PLANT AND ANIMAL PERFORMANCE IN TALL FESCUE AND TALL FESCUE/LEGUME PASTURES

by

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ABSTRACT

Plant and Animal Performance in Tall Fescue and Tall Fescue/Legume Pastures

by

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Utah State University, 2014

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Tall fescue is the one of most common grasses in irrigated pastures throughout the Intermountain West. Two limitations of tall fescue are a decrease in productivity during hot summer months and the need for supplemental nitrogen (N). The objective of this research was to compare tall fescue-alfalfa (TF+ALF), tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) on forage yield, nutritional quality, and livestock performance. Research plots were established at the Utah State University Pasture Research Facility in Lewiston, UT in 2010 and grazed in 2012 and 2013. Treatments were arranged in a randomized complete block design with four replications and divided into four paddocks per replication. Three Angus crossbred steers with an average starting weight of 380 kg were placed on each treatment and rotated to a new paddock every 7 days. A put-and-take method was used throughout the growing season such that each paddock received 80% utilization. Four forage samples were collected from each paddock just prior to grazing using a 0.5 m^2 quadrat for determination of dry matter (DM) and nutrient content. ADF, NDF, IVTD, and TDN were used to estimate nutrient content and steers were weighed every 28 days to determine livestock performance. Forage yield was highest ($P<0.05$) in TF+N (5164 kg ha^{-1}), followed by the TF+BFT (4721 kg ha^{-1}) and TF+ALF (4463 kg ha^{-1}) treatments, whereas, the TF-N treatment had the lowest yield (2920 kg ha^{-1}). In this study, TF+BFT (593 g kg^{-1}) and TF+ALF (593 g kg^{-1}) had a better ($P\leq 0.05$) season-long average TDN value than TF+N (558 g kg^{-1}), which in turn was higher ($P\leq 0.05$) than TF-N (550 g kg^{-1}). Steer average daily gains (ADG) were different ($P<0.05$) in every treatment with TF+BFT (0.73 kg d^{-1}) being the highest, followed by TF+ALF (0.67 kg d^{-1}), then TF+N (0.61 kg d^{-1}), and similar to forage yield, TF-N had the lowest ADG (0.40 kg d^{-1}). Tall fescue greatly benefits from added N whether via fertilizer or N transfer by legumes and this study showed that BFT and ALF mixed with TF increases plant and animal performance while reducing fertilizer costs and helps maintain a more environmentally sustainable pasture.

(61 pages)

PUBLIC ABSTRACT

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DEDICATION

Dedicated to my parents, and my awesome wife for the encouragement and support to continue my education

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TJ Bingham

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INTRODUCTION

In the western USA, the rising cost of nitrogen (N) fertilizer and new land policies restricting grazing on public lands has increased the need for pastures capable of supporting increased livestock use (Guldan et al., 2000; Asay et al., 2001; Waldron et al., 2002). Pasture production can be increased by establishing improved plant materials and applying more intensive grazing systems and management (Jensen et al., 2001). Irrigated pastures in the Intermountain West commonly consist of one or more species of cool season grasses (Waldron et al., 2002). Grass monocultures in pastures are preferred by producers because weeds and grazing can be easily managed (Beuselinck et al., 1994), but many struggle with N fertilizer management to maintain high yields (Moser et al., 1996). The rising cost of N fertilizer coupled with the potential negative environmental effects of N application have created a critical need to maintain or increase pasture production while reducing N fertilizer inputs (Solomon et al., 2011).

Tall fescue (TF, *Festuca arundinacea* Schreb.) is a popular pasture species in the Intermountain West due to its broad adaptation to many soil and climatic conditions. Research in the Intermountain West shows that the typical irrigated grass monoculture pasture needs between 114 to 170 kg ha^{-1} of N per year (Koenig et al., 2002). N fertilized TF contains lower amounts of neutral detergent fiber (NDF) and higher concentrations of crude protein (CP) than unfertilized TF (Gerrish et al., 1994). Under irrigation, TF has proven to produce higher yields than most other species commonly grown in the Intermountain West (Waldron et al., 2002).

Although TF can be productive in pure stands, pasture and livestock performance can be improved by introducing legumes into TF pastures (Stephenson and Prosler, 1988;

Hoveland et al., 1991). Legumes can be valuable in improving the seasonal distribution of grass monoculture pasture thereby increasing the ability of a pasture to support livestock grazing throughout the summer. In New Mexico, the binary mixture of TF and ALF maintained seasonal yields and was superior to the TF monoculture (Lauriault et al., 2003). Sleugh et al. (2000) found that grass-legume mixtures increased yield by 100% over grass monocultures. Many other studies have shown the benefit that legumes have on grass monoculture yields and seasonal distribution (Guldan et al., 2000; Wen et al., 2002; Lauriault et al., 2005, 2006; Springer et al., 2007). When grown in mixtures, perennial forage legumes can also supply N to grasses (Carlsson and Huss-Dannelll, 2003; Nyfeler et al., 2011). Mourino et al. (2003) reported that grass mixed with kura clover had lower fiber and higher CP than grass mixed with red clover. Another study done in Wisconsin showed that grass mixed with BFT also contained lower NDF and higher CP than the grass monoculture (Zemenchik et al., 2002). Little is known about how TF mixed with BFT or ALF will compare to TF monocultures in the Intermountain West.

Mixed grass-legume pastures can improve livestock performance by more uniform distribution of forage throughout the season and improved forage nutritive value. Mourino et al. (2003) reported higher steer ADG due to better forage nutritive value on kura clover mixed grass pastures than red clover mixed grass pastures. Lauriault et al. (2005) compared a tall wheat grass monoculture to a tall wheat grass/alfalfa mixture and conculuded that stocker cattle gained more weight on the mixture. Hoveland et al. (1981) reported higher average daily gains (ADG) on steers grazing tall fescue-birdsfoot trefoil compared to a tall fescue monoculture fertilized with N. In Missouri, tall fescue-birdsfoot trefoil pastures increased average daily gain and total grazing days (Wen et al., 2002). Further research on livestock performance on grass-legume mixed pastures in the Intermountain West is needed to assure those results from past studies done in different parts of the USA.

Persistence of pasture species is critical to ensuring the long-term viability of the system, a characteristic that is greatly influenced by the environment. BFT, for example, has a reputation for poor persistence in most parts of the US. Wen et al. (2002) found that the birdsfoot trefoil stand decreased dramatically in year one. Similarly Hoveland et al. (1991) reported that BFT had declined to comprise only 3% of the forage by year three. In contrast, persistence of BFT in the semi-arid Intermountain West has been high (MacAdam et al., 2011). These results indicate a need to evaluate plant and animal performance on tall fescue-birdsfoot trefoil pastures under rotational grazing in the dry Intermountain West, as opposed to previous evaluations under continuous grazing in humid regions. No research has compared the effect of legumes with different tannin compositions in mixed grass-legume pastures.

The objective of this research was to determine which TF pasture (tall fescue-alfalfa, tall fescue-birdsfoot trefoil, tall fescue with N fertilizer, or tall fescue without N fertilizer would maximize plant and animal performance in a rotational grazing system in the Intermountain West.

LITERATURE REVIEW

The federal government controls over half of the land in the Intermountain West (Jackson-Smith et al., 2006), much of which has historically been an important source of forage for livestock. Federal land management policies toward grazing are less amenable to livestock grazing today than in years past. One approach to deal with less grazing on public lands is to increase production in private pastures (Waldron et al., 2002). Pastures in the Intermountain West are typically irrigated and consist of one or more species of cool season perennial grasses (Waldron et al., 2002). The challenges associated with these pastures are maintaining forage quantity and quality throughout the grazing season and the cost of inputs such as N fertilizer.

Grass-legume mixed pastures were common in the early 1900's. With the development of synthetic N fertilizer, this practice became less common, as pastures shifted to grass monocultures in which N fertilizer was added to increase yields. With rising fertilizer cost and concern over potential negative environmental impacts of excess N, there is interest in developing pasture management strategies that require less applied N. Grass-legume mixtures in a pasture have been shown to improve seasonal yield distribution (Sleugh et al., 2000). Better forage quality can also be achieved in grass-legume mixtures versus grass monoculture. MacAdam and Griggs (2006) reported higher crude protein (CP) values in grass-legume pastures over grass monocultures. Other research suggests that the increase in CP is due to the presence the legume in the grass-legume mixture (Kleen et al., 2011). Lower concentrations of neutral detergent fiber (NDF) are often found in grass-legume mixtures than grass monocultures (Zemenchik et al., 2002). Solomon et al. (2011) found that grass-legume mixtures had higher dry matter yield (DM) than legume monocultures but not as high as grass monoculture fertilized with 180 kg N ha (Solomon et al., 2011). In that same study, livestock average daily gain (ADG) was statistically equal among grass monoculture with N, legume monoculture, and grass-legume mix pastures.

Tall Fescue (TF)

Tall Fescue is a cool-season perennial grass native to Europe that was introduced in the United States in the 1800's (Hoveland, 2009). Between 1940 and 1973, the land area planted to TF increased from approximately 1600 ha to 13 million ha, respectively, thereby becoming the predominant cool-season pasture grass in the U.S. (Buckner et al., 1979). The lower palatability of TF compared to other forage species often leads to selective grazing pressure that enables TF to outcompete other species in the pasture (Jensen et al., 2001).

TF is widely adapted to different soil and climate conditions. When irrigated, TF can produce higher yields than other grasses grown under irrigation (Jensen et al., 2001; Waldron et al., 2002). The ability of TF to grow in warm temperatures appears to be directly related to soil water availability (Wen, 2001). Buckner et al. (1979) also noted that TF is more drought tolerant and better suited for poorly drained soils than other cool-season grass species.

Due to high CP and great digestibility, TF is considered a high-quality forage grass (Bush and Buckner, 1973). TF nutritive values are lowest in the summer and highest in the fall (Bughrara et al., 1991), a trend directly correlated to soluble carbohydrate levels (Brown et al., 1963). Some TF varieties are infected with a fungal endophyte (*Acremonium coenophiallum*) which can be toxic to grazing animals

(Mcdonald et al., 1996). The fungal endophyte increases TF stand vigor and persistence, but negatively impacts animal health and productivity (Sleper and West, 1996). Livestock average daily gains (ADG) are higher on endophyte-free varieties than endophyte infected varieties (Burns and Bagley, 1996). ADG is also greatly increased when TF receives supplemental N via fertilization or is grown in the presence of a forage legume. A study by Hoveland et al. (1981) showed that steer ADG was greater on TF+BFT than TF+N (0.68 vs 0.43 kg day^{-1}).

Birdsfoot Trefoil (BFT)

Birdsfoot Trefoil (BFT, *Lotus corniculatus*), is a perennial forage legume commonly grown in pastures and for hay production. BFT is a widely distributed species that is adapted to a broad range of environments (Steiner, 1999). It is native to the Mediterranean region (Wen, 2001), but the events surrounding its introduction to the U.S. are unknown. BFT is found throughout the U.S. and is commonly grown under irrigation in the Intermountain Region (Steiner, 1999).

BFT is a non-bloating legume with high forage production potential that can be used as an alternative to alfalfa (Marten et al., 1987). BFT contains condensed tannins which both bind proteins in the rumen to help prevent bloat and helps improve protein utilization (Min et al., 2003). Wen el al. (2002) showed steers grazing a BFT monoculture gained more weight than steers grazing BFT grass-legume mixtures or grass monocultures. Although BFT monocultures increase ADG, grass-legume mixtures increase forage yield, seasonal distribution, and weed suppression (Marten and Jordan, 1979; Sheaffer et al., 1984). Stand persistence is one of the limiting factors of BFT production. Beuselinck et al. (1984) reported up to 90% stand reduction during a two year study, with the majority being lost within the first year. More recent research shows an increase in stand persistence, with a loss of only about 50% during year one (Brummer and Moore, 2000). Wen et al. (2002) reported that allowing the BFT to set seed will greatly help improve stand persistence and help suppress weeds.

Alfalfa (ALF)

Alfalfa (ALF; *Medicago sativa L.,*) is recognized as one of the oldest forage species and has a long, rich history throughout the world (Michaud et al., 1988). It originated in the Near East and Central Asia and has been grown for over 3,300 years (Bolton et al., 1972). A deep tap root allows ALF to use deep soil moisture up to 6 m or more. It also has the ability to become dormant in times of drought and cold (Michaud et al., 1988). ALF evolved in an area with cold winters and hot dry summers (Bolton et al., 1972), much like the climate in the Intermountain West. Barnes et al. (1988) stated that ALF is a popular forage throughout the United States mainly due to its N fixing capabilities, high protein production, and high livestock forage rating.

In a pasture setting, alfalfa/grass mixed pastures can provide greater DM yields and higher CP than grass monoculture pastures (Dierking et al., 2010). When interseeded into an existing pasture, ALF can establish much better than red clover, kura clover, and BFT (Cuomo et al., 2001). Bloat can be another drawback for ALF in a pasture, although in Argentina, cattle are commonly finished on alfalfa (Van Keuren and Marten, 1988). Grass-legume mixtures are considered to be bloat-safe when the legume percentage is less than 50% (Majak et al., 2003). Continuous stocking compared to rotational grazing has also been noted to reduce the potential for bloat (Lauriault et al., 2005).

Nitrogen Fixation

Forage legumes have the ability to enter into a symbiotic relationship with rhizobium bacteria to fix atmospheric bacteria (LaRue and Patterson, 1981). As it occurs, N fixed by the legume can be transferred to other companion species. Decomposion of stems, leaves, roots and nodules mineralization become available for N uptake (Dubach and Russelle, 1994), accounting for much of the long-term N transfer (Paynel et al., 2001). Paynell et al. (2001) also found that short-term N transfer is due to exudation of N compounds which can be absorbed by other plants. Perennial forage legumes are valuable in reducing the need for synthetic N (Carlsson and Huss-Dannelll, 2003). A study with alfalfa and meadow brome grown in a mixture showed that 27 to 32% of the N in meadow brome was N fixed by alfalfa (Walley et al., 1996).

Research Objectives

The Intermountain West has a semi-arid climate characterized by hot dry summers and cold wet winters. The cold winter conditions limit the growing season to around 100 -120 days. Precipitation mainly occurs during the winter months in form a snow with little to no rainfall accumulation during the growing season. Irrigation is necessary to obtain optimal yields and maintain seasonal distribution (Waldron et al., 2002). Previous grass-legume pasture research has been mainly conducted in the Australia, Europe and the Mid-western U.S. where climatic and environmental conditions don’t reflect those found in the Intermountain West. The objective of this research was to compare dry matter yield, nutrient content, and livestock performance in grass-legume mixture vs. grass monoculture pastures. We hypothesize that the grass-legume pastures will yield similar to N-fertilized TF monocultures, but will produce better ADG due to improved forage quality.

MATERIALS AND METHODS

This experiment was conducted at The Utah State University Pasture Research Farm located near Lewiston, UT (41°56'.94" N, 111°51'14.12" W, elev. 2049 m). The soils were a Kidman fine sandy loam (Coarse-loamy, mixed, superactive, mesic Calcic Haploxerolls) and Lewiston Fine Sandy Loam (Coarse-loamy, mixed, superactive, mesic Calcic Haploxerolls). The project was conducted from 13 May to 25 Sept 2012 and 24 May to 7 Oct 2013.

Treatments included monoculture tall fescue (TF, *Festuca arundinacea Schreb.* 'Fawn') with or without nitrogen (N) fertilizer (TF+N and TF-N, respectively), TF with birdsfoot trefoil (TF+BFT, *Lotus corniculatus* 'Norcen'), and TF with alfalfa (TF+ALF, *Medicago sativa* L. 'Rugged'). Treatments were arranged in a randomized complete block design with four replications. Seeding occurred in Aug 2010 with a Great Plains drill (Great Plains Ag, Salina, KS) with double disk openers spaced 15.25 cm apart. Prior to planting, soil was prepared with conventional tillage equipment. TF+N and TF-N pastures were seeded at 18 kg ha^{-1}, and the TF+BFT and TF+ALF pastures were seeded at 11 kg ha^{-1} TF and 7 kg ha^{-1} legume (BFT or ALF). Legumes were seeded separate from the TF to ensure proper depth, and they were seeded perpendicular across TF rows to minimize competition between TF and legumes during seedling stage. Pastures were not grazed in 2011, but were cut and bailed two times. Fertilizer N was applied in 2011, 2012, and 2013 to the TF+N pastures at a rate of 168 kg ha^{-1}, split equally in three applications (Apr, July, and Sept). Irrigation was applied in two 8 h applications 5 d apart, so that each paddock received 16 cm of water every 21 d. Irrigation occurred within a week after rotating steers to a new paddock.

Cattle Performance Evaluation

Livestock used in the study included 48 Angus crossbred steers, with average initial weights of 381 kg and 304 kg in 2012 and 2013, respectively. Animals were cared for in accordance with the guidelines of the Institutional Animal Care and Use Committee at Utah State University. All were treated with brucellosis vaccination, parasite treatment (Dectomax®, Pfizer Animal Health, Exton, PA), and implanted once with Ralgro® (36 mg of Zeranol, Schering Plopugh, Madison, NJ), prior to beginning grazing in the spring.

Steers were allocated to one of the four treatments (TF-N, TF+N, TF+ALF, or TF+BFT), with four replications per treatment and three steers per replication. Each treatment pasture (0.4 ha) was divided evenly into four paddocks (0.1 ha paddock^{-1}). Paddocks were divided with a single strand of poly-wire charged with a battery-powered fence charger. Each paddock was grazed for 7 d and then steers were rotated to the next paddock, such that paddocks were rested for 21 d before the steers would return to the initial paddock to begin the next grazing period (Figure 1). There were four 28 d grazing periods over each season labeled as: period one (1-28d), period two (29-56d), period three (57-84d), and period four (85-112d), and the data used for analysis were the average of the four paddocks within the respective grazing period.

A put-and-take method was implemented using a formula that included estimated forage DM and steer body weight (BW), assuming each steer would eat 2.5% of its BW (Holechek, 1988). Stocking rates were adjusted at the beginning of every grazing period by addition or removal of mature cows to achieve 80% utilization of each paddock. The

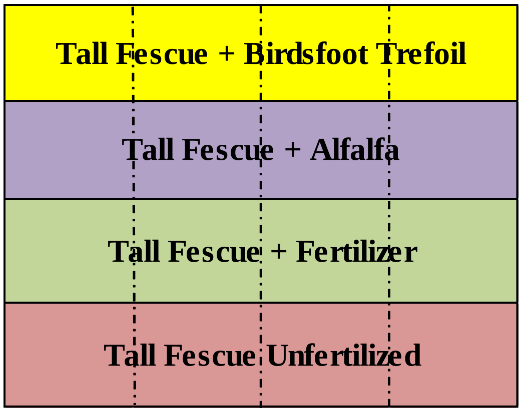

Figure 1. Layout of one replication showing the different treatments and the four different paddocks within each treatment.

rapid rate of spring growth also required the addition of mature cows between paddocks two and three during the first grazing period to get 80% utilization. Forage DM was estimated weekly by hand clipping four quadrats ($0.5m^2$) per paddock the day before rotating into a new paddock, and assuming an average dry matter percentage of 30-40%.

Cattle grazed each year for 112 days (14 May to 4 Sept, 2012 and 28 May to 17 Sept, 2013). All steers had access to water and trace mineral supplement. All animals on TF+ALF had access to bloat guard (Bloat Guard Pressed Block; Sweetlix Livestock Supplement System, Mankato, MN). Steers were weighed every 28 d to determine BW. Average daily gain (ADG) was determined by taking the average of three steers per replication. Steers were always gathered from pastures at about 0800 h so that all weights were recorded in midmorning.

At the end of the grazing season, all steers were scanned using ultrasound (Aloka SSD-500V, Wallingford, CT) to determine the carcass characteristics (backfat, ribeye area, and quality grade) using proprietary analysis software (Brethour, 1992).

Forage Evaluation

Forage samples were collected weekly throughout the experiment (13 May to 25 Sept in 2012 and 24 May to 7 Oct in 2013) one day prior to animal rotation by hand clipping four random quadrats (0.5 m^2) per paddock. Samples were placed into a paper bag and dried at 60°C. At time of clipping, plant frequency was measured with a grid system described by Vogel and Masters (2001) and, in brief, was determined by laying a grid of sixteen 3- by 3- cm quadrants over an area and determining the number of quadrants containing at least one legume plant.

Forage samples were ground using a Thomas Wiley Laboratory Model 4 mill (Arthur H Thomas Co, Swedesboro, NJ) to pass through a 1 mm screen, and were scanned with a Foss XDS near-infrared reflectance spectroscopy instrument (Foss, Eden Prairie, MN). NIRSystem software was used to calibrate existing equations so that they were appropriate for the grass monoculture and grass/legume mixtures. Random samples were selected from each year and grazing period and used for a calibration data set for wet laboratory analysis. Validation of the new equation was determined from a different set of samples selected from each year and grazing period for crude protein (CP; nitrogen x 6.25), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro true digestibility (IVTD), fatty acid (FA; ether extract -1), and ash. The r-values for validation computed across years were 0.97 for CP, 0.95 for NDF, 0.91 for ADF, 0.83 for IVTD, 0.79 for FA, and 0.82 for ash. Samples used for calibration were analyzed for N using a LECO CHN-2000 and a FP-628 Elemental Analyzer (LECO Corp., St. Joseph, MI). Following the Goering and Van Soest (1970) method as modified in the ANKOM procedures (Ankom Technology, 2005 a,b,c,d) NDF, ADF and IVTD, were determined.

Analysis for ADF and NDF were made using the ANKOM-200 Fiber Analyzer (ANKOM Technology, Macedon, NY). The first stage of the IVTD analysis consisted of a 48-hour in vitro fermentation in the ANKOM Daisy II incubator (ANKOM Technology, Macedon, NY), the second stage was performed with the NDF procedure mentioned above. Ash concentrations were determined by ashing at 550°C. Ether extract analysis was done following the AOAC 2003.05 official method by a commercial lab (Dairy One, Ithaca, NY). Total digestible nutrients (TDN) was calculated using two different formulas: one for the grass monocultures (TDNgrass = (NFC × 0.98) + (CP × 0.87) + (FA × 0.97 × 2.25) + [NDFn × (NDFDp ÷ 100)] – 10), and one for the grass/legume mixtures (TDNlegume = (CP × 0.93) + (FA × 0.97× 2.25) + [NDFn × (NDFD ÷ 100)] + (NFC × 0.98) – 7) (Saha et al., 2013). In addition, percent legume in each clipped sample was determined with NIRS. In 2012, a full range of ratios of grass/legume samples were hand mixed and ground together to build a base equation, and in 2013 one-half of all grass/legume mixtures were hand separated of which 50% were used for additional equation development and 50% were used for equation validation. Following hand separation, grass and legume components were dried and weighed to determine actual percent legume in the DM. They were then recombined and ground together in preparation for NIRS analysis. The validation r-value for percent legume was 0.97%.

Statistical Analysis

The study was arranged in a randomized complete block design (RCDB). The four mixture treatments (TF+N, TF-N, TF+ALF, and TF+BFT were each replicated four times. The average of three steers and four forage samples within each treatment-replication combination were used for statistical analysis. Data within grazing period and across years were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with treatment and year as fixed effects, and replication considered random. Year was considered a repeated measure and the appropriate covariance model (usually CS) was used (SAS Institute Inc., Cary, NC). To compare among grazing period differences, data were also analyzed with treatment, year, and grazing period considered fixed with replication being random. In this case, grazing period was considered a repeated measure and the appropriate covariance model (usually CSH) was used (SAS Institute Inc., Cary, NC). Mean comparisons were made between treatments using Fisher's Protected Least Significant Difference (LSD) test at the $P < 0.05$ level of probability (See appendix).

RESULTS AND DISCUSSION

Weather

Mean annual temperatures for 2012 and 2013 were very similar to the 30 year average, with 2012 being slightly hotter and 2013 being slightly cooler (Table 1). Interestingly when comparing May-Sept, 2013 was hotter during every month than 2012 and also hotter than the 30 year average, but 2012 was actually cooler than the 30 year average (Table 1). The hottest months seen in 2012 and 2013 were June, July and Aug, with July being the hottest in 2013 and Aug being the hottest in 2012.

Mean annual precipitation was lower than the 30 year average in 2012 and 2013 (Table1). During May-Sept there were lower precipitation totals with 2012 being 83 mm below the 30 year average and 2013 being 88 mm lower. In 2013 during the months June and Aug no precipitation was recorded, with very little recorded in July (3.4 mm) making those months very dry and hot (Table 1).

Forage Yield and Species Composition

TF+N had highest ($P \leq 0.05$) seasonal total (5164 ka ha^{-1}) followed by TF+BFT (4721 kg ha^{-1}) and TF+ALF (4463 kg ha^{-1}), and with TF-N being substantially lower than all other treatments (Figure 2). This is further reflected by TF-N having the lowest ($P \leq 0.05$) DM yield in every grazing period. TF+BFT yielded equally to TF+N during grazing periods two, three and four, but TF+ALF yielded equivalent to TF+N only during grazing period three at which time all treatments except TF-N were equal (Figure 2). Overall, the results show that DM yields deceased throughout the year regardless of treatment.

Table 1. Monthly temperature and precipitation for Lewiston, Utah for 2012 and 2013 with the difference from long-term average for temperature and precipitation (1944-2014) in parenthesis.

	Lewiston			
	Temperature†		Precipitation	
Month	2012	2013	2012	2013
	——— °C ———		——— mm ———	
January	-1.6 (4.1)	-12.7 (-7)	24.3 (-8)	22.3 (-10)
February	0.3 (3.6)	-7 (-3.7)	10.2 (-30)	7.1 (-33)
March	5.9 (2.9)	2.5 (-0.5)	21.5 (-23)	18 (-27)
April	10.3 (2.4)	7.4 (-0.5)	35.8 (-14)	33 (-17)
May	12.4 (0)	12.9 (0.5)	14.3 (-45)	37.4 (-22)
June	17.2 (0.3)	18.1 (1.2)	2.6 (-29)	0 (-31)
July	19.9 (-1)	22.7 (1.8)	12 (-9)	3.4 (-17)
August	18 (-2.2)	21.4 (1.2)	4.4 (-13)	0 (-18)
September	15.5 (0.7)	17 (2.2)	5.9 (-27)	33 (-0.39)
October	8.8 (0.1)	7.6 (-1.2)	42.3 (-2)	21.2 (-18.26)
November	4.2 (2.1)	3 (1.4)	22.6 (-17)	16.8 (-20.67)
December	-2.9 (1.6)	-7.8 (3.9)	29.7 (-6)	9.4 (-28)
Annual	9 (1.2)	7.7 (-0.08)	225.6 (-18.5)	248.8 (-20)

† Weather data was obtained from the Utah Climate Center

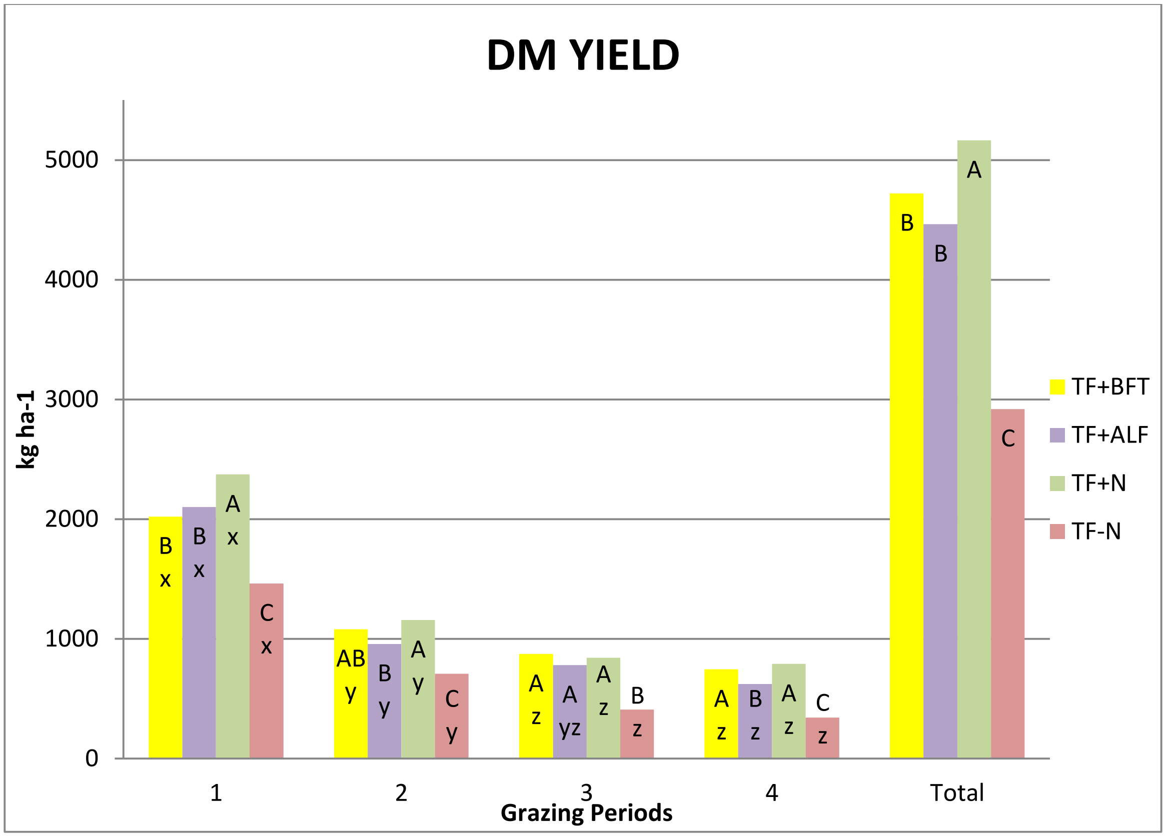

Figure 2. 2012-2013 mean DM yield (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

On average, alfalfa comprised 35% of the DM in the TF+ALF treatment, whereas BFT accounted for 30% of the forage mass in the TF+BFT pastures (Figure 3). During the first two grazing periods TF+ALF contained higher ($P \leq 0.05$) percent legume than the TF+BFT pastures, but during grazing periods three and four TF+BFT and TF+ALF were equal (Figure 3). But, both ALF and BFT percentage increased throughout the season as reflected by BFT increasing from 23% to 37% and ALF increasing from 31% to 40% from grazing period one to four, respectively (Figure 3). In contrast with percent legume, frequency of BFT was greater ($P \leq 0.05$) than ALF. After grazing period one, BFT consistently had a higher frequency than ALF (Table 2). In addition, ALF contained the same plant frequency in all grazing periods, but BFT had higher frequency in grazing periods two, three, and four as compared to grazing period one (Table 2), indicating that 80% utilization did not reduce BFT stand.

Unexpectedly, percent DM was the lowest ($P \leq 0.05$) in grazing period one (27.5%), then increased in grazing period two (39.5%), and slightly decreased in grazing period three (38%) and four (35.5%) (Table 2). Within a grazing period, TF+BFT always had the lowest ($P \leq 0.05$) percent DM (average, 32%), followed closely by TF+ALF (34%), and TF+N (35%) and lastly TF-N with the highest percent DM (44%).

In this study TF+N had higher total forage yield than all other treatments (Figure 2). Similarly, Solomon et al. (2011), reported that grass-legume mixtures out yielded unfertilized grass monocultures but were similar in yield to the grass monoculture pasture fertilized with 180 kg N ha^{-1}. We also reported that TF+BFT and TF+ALF yielded higher than the TF-N pastures, and that during the hotter months, of June, July and August, TF+BFT yielded comparable to TF+N (Figure 2). During those months BFT

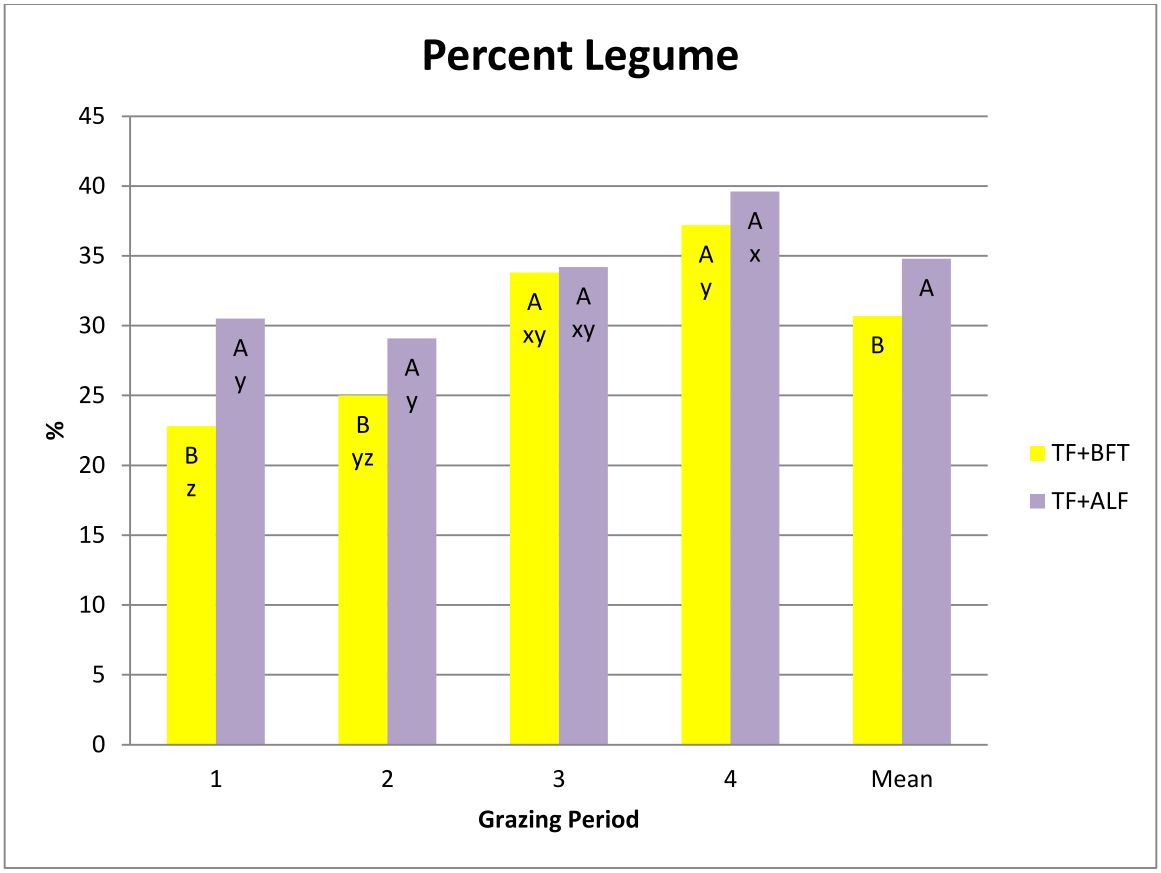

Figure 3. 2012-2013 mean percent legume in sward for tall fescue with birdsfoot trefoil (TF+BFT), and tall fescue with alfalfa (TF+ALF) pastures. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

Table 2. Combined 2012-2013 mean forage yield and composition of tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-alfalfa (TF+ALF), and tall fescue fertilized (TF+N) and unfertilized (TF-N) pastures.

Grazing Period§ and Treatments	DM¶ YIELD	DM	Freq	LEG.
	kg ha^{-1}		%	
Grazing Period 1				
TF-N	1463 c,x	33 a,z	-	-
TF+N	2373 a,x	27 b,z	-	-
TF+ALF	2102 b,x	25 c,z	31 a,y	31 a,y
TF+BFT	2022 b,x	25 c,z	23 b,z	23 b,z
Grazing Period 2				
TF-N	708 c,y	47 a,xy	-	-
TF+N	1157 a,y	40 b,w	-	-
TF+ALF	958 b,y	37 b,w	29 a,y	29 a,y
TF+BFT	1081 ab,y	34 c,x	25 b,yz	25 b,yz
Grazing Period 3				
TF-N	408 b,z	49 a,x	-	-
TF+N	843 a,z	38 b,x	-	-
TF+ALF	780 a,yz	34 c,x	34 a,xy	34 a,xy
TF+BFT	873 a,z	31 d,y	34 a,xy	34 a,xy
Grazing Period 4				
TF-N	341 c,z	45 a,y	-	-
TF+N	791 a,z	33 b,y	-	-
TF+ALF	623 b,z	33 b,y	40 a,x	40 a,x
TF+BFT	745 a,z	31 c,y	37 a,y	37 a,y
Average				
TF-N	2920 c	44 a	-	-
TF+N	5164 a	35 b	-	-
TF+ALF	4463 b	34 b	31 a,y	35 a
TF+BFT	4721 b	32 c	23 b,z	30 b

† Treatments within grazing period followed by different letters (a,b,c,d) are significantly different at $P < 0.05$ probability level.

‡ Grazing periods within a treatment followed by different letters (w,x,y,z) are significantly different at $P < 0.05$ probability level.

§ Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12- July 9 2012, June 25 -July 22 2013), Grazing Period 3= (July 10 -Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013)

¶ DM= dry matter, Freq.= grid counts # of legumes present, LEG.= legume in sward, ADF= acid detergent fiber, ND= neutral detergent fiber, IVTD= in vitro true digestibility, CP= crude protein, and FA= fatty acids contributed to roughly 33% of the forage mass (Figure 3). It was hypothesized that adding legumes to TF would help alleviate the typical cool-season grass summer yield slump, but this was not observed as tall fescue-legume mixtures did not out yield the fertilized monoculture during mid-summer grazing periods. It is well documented that legumes planted in grass pastures transfer N to the grasses (Dubach and Russelle, 1994; Paynel et al., 2001; Carlsson and Huss-Dannelll, 2003). In a study with similar percent BFT in sward Mallarino et al. (1990) it was shown that the legume transferred between 20 to 60% N to the grass, which in turn allowed for a healthier more abundant grass component. Establishment and competitiveness of ALF has shown to be better than BFT (Gist et al., 1957; Cuomo et al., 2001), but in our study legume stand frequency was higher ($P \leq 0.05$) for BFT (31%) compared to ALF (23%), with both ALF and BFT persisting well throughout the season (Table 2). Contrary to previous reports (Hoveland et al., 1981; Wen et al., 2002), BFT had great persistence in our study (Table 2). Research has shown that BFT nodules die and fall off after harvest or stress (Vance et al., 1982), but ALF nodules do not die after harvest, therefore most N transfer must be done by decaying roots (Vance et al., 1980; Ta and Faris, 1987). This could explain the higher DM yield in TF+BFT pastures that were seen during different grazing periods even though ALF contributed equally or more to the sward (Figures 2 and 3).

Forage Nutritive Value

Crude Protein seasonal mean concentrations were highest ($P \leq 0.05$) in TF+ALF (164 g ka^{-1}) followed by TF+BFT (148 g ka^{-1}), TF+N (138 g ka^{-1}), and TF-N (114 g ka^{-1}). This is further reflected in that TF+ALF ranked the highest for CP throughout the season, with TF+BFT being equal to TF+ALF only during the first two grazing periods.

Tall fescue monocultures had the lowest CP content with TF+N equal to TF+BFT only during grazing period four and TF-N contained the lowest ($P \leq 0.05$) CP in every grazing period (Figure 4). Overall, CP in TF+BFT and TF+ALF steadily increased from grazing period one to grazing period four, whereas TF+N and TF-N crude protein remained level in the first two grazing periods and then increased in grazing periods three and four.

Digestibility (IVTD) was comparable between TF+ALF (795 g kg^{-1}), TF+BFT (792 g kg^{-1}), and TF+N (789 g kg^{-1}), but lower ($P \leq 0.05$) digestibility was found in the TF-N (782 g kg^{-1}) (Figure 5). Furthermore, digestibility of TF+ALF, TF+BFT, and TF+N were equal within all grazing periods, except in grazing period one in which TF+N was lower ($P \leq 0.05$) (Figure 5). Digestibility values were lowest in all treatments during grazing periods two and three, but all treatments with exception of TF+BFT regained digestibility values in grazing period four similar to with those achieved during grazing period one (Figure 5). Even though TF+BFT did not recover as well as other treatments it still maintained one of the highest season averages.

Fiber values NDF and ADF are inversely related to forge nutritive value. As a result, lower NDF and ADF values signify better forage nutritive values. On average and within grazing periods, TF+ALF and TF+BFT both had similar and lower ($P \leq 0.05$) NDF concentrations than TF+N and TF-N (Figure 6). TF+BFT and TF+ALF were equal in all grazing periods except grazing period four where TF+ALF had slightly lower NDF. Furthermore, NDF values computed for each treatment ranged from a low of 461 g kg^{-1} (TF+ALF) to 606 g kg^{-1} (TF-N). NDF concentrations of TF+N and TF-N were the same during grazing period one but were different in grazing periods two, three, and four, with TF+N being better (Figure 6). Similar, but less pronounced trends were also seen in ADF

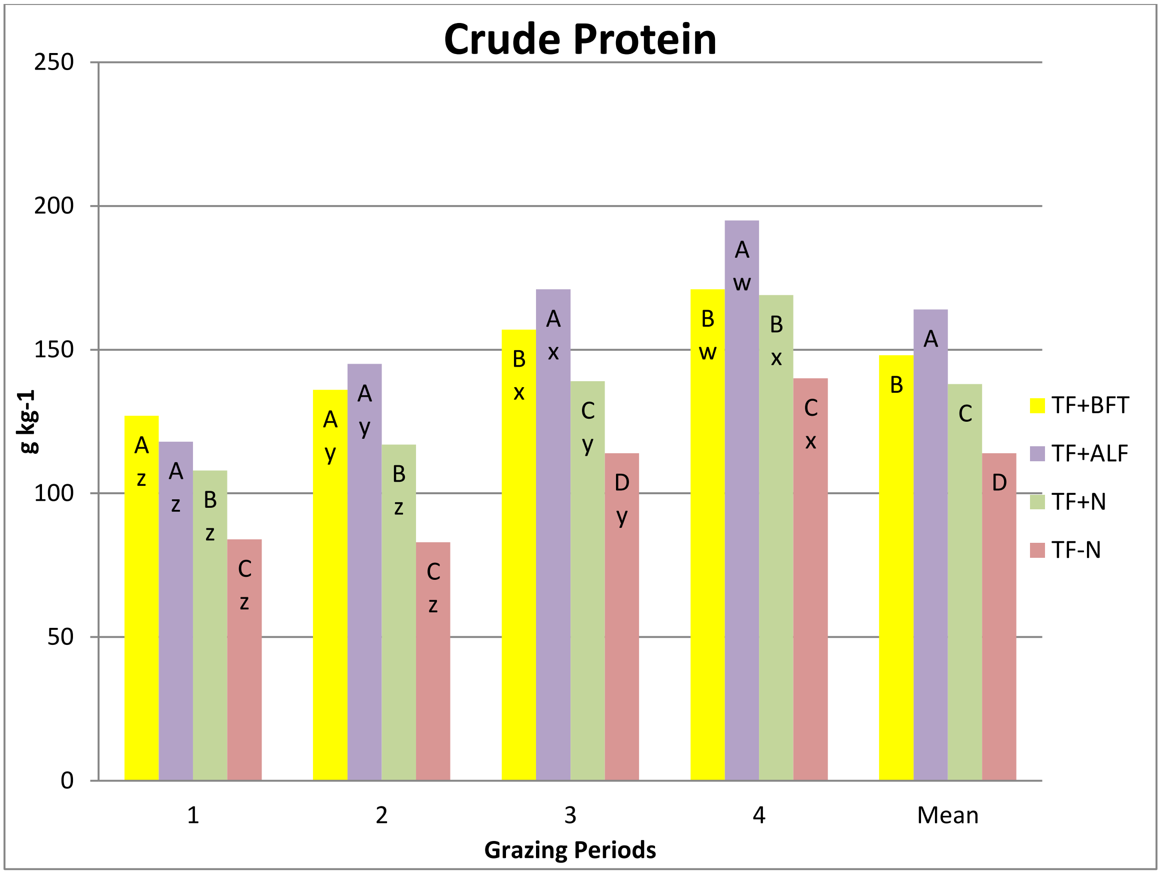

Figure 4. 2012-2013 mean crude protein (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (w, x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

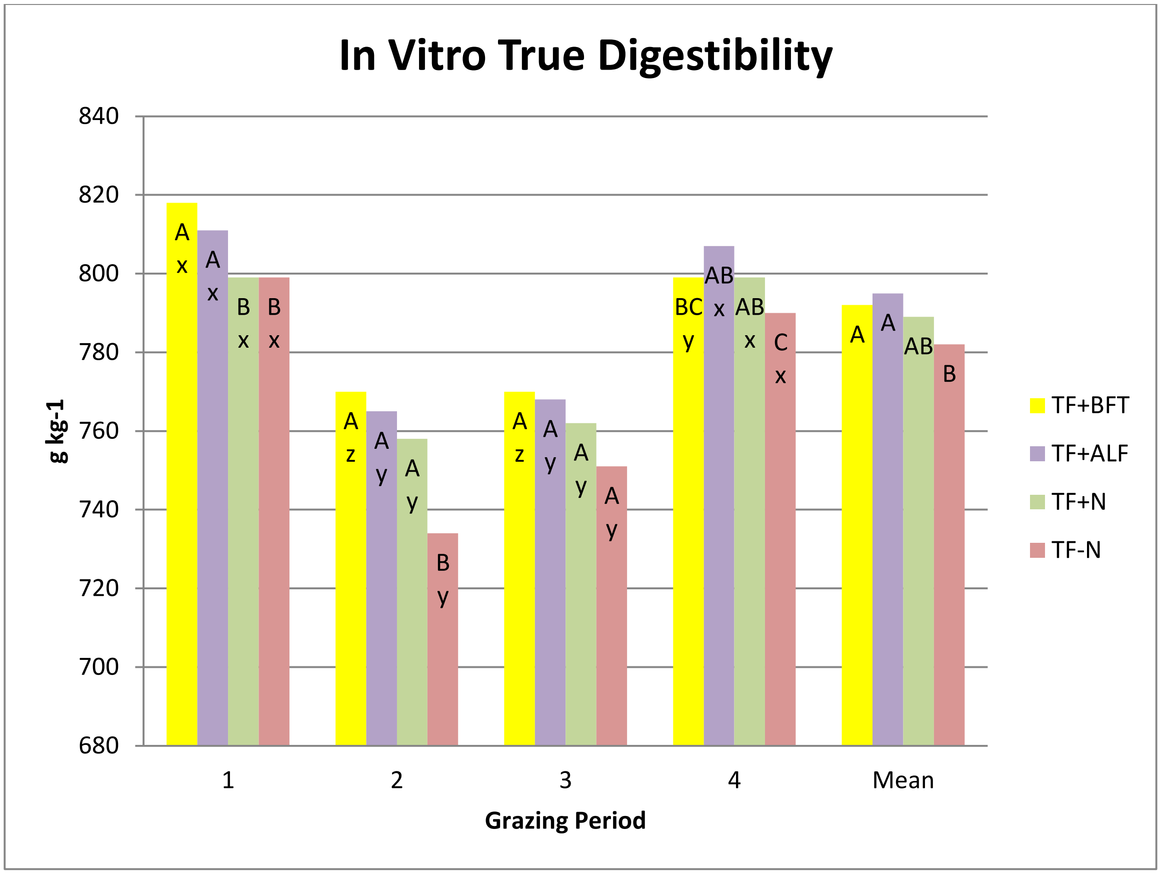

Figure 5. 2012-2013 mean in vitro true digestibility (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

concentrations (Figure 7). Different than NDF, TF-N had higher ($P \leq 0.05$) ADF than TF+N during grazing periods two, three, and four (Figure 7). Overall TF+ALF maintained lower ADF than TF+N and TF-N.

Grass-legume pastures have been known to have higher CP values than grass monoculture pasture (Zemenchik et al., 2002; Macadam and Griggs, 2006). CP values in this study were highest on treatments TF+ALF and TF+BFT. Kleen et al. (2011) stated that the increase in CP is mainly driven by the legume in the mixture. Our study is in agreement, as there were consistently higher CP concentrations throughout the year in the grass-legume pastures versus grass monoculture pastures (Figure 4). Protein deficiency in cattle occurs when forages contain less than 70 g kg^{-1} CP (Chiba, 2009). According to this requirement all treatments contained sufficient CP with the lowest being TF-N (83 g kg^{-1}) during grazing period two.

Nitrogen fertilizer affected CP (Figure 4), but did not show an effect on the NDF concentrations of TF (Figure 6). Other studies have also shown that N fertilizer does not influence NDF concentration in cool seasons grasses (Buxton, 1996; Valk et al., 1996; Noviandi et al., 2012). In addition, Buxton (1996) noted that fiber will increase and digestibility will decrease during the hot summer months due to the stress on the grass. As result, concentrations of NDF, as well as ADF, and IVTD were less desirable in grazing periods two and three than in grazing periods one and four (Figures 5, 6, and 7).

Energy expressed as TDN is directly related to digestible energy and is a sum of digestible fiber, protein, lipid, and carbohydrate components (Rasby and Martin, 2013; Saha et al., 2013). In this study, TF+BFT (593 g kg^{-1}) and TF+ALF (593 g kg^{-1}) had a better ($P \leq 0.05$) season-long average TDN value than TF+N (558 g kg^{-1}), which in turn

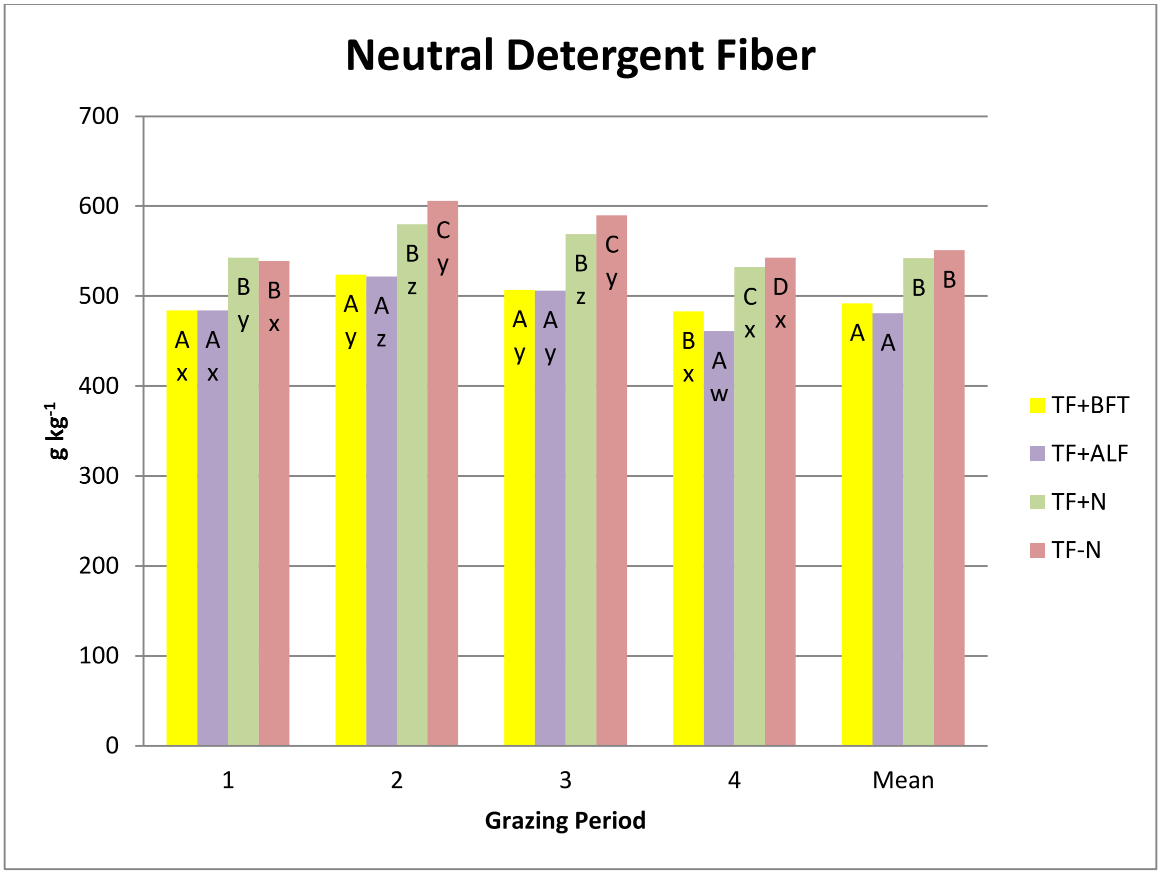

Figure 6. 2012-2013 mean neutral detergent fiber (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (w, x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

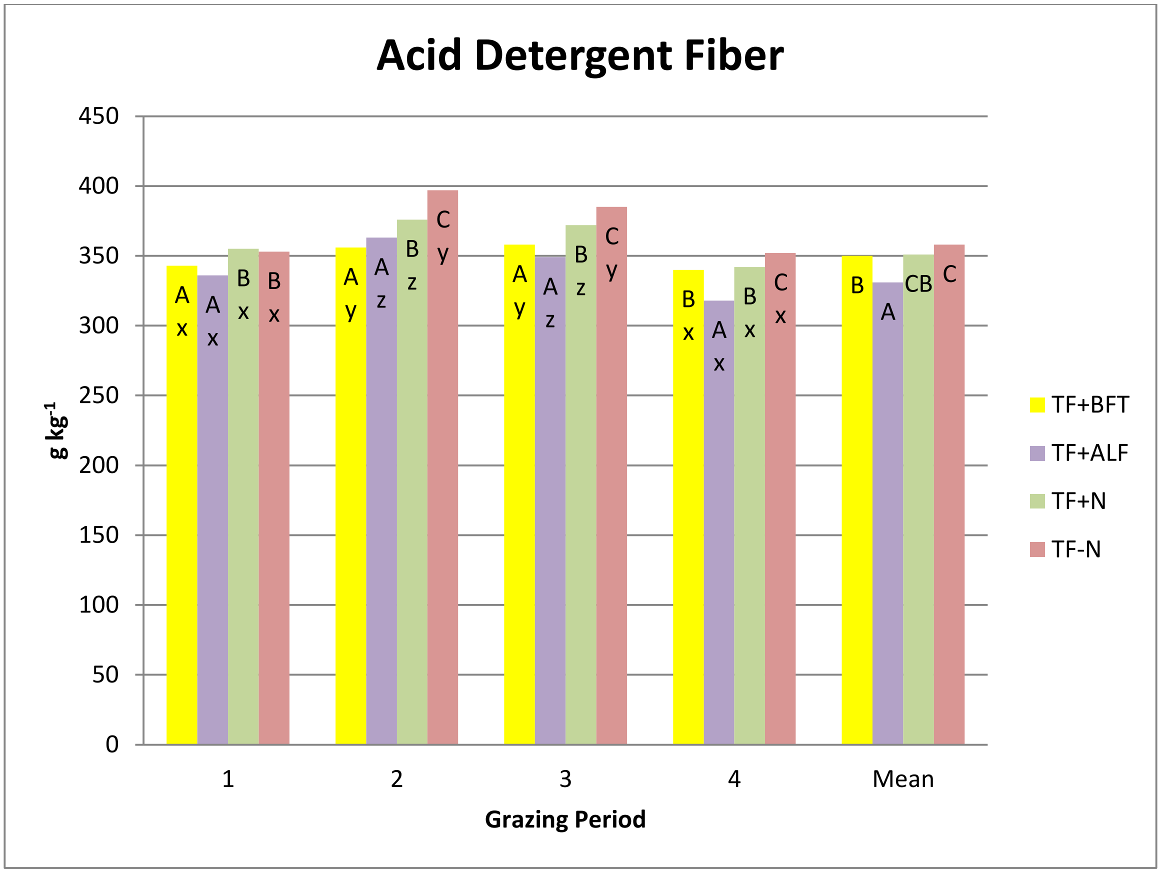

Figure 7. 2012-2013 mean in vitro true digestibility (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

was higher ($P \leq 0.05$) than TF-N (550 g kg^{-1}). Overall, TDN decreased in all treatments from grazing period one to grazing periods two then went back up in grazing period four, with TDN of TF+N and TF+ALF during grazing period four equal to the respective TDN levels of grazing period one. TF+BFT had the highest TDN in grazing period one and TF+ALF had the highest ($P \leq 0.05$) TDN in grazing period four, and both had higher TDN than TF+N and TF-N in all grazing periods (Figure 8). Nitrogen fertilizer did have an effect on TDN of tall fescue monocultures, with similar TDN for TF+N and TF-N during grazing periods one and three but higher TDN in the TF+N treatment in grazing periods two and four (Figure 8). This is the first study to document and suggest that pasture mixtures with legumes result in higher energy content.

Steer Average Daily Gain and Carcass Characteristics

Season-long steer ADG were different ($P \leq 0.05$) amongst all treatments with TF+BFT (0.73 kg day^{-1}) being the highest followed by TF+ALF (0.67 kg day^{-1}), TF+N (0.61 kg day^{-1}), and TF-N (0.40 kg day^{-1}) (Figure 9). During the season, steer ADG decreased dramatically after grazing period one and remained fairly constant in grazing periods two, three, and four (Figure 9). Gains during grazing period were similar between TF+ALF (1.5 kg day^{-1}), TF+BFT (1.3 kg day^{-1}), and TF+N (1.17 kg day^{-1}), with TF-N being significantly lower ($P \leq 0.05$) than TF+BFT and TF+ALF but not TF+N (Figure 9). After grazing period one there were no ADG differences among TF+ALF, TF+N, or TF-N until grazing period four, when TF-N had the lowest ($P \leq 0.05$) ADG (Figure 9). During grazing period three ADG for TF+BFT somewhat rebounded from the dramatic decrease observed in grazing period two and was 45% higher than TF+ALF, being the only grazing period that TF+BFT had higher ADG than TF+ALF (Figure 9).

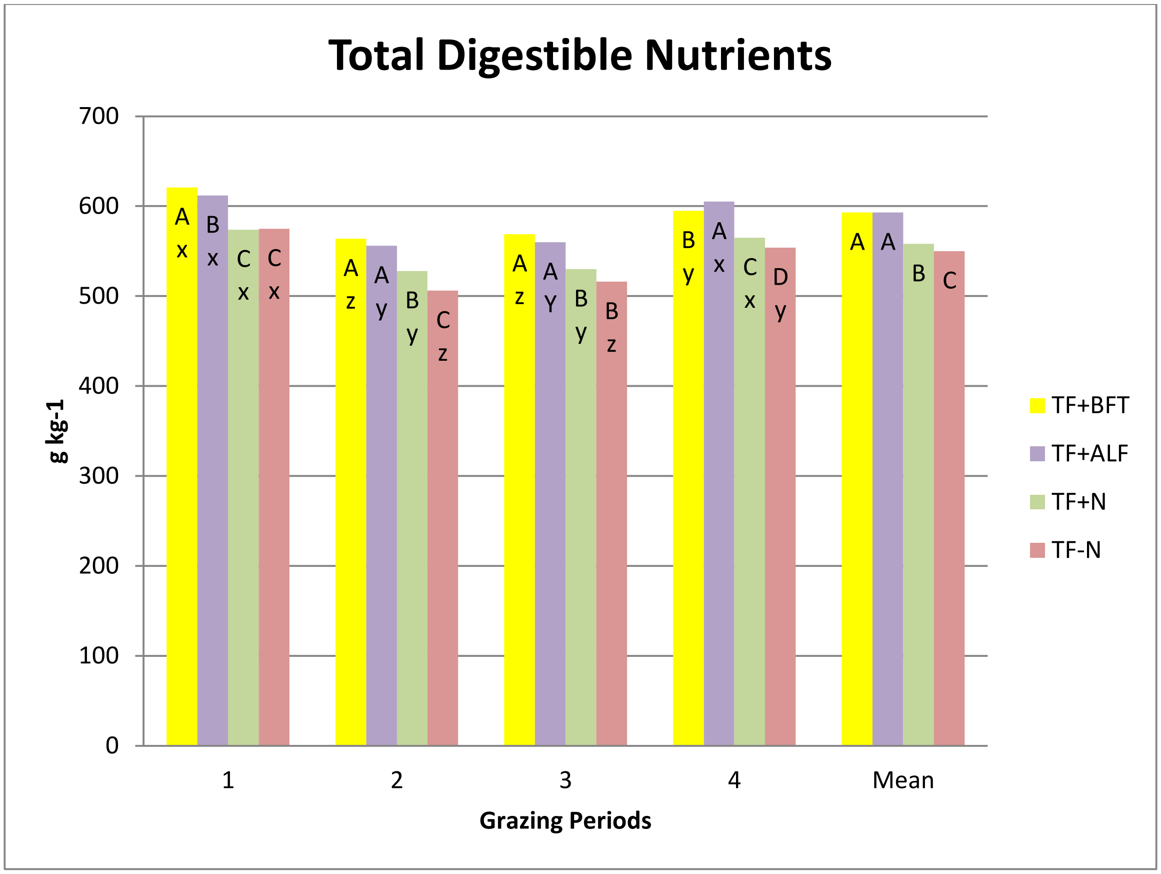

Figure 8. 2012-2013 mean total digestible nutrients (TDN) (g kg^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

There were no differences amongst treatments for steer carcass characteristics. All treatments resulted in carcass grade of Select (-) (Sel-). Intramuscular fat (IMF) was also the same with an average of 3.21% across all treatments. Rib eye area (REA) was measured in cm^2, with all treatments being the same with an average of 8.53 cm^2. Values for rib fat (RIBFT), calculated percent yield grade (CYPG), and meat score (MS) also showed no differences across treatments (Table 3).

The best steer gains in this study were from TF+BFT treatment (Figure 9). This agrees with a previous study comparing TF+BFT to TF+N, where TF+BFT also showed greater steer ADG (Hoveland et al., 1981). Furthermore in our study steers grazing TF+N had better ADG then those steers grazing TF-N (Figure 9). Noviandi et al. (2012) compared steers grazing TF+N to TF-N and also noted that steer ADG were better on TF+N pastures. Steers on TF+ALF pastures gained slightly less (0.67 kg day^{-1}) than TF+BFT (0.71 kg day^{-1}), but this difference is hard to explain in that TF+ALF had equal if not better forage nutritive value. This difference was especially seen during grazing period three in which TF+BFT ADG was roughly 45% higher than TF+ALF. Condensed tannins (CT) that are found in BFT may explain this difference, in that they have been shown to protect proteins in the rumen, promote amino acid absorption, and improve utilization of nutrients (Waghorn et al., 1998). Other research has also shown that CT improves animal performance resulting in better milk production, wool growth, and ADG (Douglas et al., 1995; Waghorn et al., 1998; Wen et al., 2002, 2003; Min et al., 2003). Therefore, we speculate that ADG differences between TF+BFT and TF+ALF noted in our study were due to condensed tannins found in BFT, given that TF+ALF contained better values of the forage nutritive measurements made in this study. Hoveland et al.

Table 3. Steer carcass characteristics on tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-alfalfa (TF+ALF), and tall fescue fertilized (TF+N) and unfertilized (TF-N).

Treatments	QG†	IMF	RIBFT	REA	MS	CYPG
		%	cm	cm^2	%	%
TF-N	Sel-	3.06	0.24	8.40	4.00	2.60
TF+N	Sel-	3.27	0.27	8.53	4.16	2.67
TF+ALF	Sel-	3.34	0.26	8.68	4.22	2.65
TF+BFT	Sel-	3.17	0.25	8.51	4.09	2.62

† QG= quality grade, IMF= intramuscular fat, RIBFT= rib fat, REA= rib eye area, MS= meat score, and CYPG= calculated percent yield grade

(1981) showed that steers grazing TF+BFT gained 0.68 kg day^{-1} and Wen et al. (2008) showed steers gained between 0.68 to 0.93 kg day^{-1} on TF+BFT pastures. These gains are very similar to gains that we have reported with mean steer ADG of 0.73 kg day^{-1} for TF+BFT and 0.67 kg day^{-1} for TF+ALF. Another study comparing kura clover–grass mixtures to red clover-grass mixtures reported greater ADG (1.24 kg day^{-1} and 1.12 kg day^{-1}, respectively) than our research, but is likely due to better forage nutritive values than those we observed (Mourino et al., 2003).

We report that TF+BFT and TF+ALF had the highest TDN throughout the entire season (Figure 7). Rayburn (2009) reported that a medium frame steer weighing 360 kg would need 680 g kg^{-1} TDN to gain 0.9 kg day^{-1}, 630 g kg^{-1} to gain 0.68 kg day^{-1}, or 590 g kg^{-1} to gain 0.45 kg day^{-1}. The gains we observed are slightly higher but fairly representative of those predicted by Rayburn (2009). This suggests that plant species with inherently higher TDN could increase ADG. Close examination of the TDN equation further indicates that our CP was adequate, but fiber content (NDF) is a limiting

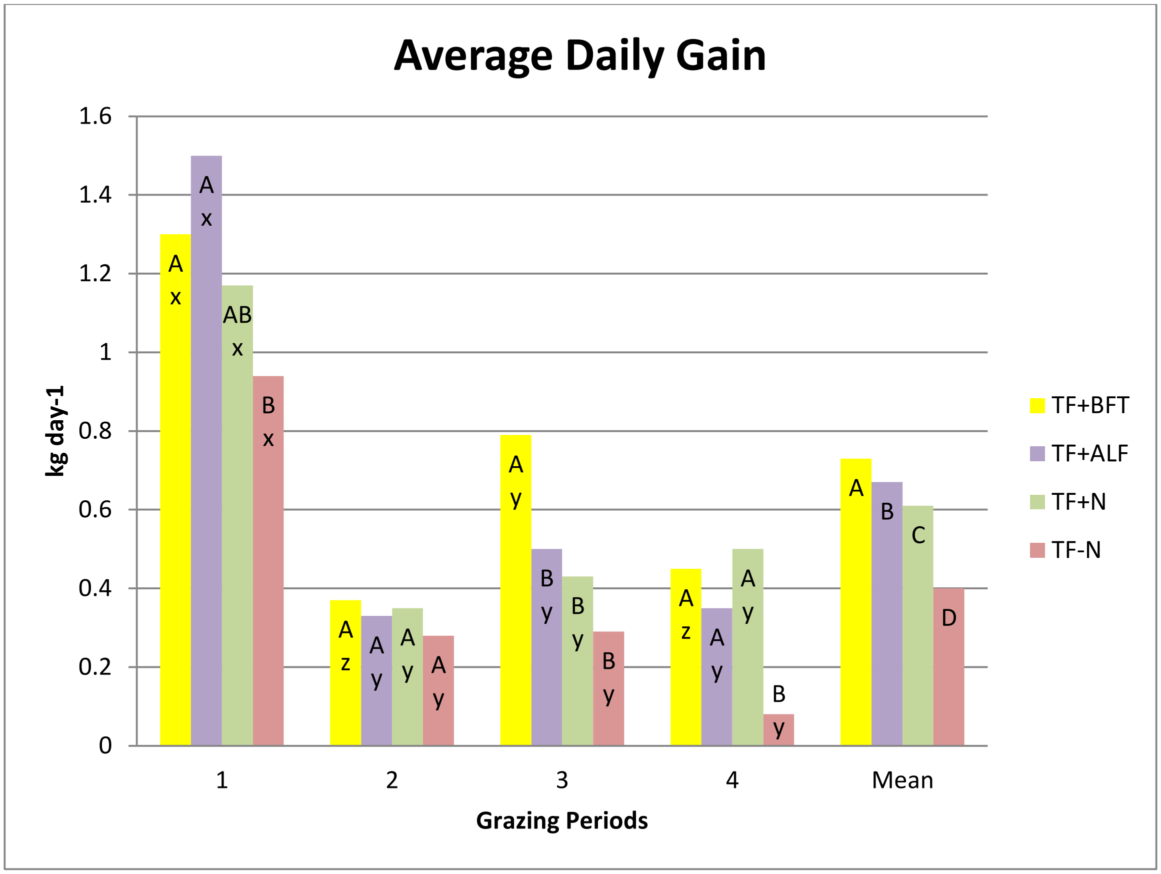

Figure 9. 2012-2013 mean steer average daily gain (kg day^{-1}) for tall fescue with birdsfoot trefoil (TF+BFT), tall fescue with alfalfa (TF+ALF), tall fescue with nitrogen fertilizer (TF+N), and tall fescue without nitrogen fertilizer (TF-N) by grazing period. Capital letters (A, B, C, D) show difference across treatments within grazing period and lower-case letters (x, y, z) show difference within treatments across grazing periods at the 0.05 probability level.

factor for these species. TDN effect on ADG is directly related to dry matter intake (DMI) which was not recorded in this research. This would have been beneficial in that it would allow for a better comparison to other research. Without actual steer DMI one can only assume that steers on TF+N had a higher DMI. In a similar study done at the same location, steer DMI ranged from 23.6 g kg^{-1} BW to 14.5 g kg^{-1} BW, but did not show DMI intake differences between TF+N and TF-N (Noviandi et al., 2012). A study comparing DMI on tall fescue and alfalfa pastures showed that steers preferred alfalfa resulting in higher DMI (Boland et al., 2012).

CONCLUSION

In summary, both TF+BFT and TF+ALF result in better steer ADG and forage nutritive value, including energy content, than either TF+N or TF-N. Tall fescue monoculture without N fertilizer had the lowest forage yield and CP in all grazing periods and season-long mean. Consequently, steer ADG was also the lowest for TF-N. Steer gains from TF+BFT was higher than all other treatments even though TF+ALF contained equal and sometimes better forage nutritive value. This suggests that either the steers had higher DMI on TF+BFT or that the CT in BFT resulted in improved utilization of nutrients in the rumen. Tall fescue greatly benefits from added N whether via fertilizer or N transfer by legumes and this study showed that BFT and ALF mixed with TF increases plant and animal performance while reducing fertilizer costs and helps maintain a more environmentally sustainable pasture. Steer gains were lower than had originally hypothesized. We did not have shade structures and one study showed increase calf ADG when there were shade structures in the pasture (McDaniel and Roark, 1956). Also, Mourino et al. (2003) had higher ADG than our research, but they also reported double the percent legume in their swards resulting in better forage nutritive value. Future research should look at the influence of shade structures on steer ADG and determine if increasing the percentage of BFT and/or ALF in the sward will increase forage nutritive value, resulting in better steer ADG.

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APPENDIX

Table 4. Degrees of freedom (DF) and p values for interactions: grazing period (GRAZEVENT), year (YR), and grazing event x year (GRAZEVENT*YR).

Grazing Period† and Measurements‡	GRAZEVENT		YR		GRAZEVENT*YR	
	DF	Pr>F	DF	Pr>F	DF	Pr>F
TF+BFT						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	< 0.0001
% Leg	21	0.0067	21	0.2133	21	0.2128
CP	21	< 0.0001	21	< 0.0001	21	< 0.0001
IVTD	21	< 0.0001	21	< 0.0001	21	0.0014
ADF	21	0.0001	21	< 0.0001	21	0.0051
NDF	21	0.0001	21	< 0.0001	21	0.0115
ASH	21	< 0.0001	21	< 0.0001	21	0.0002
FA	21	< 0.0001	21	< 0.0001	21	< 0.0001
NFC	21	< 0.0001	21	< 0.0001	21	0.2774
TDN	21	< 0.0001	21	< 0.0001	21	0.0436
ADG	21	< 0.0001	21	0.8598	21	0.5401
TF+ALF						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	< 0.0001
% Leg	21	0.0246	21	0.0078	21	0.297
CP	21	< 0.0001	21	0.1075	21	0.1061
IVTD	21	< 0.0001	21	< 0.0001	21	0.0068
ADF	21	< 0.0001	21	< 0.0001	21	0.0374
NDF	21	< 0.0001	21	< 0.0001	21	0.1000
ASH	21	< 0.0001	21	< 0.0001	21	0.0586
FA	21	< 0.0001	21	< 0.0001	21	< 0.0001
NFC	21	< 0.0001	21	0.0003	21	0.309
TDN	21	< 0.0001	21	< 0.0001	21	0.0387
ADG	21	< 0.0001	21	0.0143	21	0.0548
TF+N						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.0001
% Leg	21	-	21	-	21	-
CP	21	< 0.0001	21	0.2295	21	< 0.0001
IVTD	21	< 0.0001	21	< 0.0001	21	< 0.0001
ADF	21	< 0.0001	21	< 0.0001	21	< 0.0001
NDF	21	< 0.0001	21	< 0.0001	21	< 0.0001
ASH	21	< 0.0001	21	< 0.0001	21	0.0259
FA	21	< 0.0001	21	< 0.0001	21	< 0.0001
NFC	21	< 0.0001	21	< 0.0001	21	< 0.0001
TDN	21	< 0.0001	21	0.0008	21	0.0001
ADG	21	0.0005	21	0.3017	21	0.5874

TF-N						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	< 0.0001
% Leg	21	-	21	-	21	-
CP	21	< 0.0001	21	< 0.0001	21	0.0107
IVTD	21	< 0.0001	21	< 0.0001	21	0.0548
ADF	21	< 0.0001	21	< 0.0001	21	0.0959
NDF	21	< 0.0001	21	< 0.0001	21	0.0098
ASH	21	< 0.0001	21	< 0.0001	21	0.0018
FA	21	< 0.0001	21	< 0.0001	21	< 0.0001
NFC	21	< 0.0001	21	0.0002	21	0.0003
TDN	21	< 0.0001	21	0.0119	21	0.0863
ADG	21	< 0.0001	21	0.4442	21	0.0384

†Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12- July 9 2012, June 25 -July 22 2013), Grazing Period 3= (July 10 - Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013).

‡DM= dry matter, Freq.= grid counts # of legumes present, % Leg=% legume in sward, ADF= acid detergent fiber, NDF= neutral detergent fiber, IVTD= in vitro true digestibility, CP= crude protein, FA= fatty acid, TDN= total digestible nutrients, and ADG= average daily gains

Table 5. Degrees of freedom (DF) and p values (Pr>F) for interactions: treatment (TRMT), year (YR) and treatment x year (TRMT*YR).

Grazing Period† and Measurements ‡	**TRMT**		**YR**		**TRMT*YR**	
	DF	Pr>F	DF	Pr>F	DF	Pr>F
Grazing Period 1						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.3391
% Leg	21	< 0.0001	21	0.0007	21	0.0048
CP	21	< 0.0001	21	0.5673	21	0.6748
IVTD	21	0.0045	21	< 0.0001	21	0.8025
ADF	21	< 0.0001	21	< 0.0001	21	0.8406
NDF	21	< 0.0001	21	< 0.0001	21	0.8627
ASH	21	0.0002	21	< 0.0001	21	0.5146
FA	21	< 0.0001	21	< 0.0001	21	0.77
NFC	21	< 0.0001	21	< 0.0001	21	0.8725
TDN	21	< 0.0001	21	< 0.0001	21	0.8902
ADG	21	0.0172	21	0.8364	21	0.0607
Grazing Period 2						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.2536
% Leg	21	< 0.0001	21	0.0123	21	0.0635
CP	21	< 0.0001	21	< 0.0001	21	0.4416
IVTD	21	0.0001	21	< 0.0001	21	0.1498
ADF	21	< 0.0001	21	< 0.0001	21	0.2415
NDF	21	< 0.0001	21	< 0.0001	21	0.4502
ASH	21	< 0.0001	21	< 0.0001	21	0.1637
FA	21	0.0356	21	< 0.0001	21	0.353
NFC	21	< 0.0001	21	0.0015	21	0.3536
TDN	21	< 0.0001	21	< 0.0001	21	0.0134
ADG	21	0.9039	21	0.3925	21	0.0514
Grazing Period 3						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.0016
% Leg	21	< 0.0001	21	0.9689	21	0.7846
CP	21	< 0.0001	21	0.0049	21	< 0.0001
IVTD	21	0.2418	21	< 0.0001	21	< 0.0001
ADF	21	< 0.0001	21	< 0.0001	21	< 0.0001
NDF	21	< 0.0001	21	< 0.0001	21	< 0.0001
ASH	21	< 0.0001	21	< 0.0001	21	0.0145
FA	21	0.0136	21	< 0.0001	21	0.1176
NFC	21	< 0.0001	21	< 0.0001	21	0.0004
TDN	21	< 0.0001	21	< 0.0001	21	< 0.0001
ADG	21	0.0059	21	0.0215	21	0.1012

Grazing Period 4						
DM kg ha^{-1}	21	< 0.0001	21	0.1995	21	0.0007
% Leg	21	< 0.0001	21	0.871	21	0.7433
CP	21	< 0.0001	21	0.3975	21	0.253
IVTD	21	0.0026	21	0.0024	21	0.2199
ADF	21	< 0.0001	21	< 0.0001	21	0.3085
NDF	21	< 0.0001	21	< 0.0001	21	0.0093
ASH	21	< 0.0001	21	< 0.0001	21	0.0109
FA	21	0.0006	21	< 0.0001	21	0.0094
NFC	21	< 0.0001	21	< 0.0001	21	< 0.0001
TDN	21	< 0.0001	21	0.0175	21	0.0455
ADG	21	0.0008	21	0.2895	21	0.167
MEAN						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.0061
% Leg	21	< 0.0001	21	0.52	21	0.821
CP	21	< 0.0001	21	0.0121	21	0.1938
IVTD	21	0.0538	21	0.0001	21	0.0353
ADF	21	< 0.0001	21	< 0.0001	21	0.1207
NDF	21	< 0.0001	21	< 0.0001	21	0.0219
ASH	21	< 0.0001	21	< 0.0001	21	0.0152
FA	21	0.0002	21	< 0.0001	21	0.6469
NFC	21	< 0.0001	21	< 0.0001	21	0.0053
TDN	21	< 0.0001	21	< 0.0001	21	0.0024
ADG	21	< 0.0001	21	0.3885	21	0.4413

†Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12-July 9 2012, June 25 -July 22 2013), Grazing Period 3= (July 10 - Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013).

‡DM= dry matter, Freq.= grid counts # of legumes present, % Leg=% legume in sward, ADF= acid detergent fiber, NDF= neutral detergent fiber, IVTD= in vitro true digestibility, CP= crude protein, FA= fatty acid, TDN= total digestible nutrients, and ADG= average daily gains

Table 6. Combined 2012-2013 mean forage nutritive values of tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-alfalfa (TF+ALF), and tall fescue fertilized (TF+N) and unfertilized (TF-N) pastures.

Grazing Period§ and Treatments	ADF	NDF	IVTD	CP	FA	ASH
	g kg^{-1}					
Grazing Period 1						
TF-N	353 b,x	539 b,x	799 b,x	84 c,z	12 a,yz	132 b,z
TF+N	355 b,y	543 b,y	799 b,x	108 b,z	12 a,z	130 b,z
TF+ALF	336 a,y	484 a,x	811 a,x	118 a,z	10 c,z	124 a,y
TF+BFT	343 a,x	484 a,x	818 a,x	127 a,z	11 b,z	125 a,z
Grazing Period 2						
TF-N	397 c,y	606 c,y	734 b,y	83 c,z	11 ab,z	153 c,xy
TF+N	376 b,z	580 b,z	758 a,y	117 b,z	12 a,z	144 b,y
TF+ALF	363 a,z	522 a,z	765 a,y	145 a,y	10 b,z	136 a,x
TF+BFT	356 a,y	524 a,y	770 a,z	136 a,y	11 a,z	138 a,x
Grazing Period 3						
TF-N	385 c,y	590 c,y	751 a,y	114 d,y	14 ab,y	157 c,x
TF+N	372 b,z	569 b,z	762 a,y	139 c,y	15 a,y	153 b,x
TF+ALF	349 a,z	506 a,y	768 a,y	171 a,x	12 c,y	137 a,x
TF+BFT	358 a,y	507 a,y	770 a,z	157 b,x	13 bc,y	135 a,xy
Grazing Period 4						
TF-N	352 c,x	543 d,x	790 c,x	140 c,x	18 a,x	149 c,y
TF+N	342 b,x	532 c,x	799 ab,x	169 b,x	17 a,x	144 b,y
TF+ALF	318 a,x	461 a,w	807 ab,x	195 a,w	16 b,x	133 a,x
TF+BFT	340 b,x	483 b,x	799 bc,y	171 b,w	14 b,x	132 a,y
Average						
TF-N	358 c	551 b	782 b	114 d	15 ab	145 c
TF+N	351 cb	542 b	789 ab	138 c	15 a	141 b
TF+ALF	331 a	481 a	795 a	164 a	12 c	131 a
TF+BFT	350 b	492	792 a	148 b	14 b	131 a

† Treatments within grazing period followed by different letters (a,b,c,d) are significantly different at $P < 0.05$ probability level.

‡ Grazing periods within a treatment followed by different letters (w,x,y,z) are significantly different at $P < 0.05$ probability level.

§ Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12- July 9 2012, June 25 -July 22 2013), Grazing Period 3= (July 10 -Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013)

¶

Table 7. Combined 2012-2013 mean forage energy of tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-alfalfa (TF+ALF), and tall fescue fertilized (TF+N) and unfertilized (TF-N) pastures.

Grazing Period§ and Treatments	TDN¶	NFC	NEg
Grazing Period 1	——— g kg^{-1}———		Mcal kg^{-1}
TF-N	575 c,x	261 b,x	0.66 c,x
TF+N	574 c,x	235 c,x	0.66 c,x
TF+ALF	612 b,x	280 a,x	0.77 b,x
TF+BFT	621 a,x	288 a,x	0.79 a,x
Grazing Period 2			
TF-N	506 c,z	179 b,y	0.46 c,z
TF+N	528 b,y	178 b,y	0.52 b,y
TF+ALF	556 a,z	214 a,yz	0.60 a,z
TF+BFT	564 a,z	219 a,y	0.63 a,z
Grazing Period 3			
TF-N	516 b,z	156 c,z	0.49 b,z
TF+N	530 b,y	154 c,z	0.53 b,y
TF+ALF	560 a,y	200 b,z	0.61 a,y
TF+BFT	569 a,z	213 a,y	0.64 a,z
Grazing Period 4			
TF-N	554 d,y	178 b,y	0.6 d,y
TF+N	565 c,x	165 c,yz	0.63 c,x
TF+ALF	605 a,x	219 a,y	0.74 a,x
TF+BFT	595 b,y	223 a,y	0.72 b,y
Average			
TF-N	550 b	203 b	0.58 b
TF+N	558 b	192 c	0.61 b
TF+ALF	593 a	235 a	0.71 a
TF+BFT	593 a	240 a	0.71 a

† Treatments within grazing period followed by different letters (a,b,c,d) are significantly different at $P \leq 0.05$ probability level.

‡ Grazing periods within a treatment followed by different letters (w,x,y,z) are significantly different at $P \leq 0.05$ probability level.

§ Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013),
Grazing Period 2= (12- July 9 2012, June 25 -July 22 2013),
Grazing Period 3= (July 10 - Aug 6 2012, July 23- Aug. 19, 2013), and
Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013)

¶ TDN=total digestible nutrients, NFC= non- fibrous carbohydrates, and NEg= net energy gain

Table 8. 2012 and 2013 steer average daily gains on tall fescue-birdsfoot trefoil (TF+BFT), tall fescue-alfalfa (TF+ALF), and tall fescue fertilized (TF+N) and unfertilized (TF-N) pastures.

Grazing Period§ and Treatment	Average Daily Gain		
	2012	2013	Mean
	$g\ kg^{-1}$		
Grazing Period 1			
TF-N	1.13 a	0.74 c	0.94 b,x
TF+N	1.32 a	1.03 bc	1.17 ab,x
TF+ALF	1.27 a	1.73 a	1.5 a,x
TF+BFT	1.24 a	1.36 ab	1.3 a,x
Grazing Period 2			
TF-N	0.01 a	0.55 a	0.28 a,y
TF+N	0.39 a	0.31 a	0.35 a,y
TF+ALF	0.39 a	0.27 a	0.33 a,y
TF+BFT	0.39 a	0.35 a	0.37 a,z
Grazing Period 3			
TF-N	0.32 b	0.26 c	0.29 b,y
TF+N	0.33 b	0.53 bc	0.43 b,y
TF+ALF	0.29 b	0.72 ab	0.5 b,y
TF+BFT	0.74 a	0.85 a	0.79 a,y
Grazing Period 4			
TF-N	0 b	0.18 b	0.08 b,y
TF+N	0.5 a	0.51 a	0.5 a,y
TF+ALF	0.53 a	0.17 b	0.35 a,y
TF+BFT	0.57 a	0.32 b	0.45 a,z
Total			
TF-N	0.36 b	0.43 c	0.4 d
TF+N	0.63 a	0.59 b	0.61 c
TF+ALF	0.62 a	0.72 a	0.67 b
TF+BFT	0.74 a	0.72 a	0.73 a

† Treatments within grazing period followed by different letters (a,b,c,d) are significantly different at $P \leq 0.05$ probability level.

‡ Grazing periods within a treatment followed by different letters (w,x,y,z) are significantly different at $P \leq 0.05$ probability level.

§Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12- July 9 2012, June 25 -July 22 2013), Grazing 3= (July 10 - Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013).

Table 8. Degrees of freedom (DF) and p values (Pr>F) for interactions: treatment (TRMT), year (YR) and treatment x year (TRMT*YR).

Grazing Period† and Measurements ‡	TRMT		YR		TRMT*YR	
	DF	Pr>F	DF	Pr>F	DF	Pr>F
Grazing Period 1						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.3391
% Leg	21	< 0.0001	21	0.0007	21	0.0048
CP	21	< 0.0001	21	0.5673	21	0.6748
IVTD	21	0.0045	21	< 0.0001	21	0.8025
ADF	21	< 0.0001	21	< 0.0001	21	0.8406
NDF	21	< 0.0001	21	< 0.0001	21	0.8627
ASH	21	0.0002	21	< 0.0001	21	0.5146
FA	21	< 0.0001	21	< 0.0001	21	0.77
NFC	21	< 0.0001	21	< 0.0001	21	0.8725
TDN	21	< 0.0001	21	< 0.0001	21	0.8902
ADG	21	0.0172	21	0.8364	21	0.0607
Grazing Period 2						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.2536
% Leg	21	< 0.0001	21	0.0123	21	0.0635
CP	21	< 0.0001	21	< 0.0001	21	0.4416
IVTD	21	0.0001	21	< 0.0001	21	0.1498
ADF	21	< 0.0001	21	< 0.0001	21	0.2415
NDF	21	< 0.0001	21	< 0.0001	21	0.4502
ASH	21	< 0.0001	21	< 0.0001	21	0.1637
FA	21	0.0356	21	< 0.0001	21	0.353
NFC	21	< 0.0001	21	0.0015	21	0.3536
TDN	21	< 0.0001	21	< 0.0001	21	0.0134
ADG	21	0.9039	21	0.3925	21	0.0514
Grazing Period 3						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.0016
% Leg	21	< 0.0001	21	0.9689	21	0.7846
CP	21	< 0.0001	21	0.0049	21	< 0.0001
IVTD	21	0.2418	21	< 0.0001	21	< 0.0001
ADF	21	< 0.0001	21	< 0.0001	21	< 0.0001
NDF	21	< 0.0001	21	< 0.0001	21	< 0.0001
ASH	21	< 0.0001	21	< 0.0001	21	0.0145
FA	21	0.0136	21	< 0.0001	21	0.1176
NFC	21	< 0.0001	21	< 0.0001	21	0.0004
TDN	21	< 0.0001	21	< 0.0001	21	< 0.0001
ADG	21	0.0059	21	0.0215	21	0.1012

Grazing Period 4						
DM kg ha^{-1}	21	< 0.0001	21	0.1995	21	0.0007
% Leg	21	< 0.0001	21	0.871	21	0.7433
CP	21	< 0.0001	21	0.3975	21	0.253
IVTD	21	0.0026	21	0.0024	21	0.2199
ADF	21	< 0.0001	21	< 0.0001	21	0.3085
NDF	21	< 0.0001	21	< 0.0001	21	0.0093
ASH	21	< 0.0001	21	< 0.0001	21	0.0109
FA	21	0.0006	21	< 0.0001	21	0.0094
NFC	21	< 0.0001	21	< 0.0001	21	< 0.0001
TDN	21	< 0.0001	21	0.0175	21	0.0455
ADG	21	0.0008	21	0.2895	21	0.167
MEAN						
DM kg ha^{-1}	21	< 0.0001	21	< 0.0001	21	0.0061
% Leg	21	< 0.0001	21	0.52	21	0.821
CP	21	< 0.0001	21	0.0121	21	0.1938
IVTD	21	0.0538	21	0.0001	21	0.0353
ADF	21	< 0.0001	21	< 0.0001	21	0.1207
NDF	21	< 0.0001	21	< 0.0001	21	0.0219
ASH	21	< 0.0001	21	< 0.0001	21	0.0152
FA	21	0.0002	21	< 0.0001	21	0.6469
NFC	21	< 0.0001	21	< 0.0001	21	0.0053
TDN	21	< 0.0001	21	< 0.0001	21	0.0024
ADG	21	< 0.0001	21	0.3885	21	0.4413

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†Grazing Period 1= (May 15 -June 11 2012, May 28- June 24 2013), Grazing Period 2= (June 12- July 9 2012, June 25 -July 22 2013), Grazing Period 3= (July 10 - Aug 6 2012, July 23- Aug. 19, 2013), and Grazing Period 4= (Aug 7 - Sept. 3 2012, Aug. 20- Sept. 16 2013).

‡DM= dry matter, Freq.= grid counts # of legumes present, % Leg=% legume in sward, ADF= acid detergent fiber, NDF= neutral detergent fiber, IVTD= in vitro true digestibility, CP= crude protein, FA= fatty acid, TDN= total digestible nutrients, and ADG= average daily gains