Grazing Evaluation of Cool-Season Grasses with and without Legumes

by

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Abstract

Reducing the length of time that cattle must be sustained on stored forages during the winter by extending the grazing season is a growing interest of cattle producers in the Southeast. This project was conducted to evaluate several of the predominant cool-season forages and forage mixtures for their capability to extend the grazing season. Six cool-season forage treatments were assigned to 0.8-ha paddocks in an incomplete block design with two replications and continuously grazed at a fixed stocking rate of 4 steers/paddock. The treatments were as follows: ‘Texoma’ MaxQ II novel endophyte tall fescue grown in combination with ‘Durana’ white clover (TF+WC) or treated with 50.5 kg N/ha (TF), ‘Nelson’ annual ryegrass grown in combination with ‘Dixie’ crimson clover (RG+CC) or treated with 50.5 kg N/ha (RG), and a mixture of ‘Graze King 90’ cereal rye and ‘Nelson’ annual ryegrass grown in combination with ‘Dixie’ crimson clover (RG+R+CC) or treated with 50.5 kg N/ha (RG+R). Steers were put on treatment when forages emerged from winter dormancy and available forage DM was estimated to be greater than 2000 kg/ha. Steers were taken off treatment when steer average daily gains (ADG) fell below 0.45 kg/d or forage DM availability fell below 1120 kg DM/ha. In year one treatments containing tall fescue furnished 75 days of grazing while all other treatments furnished 68 days. In year two treatments containing tall fescue provided 84 days, RG+R and RG+R+CC 57 days, and RG and RG+CC provided 85 days of grazing. In year one steer ADGs were greatest on RG+CC and RG+N but did not differ significantly from TF+WC, which was similar to all treatments. In year two steer ADGs were greatest on the annual treatments, which did not differ. With the exception of TF and TF+WC in year one, clover inclusion or N treatment had no effect on ADG or G/ha in either year within grass and small grain-grass treatments. Legume inclusion increased total forage DM yields of annual ryegrass and novel endophyte tall fescue in year two only. Results indicate that crimson clover can replace N fertilizer for spring grazing on annual ryegrass and annual ryegrass-cereal rye pastures.

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I. LITERATURE REVIEW

Background

A 2007 USDA ERS census found 248 million ha in the United States to be pasture and rangelands (USDA ERS, 2011). In 1975 Allen and Devers reported that grazing lands provided 74% of feed for beef cattle, and these lands comprised 48% of the total land area in the southeastern United States. Over 12 million beef cows (*Bos taurus* spp.) with calves can be found in the southeastern United States. Weaned calves are generally sold to producers in the Midwest or the Great Plains (Hoveland, 1986). Nonetheless, in the southeastern United States, increasing numbers of weaned calves are retained in stocker systems that have the potential to make efficient use of forage during the winter and early spring (Allen et al., 1992). Despite great potential, low beef production obtained per hectare makes the southeastern stocker industry an inefficient enterprise (Hoveland, 1986). Utilization of recommended management practices could increase productivity per hectare. Therefore there is potential for increased profitability for the southeastern beef stocker industry by utilizing high-quality pastures (Hoveland, 1986).

High-quality, cool-season forage systems have proven successful complements to the warm-season grass-based forage systems common to the Southeastern stocker industry (Beck et al., 2008; Gunter et al., 2012). However, in the southeastern United States, cold weather limits winter forage production, so cattle must be fed hay or other stored feeds for at least 8 weeks during the winter (Harris et al., 1972). Due to increased costs of production, reducing the length of time livestock must be fed stored forages is of growing interest for the stocker cattle industry in the Southeast (White et al., 1989; Gunter et al., 2002). Utilization of cool-season forages can reduce winter hay and feed requirements by extending the grazing season (Hoveland et al., 1978; Bagley et al., 1988; DeRouen et al., 1991; Gunter et al., 2005) while providing high-quality forage throughout the spring (Beck et al. 2008).

Forage quality

Forage quality is defined by Paterson et al. (1994) as “a function of both forage intake and digestibility” and is best assed by the performance of the animal to which the forage is made available (Mott, 1959). Customary methods utilized to estimate forage quality include measurement of crude protein (CP), plant cell walls, in vitro or in vivo digestibility (IVDMD), and, conclusively, animal performance (Paterson et al., 1994). Animal performance is the result of forage availability, intake, digestibility, and nutrient and energy content and metabolism, and it is typically reported in the forms of average daily gain (ADG) and gain per unit area (Mertens, 1994).

Mertens (1994) stated forage quality is usually quantified with the presumption that forage availability is not a limiting factor and, of the remaining factors affecting forage quality, the most significant is intake. Congruently, cell wall content is commonly considered as the most important plant factor influencing forage quality due to its role as a major constituent of forage dry matter (DM) and its strong negative correlation with intake and digestibility (Paterson et al., 1994).

There are several plant factors that influence forage quality. In temperate grasses, digestibility and nutritive value decrease with increasing stand maturity (Collins and Casler, 1990). Morrison (1980) reported the decrease in digestibility could be attributed to increased fiber concentrations and lignification of cell walls.

Several laboratory processes have been developed that estimate cell wall content. These include neutral detergent fiber (NDF) and acid detergent fiber (ADF) following extraction with detergent solutions. The NDF process extracts soluble cellular components leaving a residue of celluloses, hemicelluloses, and lignin, the components of cell walls. The ADF process extracts hemicelluloses leaving a residue of ligno-cellulose and other indigestible non-carbohydrate fractions (Van Soest, 1963;

Van Soest, 1994). These fiber fractions have been shown to correlate negatively with forage intake and digestion.

Although lignified fiber fractions are considered indigestible, sufficient rumination will not occur if no lignified material is ingested (Van Soest, 1994). Ruminant microbes have adapted to ferment a variety of carbohydrates that can be found in plant cell walls into the three primary volatile fatty acids (acetic, propionic, and butyric) as well as methane and carbon dioxide (Merchen and Bourquin, 1994).

Selection or preference by the grazing animal often has a strong influence on intake. Cattle are generally considered to be selective grazers, although they can be indiscriminate under certain conditions such as inadequate forage availability. If adequate forage is available, cattle will select for forage species or a particular part of the forage plant and these preferences have been closely related to intake (Solomon et al., 2013)

TALL FESCUE

Background

Tall fescue [*Lolium arundinacea* (Schreb.) Darbysh. = *Schedonorus arundinaceous* (Schreb.) Dumort.] is a cool-season perennial grass indigenous to Europe, North Africa, and Eurasia. In the United States, tall fescue is grown on close to 15 million ha and is considered the most important cultivated pasture grass (Buckner et al. 1979). It is a long-lived bunchgrass tolerant to soil acidity, soil alkalinity, poor drainage, drought, and low fertility but responds well to fertilization. It is well adapted to latitudes 35° to 45° where it exhibits seasonal production from September to December and March to June or July (Ball et al., 2007; Schmidt and Osborn, 1993; Stuedemann and Hoveland 1988).

Production and utilization in U.S.

The adaptability of tall fescue to a wide range of climatic conditions and soil characteristics in combination with the species' coarse, deep root system make it highly valuable. It is an ideal species for soil conservation and reparation, earning an endorsement from the Soil Conservation Service that helped to promote its propagation in the transition zone (Schmidt and Osborn, 1993). Agriculturally, tall fescue is utilized mainly as a forage crop for livestock, feeding over 8.5 million head of beef cattle (Ball et al., 2007). Its tolerance to heavy grazing, pests, and abiotic stresses combined with its ability to perennially persist and provide grazing over much of the year make it an ideal species for low-maintenance pastures (Hoveland, 2009).

History and classification

In 1771, German botanist Schreber recognized and described tall fescue as a robust pasture species and designated it *Festuca arundinacea* (Buckner et al., 1979). It was first introduced into the United States in the late 1800's (Cherney and Johnson, 1993) and received little attention due to the prevalence of meadow fescue (*Festuca pratensis* Huds.), a similar species (Buckner et al., 1979). It is postulated that tall fescue seed first arrived in the United States from England as a contaminant in meadow fescue seed (Hoveland, 2009). Early grass trials in Kentucky cite superior growth, height, competitive ability, and drought tolerance of tall fescue over meadow fescue (Garman, 1900). In 1931 E.N. Fergus, Professor of Agronomy, University of Kentucky, noticed a particularly impressive stand of tall fescue growing on the farm of W.M. Suiter in Menifee County, KY. Seed was obtained from this site and in 1943, after evaluation in small plots at the Kentucky Agricultural Experiment Station, the cultivar 'Kentucky-31' ('KY-31') was released (Buckner et al., 1979; Hoveland, 2009). Following the release of 'KY-31', tall fescue establishment rapidly spread throughout the southern United States, and 'KY-31' is the most common cultivar found in the southeast today (Cherney and Johnson, 1993).

Anti-quality issues

After an increase of 'Kentucky-31' in pastures there were soon reports of poor animal performance and visible disorders (Stuedemann and Hoveland, 1988). Grazing studies confirmed these reports (Blaser et al., 1956; Harris et al., 1972), which was perplexing because tall fescue exhibited high forage nutritive value in the form of digestible dry matter, crude protein, amino acids, and minerals; thus should support good animal performance (Bush and Buckner 1973).

With the goal of explaining this anomaly, research into the physiology of tall fescue began and in 1977 Bacon et al. reported the presence of *Acremonium coenophialum*, now classified as *Neotyphodium coenophialum*, a fungal endophyte, in samples of toxic tall fescue. Soon thereafter, Hoveland et al. (1980) reported a negative correlation between the extent of endophyte infection and performance of steer grazing tall fescue.

The semblance of fescue foot, a common symptom of cattle grazing endophyte infected (E+) tall fescue, to ergotism led researchers to suspect ergot alkaloids with vaso-activity as the causative agent of the toxicities associated with tall fescue (Rottinghaus et al., 1991). Further research identified substantial amounts of ergot alkaloids in extracts of tall fescues from pastures that induced fescue foot in cattle (Yates et al., 1985). Finally, Lyons et al. (1986) linked the endophyte to ergot alkaloids when they were found in E+ tall fescue but not in endophyte free tall fescue (E-).

The ergot alkaloid ergovaline is the primary alkaloid isolated from E+ tall fescue that causes toxicity to cattle (Nihsen et al., 2004) which is evidenced by data showing performance of cattle grazing tall fescue infected with endophyte strains that do not produce ergovaline was similar to the performance of cattle grazing E- tall fescue (Nihsen et al., 2004). Symptoms of fescue toxicosis include hyperthermia, poor appetite, rough hair coat, reduced gains, and excessive salivation, and are further intensified by high ambient temperatures (Stuedemann and Hoveland, 1988; Schmidt and Osborn, 1993).

Several disorders of cattle grazing E+ tall fescue have been attributed to vasoconstriction (Schmidt and Osborn, 1993). Vasoconstriction can cause thrombosis in cattle, resulting in necrotic lesions and sloughing of the extremities such as ears, tails, and, in extreme cases, feet (Jensen et al., 1956; Yates et al., 1979; Schmidt and Osborn, 1993). These symptoms are intensified by cooler ambient temperatures which normally induce vasoconstriction to conserve body heat (Curtis, 1983). Conversely, ergot induced vasoconstriction in high ambient temperatures can result in hyperthermia and subsequently reduce forage intake due to an increase in the amount of time animals spend standing in shade or water, reducing the amount of time spent grazing (Schmidt and Osborn, 1993).

Bovine fat necrosis, also known as liptomatosis, is another disorder commonly occurring in cattle grazing E+ tall fescue. This disorder is characterized by the presence of hardened or necrotic fat masses in the adipose tissue of the abdominal cavity (Wilkinson et al., 1983; Waller, 2009). These fat masses can cause digestive and reproductive complications due to occupancy of critical space in the abdominal cavity (Waller, 2009). Bovine fat necrosis is most likely to occur in cattle grazing pastures of pure E+ tall fescue that have received high levels of N fertilization (Wilkinson et al., 1983).

Finally, cattle and other animals grazing E+ tall fescue exhibit lower reproductive efficiency than those grazing E- tall fescue. Animals have lower conceptions rates, greater percentages of stillbirths and abortions, and lower milk production (Strickland et al., 2009).

Cattle grazing tall fescue infected with the fungal endophyte *Neotyphodium coenophialum* can experience a myriad of problems collectively referred to as fescue toxicosis. Hoveland (1993) estimated the annual economic impact of fescue toxicosis on the U.S. beef industry at over $600 million, but Allen and Segarra (2001) argued that this estimate was too low when both growth and reproduction losses are taken into consideration.

Solutions to fescue toxicity

Due to poor animal performance related to fescue toxicosis, research began that focused on mitigating the negative effects of grazing E+ tall fescue. Several solutions have evolved over time, and the most practical ones are presented below.

1. Dilution of the infected forage is perhaps the simplest solution to dealing with E+ tall fescue. This is commonly done by interseeding existing stands of E+ tall fescue with other forage species such

as forage legumes (Roberts et al., 2009). Grazing animals consume lower amounts of endophyte-infected tissues due to the presence of other forages, helping to alleviate fescue toxicity (Schmidt and Osborn, 1993).

2. Removal of the toxic endophyte resulted in the release of several E- tall fescue varieties as a solution to the problems associated with cattle grazing E+ tall fescue. E- tall fescue can produce excellent animal performance without the negative side effects attributed to the toxic endophyte (Hoveland et al., 1983; McMurphy et al., 1990; Hoveland et al., 1997). However, after further evaluation, drought and grazing intolerance of these varieties often resulted in complete stand losses within 3 to 4 years of establishment (Coombs et al., 1999; Gunter and Beck, 2004; Beck et al., 2009). From grazing and variety trials, it was concluded that infection by the fungal endophyte enhances the stress tolerance and persistence of tall fescue (West et al., 1993; Gunter and Beck 2004; Beck et al., 2008).
3. The discovery of endophyte strains that do not produce the ergot alkaloid compounds responsible for the problems associated with endophyte infected tall fescue have resulted in the development of novel-endophyte infected (NE+) tall fescue varieties (Gunter and Beck, 2004; Beck et al., 2008). Numerous studies have shown NE+ tall fescue varieties exhibit the persistence and stress tolerance of toxic endophyte infected tall fescues combined with increased animal performance comparable with that of E- tall fescue (Parish et al., 2003; Hopkins and Allison, 2006; Beck et al., 2008). Gunter and Beck (2004) reported ADG of beef cattle grazing these NE+ tall fescues was 47% greater than cattle grazing endophyte infected tall fescue and that cattle show no signs of fescue toxicosis. Despite the variety of strategies to alleviate or prevent fescue toxicity, total pasture renovation with recently developed NE+ tall fescue varieties is the best option for heavily infected pastures (Roberts et al., 2009).

Benefits of the endophyte

The endophytic *Neotyphodium* species are biotrophs that form mutualistic symbiotic relationships with grasses in the subfamily Pooideae (Schardl et al., 2004). An indirect but major factor of the symbiotic relationship is the deterrence of herbivory (Belesky and West, 2009). Antiherbivory characteristics of E+ tall fescue is a result of large amount of alkaloids such as ergovaline, peramine, lolitrem B, and lolines that are produced by endophytes (Christensen and Voisey, 2009). Greater drought tolerance is a result of the deterrence of grazing animals and insect pests from feeding on leaves, tillers, and roots (Belesky and West, 2009).

Another benefit of the endophyte-host plant relationship is increased phosphorus (P), water and other nutrient uptake similar to the response of other plant species growing in symbiosis with mycorrhizal fungi (Wittenmayer and Merbach, 2005), which is a result of increases in length and number of root hairs of E+ tall fescue compared with E- tall fescue (Malinowski et al., 1998). Other benefits include more efficient conversion of nitrogen (N) to growth in E+ tall fescue than E- (Archevaleta et al., 1989) and decreased uptake of metals such as copper (Cu) (Dennis et al., 1998) and Zinc (Zn) (Malinowski et al., 1998) in E+ tall fescue compared with E-.

Development of novel endophyte strains

Isolation of naturally occurring, non-toxic endophyte strains and subsequent infection by these non-toxic endophyte strains into superior tall fescue cultivars is the apex of tall fescue variety and endophyte research. The first commercially available non-toxic endophyte strain, AR542 (MaxQ® , a trademark of Grasslanz Technology Ltd., Palmerston North, New Zealand), was first available in ‘Jesup’ tall fescue and sold in the United States by Pennington Seed Co., Madison, GA after extensive collaborative research by the University of Georgia and AgResearch Ltd., New Zealand (Bouton, 2009). In a variety trial, ‘Jesup’ MaxQ® exhibited improved stand persistence over E- tall fescue (Bouton et al., 2002). In grazing trials, ‘Jesup’ MaxQ® supported animal performance equivalent to that of E- ‘Jesup’ tall fescue and greater than E+ ’Jesup’ tall fescue (Bouton et al., 2002; Parish et al., 2003). Despite improved stand performance over E- tall fescue, the MaxQ® cultivars began to show long-term stand life and endophyte viability issues (Bouton, 2009; Hill and Roach, 2012).

In 1997, a collection of tall fescue varieties was taken at the Samuel Roberts Noble Foundation's Pasture Demonstration Farm northwest of Ardmore, OK. These samples were found to contain an endemic toxic endophyte and were labeled PDF E+. After 4 years of grazing and variety trials, seed from the superior varieties were collected, and the endemic endophyte in these PDF E+ varieties was killed using a treatment of heat and humidity and replaced with a number of non-toxic novel endophyte strains, including AR584 [*Neotyphodium coenophialum* (Morgan-Jones and Gams.) Glenn, Bacon, and Hanlin comb. nov.], by inoculating seedlings according to the procedures outlined by Latch and Christensen (1985). Seventy plants were inoculated with AR584 (Grasslanz Technology Ltd., Palmerston North, New Zealand). The resulting varieties were evaluated for forage yield, grazing tolerance, drought tolerance, persistence, and at trials in Linn Creek, MO, Ardmore, OK, and Lexington, KY. The superior cultivar was released in 2009 under the commercial label 'Texoma' MaxQ II® (Hopkins et al., 2011).

ANNUAL RYEGRASS

Background

Annual ryegrass (*Lolium mulitflorum* Lam.) is a high quality cool-season annual bunchgrass grown for pasture, hay, and haylage in the southern United States. It is indigenous to southern Europe, northern Africa, and western Asia, but the actual date of introduction to the United States is unknown (Nelson et al., 1997).

Growth, production, and use

According to a 1992 survey of state Extension forage specialists, 1.1 million ha of annual ryegrass are utilized as forage in the U.S. (Evers et al., 1997). More recent reports claim more than 1 million ha of annual ryegrass are grown in the Southeast alone (Blount and Prine, 2000; Ball et al., 2007), which is largely due to the recent increase in its use as a cover crop (SARE, 2013) and in pasture applications. As a pasture constituent, it is often over-seeded into existing warm-season perennial sods and or grown in combination with legumes and or small grains. This management strategy is employed to extend the grazing season by 2 to 5 months in areas where lower quality hay and or stockpiled forages must be fed to livestock during the winter season (Hoveland et al., 1978; Rouquette et al., 1997).

In the Southeast, seeding annual ryegrass into a prepared seedbed from mid-September to mid-October results in the highest forage yields (Evers et al., 1997). A seeding rate of 22 to 34 kg ha^{-1} for monocultures and 11 to 17 kg ha^{-1} in mixtures is recommended (Ball et al., 2007). Annual ryegrass seeds were found to germinate best at temperatures between 10°C and 25°C (Hill et al., 1985). This is consistent with the findings of Young et al. (1975) who reported highest germination percentage of annual ryegrass seed at day/night temperatures of 10/5°C and 30/10°C of one-month and three-month-old seed, respectively.

Nitrogen is typically the most limiting nutritional factor affecting annual ryegrass growth (Miller and Reetz, 1995). It is typically fertilized in the fall after establishment and in the spring when rapid growth is imminent (Wedin, 1974). This fertilization regime resulted in the highest forage yields of mixtures of a small grain, annual ryegrass, and crimson clover (Cummins et al., 1965).

Cultivar development

Annual ryegrass has the ability to adapt to a wide range of environmental conditions and may be found growing throughout many regions of the world due to its high genetic variability and variation within cultivars resulting from cross-pollination (Nelson et al., 1997). Both tetraploid and diploid cultivars of annual ryegrass exist. In general, tetraploids are more robust, have wider leaf blades and are higher yielding (Blount and Prine, 2000), while diploids show greater growth rates after emergence (Sulc and Albrecht, 1996). Contrarily, Nelson et al., (1997) stated: “No tetraploid cultivar has shown superior forage yield, compared to diploid types, to warrant significant acreage in the southern USA”. Breeding efforts to produce superior tetraploid cultivars resulted in some commercial cultivars such as ‘Nelson’, ‘Jumbo’, and ‘Big Daddy’ (Nelson et al., 1997; Blount and Prine, 2000). Diploid cultivars include ‘Marshall’, ‘Gulf’, and ‘Surrey’ (Sulc and Albrecht, 1996). Review of cultivars leads to the conclusion that advantages and disadvantages of specific cultivars vary with no correlation to ploidy level (Blount and Prine, 2000). However, the most successful cultivars of annual ryegrass show improved cold tolerance, altered dates of maturity, improved yield components, improved reseeding ability, and greater disease resistance (Nelson et al., 1997).

Animal performance

Annual ryegrass is a high-quality forage species that is very tolerant of frequent defoliation (Rouquette et al., 1997). In the vegetative growth stage it can exhibit dry matter digestibility (DMD) greater than 70% (Lippke, 1986) with protein content ranging from 20-30%. Several grazing studies reported animal performance data that reinforce these claims.

In a grazing study conducted in northern Arkansas, Beck et al. (2005) reported steer ADG of 1.27 kg on pure stands of annual ryegrass averaged over three spring grazing periods. In a similar study conducted in Arkansas by Coffey et al. (2001), researchers reported an ADG of 1.0 kg over 114 days, averaged over three years, of steers grazing pure stand of annual ryegrass. Beck et al. (2008) reported ADG of steers grazing monocultures of annual ryegrass near Batesville, AR to be 1.12 kg, which was similar to the ADGs of steers grazing ‘Jesup’ MaxQ tall fescue, ‘HiMag’ novel endophyte #11 tall fescue, and a mixture of wheat and cereal rye. Utley et al. (1976) conducted a study in Tifton, GA that found steer ADG on annual ryegrass seeded into a prepared seedbed or overseeded into perennial sods to be 1.07 and 1.15 kg, respectively. From these studies it can be concluded that monocultures of annual ryegrass can support steer ADG of 1+ kg during the spring grazing period in the southeastern U.S.

‘Nelson’ annual ryegrass

‘Nelson’ annual ryegrass was released in 2009 and is a forage-type tetraploid annual ryegrass developed by Texas A&M AgriLife Research Program. It was developed for high forage production and resistance to crown rust in the southern United States and has shown superior forage yields, longer flag lengths, and greater number of spikelets compared with ‘Gulf’, a benchmark cultivar (Nelson and Crowder, 2010). In a study conducted by Solomon et al. (2013) in Raymond, MS, ‘Nelson’, ‘Gulf’, ‘Marshall’, and ‘Maximus’ annual ryegrasses were compared for forage quality and grazing preference. They reported a greater preference for ‘Nelson’ over ‘Gulf’ and ‘Marshall’. They also reported lower NDF and ADF values, and higher digestibility for ‘Nelson’ than ‘Gulf’ and ‘Marshall’ in the first year of the study, but no difference in any of these indices was seen in year two of the study. ‘Nelson’ exhibited greater leaf blade DM percentages in both years of the study, showing a positive correlation with selection and digestion by the grazing animal and a negative correlation with NDF and ADF percentages.

CEREAL RYE

Background

Cereal rye (*Secale cereale* L.) is an important forage and grain crop worldwide, with most of the area harvested for grain in Poland, Russia, Germany, Belarus, and the Ukraine (FAOSTAT, 2011). In the United States, very little cereal rye is harvested for grain but rather utilized as a cool-season annual forage and a cover crop. In 2011 the total area of cereal rye planted as a forage crop in the U.S. was estimated to be 13 million ha (Newell and Butler, 2012). Compared with other small grains such as wheat (*Triticum aestivum* L.) and oats (*Avena sativa* L.), rye is more tolerant to soil acidity and matures faster. However, the quick maturation of cereal rye can be a drawback due to its tendency to shade out co-seeded species and rapid decline in quality as it enters the reproductive growth phase. For decades southeastern stocker cattle producers have depended on small grains, namely cereal rye and wheat, for grazing from autumn to spring (Ball et al., 2007).

Cultivar development

Cereal rye is a diploid, a unique feature among the small grains. Breeding efforts have mainly focused on grain yields however; the breeding objectives of several studies have focused on autumn and total forage yields. Forage yields have not increased over time due in part to minimal breeding efforts. Consequently, there is potential for development of improved cereal rye cultivars for forage (Newell and Butler, 2012).

A study conducted by Samples et al. (1996) in southern Ohio compared cultivars of cereal rye. They reported early spring harvest dry matter yields ranging from 1979 to 2980 kg ha^{-1}, crude protein levels from 21.5 to 27%, and NDF ranging from 44.5 to 47.5%. Samples et al. (1996) also reported the canopy heights of different cereal rye cultivars. Experimental plots were established on 6 September 1994, and recordings taken on 31 March 1995 report canopy heights of 29.3 cm for 'Winter King', the highest among cultivars tested. From these results it can be concluded that cereal rye has the potential to produce greater than 2 Mg/ha of forage with greater than 21% crude protein for late winter and spring grazing. The early and rapid growth of cereal rye explains its popularity as a cover crop and as winter forage (Maloney et al., 1999).

Cereal rye is typically utilized in a graze-out production system where the crop is used as forage and or cover crop until late spring when warm-season forages begin growth or seeding of warm-season crops is initiated (Morey and Barnett, 1980; Bowman et al., 2008). Cereal rye can be, but seldom is, used in a graze-grain system where cattle are removed at jointing and grain can be harvested with only slight reduction in yields (Rao et al., 2000; Newell and Butler, 2012).

Growth, production, and use

In the southern United States cereal rye is planted in late summer or early autumn and can provide forage in late autumn and spring (Maloney et al., 1999). Cereal rye can be seeded in monoculture at a rate of 100 to 135 kg ha^{-1} and in mixtures at a rate of 65 to 100 kg ha^{-1}. It is more common to find cereal rye seeded in mixtures with other cool-season species than in monoculture due to its quick early growth. Bagley et al. (1988) found cool-season forage mixtures containing cereal rye provided more animal grazing days in December and January when forage growth of co-seeded species, ryegrass and clover, was limited.

Inclusion of cereal rye into a cool-season forage mixture helps to provide more uniform forage distribution throughout the cool season (Lippke and Ellis, 1997). Several studies have been conducted to evaluate the effect of co-planting annual ryegrass and small grains on animal and pasture performance. In a study conducted in 2009 at the Wiregrass Research and Extension Center in Headland, AL, different mixtures of annual ryegrass and small grains were compared. Mullenix et al. (2012) found greater forage availability for cereal rye-annual ryegrass compared with oats-annual ryegrass and oats-annual ryegrass-cereal rye from 8 January to 5 February. However, as the spring grazing season progressed, Mullenix et al. (2012) saw the oats-annual ryegrass treatment surpass cereal rye-annual ryegrass in forage DM production, and oats-cereal rye-annual ryegrass equal that of the cereal rye-annual ryegrass treatment during the March-April sampling period. Another study conducted by Coffey et al. (2001) in Arkansas compared monocultures of annual ryegrass with cereal rye-annual ryegrass, wheat-annual ryegrass mixtures, and a hay-supplement treatment. They reported similar ADG for steers on all three forage treatments in all three years of the study, which were greater than the hay-supplement treatment in years one and two. They also reported higher forage masses for cereal rye-annual ryegrass mixture than the annual ryegrass monoculture in the first 28 and 83 days of years 1 and 2 of the study, respectively.

Hoveland et al. (1991) reported higher stocking rates in north Georgia during spring grazing periods of 1985 and 1987, but fewer days grazed in spring 1985 for mixtures containing cereal rye, annual ryegrass, and crimson clover compared with a monoculture of tall fescue and mixtures containing tall fescue and a forage legume.

FORAGE LEGUMES

Background

Forage legumes have long been an important component of livestock feed both as pasture and as stored forage (Van Keuren and Hoveland, 1985). The widespread use of forage legumes is due to the several potential benefits they offer to pasture systems. These include biological nitrogen fixation, increased forage quality, and increased forage distribution (Butler et al., 2012). Despite these potential benefits, there are several liabilities associated with forage legumes. The sensitivity of legumes to soil and climatic conditions as well as factors related to establishment that directly affect plant emergence and subsequent realization of aforementioned benefits are the most pertinent risks associated with legumes (Van Keuren and Hoveland, 1985). Rising synthetic nitrogen (N) prices have increased interest in utilizing N-fixing legumes in pasture ecosystems (Allen et al., 2000; Hopkins and Alison, 2006). However, the certainty of chemical N fertilizer provides a failsafe N source for producers.

Crimson clover

Crimson clover (*Trifolium incarnatum* L.) is a winter annual legume that was first introduced to the United States from Europe in 1818 (Kephart, 1920). Crimson clover is known for its rapid growth in the fall and spring and high annual production (Knight, 1985). It is an important annual forage legume in the southeast due to its adaptability to a wide range of soil and climatic conditions, N fixing efficacy, good seedling vigor, and ease of establishment (Hoveland and Evers, 1995).

Crimson clover is typically seeded between mid-August and November, depending on the intended use. Crimson clover is commonly grown in combination with small grains or winter annuals such as rye, wheat, and annual ryegrass. It is also common to find crimson clover over seeded into existing perennial warm-season grass sods (Van Keuren and Hoveland, 1985). Due to its rapid growth, grazing of crimson clover can begin earlier than other forage legumes. Early spring yields between 3000 and 6000 kg ha^{-1} are commonly achieved (Hoveland and Evers, 1995).

‘Dixie’ crimson clover was released in 1946, the first cultivar released and the most commonly planted cultivar today. ‘Dixie’ was selected for a higher hard seed percentage resulting in a greater reseeding ability (Knight, 1985). In a grazing study, Hoveland et al. (1991) reported a steer ADG of 1.16 kg for mixtures of rye, annual ryegrass, and ‘Dixie’ crimson clover.

White clover

White clover (*Trifolium repens* L.) is one of the most common perennial forage legumes in the world (Pederson, 1995). If was first introduced by early settlers to America from the Mediterranean region where it may have evolved from primitive clovers originating in North America. It has a wide area of adaptation and high nutritional value for grazing animals. White clover grows anywhere that soil moisture, from rainfall and irrigation, and fertility are adequate (Pederson, 1995). Duke (1981) estimated that about half of the 45 million ha of humid or irrigated pastures in the U.S. contain some white clover.

White clover’s suitability as a pasture species has been questioned due to its sensitivity to drought and heat, in addition to persistence issues (Brink et al., 1998). Its relative success as a forage is largely due to its prostrate growth pattern via stolons (Pederson, 1995). Resultantly, improved cultivar development has focused in part on increased stolon density. In performance trials, ‘Durana’ showed the highest stolon density of several improved cultivars of white clover as well as the highest sward percentage when grown in combination with tall fescue (Bouton et al., 2005). ‘Durana’, an intermediate type white clover, is one of the most persistent cultivars available today (Stewart et al., 2008; Han et al., 2012).

Nitrogen fixation

Stocker cattle producers require a constant source of high-quality forage to support consistent animal production. Cool-season grasses fertilized with commercial N fertilizer have traditionally been used to meet forage demands during the fall and spring (Butler et al., 2012; Gunter et al., 2012). Over the past several years, the price of synthetic sources of N has continually increased. From 2010 to 2013 the average price of synthetic N increased by 40% (USDA, 2014). Furthermore, when chemical N is applied to soils it is often present as nitrate or quickly converted to nitrate, which is available for plant uptake but is highly leachable (Wu and McGrechan, 1999). Nitrate leachate is of increasing concern due to risks of eutrophication of surface and groundwater, negative effects of human and animal health due to elevated nitrate levels in drinking water, and the emissions of the greenhouse gas N_2O (Wu and McGrechan 1999; Gunter et al., 2012). For these reasons there is an increased interest in the reduction of N applications to pasture (Butler et al., 2012; Gunter et al. 2012; Interrante et al., 2012).

White and crimson clovers grown in combination with grasses has shown N fixation levels of 100-200 kg N ha^{-1} yr^{-1} and 125-185 kg N ha^{-1} yr^{-1}, respectively (Ledgard and Steele, 1992). Despite this data there is still reluctance to depend on clovers for pasture N needs. This reluctance is due largely to the high level of variability in the amount of N fixed by legumes. Most variation in N fixation can be attributed to the availability of mineral N in the soil and climatic conditions (Crush et al., 1982; Ledgard et al., 1998; Wu and McGechan 1999). Variation resulting from climatic conditions is explained by the high sensitivity of clovers to drought and extreme temperatures that can cause a reduction in the amount of clover in the pasture sward (Hoveland et al., 1991; Peterson et al., 1992; Peoples et al., 2001). In a study conducted by Ledgard et al. (1998), white clover was evaluated for production and N fixation when grown in combination with annual ryegrass under two N fertilization treatments, 0 and 390 kg ha^{-1} yr^{-1}. Compared to the 0 N treatments, the N fertilization treatments showed an increase in average total pasture DM production by 3180 kg ha^{-1} yr^{-1} but a reduction in white clover production by 630 kg DM ha^{-1} yr^{-1}. Furthermore, Ledgard et al. (1998) found N fertilization decreased the amount of N fixed by clover from 111 to 47 kg N ha^{-1} yr^{-1}, which they attributed to the reduced amount of clover DM production and decreased amount of clover N derived from atmospheric N_2. In concurrence, Høgh-Jensen and Schjoerring (1997) measured the amount of atmospherically derived N to be equal to 83, 71, 68, and 60 kg N ha^{-1} in mixtures of white clover and annual ryegrass treated with 2, 24, 48, and 72 kg N ha^{-1}, respectively. They also found quantities of atmospherically derived N in pure stands of white clover to be 109, 110, 103, and 90 kg N ha^{-1}, respectively for the aforementioned N treatments.

Nitrogen transfer

Increased availability of soil N in legume-grass mixed swards is a result of several mechanisms including decomposition of N-rich legume tissues, recycling of N in urine and feces of grazing animals, and release of surplus N into the soil (Heichel and Henjum, 1991). These processes are collectively referred to as N transfer. Wilson (1942) reported white clover lost about a third of its nodules after defoliation in the form of grazing or mowing, increasing the amount of soil available N due to decomposition of sloughed nodules. As a result, N transfer from N-fixing legumes to grasses could be a good alternative to chemical N application particularly in pastures utilized for hay or grazing (Sleugh et al., 2000; Interrante et al., 2012). In mixed pastures of forage legumes and grasses, N transfer has been estimated between 26 and 154 kg N ha^{-1} depending on species composition, management, plant productivity, and duration of growth (Brophy et al. 1987; Dear et al., 1999; Peoples et al., 2001). Brennan and Evans (2001) determined the economic benefit of planting N-fixing legumes versus chemical N application depends on legume species and the cost of N fertilizer at the time.

Animal performance and forage quality of clovers

In a review of grazing studies it was concluded that, on average, the inclusion of legumes in grass pastures increased ADG by 0.136 kg and final weight of steers by 27.21 kg (Burns and Standaert, 1985). Concentration of CP in legumes was found to be higher than co-seeded grass species (Weller and Cooper, 2001; Butler et al., 2012). The increased animal performance can partly be attributed to the increased CP of the total sward (Gleghorn et al., 2004).

In addition to high levels of CP, the leaves of clovers generally exhibit lower levels of indigestible, lignin-rich fiber than grasses. This is due in part to clover leaves’ lack of fibrous mid-rib(s) and other vascular tissues that are common to grass species. This lower fiber content allows for increased ruminant access to the nutrient dense photosynthetic mechanisms contained within the leaf tissues (Van Soest, 1994).

SUMMARY

The stocker cattle industry is experiencing great demands for increased profitability and environmental sustainability with little or no negative impacts on yields. The economic and environmental impacts of producing hay or other stored feed are marginally sustainable at best. As a result, extending the grazing season should be a top priority of many cattle producers. In much of the Upper South, tall fescue is the predominant forage species while in the lower south cool-season annual pastures have complemented warm season perennial pastures, serving to extend the grazing season and, as a result, reducing stored forage and feed inputs during periods of minimal forage production. In both of these systems, N fertilization represents a large portion of the economic inputs, and forage legumes could help mitigate N fertilization needs. Despite the prevalence of these forages in the Southeast, little research has been successfully conducted to evaluate these forages and forage mixtures in a side-by-side comparison in the region.

II. MATERIALS AND METHODS

All procedures and experimental protocols were approved by the Auburn University Institutional Animal Care and Use Committee (IACUC) (Protocol No. 2013-2367).

Experimental site

The grazing experiment was conducted at the Alabama Agricultural Experiment Station Sand Mountain Research and Extension Center (SMREC) located in Crossville, AL (34° 17’N, 85°59’W; elevation 349 m). The soil type of the experimental site was Hartsells fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults).

Experimental paddocks had previously been utilized for tall fescue [*Lolium arundinaceum* (Shreb.) Darbysh.] grazing experiments and hay production. Existing tall fescue stands had been seeded between 26 and 28 October 2011. Existing ‘Duramax Gold’ tall fescue stands in paddocks 3, 9, 11, 14, and 15 and ‘Kentucky-31’ tall fescue stands in paddocks 1, 4, and 10 were eradicated in August of 2013 by a spray-smother-spray method (Glyphosate [N-(phosphonomethyl)glycine] at a rate of 2.25 L a.i./ha). The existing ‘Texoma MaxQ II’ novel endophyte (NE+) tall fescue (Pennington Seed, Madison, GA) stands in paddocks 2, 8, 12, and 13 were maintained to be utilized as a perennial treatment for the current grazing evaluation.

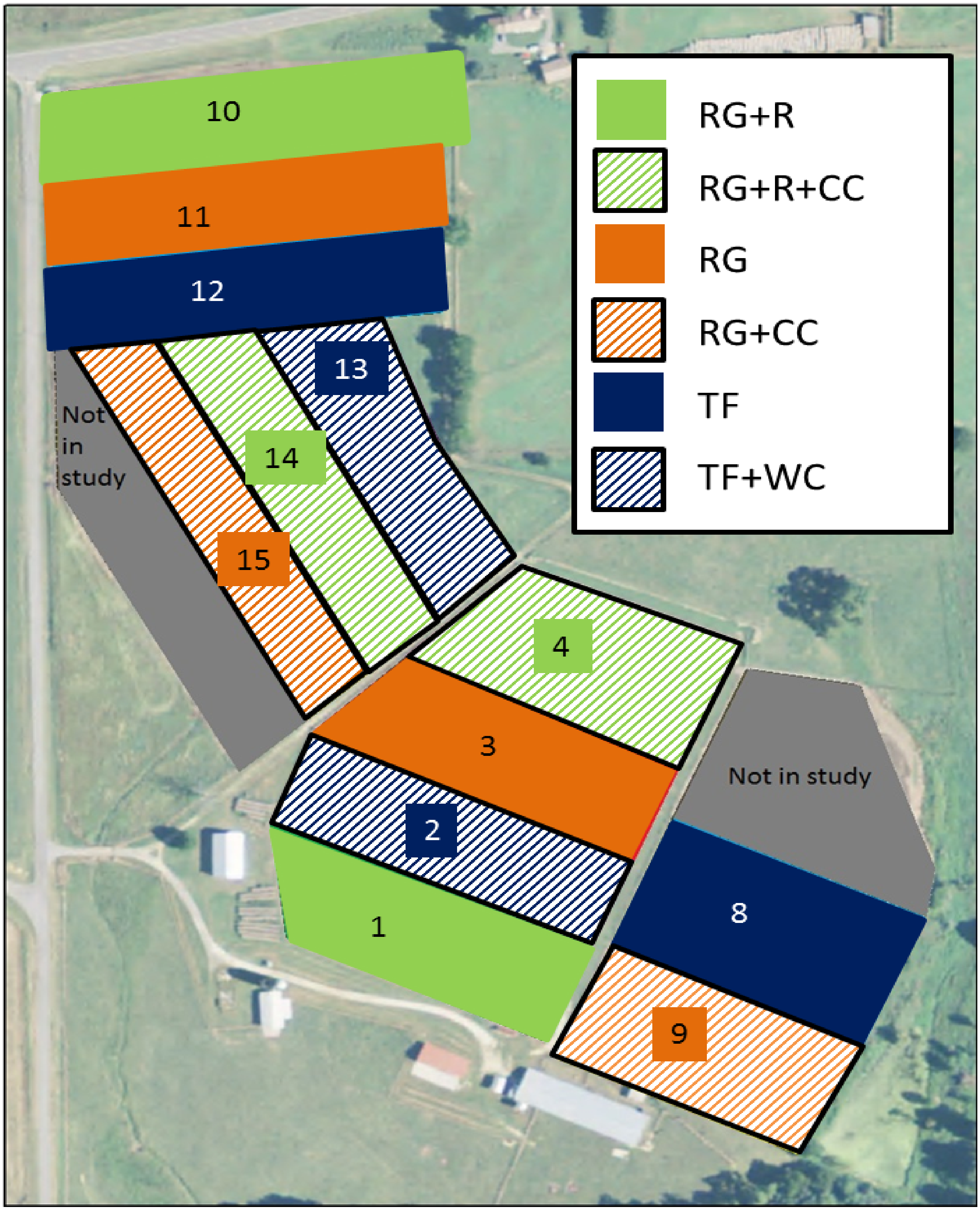


Figure 1. Layout of experimental paddocks.

Experimental design

A 2-yr grazing evaluation was conducted in the spring seasons of 2014 (year one) and 2015 (year two). Four annual cool-season forage treatments with two replications were randomly assigned to eight 0.8 ha paddocks, and two perennial forage treatments were randomly assigned to four existing ‘Texoma MaxQ II’ tall fescue 0.8 ha paddocks with two replications.

The perennial forage treatments were ‘Texoma MaxQ II’ NE+ tall fescue treated with chemical nitrogen fertilizer or overseeded with ‘Durana’ white clover (*Trifolium repens* L.) (Pennington Seed Madison, GA). The four annual forage treatments were ‘Nelson’ annual ryegrass (*Lolium multiflorum* L.) (Wax Seed Company, Amory, MS) treated with nitrogen fertilizer or co-planted with ‘Dixie’ crimson clover (*Trifolium incarnatum* L.) and ‘Nelson’ annual ryegrass planted with ‘Graze King 90’ cereal rye (*Secale cereal* L.) treated with nitrogen fertilizer or seeded with ‘Dixie’ crimson clover. From this point forward the treatments will be referred to as:

Novel endophyte tall fescue treated with chemical nitrogen fertilizer: TF

Novel endophyte tall fescue overseeded with ‘Durana’ white clover: TF+WC

Annual ryegrass treated with nitrogen fertilizer: RG

Annual ryegrass planted with crimson clover: RG+CC

Annual ryegrass planted with cereal rye and treated with nitrogen fertilizer: RG+R

Annual ryegrass planted with cereal rye and crimson clover: RG+R+CC

Animal management

Yearling crossbred steers (*Bos taurus* L.) of approximately 239 kg in body weight were obtained from a local collaborator on contract and delivered to the research site in January of both years; steers were predominantly Angus crossbreeds. Steers were sorted for culling purposes based on demeanor and visual evaluation of body condition score (BCS). Criteria for selecting treatment steers were a calm temperament and a BCS of 4 to 6. Treatment steers were shrunk for 8 hours and weighed. Shrunk weights were used to assign treatment steer to treatment groups of 4 steers each in a manner that minimized variance in mean animal body weight among treatment groups. These groups were then randomly assigned to treatment paddocks.

Initial mean body weights in year one and year two were 239 ± 45 kg and 239 ± 36 kg, respectively. Before being put on treatment paddocks steers were backgrounded for a minimum period of 30 days on bermudagrass [*Cyondon dacylon* (L.) Pers.] hay and water provided *ad libitum* in a nearby pasture. Steers were provided free-choice mineral mix containing lasalocid (VMS Kowpoke 4 B1200, Ridley Block Operations, Mankato, MN) and water *ad libitum* throughout the study.

Steers were treated with Cydectin Pour-On Antiparasitic (moxidectin) (Boehringer Ingelheim Vetmedica, St. Joseph, MO) on 28 March and 6 March of year one and year two, respectively, and were treated with Saber Pour-On Insecticide (lambdacyhalothrin) (Merck Animal Health, Kenilworth, NJ) on 5 June and 18 June of year one and year two, respectively.

Pasture management

In early October of year one and late September of the second year, cereal rye, annual ryegrass, and crimson and white clovers were drilled with a no-till drill (706NT, Great Plains Ag, Salina, KS) at 18.75 cm row spacing. Cereal rye was drilled at 112 kg/ha to a depth of 3.75 cm. Annual ryegrass was planted to a depth of 1.25 cm at a rate of 17 kg/ha. Crimson clover was drilled at 28 kg/ha to a depth of 1.25 cm. White clover was over-seeded to a depth of 1.25 cm into existing tall fescue stands at 3.3 kg/ha. In both years, paddocks planted with cereal rye were fertilized with 56 kg N/ha, and ryegrass and ryegrass-crimson clover mixtures were fertilized with 45 kg N/ha at seedling emergence in the form of ammonium nitrate (34-0-0) as *per* the cool-season forage establishment recommendations of Duell (1974) and Wedin (1974). All tall fescue paddocks received ammonium nitrate at a rate of 67 kg N/ha in the fall. The RG, RG+R, and TF treatments received an additional 50.5 kg N/ha in the form of ammonium nitrate in March of both years.

All paddocks were continuously grazed at a fixed stocking rate of 5 steers/ha (4 steers per paddock).

Animal responses

In both years one and two test steers were shrunk for a period of 8 hours prior to weighing at initiation and termination of grazing. Non-shrunk steer weights were taken at 28-d intervals during the grazing period.

Pasture responses

Available forage dry matter (DM) was estimated at the initiation, termination, and every 28 days of the grazing period utilizing a calibrated falling disc meter with a radius of 22.86 cm as described in Bransby et al. (1977). In this study, available forage DM is defined as the plant material that is greater than 5 cm from the soil surface. Concurrent forage samples for forage quality analysis were collected. Thirty disc meter readings were randomly taken from each paddock. Five calibration samples were taken from each paddock covering the range of available forage DM. Forage was clipped to 5 cm above soil level from within a ring with a radius of 22.86 cm and placed in cloth bags. The 5 calibration samples also served as samples for forage quality analysis. Fresh forage mass from all forage samples was promptly taken after clipping. Forage samples were transported to the Auburn University Forage Quality Laboratory and dried to a constant weight in a forced air oven at 60°C. Samples were weighed and ground to pass through a 1-mm screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ).

All forage samples were scanned using a Perstorp Analytical 5000 near infrared spectrophotometer (NIR) (Foss North America, Eden Prairie, MN). Acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and total digestible nutrients (TDN) were estimated using prediction equations developed by the NIRS Forage and Feed Testing Consortium (Hillsboro, WI). Subsamples of forage samples were analyzed for NDF and ADF according to Van Soest et al. (1991) and for total N concentration by combustion analyzer (Elementar CNS, Elementar Americas Inc., Mt. Laurel, NJ). These values were compared to those predicted by the NIRS Forage and Feed Testing Consortium equations for verification.

Percent of legume in the swards of the legume inclusion treatments was estimated at the initiation, termination, and every 28 days of the grazing period by a step-point method.

Pre- and post-grazing soil samples were taken at a depth of 10 cm from each paddock in February and July of both years and analyzed for total soil N and carbon concentrations by combustion analyzer (Elementar CNS, Elementar Americas Inc., Mt. Laurel, NJ). Soil pH was analyzed as a 1:1 soil:deionized water solution as specified by AOAC method 994.16 (AOAC, 1995).

In both years, grazing was initiated when forages emerged from winter dormancy and available forage DM was estimated to be above 2000 kg/ha. Grazing was terminated when steer average daily gains (ADG) fell below 0.45 kg/d *per* IACUC approved experimental protocol or available forage DM was estimated to be less than 1120 kg/ha, which is approximately the amount of available forage DM required to support steer gain of 0.45 kg/d at the stocking rate utilized in this study (Beck et al., 2013).

Weather data

Daily minimum and maximum ambient temperatures and daily total precipitation data were collected by weather instruments operated by the National Oceanic and Atmospheric Administration (NOAA) station located in Huntsville, AL. Weather data instruments were located 1.5 km from the research site.

Statistical analysis

All statistical analysis was conducted using PROC MIXED procedure in SAS 9.4 (SAS Institute, Cary, NC). Average daily gain (ADG) was calculated per animal by dividing the difference in initial and final shrunk steer weights by the total days spent on treatment. These values were then averaged per paddock for analysis by treatment within years. Total gain per hectare (G/ha) was analyzed as the difference between initial and final shrunk steer weights summed for all steers on each paddock divided by the area of each paddock, 0.8 ha, analyzed by treatment within years. Percent clover in the treatment sward was analyzed as the average percent of legume over the entire grazing season for each paddock by treatment within years. Forage dry matter (DM) yield was analyzed as the sum DM yield over the entire grazing season of each paddock by treatment within years. Forage quality indices were analyzed as weighted averages. For each sampling date the forage quality readings for each paddock were multiplied by the percent of total forage DM yield for that sampling date and paddock. These values were then summed for each paddock over each grazing season and analyzed.

III. RESULTS AND DISCUSSION

Temperature and precipitation

Monthly mean ambient temperatures (Figure 2) during the first year were below the 30-yr averages during November, January, February, and March. January mean ambient temperature was below 0 °C, well below the 4 °C threshold for vegetative growth of cereal rye proposed by Stoskopf (1985) and the 6 °C minimum for growth of annual ryegrass and crimson clover as reported by Evers et al. (1997) and Knight (1985). Consequently, forage production of these species was delayed in year one, resulting in later initiation of grazing on the annual treatments in year one compared with year two.

Temperatures in the second year of this evaluation were higher during December and consistent with the 30-yr average during January, allowing for earlier dates of grazing initiation on the annual treatments than in the first year. Two successive nights with a low ambient temperature of -14 °C occurred on 19 and 20 February, causing frost damage to annual ryegrass and crimson clover stands. Forage availability on the RG and RG+CC treatments were estimated to be below 1120 kg DM/ha on the March 6 sampling date and steers were temporarily removed from these treatments. Steers were put back on the RG and RG+CC treatments on 26 March after a 20-d rest period once forage availability was estimated to be above 1120 kg DM/ha.

Below-average temperatures during the winter months did not affect the growth and forage production of tall fescue from year to year. In the transition zone, tall fescue is typically dormant until March irrespective of weather conditions during the winter months (Roberts et al., 2009). The relative cold tolerance of tall fescue can be attributed to its extensive root and rhizome systems (Craven et al., 2009).

Monthly precipitation totals (Figure 3) were within 25% of the 30-yr average in September, November, February, March, and May of the first year. Below-average precipitation, 9, 36, and 68% of the 30-yr averages, was recorded at the research site during the months of October, January, and July of the first year, respectively, and above average precipitation, 190, 204, and 197% of the 30-yr average monthly totals, was received during the months of August, December, and April, respectively. In the second year, monthly precipitation totals varied more from the 30-yr average than in year one. Only March, May, and July were within 25% of the 30-yr average. Below-average precipitation, 48, 38, 66, 72, 69, and 29% of the 30-yr average, was recorded during the months of August, September, November, January, February, and June of year two, respectively. During October, December, and April, the research site received 177, 136, and 167%, respectively, of the 30-yr average. Below- and above-average rainfall may have negatively affected forage growth and production of annual ryegrass and cereal rye as reported by Beck et al. (2005) in a 3-yr study conducted in northern Arkansas. It should be noted that all treatment paddocks were not utilized during the fall; the forages were not under any defoliation stress during those months, making them less susceptible to water stress.

Figure 2. Mean ambient temperatures (°C) and the 30-yr average for the months of August through July for the first (2013/2014) and second (2014/2015) years of the grazing evaluation. Collected from NOAA weather station located 1.5 km from research site

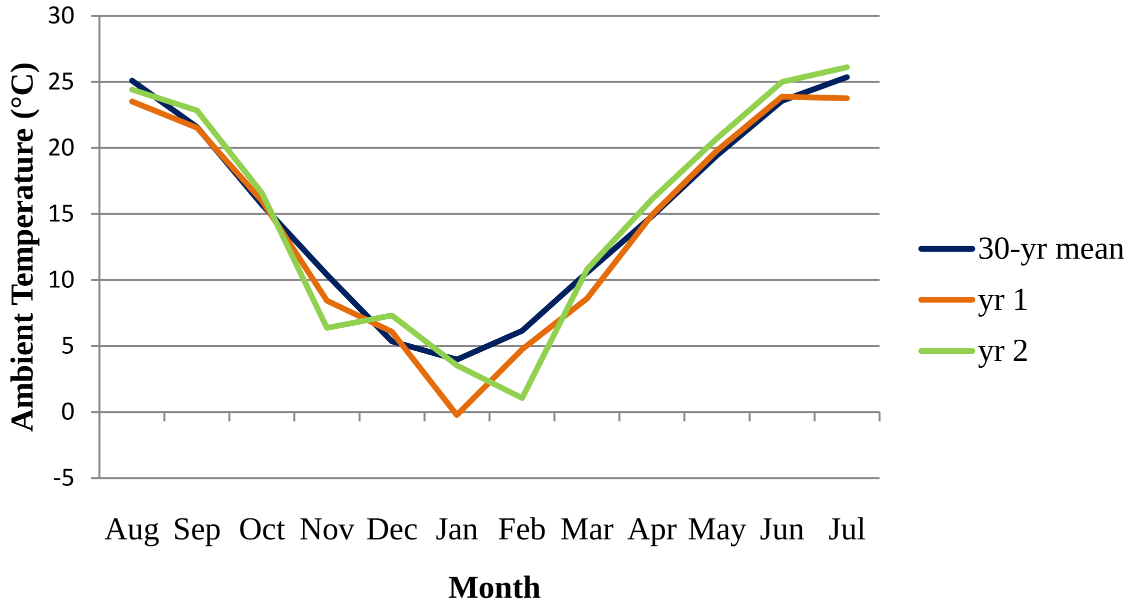
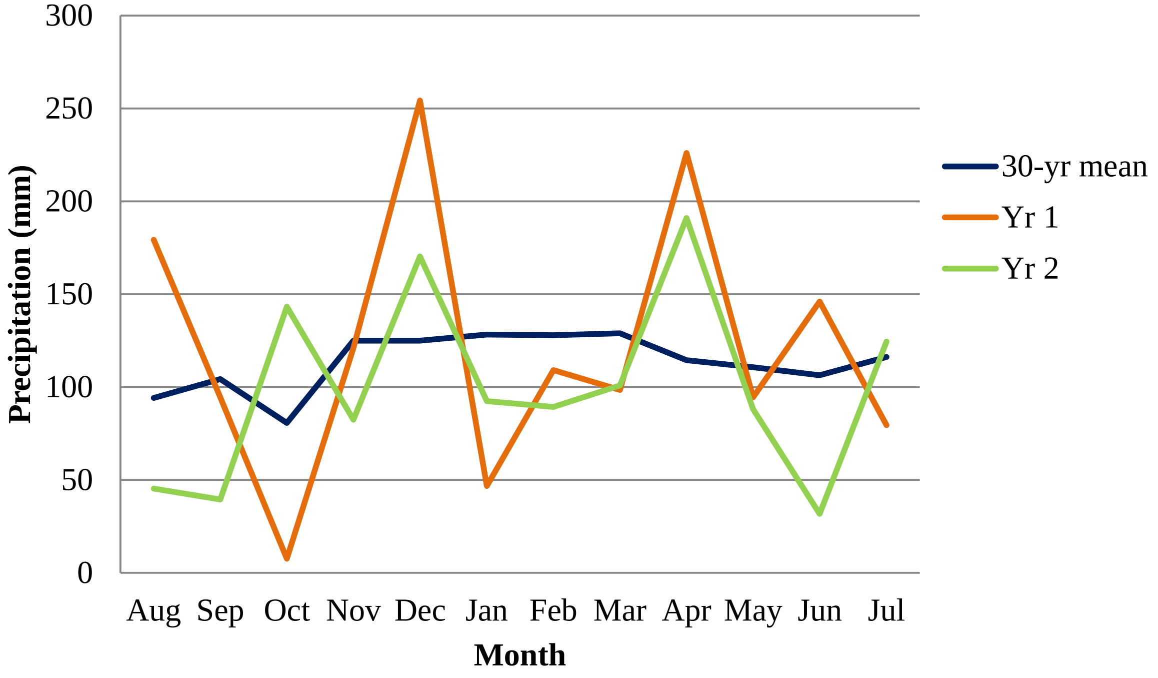


Figure 3. Mean total precipitation (mm) and the 30-yr average for the months of August through July for the first (2013/2014) and second (2014/2015) years of the grazing evaluation. Collected from NOAA weather station located 1.5 km from research site.



Soil fertility

Soil pH, percent total N, and percent carbon (Table 1) were determined as the average of all soil samples taken from each treatment. There was little variation within treatment, among years, and between before and after grazing.

Table 1. Average soil pH, percent total N (%N), and percent soil carbon (%C)†

	Treatment						
Index	RG	RG+CC	RG+R	RG+R+CC	TF	TF+WC	SE
pH	5.47	5.27	5.61	5.45	5.24	5.54	0.03
%N	0.11	0.11	0.12	0.12	0.12	0.12	0.002
%C	1.05	1.09	1.19	1.16	1.14	1.12	0.04

†%N and %C are presented as percent of air-dried soil on a mass basis

Percent legume of the pasture sward

Percent legume of the pasture sward (Table 2) is presented as the average of each treatment over the entire grazing season. There was little variation within treatment and year. Crimson clover was the only legume to yield substantial amounts of biomass of the two species of legume used in this study. White clover represented little to none of the available forage in the TF+WC treatment in both years.

Whereas soil pH levels of all treatments were suitable for cool-season grass growth, they were below the optimal pH ranges for crimson and white clover growth. Average soil pH of the TF+WC treatment was 5.54, below the optimal pH for white clover, 6.5 as stated by Gibson and Cope (1985), could have contributed to the little to no white clover presence in this treatment. Soil pH means for treatments containing crimson clover were also lower than the optimal range of 6.0 to 7.0 (USDA, 2009). However, crimson clover is more tolerant of low pH than white clover, which may be the reason for the more successful stands observed in the present study (Whyte et al., 1953). Due to the lack of white clover presence in the TF+WC swards, inferences cannot be made from this study on the effectiveness of white clover as a replacement for chemical N fertilizer on tall fescue pastures for spring grazing.

Despite the greater botanical composition estimates of crimson clover compared with white clover within treatment swards, only the RG+CC treatment in year one achieved the target sward composition threshold of 30% required to fully replace the need for chemical N fertilizer, as stated by Miller and Reetz (1995). Lower percent legume presence in treatments containing RG+R compared with treatments containing only RG may be attributed to the tendency of cereal rye to shade out co-planted species (Ball et al., 2007). Reduced stands of crimson clover in both the RG+R+CC and RG+CC treatments throughout the grazing season in year two compared with year one are probably due to the two aforementioned kill frosts occurring in February of the second year.

Table 2. Estimate of percent legume in each legume inclusion treatment by year.

Year	Treatment			SE
	RG+CC	RG+R+CC	TF+WC	
	--------------------------%	----------------------------		
2014	39^{a}	26^{b}	0^{c}	2.44
2015	14^{a}	11^{a,b}	7^{b}	2.44

^{a,b,c}Within a row, means without common superscripts differ ($P < 0.05$)

Grazing initiation and termination

In year one, grazing was initiated on RG+R and RG+R+CC treatments on 14 March and was terminated on 22 May, providing 68 total days of grazing. In year two, grazing was initiated on 6 February and terminated on 31 March for the RG+R and RG+R+CC treatments, providing 57 total days of grazing. As expected, cereal rye provided the earliest grazeable forage of all the species in the study, confirming the statements of Ball et al. (2007) and the findings of a 4-yr study conducted by Bagley et al. (1988) that cereal rye is available for grazing earlier in the growing season than other annual forages. Cereal rye proved to be the most cold-hardy of all the forage species in this evaluation, particularly in the second year when below freezing temperatures devastated annual ryegrass and crimson clover stands and tall fescue had yet to emerge from winter dormancy.

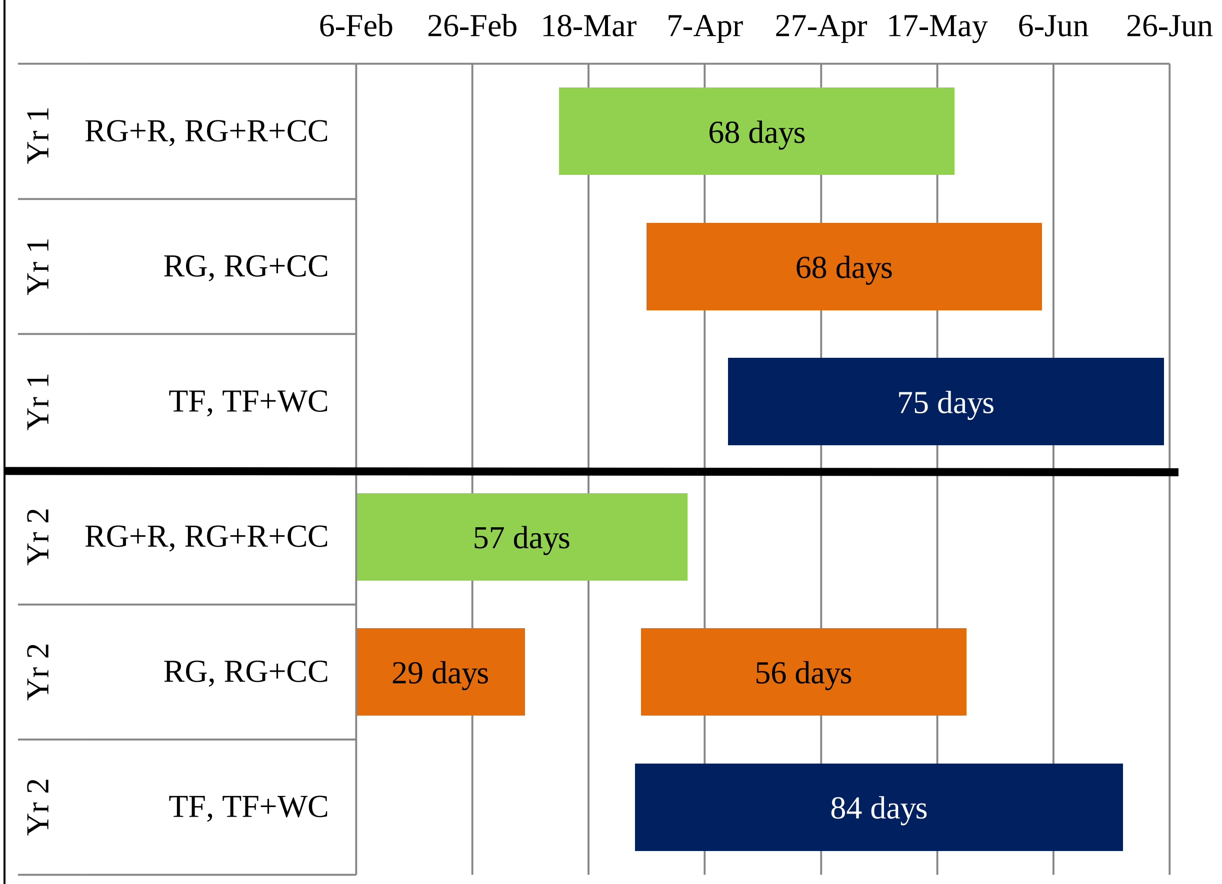
In the first year, RG and RG+CC provided 68 total days of grazing from 28 March to 5 June. In the second year, RG and RG+CC provided 29 days of grazing from 6 February to 6 March and 56 days of grazing from 26 March to 21 May; providing 85 total days of grazing in year two.

It should be noted that the bulk of the grazing on RG and RG+CC treatments occurred during and after March. Redfearn et al. (2005) reported forage production of annual ryegrass was greatest from 1 March until the end of the growing season in a 12-yr variety trial conducted at several locations. Based on these findings, annual ryegrass should be an appropriate companion species to the earlier maturing cereal rye, serving to extend the length of the grazing season offered by cereal rye further into the warmer months. However, management of mixed annual ryegrass-small grain pastures is crucial to avoid the shading out and overgrazing of the ryegrass component as observed in the first and second years of this evaluation, respectively. A 4-yr study utilizing a “put-and-take” system of grazing management, Bagley et al. (1988) reported mixed pastures of cereal rye, annual ryegrass, and a legume could support higher stocking rates than annual ryegrass-legume and annual ryegrass pastures from November to March, but in April and May, annual ryegrass-legume and annual ryegrass pastures supported higher stocking rates than the pastures planted with cereal rye, annual ryegrass, and a legume.

Grazing of TF and TF+WC paddocks was initiated on 11 April of the first year and was terminated on 26 June providing 75 total days of grazing. In year two grazing was initiated for TF and TF+WC on 26 March and was terminated on 18 June providing 84 total days of grazing. In accordance with the forage growth curves presented by Ball et al. (2007), TF and TF+WC provided forage furthest into the summer in both years and were the last treatments for which grazing was initiated.

Under the conditions of a real-world production system, treatments containing novel endophyte tall fescue provided adequate DM to continue grazing past the termination date of this study in both years but animal performance would probably be below 1 kg of BW gain per day. Tall fescue enters a summer dormancy phase when ambient temperatures are above 29 °C, often referred to as ‘summer slump’. During this phase, little forage regrowth occurs and forage quality declines (Roberts et al., 2009). It is recommended that animals be removed from novel endophyte tall fescue during the hottest months of the year in order to maintain stands for autumn grazing (J.M. Johnson, personal communication, 2014).

Figure 4. Gantt chart of grazing timing and duration of each treatment by year



Available Forage Dry Matter

Available forage DM (Table 3) was analyzed as the cumulative sum of available forage DM estimates for each treatment over the each of the grazing seasons. In the first year, available forage DM of treatments containing cereal rye was greater than the RG and RG+CC treatments (P = 0.01) and the two treatments containing novel endophyte tall fescue (P = 0.0017) (Table 3). Available forage DM of RG and RG+CC did not differ from TF and TF+WC (P = 0.10). Legume inclusion had no effect on available forage DM for TF and TF+WC (P = 0.11), RG and RG+CC (P = 0.29), or RG+R and RG+R+CC (P = 0.11).

In year two, RG+R and RG+R+CC treatments were clipped on 16 December from a height of 37.5 ±2.5 cm to a height of 22.5 ± 2.5 cm to maintain forage in a vegetative state. Available forage DM of RG+R and RG+R+CC did not differ (P = 0.77), but was less than the annual ryegrass and tall fescue treatments (P = 0.0008 and P = 0.0002, respectively). Less available forage DM of treatments containing cereal rye (5,879 kg DM/ha) compared to the other treatments (RG, RG+CC: 10,349 kg DM/ha and TF, TF+WC: 11,451 kg DM/ha) in the second year could be attributed the selective grazing of cereal rye after annual ryegrass and crimson clover stands were stunted by frost in late February. Available forage DM of RG was greater than RG+CC (P = 0.0037) and TF available forage DM was greater than TF+WC (P = 0.0431). Greater available forage DM of RG and TF (12,682 kg DM/ha and 12,747 kg DM/ha, respectively) compared to their legume inclusion treatment counterparts (8,016 kg DM/ha and 10,154 kg DM/ha, respectively) is likely due to the application of commercial N fertilizer to the RG and TF paddocks in March of year two. The two treatments containing novel endophyte tall fescue did not differ from the annual ryegrass treatments (P = 0.18). The sum of available forage DM of all treatments containing legumes compared with the sum of all treatments treated with N in March of year two were compared, and the legume inclusion treatments exhibited less available forage DM than those treated with N fertilizer (*P* = 0.0075).

Table 3. Sum of available forage DM (kg DM/ha) estimates for the entire grazing season of year 1 (2014) and year 2 (2015) by forage base and legume inclusion (+Legume) or spring treatment with N fertilizer (+N)

	Forage base					
	Ryegrass	Ryegrass + Rye	Tall fescue	SE	All forage bases[‡]	SE
			2014			
	--------------------kg DM/ha-----------------				--kg DM/ha--	
+Legume	11,791	15,801	10,047	1,014	12,546	585
+N	12,957	13,925	11,945	1,014	12,942	585
Mean[†]	12,374[x]	14,863[y]	10,996[x]	717	-	-
			2015			
+Legume	8,016	6,036	10,154	1,014	8,069	585
+N	12,682[a]	5,721	12,747[a]	1,014	10,383[a]	585
Mean[†]	10,349[x]	5,879[y]	11,451[x]	717	-	-

[a] Within a column, totals without common superscripts differ ($P < 0.05$)

[x,y] For comparison among forage base means only, within a row, means without common superscripts differ ($P < 0.05$)

[‡] Averaged over all forage bases with or without a legume for comparison of legume inclusion vs. spring N application

[†] With and without legume treatments averaged within forage base for comparison among forage bases

Table 4. Estimate of available forage dry matter (kg/ha) by treatment and harvest date. Standard error values presented next to each estimate in parenthesis.

	Treatment						
Date	RG	RG+CC	RG+R	RG+R+CC	TF	TF+WC	SE
2014							
	---------------------------------------kg/ha-----------------------------------						
14-Mar	-	-	3,509	1,989	-	-	198.2
28-Mar	2,846	2,604	-	-	-	-	37.6
11-Apr	-	-	3,643	3,999	2,907	2,291	216.5
24-Apr	4,204	3,928	-	-	-	-	169.3
8-May	-	-	3,882	5,094	3,323	3,236	350.1
22-May	3,348	3,007	2,890	4,719	-	-	208.8
5-Jun	2,559	2,253	-	-	3,365	3,117	149.6
26-Jun	-	-	-	-	2,350	1,403	100.8
2015							
	---------------------------------------kg/ha--------------------------------						
6-Feb	5,338	3,570	3,734	3,814	-	-	143.5
6-Mar	0	0	1,986	2,222	-	-	27.6
26-Mar	1,524	1,547	-	-	2,297	1,745	146.2
3-Apr	-	-	0	0	-	-	0
23-Apr	2,551	1,719	-	-	2,783	2,130	139.4
21-May	3,269	1,179	-	-	4,084	2,783	148.9
18-Jun	-	-	-	-	3,583	3,496	46.9

Forage Quality

As expected, the forage quality of all treatments generally declined as the grazing season progressed in both years. Plant maturity is the primary factor impacting forage quality (Buxton and Fales, 1994). In response to increasing ambient temperatures and day lengths, plants will initiate the process of flowering. During the early reproductive phase of grasses and small grains, the terminal bud stops leaf and axillary bud initiation as it begins to form the inflorescence (Nelson and Moser, 1994). This process involves the elongation of stem internodes to elevate the inflorescence above the sward canopy for wind pollination and the strengthening of the stem by lignification, decreasing the leaf:stem ratio of the whole plant. The decrease in the leaf:stem ratio is the primary factor affecting the decline in forage quality as plant maturity increases (Ugherughe, 1986). As the stem proportion of the plant increases, structural carbohydrate content (NDF and ADF) increases, reducing forage digestibility and intake (Nelson and Moser, 1994).

Increasing ambient temperatures reduce the total nonstructural carbohydrate content (TNC) of the leaves. The TNC fraction is nearly 100% digestible, greatly improving forage quality (Nelson and Moser, 1994). In a TNC assay of the leaves of 128 cool-season grasses grown at 10°/5°C (light/dark) and 25°/15°C, Chatterton et al. (1989) found TNC content to be 312 mg/kg and 107 mg/kg, respectively.

In an evaluation conducted by Gleghorn et al. (2004), crude protein (CP) concentration showed a positive correlation with ADG; with a maximum of 13% CP. Minson (2012) reported 13% as the average CP value for cool-season grasses. The CP values reported for this study varied by year, treatment, and over the grazing season. Generally, CP comprised the highest portion of DM at the beginning of the evaluation for all treatments in both years. With the exception of RG+R+CC in year one, the weighted average CP values were equal to or greater than 13% for all treatments in both years.

In year one, treatments containing a legume exhibited lesser concentrations of crude protein (CP) ($P = 0.0001$) and total digestible nutrients (TDN) ($P = 0.0030$) and greater concentrations of acid detergent fiber (ADF) ($P = 0.0098$) and neutral detergent fiber (NDF) ($P = 0.0411$) than those treated with N fertilizer (Table 7). In year two, treatments containing a legume showed a greater concentration of NDF ($P = 0.0002$) and a lesser concentration of CP ($P = 0.0002$) compared to treatments receiving N fertilizer in the spring. No difference was observed for ADF ($P = 0.4041$) or TDN ($P = 0.4786$) between treatments with a legume and those treated with N in the spring of year two.

In year one, RG and RG+CC treatments exhibited no difference on the basis of CP ($P = 0.1844$) and ADF ($P = 0.4785$), but NDF and TDN differed ($P = 0.0355$ and $P = 0.0462$, respectively), with RG+CC exhibiting a lesser concentration of TDN but a greater concentration of NDF than RG. In year two, RG exhibited greater concentrations of CP ($P = 0.0337$), NDF ($P = 0.0081$), and ADF ($P = 0.0255$) but a lesser concentration of TDN ($P = 0.0165$) than RG+CC.

In years one and two, RG+R exhibited greater concentrations of CP ($P < 0.0001$ and $P = 0.0009$, respectively), ADF ($P = 0.0065$ and $P = 0.0461$, respectively) and TDN ($P = 0.0006$ and $P = 0.0429$, respectively) than RG+R+CC. On the basis of NDF, RG+R+CC was observed to have a greater concentration than RG+R in year one ($P = 0.003$), but no difference was observed in year two ($P = 0.0667$).

The observed concentrations of CP were greater for TF than TF+WC in years one and two ($P = 0.0022$ and $P = 0.0019$, respectively). In year one, no difference was observed between

TF and TF+WC on the basis of ADF ($P = 0.1547$), NDF ($P = 0.05326$), and TDN ($P = 0.14729$). In year two, TF and TF+WC did not differ with respect to ADF ($P = 0.0925$), NDF ($P = 0.5036$), and TDN ($P = 0.087$).

In year one, treatments containing cereal rye exhibited lesser concentrations of CP ($P = 0.0008$) and TDN ($P < 0.0001$) but greater concentrations of ADF ($P < 0.0001$) and NDF ($P < 0.0001$) than the RG and RG+CC treatments. In year two the RG+R and RG+R+CC were lower in CP ($P = 0.0067$), ADF ($P = 0.0003$), NDF ($P = 0.0211$), but greater in TDN ($P = 0.0003$) than RG and RG+CC. Compared to the novel endophyte tall fescue treatments, RG+R and RG+R+CC exhibited greater concentrations of ADF ($P = 0.0005$) and NDF (0.0002) but lesser concentrations of CP ($P < 0.0001$) and TDN ($P = 0.0004$) in year one. In year two, treatments containing cereal rye were observed to be greater in concentrations of CP ($P < 0.0001$) and TDN ($P < 0.0001$) and lower concentrations of ADF ($P < 0.0001$) and NDF ($P < 0.0001$) than the novel endophyte tall fescue treatments.

In year one, the TF and TF+WC treatments exhibited greater concentrations of CP ($P = 0.0060$), ADF ($P = 0.0071$), and NDF ($P = 0.0001$), but a lesser concentration of TDN ($P = 0.0018$) than RG and RG+CC. In year two, the novel endophyte tall fescue treatments were observed to have lower concentrations of CP and TDN, ($P < 0.0001$ and $P < 0.0001$, respectively), and higher concentrations of ADF and NDF, ($P < 0.0001$ and $P < 0.0001$, respectively), than the RG and RG+CC treatments.

Table 5. Chemical composition of forage samples collected during the 2014 and 2015 grazing seasons. Values calculated as weighted average of forage DM yield estimates. All data presented as g/kg of DM.

	Forage base					
	Annual ryegrass	Annual ryegrass + cereal rye	Novel endophyte tall fescue	SE	All[†]	SE
			2014			
	-------------------------------g/kg of DM----------------------------					
CP						
+Legume	134.3	100.9^{a}	138.9^{a}	4.15	124.7^{a}	2.40
+N	140.5	137.7	160.2	5.15	146.1	2.40
Mean[ǂ]	137.4^{x}	119.3^{y}	149.6^{z}	2.94	-	-
ADF						
+Legume	334.4	392.7^{a}	354.8	6.24	360.6^{a}	3.61
+N	329.6	367.3	344.6	6.24	347.2	3.61
Mean[ǂ]	332.0^{x}	380.0^{y}	349.7^{z}	4.42	-	-
NDF						
+Legume	545.8^{a}	684.1^{a}	627.5	8.46	619.1^{a}	4.88
+N	568.6	643.6	607.2	8.46	606.5	4.88
Mean[ǂ]	557.2^{x}	663.9^{y}	617.3^{z}	5.98	-	-
TDN						
+Legume	644.3^{a}	577.7^{a}	621.0	6.97	614.3^{a}	4.02
+N	661.8	606.7	632.6	6.97	633.7	4.02
Mean[ǂ]	653.0^{x}	592.2^{y}	626.8^{z}	4.93	-	-
			2015			
CP						
+Legume	182.8^{a}	164.0^{a}	133.8^{a}	4.15	160.2^{a}	2.40
+N	194.2	189.3	155.7	4.15	179.7	2.40
Mean[ǂ]	188.5^{x}	176.7^{y}	144.8^{z}	2.94	-	-
ADF						
+Legume	267.6	252.4^{a}	362.8	6.24	300.4	3.61
+N	286.0^{a}	236.8	350.4	6.24	284.9	3.61
Mean[ǂ]	276.8^{x}	244.6^{y}	356.6^{z}	4.42	-	-
NDF						
+Legume	475.3^{a}	482.7	639.9	8.46	619.1^{a}	4.88
+N	508.2	463.8	615.5	8.46	606.5	4.88
Mean[ǂ]	491.8^{x}	473.2^{y}	627.7^{z}	5.98	-	-
TDN						
+Legume	720.5^{a}	737.8^{a}	611.8	6.97	690.0	4.02
+N	697.5	755.6	626.0	6.97	693.1	4.02
Mean[ǂ]	709.0^{x}	746.7^{y}	618.9^{z}	4.93	-	-

[a] Within year, forage quality index, and column, means without common superscripts differ ($P<0.05$)

[x,y,z] Within a row, means without common superscripts differ ($P<0.05$)

[†] Averaged over all forage bases with or without a legume for comparison of legume inclusion vs. spring N application

[ǂ] Averaged within forage base for comparison among forage bases.

Average daily gain

In year one, ADG of steers grazing TF+WC was different from the steers grazing TF (P = 0.0035). The higher ADG of steers grazing TF+WC (1.00 kg/d) than steers grazing TF (0.70 kg/d) in year one cannot be attributed to the inclusion of a legume, as there was no observed white clover in the sward (Table 2). Greater ADG of steers grazing TF+WC than those grazing TF in year one might be attributable to differences in steer performance potential. No other significant differences were observed between steers on treatments containing a legume and those treated with N fertilizer on the basis of ADG in either year.

Steer ADG for TF and TF+WC treatments did not differ (P = 0.4505) from RG+R and RG+R+CC treatments but was lower than the RG and RG+CC treatments in year one (P = 0.0006). In year two, steers on the TF and TF+WC exhibited lower ADG than those on all annual treatments (RG and RG+CC: P = 0.031, RG+R and RG+R+CC: P = 0.0383). Steer ADG for treatments containing tall fescue were similar to those reported by Hoveland et al. (1991) in both years.

In year one, ADG of steers grazing the RG and RG+CC treatments was greater than those grazing RG+R and RG+R+CC ($P < 0.0001$); however, no difference was observed in year two (P = 0.9287). Lower steer ADG on RG+R and RG+R+CC in the first year (0.80 kg/d) compared with the second year (1.12 kg/d) might be attributed to the decline in forage quality as cereal rye entered the reproductive growth phase. The decline in forage quality of RG+R and RG+R+CC in the first year is manifested in the declining ADG values for animals on RG+R and RG+R+CC treatments as the grazing season progressed (Table 9). Beck et al. (2005) reported that under warm conditions with adequate rainfall as observed during this study in the spring of the first year, cereal rye will increase in maturity and decline in forage quality, resulting in reduced animal performance. Because steers were on the treatments containing cereal rye earlier in year two and cold weather favored the growth of cereal rye over the co-planted species, annual ryegrass and crimson clover, cereal rye was maintained in a vegetative growth phase by grazing pressure and sustained higher forage quality.

Table 6. Average daily gain† (kg/d) of steers by year, forage base, and legume inclusion (+Legume) or treatment with N fertilizer (+N)

	Forage base					
	Annual ryegrass	Annual ryegrass + cereal rye	Novel endophyte tall fescue	SE	All[Ɨ]	SE
			2014			
	--------------------kg/d-------------------				--kg/d--	
+Legume	1.14	0.76	1.00[a]	0.12	0.97	0.07
+N	1.12	0.85	0.70	0.12	0.89	0.07
Mean[‡]	1.13[x]	0.80[y]	0.85[y]	0.09	-	-
			2015			
	---------------------kg/d------------------				--kg/d--	
+Legume	1.09	1.07	0.93	0.12	1.03	0.07
+N	1.16	1.16	0.99	0.12	1.10	0.07
Mean	1.12	1.12	0.96[x]	0.09	-	-

[a] Within a column and year, means without common superscripts differ (*P* < 0.05)

[x,y] For comparison among forage base means only, within a row, means without common superscripts differ (*P* < 0.05)

†Difference in initial and final shrunk body weight divided by total days on treatment, averaged for all steers on same treatment

ƗAveraged over all forage bases with or without a legume for comparison of legume inclusion vs. spring N application

‡Averaged within forage base for comparison among forage bases.

Gain per hectare

In the first year, TF+WC differed from TF on the basis of G/ha (Table 10) (*P* = 0.0323). TF+WC supported greater G/ha (383 kg/ha) than TF (263 kg/ha). No other significant difference was observed on the basis of G/ha between treatments containing a legume and those treated with N fertilizer in either year.

The RG and RG+CC treatments supported greater G/ha than the RG+R and RG+R+CC treatments in both year one and year two (*P* = 0.0113 and *P* = 0.002, respectively). Total G/ha of RG and RG+CC treatments did not differ from TF and TF+WC in year one (*P* = 0.0939) and in the second year (*P* = 0.05). Treatments containing novel endophyte tall fescue provided greater G/ha than those containing cereal rye in year two (*P* = 0.0329), but not in year one (*P* = 0.1569).

Based on animal performance data alone, inclusion of a legume offered a viable alternative to spring N fertilizer application for spring forage production. However, RG and TF Treatments receiving N fertilizer in the spring of the second year showed increased DM yields over RG+CC and TF+WC, respectively, and therefore could have supported higher stocking rates. A higher stocking rate may have increased the forage quality of the treatments without a legume by maintaining forage in a vegetative growth phase resulting in increased ADG of steers and higher G/ha on the RG and TF treatments.

Table 7. Total animal BW gain[†] (kg/ha) by forage base, legume inclusion (+Legume) or spring treatment with N fertilizer (+N), and year.

	Forage Base					
	Annual ryegrass	Annual ryegrass + cereal rye	Novel endophyte tall fescue	SE	All[‡]	SE
			2014			
		--------------------kg/ha----------------				
+Legume	386	259	383[a]	43	343	24
+N	380	287	263	43	310	24
Mean[‡]	383^{x}	273^{y}	323^{xy}	31	-	-
			2015			
		------------------kg/ha-------------------				
+Legume	461	306	391	43	386	24
+N	494	330	414	43	413	24
Mean[‡]	477^{x}	318^{y}	402^{x}	31	-	-

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[a] Within a column and year, means without common superscripts differ (*P*<0.05)

IV. CONCLUSIONS

Results of this study indicate that annual ryegrass and mixtures of annual ryegrass and cereal rye treated with N fertilizer or planted with crimson clover into a prepared seedbed in the fall can provide high quality forage during the late winter and early spring when production of other forages is limited. The annual treatments proved to be a viable option for extending the grazing season serving to mitigate reliance on stored feeds during the coldest months in the Southeast. Tall fescue was available for grazing further into the late winter/early spring months, providing forage between the mid-point to end of the grazing season provided by early maturing cool-season annual forages and the time period when warm-season forages are typically available for grazing. Several differences in factors affecting forage quality were observed between legume inclusion and exclusion treatments but these were not manifested in the animal performance data. Further research is needed to evaluate these treatments utilizing a range of fixed stocking rates to determine the optimal stocking rate for each treatment. A year-long grazing evaluation of these treatments is needed to determine when they can provide grazing on an annual basis and how and where further improvements can be made to extend the grazing season.

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Appendix

Forage quality data from 2014. Forage quality data from 2015. All data except for RFQ are presented as % of DM

Date	Paddock	DMR	CP	ADF	NDF	TDN	RFQ
31314	1	12	19.80	22.27	45.26	77.17	174.10
31314	1	15	15.58	23.39	47.10	75.88	182.89
31314	1	18	19.79	23.48	46.75	75.78	173.05
31314	1	22	20.37	24.21	47.94	74.96	162.03
31314	1	26	25.44	24.78	47.76	74.31	120.51
31314	4	8	14.45	23.56	45.86	75.69	182.39
31314	4	11	17.00	25.37	50.59	73.63	173.30
31314	4	16	16.21	27.12	52.60	71.64	171.46
31314	4	19	16.38	24.55	48.57	74.57	183.69
31314	4	23	15.47	27.05	51.95	71.72	168.05
31314	10	12	16.79	24.50	48.32	74.62	176.13
31314	10	16	18.37	23.58	47.56	75.67	174.56
31314	10	19	20.00	24.18	48.41	74.99	161.68
31314	10	27	24.07	24.64	47.32	74.46	134.68
31314	10	27	22.61	24.51	47.55	74.60	146.15
31314	14	11	13.50	25.36	48.48	73.64	172.35
31314	14	13	12.78	25.68	47.41	73.28	172.74
31314	14	16	12.55	25.26	47.89	73.75	177.44
31314	14	24	17.32	25.37	50.19	73.63	171.61
31314	14	31	15.78	25.61	50.46	73.36	173.03
32714	3	8	17.80	20.69	37.19	78.96	193.52
32714	3	10	19.41	21.64	41.00	77.89	181.12
32714	3	13	13.29	25.15	45.37	73.88	177.61
32714	3	15	19.16	22.50	42.59	76.90	183.38
32714	3	18	14.87	24.20	43.43	74.97	183.10
32714	9	7	13.67	25.19	41.24	73.84	175.91
32714	9	11	13.00	25.14	44.00	73.89	181.51
32714	9	14	17.46	23.90	43.35	75.31	183.68
32714	9	16	22.08	21.91	34.01	77.58	169.58
32714	9	22	24.65	19.73	39.81	80.06	149.65
32714	11	8	16.33	22.47	41.94	76.94	178.64
32714	11	12	17.10	21.12	39.09	78.48	192.69
32714	11	14	25.38	22.43	40.45	76.99	139.77
32714	11	18	22.36	21.05	40.25	78.56	168.56
32714	11	22	19.47	22.52	42.48	76.88	170.57
32714	15	6	11.55	24.66	36.37	74.44	188.29
32714	15	8	18.07	23.78	36.23	75.45	176.09
32714	15	10	12.12	27.07	45.51	71.69	174.18

32714	15	13	12.19	25.84	46.17	73.09	170.70
32714	15	15	12.45	26.83	46.64	71.96	181.31
41014	1	27	15.32	33.15	60.24	64.75	125.96
41014	1	32	13.19	34.23	63.57	63.53	122.41
41014	1	34	16.58	31.94	58.87	66.14	125.90
41014	1	46	14.26	33.83	62.30	63.99	121.32
41014	1	54	12.67	34.58	63.95	63.12	122.63
41014	2	17	15.95	30.44	58.59	67.84	129.55
41014	2	17	16.39	29.48	55.78	68.94	134.53
41014	2	19	16.45	29.53	56.66	68.88	136.22
41014	2	22	16.61	30.26	56.83	68.05	132.15
41014	4	23	13.19	33.86	61.89	63.94	128.02
41014	4	27	13.50	33.82	61.79	64.00	127.72
41014	4	34	14.32	33.35	61.43	64.53	131.99
41014	4	40	11.75	34.45	65.70	63.28	125.15
41014	4	58	10.72	36.81	67.57	60.59	112.50
41014	8	7	21.08	23.28	47.11	76.01	148.77
41014	8	11	22.87	22.74	45.27	76.62	144.47
41014	8	16	18.80	27.28	51.46	71.45	139.23
41014	8	22	21.82	27.87	52.52	70.78	117.55
41014	8	24	22.42	27.00	51.09	71.77	116.98
41014	9	11	16.55	26.89	44.63	71.90	174.87
41014	9	16	18.96	25.86	41.05	73.07	158.89
41014	9	19	17.42	27.53	44.47	71.16	163.06
41014	9	22	15.77	28.16	44.83	70.45	156.99
41014	9	24	17.40	28.08	42.84	70.54	160.47
41014	10	19	17.49	30.63	59.22	67.64	128.34
41014	10	23	15.38	32.07	59.66	65.99	127.60
41014	10	29	16.76	33.62	60.21	64.22	117.35
41014	10	30	17.41	32.70	59.97	65.27	119.27
41014	10	37	12.63	35.74	64.31	61.80	114.17
41014	12	11	17.91	25.40	49.53	73.60	155.75
41014	12	12	16.36	27.50	53.00	71.20	142.41
41014	12	16	16.70	28.93	54.14	69.56	134.71
41014	12	21	19.05	29.03	54.24	69.45	128.14
41014	12	23	17.68	29.07	54.25	69.41	134.18
41014	13	8	16.36	27.98	51.47	70.65	149.04
41014	13	14	15.21	29.27	56.05	69.18	135.94
41014	13	16	15.64	29.22	54.71	69.24	138.70
41014	13	19	15.08	29.16	54.97	69.31	144.11
41014	13	21	17.35	28.79	54.93	69.73	137.57
41014	14	13	12.84	33.36	61.65	64.52	129.70
41014	14	18	10.68	31.75	60.18	66.35	137.77

41014	14	25	9.10	32.44	60.89	65.57	135.64
41014	14	36	8.53	35.58	64.95	61.98	120.96
41014	14	39	8.50	34.59	63.89	63.12	124.74
42414	3	7	19.24	30.40	52.31	67.89	121.15
42414	3	12	10.95	30.69	51.22	67.56	155.27
42414	3	14	8.63	33.17	53.32	64.73	134.93
42414	3	20	9.80	33.10	54.92	64.81	137.14
42414	3	30	18.42	30.92	54.20	67.30	129.25
42414	9	9	14.53	31.08	47.20	67.12	152.56
42414	9	11	9.97	34.06	55.41	63.72	131.20
42414	9	14	17.49	32.16	46.29	65.88	139.55
42414	9	19	16.81	32.38	46.80	65.64	140.66
42414	9	22	12.83	34.04	52.22	63.74	138.81
42414	11	10	14.38	29.19	51.21	69.28	150.44
42414	11	11	12.53	30.35	52.14	67.95	151.64
42414	11	13	11.69	29.83	51.35	68.54	157.98
42414	11	18	12.49	30.22	52.41	68.10	155.32
42414	11	20	16.41	31.34	54.21	66.82	138.60
42414	15	8	14.04	32.54	52.33	65.45	137.15
42414	15	11	10.13	30.52	51.01	67.75	156.04
42414	15	14	8.62	31.91	50.45	66.17	141.47
42414	15	20	7.97	32.45	52.02	65.56	140.81
42414	15	23	10.50	32.44	53.90	65.56	142.05
50814	1	11	11.48	41.75	71.69	54.95	82.77
50814	1	17	11.99	41.15	70.51	55.64	86.20
50814	1	29	8.93	41.80	72.99	54.89	87.60
50814	1	31	9.91	45.06	74.73	51.17	71.77
50814	1	58	8.04	40.18	71.29	56.74	99.34
50814	2	8	13.58	34.68	62.85	63.01	106.33
50814	2	12	12.80	36.60	65.82	60.83	101.24
50814	2	15	13.26	37.54	66.60	59.75	93.71
50814	2	18	12.67	37.93	67.70	59.31	92.05
50814	2	23	13.37	38.02	67.34	59.20	91.25
50814	4	14	10.72	43.12	74.07	53.39	76.87
50814	4	25	9.73	40.13	72.00	56.79	93.52
50814	4	27	8.88	42.12	73.02	54.53	83.67
50814	4	33	7.85	40.07	72.07	56.86	99.06
50814	4	46	7.64	40.53	70.95	56.35	92.96
50814	8	8	15.70	33.89	61.20	63.91	104.72
50814	8	17	15.39	36.07	62.83	61.43	96.83
50814	8	19	16.66	33.83	60.84	63.98	103.25
50814	8	25	14.34	37.10	65.25	60.25	98.60
50814	8	32	15.84	35.56	62.20	62.01	100.58

50814	10	13	8.91	42.58	73.38	54.01	79.23
50814	10	18	8.69	43.80	75.25	52.61	75.54
50814	10	26	8.64	42.54	72.63	54.05	81.44
50814	10	38	8.88	42.85	72.59	53.69	80.87
50814	10	53	9.68	40.43	70.59	56.45	91.72
50814	12	9	17.84	34.56	61.52	63.15	93.31
50814	12	13	13.87	35.03	63.10	62.62	107.35
50814	12	18	18.45	32.79	60.39	65.17	102.57
50814	12	25	13.70	37.75	65.67	59.51	99.64
50814	12	32	12.90	38.19	66.72	59.01	95.14
50814	13	9	12.64	36.37	64.35	61.08	105.21
50814	13	14	12.69	35.93	64.71	61.59	108.78
50814	13	22	11.68	39.32	67.73	57.72	92.60
50814	13	23	12.19	36.28	64.88	61.19	107.77
50814	13	28	11.94	36.84	65.34	60.55	106.26
50814	14	10	9.12	40.00	70.92	56.94	102.00
50814	14	14	7.75	40.46	71.14	56.41	94.36
50814	14	16	9.25	43.81	73.49	52.60	81.17
50814	14	37	6.87	42.25	73.79	54.38	85.40
50814	14	43	6.74	43.26	75.75	53.22	84.80
52114	1	13	8.03	49.48	77.88	46.13	51.43
52114	1	15	8.48	51.25	79.58	44.12	45.00
52114	1	20	7.17	49.51	78.60	46.10	52.42
52114	1	30	9.46	47.52	75.70	48.37	61.64
52114	1	35	8.39	45.87	75.88	50.25	65.29
52114	3	8	10.72	39.67	66.42	57.32	89.22
52114	3	11	9.19	40.38	68.51	56.52	88.50
52114	3	15	9.47	38.78	66.92	58.33	96.59
52114	3	18	13.80	35.71	62.29	61.83	103.90
52114	3	23	6.86	42.43	69.90	54.17	78.97
52114	4	20	7.19	47.47	77.23	48.42	58.58
52114	4	24	8.35	46.75	76.60	49.25	61.82
52114	4	38	8.52	44.28	75.10	52.07	69.16
52114	4	46	6.56	44.80	75.45	51.47	68.33
52114	4	55	5.80	44.41	75.97	51.92	69.00
52114	9	6	13.33	38.65	62.84	58.49	95.04
52114	9	11	13.21	40.19	58.89	56.72	93.00
52114	9	14	13.62	36.57	60.06	60.86	108.50
52114	9	18	13.24	39.74	59.28	57.25	96.94
52114	9	22	12.75	41.34	59.20	55.42	90.75
52114	10	12	8.35	47.10	76.82	48.85	58.32
52114	10	14	8.24	47.53	77.39	48.36	57.00
52114	10	24	8.63	46.45	75.72	49.59	62.02

52114	10	28	8.14	46.11	75.78	49.98	61.54
52114	10	38	7.87	45.90	76.24	50.22	64.15
52114	10	43	8.49	44.56	74.95	51.74	68.58
52114	11	6	14.63	33.69	60.85	64.14	111.17
52114	11	7	11.41	38.82	66.92	58.30	92.24
52114	11	14	12.08	38.28	64.54	58.90	96.12
52114	11	15	10.13	38.84	66.17	58.27	97.59
52114	14	17	6.36	47.10	78.28	48.84	59.11
52114	14	27	7.63	46.25	76.41	49.82	64.26
52114	14	31	7.45	47.57	77.32	48.31	58.16
52114	14	35	6.87	47.75	77.33	48.11	58.76
52114	14	47	6.55	45.62	77.57	50.53	64.45
52114	15	7	9.48	40.39	64.20	56.50	94.96
52114	15	9	11.23	37.27	63.85	60.06	99.43
52114	15	11	10.57	39.30	64.79	57.75	92.50
52114	15	14	13.02	36.04	61.33	61.46	106.42
52114	15	19	10.00	39.89	66.48	57.07	90.29
60514	2	10	14.78	36.60	61.85	60.82	98.17
60514	2	?	12.46	39.25	67.59	57.81	86.19
60514	2	11	13.82	36.37	63.69	61.08	99.18
60514	2	12	12.59	39.92	68.07	57.03	86.09
60514	2	15	12.13	39.80	66.21	57.17	94.53
60514	3	5	12.70	39.56	66.91	57.44	87.53
60514	3	6.1	12.35	41.27	67.82	55.50	85.70
60514	3	6.2	9.92	44.04	71.82	52.34	74.64
60514	3	9	9.28	45.33	72.91	50.87	71.49
60514	3	10	14.73	36.36	63.36	61.09	94.47
60514	8	8	15.96	37.12	63.00	60.23	86.46
60514	8	8	15.30	36.37	63.44	61.08	94.65
60514	8	9	14.29	38.84	64.86	58.27	86.54
60514	8	13	13.62	39.96	66.39	56.99	83.05
60514	8	16	12.33	43.28	65.67	53.20	81.08
60514	9	3	11.05	44.82	67.07	51.45	76.14
60514	9	5	11.02	46.84	67.63	49.14	70.74
60514	9	6	12.94	38.11	64.41	59.10	95.65
60514	9	6	10.55	45.36	68.80	50.83	74.88
60514	9	7	11.62	38.44	65.41	58.72	96.27
60514	11	4	12.21	40.37	67.08	56.53	88.70
60514	11	5	13.55	40.22	66.80	56.70	83.93
60514	11	6	12.14	40.38	67.06	56.51	87.88
60514	11	7	12.15	40.58	67.46	56.28	87.45
60514	11	9	9.64	38.70	66.58	58.43	96.51
60514	11	17	15.17	33.88	61.23	63.92	106.70

60514	12	5	16.57	33.45	60.14	64.41	104.03
60514	12	8	15.99	35.32	61.66	62.29	96.59
60514	12	11	19.06	31.08	56.24	67.12	103.78
60514	12	15	13.00	38.12	66.28	59.09	92.92
60514	12	16	14.38	36.21	63.94	61.27	96.10
60514	13	5	16.43	33.86	60.30	63.95	103.32
60514	13	7	12.31	37.73	66.60	59.54	94.90
60514	13	10	14.88	36.38	64.37	61.07	93.87
60514	13	12	11.62	39.59	67.67	57.41	90.38
60514	13	19	13.65	37.19	61.89	60.15	102.82
60514	15	3	13.33	37.44	62.07	59.87	99.63
60514	15	5	11.79	39.53	66.07	57.48	91.47
60514	15	5	11.42	41.90	65.34	54.78	84.78
60514	15	7	11.50	39.39	65.91	57.64	93.10
60514	15	7	17.03	32.41	58.73	65.60	104.21
62614	2	6	13.20	37.18	65.57	60.17	94.03
62614	2	10	20.39	31.09	56.98	67.10	99.03
62614	2	14	12.43	38.44	66.57	58.72	89.90
62614	2	15	12.50	38.25	66.54	58.94	88.34
62614	2	17	13.83	38.05	65.10	59.17	88.22
62614	8	8	12.34	39.45	67.87	57.58	84.43
62614	8	10	14.54	38.29	64.80	58.90	86.77
62614	8	14	12.04	40.29	68.28	56.62	82.98
62614	8	16	16.18	35.46	61.07	62.12	93.83
62614	8	19	18.68	31.75	57.01	66.35	103.70
62614	12	7	14.79	35.17	63.21	62.45	99.14
62614	12	10	18.50	33.95	58.84	63.84	93.31
62614	12	12	12.94	40.10	67.47	56.83	83.31
62614	12	16	12.09	40.24	67.75	56.67	84.68
62614	12	20	18.26	32.14	58.02	65.90	101.58
62614	13	9	18.57	33.01	58.89	64.92	97.07
62614	13	10	12.13	40.31	69.51	56.59	82.67
62614	13	13	12.54	38.57	67.40	58.57	89.89
62614	13	15	13.21	39.49	65.96	57.53	85.07
62614	?	27	13.06	39.61	67.01	57.39	83.18

Forage quality data from 2015. All data except for RFQ are presented as % of DM

DATE	PAD	DMR	CP	ADF	NDF	TDN	RFQ
20615	1	6	16.17	23.84	46.27	75.37	178.77
20615	1	8	22.06	19.82	42.04	79.95	177.17
20615	1	9	14.63	23.60	46.29	75.65	181.40
20615	1	10	19.63	19.02	40.27	80.87	195.28
20615	1	13	23.13	20.84	42.35	78.79	162.34
20615	3	3	21.23	18.48	34.94	81.48	167.65
20615	3	4	19.93	17.85	34.54	82.20	187.81
20615	3	7	23.71	19.44	38.51	80.40	141.79
20615	3	9	21.88	18.41	36.42	81.57	167.34
20615	3	11	16.25	21.39	39.74	78.17	179.55
20615	4	6	22.25	23.54	45.23	75.72	138.06
20615	4	11	18.96	24.23	46.10	74.93	169.28
20615	4	12	16.91	22.45	44.50	76.96	193.23
20615	4	17	19.11	22.26	43.23	77.18	187.13
20615	4	15	16.72	22.93	45.22	76.42	184.11
20615	9	?	21.17	20.44	39.81	79.25	157.26
20615	9	6	20.40	19.05	36.36	80.83	172.38
20615	9	9	21.74	20.33	39.36	79.37	154.92
20615	9	13	17.10	22.88	42.06	76.46	166.00
20615	9	16	19.54	23.16	44.07	76.15	153.75
20615	10	4	21.18	27.36	51.73	71.36	129.82
20615	10	6	20.51	26.58	51.52	72.24	139.91
20615	10	10	19.04	21.60	43.10	77.93	179.72
20615	10	11	21.95	20.29	41.61	79.42	170.03
20615	10	16	19.73	21.60	42.60	77.92	175.05
20615	11	5	21.46	27.23	50.69	71.50	119.98
20615	11	9	23.93	26.90	50.06	71.89	94.67
20615	11	11	20.67	30.67	56.08	67.58	104.90
20615	11	15	21.35	26.07	48.98	72.84	121.72
20615	11	17	20.81	27.28	48.69	71.45	135.34
20615	14	5	18.15	25.99	50.60	72.92	161.14
20615	14	7	16.16	24.44	49.09	74.69	181.14
20615	14	10	15.37	24.43	45.99	74.70	182.46
20615	14	12	15.06	24.85	47.83	74.22	185.66
20615	14	14	16.48	25.22	47.96	73.80	181.69
20615	15	5	21.76	30.73	56.59	67.51	94.53
20615	15	7	25.44	27.20	50.98	71.55	74.54
20615	15	13	21.78	21.88	42.35	77.61	146.37
20615	15	16	17.94	25.43	46.10	73.57	159.40
20615	15	19	18.53	24.52	45.85	74.60	152.33

30615	1	4	13.95	28.73	54.27	69.80	161.54
30615	1	5	12.93	25.73	50.34	73.22	175.60
30615	1	7	13.43	24.88	47.44	74.19	172.75
30615	1	8	15.51	27.66	53.31	71.01	169.92
30615	1	10	18.80	26.94	51.51	71.84	163.44
30615	4	5	14.58	30.57	55.18	67.70	142.46
30615	4	8	15.96	28.10	52.99	70.51	164.45
30615	4	9	13.33	28.17	52.68	70.43	165.19
30615	4	12	15.16	28.52	52.53	70.04	172.19
30615	4	7	18.04	26.95	51.17	71.82	160.00
30615	10	5	15.95	29.67	53.82	68.72	149.99
30615	10	7	20.67	27.86	52.36	70.79	138.42
30615	10	8	18.12	28.48	52.92	70.09	151.45
30615	10	13	15.25	28.67	54.74	69.86	157.10
30615	10	9	17.83	30.90	54.10	67.33	140.01
30615	14	5	15.22	29.99	54.12	68.36	145.95
30615	14	6	19.34	26.24	49.09	72.64	147.19
30615	14	7	16.95	28.49	53.04	70.07	161.14
30615	14	9	15.60	27.75	52.46	70.91	165.39
30615	14	10	13.27	27.69	52.15	70.98	168.82
32615	2	7	15.88	30.84	58.24	67.39	127.71
32615	2	8	18.67	32.07	57.28	65.99	113.02
32615	2	9	14.98	31.58	58.09	66.55	125.33
32615	2	12	17.17	30.36	55.72	67.94	133.85
32615	2	15	15.90	32.46	58.42	65.55	133.58
32615	3	5	33.22	26.36	37.73	72.50	18.77
32615	3	6	31.31	20.94	40.14	78.68	55.01
32615	3	8	31.53	23.38	39.79	75.90	42.39
32615	3	11	30.80	21.44	40.59	78.12	57.75
32615	3	12	27.66	24.03	43.62	75.16	114.50
32615	8	6	20.66	30.50	55.93	67.78	123.27
32615	8	8	18.09	31.15	58.56	67.03	124.86
32615	8	11	21.84	28.77	53.64	69.75	113.60
32615	8	14	19.65	31.29	56.91	66.87	114.81
32615	8	16	20.61	30.67	56.24	67.58	122.01
32615	9	5	24.94	22.47	41.84	76.94	125.35
32615	9	6	25.87	21.48	39.19	78.06	120.61
32615	9	9	21.55	25.45	43.57	73.54	137.90
32615	9	11	20.99	25.75	45.24	73.19	154.60
32615	9	14	21.72	25.20	44.95	73.82	146.47
32615	11	4	30.76	20.15	40.02	79.58	55.24
32615	11	6	30.01	22.45	42.44	76.96	65.94
32615	11	8	28.33	23.27	43.26	76.02	79.84

32615	11	9	31.08	20.86	41.16	78.78	50.12
32615	11	10	29.10	23.00	42.82	76.33	72.19
32615	12	6	19.38	30.97	58.28	67.25	118.34
32615	12	8	19.72	30.07	56.56	68.27	124.61
32615	12	10	18.96	31.64	59.13	66.47	122.80
32615	12	12	19.64	31.74	57.49	66.37	114.91
32615	12	15	19.60	32.33	57.90	65.69	117.08
32615	13	6	19.35	27.69	51.54	70.98	133.00
32615	13	7	18.74	29.44	53.49	68.98	123.97
32615	13	5	19.03	29.10	54.14	69.37	126.40
32615	13	11	17.56	30.63	57.37	67.63	128.36
32615	13	17	20.01	30.57	55.13	67.70	124.15
32615	15	5	21.53	26.45	44.06	72.40	151.33
32615	15	6	26.36	22.45	42.50	76.95	107.67
32615	15	8	22.42	26.30	47.45	72.57	124.92
32615	15	11	25.55	24.96	45.93	74.09	106.95
32615	15	15	23.42	25.16	46.11	73.86	126.56
42315	2	13	17.67	31.13	56.61	67.06	129.70
42315	2	15	13.76	34.19	60.89	63.57	115.58
42315	2	18	13.73	34.94	62.95	62.72	107.65
42315	2	25	15.08	28.41	48.54	70.17	156.68
42315	2	12	13.53	35.22	62.22	62.39	108.64
42315	3	12	17.24	29.24	48.30	69.22	145.13
42315	3	13	13.10	27.66	45.09	71.02	170.90
42315	3	14	17.32	32.65	58.77	65.32	114.83
42315	3	17	20.57	26.12	47.34	72.78	142.83
42315	3	24	22.26	25.88	46.43	73.05	135.10
42315	8	10	16.32	32.84	59.12	65.11	111.81
42315	8	12	15.72	33.27	59.27	64.63	112.74
42315	8	17	15.62	33.01	59.05	64.91	114.45
42315	8	20	16.06	35.22	60.62	62.39	103.07
42315	8	29	15.67	35.33	61.02	62.27	110.27
42315	9	7	12.30	30.25	50.48	68.06	150.09
42315	9	22	13.19	29.96	51.05	68.39	153.50
42315	9	30	12.69	30.87	52.77	67.35	149.96
42315	9	39	11.52	34.71	58.63	62.98	128.89
42315	9	?	12.48	28.35	47.52	70.23	169.42
42315	11	7	17.22	27.50	47.40	71.20	149.42
42315	11	9	18.84	25.28	45.33	73.73	158.74
42315	11	12	20.87	24.18	45.08	74.99	149.49
42315	11	18	18.28	28.21	48.82	70.38	145.20
42315	11	35	18.69	29.62	50.99	68.79	136.74
42315	12	6	18.80	30.42	55.42	67.87	116.04

42315	12	8	15.13	32.73	60.58	65.24	119.16
42315	12	16	16.63	34.41	59.28	63.32	112.42
42315	12	18	16.51	34.38	59.19	63.35	110.81
42315	12	22	16.14	36.25	61.17	61.22	105.94
42315	13	?	19.11	32.94	56.31	65.00	106.15
42315	13	7	13.91	32.55	60.07	65.44	123.28
42315	13	15	15.98	31.60	60.42	66.52	123.57
42315	13	17	13.77	34.79	62.83	62.89	109.46
42315	13	22	13.35	37.19	64.33	60.15	102.23
42315	15	18	17.13	29.26	50.00	69.19	146.38
42315	15	4	15.67	30.19	48.27	68.14	144.74
42315	15	13	16.03	29.68	51.12	68.71	147.01
42315	15	15	12.50	30.90	51.42	67.32	150.25
42315	15	24	15.49	31.01	53.08	67.19	144.14
52115	2	6	15.24	35.75	62.30	61.80	104.97
52115	2	10	15.54	34.62	61.96	63.08	102.37
52115	2	12	11.98	37.34	65.52	59.98	97.92
52115	2	15	13.37	39.42	65.69	57.61	91.21
52115	2	19	11.95	37.96	65.65	59.27	95.61
52115	3	9	10.21	35.18	60.54	62.44	120.01
52115	3	10	13.00	35.97	59.52	61.55	110.32
52115	3	12	17.97	35.52	57.61	62.05	106.69
52115	3	24	10.99	37.53	63.79	59.76	107.36
52115	3	39	9.46	37.79	63.70	59.47	105.74
52115	8	6	14.53	36.79	63.21	60.61	95.84
52115	8	10	17.36	34.00	59.93	63.79	100.06
52115	8	13	11.93	39.95	66.02	57.00	91.62
52115	8	14	12.30	40.51	67.69	56.37	88.51
52115	8	15	14.35	34.35	57.42	63.39	122.14
52115	8	18	12.34	39.13	65.15	57.94	92.78
52115	9	7	10.52	35.78	61.02	61.76	112.90
52115	9	15	10.55	39.12	64.24	57.94	101.51
52115	9	16	9.35	39.12	63.63	57.95	102.91
52115	9	27	9.03	39.76	65.12	57.22	97.50
52115	9	28	12.39	37.24	62.97	60.09	110.66
52115	11	8	15.50	36.02	59.13	61.49	116.56
52115	11	12	11.45	36.11	61.59	61.38	112.69
52115	11	15	11.35	36.94	61.02	60.43	112.17
52115	11	29	10.91	36.95	62.72	60.43	110.70
52115	11	32	10.52	36.89	63.68	60.49	113.91
52115	12	7	16.81	33.83	60.13	63.98	100.14
52115	12	9	16.11	36.13	61.66	61.36	96.35
52115	12	16	14.21	36.95	63.51	60.43	98.49

52115	12	18	14.16	39.32	65.71	57.72	90.50
52115	12	18	14.24	36.75	63.78	60.65	98.66
52115	13	7	11.10	39.47	68.29	57.55	94.14
52115	13	10	12.08	38.14	66.14	59.06	95.03
52115	13	14	10.54	40.56	69.60	56.31	87.77
52115	13	17	10.30	40.66	69.52	56.19	89.47
52115	13	21	9.92	41.66	70.41	55.05	83.35
52115	15	12	11.15	37.56	61.68	59.73	109.12
52115	15	3	20.41	28.92	51.44	69.57	118.98
52115	15	11	12.71	36.39	60.96	61.06	119.01
52115	15	15	11.79	36.35	58.30	61.11	112.19
52115	15	29	14.13	39.69	66.17	57.29	88.14
61815	2	4	14.10	34.45	62.60	63.28	101.92
61815	2	4	12.08	37.39	66.56	59.93	92.98
61815	2	5	12.52	37.42	65.92	59.89	94.12
61815	2	9	10.60	40.60	70.74	56.26	80.88
61815	2	11	12.74	38.11	66.27	59.10	91.42
61815	8	6	13.64	36.35	63.79	61.11	92.98
61815	8	8	14.05	36.62	63.48	60.80	91.78
61815	8	8	13.18	36.62	64.71	60.80	94.81
61815	8	9	12.36	38.18	66.05	59.02	89.85
61815	8	16	15.81	34.25	61.29	63.51	101.46
61815	12	4	12.37	37.06	65.58	60.30	95.15
61815	12	6	16.35	34.00	61.20	63.79	98.01
61815	12	11	11.33	38.26	68.52	58.93	91.08
61815	12	12	14.09	36.24	61.87	61.24	96.68
61815	12	13	11.27	38.47	69.03	58.69	90.28
61815	13	6	12.50	37.12	65.49	60.23	95.53
61815	13	9	9.83	41.05	70.58	55.75	81.78
61815	13	10	9.62	41.64	71.48	55.07	79.28
61815	13	12	12.86	37.22	64.63	60.12	95.87
61815	13	17	10.02	41.56	71.96	55.17	78.96

Disc meter readings from RG treatments during the 2014 grazing season.

3/28/2014	3/28/2014	4/24/2014	4/24/2014	5/22/2014	5/22/2014	6/5/2014	6/5/2014
P3	P11	P3	P11	P3	P11	P3	P11
19	14	13	22	9	7	5	5
19	15	32	26	15	10	6	6
19	16	19	24	8	11	5	11
20	21	28	26	6	8	4	7
20	15	26	28	11	10	8	10
19	17	19	22	10	10	8	6
19	16	14	29	16	13	6	12
21	18	22	32	7	14	5	7
21	19	21	22	9	13	5	5
17	16	18	32	10	12	4	6
19	16	16	19	9	11	5	6
18	17	19	24	10	10	8	7
17	17	17	27	8	11	4	10
14	17	30	27	10	13	6	7
20	18	32	31	11	7	5	7
19	19	24	30	8	12	4	4
20	18	16	22	9	13	14	10
19	18	13	32	8	12	5	6
19	20	22	27	12	10	6	7
17	19	26	29	12	13	6	8
17	18	26	25	11	11	7	9
17	19	21	25	10	10	5	5
17	19	19	33	9	11	8	6
16	17	26	27	9	12	14	4
17	21	22	27	7	11	6	6
19	17	17	23	11	10	5	6
17	18	24	27	8	19	5	5
17	16	30	19	11	13	6	10
17	16	18	24	9	8	8	5
18	14	23	18	8	10	7	6

Disc meter readings from the RG treatments during the 2015 grazing season.

2/6/2015	2/6/2015	3/26/2015	3/26/2015	4/23/2015	4/23/2015	5/21/2015	5/21/2015
P3	P11	P3	P11	P3	P11	P3	P11
11	10	7	4	14	17	27	15
12	16	8	4	19	25	20	20
5	10	8	9	19	23	16	15
12	15	9	7	10	6	17	12
16	16	7	10	23	13	13	18
13	18	12	13	21	13	10	18
15	17	17	9	20	13	6	13
16	15	10	10	14	12	11	6
12	13	9	8	8	19	15	11
13	11	8	9	14	27	14	19
17	14	9	10	13	23	8	42
13	14	11	5	32	23	15	30
16	15	4	8	19	18	12	13
12	17	10	9	27	26	19	24
9	17	7	13	16	5	12	14
12	18	11	6	15	22	21	31
14	21	11	10	22	22	12	12
5	19	11	9	14	24	20	6
16	17	8	10	21	22	12	9
11	16	6	11	21	22	14	11
9	17	5	11	16	23	9	14
16	14	5	8	19	26	9	14
11	14	11	10	25	22	7	10
9	16	7	11	24	25	12	10
8	15	9	8	22	6	8	8
9	17	18	12	21	14	7	13
14	14	9	8	29	31	4	10
14	14	7	9	16	26	15	19
17	8	13	5	15	8	8	16
11	19	6	8	14	7	4	17

Disc meter readings from the RG+CC treatments during the 2014 grazing season

3/28/2014	3/28/2014	4/24/2014	4/24/2014	5/22/2014	5/22/2014	6/5/2014	6/5/2014
P9	P15	P9	P15	P9	P15	P9	P15
18	14	20	11	8	8	7	7
16	17	19	17	12	10	7	6
18	16	15	17	12	9	8	7
17	14	29	19	11	10	4	16
18	14	18	20	12	10	3	9
16	14	15	19	10	13	5	5
17	17	21	16	11	12	5	6
17	17	23	18	11	10	4	5
18	15	23	16	9	7	6	8
19	17	22	19	13	14	7	7
17	16	31	20	12	10	7	9
18	15	25	20	11	11	6	5
16	17	23	16	10	10	6	4
15	17	20	22	8	10	4	5
16	17	17	21	12	6	7	7
17	16	20	19	9	7	6	7
15	18	25	21	11	10	3	8
15	15	17	22	9	8	7	6
16	16	31	22	12	10	8	16
15	16	23	16	11	11	6	7
16	15	21	23	10	10	4	5
16	22	22	19	9	10	7	9
14	20	15	23	10	11	5	7
13	16	20	17	12	10	6	5
13	13	19	17	11	11	5	9
17	14	20	20	12	9	7	6
17	16	30	13	13	14	4	7
14	18	24	18	11	13	6	5
16	14	17	16	12	12	4	5
13	16	19	23	13	11	6	4

Disc meter readings from the RG+CC treatments during the 2015 grazing season

2/6/2015	2/6/2015	3/26/2015	3/26/2015	4/23/2015	4/23/2015	5/21/2015	5/21/2015
P9	P15	P9	P15	P9	P15	P9	P15
14	16	12	7	17	8	15	3
10	17	8	5	20	14	19	6
8	12	7	9	19	18	5	12
14	17	11	9	15	10	13	12
14	14	6	7	16	6	7	10
12	18	7	6	18	8	11	5
12	21	10	8	18	6	6	5
11	19	11	4	16	10	8	5
11	24	11	7	12	7	7	3
13	19	8	7	14	11	9	5
13	19	10	7	16	7	12	2
14	18	14	8	13	10	6	2
12	14	8	8	12	8	6	4
12	13	10	6	16	5	7	3
15	11	10	9	18	8	7	6
14	15	14	9	23	4	5	3
12	17	7	9	27	7	6	4
14	12	14	9	13	14	13	4
16	15	16	9	16	6	5	5
16	15	10	6	17	11	7	5
13	14	9	7	15	6	8	4
9	14	8	9	11	4	15	4
16	13	9	9	12	14	10	5
15	9	11	8	13	12	11	6
16	15	7	7	16	4	6	4
14	14	12	7	15	9	10	7
14	15	8	6	18	16	10	5
19	16	9	7	18	9	12	6
15	19	14	8	22	7	5	8
20	14	7	8	14	8	9	11

Disc meter readings from the RG+R treatments during the 2014 grazing season

3/14/2014	3/14/2014	4/10/2014	4/10/2014	5/8/2014	5/8/2014	5/22/2014	5/22/2014
P1	P10	P1	P10	P1	P10	P1	P10
18	24	29	12	25	7	11	12
23	29	28	29	21	15	5	17
18	25	28	38	20	9	4	17
19	29	28	15	14	10	6	18
23	27	26	30	16	8	5	18
18	22	25	47	21	8	6	18
19	28	31	32	18	17	5	16
19	21	26	27	25	15	3	25
19	23	24	12	16	11	5	23
21	21	25	50	23	9	5	24
20	22	24	27	20	12	5	26
18	22	23	30	22	14	12	17
21	23	27	36	10	15	7	17
21	22	25	18	23	23	13	12
16	18	31	15	15	13	6	17
16	20	29	21	14	18	12	18
16	17	28	40	25	12	6	18
18	24	25	18	19	16	11	17
13	19	24	17	15	13	14	18
17	19	24	27	19	11	7	25
22	19	30	46	14	15	10	23
16	22	30	41	21	15	6	16
17	16	37	32	25	10	11	26
16	21	37	18	18	9	20	17
18	22	38	27	10	11	17	18
17	20	45	40	21	8	6	24
18	22	34	32	22	15	13	18
19	21	32	21	19	12	11	18
18	16	34	37	21	14	10	18
18	18	35	25	16	13	10	17

Disc meter readings from the RG+R treatments during the 2015 grazing season

2/6/2015	2/6/2015	3/6/2015	3/6/2015
P1	P10	P1	P10
10	11	6	6
3	11	9	7
11	16	9	6
6	10	11	6
9	15	10	9
10	11	8	11
12	11	9	12
11	8	9	8
16	10	9	15
15	16	13	8
14	11	8	12
7	8	11	12
15	4	13	8
13	14	9	9
10	10	7	7
9	13	11	11
8	9	12	9
13	15	10	8
12	7	11	9
12	17	7	6
11	16	8	9
13	12	6	11
14	5	11	11
10	12	6	12
10	10	14	10
8	17	9	10
10	14	7	6
11	16	9	12
17	14	9	6
10	15	7	4

Disc meter readings from the RG+R+CC treatments during the 2015 grazing season.

3/14/2014	3/14/2014	4/10/2014	4/10/2014	5/8/2014	5/8/2014	5/22/2014	5/22/2014
P4	P14	P4	P14	P4	P14	P4	P14
17	20	41	16	24	17	17	10
19	20	36	19	19	10	17	8
19	22	29	21	24	14	20	5
18	23	27	31	21	13	20	5
18	20	27	24	19	12	23	4
17	19	32	15	19	11	26	6
16	19	30	16	28	14	26	11
17	17	29	22	25	20	26	17
13	24	31	26	15	19	20	11
18	18	22	25	23	12	20	13
16	21	33	30	25	13	19	6
15	24	33	14	25	13	21	7
14	18	29	27	26	14	19	11
18	20	29	30	24	11	19	9
18	19	33	36	24	11	17	7
17	26	35	35	26	16	20	10
19	22	36	19	25	15	20	11
14	22	24	35	23	11	21	10
15	18	24	27	19	13	17	7
16	25	25	15	25	12	19	12
16	23	27	14	23	14	26	10
16	20	26	32	21	14	20	8
17	22	34	19	24	13	20	11
17	19	35	34	19	10	19	11
20	14	29	26	15	9	20	10
22	23	31	24	23	14	23	12
21	19	36	21	19	6	20	10
19	25	33	15	23	10	26	10
16	19	32	33	22	14	26	7
16	23	32	22	21	12	19	4

Disc meter readings from the RG+R+CC treatments during the 2015 grazing season

2/6/2015	2/6/2015	3/6/2015	3/6/2015
P4	P14	P4	P14
9	11	8	9
8	14	10	10
15	17	11	14
11	9	12	6
13	11	10	10
15	15	11	3
13	14	11	10
12	11	12	12
7	19	6	12
13	14	4	11
7	17	8	10
14	17	7	10
11	14	7	7
12	16	1	10
10	11	6	10
14	12	16	9
14	16	14	10
14	15	17	10
10	8	9	13
6	13	12	11
11	11	13	9
12	11	8	13
13	19	10	12
14	12	10	13
10	17	13	16
13	16	13	13
11	13	11	8
13	13	10	10
15	14	6	13
13	8	8	18

Disc meter readings from the TF treatments during the 2014 grazing season.

4/10/2014	4/10/2014	5/8/2014	5/8/2014	6/5/2014	6/5/2014	6/25/2014	6/25/2014
P8	P12	P8	P12	P8	P12	P8	P12
14	14	11	18	10	14	15	9
16	15	20	10	11	10	10	10
16	14	21	12	9	14	9	12
20	16	20	24	13	13	11	13
19	21	19	17	11	12	11	13
19	14	19	20	9	10	10	14
20	15	19	29	11	20	12	13
18	16	19	16	14	11	13	9
17	15	20	20	13	18	10	15
19	18	20	20	9	18	12	14
20	14	21	17	12	13	12	13
18	21	22	19	11	13	11	10
18	17	19	20	13	12	10	13
18	11	22	23	14	23	12	13
18	12	21	26	1	13	15	12
17	19	20	26	12	15	9	15
16	21	22	17	11	12	12	14
17	14	21	18	8	16	13	13
20	15	19	18	12	13	12	13
19	14	20	15	12	10	10	13
17	15	21	22	10	12	12	13
17	18	11	21	13	15	12	9
21	17	20	17	15	11	10	15
22	15	22	16	16	16	11	13
25	19	21	21	15	13	11	10
21	16	19	23	13	13	12	13
21	19	22	16	13	14	13	14
19	20	19	18	14	14	10	13
23	18	22	16	15	17	9	13
21	23	20	21	15	17	15	9

Disc meter readings from the TF treatments during the 2015 grazing season.

3/26/2015	3/26/2015	4/23/2015	4/23/2015	5/21/2015	5/21/2015	6/18/2015	6/18/2015
P8	P12	P8	P12	P8	P12	P8	P12
17	14	9	14	16	12	11	16
13	10	15	14	14	7	11	15
13	12	18	15	11	13	12	14
13	12	15	15	10	9	12	13
10	11	13	13	12	10	12	11
10	17	13	12	13	11	13	8
10	14	11	11	14	13	13	11
11	9	12	18	12	7	14	11
13	11	7	7	15	9	16	20
11	14	8	15	11	11	7	17
12	10	15	16	16	10	10	15
12	18	14	14	13	10	10	7
13	7	18	14	14	14	11	9
16	13	15	9	13	18	12	10
14	15	12	9	13	10	12	7
16	18	16	13	13	13	8	9
14	12	12	22	12	13	8	9
12	11	13	8	15	11	11	10
12	11	14	10	11	22	12	11
13	12	17	11	13	12	12	11
11	11	20	12	15	12	7	11
11	12	19	13	13	21	8	12
11	14	26	15	12	12	10	8
12	8	18	14	12	10	12	10
16	12	10	12	14	14	14	11
15	15	15	17	13	9	14	12
14	16	16	17	16	18	9	9
12	13	13	16	10	19	14	11
11	8	17	11	19	10	15	9
10	9	18	12	11	13	9	7

Disc meter readings from the TF+WC treatments during the 2014 grazing season.

4/10/2014	4/10/2014	5/8/2014	5/8/2014	6/5/2014	6/5/2014	6/25/2014	6/26/2014
P2	P13	P2	P13	P2	P13	P2	P13
17	14	21	17	17	15	11	10
21	17	14	16	10	12	13	7
17	15	22	11	8	14	12	8
14	12	23	13	10	13	9	10
14	14	21	22	9	17	9	10
15	16	21	18	9	18	15	8
13	14	20	21	13	19	11	10
14	20	14	17	10	18	10	10
12	15	19	18	14	12	9	8
11	19	17	18	15	21	12	9
14	17	22	18	14	20	11	10
19	18	16	23	15	14	8	7
14	19	17	19	9	10	13	9
13	15	15	19	11	11	11	10
20	15	21	15	9	15	15	8
15	19	16	15	17	13	11	10
15	18	15	15	16	14	9	9
14	13	20	13	9	11	9	8
15	10	22	16	15	15	13	8
15	19	23	14	12	16	8	10
14	12	15	17	10	16	9	10
15	12	19	21	13	17	10	9
15	11	17	17	10	13	9	8
18	11	21	13	14	17	11	10
16	12	21	17	14	19	15	7
17	12	15	16	12	16	11	10
17	12	16	16	15	11	10	8
16	15	17	10	11	13	11	8
16	14	16	12	10	15	15	8
18	12	16	9	12	19	13	10

Disc meter readings from the TF+WC treatments during the 2015 grazing season.

3/26/2015	3/26/2015	4/23/2015	4/23/2015	5/21/2015	5/21/2015	6/18/2015	6/18/2015
P2	P13	P2	P13	P2	P13	P2	P13
9	6	13	16	11	10	5	9
7	14	13	19	10	8	9	9
11	9	13	10	8	17	8	8
11	10	13	11	15	17	9	10
15	15	13	12	11	10	9	13
9	10	13	10	12	12	9	12
10	11	17	19	11	15	9	13
11	14	17	14	10	11	10	9
12	12	17	19	10	12	10	6
12	12	16	20	12	11	11	5
12	12	16	19	10	12	11	4
12	6	11	19	6	25	10	5
20	7	18	16	17	23	9	7
7	8	15	14	9	12	13	5
8	11	15	13	11	17	8	11
9	13	15	16	10	11	9	10
10	10	16	17	8	12	8	8
10	8	12	16	16	14	10	7
10	13	12	10	16	17	9	9
12	10	18	11	16	14	10	10
12	11	19	12	10	20	12	10
10	10	20	16	14	15	8	12
10	13	17	15	16	22	9	15
8	8	15	14	13	16	10	14
8	11	12	14	7	38	9	14
9	11	11	16	10	20	11	17
10	13	6	13	8	17	8	16
8	8	9	8	12	11	6	10
9	12	10	5	8	14	7	8
13	12	18	17	13	12	11	7

Available forage DM calibration samples

Date	Paddock	DMR	TARE (g)	WET (g)	DRY (g)
3/14/2014	1	15	46.24	224	92
3/14/2014	1	26	49.8	332	107.4
3/14/2014	1	18	48.5	260	95.4
3/14/2014	1	12	49.4	212	86.9
3/14/2014	1	22	35.4	282	91
3/14/2014	10	27	50.1	416	124.3
3/14/2014	10	16	52.3	268	102.3
3/14/2014	10	12	40.5	202	84.7
3/14/2014	10	27	35.4	706	150.8
3/14/2014	10	19	49.9	282	102.3
3/14/2014	4	11	36.2	250	87.9
3/14/2014	4	23	50.2	360	125.2
3/14/2014	4	8	33.7	120	58.5
3/14/2014	4	19	52.6	266	105.1
3/14/2014	4	16	36.1	220	90.2
3/14/2014	14	24	52.5	332	116.8
3/14/2014	14	16	36.1	178	78.3
3/14/2014	14	13	37.9	180	80.8
3/14/2014	14	31	51.9	416	132.9
3/14/2014	14	11	55.1	148	83.7
4/10/2014	1	54	34.6	532.3	139.6
4/10/2014	1	46	49.4	724.7	186.4
4/10/2014	1	32	51.3	414.3	126.1
4/10/2014	1	34	49.7	380.1	118.9
4/10/2014	1	27	35.4	370.4	102.4
4/10/2014	10	30	49.1	398.9	110.3
4/10/2014	10	37	48.2	698.1	186.3
4/10/2014	10	29	43.8	538.1	135.2
4/10/2014	10	19	50.1	278.4	94
4/10/2014	10	23	46	266.4	91.7
4/10/2014	4	23	36	437.5	118.3
4/10/2014	4	27	35.9	391.3	108.9
4/10/2014	4	58	52.1	601.5	168.1
4/10/2014	4	34	50.2	443.2	127.9
4/10/2014	4	40	36.2	460.1	126
4/10/2014	14	13	34.5	199.2	71.2
4/10/2014	14	25	35.6	214.2	83.4
4/10/2014	14	36	45.6	364.1	118.6
4/10/2014	14	18	46.7	242.4	92.2
4/10/2014	14	39	46	352.6	124.2
5/8/2014	1	11	38.4	109.8	69.7

5/8/2014	1	58	49.3	608.1	307.14
5/8/2014	1	27	38.4	367.7	172.6
5/8/2014	1	31	48.2	312.1	134.39
5/8/2014	1	17	50.8	203.1	104.04
5/8/2014	10	53	51.6	471.1	212.18
5/8/2014	10	38	48.3	462.8	205.52
5/8/2014	10	18	33.3	246.4	135.6
5/8/2014	10	13	48.6	196.8	116.57
5/8/2014	10	26	40.6	248.7	125.45
5/8/2014	4	14	49.8	168.1	102
5/8/2014	4	46	50	520.7	246.57
5/8/2014	4	27	48	309.7	154.18
5/8/2014	4	33	46.1	593.3	269.3
5/8/2014	4	25	49.2	393.5	190.4
5/8/2014	14	10	48.8	124.6	87.82
5/8/2014	14	43	49.2	412.6	196.8
5/8/2014	14	37	46.7	427.2	202.13
5/8/2014	14	16	48.8	203.4	108.28
5/8/2014	14	14	49.8	262.6	133.76
5/22/2014	1	30	50	252.4	140.56
5/22/2014	1	15	48.2	176.1	120.41
5/22/2014	1	13	49	142.4	108.58
5/22/2014	1	35	49.7	336.9	182.34
5/22/2014	1	20	51.3	192.3	143.5
5/22/2014	10	43	36.4	341.3	177.5
5/22/2014	10	28	33.49	235.2	140.06
5/22/2014	10	38	50.1	385.9	213.38
5/22/2014	10	14	49.5	161.5	117.03
5/22/2014	10	12	46	130.6	93.23
5/22/2014	4	38	49.4	370.4	196.2
5/22/2014	4	20	45.9	198.1	129.26
5/22/2014	4	55	35.4	365.5	189.79
5/22/2014	4	46	46.8	360.1	205.64
5/22/2014	4	24	48.6	209.8	144.51
5/22/2014	14	17	32.9	207.8	129.75
5/22/2014	14	31	36.1	214.9	129.97
5/22/2014	14	47	49.1	400.2	217.73
5/22/2014	14	27	46.9	291.8	161.28
5/22/2014	14	35	37.5	220.4	123.95
3/28/2014	3	13	49.4	157.9	80.3
3/28/2014	3	18	38.3	338.8	106.6
3/28/2014	3	15	48.8	214.6	88
3/28/2014	3	10	47.5	200.6	84.7

3/28/2014	3	8	37.5	97.8	51.75
3/28/2014	11	11.5	35	136.5	60.8
3/28/2014	11	14	37.6	176.1	65.5
3/28/2014	11	22	49.36	340	106.54
3/28/2014	11	17.5	38.9	196.7	69.54
3/28/2014	11	7.5	39.3	121.1	60.78
3/28/2014	9	7	51	107	67
3/28/2014	9	11	50.06	172.9	84.75
3/28/2014	9	16	35.1	452.8	102.41
3/28/2014	9	14	50.64	187.7	86.2
3/28/2014	9	22	50.13	250	87.48
3/28/2014	15	15	49.72	165	87.4
3/28/2014	15	6	42.6	106.6	61.3
3/28/2014	15	10	49.29	151.2	84.95
3/28/2014	15	7.5	50.44	218	88.1
3/28/2014	15	13	50.43	172.5	93.85
4/24/2014	3	20	48.9	310	113.4
4/24/2014	3	12	52.4	307	114.3
4/24/2014	3	14	50.4	181.4	86.5
4/24/2014	3	30	52.8	593.4	146.9
4/24/2014	3	7	36.7	232	75.4
4/24/2014	11	10	44.5	169.2	69.6
4/24/2014	11	20	49.1	405.4	118.3
4/24/2014	11	11	49.8	259.9	92.8
4/24/2014	11	18	51	389	124.9
4/24/2014	11	13	49.7	320.5	106.3
4/24/2014	9	19	50.2	602.4	145.6
4/24/2014	9	22	49	394.7	116
4/24/2014	9	11	32.1	151.8	63.2
4/24/2014	9	9	50	318.9	104.4
4/24/2014	9	14	49.6	551.5	132.2
4/24/2014	15	11	50.6	140	74.1
4/24/2014	15	8	49.5	181.3	74.9
4/24/2014	15	14	48.9	147.8	74.8
4/24/2014	15	23	45.2	309.8	112.8
4/24/2014	15	20	49.5	173	91.1
5/22/2014	3	23	47.7	358.5	162.4
5/22/2014	3	11	49.1	202.7	100.04
5/22/2014	3	18	43.8	428	156.54
5/22/2014	3	15	47.5	249.5	123.43
5/22/2014	3	8	34.5	168.1	81.04
5/22/2014	11	17	46	254.1	112.05
5/22/2014	11	7	35.6	198.7	93.85

5/22/2014	11	6	36.2	95.9	54.05
5/22/2014	11	14	35.9	255.5	102.34
5/22/2014	11	15	50.2	303.4	125.66
5/22/2014	9	22	36	380.9	135.6
5/22/2014	9	14	48.7	347.8	128.55
5/22/2014	9	18	49	502.7	184.5
5/22/2014	9	6	49.7	133.3	79.67
5/22/2014	9	11	51.3	200.4	94.69
5/22/2014	15	11	52.1	180.4	91.9
5/22/2014	15	14	45.6	359.9	121.56
5/22/2014	15	7	54.9	192.3	98.61
5/22/2014	15	9	48.2	114.5	69.76
5/22/2014	15	19	46.7	211.1	93.68
6/5/2014	3	5	40.6	155	84.39
6/5/2014	3	6	39.4	137	79.15
6/5/2014	3	10	52.3	212	118.47
6/5/2014	3	9	49.6	176	104
6/5/2014	3	6	46.4	104	70.9
6/5/2014	11	7	38.1	135	78.48
6/5/2014	11	9	53.5	196	104.96
6/5/2014	11	4	49.2	86	66.95
6/5/2014	11	6	52.9	184	96.45
6/5/2014	11	5	50.1	169	91.3
6/5/2014	9	6	49.08	123	76.2
6/5/2014	9	7	48.6	192	105.54
6/5/2014	9	3	51.5	96	75.01
6/5/2014	9	5	48.7	118	78.8
6/5/2014	9	6	50.9	162	98.13
6/5/2014	15	5	49.7	108	72.5
6/5/2014	15	3	49.1	91	64.61
6/5/2014	15	5	50	111	73.36
6/5/2014	15	7	47.4	185	95.75
6/5/2014	15	7	50.2	97	68.87
4/10/2014	2	17	46.8	200.4	95.1
4/10/2014	2	22	50	298.7	127.3
4/10/2014	2	9	47.5	82.1	58.9
4/10/2014	2	17	47.7	148.5	84.5
4/10/2014	2	19	48.9	305.5	124
4/10/2014	13	8	33.49	61.9	42.1
4/10/2014	13	21	36.1	309.3	103.8
4/10/2014	13	14	36.4	135.6	63.6
4/10/2014	13	16	54.9	168.7	90.2
4/10/2014	13	19	48.2	195.8	89.3

4/10/2014	8	11	48.7	184.3	75.9
4/10/2014	8	7	49	117.6	67.4
4/10/2014	8	24	49.8	350.4	115.7
4/10/2014	8	22	45.9	402.1	128.7
4/10/2014	8	16	48.7	322	112.9
4/10/2014	12	23	46.9	230.8	91.2
4/10/2014	12	11	32.5	122.1	55.1
4/10/2014	12	16	32.9	171	68.3
4/10/2014	12	21	49.1	283.4	99.8
4/10/2014	12	12	34.6	128.4	59
5/8/2014	2	15	45.8	178.5	93.32
5/8/2014	2	8	40.2	86.2	57.26
5/8/2014	2	23	46.6	178.8	91.88
5/8/2014	2	18	45.2	169	87.82
5/8/2014	2	12	49.4	145.1	86.93
5/8/2014	13	23	47.3	256.2	104.82
5/8/2014	13	28	49.9	357.8	138.7
5/8/2014	13	22	50.7	457.1	160.3
5/8/2014	13	9	49.1	144	79.08
5/8/2014	13	14	47.6	227.9	99.82
5/8/2014	8	25	34.8	278.8	109.57
5/8/2014	8	32	49.9	331.9	129.53
5/8/2014	8	8	36.4	120.3	62.75
5/8/2014	8	19	50.8	207.6	98.67
5/8/2014	8	17	51.4	202.4	100.26
5/8/2014	12	9	48.8	194.9	92.52
5/8/2014	12	18	44.4	262.9	98.91
5/8/2014	12	32	59.6	344.6	140.14
5/8/2014	12	13	50	199.6	93.52
5/8/2014	12	25	47.3	261.3	104.64
6/5/2014	2	12	46.04	143	79.41
6/5/2014	2	11	48.27	135	81
6/5/2014	2	10	50.7	131	76.5
6/5/2014	2	10	42.95	116	68.21
6/5/2014	2	15	50.73	204	104.9
6/5/2014	13	10	33.5	149	73.1
6/5/2014	13	19	45.4	323	134
6/5/2014	13	7	44.9	136	72.35
6/5/2014	13	5	47.7	114	72.6
6/5/2014	13	12	34.7	178	81.31
6/5/2014	8	9	58.7	170	76.56
6/5/2014	8	13	40	302	166.6
6/5/2014	8	8	53.2	103	69.51

6/5/2014	8	8	50	201	96.93
6/5/2014	8	16	50.7	256	116.7
6/5/2014	12	15	34.9	226	79.7
6/5/2014	12	8	46.2	97	60.84
6/5/2014	12	16	35.4	211	91.69
6/5/2014	12	5	51.8	126	76.45
6/5/2014	12	11	48.7	189	86.4
6/26/2014	2	17	38.7	284	93.3
6/26/2014	2	14	46.04	339.7	93.4
6/26/2014	2	6	42.95	128.8	59.4
6/26/2014	2	10	52.5	258.3	91.3
6/26/2014	2	15	50.73	425.3	124.9
6/26/2014	13	15	49.1	225.4	88.6
6/26/2014	13	13	37.4	264.3	89.3
6/26/2014	13	7	49.2	187	73.6
6/26/2014	13	27	42.4	597.7	148.5
6/26/2014	13	10	52.4	268.5	88.1
6/26/2014	8	10	50	276.7	101.7
6/26/2014	8	16	49.3	326.8	113.2
6/26/2014	8	19	34.5	459.1	111.3
6/26/2014	8	8	48.3	275.1	92.8
6/26/2014	8	14	51.5	473.1	138.8
6/26/2014	12	20	53.5	477.4	148.2
6/26/2014	12	10	50.7	193.4	79.8
6/26/2014	12	12	57.8	461.5	144.4
6/26/2014	12	7	49.2	174.1	68.9
6/26/2014	12	16	36.5	531	131.5
2/6/2015	1	6	52.4	153	83.1
2/6/2015	1	8	36.5	175	76.7
2/6/2015	1	10	34.2	267	99.1
2/6/2015	1	9	40.5	137	72
2/6/2015	1	13	67.8	470	167.9
2/6/2015	3	11	44	287	106.7
2/6/2015	3	7	37.4	189	79.6
2/6/2015	3	4	41.3	105	58.7
2/6/2015	3	3	40.2	112	61.4
2/6/2015	3	9	49.5	374	104.9
2/6/2015	4	15	40.5	261	108.2
2/6/2015	4	6	40.3	89	55.7
2/6/2015	4	11	39.8	237	106.7
2/6/2015	4	13	39.8	281	110.2
2/6/2015	4	14	38.3	294	111.1
2/6/2015	9	9	36	193	81.4

2/6/2015	9	16	51.2	300	113.7
2/6/2015	9	13	43.5	187	86
2/6/2015	9	6	43.6	110	63.8
2/6/2015	9		40.7	325	112.5
2/6/2015	10	6	49	187	94.3
2/6/2015	10	4	47.7	132	78.2
2/6/2015	10	11	33.5	282	94.2
2/6/2015	10	10	44.9	197	84.6
2/6/2015	10	16	50	234	118.5
2/6/2015	11	11	43	183	104.4
2/6/2015	11	5	44.5	259	128.6
2/6/2015	11	15	49	359	152.3
2/6/2015	11	9	50	187	100.7
2/6/2015	11	17	46	442	159
2/6/2015	14	5	47.4	196	103.6
2/6/2015	14	7	34.2	228	99.4
2/6/2015	14	10	49.1	178	90.7
2/6/2015	14	14	45.4	262	112.5
2/6/2015	14	12	49.7	192	95.8
2/6/2015	15	13	33.4	321	115.3
2/6/2015	15	5	41.1	134	89.7
2/6/2015	15	16	49.4	239	110.4
2/6/2015	15	19	51.4	251	113.9
2/6/2015	15	7	38.2	104	75.4
3/6/2015	1	7	41.3	115	60.5
3/6/2015	1	4	49.7	159	72.2
3/6/2015	1	8	67.8	242	104.7
3/6/2015	1	15	38.3	150	66.3
3/6/2015	1	10	45.4	280	91.5
3/6/2015	4	7	49	187	81.9
3/6/2015	4	5	49.1	123	63.7
3/6/2015	4	9	50	189	80.5
3/6/2015	4	8	39.8	187	70.6
3/6/2015	4	12	51.2	235	90
3/6/2015	14	7	34.2	156	58.3
3/6/2015	14	9	43	213	74.5
3/6/2015	14	5	49.4	137	67.3
3/6/2015	14	6	43.5	94	52.9
3/6/2015	14	10	36.5	226	75.6
3/6/2015	10	5	44.9	151	66.6
3/6/2015	10	7	40.2	264	79
3/6/2015	10	7	46	178	69.9
3/6/2015	10	13	38.2	260	85.7

3/6/2015	10	8	50	212	80
3/26/2015	3	11	35.65	270	60.1
3/26/2015	3	6	51.2	210	70
3/26/2015	3	5	48.2	130	60
3/26/2015	3	8	49.5	210	68
3/26/2015	3	12	44.8	330	85.4
3/26/2015	13	7	54.4	130	64.5
3/26/2015	13	17	48.7	300	103.5
3/26/2015	13	8	36	90	49.3
3/26/2015	13	11	38	150	66.5
3/26/2015	13	6	45	90	55.3
3/26/2015	12	10	48.3	190	88.9
3/26/2015	12	12	52.7	290	108.4
3/26/2015	12	6	47.2	100	62
3/26/2015	12	8	48.6	120	68.3
3/26/2015	12	15	41.2	330	104.5
3/26/2015	2	7	47.37	110	64
3/26/2015	2	12	31.6	120	55.5
3/26/2015	2	15	45.8	270	102.2
3/26/2015	2	9	52.4	150	70
3/26/2015	2	13	47.16	250	99
3/26/2015	8	11	47.8	190	78
3/26/2015	8	8	38.3	140	67.8
3/26/2015	8	14	67.8	350	137
3/26/2015	8	16	50	240	97.9
3/26/2015	8	6	45.4	90	58.9
3/26/2015	9	10	43	210	66.6
3/26/2015	9	6	51.2	170	67.4
3/26/2015	9	11	39.8	260	73.9
3/26/2015	9	5	49	150	62.1
3/26/2015	9	14	36.5	370	82.3
3/26/2015	15	6	40.2	190	60.65
3/26/2015	15	5	49	150	64
3/26/2015	15	11	43.6	320	76.9
3/26/2015	15	15	50	300	83.1
3/26/2015	15	8	49.7	270	78.8
3/26/2015	11	4	43.38	110	51.3
3/26/2015	11	6	48	240	70.9
3/26/2015	11	7	37.75	250	61.6
3/26/2015	11	9	48.45	240	69.6
3/26/2015	11	10	44.8	300	72.3
4/23/2015	3	18	40.5	410	90
4/23/2015	3	7	41	121	54.6

4/23/2015	3	17	45	322	79.8
4/23/2015	3	12	49	245	77
4/23/2015	3	24	34	602	96.7
4/23/2015	13	22	46	342	108.3
4/23/2015	13	8	35.3	118	51.6
4/23/2015	13	7	46.5	152	67.3
4/23/2015	13	15	34	183	63.6
4/23/2015	13	17	41	213	77.6
4/23/2015	12	6	45	102	55.2
4/23/2015	12	16	49.4	347	105.7
4/23/2015	12		44	302	85.5
4/23/2015	12	12	44.1	374	113.2
4/23/2015	12	18	40.8	267	86.5
4/23/2015	2	18	34	196	74.3
4/23/2015	2	15	49	219	86.2
4/23/2015	2	8	48	130	65.5
4/23/2015	2	25	47	368	110.4
4/23/2015	2	12	35	178	69.75
4/23/2015	8	20	39	341	104.3
4/23/2015	8	29	46	428	130.4
4/23/2015	8	12	48	221	84
4/23/2015	8	10	51	236	87.9
4/23/2015	8	17	33	249	78.5
4/23/2015	9	39	51	651	136.3
4/23/2015	9	22	48.5	303	91.6
4/23/2015	9	7	34	123	48.9
4/23/2015	9		38.5	234	72.65
4/23/2015	9	30	39	507	112.5
4/23/2015	15	4	47.4	116	59.2
4/23/2015	15	10	46.9	211	68
4/23/2015	15	24	49	620	124.9
4/23/2015	15	13	51.5	233	72.8
4/23/2015	15	15	44.5	239	72.9
4/23/2015	11	9	48.4	225	71.3
4/23/2015	11	18	34	383	74.9
4/23/2015	11	35	35	687	106.9
4/23/2015	11	7	48	150	62.1
4/23/2015	11	12	50.7	273	76.2
5/21/2015	3	39	34.5	663	153
5/21/2015	3	10	33	367	97.8
5/21/2015	3	24	48.5	547	158.5
5/21/2015	3	12	47	366	93.5
5/21/2015	3	9	49	196	83

5/21/2015	13	21	49	343	130
5/21/2015	13	17	47	269	102
5/21/2015	13	7	38	121	59.77
5/21/2015	13	14	46	292	107.3
5/21/2015	13	10	45	213	88
5/21/2015	12	14	45.5	317	103
5/21/2015	12	9	46	223	79.15
5/21/2015	12	18	40	366	156.6
5/21/2015	12	7	34.5	181	67
5/21/2015	12	18	38	618	111.7
5/21/2015	2	15	48	229	90.5
5/21/2015	2	6	49	106	63
5/21/2015	2	19	48	217	92.7
5/21/2015	2	10	47	203	87
5/21/2015	2	12	47	189	90.5
5/21/2015	8	6	51	201	89
5/21/2015	8	14	49	402	130
5/21/2015	8	13	47	363	129
5/21/2015	8	18	49.5	432	158
5/21/2015	8	10	36	228	76.5
5/21/2015	9	28	49	415	115.5
5/21/2015	9	7	39	126	63
5/21/2015	9	27	46	384	122
5/21/2015	9	15	48	255	95
5/21/2015	9	16	40.7	129	64
5/21/2015	15	16	45	324	99.3
5/21/2015	15	3	53	73	57
5/21/2015	15	8	47.5	139	65.5
5/21/2015	15	29	36	576	150
5/21/2015	15	11	49	268	92
5/21/2015	11	32	47	509	133.25
5/21/2015	11	12	52	257	93
5/21/2015	11	8	49	180	72
5/21/2015	11	29	38	515	115.5
5/21/2015	11	15	49	341	107
6/18/2015	13	10	48.5	192	114.5
6/18/2015	13	6	36.5	120	78.7
6/18/2015	13	12	44.5	230	110.9
6/18/2015	13	17	51	277	153.9
6/18/2015	13	9	32	157	91.2
6/18/2015	12	12	39.5	214	95.4
6/18/2015	12	4	48	104	77.2
6/18/2015	12	13	39.7	233	119.2

6/18/2015	12	6	48.5	190	91.3
6/18/2015	12	11	48	221	118.8
6/18/2015	2	4	47.5	115	73.7
6/18/2015	2	5	36	120	70.7
6/18/2015	2	11	47	192	101.5
6/18/2015	2	4	44	90	60.3
6/18/2015	2	9	36	164	95.3
6/18/2015	8	16	47.8	312	121.7
6/18/2015	8	8	48	183	95.7
6/18/2015	8	6	35	194	87.55
6/18/2015	8	8	47.5	181	96.9
6/18/2015	8	9	49	222	120.2

Steer weight data

YR	TAG	PAD	TRT	GAIN	DAYS
1	190	1	RG+R	51.70949	68
1	250	1	RG+R	61.68851	68
1	22	1	RG+R	48.08075	68
1	337	1	RG+R	54.43104	68
1	287	2	TF+WC	118.8411	75
1	343	2	TF+WC	81.64656	75
1	173	2	TF+WC	63.50288	75
1	264 L	2	TF+WC	76.65705	75
1	60	3	RG	59.87414	68
1	299	3	RG	91.17199	68
1	466	3	RG	73.4819	68
1	5x	3	RG	79.83219	68
1	150	4	RG+R+CC	56.24541	68
1	66	4	RG+R+CC	49.89512	68
1	210	4	RG+R+CC	47.17357	68
1	264 B	4	RG+R+CC	42.63765	68
1	342	8	TF	60.78133	75
1	515	8	TF	65.31725	75
1	328	8	TF	57.15259	75
1	297	8	TF	40.82328	75
1	244	9	RG+CC	73.9355	68
1	295	9	RG+CC	49.89512	68
1	226	9	RG+CC	88.90403	68
1	325	9	RG+CC	55.33822	68
1	436	10	RG+R	66.67802	68
1	133	10	RG+R	57.60618	68
1	175	10	RG+R	66.22443	68
1	186	10	RG+R	53.52386	68
1	20	11	RG	66.22443	68
1	153	11	RG	83.91452	68
1	130	11	RG	88.90403	68
1	310	11	RG	64.86366	68
1	318	12	TF	44.45202	75
1	160	12	TF	38.10173	75
1	192	12	TF	45.81279	75
1	231	12	TF	68.0388	75
1	332	13	TF+WC	77.11064	75
1	335	13	TF+WC	64.41006	75
1	36	13	TF+WC	57.60618	75
1	271	13	TF+WC	72.57472	75
1	306	14	RG+R+CC	55.33822	68

1	140	14	RG+R+CC	49.89512	68
1	211	14	RG+R+CC	43.54483	68
1	404	14	RG+R+CC	69.85317	68
1	114	15	RG+CC	89.81122	68
1	252	15	RG+CC	84.36811	68
1	374	15	RG+CC	73.4819	68
1	249	15	RG+CC	103.419	68
2	821	1	RG+R	67.58521	57
2	752	1	RG+R	72.57472	57
2	562	1	RG+R	68.0388	57
2	768	1	RG+R	80.73938	57
2	23	2	TF+WC	81.64656	84
2	686	2	TF+WC	63.50288	84
2	626	2	TF+WC	94.34714	84
2	157/700	2	TF+WC	91.62558	84
2	619	3	RG	92.53277	85
2	766	3	RG	94.34714	85
2	639	3	RG	126.0986	85
2	751	3	RG	100.2438	85
2	709	4	RG+R+CC	45.3592	57
2	54	4	RG+R+CC	59.87414	57
2	653	4	RG+R+CC	58.05978	57
2	689	4	RG+R+CC	56.699	57
2	692	8	TF	88.45044	84
2	705	8	TF	87.08966	84
2	703	8	TF	87.99685	84
2	585	8	TF	105.2333	84
2	657	9	RG+CC	113.8516	85
2	644	9	RG+CC	97.52228	85
2	733	9	RG+CC	82.55374	85
2	655	9	RG+CC	96.1615	85
2	708	10	RG+R	48.08075	57
2	723	10	RG+R	63.50288	57
2	276	10	RG+R	67.13162	57
2	584	10	RG+R	60.78133	57
2	726	11	RG	92.07918	85
2	755	11	RG	111.13	85
2	718	11	RG	80.73938	85
2	742	11	RG	92.53277	85
2	699	12	TF	67.13162	84
2	781	12	TF	67.13162	84
2	611	12	TF	80.73938	84
2	645	12	TF	78.92501	84

2	736	13	TF+WC	92.53277	84
2	701	13	TF+WC	49.44153	84
2	711	13	TF+WC	67.13162	84
2	732	13	TF+WC	85.2753	84
2	322	14	RG+R+CC	80.73938	57
2	21	14	RG+R+CC	62.5957	57
2	668	14	RG+R+CC	68.94598	57
2	770	14	RG+R+CC	57.60618	57
2	716	15	RG+CC	78.01782	85
2	596	15	RG+CC	97.97587	85
2	20	15	RG+CC	90.7184	85
2	778	15	RG+CC	81.19297	85