COMPARISON OF THREE TALL FESCUE-BASED STOCKER SYSTEMS

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by
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The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled:

COMPARISON OF THREE TALL FESCUE-BASED STOCKER SYSTEMS

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This dissertation is firstly dedicated to the animals that participated in the study. They gave-up more than I would have to become steers in this study. Their sacrifice is greatly appreciated. Secondly, as seems customary, this dissertation is dedicated to any family member, friend, or random acquaintance that for some reason or another thinks I am now a better person than before. Finally, the last dedication of this dissertation is to the one person that knows I’m not any better person than before; my wife (now anyone that is still reading this other than the wife please turn your head while reading the following sentence, after all this is personal). I know that it has always been your life’s dream since you were a little girl to have a dissertation based on cattle dedicated to you, so here you are. I hope now you can consider your life as complete as I do.
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\(^1\) I assure you that that is not one of them backhanded compliments he is always talking about.
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Generally, stocker operators purchase small sets of lightweight calves that often need castrated, dehorned, and vaccinated. Revenue is generated upon resale of the improved heavier animals in uniform groups large enough to occupy a single pen in a feedlot. The retention time of the animals during the stocker phase generally ranges from 6-12 months, and is dependent upon animal response to management, their inherent genetic ability to grow, and the forage management philosophy of the producer. In a humid environment such as Missouri, tall fescue predominates as the main forage, and issues such as poor animal performance manifest themselves during midsummer months. At this time of year, tall fescue growth slows, and nutritive value declines. To remain economically viable, it is imperative that the stocker operator keeps calves growing at an acceptable rate. It is during this midsummer period that the grazing philosophy of the producer is tested in regards to maintaining animal performance. One approach to maintaining animal performance during the midsummer months is to supplement the calves with grain, byproduct feed, or a commercial mixture. This approach generally produces the desired effect in the sense that animal growth rate is increased. However, the response is often unpredictable. This study supplemented stocker calves on pasture with the intention to generate a predictable animal growth rate response. The amount of supplement (DDGS) offered to the calves was contingent upon forage nutritive value, and a target ADG of 0.9 kg day\(^{-1}\). The supplemented treatment was termed “DISTILLERS”.

This two year study also included two other treatments, one was to act as a control (CONTROL), and the other to determine if similar ADG could be generated by increased forage management practices termed “SILAGE”. All three treatments were rotationally stocked with six paddocks. No forage was mowed, except in the SILAGE treatment. In this treatment excess forage produced in the spring was removed and stored as round bale silage. Pasture area for each treatment was 1.62 ha in size, replicated three times, and stocked at 567 kg ha\(^{-1}\) live-weight. Within each year, two sets (a spring set and a fall set) of crossbred steers were stratified by weight and randomly assigned to one of three treatments. The spring set (n = 72; 229 ± 11 kg), was on pasture from early April to mid August, and the fall set (n = 72; 248 ± 18 kg) was on pasture from early July to late October. There was a five week overlap between the two sets of steers within each year. The CONTROL steers total gain ha\(^{-1}\) (276 kg) was less \((P < 0.01)\) than the DISTILLERS (459 kg) and SILAGE (402 kg) steers, which were equivalent to each other \((P = 0.09)\). Steer ADG for the spring set was equivalent for SILAGE and DISTILLERS \((P = 0.51)\), but greater than CONTROL \((P = 0.01)\). The ADG for steers in the spring set was 0.79, 0.81, and 0.62 kg for DISTILLERS, SILAGE, and CONTROL, respectively. For the fall set, ADG for all three treatments was different \((P = 0.02)\). The fall set, steer ADG was 0.72, 0.53, and 0.29 kg for DISTILLERS, SILAGE, and CONTROL, respectively. The only treatment that had equivalent ADG between the spring set and the fall set was the DISTILLERS treatment \((P = 0.07)\). Adjusting the amount of DDGS supplemented to the steers based on forage nutritive value resulted in consistent gains, but not as predictable as desired. Several factors may have contributed to the lower than anticipated ADG in the DISTILLERS treatment including; unaccountable energy expended for walking during
grazing, fly infestation, unknown, random, and potentially poor quality cattle, castration of some animals, and so on. Controlling the forage maturity level by mechanical removal in the SILAGE treatment resulted in total gains ha\(^{-1}\) equivalent to the DISTILLERS treatment. Stocker operators who need consistent gains throughout the season should supplement based on forage nutritive value, but stocker operators only concerned with total gains should consider either supplementing or controlling forage maturity by mechanical removal and storage. If the stocker operator has management objectives in addition to cattle responses, such as pasture aesthetics, then they should consider the SILAGE treatment, as the pastures were grazed evenly and seemed more visually appealing.
CHAPTER 1

GENERAL INTRODUCTION

Beef Supply

The U.S. beef industry is complex. It takes substantial coordination across all sectors to supply the consumer with fresh beef throughout the year. The major sectors of the beef industry are the cow/calf producer, backgrounder/stocker operator, feeder, packer, and retailer. Since approximately 70% of the cow herd calves in the spring months and approximately 30% calve in the fall months, it would seem intuitive that the beef supply to the consumer would be seasonal, with 70% of fed cattle finishing at one part of the year and the remaining 30% finishing at another part of the year. However, this is not the case. The consumer has a seemingly uninterrupted supply of beef throughout the year. This steady supply throughout the year is largely the result of stocker operators, and is the focus of the following document.

Stocker Calves

The definition of a stocker calf is difficult to delineate since animals may change status based on industry movement, cost of grain and other feedstuffs, and cattle price cycles. For example, stocker heifers may become replacement heifers if the market is favorable. And calves purchased from a salebarn generally have low feed intake upon arrival to a new facility (especially if they are not weaned). To meet energy requirements, a high concentrate diet characteristic of feeder calves is generally offered to newly
received stocker calves (Rossi et al., 2005). The feeding of concentrates may extend to 60
days before the calves go to pasture. Before the calves come off pasture, many producers
of stocker cattle feed concentrates for increased daily gains. Since the diet of a stocker
calf is forage based (Bock et al., 1991; Cherney and Kallenbach, 2007), the high levels of
concentrates at the beginning and end of the stocker phase blur the lines between
backgrounder, stocker, and feeder calf. For the purpose of this manuscript, a stocker calf
is defined as a weaned, growing beef animal (less than approximately 375 kg) whose diet
is primarily forage.

Approaches to Managing Stocker Calves

The ability of the stocker sector to smooth-out the supply of beef to the feedlot,
and ultimately to the retailer, is due largely to the varying philosophical approaches to
managing stocker cattle (Peel, 2000). Because of the diverse approaches, calves grow at
different rates, thus supplying feeder calves to the feedlot at different times of the year.
Although there are several approaches to managing forage and grazing cattle, some
generalities can be made. The following discussion will be limited to three broad
approaches to managing forage resources in a rotationally stocked system for growing
cattle.

The first approach to stocking cattle, which is more in line with what is
traditionally practiced, is to rotate animals to new pastures when the forage is grazed
down in the occupied pasture. Under this management practice, it is not uncommon that
producers hold animals in each paddock too long in an attempt to graze the forage down
to acceptable residual heights. This results in two things: 1) forage intake limits animal
performance (Minson, 1990), and 2) the remaining paddocks that are not accessed early in the season become mature and low in nutritive value before being grazed. If the animals are rotated to a new paddock too soon, forage in the paddock that was not grazed low enough the first time through will become mature and will likely be rejected on the following rotation. The area of rejected forage tends to amass, and as the season progresses the harvested area becomes smaller than the actual paddock area (Parsons, 1988). As a result of either too slow or too fast rotation, forage nutritive value declines in pastures due to forage maturity, and the stocking area is essentially reduced. As a consequence, animal gains decline later in the season and annual forage utilization is low.

Producers rationalize this type of management by convincing themselves that the soil and plants in the pasture will ultimately benefit from more organic matter accumulation (from rejected biomass being recycled) and plant root recovery in the rejected areas (Savory and Butterfield, 1999; Parsons and Chapman, 2000). The producer also realizes that to a point, forage quantity is nearly as important to calf growth as forage nutritive value (Mertens, 1994; Paterson et al., 1994). The beneficial aspect to this system is that labor requirements are low since all that is required is the movement of animals to new pastures as needed. Also, with young growing animals, some of the rate of weight gain can be made-up when they are subsequently moved to pastures with a higher nutritive value, or to the feedlot (Ryan et al., 1993). The low labor requirements of this system allow time to be allocated to other duties, which is especially beneficial if the producer also raises row crops or works off the farm.

The second approach to stocking cattle is identical to the first with the exception of offering a protein or energy supplement to the calves. The reasons to supplement
calves vary depending on the goals of the operator. Some operators use supplements to augment daily gains, check for health issues, encourage consistent intake of mineral/ionophore, stretch forage supply, increase carrying capacity, influence cattle behavior (Paterson et al., 1994; Kunkle et al., 2000), or to foster the relationship between producer and animals. Supplements can be whole or processed grains, grain byproducts, or a commercially produced feedstuff. The type of feedstuff and the amount fed can vary depending on time of year and forage nutritive value. For example, small quantities of a high energy, low protein (or high rumen undegradable protein) supplement may be offered during spring and fall months when forage is plentiful and high in soluble protein, whereas greater amounts of high protein supplement may be offered during the summer and winter months when forage growth slows and protein levels decline (Paterson et al., 1994). Generally, studies investigating supplementation of stocker calves on pasture have fed preset amounts of supplement to calves, and then compared the influence of different supplements against themselves or to different forage bases.

The third approach to managing forage for stocker calves is to remove and store the excess forage produced in pasture during the spring months as hay or round bale silage. The stored forage is fed back to the calves in the system as needed. Labor and fixed overhead costs related to this system are higher than the other two systems, but the forage-on-offer contains greater nutritive value and the pastures are easier to manage based on forage regrowth and grazing patterns. Unlike forage removal by the grazing animal, mechanical harvesting removes all the stems and leaves resulting in uniform regrowth. The animals upon reentry into the pastures remove the regrowth more uniformly compared to the other two systems. Average daily gain of calves is generally
in line with the moderately supplemented system because of higher nutritive value of the forage-on-offer.

**Tall Fescue**

Tall fescue \([Lolium arundinaceum \text{ (Schreb.) Darbysh.} = (Schedonorus arundinaceus \text{ (Schreb.) Dumort.})]\) is the most commonly used grass for cattle in the transition zone of the U.S. (Sleper and West, 1996). Details regarding the history, distribution, macromorphological characteristics, growth habits, and management of tall fescue can be found in Cowan (1956), Buckner and Bush (1979), Matches (1979), Sleper and Buckner (1995), and Sleper and West (1996). General characteristics of tall fescue are that it is a drought tolerant rhizomatous bunch (to sod-forming) grass that grows relatively well on soils low in nutrients. It responds well to N fertilizer, providing approximately 30 kg of DM produced for every kg of N applied (Matches, 1979), and generally produces acceptable daily gains for grazing animals. Tall fescue pastures can produce 7 to 12 Mg ha\(^{-1}\) year\(^{-1}\) DM under optimum management and adequate soil water.

The nutritive value of tall fescue depends on stage of growth, soil fertility, genetic background, amount of accumulated DM, season of year, and level of endophyte \((Neotyphodium coenophialum)\) infection (Matches, 1979; Sleper and Buckner, 1995; Roberts and Andrae, 2004). Generally, the nutritive value of tall fescue is lowest during summer and highest during spring and fall (Probasco and Bjugstad, 1980; Sleper and Buckner, 1995). Crude protein (CP) and digestible dry matter of tall fescue pastures ranges from 80 to 200 g kg\(^{-1}\) and 500 to 750 g kg\(^{-1}\) respectively; with CP and digestible dry matter levels greatest early spring (Matches, 1979). After mid-spring, the levels of CP
and digestible dry matter decline until new growth commences during the late summer/fall months (Matches, 1979).

**Energy Supplementation of Calves on Tall Fescue-Based Pastures**

Performance of stocker calves grazing tall fescue-based pasture systems declines in the midsummer months. The reason for poor animal performance during this period of year is due not only to the deleterious effects of ergovaline produced by the tall fescue endophyte fungus (Roberts and Andrae, 2004), but also the relatively low energy and protein content of the grass (Henning et al., 1993; Smith et al., 2002). Tall fescue is a cool-season grass that produces forage vigorously in spring and again in fall, but the grass generally becomes semi-dormant under hot and dry weather conditions in summer (Spooner and McGuire, 1979; Sleper and West, 1996). To maintain cattle performance throughout the mid-summer months, stocker cattle need access to high-quality supplemental feed and/or forage to mitigate the declining supply of good quality pasture.

Supplementing steers on tall fescue with crimped corn (10 g kg\(^{-1}\) body weight (BW)) and cracked corn (3.4 g kg\(^{-1}\) BW) pasture has been shown to increase ADG and carrying capacity (Mott et al., 1971; Hess et al., 1996). The increase in carrying capacity is partly due to the substitution of corn for forage. However, cattle supplemented with corn can have reduced DM intake because the high starch levels reduce rumen pH and fiber digestion (Caton and Dhuyvetter, 1997), especially when the amount of starch exceeds approximately 300 g kg\(^{-1}\) intake (Galyean and Goetsch, 1993). The increase in starch supply and the concomitant reduction in rumen pH often shift the rumen microbial population and decreases the digestion rate of fibrous feeds. As digestion rates decrease,
the resident time of forage within the rumen increases, and this may cause a reduction in DM intake.

Distillers dried grain with solubles (DDGS) is a low-starch byproduct of corn milling during ethanol production (Singh et al., 2001). It has approximately 100 g kg⁻¹ fat, 460 g kg⁻¹ neutral detergent fiber (NDF), 300 g kg⁻¹ CP, and 50 g kg⁻¹ ash (NRC, 1996). The metabolizable energy, net energy maintenance (NEₘ), and net energy gain NE₉ is 3.18, 2.18, and 1.50 Mcal kg⁻¹, respectively (NRC, 1996). Since DDGS is a low starch feed, fiber digestion and DM intake should not be considerably depressed compared to feeding corn (Caton and Dhuyvetter, 1997; Corners, 2004).

Ham et al. (1994) reported no difference in gains of calves fed wet distillers grains (with thin stillage) or DDGS. Wet distillers grain was 170, 330, and 290 g kg⁻¹ greater in energy than dry-rolled corn when fed to calves at 52, 126, and 400 g kg⁻¹ of diet DM (Larson et al., 1993). Calves fed increasing levels of wet distillers grain consumed less DM, gained faster, and were more efficient than the control calves not fed wet distillers grains (Larson et al., 1993). Corners (2004) found ADG of growing cattle on tall fescue pasture peaked when supplemented 0.91 kg DDGS d⁻¹. However, he did not adjust the quantity of DDGS fed based on the nutritive value of the forage.

**Frequency of Supplementation**

Results from studies are inconclusive on the effect of growth rates of cattle supplemented daily or on alternate days (Kunkle et al., 2000; Loy et al., 2008; Aiken et al., 2005). Aiken et al. (2005) found no difference in the daily growth rates of steers grazing bermudagrass supplemented with corn every day compared to every other day.
Alternatively, Loy et al. (2008) reported approximately 10% higher daily growth rate (0.62 kg d\(^{-1}\) compared to 0.56 kg d\(^{-1}\)) of heifers supplemented daily with DDGS as compared to heifers supplemented on alternate days. However, Loy et al. (2008) only offered supplement on Monday, Wednesday, and Friday; they excluded the weekends. Their findings may have been different if the calves were truly supplemented on alternate days. If the reduction in ADG is a reality, producers would have to determine if a 0.06 kg reduction in ADG would be worth the extra labor involved in supplementing daily.

Energy and nutrient requirements have been extensively studied to maximize profits and daily gains for feedlot cattle. However, energy requirements for grazing systems are not fully defined (Caton and Dhuyvetter, 1997). Grazing animals may expend 1.08 to 1.30 times more energy than cattle in a drylot through forage intake and walking (Di Marco and Aello, 2001). Therefore, the NE\(_g\) requirements between cattle grazing and those in a confinement setting may not be equivalent. Since optimal performance of grazing cattle fed supplements is contingent upon supplying energy and protein consistently to the rumen (Weston and Poppi, 1987; Cherney and Cherney, 1999), it is essential to adjust the amount of supplement according to forage digestible dry matter and CP levels to optimize daily gains.

Studies have been conducted to assess daily growth rates and nutritive value of tall fescue-based pastures (Burns et al., 2002). And several studies have been conducted with DDGS supplemented throughout the grazing period (Larson et al., 1993; Loy et al., 2003; Corners, 2004), but no studies could be found where the amount of DDGS supplemented was adjusted based on nutritive value of the forage to maintain desired daily gains of the grazing animal.
Methods of Storing Forage

In tall fescue-based forage systems, excess spring growth is commonly harvested as hay and fed back to livestock when pasture growth is limiting. The main disadvantage to this system is that the nutritive value of the stored forage is lower than the fresh forage. Forage is field dried to approximately 150-200 g kg⁻¹ water content before being baled. The time it takes to dry the forage is largely contingent upon weather conditions; during the spring months forage is often exposed to rain during field curing. Rain damage (leaching of nutrients and oxidation of DM by heterotrophic bacteria and fungi) results in hay of variable composition and low nutritive value. The poor and inconsistent quality of rain damaged hay leads to unacceptable daily gains of cattle when fed alone (McDonald, 1981; Allen et al., 1992; Crawford and Garner, 1993). In an attempt to avoid rain damage, producers often delay haymaking until later in the growing season. As a result, the forage is often mature at harvest, resulting in hay that is low in digestibility, energy, and crude protein (Perry et al., 1999; Smith et al., 2002). Producers that feed hay during the summer when pasture growth slows may not be maximizing production from the system due to the limitations of forage quality, DM losses, and production costs associated with haymaking.

Alternatively, excess spring growth from tall fescue pastures can be harvested as round bale silage. The advantage of making round bale silage instead of hay is that round bale silage can be successfully harvested in spring. Round bale silage is field-dried to approximately 500-600 g kg⁻¹ water content prior to baling, so the forage has less
exposure time to detrimental weather events when compared to making hay. Additionally, leaf loss is reduced when mechanically harvesting moist forage.

Successful preservation of forage harvested with a high water concentration depends on achievement of anaerobic conditions. In the case of large round bale silage, this is attained by wrapping bales with non-permeable plastic. Aerobic microbial and plant respiratory enzymes quickly utilize available oxygen within the wrapped bale during oxidation of reduced carbon substrates. Depletion of oxygen within the sealed bale discourages growth of obligate aerobic microorganisms and creates an anaerobic environment conducive to lactic acid bacterial growth. The lactic acid bacteria suppress growth of additional detrimental microbes (often toxin producing), such as clostridia, by lowering the pH of the forage through the production of lactic acid (McDonald, 1981). The result of forage preserved through fermentation is a feed that may be of higher nutritive value and consistency than hay (Hannaway et al., 1999; Perry et al., 1999).

**Study Basis**

Weight gains of stocker cattle decline during the summer months in a rotationally stocked tall fescue-based system. Stocker operators need to maintain daily gain of calves throughout the grazing season for two reasons. The first is to deliver contracted cattle of a known weight at a certain date. The second is to increase flexibility regarding the destocking of pastures if circumstances dictate. If the stocker operator needs to destock during the summer months when gains are poor, the fixed costs associated with maintaining calves during this period often reduces profits substantially.
To maintain gains and stocking density, stocker operators may supplement calves with hay produced from excess spring growth from a portion of available paddocks within the system. When only a portion of the total pastures are harvested as hay, patchy grazing persists throughout the remainder of the season of non-hayed paddocks since a large portion of these paddocks have mature forage that was rejected when the paddocks were grazed the first time through. Weight gain of the calves will decline due to limited forage availability and low nutritive value of formerly rejected forage. Other stocker operators may supplement calves with grains, grain byproducts, or a commercial feed. This often increases gains over unsupplemented calves, but the gains are unpredictable due to variation in forage nutritive value.

Two alternatives are: 1) offer a supplement to the stocker calves, but base the supplement amount on forage nutritive value, and 2) try to manage pastures for a more consistent quality by removing excess spring growth as hay or round bale silage from all paddocks within the system. This study included one treatment that adjusted the amount of DDGS fed2 to steers based on forage nutritive value, and one treatment that stored excess forage as round bale silage made from all paddocks within the system.

Objectives

The objective of this study was to determine stocker steer response to three different tall fescue-based systems.

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2 Cattle in the supplemented treatment were supplemented on alternate days even though Loy et al. (2008) reported a 10% reduction in ADG for heifers supplemented on alternate days. We were not concerned with any potential reduction in ADG for two reasons: Loy et al. (2008) supplemented heifers consuming native grass hay in a confined setting, and excluded supplementing on weekends. Our study supplemented implanted steers on improved cool season pasture truly on alternate days, and assumed 10% decrease in potential ADG could not be detected because of alternate day feeding effect alone. Other variables such as energy expended for walking (Caton and Dhuyvetter, 1997; Di Marco and Aello, 2001), endophyte infection of tall fescue (Roberts and Andrae, 2004), higher intrinsic daily rates of gain of steers compared to heifers (which may narrow the effect of percent difference in daily gains) and other environmental factors, would potentially have a greater effect than frequency of supplementation.
Abstract

A two-year study was conducted on tall fescue-based pastures to evaluate three approaches to rotationally stocking stocker calves. Within each year, two sets (a spring set and a fall set) of crossbred steers were stratified by weight and randomly assigned to one of three treatments. The spring set (n = 72, 229 ± 11 kg), was on pasture from early April to mid August, and the fall set (n = 72, 248 ± 18 kg) was on pasture from early July to late October. There was a five week overlap between the two sets of steers within each year. The three treatments were: 1) rotationally stocked only (CONTROL) – steers rotated to a new paddock as forage availability dropped below acceptable levels in the occupied paddock, 2) rotationally stocked with distillers grains (DISTILLERS) – this was the same as treatment one except steers were supplemented with varying amounts of distillers dried grains with solubles (DDGS) based on forage nutritive value, and 3) rotationally stocked with round bale silage (SILAGE) – excess forage in spring was harvested and stored as round bale silage, and fed back as forage availability became limiting. Total gain ha\(^{-1}\) over the entire grazing season did not differ between DISTILLERS and SILAGE (\(P = 0.09\)) steers, but both were greater than CONTROL (\(P < 0.01\)). Total gain ha\(^{-1}\) for DISTILLERS, SILAGE, and CONTROL was 459, 402, 276 kg, respectively. Steer ADG for the spring set was equivalent for SILAGE and DISTILLERS
(P = 0.51), but greater than CONTROL (P = 0.01). The ADG for steers in the spring set was 0.79, 0.81, and 0.62 kg for DISTILLERS, SILAGE, and CONTROL, respectively. For the fall set, ADG for all three treatments was different (P = 0.02). The fall set, steer ADG was 0.72, 0.53, and 0.29 kg for DISTILLERS, SILAGE, and CONTROL, respectively. The only treatment that had equivalent ADG between the spring set and the fall set was the DISTILLERS treatment (P = 0.07). Adjusting the amount of DDGS supplemented to the steers based on forage nutritive value resulted in consistent gains throughout the grazing study, whereas the steers in the SILAGE and CONTROL treatments gained less during the latter portion of the season. Controlling the forage maturity level by mechanical removal in the SILAGE treatment resulted in total gains ha⁻¹ equivalent to the DISTILLERS treatment. Stocker operators that need consistent gains throughout the season should supplement based on forage nutritive value, but stocker operators only concerned with total gains should consider either supplementing or controlling forage maturity by mechanical removal and storage.

**Introduction**

There are a number of reasons stocker operators offer a supplement to calves on pasture (Paterson et al., 1994; Kunkle et al., 2000). Whatever the reason(s) deemed necessary by operators, it is economically imperative they feed no more than is necessary to obtain the desired calf responses. Studies regarding supplementation of energy to calves on pasture generally show daily weight gains are increased, but the gains are variable and unpredictable (Bowman and Sowell, 1997). Since many of these studies used constant preset levels of supplementation (e.g. 0.5, 1.0, 2.0 kg steer⁻¹ d⁻¹), the
variation in ADG may be attributed to fluctuation in forage nutritive value over the course of the study. No studies could be found that adjusted the amount of supplementation to stocker calves based on fluctuating forage nutritive value over the course of the growing season.

This study was conducted to determine if stocker steer ADG could be maintained by adjusting the amount of supplementation based on the nutritive value of forage-on-offer. The supplement was distillers dried grains with solubles (DDGS), and the amount fed was based on weekly forage nutritive values with a target steer ADG of 0.9 kg. To assess the significance of supplementation, we included two other treatments in the study. The first treatment was essentially the base system of the supplementation treatment in that the animals and forage were managed similarly, but supplementation was excluded. The second treatment also did not include supplementation, but the forage was managed differently such that excess forage was removed and fed-back as round bale silage. The forage in all three systems was a mixture of tall fescue [Lolium arundinaceum (Schreb.) Darbysh. = (Schedonorus arundinaceus (Schreb.) Dumort.)], red clover (Trifolium pratense L.) and white clover (Trifolium repens L.). We hypothesized that the total weight gains of stocker cattle would be similar between the supplemented system and the system with forage maturity level controlled by removal as round bale silage, and both would be greater than the system with rotation of animals only.
MATERIALS AND METHODS

A two-year grazing study was conducted at the University of Missouri South Farm (38° 53' 25" N, 92° 15' 52" W) located near Columbia, Missouri during 2006 (yr 1) and 2007 (yr 2). The soils at this location were classified as Armstrong loam (Fine, smectitic, mesic Aquertic Hapludalf) 5 to 9% slope, Mexico silt loam (Fine, smectitic, mesic Aeric Vertic Epiaqualf) 1 to 3% slope, and Vanmeter clay loam (Fine, illitic, mesic Oxyaquic Eutrudept) 5 to 14% slope. In preparation for the study, the soils were tested for pH, phosphorus, and potassium. Fertilizer was applied to pastures as needed based on the recommendations of University of Missouri Soil Testing Laboratory (Brown and Rodriguez, 1983) before yr 1. Phosphorus and potassium were applied on 23 February 2006 to pastures determined deficient from soil analyses. Phosphorus was brought up to a minimum of 33 kg ha⁻¹ Brady 1, and potassium was brought up to a minimum of 225 kg ha⁻¹. Correction of soil pH was not necessary as the mean soil test pH value was 6.71 ± 0.22. Excluding ragweed in some areas, the majority of the study pastures were approximately 50% tall fescue and 30% red and white clover (based on visual estimation). The remaining 20% was a mixture of Kentucky bluegrass (Poa pratensis L.), orchardgrass (Dactylis glomerata L.), and various dicotyledonous forbs. All pastures were broadcast seeded with 6 kg ha⁻¹ medium red clover and 0.5 kg ha⁻¹ ‘Durana’ white clover on 22 February 2006. The University of Missouri Animal Care and Use Committee reviewed and approved all animal management procedures.
Treatments and Experimental Design

Treatments were: 1) rotationally stocked only (CONTROL) – steers rotated to a new paddock as forage-on-offer in the occupied paddock was grazed to a predetermined residual height, 2) rotationally stocked with DDGS (DISTILLERS) – identical to treatment 1 except steers were supplemented with appropriate amounts of DDGS to maintain 0.9 kg d\(^{-1}\) gain based on weekly forage nutritive value analyses, and 3) rotationally stocked with round bale silage (SILAGE) – excess spring forage harvested and stored as round bale silage, then fed back to the steers as forage-on-offer became limiting during the summer months. Two sets of steers were stocked in each system each year; a spring set and a fall set.

Forage Characterization and Paddock management

Each tall fescue-based system was divided into six, 0.27 ha paddocks (Bertelsen et al., 1993). The paddocks were rotationally stocked starting in spring when the tall fescue reached approximately 10 cm in height. A common alleyway for each system provided access to water, mineral, ionophore, and facilitated rotation of animals.

Since stocking rate has a profound influence on animal performance (Sollenberger et al., 2005), all three treatments were stocked at the same rate to avoid confounding the results. Pastures were initially stocked at 567 kg ha\(^{-1}\) live-weight. Based on estimated forage intake, anticipated forage production and utilization, this stocking rate was estimated to be suitable for this environment and site (Gerrish, 2000). Gerrish (2000) indicated that available NE\(_{\text{m}}\) ha\(^{-1}\) was highest with initial stocking rates at turnout between 336 and 672 kg ha\(^{-1}\) live-weight. It was expected that low forage nutritive value
and poor steer ADG would occur in the CONTROL treatment during the summer months due to excess springtime forage production and accumulation. The same forage accumulation and decline in forage nutritive value for the DISTILLERS treatment was also expected, but the anticipated decline in steer ADG were to be mitigated by feeding DDGS to the steers. Accumulated forage of low nutritive value was grazed by the calves in the CONTROL and DISTILLERS treatments.

Forage made into round bale silage in the SILAGE treatment was cut on 2 May, 12 May, and 9 June 2006, and 16 May 2007. Residual height of the forage was approximately 10 cm. Leaving that amount of leaf area as residual at that time of year was expected to slow growth rates little since more than 50% of the leaves of tall fescue is generally below this height (Wolf et al., 1979). The tall fescue was in the late vegetative to boot stage at cutting and was baled and wrapped at 500-600 g kg\(^{-1}\) water content. No other paddocks in any of the systems were mowed except for two paddocks in one replication of DISTILLERS treatment in yr 2 due to excessive ragweed pressure.

Forage-on-offer was assessed weekly by taking 50 rising plate meter readings within each paddock (Earle and McGowan, 1979). The rising plate meter measurements were calibrated every 21 d by collecting and weighing forage cut to a height of 2 cm from 10 strips, 0.82 x 4.6 m in dimension. The strips were cut with a flail-type harvester from the most recently stocked and next-to-be-stocked paddocks in each replication. The forage collected from the strips was subsampled \([300 \pm 50 \text{ g fresh mass}]\), and placed in a forced air oven at 50°C until weight stabilization to determine water content. The DM value of the collected subsamples was used to calculate DM for each strip, then for each paddock on a kg ha\(^{-1}\) basis. The values of each most recently stocked and next-to-be-
stocked paddocks along with its corresponding RPM measurements were then used in a multiple regression equation ($R^2 = 0.93$) to estimate forage for each paddock within the replication. The regression equation used to predict forage DM amounts (including pre and post silage removal) was:

Equation 1. DM prediction

$$Y = (YR^2) \times -29.1 + ((\sqrt{RPM}) \times 1085.0) + (DOY^2) \times 0.07389$$

$$+ (DOY^3) \times -0.00019764$$

Where YR was year, RPM was rising plate meter reading, and DOY was ordinal day of year.

After pre-grazing and post-grazing forage yields were calculated, growth rate for each stocking period was determined by averaging the growth rates of the unoccupied paddocks within each treatment. The forage growth while animals were grazing an individual paddock was then added to pre-grazing yield to accurately estimate the amount of forage available for grazing. Growth rate of pastures was greater than consumption early in the season which led to a long stocking period within some individual paddocks. The animals were not removed from an individual paddock until forage was grazed to an average canopy height of about 7.5 cm (excluding refused forage – especially around dung pats and suspected urine patches).

Forage samples were hand collected on a weekly basis for nutritive value assessment by cutting forage to a 2-cm height from the paddock in each treatment where livestock were expected to be stocked for the majority of the coming week. The samples
were collected regardless of apparent forage quality or pattern of animal grazing, although it was understood that nutritive value declined with canopy height and cattle are reluctant to graze stems of mature tall fescue (Krysl and Hess, 1993; Mertens, 2007).

The forage samples were dried, ground, and passed through a 1-mm screen for tissue analysis of crude protein (CP) and in vitro true digestibility (IVTD) using near infrared reflectance spectroscopy (NIRS). The NIR spectrophotometer was a Pacific Scientific 6250 scanning monochromator (NIRSystems, Silver Spring, MD) operating with software developed by Infrasoft International (Port Matilda, PA). The spectrophotometer was calibrated for CP and IVTD by regressing chemically-derived data against spectral data using modified partial least squares regression (Westerhaus et al., 2004; Table 1). The calibration for N was determined by thermal conductivity detection with a LECO FP-428 nitrogen analyzer (LECO Corp., St. Joseph, MI). Crude protein values were calculated by multiplying g kg\(^{-1}\) N of the plant tissue by 6.25. Samples analyzed for IVTD were digested 48-h in vitro, and then washed with NDF solution (Spanghero et al., 2003). The rumen fluid used for the digestion was collected from a cannulated cow fed a forage-based diet.

Nutritive value samples for the DISTILLERS treatment were collected as all others were each week, but a portion of these samples were immediately analyzed for acid detergent fiber (ADF) and neutral detergent fiber (NDF) to adjust the amount of DDGS fed in an attempt to maintain the recommended (NRC, 1996) caloric intake for the calves to gain 0.9 kg d\(^{-1}\). Acid detergent fiber and NDF samples for DISTILLERS were determined with an ANKOM 200 Fiber Analyzer (ANKOM Technology, Fairport, NY).
The equations used to calculate net energy maintenance (NE\textsubscript{m}) and NE\textsubscript{g} of forage-on-offer were:

Equation 2. NE\textsubscript{m} 
\[ \text{Mcal kg}^{-1} = 2.205 \times (0.996 - (0.0112 \times \%\text{ADF})) \]

Equation 3. NE\textsubscript{g} 
\[ \text{Mcal kg}^{-1} = 2.205 \times \left(0.78 \times (\text{NE}_\text{m} \times 2.2) - \frac{0.41}{2.2}\right) \]

Once the amount to supplement was determined (described below), the adjusted amount was started the following Monday. It was assumed at the beginning of the study that each batch of DDGS would vary in nutrient concentrations (Spiehs et al., 2002). Therefore, to accurately compensate for the fluctuation of tall fescue nutritive value and maintain steer ADG at 0.9 kg, the DDGS was sampled and analyzed by batch. Analysis of the DDGS is given in Table 2.

**Steer management**

Calves were purchased from a local sale barn as long as five weeks in advance of turnout to ensure procurement of adequate study animals. Upon arrival, the calves were placed in a drylot and given a typical receiving diet. Within two weeks of arrival, calves were castrated if necessary, vaccinated with 7-way blackleg with haemophilus (Ultrabac 7/Somubac, Pfizer, Exton, PA) and modified live virus (Pyramid 4+ Presponse SQ, Fort Dodge Animal Health, Fort Dodge, IA), and given an ear identification tag. Approximately three weeks after the initial administration of vaccines, the steers were
poured with the anthelmintic moxidectin or ivermectin, fly tagged with pyrethroid and organo-phosphate insecticide impregnated ear tags, implanted with zeranol, and had a second round of the initial vaccines administered to ensure proper immunity. Any animals during this period displaying symptoms of respiratory ailments were treated with tilmicosin or florfenicol.

Beginning and ending grazing dates are given in Table 3. The day grazing began, steers were deprived of feed for 15 ± 1 hours, weighed (239.0 ± 18.0 kg), stratified by weight into nine groups of four steers each, and groups then randomly assigned to one of the three treatments. Animal appearance at turnout ranged from moderately fleshy to nearly unthrifty. Each treatment had three replications for a total of 36 (3 treatments x 3 replications x 4 steers) steers in the spring set, and 36 steers in the fall set each year. Upon removal from pasture, steers were again deprived of feed for 15 ± 1 hours and weighed. The second set for yr 2 was removed from pasture 29 October 2007 except for one replication of the CONTROL, which was removed from study on 15 October 2007 due to inadequate forage. Four steers were removed prematurely from study for reasons unrelated to the study treatments. The removed steers were immediately replaced by extra steers held for this purpose in an adjacent pasture. Replacement steers had no data collected on them other than initial live-weight.

Forage intake for steers in the DISTILLERS treatment was assumed to be 12.5 g kg⁻¹ BW d⁻¹ in NDF (Mertens, 1994). Based on forage NDF values and Mcal kg⁻¹ forage DM during the course of the grazing period, forage-on-offer always met maintenance requirement for animals. According to the NRC (1996), a 250-350 kg steer requires 4.84 – 6.23 Mcal d⁻¹ for maintenance. Therefore, all DDGS supplemented was for gain. Each
replication was supplemented its own rate and was started when two consecutive weeks indicated that 1Mcal steer\(^{-1} \text{d}^{-1}\) of net energy gain was needed to maintain steer ADG at 0.9 kg.

For the spring set, DDGS supplementation started 10 May 2006 and 14 May 2007 for all three replications and ended when stock were removed from pasture in August. Steers in the fall set required supplement the entire time on pasture. Distillers dried grains with solubles was supplemented on alternate days. Any steers reluctant to approach the troughs were directed to them until they were trained to approach under their own volition. Once trained, all steers partook in the consumption of DDGS freely at every feeding. Although the amount fed varied weekly based on forage nutritive value, for the period supplement was provided, the average amount fed was 1.2 kg steer\(^{-1} \text{d}^{-1}\) for the spring set and 1.7 kg steer\(^{-1} \text{d}^{-1}\) for the fall set. The specific amounts fed on a weekly basis are provided in Figure 1. As the steers grew and their net energy gain (NE\(_g\)) requirements increased, the amount of DDGS supplemented was adjusted accordingly as the animals met the weight increments in Table 9-1 of the NRC (1996).

Round bale silage was fed to the steers in modified sheep hay feeders. The feeder allowed the silage to remain off the ground while being consumed by steers. Additional silage was fed to the steers as previously fed silage disappeared. The first feeding of silage occurred on 7 July 2006 and 7 July 2007. The initiation of silage-feeding coincided with the placement of the fall set of steers on pasture due to limited forage availability in late summer. Forage-on-offer in the SILAGE treatment was approximately 3,000 kg ha\(^{-1}\) (Figure 2) when silage was first fed-back to the steers. In vitro true digestibility, CP, and DM was determined for the silage at every feeding. The mean IVTD and CP content of
round bale silage when fed to the steers was 740 and 115 g kg\(^{-1}\) on a DM basis, respectively. The final silage feeding dates (using treatment produced silage) were 25 August 2006 and 31 August 2007. Due to the forage shortage in yr 2, 245 ± 143 kg of round bale silage produced from outside the treatment pastures was fed to steers in the SILAGE treatment from 12 October to 19 October 2007. The silage was produced from adjacent pastures of similar composition stored for this specific purpose.

A commercial free-choice mineral was offered to steers in all treatments. The manufacturer guaranteed analysis of the mineral was 150-170 g kg\(^{-1}\) Ca, 75 g kg\(^{-1}\) P, 150-170 g kg\(^{-1}\) NaCl, 15 g kg\(^{-1}\) Mg, 1 g kg\(^{-1}\) K, 1330 mg kg\(^{-1}\) Cu, 26.6 mg kg\(^{-1}\) Se, 6700 mg kg\(^{-1}\) Zn, 4500 mg kg\(^{-1}\) Mn, 882000 IU kg\(^{-1}\) Vit A, 1852 IU kg\(^{-1}\) Vit D, 5.3 IU kg\(^{-1}\) Vit E. The ionophore lasalocid was included at 1.6 g kg\(^{-1}\), and expected mineral mix intake was 113 g steer\(^{-1}\) d\(^{-1}\).

**Statistical Analyses**

The model was a completely randomized design (Steel and Torrie, 1980) with four steers in each of three replications of each treatment. The experiment was repeated for two years. Main effects were forage systems (CONTROL, SILAGE, or DISTILLERS), replication, set, and year. Replication and year were considered random variables. Individual experimental units were a group of four steers in each replication. SAS (SAS Inst. Inc., Cary, NC) was used to test all main effects and all possible interactions. PROC MIXED with orthogonal contrast was used to compare ADG, total animal gain ha\(^{-1}\), and total forage ha\(^{-1}\) produced. Repeated measures procedures assuming first-order autoregressive correlation were used to test effects of treatments for the
amount of forage produced. Forage dry matter produced for each system was predicted using the PROC REG statement in SAS with stepwise selection to determine variables to include in the model. Significance level for variables to enter (SLE) and stay (SLS) in the model was set at 0.01.
RESULTS AND DISCUSSION

Pasture Growth and Nutritive Value

There was no year effect \((P > 0.14)\) for total forage production or IVTD, nor was there an interaction of treatments and years for either of the two \((P > 0.33)\). In addition, there was no interaction of treatments and years \((P > 0.68)\) for forage-on-offer or CP. Data were combined over years. Total forage produced did not differ between treatments \((P = 0.44)\) with treatments averaging over 6,600 kg ha\(^{-1}\). As well, forage-on-offer did not differ across treatments until forage harvest in May for the SILAGE treatment (Figure 2). Further, forage-on-offer (Figure 2) and IVTD (Figure 3) did not differ \((P > 0.12)\) between the CONTROL and DISTILLERS treatments. In vitro true digestibility of pasture was higher \((P < 0.01)\) for the SILAGE treatment compared to the CONTROL and DISTILLERS.

At the inception of the study, it was postulated that the SILAGE treatment would produce more forage than the DISTILLERS and CONTROL treatments. The rationale was the paddocks not grazed until later in the grazing season in the DISTILLERS and CONTROL treatments would have a zero net gain in forage DM once the ceiling yield was reached due to leaf senescence and turnover. Net primary production climaxes when the canopy intercepts all incident light (Parsons and Chapman, 2000). This occurred in some of the paddocks in the CONTROL and DISTILLERS treatments that were not grazed until later in the season. Conversely, paddocks in the SILAGE treatment generally were below the DM levels required to capture all incident light (Parsons and Chapman, 2000). In addition, the forage in the SILAGE treatment was cut early and with a high residual height (approximately 10 cm). Tall fescue cut at this height should generate rapid
regrowth since more than 50% of the leaves are generally below this level (Wolf et al., 1979).

Although high residual leaf area after silage removal in the SILAGE treatment should have generated fast forage regrowth, and net primary production of DM climaxed in some paddocks of the CONTROL and DISTILLERS treatments, total forage produced in the SILAGE treatment was not greater than the DISTILLERS and CONTROL treatments (Table 4). This may partially be attributable to lower than average precipitation and removal of fertilizer nutrients as round bale silage. Dry weather conditions precluded high regrowth rates in the SILAGE treatment as both years experienced lower than average precipitation during critical periods of the growing season (Figure 5). Net primary production likely would have been greater if normal precipitation patterns would have prevailed.

Much of the forage produced in the CONTROL and DISTILLERS treatments was not utilized in some of the paddocks due to leaf turnover and DM loss. In an attempt to maximize forage regrowth nutritive value, steers were held in individual paddocks long enough to graze forage to acceptable residual height. Doing so resulted in some of the other paddocks within the CONTROL and DISTILLERS treatments to remain ungrazed for periods exceeding 57 days. Tall fescue leaf lifespan is 57 days (Parsons and Chapman, 2000), and remain photosynthetically active for about 42 days during spring and summer (Wolf et al., 1979). This resulted in leaf turnover and loss of DM production. The amount of forage lost to turnover was not measured in this study. However, the majority of DM produced may be lost to leaf turnover in ungrazed paddocks (Parsons and Chapman, 2000), and 400 g kg\(^{-1}\) may be lost under lax grazing (Parsons and Leafe, 1981
as cited by Nelson and Sleper, 1990). The DM loss in the CONTROL and DISTILLERS treatments may have approached DM losses in the SILAGE treatment due to the harvesting process and storage.

Round bale silage produced in the SILAGE treatment averaged 1,909 ± 582 kg ha⁻¹. Total silage fed back for each replication in the SILAGE treatment was 1889 ± 387 kg. Dry matter loss associated with individually wrapped round bale silage ranges from 30 to 400 g kg⁻¹, with expected losses of about 80 g kg⁻¹ under good management (Muck and Kung, 2007). Regardless of the amount of DM lost in this study during the silage making and feeding process, it is possible that the DM loss in the SILAGE treatment did not exceed losses in the CONTROL and DISTILLERS due to leaf turnover.

**Steer Gain**

Since stocking density, grazing days (except for one CONTROL replication in yr 2 as mentioned above), and forage produced in this study were the same across all three treatments, either ADG or total gain ha⁻¹ could be used to assess treatment differences based on live-weight gain. Average daily gain will be used to explain treatment differences since there was a set by treatment interaction \((P = 0.02)\). Although ADG will be used to discuss treatment differences in detail, total gain ha⁻¹ was 459 (2SEM = 23.0), 402 (2SEM = 62.0), and 276 (2SEM = 52.4) kg for DISTILLERS, SILAGE, and CONTROL, respectively. Total gain ha⁻¹ for both DISTILLERS and SILAGE were equivalent \((P = 0.09)\), and both were greater than the CONTROL \((P < 0.01)\).

There was no year effect or year by treatment interaction for ADG \((P > 0.14)\), therefore data were combined over years. For the spring set, steer ADG in the
DISTILLERS (0.79 kg, 2SEM = 0.07) and SILAGE (0.81 kg, 2SEM = 0.09) treatments were equivalent ($P = 0.51$), but steers in the CONTROL (0.62 kg, 2SEM = 0.09) treatment gained less ($P = 0.01$, Table 5). All treatments had adequate forage-on-offer (> 3000 kg ha$^{-1}$) when the spring set was removed from pasture (Figure 2), but by this time the forage nutritive value in the CONTROL and DISTILLERS treatment had declined. Crude protein had fallen to approximately 90 g kg$^{-1}$, and IVTD had dropped to approximately 650 g kg$^{-1}$ (Figures 3 and 4). In contrast, CP and IVTD values in the SILAGE treatment remained relatively high at about 140 and 800 g kg$^{-1}$, respectively. Due to the greater nutritive value of the forage-on-offer in the SILAGE treatment, these steers would have been expected to gain more than the steers in the CONTROL treatment. Based on weekly ADF and NDF analyses (data not shown) from the DISTILLERS treatment, the expected ADG of the CONTROL steers was about 0.4 kg from June to removal from pasture in August (Figure 1). This value was obviously less than the target ADG of 0.9 kg for the supplemented steers in the DISTILLERS treatment, and less than the anticipated steer ADG in the SILAGE treatment based on greater forage nutritive values.

For the fall set, ADG was different across all three treatments ($P = 0.02$). Steers in the DISTILLERS, SILAGE, and CONTROL treatments in the fall set gained 0.72 (2SEM = 0.08), 0.53 (2SEM = 0.11), and 0.29 (2SEM = 0.11) kg d$^{-1}$, respectively (Table 5). By this time, the amount and nutritive value of forage-on-offer had declined in the CONTROL treatment which negatively influenced steer ADG. Forage nutritive value in the SILAGE treatment remained relatively high, but forage-on-offer declined to levels that may have reduced intake. Steers in the DISTILLERS treatment had adequate
amounts of forage compared to the SILAGE treatment, and the low nutritive value of the forage-on-offer was alleviated by supplementation of DDGS. Given the characteristics of each pasture system, and the fact that steers in the DISTILLERS treatment were supplemented with energy and protein, it is not surprising that ADG varied across three treatments for the fall set.

Average daily gains of steers for the spring set was greater \( (P < 0.01) \) than the fall set in the CONTROL and SILAGE treatments (Table 5). The ADG for steers in the CONTROL treatment for the spring set was 0.62 (2SEM = 0.09) kg, and 0.29 (2SEM = 0.11) kg for the fall set. The spring set of steers in the SILAGE treatment gained 0.81 (2SEM = 0.09) kg d\(^{-1}\), while the fall set gained 0.53 (2SEM = 0.11) kg d\(^{-1}\). In contrast, steers in the DISTILLERS treatment had equivalent \( (P = 0.07) \) ADG for the spring set [0.79 (2SEM = 0.07) kg] and the fall set [0.72 (2SEM = 0.08) kg]. The discrepancy in steer ADG between the spring and fall sets in the SILAGE and CONTROL treatments is likely due to low forage availability during the latter portion of the grazing period (Figure 2), especially in yr 2. The below average precipitation (Figure 5) influenced all treatments, but especially the SILAGE and CONTROL since no feed from outside the system was brought in to supplement forage as was the case in the DISTILLERS treatment.

For the SILAGE treatment specifically, the low forage regrowth resulted in the steers consuming silage almost exclusively at times instead of a pasture and silage combination. Round bale silage can be of lower nutritive value than fresh forage, especially regarding true protein levels. The destructive nature of the fermentation process converts much of the true protein of the fresh forage (some of which may be
rumen undegradable protein) to rumen degradable protein (McDonald, 1981; Titgemeyer and Loest, 2001). In addition, the silage was fed during periods of low energy value in the pasture. Titgemeyer and Loest (2001) found that the energy value of silage is less than the original forage before the fermentation process, which may explain a portion of the less than anticipated ADG. However, since many of the products of fermentation are of equal or higher energy value than the original substrate, only dry matter is lost during the fermentation process and not gross energy value (McDonald, 1981). In addition, forage-on-offer for the SILAGE treatment was less than 2,000 kg ha\(^{-1}\) during the last four weeks of yr 2 (data not shown) which likely reduced forage intake (Minson, 1990).

Similar steer ADG in the DISTILLERS and SILAGE treatments was expected since the target ADG for steers in the DISTILLERS treatment was designed to match the anticipated ADG of steers in the SILAGE treatment. The anticipated ADG of steers in the SILAGE treatment was 0.9 kg. The actual ADG for steers in the SILAGE treatment for the spring set was 0.81 (2SEM = 0.09) kg (which approached the anticipated ADG) and was equivalent to ADG of steers in the DISTILLERS treatment 0.79 (2SEM = 0.07) kg d\(^{-1}\) \((P = 0.51)\). Steers in the fall set had an ADG of 0.53 (2SEM = 0.11) kg in the SILAGE treatment which was well below the target of 0.9 kg. Steer ADG in the SILAGE treatment was different \((P < 0.01)\) between the spring and fall sets, as mentioned above.

Average daily gains of steers over both sets combined were 0.76 (2SEM = 0.05), 0.67 (2SEM = 0.07), and 0.46 (2SEM = 0.07) kg d\(^{-1}\) for DISTILLERS, SILAGE, and CONTROL, respectively. Steer ADG in the DISTILLERS and SILAGE treatments were equivalent \((P = 0.09)\), and both were greater than the CONTROL \((P = 0.01)\). The greater overall ADG of steers in the SILAGE treatment compared to the steers in the CONTROL
treatment can be attributed to higher nutritive value of forage-on-offer in the SILAGE treatment (Figure 3 and 4). The higher nutritive value would encourage higher rates of intake by the steers, thus partially explaining the greater ADG for the steers in the SILAGE treatment compared to steers in the CONTROL treatment (Collins and Fritz, 2003; Mertens, 2007). Also, since the forage production was equivalent and a greater proportion of total forage produced was likely consumed by the SILAGE steers compared to the CONTROL steers, their intake would have been greater, resulting in greater gains.

Steer ADG in the DISTILLERS treatment was less than anticipated. Several factors might account for this difference including the inability to accurately estimate the ability of the steers to selectively consume high-quality plants (Kunkle et al., 2000). In addition, maintenance requirement for the steers was calculated for confined cattle. This requirement does not account for additional energy expended for grazing (Caton and Dhuyvetter, 1997). Grazing animals may expend 1.08 to 1.30 times more energy than confined cattle through forage intake and walking (Di Marco and Aello, 2001). Also, the NDF intake was estimated to be 12.5 g kg\(^{-1}\) BW d\(^{-1}\), which may not truly reflect the actual intake of the animal (Mertens, 1994; Ketelaars and Tolkamp, 1996). In addition, Loy et al., (2008) reported that feeding alternate days resulted in 10% lower average daily gains than when supplemented daily. However, they did not feed on weekends, so the calves were not truly supplemented on alternate days as the steers in this study. Incidentally, Aiken et al. (2005) did not see a difference in ADG of calves grazing bermudagrass supplemented with ground corn everyday compared to every-other-day.
Implications

Results from this study indicate that consistent daily gains of stocker steers can be attained by adjusting the amount of DDGS supplement based on forage nutritive value. The specifics of attaining absolute daily gains with a supplement can be worked-out elsewhere. It is important that the daily gains were repeatable and consistent between years and sets. A number of factors (other than previously mentioned) may also influence ADG of steers on pasture, for example: the variable (and often unknown) genetic potential of calves purchased from a sale barn, fly infestation, exposure and effects of respiratory disease (Pinchak et al., 2004), and perhaps most importantly the long lasting effects of castration on this age of animal (Bretschneider, 2005). Some of the animals as mentioned in the materials and methods were castrated. When the source of steers is the salebarn, it is not uncommon that some of the steers will actually be intact bulls. Although ADG may be reduced after castration for a relatively long period, it was deemed necessary to include these animals in the study due to the frequency of such occurrences regarding stocker calves.

Since steer ADG did not differ in the spring between DISTILLERS and SILAGE, it may be more economical to withhold supplement until forage nutritive value declines. Grazing patterns were more uniform in the SILAGE treatment compared to DISTILLERS and CONTROL treatments. This was the result of removing excess forage as silage before the forage matured and produced stems that cattle are reluctant to graze. Although the initial stocking rates were equivalent across all three treatments, steers in the SILAGE treatment essentially had a larger area to graze since refused forage was kept to a minimum. Further research regarding constant stocker steer ADG with
supplementation on pasture should attempt to avoid the dramatic swing in forage nutritive value by including a treatment that has in conjunction both forage removed as silage and the supplementation rate based on forage nutritive value.
Table 1. Calibration statistics for near-infrared spectroscopic determination of crude protein and IVTD content of rotationally stocked tall fescue-based pastures

<table>
<thead>
<tr>
<th>Constituent, g kg(^{-1}) DM</th>
<th>n</th>
<th>(R^2)</th>
<th>Mean</th>
<th>SEC(^1)</th>
<th>SECV(^3)</th>
<th>1-VR(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>72</td>
<td>0.99</td>
<td>124</td>
<td>0.35</td>
<td>0.69</td>
<td>0.97</td>
</tr>
<tr>
<td>In vitro true digestibility</td>
<td>71</td>
<td>0.99</td>
<td>751</td>
<td>1.00</td>
<td>1.93</td>
<td>0.95</td>
</tr>
</tbody>
</table>

\(^1\)SEC = standard error of calibration calculated in modified partial least squares regression.
\(^3\)SECV = standard error of cross-validation calculated in modified partial least squares regression.
\(^4\)1-VR = 1 minus the variance ratio calculated in cross-validation in modified partial least squares regression.
Table 2. Distillers dried grains with solubles on a DM basis. Samples averaged 920 ± 8.4 g kg⁻¹ DM

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>StdDev</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Crude Protein, g kg⁻¹</td>
<td>5</td>
<td>286.9</td>
<td>27.1</td>
<td>240.9</td>
<td>312.9</td>
</tr>
<tr>
<td>ADF, g kg⁻¹</td>
<td>5</td>
<td>91.8</td>
<td>9.2</td>
<td>76.3</td>
<td>100.0</td>
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<tr>
<td>NDF, g kg⁻¹</td>
<td>3</td>
<td>330.2</td>
<td>15.3</td>
<td>319.0</td>
<td>347.7</td>
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<tr>
<td>TDN, g kg⁻¹</td>
<td>5</td>
<td>888.2</td>
<td>23.2</td>
<td>869.4</td>
<td>928.6</td>
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<tr>
<td>Crude Fat, g kg⁻¹</td>
<td>5</td>
<td>103.3</td>
<td>4.7</td>
<td>98.0</td>
<td>110.0</td>
</tr>
<tr>
<td>N, g kg⁻¹</td>
<td>5</td>
<td>45.9</td>
<td>4.4</td>
<td>38.5</td>
<td>50.1</td>
</tr>
<tr>
<td>Ca, g kg⁻¹</td>
<td>5</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>P, g kg⁻¹</td>
<td>5</td>
<td>8.1</td>
<td>0.6</td>
<td>7.3</td>
<td>8.7</td>
</tr>
<tr>
<td>NE₇, MCal kg⁻¹</td>
<td>5</td>
<td>0.69</td>
<td>0.02</td>
<td>0.67</td>
<td>0.73</td>
</tr>
<tr>
<td>NE₈, MCal kg⁻¹</td>
<td>5</td>
<td>1.00</td>
<td>0.03</td>
<td>0.97</td>
<td>1.05</td>
</tr>
<tr>
<td>Digest. Energy, MCal kg⁻¹</td>
<td>5</td>
<td>1.15</td>
<td>0.34</td>
<td>0.97</td>
<td>1.76</td>
</tr>
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</table>
Table 3. Dates steers began and ended grazing tall fescue-based systems for each set and year

<table>
<thead>
<tr>
<th>Set</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grazing Started</td>
<td>Grazing Ended</td>
</tr>
<tr>
<td>Spring</td>
<td>11 April</td>
<td>8 August</td>
</tr>
<tr>
<td>Fall</td>
<td>5 July</td>
<td>2 November</td>
</tr>
</tbody>
</table>
Table 4. Total annual forage produced by treatment during the stocking period of rotationally stocked tall fescue-based pastures grazed by stocker steers. There were no differences across treatments ($P = 0.44$), and both years were combined.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CONTROL $^1$</th>
<th>DISTILLERS $^2$</th>
<th>SILAGE $^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha$^{-1}$</td>
<td>6420</td>
<td>7264</td>
<td>6240</td>
</tr>
<tr>
<td>n</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2SEM</td>
<td>406</td>
<td>729</td>
<td>340</td>
</tr>
</tbody>
</table>

$^1$CONTROL = rotationally stocked only  
$^2$DISTILLERS = rotationally stocked supplemented with DDGS  
$^3$SILAGE = rotationally stocked with forage removed, stored, and fed back as silage
Table 5. Average daily gain of stocker steers rotationally stocked for the spring set (early season stocked) and the fall set (late season stocked) for all treatments. The weight of the steers when grazing started was 229 ± 11 kg for the spring set, and 248 ± 18 kg for the fall set. Both years were combined.

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Contrast, P value</th>
</tr>
</thead>
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<tr>
<td></td>
<td>CONTROL¹</td>
<td>DISTILLERS²</td>
</tr>
<tr>
<td>Spring set</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, kg</td>
<td>0.62</td>
<td>0.79</td>
</tr>
<tr>
<td>n</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>2SEM</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>Fall set</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, kg</td>
<td>0.29</td>
<td>0.72</td>
</tr>
<tr>
<td>n</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>2SEM</td>
<td>0.08</td>
<td>0.06</td>
</tr>
</tbody>
</table>

¹CONTROL = rotationally stocked only
²DISTILLERS = rotationally stocked supplemented with DDGS
³SILAGE = rotationally stocked with forage removed, stored, and fed back as silage
Figure 1. Amount of DDGS fed daily to steers and expected ADG of steers before supplementation based on forage nutritive value. Supplementation started when forage nutritive value analyses for two consecutive weeks indicated that 1Mcal steer\(^{-1}\) d\(^{-1}\) of net energy gain was needed to maintain steer ADG of 0.9 kg. Both years were combined, and bars equal 2SEM.
Figure 2. Estimated forage-on-offer for all paddocks within each tall fescue-based system. All treatments were grazed by stocker steers with excess forage in the SILAGE treatment removed as round bale silage starting early to mid-May. Both years were combined, and bars equal 2SEM
Figure 3. In vitro true digestibility of forage-on-offer of the paddock steers were likely to be stocked in the week after sample collection. All paddocks were tall fescue-based and rotationally stocked. Both years were combined, and bars equal 2SEM.
Figure 4. Crude protein of forage-on-offer of the paddock steers were likely to be stocked in the week after sample collection. All paddocks were tall fescue-based and rotationally stocked. Both years were combined, and bars equal 2SEM.
Figure 5. Total precipitation by month for yr 1, yr 2 and the 30-yr mean during the grazing period. Dark portion of bars indicates precipitation that fell the first half of month, and the patterned top indicates precipitation that fell during the second half of month. Total length of bars indicates total month precipitation.
References Cited


Appendix

Pearl Millet

Pearl millet (*Pennisetum glaucum* L.) is a leafy warm-season annual grass that produces most of its biomass during the mid-summer months. It is drought tolerant, tolerates acidic soils, and re-grows well after grazing (Banks and Stewart, 1998; Ball et al., 2002). Nutritive value of pearl millet is equivalent to or higher than other warm-season annuals (Andrews and Kumar, 1992), with approximate CP content of 170 g kg\(^{-1}\) and "in-vitro" dry matter digestibility (IVDMD) of 590 g kg\(^{-1}\) (Banks and Stewart, 1998; Ball et al., 2002). Pearl millet can produce up to 15 MG ha\(^{-1}\) DM as a monoculture with adequate soil fertility and water. In addition, it generally produces thinner stems than other warm-season annuals such as forage sorghums, and is considered more drought tolerant than the latter (Bishnoi et al., 1993).

Pearl millet does not contain prussic acid, but the stalks may accumulate nitrates under excessive nitrogen applications and under prolonged drought conditions (Banks and Stewart, 1998; Ball et al., 2002). Since cattle preferentially graze leaves before the stalks, potential nitrate issues can generally be circumvented by moving the cattle to new forage in a timely manner. Pearl millet should not be grazed shorter than 6 to 8 inches (Mays and Washko, 1962). McCartor and Rouquette (1977) reported ADG of up to 2.23 lb for steers grazing pearl millet. It may be a good choice as supplemental summer forage in tall fescue-based systems (Fribourg, 1995).
Seeding into tall fescue

Hart et al. (1971) reported that planting sorghum x sudangrass into mowed-only tall fescue sod resulted in poor yields when rainfall was limiting. However, when they suppressed tall fescue with paraquat (0.13 lb acre\(^{-1}\)) before the sorghum x sudangrass was seeded, tall fescue-sorghum x sudangrass plots yielded up to 67% more forage than did tall fescue or sorghum x sudangrass alone if the N fertilizer was drilled below the seed at time of planting. If the N fertilizer was broadcast, the total yield increase was only 34% greater than either tall fescue or sorghum x sudangrass alone.

Belesky et al. (1981) killed tall fescue in 10 inch strips (20 inch centers) with paraquat (0.25 lb acre\(^{-1}\)) and planted sorghum x sudangrass into the killed areas. The same strips were subsequently re-treated and seeded the following two years. The three year average for total forage production was 3.17 tons acre\(^{-1}\) (1.06 tons acre\(^{-1}\) for tall fescue and 2.11 tons acre\(^{-1}\) for sorghum x sudangrass). The tall fescue control, which had no paraquat applied, averaged 2.23 tons acre\(^{-1}\).

Reinbott and Blevins (1995) killed tall fescue in 12 inch wide strips (30 inch centers) with glyphosate (0.6 lb acre\(^{-1}\)). Sorghum x sudangrass was planted in the same strips for three years without re-treatment. Total forage production averaged 5.42 tons acre\(^{-1}\) across all three years. The tall fescue control, averaged over the second and third year of the study, produced 2.93 tons acre\(^{-1}\) (the first year tall fescue control was not fertilized). Additionally, they reported that sorghum x sudangrass yields declined each year. The decrease in production of the sorghum x sudangrass was attributed to increased competition from tall fescue as it encroached back into the killed strips the second and third year of the study. A decline in tall fescue production in the plots interseeded with
sorghum x sudangrass was not observed for spring growth, but was less than the tall fescue control during the summer. They attributed the difference in tall fescue yields over summer to competition from the sorghum x sudangrass.

Belesky et al. (1981) and Reinbott and Blevins (1995) studies indicate that the potential exists to grow a warm-season annual grass for forage production when tall fescue is semi-dormant during the summer months. It was our intent during this grazing study to expand on their plot study findings. This original study included a treatment with adapted methods used by Reinbott and Blevins (1995).

Pearl millet (PP202M) was interseeded into two of the six paddocks of system 4. The two paddocks in the system designated to receive pearl millet were sprayed in eight inch wide strips with glyphosate (0.6 lb acre\(^{-1}\)) on 16 inch centers. Pearl millet was seeded (20 lb acre\(^{-1}\) PLS) and N (50 lb acre\(^{-1}\)) applied to the paddocks. The second year pearl millet was seeded into the same killed strips as year 1. Year 2 had gramoxone broadcast sprayed onto the paddocks designated for pearl millet. The pearl millet was seeded into the same strips as year 1. The paddocks were planted mid-May after the soil warmed to 12°C (Banks and Stewart, 1998).

**Results**

Too much pressure from other warm season annuals such as green foxtail, crabgrass, and other grasses such as barnyardgrass precluded much pearl millet growth. If sod had been dense and only tall fescue as Reinbott and Blevins (1995), then our efforts may have been successful, but if a producer had a good thick sod of tall fescue, then a better recommendation would be to fertilize with N end of May to stimulate growth to carry through summer instead if damaging his tall fescue stand.
References Cited for Appendix


Appendix Table 1. Nutrient analysis on free choice mineral label. Expected mineral mix intake was approximately 115 g steer\(^{-1}\) d\(^{-1}\)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium, not less than</td>
<td>15.0%</td>
</tr>
<tr>
<td>Calcium, not more than</td>
<td>17.0%</td>
</tr>
<tr>
<td>Phosphorus, not less than</td>
<td>7.5%</td>
</tr>
<tr>
<td>Salt, not less than</td>
<td>15.0%</td>
</tr>
<tr>
<td>Salt, not more than</td>
<td>17.0%</td>
</tr>
<tr>
<td>Sodium, not less than</td>
<td>6.0%</td>
</tr>
<tr>
<td>Sodium, not more than</td>
<td>9.0%</td>
</tr>
<tr>
<td>Magnesium, not less than</td>
<td>1.5%</td>
</tr>
<tr>
<td>Potassium, not less than</td>
<td>0.1%</td>
</tr>
<tr>
<td>Copper, not less than</td>
<td>1,330 mg kg(^{-1})</td>
</tr>
<tr>
<td>Selenium, not less than</td>
<td>26.6 mg kg(^{-1})</td>
</tr>
<tr>
<td>Zinc, not less than</td>
<td>6,700 mg kg(^{-1})</td>
</tr>
<tr>
<td>Manganese, not less than</td>
<td>4,500 mg kg(^{-1})</td>
</tr>
<tr>
<td>Iodine, not less than</td>
<td>130 mg kg(^{-1})</td>
</tr>
<tr>
<td>Vitamin A, not less than</td>
<td>882000 IU kg(^{-1})</td>
</tr>
<tr>
<td>Vitamin D, not less than</td>
<td>1852 IU kg(^{-1})</td>
</tr>
<tr>
<td>Vitamin E, not less than</td>
<td>5.3 IU kg(^{-1})</td>
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<tr>
<td>Lasalocid</td>
<td>1.6 g kg(^{-1})</td>
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## Appendix Table 2. Start weight of Steers kg

<table>
<thead>
<tr>
<th>Year</th>
<th>Set</th>
<th>Treatment</th>
<th>n</th>
<th>Mean</th>
<th>StdDev</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>CONTROL</td>
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</tr>
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<td>DISTILLERS</td>
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<td>224.5</td>
<td>8.0</td>
<td>213.2</td>
<td>238.1</td>
</tr>
<tr>
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<td>Fall</td>
<td>CONTROL</td>
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<td>276.2</td>
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<td>240.4</td>
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<td>213.6</td>
<td>264.4</td>
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Appendix Table 3. Round bale silage produced and fed back by replication and year

<table>
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<th>Replication</th>
<th>Year 1</th>
<th>Year 2</th>
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<tr>
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<td>Silage produced, kg</td>
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<td>Silage fed back, kg</td>
<td>1761</td>
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<tr>
<td></td>
<td>Silage brought in, kg</td>
<td>469</td>
</tr>
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<table>
<thead>
<tr>
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<td>2069</td>
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<tr>
<td>Silage fed back, kg</td>
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<td>Year 2</td>
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<tr>
<td>Silage produced, kg</td>
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<tr>
<td>Silage brought in, kg</td>
<td>469</td>
<td>459</td>
<td>182</td>
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Appendix Figure 1. Digestible DM in kg ha\(^{-1}\) for the entire grazing study. Digestible DM values were determined by multiplying IVTD% by forage on offer for each week. It was thought that the traces would more or less overlap since IVTD was higher in the SILAGE treatment compared to the CONTROL and DISTILLERS treatments. Both years were combined and bars are 2SEM.
Vita

Neal James Bailey was the middle son of three born to Gary and Marcia Bailey in Salina, KS on June 4th in the year of our Lord 1974. Shortly after Neal’s birth, the family moved to Cimarron, KS, where the father had been raised for a portion of his life and where he graduated high school. Neal was raised a Catholic, but was not baptized into the faith until about the age of 5, when his mother (a strong, devout Catholic) finally convinced his father (later a convert) to allow the baptism of all three boys. Incidentally, the baptisms occurred simultaneously and within 24 hours of the agreement. Neal attended the government school system from k-12 at Cimarron graduating somewhere probably in the middle in class ranking. After discussions with a few area junior colleges to play sports, Neal decided that getting into the work force as quickly as possible with some sort of post secondary education was the proper route for him to take. Neal attended North Central Kansas Area Vocational Technical School in Beloit, KS and majored in electronic technology. He graduated in 1994 with his associate’s degree in electronic technology. Neal took the early-out option from the vo-tech and started work for a Modern Radio and TV (a TV/radio sales and repair shop) in Garden City, KS, a beautiful little meat packing town just west of his home town about 36 miles. The job paid less than what he could have made doing other menial type work without paying for training the previous two years, but stuck with it in hopes that an opportunity of some sort would materialize. Shortly after he was hired on, and likely the original intention of the store owner, Neal began to install KU band satellite systems for the company. The little
satellite dishes had just came out and were very popular with customers. The dishes were Primestar, Directv, Dish, etc. Neal had started to settle into his role as the satellite installer/service technician when the Internal Revenue Service suspended all business activity of the store. Apparently, the store owner was not familiar with the sixteenth amendment and thought that paying taxes was an option and not an obligation. As the doors shut, Neal went back to carpentry work in his home town (which he did off and on throughout high school). During high school he also worked for a small 5000 head feedlot, a mixed practice veterinary hospital, and other jobs he could find. Neal was not too proud and with his strong back and weak mind would work about any physically demanding job available. After the IRS closed Modern Radio and TV (and the short period of carpentry work), Neal began working for National Cable Network based out of Kansas City, KS. The company had a branch office in Dodge City, KS and was looking for someone to install satellite dishes, (just as Neal had been doing for Modern Radio and TV). Neal had only worked there for about 3 months when a small cable company based out of Tucson, AZ called and wanted him to manage their satellite installation department. A salesman for National Cable Network had recommended Neal for the job and he was hired over the phone. After finishing contracted jobs, Neal moved to Tucson immediately. Neal worked there for about 2 years and when business slowed down due to various reasons, he decided to pick-up and move to Denver, CO. Before moving to Denver, Neal decided to spend a few months in Cimarron since it was about summer and he could make some quick money roofing houses. While in Cimarron for the summer, he met his future wife, the beautiful Ms. April Calhoun. April was fresh out of high school, free spirited, and full of ambition, not to mention easily impressed with the much older
gentleman (22 years old at this time). She had been accepted to the University of Colorado located in the “Republic of Boulder” and would move there that summer to begin her coursework. Neal moved to the Denver suburb of Westminster around September of that year and found a job in Denver for a large Fortune 500 company called Greybar Electric. Greybar Electric sold electrical and telecommunication supplies and Neal started as an order picker in their warehouse. Neal moved quickly up the ranks of the warehouse to shipping supervisor within 3 months, and was offered further advancement to an office position, but declined. Neal worked there for about 1.5 years before deciding to return to school to pursue a BS in Biological Sciences. He decided to move back to Kansas with his then fiancé April and both would attend Fort Hays State University. While attending FHSU, Neal worked for Running W Ranch, which ran about 5000 cows on pasture, 5000 head of lightweight calves in a starter yard, 750 acres of alfalfa, and a few other various things to keep everyone out of trouble. Neal and April were wed July 31, 1999 and April bore their first child Samarah Gabrielle on February 4th, 2001. Neal graduated FHSU in the spring of 2002 and the family moved to the Columbia, MO area in December. Neal began work for a tree trimming service based out of Fulton, MO clearing out power lines and right-of-ways for the electric company. Although Neal was familiar with heights having been a roofer and also hunted deer from tree stands, he realized that he was not fond of heights above about 40-50 feet. He realized that he needed to get back to a campus and try more education. Peter Motavalli with the University of Missouri Soils and Atmospheric Sciences department needed a temporary technician through spring and summer of 2003 to help with field work. Neal was hired for this position and worked until the end of the summer for Peter. Neal then
started his masters under Peter of that same year to look at nitrous oxide and carbon
dioxide emissions from an agroforestry watershed located in northeast Missouri. Neal
finished his masters in the summer of 2005 and submitted the manuscript from the work
for publication. Neal started his doctorate under Dr. Robert Kallenbach of the division of
plant, insect, and microbial sciences at the University of Missouri in the fall of 2005
looking at the tall fescue-based stocker study included in this work. At the time of this
writing, and upon completion of his training Neal was uncertain of the direction to go,
but was optimistic that something would come-up.