentrations in grass vary when applied with N fertilizers. Forage S concentrations have been reduced when forage S already low (Goh and Kee, 1978), but may increase S when supplies are plentiful (Salette, 1978). Sometimes there is little or no effect (Rahman et al. 1960). In the United Kingdom, fertilizer N increased forage S at the first seasonal harvest and later decreased possibly when S inputs (i.e. atmosphere and fertilizer use) are lower in summer compared to spring (McLaren, 1976; Hopkins et al., 1994).

Nutrition Imbalances Causing Grass Tetany

One of the most researched grass deficiencies among beef cattle is grass tetany. Symptoms of grass tetany in beef cattle are undue excitement, uncoordination, muscle twitching, teeth grinding, general tetanic contractions, labored breathing, pounding heartbeat, convulsions, and mortality (Fontenot, 1979.) Grass tetany results from lower

Mg levels relative to forage K and Ca. Overapplication of K suppresses Mg and Ca uptake. Forages nutrients identified at risk for grass tetany are concentrations of Ca below 4 g/kg and Mg below 2 g/kg (Mayland and Grunes, 1979). These critical levels are just indicators that pastures or fields maybe at risk. Cows with low blood serum Mg levels below 18 ppm or with a high K/(Mg + Ca) ratio above 2.2 are diagnostically identified as the animals considered most prone to symptomatic affects of grass tetany (Lock et al. 2004; Cherney et. al., 2002). The K/(Ca+Mg) ratio is a valuable tool since it considers the imbalance of monovalent K ions to divalent Ca and Mg ions (Hank Mayland, USDA-ARS, Kimberly, ID personal communication). The ratio has utility especially when forage Ca concentrations are low, but could be misleading when Ca concentrations are high. Ratios of K/ (Mg + Ca) used by Reynolds on tall fescue in Tennessee never exceeded 2.2, but increased with increasing K fertilization and followed closely the seasonal trend of K (West and Reynolds, 1984).

Pastures heavily laden with various animal manures are at high risk for grass tetany. In Georgia, fourteen cases of grass tetany were observed on broiler litter amended pasture compared to eight cases grazed using a moderate N fertilizer rate of 224 kg N ha/year. No cases were observed on pasture fertilized with a low N fertilizer rate of 84 kg N ha/year. The tall fescue pastures were grazed at 0.4 ha per cow-calf on USDA-ARS land in Georgia (Wilkinson et al., 1979). In a six-year study tall fescue plots in New York fertilized with dairy manure rates of 16.8 and 33.6 Mg/ha (Table 5) showed an increasing risk for tetany, but never exceeded the K/(Ca+Mg) ratio of 2.2 to be considered at risk (Cherney et al. 2002).

Table 5. Nitrogen applied from dairy manure applied at 16.8 and 33.6 Mg/ha in upstate New York.

Year	Total N applied
1994	55 and 111 N kg/ha
1995	123 and 246 N kg/ha
1996	114 and 228 N kg/ha
1997	89 and 178 N kg/ha

(Cherney et al. 2002)

Factors effecting Mn and Zn concentrations

Nitrogen fertilizer can reduce pH and influence Mn and Zn concentrations bioavailability (Whitehead, 2000). Manganese and Zn availability is greater with decreasing pH. Manganese uptake by plants will increase with increasing acidity and when N is applied as an acidifying fertilizer like calcium sulfate (Whitehead, 1995). Additionally, basic cations (Mg, K, Na, or Ca) can be leached out of the soil solution and freeing up exchange sites for Zn and Cu absorption. Seasonal effects brought on by weather conditions will effect Zn availability. In Pennsylvania, tall fescue Zn concentrations decreased from May to October with concentrations below 30 g/kg required for beef cattle (Belesky and Jung, 1982). Belesky suggests with seasonal changes that Zn availability is affected when solubility is limited.

Copper status in response to endophyte and N fertilization

Nutrient status of Cu in tall fescue pastures is partly influenced by the endophyte, *Neotyphidium coenophialum*, putting cattle at risk of a Cu deficiency. Forage Cu concentrations respond to nitrogen fertilization are influenced by soil pH. Research in Virginia showed Cu concentrations increased linearly in tall fescue when applied with 0, 40, and 80 kg N/ha (Dennis et al., 1998). Both endophyte infected (E+) and endophyte free (E-) tall fescue showed differences in Cu concentrations. Concentrations were significantly lower in E+ compared to E- at each level of N fertilizer (Dennis et al., 1998). Concentrations of Cu were still below 10 mg/kg and borderline deficient (Gill et al., 2004; NRC, 1996). Other research from Virginia showed fungal endophytes compromised the immune system of young steers (Saker et al., 1998). Forage Cu concentrations from this study averaged 5.9 mg/kg when steers grazed endophyte infected tall fescue that did not satisfy recommended Cu requirements (10 mg/kg) for beef cattle (Saker et al., 1998, NRC, 1996).

Cattle Health and Appearance on Nutrient Deficient Forage

Cattle grazing copper deficient fescue have rough hair coats that shed poorly. In Angus cattle these hairs coats will appear bronze or have a rusty colored appearance (Figure 1), while hair on polled Hereford breeds have bleached out appearances (Oliver et al., 2000). Cattle with these effects may exhibit low blood serum levels of Cu. In Tennessee steers grazing endophyte infected tall fescue had blood serum levels 0.62 ppm (marginally deficient) compared to steers that grazed endophyte free fescue, which had blood levels of 0.72 ppm (borderline normal) (Oliver et al., 2000).

Copper deficiency in forage, especially in tall fescue (whether it is endophyte free or infected), is related to soil fertility.

Figure 1. Angus steers with both a normal hair coat and a bronze colored hair coat (right) resulting from a Cu nutrient deficiency. (Photo Courtesy of W. Gill).

Fields that have received long-term applications of N, P, and K are likely to be Cu deficient. Copper concentrations can be increased with animal manure applications, but fertilizer applications can result in forage nutrient imbalances. Without annual long-term fertilizer applications soil Cu concentrations will not be replenished. Copper uptake can be either suppressed or antagonized by changes in other forage nutrient concentrations from long-term fertilization practices. Nutrient antagonists of Cu include Mo, S, and Fe (Gill et al. 2004). Gill suggested this when S concentrations greater than 2.1 g/kg decreased low concentrations of Cu during a recent survey (Gill et al. 2005).

Existing copper concentrations in new forage tissues can be deficient as a result of soil conditions, management practices, and plant species (Gartrell, 1981). Such factors might include:

i) Low available copper in the soil or restricted root development of where copper is present in soil root zones.

ii) Inability of plant roots to absorb Cu.

iii) Limited copper movement within the plant.

iv) High plant demand for Cu due to prolific and rapid growth of plant tissue.

Selenium Deficiencies

Selenium is an important trace element for beef producers and can result in nutrition imbalances for cattle grazing or fed Se deficient hay. Selenium is essential for growth and fertility in livestock and is responsible for the prevention of various diseases (Underwood and Suttle, 1999). Symptoms for beef cattle experiencing Se deficiency range from compromised immune systems to retained placenta within the cow (Gill et al., 2004). National Research Council recommended levels for Se in forage are 0.10 mg/kg and blood serum levels considered deficient range between 0.002 to 0.025 ppm (NRC, 1996; Gill et al. 2005).

Selenium availability is present in many forms, but predominates in the selenite ($SeO3$), selenate ($SeO4$), and elemental form (Se). Selenate forms are highly soluble and very mobile, similar to sulfate, requiring positive surface for retention while predominating in soils with alkaline and oxidizing conditions. Selenate forms often absorbed more by plants than selenite (Hank Mayland, personal communication). Selenite absorption decreases with increasing soil pH above 6, and is predicted to predominate in a suboxic soil zones (Essington, 2004). Selenite is strongly adsorbed to soil particles when these conditions are acidic

Fertilization effects on selenium are inconsistent. In a tall fescue pot experiment, fertilized with cow manure and inorganic Se (1.5 Se mg/kg added), $SeO3$ and $SeO4$

decreased (Ajwa et al., 1998). Ajwa suggests that some Se concentrations may have volatized and some Se did accumulate in the soil with affecting SeO3 and SeO4 forms. Fertilizer N seems to have very little effect on Se concentrations and may even dilute existing plant Se concentrations (Gissel-Nielson et al. 1984). Low soil moisture also reduced Se when tall fescue growth was limited during a greenhouse study conducted by Tennant & Wu (1999).

Managing for forage quality compared to quantity

When applying fertilizer amendments to pasture and hay fields higher yields can be achieved with higher NPK fertilizer rates. However, higher rates of NPK fertilization can lead to a decline in forage quality affecting cattle performance, if N or K is overapplied. High yields of harvested forage may require changing feed requirements for maintaining desired animal performance if forage quality has changed (Norton et al., 1997). Maintaining feed requirements means extra purchasing of grain and protein, which increase producer expense. Low quality hay alone cannot meet changing nutrient requirements for rebreeding and milk for calving during winter months when pasture growth is limited (Ball et al. 2002). Using fertilizer amendments recommended by soil test results or manure analysis can increase hay nutritive value.

Measuring nutritive value

Nutritive value can be determined by proximate analysis and Van Soest wet chemistry methods or using near infrared reflectance spectroscopy (NIRS) (Table 6). The proximate analysis wet chemistry method has over 100 years of use. Analyzed

Table 6. Forage quality parameters evaluated when using Proximate Analysis and Van Soest laboratory methods.

Proximate Analysis	Van Soest Method	
	Soluble Portion	Insoluble Portion
Dry Matter Content		
Crude Protein	Sugars	NDF
Either Extract (lipids and fats)	Starch	ADF
Crude Fiber (cellulose and some lignin)	Pectin	
	Soluble Carbohydrates	
	Protein, Non-protein N	
	Lipids (fats)	
	Lignin	
	Silica, Cellulose, and Hemicellulose	

parameters from proximate analysis can estimate N free extract and total digestible energy (Pioneer Hi-Bred International, 1995). Limitations from proximate analysis are underestimating good quality forages and overestimating poorer quality forage when distinguishing digestible portions of the plant’s cell wall (Pioneer Hi-Bred International, 1995). Proximate analysis can only describe the overall effect of the plant cell wall on digestibility, but using Van Soest method can differentiate individual cell wall components that generate accurate energy estimates over a wide range of forage species and maturities. This method was developed by Peter Van Soest, in the 1960’s at the USDA Beltsville Nutritional research facility and evaluates nutritive value parameters described in Table 6. Wet chemistry methods are well established and maybe preferred over NIRS for forage analysis.

Compared to wet-chemistry methods NIRS is quick and requires less sample preparation for analysis. This method measures reflected light from forage samples in the near infrared region. Specific filters then scan for selected wavelengths. Absorbance from the wavelengths can be correlated to various quality components. Quality components from forage samples are due to the rotational or vibrational energies of hydrogen bonds. These vibrations to other atoms are measured indirectly through the amount of near absorbed radiation.

All three methods described measures the crude fiber portion of the forage samples. The crude fiber composition evaluates the digestible portions of the forage based on cell wall residue. Insoluble portions of crude fiber content determined from the Van Soest method are ADF (acid detergent fiber) and NDF (neutral detergent fiber). Neutral detergent fiber contains cellulose, lignin, and silica portions of the plant cell wall. and increases with advancing maturity reducing digestibility for cattle. NDF is a good indicator of forage intake when feed rations are formulated (Pioneer Hi-Bred International, 1995). ADF is the remaining forage content tested with a detergent under acid conditions (from wet chemistry) and is made up of silica, cellulose, and lignin. Acid detergent fiber is also correlated with forage digestibility effects on cattle.(Pioneer Hi-Bred International, 1995).

From these crude fiber portions; crude protein (CP) and total digestible nutrients (TDN) can be estimated for forage energy or digestibility. However, TDN does not account for energy lost through fermentation and metabolic processes (Pioneer Hi-Bred International, 1995; Jurgens, 1988). Energy losses through metabolic processes are large so improved measures for estimating energy is used to compensate for energy loss. Table 7 describes NRC nutritive value parameters associated with tall fescue in the early stages of growth and later in maturity. Improved energy measurements developed by animal

Table 7. National Research Council nutritive value parameters of 'Kentucky 31' tall fescue harvested in early stages of plant growth compared at later stages maturity (NRC, 1996).

Early Stages of Plant Growth	**Later Stages of Advanced Maturity**
61% TDN	44% TDN
15 % CP	10.8% CP
62% NDF,	70% NDF
1.34Mcal/kg Nem	0.75 Mcal/kg Nem
0.77Mcal/kg NEg	0.22 Mcal/kg NEg

nutritionists include net energy-maintenance (NEM), net-energy gain (NEG) and net energy-lactation (NEL) (Pioneer Hi- Bred International, 1995; Jurgens, 1988).

Fertilizer Effects on Crude Protein

Nutritive value parameters using CP are related to N and responses to N should be expected if fertilizer amendments are used. Research from Georgia in mixed bermudagrass-tall fescue pastures (used for continuous and rotational stocking of steers) showed increases of CP from repeated broiler litter applications over a four-year period (Kuykendall et al., 1999). Litter rates applied ranged from 5.9 to 8.9 Mg/ha (270 to 507 N kg/ha). Nitrogen rates for each year varied probably due to management from litter sources. Average CP value was 184 g/kg exceeding nutritional requirements for growing steers since excessive nitrogen was used.

Crude protein increases can also be expected using inorganic fertilizer N sources. Burns obtained average CP concentrations of 132 g/kg using 67 N kg/ha applied every July if stockpiling tall fescue for winter (Burns and Chamblee, 2000). In Tennessee, CP concentrations were significant during the spring growing season using complete NPK fertilizer rates and ammonium nitrate (Reynolds and West, 1982). Seasonal effects and plant maturity from this experiment, however, kept crude protein concentrations low.

Chapter 3. Materials & Methods

Established stands of tall fescue on a Dewey silt loam (fine, kaolinitic, thermic Typic Paleudult) at the University of Tennessee Research and Education Center at Greeneville (Greeneville, TN) were used for evaluating tall fescue hay amended with broiler litter and commercial fertilizer. The approximate location of the research center is N 36° 06’ and W 82° 51’ with an elevation close to 400 m (USDA-NRCS, 2005). The Dewey soil series is formed over residuum limestone or from alluvial deposited material overlying residuum limestone (USDA-NRCS, 2005). Such limestone areas are indigenous of the Appalachian ridge and valley land resource area of eastern Tennessee. Soils of the Dewey series are on gently sloping or steep uplands with 2 to 40% percent slopes (USDA-NRCS, 2005).

Annual yearly rainfall for the project location ranges from 1,016 to 1,270 mm due to close proximity of the Appalachian Mountains with mean annual air temperature of 12°C (USDOC, 2005). Figures 2 and 3 illustrate weather conditions in Greene County, TN from January 1, 2004 to June 30, 2005 (USDOC, 2005).

Treatment Applications

Nine different fertilizer treatments were applied in a randomized complete block design with four replications. Treatment plots were 18.8 m by 2.1m with a 1.5 m alley between plots maintained by use of tractor and bushog implement. Figure 4 is a schematic of plot layout.

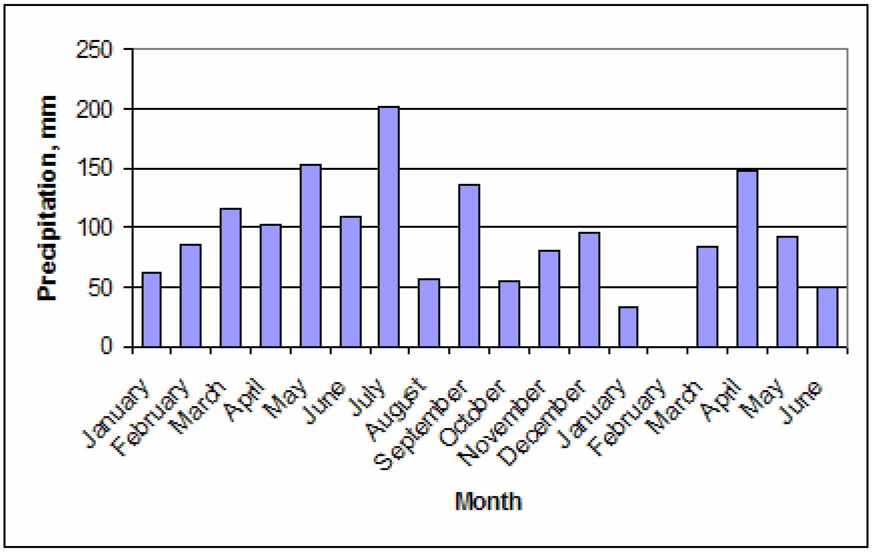

Figure 2. Annual monthly precipitation, Research and Education Center at Greeneville, TN.

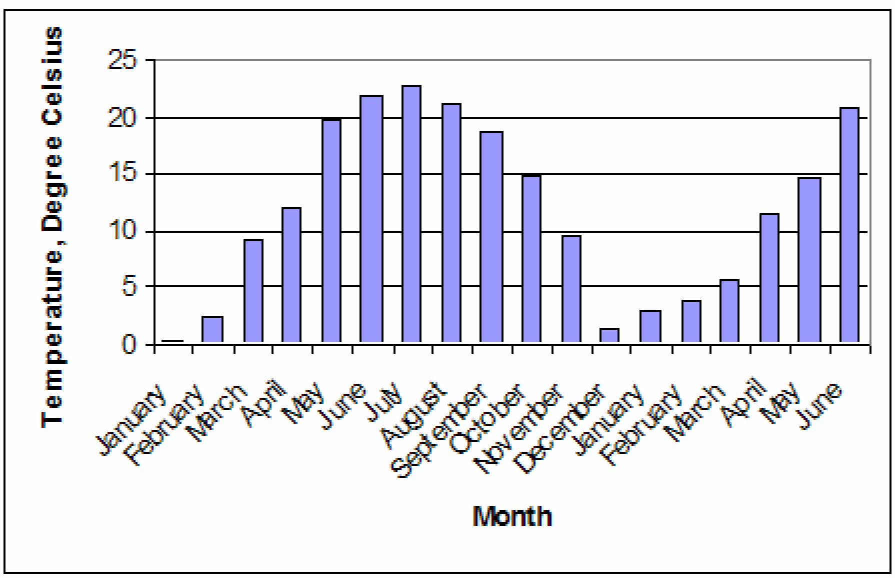

Figure 3. Annual monthly temperature, Research and Education Center at Greeneville, TN.

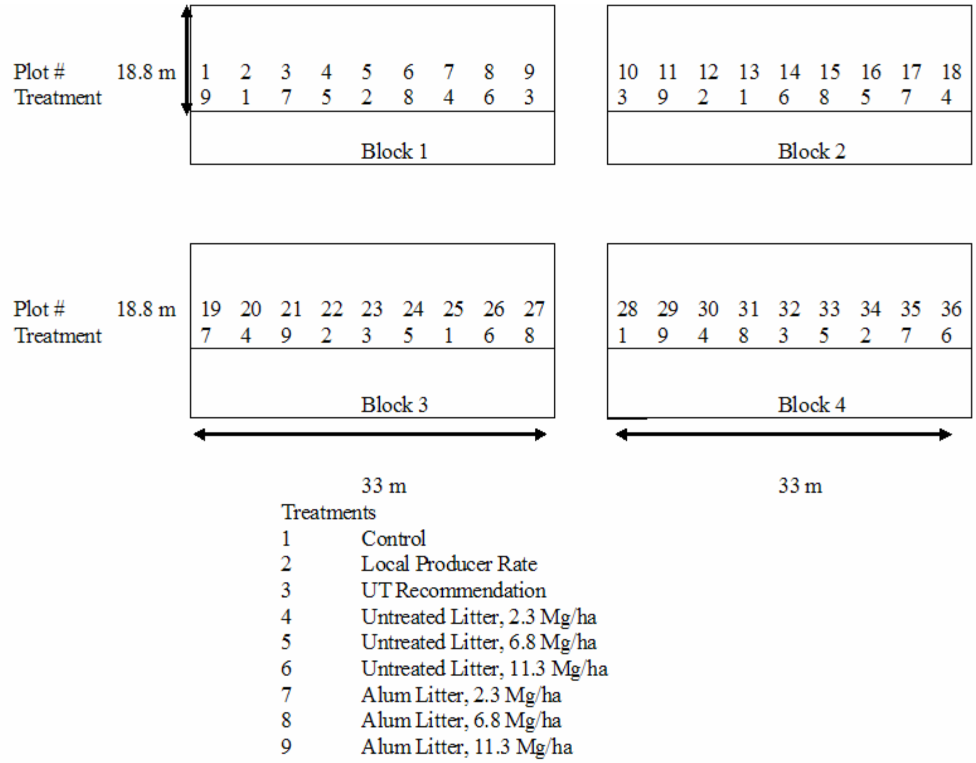

Figure 4. Schematic of plot plan and project layout.

Treatments applied March 20, 2004 and March 14, 2005 were:

i.) Unfertilized control

ii.) University of Tennessee Extension recommended NPK rate, 114-30-28 kg/ha (100-60-30 lbs/acre), (Savoy and Joines, 2001)

iii.) Local producer NPK rate at, 65-28-54 kg/ha (57-57-57 lbs NPK/acre)

iv.) Alum treated litter applied at rates of 2.3 Mg/ha, 6.8 Mg/ha, and 11.3 Mg/ha (1, 3, and 5 tons per acre)

v.) Untreated litter applied at rates of 2.3 Mg/ha, 6.8 Mg/ha, and 11.3 Mg/ha (1, 3, and 5 tons per acre)

Included in the UT recommendation required an additional application of 51 kg/ha of nitrogen (45 lbs/acre) after the first hay cutting in preparation for a second harvest in 2004 and 2005, and an additional 68 kg N/ha (60 lbs/acre) applied in September after the second hay cutting. Application rates of both litter and commercial fertilizer used for 2004 and 2005 are described in Tables 8 and 9. Calcium, carbon (C), Mg, S, Al, Fe, Mn, Zn, and Cu were not analyzed for commercial fertilizers.

Soil Analysis

In March 2004 and March2005, soil samples were removed from the upper 15 cm from each plot to determine soil test levels of P, K, Mg, Ca, Zn, Cu, Mn, and Fe using Mehlich I soil extractant. Soil samples were sent to the University of Tennessee Soil and Forage Test Laboratory (Nashville, TN). Atomic absorption spectrophotometer was used to analyze soil K, Ca, Mg, Zn, Mn, and Fe (Perkins-Elmer, Norwalk, CONN). Phosphorus was analyzed with a Perkins-Elmer UV/VIS spectrophotometer. Soil pH measurements were taken with a pH meter (Denver Instruments, Denver, CO). Table 10 summarizes soil test levels of nutrients and pH prior to treatment application.

Broiler Litter Analysis

A local poultry producer in Greene County, TN supplied untreated and alum-treated broiler litter. Alum treated litter was amended with dry alum (Al+Clear, General Chemical Corporation, Parsippany, NJ) five times between flock grow outs. Alum was applied at 490 kg/m^2 or (100lbs dry alum per 1,000 square feet) to the brood half of the poultry house between grow-outs during fall and winter before spring litter clean out in March or April.

Table 8. Rates of amendments applied on tall fescue in March 2004.

Treatments	Fertilizer Nutrient Rates Applied (kg/ha)											
	N	P	K	Ca	C	Mg	S	Al	Fe	Mn	Zn	Cu
Control	0	0	0	0	0	0	0	0	0	0	0	0
65-28-54 or 57-57-57 (lbs/acre)	65	28	54	*	*	*	*	*	*	*	*	*
114-30-28 or UT Recommended	114	30	28	*	*	*	*	*	*	*	*	*
Untreated Litter (2.3 Mg/ha)	33	34	56	58	611	13	10	2	0	0	1	1
Untreated Litter (6.8 Mg/ha)	100	102	167	173	1,832	38	31	5	0	0	2	2
Untreated Litter (11.3 Mg/ha)	166	170	278	288	3,053	64	51	8	0	0	4	4
Alum Litter (2.3 Mg/ha)	32	27	48	47	563	10	11	3	0	0	1	1
Alum Litter (6.8 Mg/ha	95	82	145	140	1,688	29	34	9	0	0	2	2
Alum Litter (11.3 Mg/ha)	158	137	242	234	2,814	48	57	15	0	0	3	3

Table 9. Rates of amendments applied on tall fescue in March 2005.

	Fertilizer Nutrient Rates Applied (kg/ha)											
Treatments	**N**	**P**	**K**	**Ca**	**C**	**Mg**	**S**	**Al**	**Fe**	**Mn**	**Zn**	**Cu**
Control	0	0	0	0	0	0	0	0	0	0	0	0
65-28-54 or 57-57-57 (lbs/acre)	65	28	54	*	*	*	*	*	*	*	*	*
114-30-28 or UT Recommended	114	30	28	*	*	*	*	*	*	*	*	*
Untreated Litter (2.3 Mg/ha)	36	44	73	79	618	0	15	2	1	1	1	1
Untreated Litter (6.8 Mg/ha)	109	133	218	236	1,855	0	44	7	2	4	3	3
Untreated Litter (11.3 Mg/ha)	182	222	363	437	3,092	0	74	12	3	4	5	5
Alum Litter (2.3 Mg/ha)	35	42	78	77	1,927	0	20	4	1	1	1	1
Alum Litter (6.8 Mg/ha	106	125	233	231	642	0	60	12	2	3	3	3
Alum Litter (11.3 Mg/ha)	176	208	388	385	3,212	0	102	20	3	6	6	5

Table 10. Initial soil test and pH values prior to application of fertilizer treatments of Spring 2004.

	pH	P	K	Ca	Zn	Cu	Mn
				mg kg-1			
Fertilizer Treatment							
Control	6.7*	2.0	51.8	318.6	1.9	0.8	15.9
Local producer rate	6.6	4.0	65.3	290.5	1.8	0.5	15.4
UT Recommended	6.5	5.0	70.0	297.9	1.8	0.5	17.5
Untreated Litter, 2.3 Mg/ha	6.5	3.0	81.1	273.3	1.4	0.4	16.4
Untreated Litter, 6.8 Mg/ha	6.5	3.5	48.0	273.3	1.1	0.5	15.1
Untreated Litter, 11.3Mg/ha	6.6	5.8	60.4	294.9	1.5	0.5	16.8
Alum Litter, 2.3 Mg/ha	6.5	3.8	73.6	289.1	2.5	2.1	18.3
Alum Litter, 6.8 Mg/ha	6.6	2.0	62.4	316.9	1.5	0.5	15.1
Alum Litter, 11.3 Mg/ha	6.6	5.0	52.6	294.0	1.6	0.5	16.0

***All initial soil test levels were not significant from treatment interactions the $p < 0.05$.**

Broiler litter samples were collected March 24, 2004 and March 14, 2005 and sent to the University of Arkansas, Agricultural Diagnostics Lab, in Fayetteville for nutrient analysis on March 31, 2004 and March 22, 2005. Nutrients analyzed for whole litter content included N, P, K, Ca, C, S, Al, Zn, and Cu. Mg was analyzed in 2004 and Mn was analyzed in 2005. Litter samples were digested using concentrated nitric acid and hydrogen peroxide on a heating block then analyzed using inductively coupled plasma emission spectroscopy (SPECTRO, Kleve, Germany) or ICP. Total N was determined using combustion with a nitrogen analyzer (LECO, St. Joseph, MI). Table 11 summarizes composition of litter nutrients.

Plots were sampled and harvested on May 21, 2004, September 14, 2004, and May 12, 2005. Equipment used for harvest was a rotary mower and round hay baler pulled behind a tractor. Fresh weight biomass was measured on truck scales (Intercomp Company, Minneapolis, MN). Accuracy of truck scales was + / - 1% or 4.5 kg (10lbs). The May 2004 and 2005 harvests were cut during the boot stages of plant growth. During the September harvests, the tall fescue was coming out of summer dormancy in early vegetative or boot growth stages.

The September 2005 harvest was canceled due to poor growth in the warm fall months and lack of adequate moisture. Plots were also sprayed with Redeem® (active ingredient: chlorpyralid + triclopyr amine) for control of Johnsongrass (*Sorghum halpense*) and broadleaf weeds. Applications were made after the May harvests later in the summer and prior to the September harvest.

Table 11. Composition of litter nutrients.

	Years of Litter Application			
	2004		**2005**	
Litter Nutrients	**Untreated**	**Alum-Treated**	**Untreated**	**Alum-Treated**
Total N, (g/kg)	29	28	32	31
Total P, (g/kg)	15	12	19	18
Total K, (g/kg)	24	21	32	34
Total Ca, (g/kg)	25	21	35	34
Total C, (g/kg)	269	248	272	283
Mg, (g/kg)	6	4	*	*
S, (g/kg)	5	5	7	9
Mn, (g/kg)	*	*	590	509
Cu, (mg/kg)	361	299	470	457
Zn (mg/kg)	354	289	473	494
Al (mg/kg)	668	1,330	1,089	1,812

***Not measured**.

Sample Preparation

Subsamples were collected prior to harvest by randomly hand grabbing throughout the plot area. The subsamples were then collected and weighed from the plot area, and placed in a dry oven at 15.5ºC. After drying for two days, the forage susbsamples were weighed for moisture content determination. The moisture content value was then used to calculate percent dry matter in converting the harvested fresh weights into total dry matter yields harvested.

After drying, the subsample was processed in a Thomas-Wiley mill in preparation of elemental analysis and determination of nutritive value for forage quality evaluation. Subsamples were then sent to a commercial forage-testing lab (Sure-Tech, Indianapolis, IN) for determining nutritive value parameters using near infrared spectrometry (NIRS, Silver Spring, MD). Model used for analysis was using a Nirsystems 5000. Parameters determined for nutritive value are crude protein (CP), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, fat, ash, net energy lactation (Nel & Mcal/kg), net energy maintenance (Nem & Mcal/kg), and net energy gain (Neg & Mcal/kg). Calibrations of nutritive value parameters were based on wet chemistry data for each constituent. The Association of Analytical Communities (AOAC) except NDF validates reference methods for the following parameters and their calibrations:

i.) Crude Protein (AOAC 990.03, 1999)

ii.) ADF (AOAC 973.18, 1999)

iii.) NDF (Understander, 1993)

iv.) Fat (AOAC 920.39, 1999)

v.) Lignin (AOAC 973.18, 1999)

vi.) Ash (AOAC 942.05, 1999)

The NDF was made available by refluxing in an amylase solution to avoid fibrous constituent degradation during analysis. The ADF fraction determined from the NIRS analysis was then used in regression analysis developed by Pennsylvania State University to calculate Nel, Neg, Nem, and TDN (Ishler et al. 1996). Forage analysis conducted by Sure-Tech was with ICP (Thermo-Jarrel Ash, Waltham, MASS) for Ca, P, Mg, K, S, Na, Cu, and Zn with nitric acid digestion prior to analyzing.

In July of 2005, samples were dry ashed for Al, P, K, Mg, Ca, Se, S, Zn, Cu, Mn, and As for in-house wet chemistry analysis using ICP manufactured by SPECTRO at the University of Tennessee Biosystems Engineering and Soil Science department. A half-gram of plant material was placed in a muffle furnace heated to 450ºC and held there until all carbon content was consumed (at least 4 hours). The material was left to cool and then oxidized with 10 ml of 1 N nitric acid by allowing it to evaporate slowly until dry using a hot plate. The sample was cooled then 10 ml of 1 N of hydrochloric acid was added to dissolve the remaining residue. The remaining material was barely brought to boiling then transferred to a 100 ml volumetric flask. The sample was then filtered through a 9 cm no. 42 Whatman filter followed by diluting the flask up to volume with deionized water. Blanks were always prepared with each run of dry ashed samples prior to ICP analysis. Tetany index ratios (K/(Mg +Ca)) were calculated on an equivalent basis to determine grass tetany risk in the forage crop.

Statistics

Data were analyzed using the mixed model procedure of SAS (PROC MIXED) with repeated measures analysis to assess statistically significant differences in soil test levels (SAS Inst., 2003) since only one set of soil data had treatment interaction. Repeated measures variables were harvesting dates and date of sampling for soil data. Replicates and interactions with replicates were assumed to be random effects. Fixed effects were treatments, harvest date, and soil sampling date. Main effects and interactions were compared using least square means when statistically significant. Forage nutrient content, dry matter yields, and nutritive value parameters were analyzed using a complete randomized design with repeated measures and replicates. Fixed effects with regarding the complete randomized design are treatment and season, which is a repeated measure. Experimental replicates were random effects. Alpha $p < 0.05$ was used for all statistical tests throughout the project. Standard errors and deviations were calculated with MEANS Procedure (See Appendix).

Chapter 4. Results and Discussion

Soil Analyses Results for 2004 and 2005

The addition of both commercial fertilizer and broiler litter and harvest of biomass did not significantly change pH, K, Ca, Cu, and Mn soil test concentrations compared to the unfertilized control (Table 12). Soil test concentrations of P and Zn significantly increased compared to the unfertilized control (Table 13).

The only significant treatment increase in soil P was observed when untreated litter was applied at 11.3 Mg/ha. Soil test P increased significantly compared to unfertilized control. Untreated litter applied 11.3 Mg/ha significantly increased soil test P concentrations, but alum treated litter did not. The data suggests increased soil P results from the higher P application rates of untreated litter concentrations of untreated litter compared to alum-treated litter at all litter rates applied (Table 13). Another possible explanation is that alum reduced soil P during in-house treatment before land application (Moore et al., 1999; Moore 1994). The studies from Moore showed that alum applied to poultry litter reduces P solubility within the litter, and soil test P levels did not increase even after long-term applications. Tables 14 and 15 summarize nutrient uptake during crop harvesting in May and September 2004. Nutrient uptake of P, K, Mg, Ca, and S was significantly higher at the highest rate (11.3 Mg/ha) of alum-treated and untreated litter and the UT recommended fertilized rate compared to the unfertilized control in May (Table 14) and September 2004 (Table 15). In May 2004 (Table 14), Na uptake was not significantly different to the unfertilized control.

Table 12. Soil test and pH values influenced by nine different fertilizer treatments during Spring 2005.

	pH	P	K	Ca	Zn	Cu	Mn
				mg kg-1			
Fertilizer Treatment							
Control	6.7	5.5bc	61.4	247.5	1.6c	0.1	8.5
Local producer rate	6.1	5.5bc	51.6	225.0	1.8c	0.2	9.8
UT Recommended	5.9	6.3bc	68.1	210.0	1.8bc	0.2	10.0
Untreated Litter, 2.3 Mg/ha	6.5	3.5c	58.9	216.3	1.6c	0.2	7.0
Untreated Litter, 6.8 Mg/ha	6.3	8.5bc	46.5	226.3	1.9bc	0.2	7.8
Untreated Litter, 11.3 Mg/ha	6.4	22.0a	90.0	225.0	2.8a	0.3	9.0
Alum Litter, 2.3 Mg/ha	6.2	4.3c	49.9	223.8	1.5c	0.2	13.9
Alum Litter, 6.8 Mg/ha	6.2	5.8bc	54.4	227.5	1.6c	0.3	7.3
Alum Litter, 11.3 Mg/ha	6.1	10.0b	52.1	231.3	2.5ab	0.4	7.4

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Table 13. Changes in soil nutrients and pH values from spring 2004 to spring 2005 as influenced by fertilizer treatment application.

	pH	P	K	Ca	Zn	Cu	Mn
			mg kg-1				
Fertilizer Treatment*							
Control	0.0	+3.5bc	+9.6	-71.1	-0.3c	-0.6	-7.4
Local producer rate	-0.5	+1.5bc	-13.9	-65.5	0.0c	-0.3	-5.6
UT Recommended	-0.6	+1.3bc	-1.9	-87.9	+0.1bc	-0.3	-7.5
Untreated Litter, 2.3 Mg/ha	-0.1	+0.5c	-22.3	-57.0	+0.2c	-0.2	-9.4
Untreated Litter, 6.8 Mg/ha	-0.3	+5.0bc	-1.5	-47.0	+0.7bc	-0.3	-7.4
Untreated Litter, 11.3 Mg/ha	-0.2	+16.3a	+29.6	-69.9	+1.3a	-0.2	-7.8
Alum Litter, 2.3 Mg/ha	-0.3	+0.5c	-23.8	-65.4	-1.0c	-1.9	-4.4
Alum Litter, 6.8 Mg/ha	-0.4	+3.8bc	-8.0	-89.4	+0.1c	-0.2	-7.9
Alum Litter, 11.3 Mg/ha	-0.5	+5.0b	-0.5	-62.8	+0.9ab	-0.1	-8.6

Table 14. Forage nutrient uptake of tall fescue hay from commercial fertilizer and broiler litter use in May 2004.

	P	K	Ca	Mg	S	Na
			kg ha-1			
Fertilizer Treatment						
Control	9.8e	76.0e	14.9c	9.4d	9.2d	0.6abc
Local producer rate	16.2abc	138.1bc	22.7ab	13.7abc	13.4bc	0.5c
UT Recommended	17.3ab	161.3ab	26.7a	16.0a	16.6ab	1.2ab
Untreated Litter, 2.3 g/ha	15.0bcd	124.4cd	19.5abc	12.5bcd	13.4bc	0.5c
Untreated Litter, 6.8 Mg/ha	15.8abcd	129.3bc	19.1abc	11.9bcd	14.2bc	0.6bc
Untreated Litter, 11.3 Mg/ha	18.0ab	154.8abc	27.4a	13.6abc	16.8ab	1.2a
Alum Litter, 2.3 Mg/ha	12.0de	94.3de	17.5bc	10.7cd	11.5cd	0.4c
Alum Litter, 6.8 Mg/ha	13.2cde	127.0bcd	18.6abc	11.5cd	13.9bc	0.5c
Alum Litter, 11.3 Mg/ha	19.7a	181.5a	23.1ab	15.2a	19.1a	1.1a

***Means followed by different letters within are significantly different at $p < 0.05$.**

Table 15. Forage nutrient uptake of tall fescue hay from commercial fertilizer and broiler litter use in September 2004.

	P	K	Ca	Mg	S	Na
			kg ha-1			
Fertilizer Treatment						
Control	7.1d	52.4d	9.7d	8.6c	7.0e	0.2de
Local producer rate	8.4cd	62.9cd	10.9bcd	10.1bc	8.4cde	0.2cde
UT Recommended	9.5bcd	83.3bcd	15.2ab	14.2a	10.9bcd	0.4abcd
Untreated Litter, 2.3 Mg/ha	11.7abc	90.6bc	14.8abc	13.5ab	11.4bc	0.4abc
Untreated Litter, 6.8 Mg/ha	13.5a	91.2bc	15.4ab	15.3a	12.1ab	0.3bcde
Untreated Litter, 11.3 Mg/ha	14.9a	129.7a	18.6a	16.1a	14.0ab	0.6a
Alum Litter, 2.3 Mg/ha	7.6d	54.6d	9.9cd	9.3c	7.6de	0.2e
Alum Litter, 6.8 Mg/ha	13.0ab	102.5ab	17.1a	15.7a	12.8ab	0.5ab
Alum Litter, 11.3 Mg/ha	15.4a	108.9ab	18.4a	16.0a	15.0a	0.4ab

***Means followed by different letters within are significantly different at $p < 0.05$.**

Sodium uptake although was significantly higher in September 2004 (Table 15) from the high untreated litter applied at 11.3 Mg/ha. With applications of 166 kg P/ha from the 11.3 Mg/ha broiler litter only 10 and 12 kg/ha of P were removed during the May 2004 harvest suggesting more P is applied than removed. In May 2004 more P although was taken up by tall fescue with uptake significantly higher than the unfertilized control. Lower quantities of P were taken up in September 2004 from all treatments Uptake was highest in May 2004 when weather conditions were good for tall fescue growth, but lower in September 2004 when the conditions depressed dry matter yields from warmer temperature conditions (Figures 2 and 3).

The high litter rates (11.3 Mg/ha) had similar concentrations of P uptake with no distinguishable effect between alum and untreated litter since these rates apply high amounts of nutrients that replenished soil test levels prior to application (Table 10). Also these rates allowed P to be carried over into the fall. With increased litter applications P will increase with depth and less will be removed with biomass harvest as observed in Texas. Soil test P levels did increase with depth on bermudagrass pasture from high P (519 to 590 kg P/ha) supplied in untreated poultry litter with repeated applications of high N (1000 kg N/ha) and from 1992 to 1996 (Johnson et al., 2004). Phosphorus recovery of applied P in that study was between 6 to 11 percent. The UT recommended rate resulted in a greater uptake of nutrients compared to the local producer rate for both May (Table 14) and September 2004 (Table 15).

Stockpiling of Broiler Litter

Broiler litter nutrient concentrations increased from 2004 to 2005 from the same litter source and resulted in higher application of nutrients in 2005. This increase is the result of broiler litter stockpiling and self-composting without the frequent turning or removal for extended periods of time. An explanation supporting a nutrient increase is carbon oxidation that released carbon dioxide within compost heaps (Schellinger and Breitenbeck, 1998). Nitrogen losses may be induced by fluctuations in bulk density, pile geometry, and moisture content.

With increased concentrations in the litter more P, K, Ca, S, Fe, Zn, and Cu was applied when the same rates of litter were applied in 2005 compared to 2004 (Tables 8 and 9). In 2005, nutrient concentrations (except N) increased in both the alum treated and untreated litter compared to 2004, and explains increases in soil P and Zn and increases in forages S and K. Increases in S and K can have an antagonistic effect on the uptake of Cu, Mg, and Ca and result in imbalances in the forage. With higher applications of broiler litter (6.8 Mg/ha or higher) the risk becomes even greater for cattle health.

Increasing nutrient concentrations during composting were observed by Schellinger and Breitenbeck (1998) after composting different feedstocks. Reported concentrations from their investigation occurred with N, P, K, Ca, Cu, and Zn. Broiler litter from this study showed similar elevated trends in the same nutrients, except N that decreased during composting. Piles were turned at least once a week. It is recommended that broiler litter be monitored with annual litter testing and applied during the growing season when forage crops will utilize most of the available plant nutrients in accordance with comprehensive nutrient management planning.

Forage Nutrient Concentrations

Phosphorus

Across all harvest dates, no significant differences in plant P concentrations were observed between the fertilizer treatments and the unfertilized control. In May 2004 forage P concentrations showed an increase with higher P application rates (Figure 5). Phosphorus concentrations were probably translocated to the plant roots during the latter part of 2003 and early winter of 2004. Data from Missouri suggests a trend of P translocation to the roots in the late fall and until March when P concentrations increased from plant transport (Blevins et al., 2004). Overall P concentrations were significantly higher with the September 2004 and May 2005 harvest dates compared to the May 2004 harvest (Table 16).

Phosphorus concentrations were significantly lower in all treatments with no observed significant differences in the unfertilized control, median alum-treated litter rate (6.8 Mg/ha), and the UT recommended fertilizer rate for September 2004 (Table 17). The remaining treatments were all significantly higher (Table 17) from increased P application observed in May 2004. Trends were less pronounced in September 2004, and were opposite in May 2005. In September 2004, forage P concentrations were significantly higher for high alum treated litter rate (11.3 Mg/ha) and the median untreated litter rate (6.8 Mg/ha) compared to the unfertilized control (Table 18). The UT recommended rate was significantly lower compared to the local producer rate, but each applied similar amounts of P (30 kg P /ha). No observable significant differences were observed during the May 2005 sampling date (Table 19).

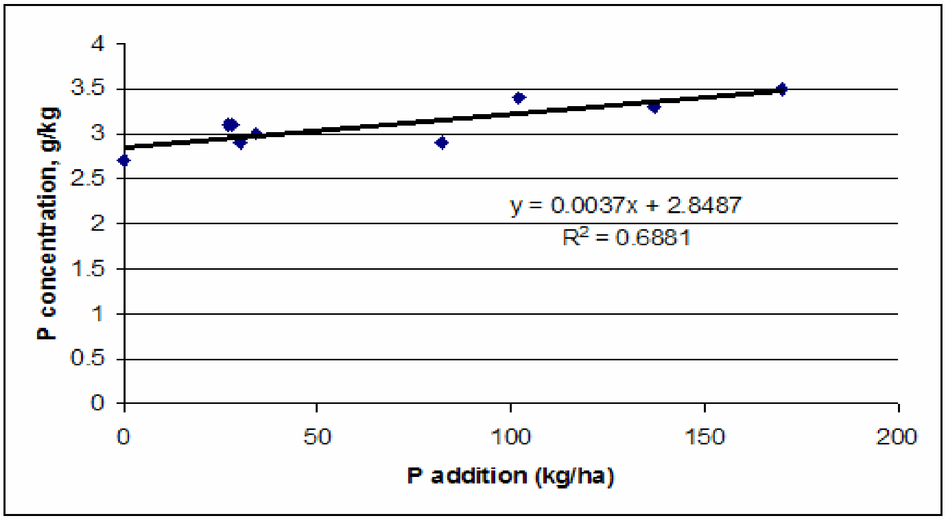

Figure 5. Forage P tissue concentrations relative to phosphorus additions, May 2004.

Table 16. Nutrient concentrations of tall fescue hay as influenced by nine different fertilizer treatments and seasonal differences during harvest collection periods.

	P	K	Ca	Mg	S	Na	Cu	Zn	K/(Mg + Ca)
		DM g kg-1					DM mg kg-1		
Fertilizer Treatment									
Control	3.2	22.0e	4.2	3.1	2.8c	0.3a	4.9c	22.9	3.6e
Local producer rate	3.4	25.3cd	4.3	3.2	2.8c	0.1b	5.2bc	22.6	4.1bcde
UT Recommended	3.1	24.6de	4.4	3.2	2.9bc	0.1b	5.5abc	24.1	3.9de
Untreated Litter, 2.3 Mg/ha	3.3	24.8d	4.2	3.0	2.9bc	0.1b	5.2bc	23.7	4.3abcde
Untreated Litter, 6.8 Mg/ha	3.5	27.0bcd	4.0	3.2	3.0abc	0.2ab	5.9ab	26.3	4.7abcd
Untreated Litter, 11.3 Mg/ha	3.5	30.6a	4.7	3.1	3.2ab	0.2ab	6.2a	24.0	4.9abc
Alum Litter, 2.3 Mg/ha	3.4	24.8d	4.4	3.3	3.0abc	0.1b	5.2bc	22.6	4.0cde
Alum Litter, 6.8 Mg/ha	3.1	27.9bc	4.0	3.1	3.0abc	0.2ab	5.8abc	22.5	4.9ab
Alum Litter, 11.3 Mg/ha	3.4	29.3ab	4.0	3.0	3.3a	0.2ab	6.3a	24.5	5.1a
Harvest Collection									
May 2004	3.1b	27.0a	4.6a	2.7b	3.0b	0.1b	4.0c	19.3c	4.4b
September 2004	3.5a	26.5a	4.6a	4.2a	3.4a	0.1b	7.2a	32.5a	3.7c
May 2005	3.4a	25.2b	3.5b	2.5b	2.5c	0.2a	5.6b	21.1b	5.0a

***Means followed by different letters within a column are significantly different at p <0.05.**

Table 17. Nutrient concentrations of tall fescue hay as influenced by nine different fertilizer treatments during the May 2004 harvest collection period.

	P	K	Ca	Mg	S	Na	Cu	Zn	K/(Mg + Ca)
	DM g kg-1						DM mg kg-1		
Fertilizer Treatment									
Control	2.7e	21.4e	4.3	2.6	2.6e	0.1c	3.0	19	3.6
Local producer rate	3.1bcd	26.9cd	4.6	2.7	2.6de	0.1c	3.7	18.2	4.3
UT Recommended	2.9de	27.8bc	4.7	2.8	2.9bcde	0.1c	4.3	21.0	4.3
Untreated Litter, 2.3 Mg/ha	3.0d	25.0d	4.1	2.5	2.7cde	0.1c	3.3	19.0	4.4
Untreated Litter, 6.8 Mg/ha	3.4ab	27.8bc	4.1	2.5	3.0abc	0.1bc	4.3	21.0	4.8
Untreated Litter, 11.3 Mg/ha	3.5a	30.4ab	6.0	2.7	3.3a	0.3a	4.3	19.0	4.3
Alum Litter, 2.3 Mg/ha	3.1cd	24.6d	4.6	2.8	3.0abcd	0.1c	3.2	19.0	3.8
Alum Litter, 6.8 Mg/ha	2.9de	28.7abc	4.2	2.6	3.1ab	0.1bc	4.7	18.2	4.8
Alum Litter, 11.3 Mg/ha	3.3abc	30.6a	4.1	2.6	3.2ab	0.2ab	5.2	20.2	5.3

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Table 18. Nutrient concentrations of tall fescue hay as influenced by nine different fertilizer treatments during the September 2004 harvest collection period.

	P	K	Ca	Mg	S	Na	Cu	Zn	K/(Mg + Ca)
		DM g kg-1					DM mg kg-1		
Fertilizer Treatment									
Control	3.3c	24.2	4.5	4.0	3.2	0.1	7.0	32.0	3.6
Local producer rate	3.4bc	25.2	4.5	4.2	3.4	0.1	6.5	33.7	4.3
UT Recommended	2.8d	25.3	4.7	4.3	3.3	0.1	6.7	30.7	4.3
Untreated Litter, 2.3 Mg/ha	3.4bc	25.7	4.4	3.9	3.3	0.1	6.7	31.7	4.6
Untreated Litter, 6.8 Mg/ha	4.0a	26.3	4.7	4.5	3.5	0.1	7.5	41.2	4.8
Untreated Litter, 11.3 Mg/ha	3.6bc	31.3	4.5	3.9	3.4	0.2	7.5	34.5	4.3
Alum Litter, 2.3 Mg/ha	3.6abc	26.2	4.8	4.4	3.6	0.1	7.0	30.7	3.8
Alum Litter, 6.8 Mg/ha	3.4bc	27.5	4.6	4.2	3.3	0.2	7.7	32.7	4.8
Alum Litter, 11.3 Mg/ha	3.7ab	26.5	4.5	3.9	3.6	0.1	7.7	35.5	5.4

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Table 19. Nutrient concentrations of tall fescue hay as influenced by nine different fertilizer treatments the May 2005 harvest collection periods.

	P	K	Ca	Mg	S	Na	Cu	Zn	K/(Mg + Ca)
	DM g kg-1					DM mg kg-1			
Fertilizer Treatment									
Control	3.7	20.3e	3.7	2.6	2.4	0.3	4.7	20.0	3.8
Local producer rate	3.8	23.8de	3.8	2.5	2.3	0.1	5.3	20.0	4.5
UT Recommended	3.5	20.5fg	3.6	2.5	2.4	0.1	5.5	22.7	4.0
Untreated Litter, 2.3 Mg/ha	4.0	23.5ef	4.0	2.4	2.5	0.1	5.5	22.5	4.7
Untreated Litter, 6.8 Mg/ha	3.1	26.7cd	3.1	2.4	2.5	0.3	6.0	22.7	5.8
Untreated Litter, 11.3M g/ha	3.5	30.0ab	3.6	2.6	2.7	0.4	6.7	21.7	5.8
Alum Litter, 2.3 Mg/ha	3.5	23.6def	3.5	2.6	2.4	0.1	5.2	20.2	4.6
Alum Litter, 6.8 Mg/ha	3.1	27.5bc	3.1	2.4	2.6	0.3	5.0	19.7	6.1
Alum Litter, 11.3 Mg/ha	3.2	30.7a	3.3	2.6	2.9	0.4	6.0	21.5	6.3

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

During September 2004 (Table 18) and May 2005 (Table 19) P concentrations were lower than the UT Recommended rate. It is unlikely that these differences were not the result of antagonistic effects of K or S. For example, no differences in K or S concentrations are observed in May 2004 (Table 17) and September 2004 (Table 18) or for S again in May 2005 (Table 19). Potassium concentrations were significantly lower for the UT recommended rate in May 2005 (Table 19).

Observed P concentrations throughout the study are similar with concentrations observed by the Tennessee fescue survey. This survey had tall fescue samples greater than 3.5 g/kg for spring and fall from 2001 to 2004 (Gill et al., 2005), and was sufficient to nutrient critical levels of 2 g/kg for beef cattle health. Similar results from Blevins in Missouri showed P concentrations maintained over 2 g/kg on stockpiled fescue (Blevins et al. 2004).

Potassium

Across all sampling dates there were significant differences in forage K concentrations between fertilizer and broiler litter rates and the unfertilized control due to luxury uptake. Potassium concentrations were significantly higher and there was no difference between high alum and untreated litter applications (11.3 Mg/ha) compared tohe unfertilized control (Table 16). The other remaining treatments were significantly higher. Overall K concentrations in May 2004 and September 2004 harvest were significantly higher than May 2005. In other studies in Tennessee, Reynolds reports similar trends of K concentrations in March and April from K fertilization (181 kg K/ha) were observed. Potassium concentrations declined when tall fescue reached later stages of maturity (West and Reynolds, 1984). In May 2004 sampling, tall fescue probably responded to K fertilization because soil concentrations were medium testing prior to application. Conditions were favorable for tall fescue growth with adequate moisture and fertilization (Table 10 and 11, Figures 2 and 3). In September 2004 tall fescue could have used utilized excess soil K when coming out of summer dormancy. During May 2005 harvest K concentrations were slightly suppressed since K soil concentrations increased in a year and higher amounts of K were applied in March 2005 from litter stockpiling.

Potassium concentrations in May 2004 (Table 17) were significantly higher with the highest rates (11.3 Mg/ha) of untreated litter and alum-treated litter compared to the unfertilized control. Similar to P, K tissue concentrations increased with higher K additions from treatment applications (Figrue 6). High additions induce luxury plant uptake of K. The trend, however, was not observed in September 2004 (Table 18) since there were no significant differences between treatments.

Significant treatment differences were observed in May 2005 (Table 19) with the high rates (11.3 Mg/ha) of alum-treated and untreated litter compared to the unfertilized control. Other treatments were not significant that could have resulted from a slight dilution in existing tissue potassium from increased N from fertilized treatments and litter

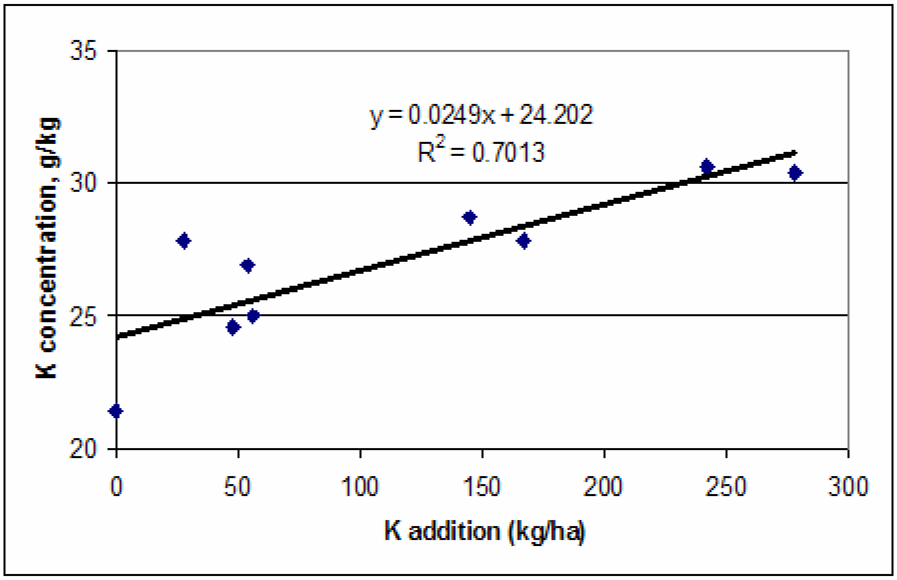

Figure 6. Forage tissue concentrations relative to potassium additions, May 2004.

stockpiling.

The observed effects could have been the result of more available K when applied at rates of greater than 150 kg K/ha in the beginning of the growing season and probably kept soil K concentrations well supplied throughout most of the growing season. Data from New York reported similar increases in forage K concentrations after three after two years of dairy manure application with varying rates as low as 34 kg K/ha and higher with 134 kg K/ha (Cherney et al. 2002). Cherney et al. also observed consistent K concentrations on tall fescue taken with four cuttings per growing season.

Average K concentrations with the fertilized treatments were the same May (Table 16) and September 2004 (Table 18) harvest periods. In May 2005 (Table 19) forage potassium concentration were significantly higher with the local producer rate since it applies 58 kg K/ha compared to 24 kg K/ha applied with UT recommended. Antagonistic effects were likely unaffected by other forage nutrients since no other concentrations mirrored K. Similar trends from other data in Tennessee reported consistent forage K concentrations when using only potassium fertilizers (181 kg K/ha) (Reynolds and West, 1984).

The average K concentrations were consistent with tall fescue observed in other studies (Cherney et al. 2002; Reynolds and West, 1984; and Gill et al., 2005). Tall fescue samples taken from the experiment were sufficient to meet beef cattle needs, however, forage potassium concentrations from the high broiler litter treatments (11.3 Mg/ha) exceeded NRC's maximum tolerable concentration of 30 g/kg putting cattle health at risk.

Calcium and Magnesium

When averaged across all treatments and harvests no there were no observed significant differences in forage Mg and Ca concentrations (Table 16). Seasonal significant differences were observed for May and September 2004 Ca concentrations (Table 16). Magnesium concentrations were significantly higher in September 2004 (Table 16). Averaged over all treatments Ca concentrations followed the same trend as forage K concentrations with significantly higher levels in May and September 2004 compared to May 2005. When comparing alum and untreated poultry litter rates there were no significant differences in Ca and Mg concentrations on any sampling dates. No significant differences were observed between the two commercial fertilizer rates.

Forage Ca and Mg concentrations are similar of those in fescue samples in the Tennessee tall fescue (Gill et al. 2005). Other data also shows observed concentrations (Reynolds and West, 1982, Blevins et al. 2004,). All Ca and Mg concentrations observed throughout the study were maintained over 4 and 2 g/kg, which either met or exceeded NRC critical levels for beef cattle.

Tetany Ratios or K/(Mg + Ca)

Treatments with observed significant differences for K/(Mg + Ca) ratios were the median (6.8 Mg/ha) and high alum-treated litter rates and untreated litter rates (11.3 Mg/ha) compared to the unfertilized control (Table 16). The median and high litter rates applied more K with antagonistic effects made from litter stockpiling in 2005. Differences between harvests were also observed. Significantly higher mean tetany ratios were also observed in May 2005 compared to September 2004. The lowest mean tetany ratio was observed in May 2004 (Table 16). There were no significant differences between treatments within a sampling event (Tables 17, 18, and 19). This suggests a climatic effect from higher rainfall in April 2005 and cooler temperatures in May 2005 made growing conditions favorable for tall fescue (Figures 2 and 3). In addition, alum used as a litter amendment had no effect regarding increases or decreases in ratio values. Fertilized treatments had no observed significant differences.

Ratios from this experiment exceed the 2.2 threshold (greater than 4.0). Rates from these treatments represent great risk of tetany potential to beef cattle. Causes are related to K luxury uptake overapplied from median and high litter treatments and increased K soil test levels. With high forage K concentrations, Mg and Ca cannot compete against K during plant uptake. Ratios from Cornell show similar trends with animal wastes with ratios greater than 3.26 from dairy manure applied at 33.6 Mg/ha for orchard grass during spring hay cuttings, and tall fescue cuttings exceeding 2.2 for just few growing seasons (Cherney et al., 2002). Ratios from Reynolds and West (1982) never exceeded 2.2, but always increased with increased forage K.

Sulfur

Forage S concentrations were significantly higher for the highest alum treated and untreated broiler litter rates (11.3 Mg/ha) compared all other treatments (Table 16). These high litter treatments applied more S compared to median and low litter applications due higher S concentrations in the litter (Tables 8 and 9). The increased S from alum did not appear to affect S concentrations. Average forage S concentrations were significantly higher in September 2004 compared to May 2004 and 2005 (Table 16). Average forage S concentrations were lowest in May 2005. Seasonal effects might have included rainfall with increased S from acid deposition in months proceeding May and September 2004 (Figures 2 and 3). Sulfur released from the atmosphere is brought on by induced emissions from industrial power plants (Brady and Weil, 1999).

In the May 2004 (Table 17) forage S were significantly higher at the median (6.8 Mg/ha) and high (11.3 Mg/ha) broiler litter applications compared to all other May 2004 treatments. High S uptake was probably related to the increased S from alum and from atmospheric deposition. No significant differences among treatments were observed for September 2004 (Table 18) and May 2005 (Table 19) harvest periods since forage S concentrations were probably already plentiful before and after application of litter and fertilizers throughout summer and fall (Goh and Kee, 1978). The fertilizer treatments had no significant effect on forage S concentrations regardless of treatment and harvest period. No significant differences were observed since S was not supplied as an individual constituent in rates that only applied NPK (Tables 8 and 9).

Forage sulfur concentrations were similar to those found in the Tennessee tall fescue survey (Gill et al., 2005). The observed forage S concentrations were highly antagonistic to forage Cu concentrations and made conditions worse when using median and high rates of alum and untreated broiler litter based on NRC criteria (Table 4). Concentrations were greater than 2.3 g/kg not considered deficient for maintained cattle health, but considered antagonistic compared to other forage nutrient concentrations.

Copper

Forage Cu concentrations were significantly higher with median (6.8 Mg/ha) and high (11.3 Mg/ha) alum-treated and untreated litter rates compared to the unfertilized control between treatments (Table 16). Significant differences are brought on by these rates increasing Cu concentrations and increases from litter stockpiling (Tables 8 and 9). Factors that support these significant trends were the higher amounts of Cu and N were applied with the median and high rates of poultry litter (Table 8 and 9). In this study rates from median and higher broiler litter applications applied more than 100 kg N/ha while commercial fertilizer rates applied between 50 and 100 kg N/ha. Dennis et al. (1998) also demonstrated that Cu concentrations do increase with N fertilization (40 and 80 kg N/ha).

Sample events with observable significant differences were during September 2004 (Tables 18) when forage Cu concentrations were at their maximum values. Slight decreases in soil pH from acidifying N for both 2004 harvest periods may have increased forage Cu uptake for September 2004 harvest. In May 2004 and 2005 (Table 16) there were no observed significant differences for forage Cu concentrations.

The fertilized treatments were not statistically different from each other when averaged across all treatments within individual harvest periods (Tables 17, 18, and 19). Forage Cu concentrations were similar with each harvest period during the entire study. It is uncertain how much Cu was applied since it was not analyzed through a fertilizer analysis. Copper concentrations may have fluctuated from seasonal growth and plant maturity effects. Seasonal growth was probably affected from cooler and warmer temperatures and varying rainfall throughout the study (Figures 2 and 3). Forage concentrations, however, were likely suppressed by antagonistic forage S concentrations.

Copper concentrations are comparable with those observed in other studies (Dennis et al., 1998 and Gill et al., 2005). The fescue sampled during this experiment did not meet the required 10 mg/kg for required cattle nutrition by the NRC. It is likely that concentrations were suppressed more by antagonistic S concentrations than by the fungal endophyte, *Neotyphidium coenophialum*, that Dennis et al. (1998) suggests.

Zinc

There were no significant differences in forage Zn concentrations between treatments (Table 16), although significant seasonal influences were observed. Forage Zn was significantly higher in September 2004 and significantly lower in May 2004 (Table 16). Climatic conditions (Figures 2 and 3) might have brought on favorable growing conditions for Zn uptake in September 2004. These seasonal conditions may affect solubility as suggested by Belesky and Jung (1982). Zinc availability maybe increased with Zn applications from the high rates of broiler litter. No significant differences were observed between treatments and individual harvest periods since Zn availabilty never increased since soil pH never decreased.

Forage zinc concentrations were similar with other zinc concentrations from other studies (Gill et al. 2005; Belesky and Jung, 1982). Zinc concentrations during the study were marginally deficient for beef cattle health with concentrations less than 30 mg/kg. However, there were no observed antagonistic effects from other nutrient concentrations influencing Zn. Only during September 2004 did forage Zn concentrations met beef cattle dietary requirements (zinc concentrations exceeded 30 g/kg).

Sodium

Litter Na concentrations were not measured in this study, but typical Na broiler litter concentrations are in the range between 5.5 to 6.5 mg/kg (NRAES, 1999). . Between treatments forage Na concentrations were significantly higher with the unfertilized control and the median (6.8 Mg/ha) and high rates (11.3 Mg/ha) of alum-treated and untreated litter (Table 16). In the unfertilized control there were fewer nutrients (Ca, K, Mg) in the soil, so increasing the percentage of Na^+ cations occupying soil exchange sites for increased Na uptake. Sodium concentrations were higher with increased applications of untreated and alum-treated broiler litter. Sodium concentrations were significantly higher in May 2005 (Table 16) probably as a result of litter stockpiling. Significant differences were not observed between all treatments during September 2004 (Table 16 and18) and May 2004 (Table 16 and 17) harvest periods. No significant differences were observed between the UT recommended and local producer fertilizer applications. The findings are similar to those observed by Gill et al. (2005), whose observed Na concentrations changed very little between seasons.

Treatment differences were significantly higher in May 2004 (Table 17). These treatments included the median (6.8 Mg/ha) and high (11.3 Mg/ha) alum-treated and untreated litter application rates. Treatments although had no significant effects on forage Na for the September 2004 (Table 18) and May 2005 (Table 19) harvest periods. With increased rates of poultry litter Na tissue concentrations will increase.

Forage Na concentrations were observed in this study is similar to tall fescue Na concentrations taken during the Tennessee survey (Gill et al., 2005). These Na concentrations were between 0.1 to 0.3 mg/kg, but were still below the 0.6 g/kg NRC critical levels for sustained beef cattle nutrition. Antagonistic effects on forage Na were not observed from this study.

Aluminum

There no significant differences in forage Al analyzed in May 2005 between treatments (Table 20). Alum treated litter contained higher Al concentrations compared to untreated litter with no differences in forage concentrations (Table 11). This suggests either that alum does not affect Al uptake when soil or litter pH is greater than 6.0 or Al chelation from *Neotyphidium coenophialum* (Sims and Luka-McCafferty, 2002; Malinowski and Belesky, 1999b). Aluminum concentrations from fertilizer treatments were not significantly lower or higher, but were similar for both the UT Recommended and the local producer rate. Identification of which rates allowed for increased Al accumulation followed no evident trend. Forage Al concentrations from this study were

Table 20. Accumulation of forage Al and Se on tall fescue in May 2005 from commercial fertilizer and broiler litter use.

Treatment*	Al (mg kg-1)	Se (mg kg-1)
Control	99.2	0.5
Local Producer Rate	70.4	1.1
UT Recommended	77.7	1.0
Untreated Litter, 2.3 Mg/ha	133.3	0.9
Untreated Litter, 6.8 Mg/ha	95.4	1.4
Untreated Litter, 11.3 Mg/ha	116.8	1.6
Alum Litter, 2.3 Mg/ha	129.3	1.6
Alum Litter, 6.8 Mg/ha	137.7	0.9
Alum Litter, 11.3 Mg/ha	109.7	1.0

*No sig. diff at p <0.05.

below the NRC maximum tolerable concentration of 1000 mg/kg and were similar to those found by Reynolds and West, 1982 in tall fescue.

Selenium

Forage Se concentrations analyzed in May 2005 had no significant differences between treatments since soil pH never decreasing below 6.0. Similar selenium concentrations were similar to those found by Mayland et al. (1976) in tall fescue. Forage Se concentrations were above 0.1 mg/kg and below the 2 mg/kg maximum tolerable concentrations recommended for beef cattle dietary requirements. Selenium toxicity was not a present concern through out this study.

Nutritive Value Results

Dry Matter Yield

Averaged across all harvest periods yield responses were significantly higher at the UT recommended and median (6.8 Mg/ha) and high rates (11.3 Mg/ha) of alum treated and untreated litter compared to the unfertilized control (Table 21). These treatments applied more nitrogen compared to the low poultry litter treatments (2.3 Mg/ha) and the local producer fertilized rate. Significantly higher yields were obtained in May 2004 (Table 21) when temperatures in early spring were between 10 to 20°C and adequate precipitation (Figures 2 and 3) promoted growth for tall fescue. Treatments in May 2004 (Table 22) with yields significantly higher than the unfertilized control include both high 11.3 Mg/ha rates of untreated and alum treated litter and the UT recommended. Significant treatments in yields differences were also observed during September 2004 (Table 23) and May 2005 (Table 24) harvest dates.

Average yields were significantly lower in September 2004 and May 2005 (Table 21). Warmer temperatures and rainfall decreases from August 2004 reduced plant growth during for September 2004 (Figures 2 and 3), while lower rainfall February and March 2005 could have reduced some of the early growth for May 2005 (Figures 2 and 3).

In September 2004 (Table 23) yield responses were significantly higher with median and high rates of untreated and alum-treated litter compared to the unfertilized control. In the May 2005 (Table 24) treatments with yield responses significantly higher than the unfertilized control were the UT recommended since it follows soil test recommendations.

Table 21. Dry matter yields and forage quality of tall fescue hay as influenced by nine different fertilizer treatments and seasonal differences during harvest collection periods.

	DM Yield	CP	ADF	NDF	TDN	Ash	Lignin	Fat	NEL	NEM	NEG
	DM kg ha-1			DM g kg-1					Mcal kg-1		
Fertilizer Treatment											
Control	2564cd*	124.2d	350.0	589.1	630.0	61.4cd	44.7	28.4b	1.43	1.41	0.82
Local producer rate	3303bcd	139.5bc	345.3	567.7	637.5	61.9bcd	43.3	30.7b	1.44	1.43	0.84
UT Recommended	3989ab	150.6ab	342.7	566.9	640.0	59.5d	42.3	31.5ab	1.45	1.44	0.84
Untreated Litter, 2.3 Mg/ha	3400abc	132.8cd	341.5	576.7	640.0	65.4abc	45.6	29.1b	1.45	1.44	0.85
Untreated Litter, 6.8 Mg/ha	3533ab	142.9abc	349.7	570.4	629.1	65.2abc	44.2	29.2b	1.43	1.41	0.81
Untreated Litter, 11.3 Mg/ha	3627ab	152.6a	341.9	559.7	641.6	68.9a	43.3	29.6b	1.40	1.45	0.85
Alum Litter, 2.3 Mg/ha	2525d	135.1cd	342.2	573.3	638.3	64.8abc	43.2	31.0ab	1.45	1.44	0.84
Alum Litter, 6.8 Mg/ha	3562ab	141.7abc	344.1	568.3	635.8	66.5ab	42.5	30.5b	1.44	1.43	0.83
Alum Litter, 11.3 Mg/ha	4224a	151.0ab	346.3	571.2	635.0	64.0bcd	43.4	34.0a	1.40	1.42	0.79
Harvest Collection											
May 2004	4815a	152.2c	352.9a	565.7b	630.0ab	59.2c	47.2a	32.4a	1.41b	1.41b	0.81b
September 2004	3200b	132.2a	340.3b	580.3a	636.1ab	68.3a	42.7b	29.9b	1.44a	1.43ab	0.83ab
May 2005	2228c	138.7b	341.3b	568.4b	643.0a	65.0b	40.9c	29.1b	1.46a	1.45a	0.85a

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Table 22. Dry matter yields and forage quality of tall fescue hay as influenced by nine different fertilizer treatments during the May 2004 harvest collection period.

	DM Yield	CP	ADF	NDF	TDN	Ash	Lignin	Fat	NEL	NEM	NEG
	DM kg ha-1			DM g kg-1					Mcal kg-1		
Fertilizer Treatment											
Control	3549e	124d	370.2	599.1	612.5	56.2	54.2a	28.6b	1.4	1.4	0.8
Local producer rate	5087abc	152abc	356.3	565.8	627.5	57.5	45.7bc	29.8b	1.4	1.4	0.8
UT Recommended	5767ab	173a	345.2	554.4	640.0	55.9	42.7c	38.3a	1.5	1.4	0.8
Untreated Litter, 2.3 Mg/ha	4961abcd	134cd	368.3	588.7	612.5	56.9	52.6ab	30.5b	1.4	1.3	0.8
Untreated Litter, 6.8 Mg/ha	4646bcde	155abc	349.6	565.5	630.0	58.7	44.6c	31.7b	1.4	1.4	0.8
Untreated Litter, 11.3 Mg/ha	5121abc	167a	342.6	538.3	642.5	63.4	44.5c	31.7b	1.3	1.4	0.9
Alum Litter, 2.3 Mg/ha	3843de	142bcd	357.2	578.3	622.5	59.3	48.9abc	32.0b	1.4	1.4	0.8
Alum Litter, 6.8 Mg/ha	4449cde	159ab	340.0	546.7	642.5	66.4	43.4c	31.4b	1.5	1.4	0.9
Alum Litter, 11.3 Mg/ha	5911a	166a	346.2	559.9	640.0	58.6	48.2abc	37.7a	1.4	1.4	0.8

***Means followed by different letters within a column are significantly different at p <0.05**.

Table 23. Dry matter yields and forage quality of tall fescue hay as influenced by nine different fertilizer treatments during the September 2004 harvest collection period.

	DM Yield	CP	ADF	NDF	TDN	Ash	Lignin	Fat	NEL	NEM	NEG
	DM kg ha-1					DM g kg-1			Mcal kg-1		
Fertilizer Treatment											
Control	2141cd	123.5	343.7	595.2	630.0	66.8	39.5	28.6	1.4	1.5	0.8
Local producer rate	2459bcd	125.3	342.6	583.1	632.5	67.5	44.6	30.9	1.4	1.5	0.8
UT Recommended	3269abc	135.0	339.3	580.3	637.5	64.7	43.1	29.1	1.4	1.5	0.8
Untreated Litter, 2.3 Mg/ha	3447ab	135.2	323.0	563.8	660.0	72.5	43.0	28.3	1.5	1.5	0.9
Untreated Litter, 6.8 Mg/ha	3422ab	134.4	341.7	567.3	632.5	72.4	44.9	27.8	1.4	1.4	0.8
Untreated Litter, 11.3 Mg/ha	4139a	138.4	339.2	575.8	640.0	74.9	44.0	27.2	1.4	1.5	0.8
Alum Litter, 2.3 Mg/ha	2087d	131.9	336.2	577.8	640.0	68.3	41.3	32.4	1.5	1.5	0.8
Alum Litter, 6.8 Mg/ha	3743a	129.9	345,4	586.6	630.0	64.7	42.9	31.4	1.4	1.4	0.8
Alum Litter, 11.3 Mg/ha	4091a	135.1	351.7	592.7	622.25	63.3	41.3	33.0	1.4	1.4	0.8

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Table 24. Dry matter yields and forage quality of tall fescue hay as influenced by nine different fertilizer treatments during the May 2005 harvest collection period.

	DM Yield	CP	ADF	NDF	TDN	Ash	Lignin	Fat	NEL	NEM	NEG
	DM kg ha-1				DM g kg-1				Mcal kg-1		
Fertilizer Treatment											
Control	2003ab	125.0	336.3	572.8	647.5	61.4	40.3	28.0	1.5	1.5	0.9
Local producer rate	2363ab	141.4	337.0	554.2	652.25	60.8	39.8	31.6	1.5	1.5	0.9
UT Recommended	2929a	143.5	343.6	566.1	642.5	57.9	41.0	27.2	1.5	1.5	0.8
Untreated Litter, 2.3 Mg/ha	1793ab	128.5	333.0	577.7	647.5	66.7	41.2	28.6	1.5	1.5	0.9
Untreated Litter, 6.8 Mg/ha	2531ab	138.2	357.9	583.4	625.0	64.4	43.2	28.2	1.4	1.4	0.8
Untreated Litter, 11.3 Mg/ha	1622b	152.9	343.8	564.9	642.5	68.4	41.3	30.0	1.5	1.5	0.9
Alum Litter, 2.3 Mg/ha	1644b	131.1	333.3	563.8	652.5	66.8	39.4	28.7	1.5	1.5	0.9
Alum Litter, 6.8 Mg/ha	2494ab	136.2	346.0	571.7	635.0	68.3	41.2	28.8	1.4	1.4	0.8
Alum Litter, 11.3 Mg/ha	2670ab	151.7	341.2	561.0	642.5	70.2	40.7	31.2	1.5	1.4	0.9

***Means followed by different letters within a column are significantly different at $p < 0.05$.**

Alum-treated litter had no significant effect on plant growth and did not reduce nutrient availability. With increasing application rates both litter types always increased plant growth. The UT recommended fertilizer application produced significantly higher yields in all sampling periods compared to the local producer rate due to the higher nitrogen application (114 kg N/ha compared to 64 N/ha).

Dry matter yield data evaluated in the study is similar to yield data from other southeastern states (Reynolds and Wall, 1982; Hallock et al., 1965; and Dobson and Beaty 1977). Tall fescue yields from these studies averaged from 1,000 to over 6,000 kg/ha with varying nitrogen applications from commercial fertilizer use. In Arkansas Self-Davis et al., (2003) reported similar yields by applying broiler litter at an 8.98 Mg/ha instead of fertilizer. Regardless of litter or fertilizer, yields will always respond significantly to the amount of N applied.

Crude Protein (CP)

Across all harvest periods CP concentrations were significantly higher with median (6.8 Mg/ha) and high (11.3 Mg/ha) alum-treated and untreated litter treatments and the UT recommended fertilized rate compared to the unfertilized control (Table 21). The increases in CP concentrations are related from the N application of these rates.

Compared to the low poultry litter rates (2.3 Mg/ha), CP significantly increased with the higher rates (Table 21). Seasonal differences from harvest sampling dates were due to climatic effects. In May 2004, CP concentrations (Table 21 and 22) were significantly higher from the cooler temperatures and increased rainfall in March and April 2004 (Figures 2 and 3). Between treatments in May 2004 median (6.8 Mg/ha) and high (11.3 Mg/ha) alum-treated and untreated litter treatments and the UT recommended fertilized rate were significantly higher compared to the unfertilized control (Table 22). No significant CP seasonal and treatment differences were observed for September 2004 (Table 23) and May 2005 (Table 24).

Alum application did not affect CP concentration or alter N applied that is necessary for amino acid production during protein synthesis. A similar CP increase in response to N fertilization with broiler litter were observed in mixed bermudagrass-tall fescue pastures for continuous and rotational stocking of steers in Georgia. The use of repeated broiler litter applications had increased CP from over a four-year period (Kuykendall et al., 1999). Kuykendall et al., (1999) used poultry litter rates from 5.9 to 8.9 Mg/ha (270 to 507 N kg/ha) with CP exceeding 184 g/kg due from excessive N.

The UT recommended maintained higher CP concentrations compared to the local producer rate. Similar effects observed in this study using two different complete NPK fertilizer rates in Tennessee are comparable to rates used by Reynolds and Wall (1982). They reported increases in CP when using a high NPK complete fertilizer rate (134-58-112 kg/ha) and reported lower CP concentrations when using a lower NPK complete fertilized rate (67-29-56 kg/ha). Crude protein concentrations in this study were always greater than 130 g/kg. Other states including Missouri, North Carolina, and Tennessee also report similar CP concentrations (Kallenbach et al. 2003; Burns and Chamblee 2000; and Reynolds and Wall, 1982).

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)

The NDF and ADF analyses showed no significant differences between treatments (Table 21, 22, 23, and 24). Average NDF and ADF differences across all treatments were significantly higher in May 2004 (Table 21) for ADF and September 2004 (Table 21) for NDF when concentrations were highest at these sampling events. Cooler temperatures and adequate moisture in March and May 2004 may have promoted and increase in ADF production (Figures 2 and 3). Weather conditions in August 2004 were warmer and drier and might have reduced ADF promoting NDF increases for September 2004 (Figures 2 and 3). Acid detergent fiber concentrations were not significantly different during the September 2004 and May 2005 harvest periods (Table 21). Neutral detergent fiber concentrations were not significantly different for the harvest dates of May 2004 and 2005. There was no clear evident trend when comparing effects of alum-treated litter, untreated litter, and commercial fertilizer in all sampling events.

Neutral detergent fiber concentrations in this study were greater than 500 g/kg, unlike Ross and Reynolds (1979) where concentrations were lower than 400 g/kg. All NDF concentrations reported from this study were greater than 500 g/kg and ADF concentrations between 350 to 370 g/kg.

Total Digestible Nutrients (TDN) and Net Energy Values

There were no observed significant differences across all treatments compared to the unfertilized control (Table 21) for TDN and net energy values for animal lactation, maintenance, and gain. No significant differences were observed for the May and September 2004 sampling events, but were significant in May 2005 (Table 21) that was proceeded by cooler temperatures and high precipitation in April 2005 (Figures 2 and 3). In addition there were no significant differences observed with individual treatments and less variation among TDN, Nel, Nem and Neg for May 2004 (Table 22), September 2004 (Table 23), and May 2005 (Table 24). The value of such parameters may have little use to beef producers in Tennessee; instead they are probably better suited for dairy and beef feedlots to maintain constant animal performance.

Lignin

No significant differences in lignin concentrations were observed across all treatments averaged across all harvest sampling dates (Table 21). There was however significant seasonal affects. Treatments did not affect lignin concentrations since there were no significant differences observed during September 2004 (Table 23) and May 2005 (Table 24). Seasonal differences were significantly higher in May 2004 (Table 21 and 22) when adequate temperatures and precipitation (Figures 2 and 3) withl fertilization increased plant growth that stimulated lignin concentrations. Lignin concentrations were significantly higher in May 2004 (Tables 22) from the low untreated litter rate (2.3 Mg/ha) and the unfertilized control since either nitrogen was under-applied or not applied, which could have promoted increased lignin within plant tissues. More N might have more vegetative growth and less reproductive tissue that would affect lignin concentration. The recommended and local producer fertilizer treatments, however, were not significantly different from each other in May 2004 (Table 22).

Lignin concentrations were probably more influenced from the seasonal effects affecting plant growth rather than fertilizer or broiler litter use. Depending on stage of maturity hay cut during harvest may have determined lignification within plant tissues. If cut earlier, lignin concentrations in plant tissue are lower and better for animal performance with increased digestibility (Ball et al. 2002). Lignin concentrations observed in this study average between 40 to 50 g/kg.

Ash

Ash concentrations were significantly higher across all treatments with high-untreated litter (11.3 Mg/ha) and median alum-treated litter (6.8 Mg/ha) compared to the unfertilized control (Table 21). No significant differences were observed with the UT recommended and local producer fertilizer rates (Table 21). Concentrations were significantly higher in September 2004 harvest compared to May 2004 and 2005 (Table 21) sampling dates. Ash was probably affected from less rainfall and warmer temperatures in August 2004, which could have affected dry matter production (Figures 2 and 3). No significant differences, however, were observed with individual treatments and harvest sampling periods of May and September 2004 and May 2005 (Table 22, 23, and 24). Since ash is the remaining inorganic fraction of plant material left after acid digestion, it is probably more influenced by plant growth and maturity rather than fertilization effects although broiler litter did increase ash from an increase in dry matter. In this study, ash as a forage quality parameter may not have any significant value to cattle producers, but is rather useful to agronomists and animal scientists evaluating forage nutrient concentrations for beef nutrition.

Fat

Fat concentrations observed across all treatments were significantly higher with the high (11.3 Mg/ha) alum-treated litter rates compared to the unfertilized control (Table 21). Fat concentrations although were not significantly different among the local producer and UT commercial fertilizer rate compared to the unfertilized control (Table 21). Harvesting in May 2004 (Table 21) was significantly higher compared to harvesting in September 2004 and May 2005 (Table 21) from adequate rainfall and cooler temperatures during March and April 2004 (Figures 2 and 3). Treatments that were significantly higher in May 2004 (Table 22) were the heavy alum-treated litter rate (11.3 Mg/ha) and UT recommended fertilizer rate compared to the unfertilized control. Treatments of September 2004 (Table 23) and May 2005 (Table 24) had no significant differences in fat concentrations. A possible factor for using alum might have been retained fat from pharmaceuticals and feed mixed in poultry litter. The most probable increase in fat is related to applied N at high rates in both broiler litter and fertilizer.

Other research has found such correlations to fat and N fertilization. Fat and lipids are part of the chloroplast membrane within plant tissue. So any increase in chloroplast membranes is the result of plant growth from increasing N (Mayland et al. 1976; Boufaied et al. 2003). Increasing fat can have negative and positive effects on cattle health. Positive effects from fatty acids can reduce cardiovascular diseases and hyperlidemia (Boufaied et al., 2003). Negative effects can increase risk of tetany because fat may reduce Mg availability during excretion. (Mayland et al., 1976).

Chapter 5. Conclusions

Forage Quality and Quantity

Typically producers aim to maximize the yield of their pastures and may overlook the quality of forage. Forage quality varies with soil fertility, nutrient uptake, maturity and height. Producers should be aware that increased plant growth and harvest time are critical to maintaining good quality forage. Forage nutritive value parameters of crude protein, fat, and ash decline significantly as plants move from vegetative growth to reproductive growth with advancing maturity. With more reproductive growth, forage becomes less palatable to grazing beef cattle. The over-application of fertilizers, not based on soil test recommendations can decrease the nutritive value of forage. The end results are low quality legumes or grasses that do not meet NRC nutritional requirements for sustaining cattle health and in some cases can be harmful to animal health.

Fertilizer rates and types favored by many producers are often not based on soil test recommendations. While they can result in increased forage yield, but forage quality may be lower compared to a recommended rate that has been tested to achieve a maximum yield. In this study, the UT recommended fertilizer rate achieved higher crude protein of 18 percent compared to 11 percent of the local producer rate and maintained 30 percent higher yields compared to the local producer rate versus an unfertilized control. Other nutritive value parameters of lignin, ADF, NDF, TDN, and net-energy values were not affected by any fertilizer treatment whether it was commercial fertilizer or broiler litter. Producers should evaluate forage nutrients such as S, K, Cu, Ca, and Mg in addition to nutritive value parameters.

Increasing broiler litter application rates above 6.8 Mg/ha (3 tons per acre) increased crude protein by 18 percent and increased yields greater than 30 percent during this study. The use of broiler litter rates above 6.8 Mg/ha over-applied S, K, Ca, and Mg, but suppressed Cu uptake. Broiler litter rates less than 2.3 Mg/ha did not over apply P and K nutrients and did promote a significant change in forage quality. Differences in yield and quality were similar whether litter is treated or not treated with alum.

Maintaining NRC Beef Cattle Nutrient Requirements

All fertilizer and litter treatments in this study achieved NRC recommended nutrient concentrations for P, Mg, Ca, S, K, and Zn. Treatments did not achieve Cu and Na concentrations necessary for beef cattle nutrition. Aluminum and Se concentration were detected well below toxicity levels and were not significantly different between the treatments. Application of broiler litter at rates greater than 6.8 Mg/ha met NRC recommended forage nutrient concentrations of P, Ca, S, K, Mg, and Zn throughout the entire study, but increased forage K and S to critical levels. Increases of forage K and S were probably due to antagonistic effects suppressing Cu uptake as well as Ca and Mg uptake. There was no difference between alum and untreated litter.

Concentrations of broiler litter nutrients (P, S, K, Cu, Ca, Mg, Zn, and N) increased when litter was stockpiled for a year. During stockpiling C and water is lost through microbial respiration and decomposition. Litter nutrients become more concentrated, and resulted in increased applications of P, K, S, Cu, and Zn in March 2005. Nitrogen concentrations were similar during the stockpiling process.

Tetany ratios or K/ (Mg + Ca) exceeded the 2.2 threshold for all treatments. Tetany ratios were higher with the higher litter application rates due to the higher assimilation of K. Highest ratios were observed with alum-treated and untreated litter applied at 6.8 and 11.3 Mg/ha. Tetany ratios of both the recommended and local producer fertilizer rates were also similar. The low rate of broiler litter applied at 2.3 Mg/ha kept forage nutrient concentration within NRC recommended concentrations during the study. Fertilized treatments of the UT recommended and local producer rate maintained similar forage P, Ca, S, K, Mg, and Zn concentrations and were considered safe for cattle herds but were deficient in Cu. All treatments showed observed antagonistic trends of increased S that suppressed forage Cu.

Soil Nutrients

After the first fertilizer application and first two harvests, soil nutrient concentrations were significantly higher for P and Zn compared to the unfertilized control. The highest soil P and Zn concentrations were observed at the higher litter application rates (alum-treated and untreated litter at 11.3 Mg/ha). At the highest litter applications (11.3 Mg/ha), P and Zn applications greatly exceeded crop removal rates. The UT recommended and local producer fertilized treatments resulted in similar Zn and P soil concentrations. With P, less was removed during harvest and a greater proportion was being retained in the soil through adsorption to the clay particles.

Recommendations

Using broiler litter at applications rates of 6.8 and 11.3 Mg/ha (equivalent to 3 and 5 tons per acre) on tall fescue gave better yields, but reduced forage quality. Reductions in quality were a result of the antagonistic effects of S and K on forage Cu, Ca, and Mg uptake. It should be noted that higher concentrations of crude protein were observed from these high rates. Forage Cu concentrations were deficient in all treatments.

It is recommended that producers in Tennessee should:

i) Utilize broiler litter at a lower rate at 2.3 Mg/ha (equivalent to 1 ton per acre in this study) that meets the K needs with additional nitrogen fertilizer to achieve good forage quality and quantity without risking nutrition imbalances to his cattle.

ii) Correct forage Cu deficiencies for cattle with available supplements. Producers would be advised to contact their local extension offices to determine which nutrient supplements are available on the market.

iii) Broiler litter should be retested routinely to monitor nutrient concentrations if litter sources are continuously stockpiling during storage or frequently turned.

iv) Follow recommendations of a nutrient management plan for proper utilization of litter nutrients and time their applications when forages will utilize most of the nutrients.

v) When using commercial fertilizer rates it is better suited to use a recommended rate based on actual soil test recommendations from UT Extension.

References

References

Ajwa, H.A., G.S. Banuelos, and H.F. Mayland. 1998. Selenium uptake by plants from soils amended with inorganic and organic materials. J. Environ. Qual. 27:1218-1227.

Bacon, C.W. 1994. Toxic Endophyte-Infected Tall Fescue and Range Grasses: Historic Perspectives. J. Anim. Sci. 173:861-870.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 1996. Southern Forages. 2nd ed. Phosphate & Potash Institute and the Foundation for Agronomic Research, Norcross, GA.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2002. Southern Forages. 3rd ed. Phosphate & Potash Institute and the Foundation for Agronomic Research, Norcross, GA.

Barker, J. C. 1994. Unpublished Databases: Livestock Manure Production and Characteristics. Raleigh, North Carolina: Department of Biological and Agricultural Engineering, North Carolina State University.

Blevins. D.G, M. Massie, and W. McClain. 2004. Phosphorus Fertilization Improves Quality of Stockpiled Tall Fescue. Better Crops. Vol. 88, (No. 4). p.7-9

Boufaïed, H., P.Y. Chouinard, G.F. Tremblay, H.V. Petit, R. Michaud, and G. Bélanger. 2003. Fatty acids in forages. I. Factors affecting concentrations. Canadian Journal of Animal Science 83:501-511.

Brady, N.C. and Weil, R.R. (1999) The Nature and Property of Soils, 12 th edition. Prentice Hall, Upper Saddle River, New Jersey, 881 pp.

Burns, J. C. and D.S. Chamblee. Adaptation. Pages 9-30 in: Tall Fescue. In R.C. Buckner and L.P. Bush (ed.) Tall Fescue. Agron. Monogr. 20. ASA, CSSA, and SSSA, Madison, WI.

Burns, J. C. and D.S. Chamblee. 2000. Summer accumulation of tall fescue at low Elevations in the Piedmont: I. Fall Yield and Nutritive Value. Agron. J. 92:211-216.

Burns, J. C. and D.S. Chamblee. 2000. Summer accumulation of tall fescue at low Elevations in the Piedmont: II. Fall and Winter Changes in Nutritive Value. Agron. J. 92:217-224.

Brown, M.A. and A.H. Brown, Jr. 2002. Relationship of milk yield and quality to preweaning gain of calves from Angus, Brahman and reciprocal-cross cows on different forage systems. J. Anim. Sci. 80:2522-2527.

Browning, Jr., R., 2004. Effects of endophyte-infected tall fescue on indicators of thermal Status and growth in Hereford and Senepol steers. J. Anim. Sci. 82:634-643.

CHAPA (Cow/calf Health and Productivity Audit. 1996. Blood selenium levels of in the US Beef Herd. Vet Services Info. Sheet available at: www.aphis.usda.gov/vs/ceah/cahm/

Cherney, J.H., E.A. Mikhailova, and D.J.R. Cherney. 2002. Tetany Potential Of Orchardgrass And Tall Fescue As Influenced By Fertilization with Dairy Manure Or Commercial Fertilizer. Journal of Plant Nutrition, 25(7):1501-1525.

Cherney, J.H., and D. J. R. Cherney. 2005. Agronomic response to cool-season grasses to low-intensity harvest management and low potassium fertility. Agron. J. 97:1216-1221.

Dai, X., and J. Boll. 2003. Evaluation of Attachment of Cryptosporidium parvum and Girardia lamblia to soil particles. J.Environ. Qual. 32:296-304.

Dennis, S.B., V.G. Allen, K.E. Saker, J.P. Fontenot, J.Y.M Ayad, and C.P. Brown. 1998. Influence of Neotyphidium coenophialum copper concentration in tall fescue. J. Anim. Sci. 76:2687-2693.

Dobson, J. W., and E.R. Beaty. 1977, Forage yield of five perennial grasses with and without clover at four nitrogen rates. J. Range Management. 30:461-465.

Essington, Michael E., 2004. Oxidation-Reduction Reactions in Soils. Pages 445-472 in Soil and Water Chemistry: An Integrative Approach. CRC Press, Boca Ratan, Florida.

Fisher, A.E., W.W. Gill, C.D. Lane, Jr., D.K. Joines, J.B.Neel and C.J.Richards. 2003. Two-Year mineral survey reveals deficiencies and imbalances in Tennessee tall fescue. Prof. Animal Scientist 19:286-289.

Fontenot, J.P. 1979. Animal Nutrition aspects of Grass Tetany. Pages 51-62 in: Grass Tetany. M. Stelly, ed. ASA, CSSA, SSSA, Madison, WI.

Gartrell, J.W. Distribution and Correction of Copper Deficiency in Crops and Pastures. p. 313-343. J.F. Loneragan, A.D. Robson, R.D. Graham. In Copper in Soils and Plants. Academic Press, Australia.

Gill, W., C. Lane, J. Neel, A. Fisher, G. Bates, and D. Joines. 2004. Mineral Nutrition in Beef Cattle. Pub. Bull. 1749. UT Extension Service, University of Tennessee, Knoxville, TN.

Gill, W., A. Fisher, C. Lane, C. Richards, D. Joines, and J. Neel. 2005. Assessing and Improving the Mineral Status of Tennessee Beef Cattle. 2005 Tennessee Nutrition Conference: Transforming Research into Results. March 3-4, Williamson County, TN.

Gissel-Nielsen, G., Gupta, U.C., Lamand, M, and Westermarck, T. 1984. Selenium in soils and plants and its importance in livestock and human nutrition. Advances in Agronomy 37:397-460.

Goh, K.M., and K.K. Kee. 1978. Effects of nitrogen and sulfur fertilization on the digestibility and chemical composition of perennial ryegrass (Lolium perenne, L.). Plant and Soil 50:161-177.

Graham, R. D. Distribution and Movement of Copper in Plants. p. 141-160. J.F. Loneragan, A.D. Robson, R.D. Graham. In Copper in Soils and Plants. Academic Press, Australia.

Hallock, D. L., R.H. Brown, and R.E. Blaser. 1965. Relative yield and composition of Kentucky 31 fescue and coastal bermudagrass at four nitrogen levels. Agronomy Journal. 57:539-542.

Hallock, D. L., R.H. Brown, and R.E. Blaser. 1966. Response of 'Coastal" and 'Midland' Bermudagrass and 'Kentucky 31' fescue to nitrogen in southeastern Virginia. Virginia Agric. Exp. Stn. Res. Rep. 112.

Harris, G., G. Gascho, and D. Kissel. 2001. Poultry Litter, Lime, and Foliar Feeding Cotton: The State Report from Georgia. 2001 Southern Soil Fertility Conference, Memphis, TN.

Haynes, R.J. and Williams, P.H. (Accumulation of soil organic matter and the forms, Mineralization potential and plant availability of accumulated organic sulfur: effects of pasture improvement and intensive cultivation. Soil Biology and Biochemistry 24:209-217.

Hopkins, A, Adamson, A.H., and Bowling, P.J. 1994. Response of permanent and Na, S, P, Mn, Zn, Cu, Co, and Mo in herbage at a range of sites. Grass and Forage Science 49, 9-20.

Ishler, V., J. Heinrichs, and G. Varga. 1996. From Feed to Milk: Understanding Rumen Function. Extension Circular 422. Penn State Cooperative Extension, State

College, PA.

Johnson, A.F., D.M. Vietor, F.M. Rouquette, Jr., and V.A. Haby. 2004. Fate of phosphorus in dairy wastewater and poultry litter applied on grassland. J. Environ. Qual. 33:735-739 (2004).

Jurgens, M. 1988. Evaluating Feedstuffs for Farm Livestock. Pages 49-69. In M. Jurgens (ed). Animal Feeding and Nutrition. Kendall/Hunt Publishing Comp., Dubuque, IA.

Kallenbach, R. L., Bishop-Hurley, G.J., M.D. Massie, G.E. Rottinghaus, and C.P. West. 2003. Herbage Mass, Nutritive Value, and Ergovaline Concentration of Stockpiled Fescue. Crop Science 43:1001-1005.

Kpomblekou-A, K., R.O. Ankumah, and H.A. Ajwa. 2002. Trace and Nontrace Elements. Contents of Broiler Litter. Commun. Soil. Sci. Plant Anal. 33(11&12): 1799-1811.

Kuykendall, H.A., C.S. Hoveland, M.A. McCann, and M.L. Cabrera. 1999. Continous Vs Rotational Stocking of Steers on Mixed Endophyt-Infected Tall Fescue-Bermudagrass Pastures Fertilized with Broiler Litter. J. Prod. Agric. 12:472-478.

Lock, T.R., R.L. Kallenbach, D.G. Blevins, T.M. Reinbott, G.J Bishop-Hurley., R.J. Crawford, Jr., M.D. Massie, and J.W. Tyler. 2004. Phosphorus Fertilization of Tall Fescue Pastures May Protect Beef Cows from Hypomagnesaemia and Improve Gain of Nursing Calves. Online. Forage and Grazinglands doi: 10.1094/FG-2004-0608-01-RS.

Loneragan, J. F. 1981. Distribution and Movement of Copper in Plants. p. 165-184. J.F. Loneragan, A.D. Robson, R.D. Graham. In Copper in Soils and Plants. Academic Press, Australia.

Malinowski, D.P, and D.P. Belesky. 1999a. Neotyphidium-coenophialum-Endphyte Infection Affects the Ability of Tall Fescue to Use Sparingly Available Phosphorus. Journal of Plant Nutrition, 22(4 & 5): 835-853.

Malinowski, D.P, and D.P. Belesky. 1999b. Tall Fescue Aluminum Tolerance Is Affected by Neotyphidium coenophialum Endophyte. Journal of Plant Nutrition, 22(8):1335-1349.

Malinowski, D.P, D. K. Brauer and D.P. Belesky. 1999c. The Endophyte Neotyphidium Coenophialum Affects Root Morphology of Tall Fescue Grown under Phosphorus Deficiency. J. Agronomy & Crop Science 183:53-60.

Mayland, H.F. and D.L. Grunes. 1979. Soil-climate-plant relationships in the etiology of grass tetany. P. 123-175. In V.V. Rendig and D.L. Grunes (ed.) Grass Tetany. ASA,CSSA, and SSS, Madison WI.

Mayland, H.F, L.F. Molloy, and T.W. Collie. 1976. Higher Fatty Acid Composition of Immature Forage as affected by N Fertilization. Agronomy Journal 68:979-982.

Mayland, H. F. 1977. Fertilization of pasture and range in the United States. Proceedings of the twenty-eighth Annuual Fertilizer Conference of the Pacific Northwest, Twin Falls, Idaho, July 12-14, 1977.

Matches, A.G. 1979. Management p. 171-199. In R.C. Buckner and L.P. Bush (eds.) Tall Fescue. Agron. Monogr. 20. ASA, CSSA, and SSSA, Madison, WI.

McLaren, R.G. (1976). Effect of fertilizers on the S content of herbage. Grass and Forage Science 31:99-104.

McDowell, L.R. 1992. Minerals in Animal and Human Nutrition. Academic Press, San Diego, CA.

McDowell, L.R. Minerals for Grazing Ruminants in Tropical Regions. University of Florida Cooperative Extension Service, University of Florida, Gainseville.

Moore, P.A., Jr., W.E. Huff, T.C. Daniel, D.R. Edwards, and T.C. Sauer. 1997. Effect of aluminum sulfate on ammonia fluxes from poultry litter in commercial broiler houses. p. 883-891. In. Proc. 5th Int. Symp. on Livestock Environ., Bloomington, MN. 29-31 May 1997. Vol. 2. Am. Soc. Agric. Eng., St. Joseph, MI.

Moore, P.A., S.Watkins, D. Carmen, and P. DeLaune. 2004. Treating Poultry Litter With Alum. Ext. Bulletin. FSA8003. Arkansas Cooperative Extension Service, University of Arkansas, Fayetteville.

Moore, Jr., P.A., T.C. Daniel, and D.R. Edwards. 1999. Reducing phosphorus runoff and improving poultry production with alum. Poultry Science 78:692-698.

Moore, Jr., P.A., and D.M. Miller. 1994. Decreasing phosphorus solubility in poultry litter with aluminum, calcium, and iron amendments. J. Eviron. Qual. 23:325-350.

Moore, K., and R. Garcia. 2001. Role, Impacts, and Management of Plant Lignin. In Karen Launchbaugh (ed.) Anti-quality Factors in Rangeland and Pastureland Forages. Bulletin # 73 Idaho Forestry, Wildlife, and Range Experiment Station, University of Idaho, Moscow, ID.

Mortimer, R.G., D.A. Dargartz and L.R. Corah. 1999. “Forage Analyses from Cow/Calf Herds in 23 States” USDA: APHIS: VS, Centers for Epidemiology and

Animal Health. Fort Collins, CO #N303.499.

NRAES, 1999. Poultry Waste Management Handbook (NRAES-132). Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701.

Norton, N.A., R.T. Clark, P.E. Reece, and K.M. Eskridge. 1997.Quality as a Factor in the Optimal Choice of Fertilization and Harvest Date of Meadow Hay. J. Prod. Agric., Vol. 10. no. 4, 1997.

Nutrient Requirements of Beef Cattle. 1996. Washington, D.C. National Research Council.

Official Methods of Analysis (1999) 16th. 5th Revision, 1999, AOAC International, Gaithersburg, MD, method 990.03.

Official Methods of Analysis (1999) 16th. 5th Revision, 1999, AOAC International, Gaithersburg, MD, method 973.18.

Official Methods of Analysis (1999) 16th. 5th Revision, 1999, AOAC International Gaithersburg, MD, method 920.39.

Official Methods of Analysis (1999) 16th. 5th Revision, 1999, AOAC International, Gaithersburg, MD, method 942.05.

Oliver, J.W., A.E. Schultze, B.W. Rohrbach, H.A. Fribourg, T. Ingle, and J.C. Waller. 2000. Alterations in hemograms and serum biochemical analytes of steers after prolonged consumption of endophyte-infected tall fescue. J. Anim. Sci. 78:1029-1035.

Pioneer Forage Manual-A Nutritional Guide. 1995. Pioneer Hi-Bred International, Inc.

Poore, M., J. Green, G. Rogers, K. Spivey, and K. Dugan. 2000. Nitrate management in beef cattle. Ext. Bulletin AG-606. North Carolina Cooperative Extension Service, North Carolina State University, Raleigh.

Porter, T.K., V.L. Lechtenberg, and C.L. Rhykerd. 1975. Effect of harvest date and nitrogen fertilization on digestibility and composition of grass hay. P.61-65. In 1975 Indiana Beef-Forage Res. Day, Purdue University.

Rahman, H., McDonald, P., and Simpson, K. (1960). Effects of nitrogen and potassium fertilizers on the mineral status of perennial ryegrass. Journal of the Science of Food and Agriculture 11, 422-428.

Reinbot, T.M., and D.G. Blevins. 1997. Phosphorus and Magnesium Fertilization

Interaction with Soil Phosphorus Level: Tall Fescue Yield and Mineral Element Content. J. Prod. Ag. 10:260-265.6

Reid, R.L., and G.A. Jung. 1965. Influence of fertilizer treatment on the intake, digestibility, and palatability of tall fescue hay. J of Animal Science 24:615-625.

Reynolds, J.H., and W.H. Wall, III. 1982. Concentrations of Mg, Ca, P, K and Crude Protein in Fertilized Tall Fescue. Agronomy Journal. 74:950-954.

Ross, J.P., and J.H. Reynolds. 1979. Nutritive-value of fall stockpiled tall fescue. Tenn. Farm Home Sci. 112:44-48.

Saker, K.E., V.G. Allen, J. Kalnitsly, C.D. Thatcher, W.S. Swecker, Jr., and J.P. Fontenot. 1998. Monocyte Immune Cell Response and Copper Status in Beef Steers that Grazed Endophyte-Infected Tall Fescue. J. Animal. Sci. 76:2694-2700.

Salette, J. 1978. Sulfur content in grasses during primary growth. In: Brogan, J.C. (ed) Sulphur in Forages. An Foras Taluntais, Dublin, pp. 142-152.

Savoy, Jr. H.J. and D. Joines. 2001. Lime and Fertilizer Recommendations for the Various Crops of Tennessee. BEES Info # 100. Tennessee Agricultural Extension Service, Univ. or Tenn., Knoxville.

Schellinger, D. A. and G. Breitenbeck. 1998. Quantifing losses of plant nutrients and elements during windrow composting of various feedstocks. Conference proceedings, Composting in the Southeast, September 9-11, Athens, GA.

Self-Davis, M.L., P.A. Moore, Jr., T.C. Daniel, D.J. Nichols, T.J. Sauer, C.P. West, G.E. Aiken, and D.R. Edwards. 2003. Forage species and canopy effects on runoff from small plots. Journal of Soil and Water Conservation 58:349-358.

Sharpley, A.N. 1997. Dispelling Common Myths about Phosphorus in Agriculture and the Environment. USDA-NRCS Watershed Science Institute Technical Paper.

Sims, J.T. and N.J. Luka-McCafferty. 2002. On-Farm evaluation of aluminum sulfate (alum) as a poultry litter amendment: Effects on litter properties. J. Of Env. Qual.31:2066-2073.

Smith, D. R., P.A. Moore, Jr., D.M. Miles, B.E. Haggard, and T.C. Daniel. 2004. Decreasing phosphorus runoff losses from land-applied poultry litter with dietary modifications and alum addition. J. Environ. Qual. 33:2210-2216.

Spears, J.W. Overview of Mineral Nutrition in Cattle: The Dairy and Beef NRC. Proceedings 13th Annual Florida Ruminant Nutrition Symposium, pp 113-126.

Stevenson, F.J. (1986) Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients. John Wiley and Sons, New York, 380 pp.

Tenant, T. and L. Wu. 2000. Effects of Water Stress on Selenium Accumulation in Tall Fescue (Festuca arundinacea Schreb) from a Selenium-Contaminated Soil. Archives Of Environmental Contaminant and Toxicology. 38:32-39.

Thompson, F.N., and L.R. Kennington. 2001. Anti-quality factors associated with alkaloids in eastern grasslands. Karen Lauchbaugh (ed). In anti-quality factors in rangeland and pastureland forages. Bulletin # 73. Idaho Forest,Wildlife, and Range Experiment Station. University of Idaho, Moscow.

Undersander, D, D.R. Mertens, and N. Thiex. 1993. Forage Analysis Procedures. National Forage Testing Association. [Online] Available at www.foragetesting.org/index.php?=lab_procedures

Underwood, E.J. and N.F. Suttle. 1999. Selenium. pp. 321-327. In E. J. Underwood and Suttle (ed.) The Mineral Nutrition of Livestock. CAB International Publishing, New York, NY.

U.S. Department of Agriculture, Economic Research Service, July 2004

U.S. Department of Agriculture, Economic Research Service, May 2005.

USDA – NRCS. 2005. Official soil series description. [Online] Available at www.soils.usda.gov/technical/classification/osd/index.html. Accessed August 25, 2005.

USDOC. 2004. Climatology of the United States no.20 1971-2000. Station: Greeneville Exp. Stn., TN. [Online] Available at www.ncdc.noaa.gov/climatenormals/clim20/tn/403679.pdf. Accessed August 25, 2005.

USDOC. 2005. Climatology of the United States. Station: Greeneville Exp. Stn., TN. http://cdo.ndc.noaa.gov/ancsum/ACS

Valle, G., L.R. McDowell, D.L. Pritchard, P.J. Chenoweth, D.L. Wright, F.G. Martin, W.E. Kunkle, and N.S. Wilkinson. 2002. Selenium Concentration of Fescue and B Bahiagrasses After Applying a Selenium Fertilizer. Commun. Soil Sci. Plant Anal, 33(9&10):1461-1472.

West, J.W., and J.H. Reynolds. 1984. Cation Composition of Tall Fescue Forage as Affected by K & Mg Fertilization. Agronomy Journal 76:676-680.

Whitehead, D.C. 1995. Grassland Nitrogen. CAB International, Wallingford, UK.

Whitehead, D.C. 2000. Macronutrient Cations: Potassium, Sodium, Calcium, and Magnesium. In Nutrient Elements in Grassland: soil-plant-animal relationships. CAB International, Wallingford, UK.

Wilkinson, S.R. and J.A. Steudemann. 1979. Tetany Hazard of Grass as Affected by Fertilization with Nitrogen, Potassium, or Poultry Litter and Methods Grass Tetany Prevention. Pages 93-121 in: Grass Tetany. M. Stelly, ed. ASA,CSSA, SSSA, Madison, WI.

Zuarov, D. E., S. Bonos, J. A. Murphy, M. Richardson, and F.C. Belanger. 2001. Endophyte infection can contribute to aluminum tolerance in fine fescues. Crop Sci. 41:1981-1984.

Appendix

A-1. May 2004, September 2004, & May 2005 Descriptive Statistics for Control Fertilizer Treatment.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.47	0.73	Protein	0.83	0.42	Protein	0.39	0.20
Fat	0.26	0.13	Fat	0.31	0.16	Fat	0.14	0.07
FiberADF	2.39	1.20	FiberADF	1.22	0.61	FiberADF	1.96	0.98
FiberNDF	2.07	1.04	FiberNDF	0.91	0.45	FiberNDF	2.47	1.23
Lignin	0.45	0.22	Lignin	0.06	0.03	Lignin	0.37	0.18
Ash	0.26	0.13	Ash	0.19	0.10	Ash	0.60	0.30
Calcium	0.11	0.06	Calcium	0.03	0.01	Calcium	0.07	0.04
Phosphorus	0.03	0.02	Phosphorus	0.03	0.01	Phosphorus	0.07	0.04
Magnesium	0.04	0.02	Magnesium	0.02	0.01	Magnesium	0.04	0.02
Potassium	0.18	0.09	Potassium	0.31	0.16	Potassium	0.12	0.06
Sulfur	0.03	0.01	Sulfur	0.02	0.01	Sulfur	0.02	0.01
Sodium	0.01	0.01	Sodium	0.01	0.00	Sodium	0.05	0.03
Copper	0.82	0.41	Copper	0.82	0.41	Copper	0.50	0.25
Zinc	1.15	0.58	Zinc	5.83	2.92	Zinc	2.16	1.08
TDN	2.63	1.31	TDN	1.41	0.71	TDN	2.63	1.31
NEL	0.03	0.02	NEL	0.01	0.01	NEL	0.03	0.01
Nem	0.04	0.02	Nem	0.02	0.01	Nem	0.04	0.02
Neg	0.04	0.02	Neg	0.02	0.01	Neg	0.04	0.02
Tetany Ratio	0.85	0.43	Tetany Ratio	0.63	0.31	Tetany Ratio	0.78	0.39
DM Yield	393.86	196.93	DM Yield	328.41	64.21	DM Yield	1278.41	639.21

A-2. May 2004, September 2004, & May 2005 Descriptive Statistics for Local Producer Commercial Fertilizer Rate.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.47	0.73	Protein	1.66	0.83	Protein	0.39	0.20
Fat	0.26	0.13	Fat	0.51	0.25	Fat	0.14	0.07
FiberADF	2.39	1.20	FiberADF	1.53	0.77	FiberADF	1.96	0.98
FiberNDF	2.07	1.04	FiberNDF	1.71	0.86	FiberNDF	2.47	1.23
Lignin	0.45	0.22	Lignin	0.55	0.28	Lignin	0.37	0.18
Ash	0.26	0.13	Ash	0.38	0.19	Ash	0.60	0.30
Calcium	0.11	0.06	Calcium	0.03	0.02	Calcium	0.07	0.04
Phosphorus	0.03	0.02	Phosphorus	0.02	0.01	Phosphorus	0.07	0.04
Magnesium	0.04	0.02	Magnesium	0.04	0.02	Magnesium	0.04	0.02
Potassium	0.18	0.09	Potassium	0.52	0.26	Potassium	0.12	0.06
Sulfur	0.03	0.01	Sulfur	0.07	0.04	Sulfur	0.02	0.01
Sodium	0.01	0.01	Sodium	0.01	0.00	Sodium	0.05	0.03
Copper	0.82	0.41	Copper	0.58	0.29	Copper	0.50	0.25
Zinc	1.15	0.58	Zinc	13.52	6.76	Zinc	2.16	1.08
TDN	2.63	1.31	TDN	1.50	0.75	TDN	2.63	1.31
NEL	0.03	0.02	NEL	0.02	0.01	NEL	0.03	0.01
Nem	0.04	0.02	Nem	0.02	0.01	Nem	0.04	0.02
Neg	0.04	0.02	Neg	0.02	0.01	Neg	0.04	0.02
Tetany Ratio	0.85	0.43	Tetany Ratio	0.82	0.41	Tetany Ratio	0.78	0.39
DM Yield	393.86	196.93	DM Yield	548.38	274.19	DM Yield	1278.41	639.21

A-3. May 2004, September 2004, & May 2005 Descriptive Statistics for UT Recommended Commercial Fertilizer Rate.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.34	0.67	Protein	1.39	0.69	Protein	1.79	0.89
Fat	0.35	0.17	Fat	0.36	0.18	Fat	0.31	0.15
FiberADF	1.99	0.99	FiberADF	1.14	0.57	FiberADF	3.15	1.57
FiberNDF	2.14	1.07	FiberNDF	1.91	0.96	FiberNDF	2.83	1.41
Lignin	0.67	0.33	Lignin	0.29	0.14	Lignin	0.23	0.12
Ash	0.34	0.17	Ash	0.82	0.41	Ash	0.68	0.34
Calcium	0.08	0.04	Calcium	0.02	0.01	Calcium	0.08	0.04
Phosphorus	0.02	0.01	Phosphorus	0.02	0.01	Phosphorus	0.08	0.04
Magnesium	0.04	0.02	Magnesium	0.04	0.02	Magnesium	0.05	0.03
Potassium	0.13	0.07	Potassium	0.49	0.25	Potassium	0.22	0.11
Sulfur	0.02	0.01	Sulfur	0.02	0.01	Sulfur	0.04	0.02
Sodium	0.01	0.01	Sodium	0.01	0.00	Sodium	0.01	0.00
Copper	0.96	0.48	Copper	1.26	0.63	Copper	0.58	0.29
Zinc	2.16	1.08	Zinc	8.06	4.03	Zinc	4.99	2.50
TDN	2.45	1.22	TDN	1.26	0.63	TDN	3.40	1.70
NEL	0.02	0.01	NEL	0.01	0.01	NEL	0.04	0.02
Nem	0.03	0.02	Nem	0.02	0.01	Nem	0.05	0.02
Neg	0.03	0.02	Neg	0.02	0.01	Neg	0.04	0.02
Tetany Ratio	0.85	0.42	Tetany Ratio	0.63	0.31	Tetany Ratio	0.91	0.45
DM Yield	1180.48	590.24	DM Yield	665.49	332.74	DM Yield	868.69	434.3

A-4. May 2004, September 2004, & May 2005 Descriptive Statistics for Untreated Litter 2.3 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.06	0.53	Protein	1.11	0.56	Protein	1.00	0.50
Fat	0.21	0.11	Fat	0.13	0.07	Fat	0.39	0.19
FiberADF	2.70	1.35	FiberADF	0.63	0.32	FiberADF	2.41	1.20
FiberNDF	2.29	1.15	FiberNDF	1.62	0.81	FiberNDF	2.34	1.17
Lignin	0.11	0.05	Lignin	0.23	0.11	Lignin	0.16	0.08
Ash	0.50	0.25	Ash	0.67	0.34	Ash	0.46	0.23
Calcium	0.10	0.05	Calcium	0.05	0.02	Calcium	0.23	0.11
Phosphorus	0.01	0.00	Phosphorus	0.02	0.01	Phosphorus	0.23	0.11
Magnesium	0.02	0.01	Magnesium	0.03	0.01	Magnesium	0.04	0.02
Potassium	0.08	0.04	Potassium	0.42	0.21	Potassium	0.18	0.09
Sulfur	0.03	0.01	Sulfur	0.02	0.01	Sulfur	0.04	0.02
Sodium	0.00	0.00	Sodium	0.01	0.00	Sodium	0.01	0.00
Copper	0.96	0.48	Copper	0.50	0.25	Copper	1.00	0.50
Zinc	1.41	0.71	Zinc	6.02	3.01	Zinc	2.38	1.19
TDN	2.63	1.31	TDN	0.82	0.41	TDN	2.87	1.44
NEL	0.03	0.02	NEL	0.01	0.00	NEL	0.03	0.01
Nem	0.04	0.02	Nem	0.01	0.01	Nem	0.04	0.02
Neg	0.03	0.02	Neg	0.01	0.00	Neg	0.04	0.02
Tetany Ratio	0.91	0.45	Tetany Ratio	0.90	0.45	Tetany Ratio	1.49	0.74
DM Yield	1260.22	630.11	DM Yield	1010.86	505.43	DM Yield	258.41	29.20

A-5. May 2004, September 2004, & May 2005 Descriptive Statistics for Untreated Litter 6.8 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.14	0.57	Protein	0.54	0.27	Protein	2.14	1.07
Fat	0.17	0.08	Fat	0.51	0.26	Fat	0.58	0.29
FiberADF	1.87	0.94	FiberADF	1.60	0.80	FiberADF	4.29	2.15
FiberNDF	2.63	1.32	FiberNDF	2.11	1.06	FiberNDF	3.97	1.98
Lignin	0.20	0.10	Lignin	0.14	0.07	Lignin	0.52	0.26
Ash	0.62	0.31	Ash	0.59	0.29	Ash	0.72	0.36
Calcium	0.05	0.02	Calcium	0.05	0.02	Calcium	0.07	0.03
Phosphorus	0.01	0.01	Phosphorus	0.02	0.01	Phosphorus	0.07	0.03
Magnesium	0.02	0.01	Magnesium	0.05	0.02	Magnesium	0.04	0.02
Potassium	0.14	0.07	Potassium	0.14	0.07	Potassium	0.22	0.11
Sulfur	0.01	0.01	Sulfur	0.02	0.01	Sulfur	0.03	0.02
Sodium	0.01	0.00	Sodium	0.00	0.00	Sodium	0.01	0.01
Copper	1.89	0.95	Copper	1.29	0.65	Copper	0.82	0.41
Zinc	2.16	1.08	Zinc	18.63	9.31	Zinc	5.12	2.56
TDN	2.31	1.15	TDN	2.06	1.03	TDN	4.80	2.40
NEL	0.02	0.01	NEL	0.02	0.01	NEL	0.05	0.03
Nem	0.03	0.02	Nem	0.03	0.02	Nem	0.07	0.04
Neg	0.03	0.02	Neg	0.03	0.02	Neg	0.06	0.03
Tetany Ratio	0.38	0.19	Tetany Ratio	0.53	0.26	Tetany Ratio	0.80	0.40
DM Yield	349.94	174.97	Yield	1202.59	601.29	DM Yield	293.44	146.72

A-6. May 2004, September 2004, & May 2005 Descriptive Statistics for Untreated Litter 11.3 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.73	0.86	Protein	1.37	0.69	Protein	2.56	1.28
Fat	0.30	0.15	Fat	0.32	0.16	Fat	0.65	0.32
FiberADF	3.03	1.52	FiberADF	2.25	1.13	FiberADF	3.33	1.67
FiberNDF	3.10	1.55	FiberNDF	2.11	1.05	FiberNDF	3.60	1.80
Lignin	0.80	0.40	Lignin	0.29	0.14	Lignin	0.39	0.20
Ash	0.78	0.39	Ash	0.61	0.30	Ash	0.68	0.34
Calcium	0.33	0.17	Calcium	0.03	0.01	Calcium	0.09	0.05
Phosphorus	0.02	0.01	Phosphorus	0.02	0.01	Phosphorus	0.09	0.05
Magnesium	0.02	0.01	Magnesium	0.03	0.01	Magnesium	0.05	0.02
Potassium	0.17	0.08	Potassium	0.44	0.22	Potassium	0.26	0.13
Sulfur	0.03	0.01	Sulfur	0.03	0.01	Sulfur	0.05	0.03
Sodium	0.01	0.00	Sodium	0.01	0.00	Sodium	0.01	0.01
Copper	1.71	0.85	Copper	0.58	0.29	Copper	0.96	0.48
Zinc	0.82	0.41	Zinc	9.75	4.87	Zinc	2.06	1.03
TDN	3.30	1.65	TDN	2.45	1.22	TDN	3.86	1.93
NEL	0.13	0.06	NEL	0.03	0.01	NEL	0.04	0.02
Nem	0.05	0.02	Nem	0.03	0.02	Nem	0.05	0.03
Neg	0.05	0.02	Neg	0.03	0.02	Neg	0.05	0.03
Tetany Ratio	1.55	0.77	Tetany Ratio	0.55	0.27	Tetany Ratio	0.83	0.42
DM Yield	1437.61	718.81	DM Yield	395.09	197.55	DM Yield	636.83	318.42

A-7. May 2004, September 2004, & May 2005 Descriptive Statistics for Alum Treated Litter 2.3 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	0.84	0.42	Protein	0.49	0.25	Protein	0.61	0.30
Fat	0.22	0.11	Fat	0.27	0.14	Fat	0.27	0.14
FiberADF	1.07	0.53	FiberADF	1.51	0.76	FiberADF	1.18	0.59
FiberNDF	0.79	0.40	FiberNDF	1.48	0.74	FiberNDF	1.29	0.65
Lignin	0.27	0.13	Lignin	0.11	0.05	Lignin	0.28	0.14
Ash	0.60	0.30	Ash	0.08	0.04	Ash	0.47	0.23
Calcium	0.08	0.04	Calcium	0.03	0.01	Calcium	0.07	0.04
Phosphorus	0.02	0.01	Phosphorus	0.02	0.01	Phosphorus	0.07	0.04
Magnesium	0.02	0.01	Magnesium	0.05	0.02	Magnesium	0.02	0.01
Potassium	0.13	0.06	Potassium	0.38	0.19	Potassium	0.07	0.03
Sulfur	0.01	0.01	Sulfur	0.02	0.01	Sulfur	0.02	0.01
Sodium	0.01	0.00	Sodium	0.01	0.00	Sodium	0.00	0.00
Copper	0.50	0.25	Copper	1.15	0.58	Copper	0.96	0.48
Zinc	1.41	0.71	Zinc	6.24	3.12	Zinc	0.96	0.48
TDN	1.50	0.75	TDN	1.83	0.91	TDN	1.26	0.63
NEL	0.02	0.01	NEL	0.02	0.01	NEL	0.01	0.01
Nem	0.02	0.01	Nem	0.02	0.01	Nem	0.02	0.01
Neg	0.02	0.01	Neg	0.02	0.01	Neg	0.02	0.01
Tetany Ratio	0.58	0.29	Tetany Ratio	0.79	0.40	Tetany Ratio	0.76	0.38
DM Yield	541.36	270.68	DM Yield	580.80	290.40	DM Yield	249.27	124.63

A-8. May 2004, September 2004, & May 2005 Descriptive Statistics for Alum Treated Litter 6.8 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	1.73	0.87	Protein	0.46	0.23	Protein	0.93	0.46
Fat	0.16	0.08	Fat	0 .19	0.09	Fat	0.38	0.19
FiberADF	3.15	1.57	FiberADF	1.15	0.58	FiberADF	2.46	1.23
FiberNDF	3.50	1.75	FiberNDF	1.02	0.51	FiberNDF	2.76	1.38
Lignin	40.66	0.33	Lignin	0.25	0.12	Lignin	0.35	0.18
Ash	0.79	0.40	Ash	0.68	0.34	Ash	0.70	0.35
Calcium	0.08	0.04	Calcium	0.02	0.01	Calcium	0.08	0.04
Phosphorus	0.01	0.00	Phosphorus	0.01	0.00	Phosphorus	0.08	0.04
Magnesium	0.03	0.01	Magnesium	0.03	0.02	Magnesium	0.05	0.02
Potassium	0.21	0.10	Potassium	0.15	0.07	Potassium	0.22	0.11
Sulfur	0.03	0.02	Sulfur	0.03	0.02	Sulfur	0.04	0.02
Sodium	0.01	0.00	Sodium	0.01	0.00	Sodium	0.01	0.00
Copper	0.96	0.48	Copper	1.71	0.85	Copper	0.82	0.41
Zinc	1.50	0.75	Zinc	9.36	4.68	Zinc	1.26	0.63
TDN	3.59	1.80	TDN	1.41	0.71	TDN	2.89	1.44
NEL	0.04	0.02	NEL	0.01	0.01	NEL	0.03	0.01
Nem	0.05	0.03	Nem	0.02	0.01	Nem	0.04	0.02
Neg	0.05	0.02	Neg	0.02	0.01	Neg	0.04	0.02
Tetany Ratio	0.50	0.25	Tetany Ratio	0.40	0.20	Tetany Ratio	1.14	0.57
DM Yield	684.66	342.33	DM Yield	792.16	396.08	DM Yield	260.96	130.48

A-9. May 2004, September 2004, & May 2005 Descriptive Statistics for Alum Treated Litter 11.3 Mg/ha.

Variable	St. Dev	Std. Error	Variable	St. Dev	Std. Error	Variable	Std. Dev	Std. Error
Protein	2.80	1.40	Protein	0.58	0.29	Protein	0.76	0.38
Fat	0.76	0.38	Fat	0.24	0.12	Fat	0.34	0.17
FiberADF	4.16	2.08	FiberADF	1.12	0.56	FiberADF	2.06	1.03
FiberNDF	3.89	1.94	FiberNDF	0.65	0.32	FiberNDF	1.82	0.91
Lignin	0.61	0.31	Lignin	0.43	0.21	Lignin	0.60	0.30
Ash	0.21	0.11	Ash	0.46	0.23	Ash	0.39	0.20
Calcium	0.07	0.03	Calcium	0.06	0.03	Calcium	0.05	0.02
Phosphorus	0.01	0.00	Phosphorus	0.05	0.02	Phosphorus	0.05	0.02
Magnesium	0.02	0.01	Magnesium	0.03	0.02	Magnesium	0.03	0.01
Potassium	0.14	0.07	Potassium	0.17	0.09	Potassium	0.21	0.10
Sulfur	0.04	0.02	Sulfur	0.04	0.02	Sulfur	0.02	0.01
Sodium	0.01	0.00	Sodium	0.00	0.00	Sodium	0.01	0.00
Copper	1.26	0.63	Copper	0.96	0.48	Copper	0.82	0.41
Zinc	1.89	0.95	Zinc	11.59	5.80	Zinc	1.73	0.87
TDN	4.76	2.38	TDN	1.50	0.75	TDN	2.22	1.11
NEL	0.05	0.03	NEL	0.02	0.01	NEL	0.03	0.01
Nem	0.07	0.04	Nem	0.02	0.01	Nem	0.03	0.02
Neg	0.06	0.03	Neg	0.02	0.01	Neg	0.03	0.02
Tetany Ratio	0.69	0.35	TetanyRatio	0.62	0.31	Tetany Ratio	0.44	0.22
DM Yield	1826.57	913.29	DM Yield	564.45	282.23	DM Yield	519.32	259.66

Vita

Stacy Clark was born in Rome, Georgia on September 30, 1977. He was raised in Perry and Byron, Ga. In 1996 he graduated from Perry High School and then attended Abraham Baldwin Agricultural College in Tifton, GA. From there he graduated from the University of Georgia in 2000. Upon completion of his bachelor of science in environmental health he worked at the Georgia Soil and Water Conservation Commission from 2001 to 2003. Currently, he is a graduate research assistant at the University of Tennessee, Knoxville.