STOCKER CATTLE PERFORMANCE AND NITROGEN USE EFFICIENCY IN OLD WORLD BLUESTEM GRAZING PROGRAMS

By

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Bachelor of Science in Animal Science

Oklahoma State University

Stillwater, Oklahoma

2010

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2016

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NITROGEN USE EFFICIENCY IN OLD WORLD

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ACKNOWLEDGEMENTS

I would like to take this opportunity to thank several people for their contributions to my life both personally and professionally.

I would like to begin by thanking my committee members Dave Lalman and Jason Warren for their guidance and wisdom while completing my thesis. Also, I owe a debt of gratitude to my advisor Gerald Horn for his friendship as well as his patience, trust, guidance, knowledge, encouragement, and unmatched work ethic that he bestowed upon me as a graduate student. I would also like to thank Phillip Lancaster and Evin Sharman for their friendship and mentorship as I was introduced into the world of scientific research.

I would like to thank Donna Perry for her expertise and stories that always seemed to make lab analysis seem to go by a little faster. I would also like to especially thank David Cox (a true man's man) for his friendship and guidance that made my time in the field the most enjoyable part of my graduate research. David's commitment to his career, family, and his many crafts is something that I strive to achieve.

I thank Bob Kropp for his support to and encouragement to begin a graduate program because he could see potential in me. I also want to thank him for introducing me to the wider world of the cattle industry and teaching me to ask questions and search for answers. Top Notch Cattle Company is a vision that he helped inspire.

Thank you to my fellow graduate students for helping with research projects, but especially Sara Linneen and Dillon Sparks. Sara continues to provide a constant example of a true friend and dedicated professional. Dillon, thank you for stepping out on a limb with me to create our vision of the future with Top Notch Cattle Company. Our ride to this point has been incredible and I look forward to many more adventures as your friend and business partner. -v-

I would like to thank Cami Jeter D.V.M. for her love, support, patience, and constant motivation to make myself a better person. I'm so proud of what you have accomplished and I look forward to what our lives have in store. I love you

Finally, thank you to my parents, Lynn and Cindy Wallis, for instilling in me a passion for learning and for providing an example of how to work hard and treat people kindly. A simple "thank you" is not enough to express my gratitude for providing me a lifetime of opportunities without any hesitation. Every day I strive to be the kind of person who you have provided me an example to be.

Thank you.

Name: Brody Donovan Wallis

Date of Degree: May, 2016

Title of Study: STOCKER CATTLE PERFORMANCE AND NITROGEN USE EFFICIENCY IN OLD WORLD BLUESTEM GRAZING PROGRAMS

Major Field: ANIMAL SCIENCE

Abstract: In grazing systems only 5-30% of ingested nitrogen (N) is retained in BW gain of growing beef cattle. A two-year study was conducted to evaluate N fertilizer and DDGS as sources of N and N use efficiency for growing beef cattle grazing Plains Old World bluestem. In year 1 (2010) heifers (n= 235; 274 ± 33 kg BW) grazed 12 pastures (3 pastures/treatment) from May 18 – Sept. 28 and in year 2 (2011) steers (n= 233; 238 ±23 kg BW) grazed 12 pastures from May 17 – July 19 in a completely randomized design comparing 4 treatments: (1) non-fertilized, low-stocked (336 kg of BW/ha) pastures (CONT); (2) N fertilized (90 kg N/ha), high-stocked (672 kg of BW/ha) pastures (NFERT); (3) N and phosphorus (P) fertilized (90 kg N/ha; 39 kg P/ha), high-stocked pastures (NPFERT); and (4) non-fertilized, high-stocked pastures plus supplementation of dried distillers grains with solubles (DDGS; 0.75% $BW \cdot hd^{-1} \cdot d^{-1}$). Year 1 weight gain per hectare (kg/ha) was highest *($P < 0.01$)* for treatment 4 and lowest for treatment 1 with 2 and 3 being intermediate. Year 2 weight gain per hectare (kg/ha) was highest *($P < 0.01$)* for treatments 3 and 4 and lowest for treatment 1 with 2 being intermediate. Treatment 1 had the lowest gain/ha due to the difference in stocking rate. In both years total N inputs (kg/ha) for treatment 4 were greater *($P < 0.01$)* than treatment 1, and both were less than treatments 2 and 3. In both years N retention in BW gain/ha for treatment 4 was higher *($P < 0.01$)* compared with treatments 1, 2, and 3, respectively. N recovery (%) was greatest *($P < 0.01$)* for treatment 1 because of the low N inputs. However, replacing N fertilizer with DDGS supplementation improved *($P < 0.01$)* N recovery by 3.0-fold in year 1 and by about 5-fold in year 2 compared with treatments 2 and 3, respectively. These data indicate that DDGS can be effectively used in stocker cattle grazing programs to increase stocking rates, increase BW gain/ha, and increase N recovery of the grazing program.

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CHAPTER I

INTRODUCTION

In the southern Great Plains the grazing of warm-season perennial grasses is a common practice for increasing weight to growing beef cattle while striving to achieve acceptable body weights and quality for entrance into feedlots. Several species of introduced warm-season forages are grazed throughout the summer months, and many of these introduced species respond well to nitrogen (N) fertilization. The use of N fertilizer is a common practice to increase forage yields in these grazing programs. Berg (1990) reported an almost linear yield response by Old World bluestem (*Bothriocholoa ischaemum* L.) to N fertilizer up to 70 kg N $ha^{-1}yr^{-1}$. This increase in yield would result in greater forage mass and increased stocking rates resulting in improved average daily gains (ADG) as reported by Ackerman et al. (2001). However, Wilkinson and Langdale (1974) reported that as N application rates increased, N fertilizer retention in beef gain decreased on warm season grasses in the southeastern USA. Therefore, reducing N applications rates and replacing N fertilizer with a N-rich, by-product feedstuff could result in greater N recovery in beef cattle grazing programs.

Dried distillers grains with solubles (DDGS), a co-product of the ethanol production industry, have proven to be an effective feed source for both grazing and confinement beef cattle programs. The improvement in ADG by DDGS supplemented grazing cattle has been widely documented (Klopfenstein et al., 2007). DDGS is typically a cost effective feed that is high in energy, protein, and phosphorus (P). Rotz et al. (2005) suggested that only 5-30% of ingested nutrients are removed from production systems in animal products such as BW gain. This results in excess N and P excreted by the animals to be recycled by the soil, plants, or lost to the atmosphere. The importance of managing nutrients in cattle production programs has been accentuated in recent years due to the increased concerns of environmental impact as well as the economic advantage of effectively utilizing these nutrients. This provides a unique opportunity for cattle grazing programs to improve nutrient retention and recycling resulting in a more sustainable grazing program that benefits the forage and improves weight gains and economic returns for cattle producers.

There have been documented improvements in weight gain (Greenquist et al., 2009) and N use efficiency (Greenquist et al., 2011) when replacing fertilizer with DDGS in cattle programs grazing smooth bromegrass (*Bromis inermis*), a cool-season grass commonly found in the northern Great Plains. Therefore, a two year study was conducted to examine the effects of DDGS supplementation and fertilization strategies on grazing performance, forage growth characteristics, N recovery, and economics of stocker cattle grazing Plains Old World bluestem.

CHAPTER II

REVIEW OF LITERATURE

Old World bluestems

Old World bluestem (*Bothriocholoa ischaemum* L.) grasses have been a part of the United States agricultural industry and land conservation efforts for the better part of the last half century. With its origin tracing back to the Middle East, Old World bluestems were introduced to the U.S. as a drought tolerate and winter hardy warm season perennial that had the ability to grow in a variety of soils with the potential to produce upwards of 6 tons of dry matter per acre under proper growing conditions (Taliaferro el al., 1972).

A thirty-six year assessment (Eck and Sims, 1984) of forages grown in Dallam County, Texas found that Old World bluestems were the dominant forages in fields where it was planted as well as volunteer fields in which other forages had been planted but had died out. This served as a measurable testament to its versatility for success in marginal soils. Old World bluestems became very popular as a grass that could establish quickly in a variety of soil types and aid in the reduction of erosion of marginal farmland as well as high traffic construction areas such as highway right-of-ways.

Berg (1990) reported an almost linear yield response of Old World bluestem to N fertilizer up to 70 kg N $ha^{-1}yr^{-1}$. Steer gains on 70 kg N ha^{-1} fertilized Old World bluestem were 200 kg $ha^{-1}yr^{-1}$ (Sims et al., 1983), whereas, steer BW gains on native rangeland in the same geographical area were 50 kg $ha^{-1}yr^{-1}$ (Shoop and McIlvain, 1971). Therefore, with the combined ease of establishment, adaptability to various soil types, positive response to fertilization, and improvement of cattle gains when fertilized Old World bluestems became a very popular forage crop for grazing cattle. In fact Berg and Sims (1995) estimated that in 1995 approximately 2 million hectares (ha) of Old World bluestem had been established in Oklahoma and Texas.

Plains Old World bluestem (*Bothriocholoa ischaemum* L. Keng) was released in the early 1970s as a joint venture between the Oklahoma Agricultural Experiment Station and the Agriculture Research Service of the United States Department of agriculture as a composite of 30 cultivars of Old World bluestems from Pakistan, Iran, Iraq, India, Turkey, and Afghanistan (Taliaferro et al., 1972). Plains Old World bluestem became very popular in the Southern Great Plains as seed was made available and the reputation for adaptability and hardiness grew. Plains bluestem was preferentially grazed compared to Caucasian bluestem, and in vitro digestibility was also greater for Plains compared to Caucasian (Taliaferro et al., 1972). Similarly Forbes and Coleman (1993) reported that Plains bluestem was more digestible than Caucasian bluestem and that cattle consumed more Plains bluestem.

Factors affecting grazing cattle performance

Stocking rate. Stocking rate has long been considered one of the most important factors that affects rate of gain in grazing cattle and in perennial forages it is vital in ensuring that there is enough residual forage for adequate carbohydrate storage to provide vigor for the next growing season. A stocking rate study on Plains Old World bluestem conducted by Ackerman et al. (2001) found that individual cattle gains decreased as stocking rate increased from 392 kg of live BW (BW) per hectare to 840 kg of BW/ha. However, gain/ha was increased as stocking rate increased. Teague et al. (1996) also conducted a study in which a continuously variable stocking rate was used to maintain different levels (1,500, 1,900, and 2,400 kg/ha) of standing biomass of Old World bluestem and it was found that maintaining a higher amount of standing biomass which resulted from a reduced stocking rate increased individual animal performance. However, gain/ha was only marginally improved with increased stocking rates. The author suggested that gain/ha may have been significantly improved if a greater forage allowance between treatments had been used in the study. Teague et al. (1996) also reported that later in the growing season an increase in forage crude protein (CP) was increased in the higher stocked shorter grazed pastures. However, they reported that continuously grazing to their trial levels of 1,500 and 1,900 kg/ha resulted in reduced root biomass and decreased the vigor of regrowth which would result in an unsustainable grazing program.

The results of these studies suggest that greater forage allowance is the driving factor in increased individual cattle gains. However, on a given land mass gain/ha may be a more important measurement of productivity and profitability to the land and cattle manager. Therefore, careful management strategies must be used to strike a balance of adequate cattle performance and stocking rates to allow adequate standing biomass to ensure long term sustainability of the grazing program.

Fertilization. For much of the 20th century the application of fertilizer N to crops and improved grasslands was a very accepted practice that yielded good returns over the added costs of production. It is widely understood that application of N fertilizer to grasslands has positive effects on forage yield and quality (particularly crude protein) providing additional resources for grazing cattle. Old World bluestems responds well to N fertilization as Berg (1990) reported an almost linear yield response of Old World bluestem to N fertilizer up to 70 kg N $ha^{-1}yr^{-1}$. Steer gains on 70 kg N ha^{-1} fertilized Old World bluestem were 200 kg $ha^{-1}yr^{-1}$ (Sims et al., 1983), whereas, steer BW gains on native rangeland in the same geographical area were 50 kg $ha^{-1}yr^{-1}$ (Shoop and McIlvain, 1971). Therefore, the beef production potential of Old World bluestem is very high. Berg and Sims (1995) suggested that the improved beef gain response to pasture N fertilization may result from increases in forage production and/or greater BW gains from higher quality forage. Nitrogen fertilization of Old World bluestems also has the potential to improve forage yields and subsequently grazing animal performance for several years after cessation of N application due to the residual N levels in the soil (Berg and Sims, 2000).

Nitrogen fertilization of Caucasian bluestem (*Bothriocholoa caucasica* Trin.) at 40 kg N $ha^{-1}yr^{-1}$ in western Oklahoma increased beef production from 115 to 200 kg $ha^{-1}yr^{-1}$ for an average efficiency of 2.1 kg of beef produced per kg of N applied (Berg and Sims, 1995). This fertilizer N efficiency in beef gain is similar to that summarized for warm season grasses fertilized at 110 kg N $ha^{-1}yr^{-1}$ in the southeastern US. However, as N application rates increased efficiency of N utilization in beef gain decreased (Wilkinson and Langdale, 1974). Berg and Sims (1995) also found that the improvement in beef gains and economic viability of fertilizing Old World bluestem was one of diminishing returns. In a 4 year study steer gains increased with N rates up to 34 or 68 kg N ha^{-1} but increased gain was negligible for the 102 kg N ha^{-1} treatment. Also, economic returns were greatest for the initial 34 kg N ha^{-1} increment, marginal for the 68 kg N ha^{-1} increment, and negligible for the third increment of 102 kg N ha^{-1}.

This reduction in N recovery within a system can be due to losses from leaching, surface water runoff, and atmospheric emissions. The practice of fertilizing improved forages for grazing continues today, but as N fertilizer prices have increased along with other production costs and awareness has increased of N losses to the environment from agriculture a major research focus has been to improve the efficiency of use of N inputs. In the Great Plains of the United States (US) much work has focused on fertilizer N use efficiency by cereal grain crops (Raun and Johnson, 1999) and warm and cool-season grasslands and the efficiency of N utilization in beef gain of growing cattle (Berg and Sims, 1995; Greenquist et al., 2009).

Proper timing of fertilizer application is also very important when considering efficiency of utilization. Factors such as moisture and temperature affect the ability of plants to utilize applied nutrients for growth. Rotz et al., (2005) suggests that at a given N input rate net N loss will decrease if more N efficient production of animal or crops is achieved. Great strides have been made (Scholefield et al., 1991) understanding and predicting how entire production systems affect N recovery and the ability to recover more N in the products that agriculture produces rather than losing it to the environment.

Supplementation. Feed supplementation of grazing cattle is a common practice to meet the goals of cattle producers and increase efficiency of production. Supplementation has long been used to provide deficient nutrients, improve animal performance, conserve forage resources, influence cattle grazing and/or gathering behaviors, provide a vehicle for feed additives, and at times can improve economic profitability of beef cattle grazing programs. Many feedstuffs with differing nutritional values can be used effectively to provide energy and/or protein supplementation.

The National Research Council (NRC) (2000) established a system in which it defined usable protein as metabolizable protein (MP), or the true protein absorbed by the intestine supplied by microbial protein and undegraded intake protein (UIP). This system has the advantage over the crude protein (CP) system because not all proteins from feedstuffs are metabolized in the same way as they pass through the animal's digestive system. Metabolizable protein is made up of microbial protein synthesized in the rumen, and UIP that bypasses the rumen. Feeding supplemental protein to cattle grazing low quality forage is common practice by many cattle managers. McCollum and Galyean (1985) reported increased voluntary forage intake, a slight increase of in vitro digestion rate, and increased passage rate of prairie hay when steers were supplemented with 800 grams of cottonseed meal per day. This increased forage intake provides more energy for rumen microbes and provides more microbial protein to the small intestine to meet the MP requirement of the animal. In non-supplemented grazing cattle, MP is mostly rumen degradable intake protein (DIP) that is rapidly degraded by rumen microorganisms.

Available DIP is determined by the protein content in the forage as well as the energy available for the rumen microbes to synthesize that protein. Excess DIP is then sent to the liver and excreted or returned to the body for use by way of the urea cycle. A smaller proportion of UIP is available from forages for grazing cattle and passes to the small intestine where it is absorbed or excreted in the urine and feces. Feedstuffs with increased UIP content such as corn gluten meal are commonly used in grazing systems. However, DIP requirements must be met by the diet if a positive performance response to UIP is to be realized (Klopfenstein, 1996). Hafley et al. (1993) reported that cattle grazing native warm season grasses did not have higher gains when fed a UIP supplement (control plus soybean and feather meals) compared to the control (cornstarch and molasses). However, when fed a combination supplement of UIP and added DIP weight gains tended to increase. This suggested that in some grazing situations growing forage may not adequately provide enough DIP to meet MP requirements. These findings have given rise to high protein (38-40%) meal based supplementation programs for growing cattle grazing warm-season perennials. This type of program supplies DIP to the cattle as CP content of the forage declines as forage maturity increases throughout the summer grazing period ensuring that cattle DIP requirements are met. However, growing calves on an immature forage based diet can have sufficient DIP but can have limited performance from being UIP deficient (NRC, 1985). Creighton et al., (2003) reported increased gains in cattle grazing immature growing smooth bromegrass in response to UIP supplementation of corn gluten feed due to a MP deficiency from high concentrations of DIP from the forage. Therefore, it is important to evaluate CP characteristics of the forage base when determining the type of protein supplement to be used in a grazing program.

Energy based feed supplements are often fed in an effort to improve weight gain when the energy available in forages does not support adequate performance or the availability of forage is a limiting factor. In a review of literature Horn and McCollum (1987) reported the substitution effects of energy supplements for forages. It was suggested that these effects were related to decreased ruminal pH as well as other metabolic influences such as physiological state and activity of the cattle and digestibility and quality of available forage. The authors suggested that fiber based energy supplements may have less of a negative effect on forage digestibility and passage rates compared to starch-based supplements which result in greater reductions in rumen pH. Horn and McCollum (1987) also suggested in their review of literature that a reduction in performance from a nitrogen deficiency can often times be created when high-energy and low-protein supplements are fed because of a reduction in total dietary protein. Therefore, balancing dietary protein and energy is important to improve cattle performance when grazing both low and high quality forages. A 3-year wheat pasture experiment was conducted and two energy supplements (high-starch and high-fiber) were fed at a rate of 0.65% of mean BW six days per week and daily gains with both supplements improved by 0.15 kg per day. Supplementation also allowed stocking density to be increased by approximately one-third (Horn et al., 1995). Bodine et al. (2001) studied the effects of feeding a protein supplement and two energy supplements (fiber based and starch based) formulated to contain the same amount of DIP to heifers grazing bermudagrass. Their results indicated an increase in gain over the unsupplemented control but no difference in performance between the three supplemented treatments. These results confirmed Horn and McCollum's (1987) suggestion that a proper energy and protein balance in the total diet can offset the typical negative associative effects of high energy supplements.

Distillers grains as a feed supplement. The rise of ethanol production in the U.S. has increased the use of large scale dry-milling in order to meet ethanol demands. This of course has increased the availability of ethanol, but it has also increased the availability of by-products of the dry-milling industry. One of those by-products is distillers grains. Stock et al. (1999) described the dry-milling process in detail, but in short it is the process of converting starch from a cereal grain into ethanol via fermentation. Once fermentation is complete ethanol can be removed or distillation can be used to remove the alcohol. The remaining mixture, considered whole stillage, is then centrifuged or filtered to remove the course grain product (distillers grain) which can then be sold as wet distillers grains (WDG) or dried and sold as dried distillers grains (DDG). The remaining liquid portion is called thin stillage and can be subjected to evaporation which will leave a syrup like substance called condensed distillers solubles (CDS). These solubles can then be added back to the distillers grains to improve the nutrient profile and increase the value of the by-product as a livestock feed of wet distillers grains with solubles (WDGS) or dried distillers grains with solubles (DDGS).

Starch makes up about two-thirds of the composition of the grains used in the dry-milling process. Therefore, when the starch is removed as ethanol the nutrient profile of the distillers grains is about three times more concentrated that that found in the original grain. On a dry matter (DM) basis the NRC (2000) reports the nutrient profile of DDGS as 29.5 % CP, 27.2 % DIP, 53.8 % UIP, 46 % NDF, 10.3% fat, 0.83% P, and 0.4% S.

About 55% (Firkens et al., 1984) to 66% (Ham et al., 1994) of the protein in DDGS bypasses rumen degradation which can be useful when considering cattle diets that lack UIP. The UIP content in DDGS along with its high metabolizable energy value (3.18 Mcal/kg; NRC, 2000) relative to other high-energy feeds like corn (3.18 Mcal/kg; NRC, 2000) and corn gluten meal (3.04 Mcal/kg; NRC, 2000) make it an attractive supplemental energy source for grazing cattle. Also attractive is the fact that there is no starch in DDGS which is related to decreased fiber digestion and forage intake. DDGS is intermediate in fiber content (46% NDF) compared to common fiber sources in feed supplements such as soybean hulls (66.3% NDF) and wheat midds (35% NDF) while being higher in CP% and energy. The unique nutrient composition of DDGS makes it an attractive feed supplement for grazing cattle in many situations.

Morris et al. (2006) supplemented steers grazing native summer Nebraska Sandhills range with DDGS at varying levels (0.26, 0.51, 0.77, and 1.03% of BW). They reported a linear increase in average daily gains as DDGS supplementation increased. The authors reported a 0.07 lb increase in daily gain per pound of increased DDGS supplementation. Another Nebraska study (Gustad et al., 2006) also reported similar results with yearlings grazing corn stalk residue. However, their results yielded a quadratic increase in daily gains as supplemental DDGS increased from 1.5 lbs/day to 6.5 lbs/day with diminishing gain returns once the supplementation rate became higher than 1.1% of BW. Morris et al. (2006) also reported that predicted forage dry matter intake (DMI) decreased linearly as ADG increased linearly with increasing levels of DDGS supplementation. In a summary of literature Klopfenstein et al. (2007) reported an average increase of 0.13 pounds per day for each 1.0 pound of distillers grain supplemented to summer grazing yearling steers on smooth bromegrass and native range in Kansas and Nebraska. The authors also noted an average substitution rate of 0.48 pounds of forage per pound of distillers grain supplemented.

A Nebraska study conducted by Loy et al. (2008) used heifers fed ad libitum grass hay and evaluated the effects of supplementation of DDGS, dried rolled corn (DRC), or DRC plus corn gluten meal (DRC+CGM). The supplements were fed individually at rates of 0.21 % of BW (LOW) or 0.81 % of BW (HIGH). DRC and DRC+CGM were fed at rates that equaled the energy and UIP supplied by DDGS. At a LOW supplementation rate heifers fed DDGS had improved gain and gain to feed ratio (G:F) compared with heifers fed DRC or DRC+CGM. Average daily gain and G:F were similar for heifers fed DDGS and DRC+CGM and both were improved compared to DRC at the HIGH supplementation level. The authors noted that the increased BW gains may have been due to a positive UIP response to DDGS and DRC+CGM compared to the DRC in addition to the reduction in starch content compared to the DRC that could have decreased fiber digestibility as noted with high starch-supplements.

Greenquist et al., (2009) compared the effects of applying N fertilizer to smooth bromegrass pastures or providing a DDGS supplement to steers. Treatments included: (1) non-fertilized pastures stocked at 6.8 animal unit months AUM / ha (CONT), (2) fertilized pastures with 90 kg of N / ha and stocked at 9.9 AUM / ha (FERT), and (3) non-fertilized pastures stocked at 9.9 AUM / ha and steers received 2.3 kg DDGS per head per day (SUPP). Higher crude protein levels were reported for bromegrass that received fertilizer over other treatments. However, BW gains were greater for steers fed DDGS over unsupplemented cattle. Body weight gain / ha was increased for steers fed

DDGS and steers that grazed fertilized pastures over steers that grazed non-fertilized pastures due to the fact that stocking rates were increased compared to CONT. Supplementation of DDGS allowed stocking rate to increase to the same level of FERT while maintaining similar standing crops probably due to the substitution effect of DDGS on forage intake all while improving steer performance. The authors suggested that the improved cattle performance was likely due to the additional energy content of DDGS as well as the UIP which would help correct a MP deficiency. This study showed that DDGS could be effectively used as a supplement for grazing cattle to increase stocking rates and improve performance, and the use of DDGS could effectively be used as a substitute for nitrogen fertilizer.

Nitrogen in cattle grazing programs

The mechanization and increase in production of American agriculture after World War II has been well documented, and much of the improvement in production was in large part due to the large supply of cheap N fertilizer. In many agricultural systems N is a limiting factor for crop and forage production second only to water. Therefore, the use of N fertilizer increased drastically in order to reach maximum yield potentials of row crops for feed, fiber, and fuel as well as grasslands for livestock grazing and hay production. However, the last 20 years have seen a dramatic increase in cost of N fertilizer causing many producers to question the economic viability of fertilizing. In more recent years interest has risen in the area of environmental quality due to the possible negative effects of leaching of nutrients from agriculture production systems caused by excessive application and excretion of nutrients.

Nutrient cycle. Nutrients enter pasture systems as inorganic and organic fertilizers, stored manure, supplemental feed, N_2 fixation, and atmospheric deposition (Rotz et al., 2005). However, nutrients exit the system only as animal products, forage removal from hay production, or losses to the environment (i.e. leaching and gaseous emissions). In grazing systems, animals only utilize 50 to 80% of annual forage production of pastureland (Rouquette et al., 1980; Teague et al., 1996). However, Rotz et al. (2005) reported that recovery of consumed nutrients in ruminant animal products such as meat and milk is only 5-30%. Thus, N from plant litter and animal excreta have a role in N availability for forage growth. Groot et al. (2003) concluded that long-term N losses can be reduced only by improving N recovery by both plants and animals. With such low proportions of nutrients being converted to usable products there is great potential to recycle inputs to increase nutrient retention.

The need to understand nutrient cycles is important in order to understand how nutrients can be utilized more efficiently in grazing systems. Nutrient cycles are very complex, but in general the cycles of nutrients in agricultural systems are more difficult to understand because of environmental factors such as climate, management differences from farm to farm, and the introduction/removal of livestock into a system. Jarvis et al. (1995) stated that the addition of livestock to a farm increases the complexity and dynamics of nutrient cycling because of chemical and biological transformations that occur during digestion and after excretion. Livestock accelerate nutrient cycling directly through decomposition and excretion of plant-derived nutrients and indirectly through the effects of grazing and excreta on soil microbiota (Bardgett and Wardle, 2003).

In natural ecosystems, the amount of biomass produced by living organisms is often limited by the supply of available N. For most microorganisms and plants, the N must be either ammonium (NH_4^+) or nitrate (NO_3), and for animals it must be mainly in the form of protein (Whitehead, 1995). Nitrogen is found in many forms in agricultural systems including ammonium and nitrate as well as several forms of N gases such as ammonia (NH_3) and nitrous oxide (N_2O). While these inorganic forms are contributors to environmental N, Greenquist (2008) suggested that the N concentration in soil organic matter from grasslands represents about 95% of total N in the soil. Soil N varies between 2000 to 4000 kg/ha in arable soils and 5000 to 15000 kg/ha in long-established grasslands (Whitehead, 1995). Therefore, total soil N differences generally reflect differing levels of soil organic matter accumulation.

Soil organic matter is the largest nutrient reservoir in a grassland ecosystem (Debeux, 2007) which includes nutrients such as N and P. Soil organic matter, which ranges in different soils from almost nil to about 70% of the soil weight, accumulates slowly, often over hundreds or thousands of years, from the decomposition of plants, animals, and microorganisms (Whitehead, 1995). Also the return of excreta to the soil and biological fixation from legumes adds to soil organic matter N concentrations. Whitehead (1995) suggested the amount of N mineralized from organic matter, plus that deposited from the atmosphere, is sufficient to produce only low crop yields. Therefore, intensive farming systems receive additional NH_4^+ and NO_3 through the application of commercial fertilizers.

Industrial fixation of atmospheric N must also be considered when exploring the N cycle and inputs into agricultural systems. Fixation is the process of converting gaseous N into nutrients such as NH_4^+. Whitehead (1995) described the industrial production of fertilizer N as a process of mixing atmospheric N_2 with hydrogen, and passing the mixture over a catalyst at a high temperature and pressure to form ammonia (NH_3). Most of the NH_3 is then chemically converted to one of the main forms of fertilizer N (i.e. urea, ammonium nitrate, or ammonium phosphate). When applied to grasslands these forms of fertilizer N are very readily available for plant uptake. In addition to the N inputs from organic N and fertilizer N small amounts of fixed N, mainly as NO_3 and NH_4^+, are added to soils and vegetation through rainfall and dry deposition from the atmosphere (Whitehead, 1995).

Nitrogen inputs are typically measured as fertilizer application, atmospheric deposition, supplemental animal feed sources, and organic matter N. Recommendations for N inputs are usually determined by a single soil test at one point in time. Aside from the mineralization of organic N these inputs can be reasonably estimated. However, the system gets more complicated when considering N outputs. In grazing systems the only desirable output is in animal products such as weight gain in growing cattle.

Grazing animals utilize 50-80% of annual forage production and have a nutrient recovery of 5-30% of ingested nutrients. Therefore, N that is not initially used in forage production or recycled back to the soil from animal excreta and decomposing plant residue (surplus N) is subject to loss from the system by leaching and denitrification. This reveals why improvements of nitrogen recovery are so important when managing soil organic matter, industrial fertilizers, or atmospheric deposition to plant usable N. Whitehead (1995) reported that the N cycle is much more simple to understand if it is broken down into subcycles of N in the atmosphere, N circulating between soils, plants and animals, and a third involving soil microorganisms and their processes of mineralization and immobilization. However, it is important to understand that at points within the cycle there are various alternative N transformations that may occur.

As discussed, soil organic N makes up a large portion of the N within a grazing system with much of the N coming from decomposing plant tissue, animal excretion, microbial biomass and biological fixation. Nitrogen from soil organic matter can lay idle for many years or it may undergo mineralization from soil microorganisms to become inorganic N. Plants can then use the absorbed NO_3 and NH_4 to synthesize proteins which are removed by grazing animals or returned to the soil in plant residue. Also, nitrification is very important in that various forms of organic, fertilizer, and atmospheric N are converted to plant usable NH_4 and NO_3. Interactions among N mineralization, immobilization, and nitrification control soil NH_3 and NO_3 concentrations (Shi et al., 2004). Plant usable inorganic N is available as mineralized organic N, industrial fertilizer, fixed N from the environment, and urinary excretion from grazing animals. However, Rotz et al. (2005) suggested that once production is maximized with respect to soil N, (resulting in surplus N) all further inputs are lost to the environment. Trott et al. (2004) indicated that N surpluses are an accurate predictor for N losses. Their five year study in Germany found that as N inputs increased in various systems surplus N also increased. This surplus N is likely lost from nitrate leaching from rainfall events, ammonia volatilization into the atmosphere, and nitrification and subsequent denitrification of N molecules to produce nitrogen gas emissions. Whitehead (1995) suggested that amounts of nitrate leached and of ammonia volatilized are likely to be 50 times greater from intensively fertilized and heavily grazed grassland than from unfertilized and lightly grazed grassland. Some transformations in the N cycle occur slowly and may take years to detect significant changes, whereas others occur rapidly and take only days for N to be recycled and utilized by the soil, plants, and animals or lost to the atmosphere (Greenquist, 2008).

Nitrogen metabolism in ruminants. In the context of nutritional value of feed for livestock, the concentration of total N is often expressed as 'crude protein' (CP). This is the concentration of total N multiplied by 6.25, a factor derived from the average concentration of N in plant proteins. Because it is based on total N, the CP includes both genuine protein and other nitrogenous constituents such as amino acids and peptides (Whitehead, 1995). Protein is the basic structural material from which all body tissues are formed. Therefore, adequate protein is essential for an animal's growth and development as well as the maintenance of body tissue (Cullison and Lowrey, 1987).

Digestion of nutrients in ruminants occurs primarily in two main phases. The first occurs in the rumen and is initiated by rumen microorganisms and the enzymes that they produce. The second phase of digestion occurs in the intestines as enzymes produced by the animal respond to residual dietary material and the microbial material produced during the first phase (Whitehead, 1995).

Microbial growth in the rumen is influenced by the amount of energy and protein available in the diet, and the ratio between them influences the utilization of dietary N. The utilization of dietary N is highest when the ratio of available N and available energy in the diet is optimal for the amount of weight gain being produced. Grazing immature plants often presents a situation in which the ratio of dietary N to energy is higher than optimum creating excess protein that leads to a relatively high proportion of excreted urea. In this situation a more balanced ratio can be achieved by providing supplemental energy. Inversely, as plants mature the protein content of the forage may be insufficient to ensure that the available energy is utilized completely. In this situation, increases in production can be obtained by providing supplementary protein (Whitehead, 1995). Whitehead (1995) also suggested that utilization of N might also be improved if the diet were modified to increase the supply of intact protein that is available to the small intestine.

More than half of the dietary protein is hydrolyzed to peptides and amino acids which are subsequently deaminated (Orskov, 1992) which results in much of the ammonia and free amino acids assimilated into microbial protein (MP) (Whitehead, 1995). Ammonia not incorporated into MP diffuses through the rumen wall and is converted to urea in the liver and a portion is recycled back into the rumen via the bloodstream or through saliva. Urea that is not recycled is excreted in the urine of the animal. The remaining microbial and dietary protein in the small intestine is then passed into the large intestine where bacterial populations can provide some additional fermentation. Any remaining undigested dietary or microbial protein is then excreted in feces (Whitehead, 1995).

Rotz et al. (2005) reported that regardless of diet, N excretion in dung was constant at about 8 g/kg of feed consumed, but the proportion of excreted N in urine increased as the dietary protein concentration increased. This is important because, whereas much of the dung content is in organic form and relatively immobile, urinary N can be readily mineralized to useable N (Jarvis et al., 1995) available for plant uptake.

However, a small proportion of organic soil N from dung is converted to ammonium and/or nitrate, and thus becomes available for uptake by plants more quickly.

Summary

Summer grazing of warm season perennial grasses in the southern Great Plains is a vital part of growing beef cattle to heavier weights prior to the feedlot/finishing phase. It is important geographically due to the location of feedyards and also the climate which provides a temperate environment with adequate rainfall and moderate temperatures to provide abundant forage resources. However, for the grazing program to be sustainable there must be proper management to maintain a forage base, achieve acceptable BW gains, and ensure economic success, while also reducing losses or inefficiencies of the entire program. Grazing Old World bluestem grasses has proven to be effective for stocker cattle production. However, care must be taken when making management decisions such as stocking rate, fertilization, and supplementation. They all have different effects on forage availability, quality, cattle performance, and efficiency of the grazing system. This has become especially important as inputs such as feed and fertilizers have increased in price while potential losses of nutrients have become a topic of increased societal concern. Therefore, it is important to adopt sustainable management practices.

It has been observed that supplementing DDGS to growing cattle grazing cool-season smooth bromegrass is effective in replacing N fertilizer by increasing cattle weight gains (Greenquist et al., 2009) and improving N use efficiency (Greenquist et al., 2011).

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CHAPTER III

STOCKER CATTLE PERFORMANCE AND NITROGEN USE EFFICIENCY IN OLD WORLD BLUESTEM GRAZING PROGRAMS

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ABSTRACT

In grazing systems only 5-30% of ingested nitrogen (N) is retained in BW gain of growing beef cattle. A two-year study was conducted to evaluate N fertilizer and DDGS as sources of N and N use efficiency for growing beef cattle grazing Plains Old World bluestem. In year 1 (2010) heifers (n= 235; 274 ± 33 kg BW) grazed 12 pastures (3 pastures/treatment) from May 18 – Sept. 28 and in year 2 (2011) steers (n= 233; 238 ±23 kg BW) grazed 12 pastures from May 17 – July 19 in a completely randomized design comparing 4 treatments: (1) non-fertilized, low-stocked (336 kg of BW/ha) pastures (CONT); (2) N fertilized (90 kg N/ha), high-stocked (672 kg of BW/ha) pastures (NFERT); (3) N and phosphorus (P) fertilized (90 kg N/ha; 39 kg P/ha), high-stocked pastures (NPFERT); and (4) non-fertilized, high-stocked pastures plus supplementation of dried distillers grains with solubles (DDGS; 0.75% BW$\cdot$hd$^{-1}\cdot$d^{-1}). Year 1 weight gain per hectare (kg/ha) was highest *($P < 0.01$)* for treatment 4 and lowest for treatment 1 with 2 and 3 being intermediate. Year 2 weight gain per hectare (kg/ha) was highest ($P < 0.01$) for treatments 3 and 4 and lowest for treatment 1 with 2 being intermediate. Treatment 1 had the lowest gain/ha due to the difference in stocking rate. In both years total N inputs (kg/ha) for treatment 4 were greater ($P < 0.01$) than treatment 1, and both were less than treatments 2 and 3. In both years N retention in BW gain/ha for treatment 4 was higher ($P < 0.01$) compared with treatments 1, 2, and 3, respectively. N recovery (%) was greatest ($P < 0.01$) for treatment 1 because of the low N inputs. However, replacing N fertilizer with DDGS supplementation improved ($P < 0.01$) N recovery by 3.0-fold in year 1 and by about 5-fold in year 2 compared with treatments 2 and 3, respectively. These data indicate that DDGS can be effectively used in stocker cattle grazing programs to increase stocking rates, increase BW gain/ha, and increase N recovery of the grazing program.

Key Words: Growing cattle, summer pasture, fertilization, dried distillers grains, N recovery

INTRODUCTION

In the southern Great Plains the grazing of warm-season perennial grasses is a common practice for adding weight to growing beef cattle while striving to achieve acceptable body weights for entrance into feedlots. Several species of introduced warm-season forages are grazed throughout the summer months, and many of these introduced species respond well to nitrogen (N) fertilization. The use of N fertilizer is a common practice to increase forage yields in these grazing programs. Berg (1990) found an almost linear yield response by Old World bluestem (*Bothriochola ischaemum* L.) to N fertilizer up to 70 kg N $ha^{-1}yr^{-1}$. This increase in yield would result in greater forage mass and increased stocking rates resulting in improved average daily gains (ADG) as reported by Ackerman et al. (2001). However, Wilkinson and Langdale (1974) reported that as N application rates increased, N fertilizer retention in beef gain decreased on warm season grasses in the southeastern USA. Therefore, reducing N applications rates and replacing N fertilizer with a N-rich, by-product feedstuff could result in greater N recovery in beef cattle grazing programs.

Dried distillers grains with solubles (DDGS), a co-product of the ethanol production industry, has proven to be an effective feed source for both grazing and confinement beef cattle programs. The improvement in ADG by DDGS supplemented grazing cattle has been widely documented (Klopfenstein et al., 2007). DDGS is typically a cost effective feed that is high in energy, protein, and phosphorus (P). Rotz et al. (2005) suggested that only 5-30% of ingested nutrients are removed from production systems in animal products such as BW gain. This results in excess N and P excreted by the animals to be recycled by the soil, plants, or lost to the atmosphere. The importance of managing nutrients in cattle production systems has been accentuated in recent years due to the increased concerns of environmental impacts as well as the economic advantage of effectively utilizing these nutrients. This provides a unique opportunity for cattle grazing systems to improve nutrient retention and recycling resulting in a more sustainable grazing program that benefits the forage and improves weight gains and economic returns for cattle producers.

There have been documented improvements in weight gain (Greenquist et al., 2009) and N use efficiency (Greenquist et al., 2011) when replacing fertilizer with DDGS in cattle programs grazing smooth bromegrass (*Bromis inermis*), a cool-season perennial grass commonly found in the northern Great Plains. Therefore, a two-year study was conducted to examine the effects of DDGS supplementation and fertilization strategies on grazing performance, forage growth characteristics, N recovery, and economics of stocker cattle grazing Plains Old World bluestem.

MATERIALS AND METHODS

Procedures for animal care, handling, and sampling were approved by the Oklahoma State University Institutional Animal Care and Use Committee before initiation of these studies.

Research Site

Two grazing trials were conducted in 2010 and 2011 at the Crosstimbers-Bluestem Stocker Range located 11 km southwest of Stillwater, OK. The primary soil types at this site are: Coyle Loam, Coyle-Lucien complex, Grainola-Lucien complex, Renfrow loam, Stephenville-Damell complex, Stephenville fine sandy loam, and Zaneis loam. Twelve pastures of Plains Old World bluestem (*Bothriochloa ischaemum* L. Keng.) ranging in size from 4.07 to 10.64 hectares and averaging 8.7 hectares were used in this study. Total precipitation for the months of March, April, May, June, July, August, and September was 65.91 cm during 2010, and 36.98 cm during 2011 compared to the 14 year (2000-2014) average of 61.72 cm (Table 1).

Cattle Management

Year 1. Two-hundred and twenty-four mixed-breed yearling heifers (274 ± 33 kg BW) purchased from two different livestock markets were used in the trial. Heifers were received April 16, 2010 and the following day were administered an estradial trenbolone acetate implant with Tylosin tartrate (Component TE-G with Tylan, Elanco Animal

Health; Greenfield, IN), a modified-live virus respiratory vaccine (Bovi-Shield Gold, Pfizer Animal Health; Florham Park, NJ), a 7-way clostridial vaccine (Vision 7 with Spur, Merck Animal Health; Summit, NJ), an injectable dewormer (Dectomax, Pfizer Animal Health; Florham Park, NJ), and were hip branded per the owners request for identification. The 133-d trial was initiated on May 18, 2010. Heifers were held off of feed and water for approximately 12-h to minimize the effect of fill (shrunk BW) and an initial BW (IBW) was measured and heifers were randomly allotted to the 12 pastures with equal proportions from each source in each pasture. Each heifer received a visual identification ear tag. On July 20 (day 63) or the approximate midpoint of the grazing season a shrunk BW (MBW) was measured. On July 21 (day 64) and continuing throughout the remainder of the trial all cattle not receiving DDGS were supplemented with a 0.45 kg/day of a 40 % CP cottonseed meal-based supplement (Table 2) prorated for a 3-d per week feeding program. This was done as a means to maintain acceptable gains throughout the rest of the growing season as the forage CP decreased. A final shrunk BW (FBW) was measured on September 28, 2010 (d133). All shrunk BWs were measured after a twelve-h removal from feed and water to minimize the effect of fill.

Year 2. Two-hundred and thirty-three mixed-breed steers (237.9 ± 23 kg) sourced from two different livestock markets were used in the trial. Steers were received March 16, 2011 from Wheeler Brothers Feedyard (Watonga, OK) where they had been backgrounded on a silage-based diet for approximately 35-d. Upon arrival at the Crosstimbers range steers were administered an estradial trenbolone acetate implant with Tylosin tartrate (Component TE-G with Tylan, Elanco Animal Health; Greenfield, IN), a modified-live virus respiratory vaccine (Bovi-Shield Gold, Pfizer Animal Health;

Florham Park, NJ), a 7-way clostridial vaccine (Vision 7 with Spur, Merck Animal Health; Summit, NJ), an injectable dewormer (Ivermec Plus, Merial; Duluth, GA) and hip branded per the owners request. The 63-d trial was initiated on May 17, 2011. Steers were shrunk and an initial BW (IBW) was measured and steers were randomly allotted to the 12 pastures and each steer was identified by a visual ear tag. On July 19 (d-63) a shrunk BW (FBW) was measured. Day 63 was the targeted midpoint of the trial, but due to severe drought during the summer of 2011 the trial was terminated because of inadequate amounts of forage and the possibility of forage stand damage of continued grazing. All shrunk BWs were measured after a twelve-h removal from feed and water to minimize the effect of fill.

Experimental Design and Treatments

Our objective was to compare cattle performance, nitrogen recovery, forage characteristics, and economic returns of four different stocker cattle summer grazing programs. Therefore, in a randomized complete block design, pastures were blocked by 1 of 2 locations and randomly assigned to one of four treatments: (1) control, targeted stocking rate of 336 kg of BW/ha and no fertilizer or DDGS supplementation (**CONT**); (2) targeted stocking rate of 672 kg of BW/ha and 90 kg of N/ha with no DDGS supplementation (**NFERT**); (3) targeted stocking rate of 672 kg of BW/ha, 90 kg of N/ha and 39 kg of P/ha with no DDGS supplementation (**NPFERT**); (4) targeted stocking rate of 672 kg of BW/ha and no fertilizer with DDGS supplementation at a level of 0.75% of BW/day (**DDGS**) prorated for a 5-d per week feeding program. Cattle were stratified by initial BW and randomly assigned to one of 12 pastures that totaled 104 ha and averaged 8.7 ha. Assignment of treatments was the same for each of the two years. Because of variations in cattle weights during each year, actual stocking rates (CONT 355 and 389, NFERT 659 and 716, NPFERT 683 and 718, DDGS 695 and 706 kg/ha; for 2010 and 2011 respectively) were different than the targeted stocking rates. Fertilizer was applied to pastures as a single application on April 29, 2010 and May 4, 2011. Broadleaf herbicide was also applied to all pastures on April 29, 2010. All cattle had ad libitum access to rural water in open tanks and plain salt throughout the grazing season.

Sampling Procedures

In each year of the study forage mass and quality samples were collected once per month throughout each trial to measure forage mass and quality in each pasture. Samples for measurement of forage mass were collected at approximately 1 sample per 2.5 hectares per pasture using GPS units to ensure that samples were collected from approximately the same locations within each pasture. Forage mass samples were collected using a 0.19 m^2 frame as a clipping guide and forage was hand-clipped to ground level. Final forage yield samples were also collected at the end of the growing season from 3 grazing exclosures (approximately 1.67 m^2 each, 6-feet x 6-feet x 6 feet triangle x 5-feet tall) placed throughout the pastures. One sample per exclosure was collected using a 0.19 m^2 frame. Three samples (approximate front 1/3, middle 1/3, and back 1/3 of each pasture) were collected monthly for measurement of forage quality by hand-clipping the top 1/3 of the standing forage. Samples of DDGS and protein supplement were collected weekly throughout the grazing trials and were composited by month for later analysis. Forage quality samples were ground and composited by pasture within clipping date.

Laboratory Analysis

All forage, DDGS, and protein supplements were dried at 55˚C in forced air ovens to constant weights. Dried weights were used to calculate forage and feed DM content and forage mass (kg DM/hectare). Forage quality and feed supplements were then ground through a 2-mm screen in a Wiley mill (Thomas Scientific, Philidelphia, PA). Forage quality samples, DDGS, and protein supplements were analyzed for ash (combusted in a 500º C muffle furnace), CP (%N x 6.25; Truspec-CN LECO Corporation, St. Joseph, MI), and sequential NDF-ADF (Ankom Tech Corporation, Fairport, NY).

Mineral analysis of the forage, DDGS, and protein supplements was conducted by the Oklahoma State University Soil, Water and Forage Analytical Laboratory. Samples that were previously ground through a 2-mm screen in the Wiley mill were then ground through a 1-mm screen using a Cyclone Sample Mill (Udi Corp., Fort Collins, CO). Then 0.5 g of the samples were digested with 10 ml of trace metal-free grade nitric acid (67-70 % NHO_3) in a vessel and allowed to sit for 1 h. Samples were then placed in a MDS 2000 Microwave Digestion System (CEM Corporation, Matthews, NC) and three cycles (6, 6, and 10 minutes; respectively) were used to digest the samples. The liquid was transferred to 50 ml closed top tubes and 40 ml of distilled water was added to dilute the samples. Minerals were analyzed by ICP for mineral concentrations.

Nitrogen Retention by Cattle

Nitrogen inputs for each pasture included feed N consumed as well as fertilizer N applied and an estimate of atmospheric N deposition from the National Atmospheric Deposition Program's Oklahoma collection sites. Nitrogen recovery was calculated as N retained in BW gain divided by total N inputs and reported as a percentage of recovery.

Protein content of BW gain of the cattle was calculated from equations in Chapter 3, "Growth and Body Reserves", in the Beef Cattle NRC (2000). Abbreviations in these equations are as follows: EBG- empty body gain, kg; EQSBW- equivalent shrunk body weight in kg; SBW- shrunk body weight in kg; SRW- standard reference weight for the expected final body fat (478 kg for animals finishing at small marbling or 28 % body fat); FSBW- actual final shrunk body weight at the body fat endpoint (580 kg estimate was used in year 1; 591 kg estimate was used in year 2); EQEBW- equivalent empty body weight, kg; RE is retained energy in Mcal/day; NPg is net protein gain in g/day; NN is net nitrogen in g/day. Initial and final shrunk body weights of the cattle as previously described were used.

EBG, kg = 0.956*SWG Eq. 3-4/3-5

EQSBW, kg = SBW*(SRW/FSBW) Eq. 3-9

EQEBW, kg = 0.891*EQSBW Eq. 3-4/3-5

RE, Mcal/day = $0.0635 \cdot EQEBW^{0.75} \cdot EBG^{1.097}$ Eq. 3-1

NPg, g/day = SWG*(268-(29.4(RE/SWG))) Eq. 3-8

NN, g/day = NP*0.16

Economic Analysis

Economic analysis of data for each year was conducted using prices incurred at the time of the trials for all commodities. Inputs or expenses included current cattle purchase value (based on USDA reports of OKC National Stockyards) of the same class and BW at the dates closest to the beginning dates of the trials, fertilizer prices paid at time of application, and feed prices paid at the time of delivery. Revenues were calculated as the current cattle sale value (based on USDA reports of OKC National Stockyards) for the same class and BW of feeder cattle at the dates closest to the ending dates of the trials. Returns were calculated as the difference in revenue and expenses. Returns are reported as returns to land, labor, management, transportation, etcetera.

Statistical Analysis

Cattle performance, forage mass and quality, N recovery, and economic data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Pasture was the experimental unit and block was considered a random effect. The model for analysis of forage mass and quality included treatment, time, and treatment*time interactions as fixed effects. The model for analysis of cattle performance, N retention, and economics included treatment as a fixed effect.

Least square means were compared using the P-DIFF procedure when a significant ($P < 0.05$) F-Test was detected.

Results and Discussion

Year 1 (2010)

Cattle Performance and Nitrogen Recovery. DDGS supplementation increased ($P < 0.05$) overall ADG and total gain of heifers during the grazing season (Table 3) compared to the fertilized treatments but was similar to CONT which had a stocking rate of just over half of DDGS. Period 1 average daily gain of DDGS heifers was improved ($P < 0.05$) compared to heifers in CONT and NFERT treatments but not over heifers in the NPFERT treatment. Throughout Period 2 DDGS and CONT heifers had improved ($P < 0.05$) ADG compared to heifers in NFERT and NPFERT treatments. Similar improvements ($P < 0.05$) were also realized in Final BW. These findings for Period 2 and Final BW could be attributed to a combination of declining forage quality (Table 6, Figures 3, 4, & 5) throughout the grazing season with DDGS receiving additional protein and energy compared to other treatments and also the increase (Table 5) of available forage in the CONT treatment late in the grazing season. Gain per hectare of DDGS heifers was improved ($P < 0.05$) compared to heifers that grazed fertilized pastures, and all three treatments had increased gain/ha compared to CONT. Total gain per hectare was increased by 75%, 80%, and 112%, respectively, for NFERT, NPFERT, and DDGS compared to CONT. This improvement in gain/ha can be attributed to the increased stocking rates of DDGS, NFERT, and NPFERT (695, 659, 683 kg/ha; respectively) compared to CONT (355 kg/ha). These results are similar to an 8-trial summary in which Klopfenstein et al. (2007) reported the increase in cattle performance from supplementing grazing cattle with dried distillers grains with solubles. These findings are also similar to findings reported by Geenquist et al. (2009b) where stocking rates were increased with

DDGS supplementation with no detrimental effects of decreased forage mass likely due to the rate of forage substitution from DDGS supplementation. Nitrogen recovery (Table 4) was greatest ($P < 0.05$) for CONT and lowest for NFERT and NPFERT with DDGS being intermediate. This is a reflection of the very low N inputs of the CONT treatment (7.4 kg/ha) compared to the increased inputs of NFERT, NPFERT, and DDGS (99.4, 99.6, and 38.0 kg/ha; respectively). However, when comparing the DDGS supplemented and fertilized treatments DDGS supplementation improved N recovery by 3.0-fold compared to NFERT and NPFERT. Economic returns (Table 7) per head were highest ($P < 0.05$) for CONT ($110), lowest for NFERT and NPFERT ($39 and $36), and intermediate for DDGS ($68). However, returns per hectare were greatest ($P < 0.05$) for DDGS ($172), intermediate for CONT ($139), and lowest for NFERT and NPFERT ($93 and $90). This is important in the stocker cattle industry where profitability is improved when returns per land area are increased. These data are in contrast with data of Greenquist et al. (2009a) due to a year effect in which the cattle price slide structure discounted the heavier DDGS cattle. However, the data are in agreement with Watson et al. (2012) who reported similar ranks of profitability. Greenquist et al. (2009b) and Watson (2012) stocked steers at 6.8 AUMs grazing unfertilized bromegrass pastures, 9.9 AUMs on bromegrass pastures fertilized with 90 kg/ha of N, or supplemented with 2.3 kg/day or 0.6% of BW of DDGS. Both studies attributed the increase in animal performance from DDGS to the combination of added MP throughout the grazing season as forage quality declined, added UIP compared to other common protein supplements, and added energy content. Data from MacDonald et al. (2007) support the suggestion that added UIP and energy increased gains of stocker cattle grazing smooth bromegrass. They reported that supplementing heifers with DDGS on smooth bromegrass pastures increased weight gains compared to corn gluten meal (UIP equivalent to that provided by DDGS) or corn oil (energy equivalent to that provided by DDGS). Since neither corn gluten meal or corn oil treatments increased weight gains independently they concluded that the combination of UIP and added energy in DDGS are vital in making it an ideal grazing supplement.

Forage Mass and Nutritive Value. Forage mass for all treatments averaged 5675 kg per hectare and was affected by treatment ($P < 0.05$; Table 5). CONT (6290 kg/ha) had the greatest forage mass and NFERT, NPFERT and DDGS did not differ (5192, 5656, and 5563 kg/ha; respectively). Forage yield (Table 5) collected at the conclusion of the trial from grazing exclosures within pastures did not differ ($P < 0.05$) among treatments. Treatment affected ($P < 0.05$) the CP (Table 5) of forage with NFERT and NPFERT (10.23 and 10.36% CP) being greater than CONT and DDGS (9.25 and 9.38% CP). This is consistent with data of Berg and Sims (1990) who reported an increase in forage CP as N fertilization rate increased up to 102 kg N/ha. Treatment did not affect ($P < 0.05$) NDF or ADF content of the forage (Table 5). Treatment also did not affect ($P < 0.05$) mineral concentrations (Table 5) for phosphorus (P), calcium (Ca), potassium (K), sodium (Na) or sulfur (S). However, treatment did affect ($P < 0.05$) magnesium (Mg). Treatment means for each sampling date are reported in Appendix Table 1.

Forage mass increased ($P < 0.05$; Table 6, Figure 2) from June - August (4432, 5594, and 6776 kg/ha; respectively) but decreased in September (5824 kg/ha) at the conclusion of the trial. These changes in forage mass are typical of what a grazing manager would hope for with proper stocking rates in a normal precipitation year for a season-long summer grazing program. Date of collection also affected (P < 0.05) forage CP content (Table 6, Figure 3). CP decreased (P < 0.05; Table 6, Figure 3) from June - August (12.46, 9.46, and 8.39% CP; respectively) but was increased at the final clipping in September (8.91 % CP). This is similar to results of Teague et al. (1996) where their heaviest stocking rate resulted in the lowest forage mass and an increase in forage quality. Date also affected (P < 0.05) NDF and ADF content (Table 6, Figures 4 and 5). Neutral detergent fiber was lower (P < 0.05) in June and August (64.24 and 65.19 % NDF) than it was in July and September (68.26 and 68.13 % NDF). Acid detergent fiber was higher (P < 0.05) in September (36.55 % ADF) compared to June, July, and August (32.70, 32.33, and 32.97 % ADF; respectively). The reduction in NDF for the August collection may be related to timing of rainfall and a flush of new forage growth which coincided with the increased August forage mass measurement (Table 6, Figure 2) and the higher CP measurement from the September clipping (Table 6, Figure 3). However, the increase in ADF content is consistent with data of Dabo et al. (1988) for changes in forage components in Old World bluestem as forage maturity increased. Collection date also affected (P < 0.05) mineral concentrations (Table 6) for phosphorus (P), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) or sulfur (S).

Year 2 (2011)

Cattle Performance and Nitrogen Recovery. During year 2 of this study drought conditions (Table 1) altered the schedule of grazing and the trial had to be terminated and pastures destocked on July 19 due to the drastic decrease of forage mass. This was originally intended to be the trial midpoint. Therefore, BW data were only collected and analyzed from an initial weight and a final weight. DDGS supplementation and NPFERT increased ($P < 0.05$) ADG and total gain (Table 8) of steers during this period compared to steers in NFERT, and CONT treatments. Final BW and total BW (Table 8) gain followed the same trend of improvement ($P < 0.05$) for DDGS and NPFERT compared to steers in NFERT and CONT treatments. DDGS and NPFERT steers also had the highest ($P < 0.05$) gain/ha (Table 8) with NFERT being intermediate and CONT being the lowest. Total gain per hectare increased by 93%, 131%, and 146% for NFERT, NPFERT, and DDGS compared to CONT. This improvement in gain/ha can be attributed to the increased stocking rates of DDGS, NFERT, and NPFERT (706, 716, 718 kg/ha; respectively) compared to CONT (389 kg/ha). Based on the NRC (2000) requirements for minerals listed in Table 10 phosphorus was a limiting nutrient from forage (Table 10) alone in the CONT, NFERT, and DDGS treatments. Therefore, increased P content in the NPFERT forage (Table 10) and the DDGS supplement (Table 2) was enough to satisfy the deficiency and allow cattle BW gains to improve compared to CONT and NFERT. Nitrogen recovery (Table 9) was greatest ($P < 0.05$) for CONT and lowest for NFERT and NPFERT with DDGS being intermediate. This is reflective of the low N inputs of the CONT treatment (6.0 kg/ha) compared to the increased inputs of NFERT, NPFERT, and DDGS (96.0, 96.0, and 22.0 kg/ha; respectively). However when comparing DDGS supplemented and fertilized treatments DDGS supplementation improved N recovery by 5.6 and 4.7-fold compared to NFERT and NPFERT, respectively. These data are similar to both Greenquist et al. (2009b) and Watson et al. (2012) that DDGS can be used to increase stocking rates, improve weight gains, and improve nitrogen recovery of grazing programs. Due to the increased Final BW (Table 8) and the cattle sale market structure, the added weight of DDGS steers was rewarded and economic returns (Table 12) per head were highest ($P < 0.05$) for DDGS ($165). Returns per hectare were greatest ($P < 0.05$) for DDGS ($490) and NPFERT ($440), lowest for CONT ($249) and intermediate for NFERT ($361). Although returns/ha for DDGS and NPFERT were statistically similar it would be very difficult to argue with the cattle owner that a $50/ha increase in profitability was not significant. This is in contrast to Greenquist et al. (2009a) data due to a year effect in which the cattle price slide structure discounted the heavier DDGS cattle. However, these data are in agreement with Watson et al. (2012) who reported similar profitability opportunities to our data. Greenquist et al. (2009b) and Watson et al. (2012) stocked steers at 6.8 AUMs grazing unfertilized bromegrass pastures, 9.9 AUMs on bromegrass pastures fertilized with 90 kg/ha of N, or supplemented with 2.3 kg/day or 0.6% of BW of DDGS. Both studies attributed the increase in animal performance from DDGS to the combination of added MP throughout the grazing season as forage quality declines, added UIP compared to other common protein supplements, and added energy content. Data from MacDonald et al. (2007) support the suggestion that added UIP and energy increasing gains in grazing cattle. They reported that supplementing heifers with DDGS on smooth bromegrass pastures increased BW compared to corn gluten meal (UIP equivalent to that provided by DDGS) or corn oil (energy equivalent to that provided by

DDGS). Because neither corn gluten meal or corn oil treatments increased weight gains compared to DDGS they concluded that the combination of UIP and added energy in DDGS is vital in making it an ideal grazing supplement.

Forage Mass and Nutritive Value. Forage mass for all treatments averaged 3529 kg per hectare and was not affected by treatment ($P < 0.05$; Table 10). Forage yield (Table 10) collected at the conclusion of the trial from grazing exclosures within pastures showed a tendency ($P < 0.11$) for DDGS to be the lowest (4753 kg/ha) compared to other treatments (CONT: 6306, NFERT: 6664, NPFERT: 8980 kg/ha). This result was not expected as the grazing exclosures were not subjected to grazing and DDGS, similarly to CONT, received no fertilizer. Therefore, this tendency for yield difference was probably due to sampling error. Treatment affected ($P < 0.05$) the CP (Table 10) of forage with NFERT and NPFERT (10.27 and 10.68% CP) being greater than CONT and DDGS (8.33 and 8.48% CP). This is consistent with data of Berg and Sims (1990) that showed an increase in forage CP as N fertilization rate increased up to 102 kg N/ha. Treatment did not affect ($P < 0.05$) NDF or ADF content of the forage (Table 10). Treatment did not affect ($P < 0.05$) mineral concentrations (Table 10) for Ca, K, or S. However, treatment did affect ($P < 0.05$) P concentration, and a tendency was evident for treatment to affect Mg ($P = 0.11$) and Na ($P = 0.06$) concentrations. Phosphorus was highest ($P = 0.05$) for NPFERT with the other treatments being lower in P concentration potentially explaining the improvement in ADG over NFERT and CONT treatments. The tendency ($P = 0.11$) for Mg to be higher for NPFERT follows the trend reported in year 1. Sodium concentration had a tendency ($P = 0.06$) to be higher in the fertilized treatments compared to CONT and DDGS.

Forage mass decreased ($P < 0.05$; Table 11, Figure 7) from June to early July to late July at trial conclusion (4182, 3325, and 3058 kg/ha; respectively). Year 2 forage mass was only 45% of forage mass at the time of the third clipping compared to year 1 (Table 6). In a typical summer grazing period it would not be expected to have the greatest amount of forage availability at cattle turnout. It is interesting to note that even in a drought year forage mass was not different ($P < 0.05$) among treatments even with the nearly doubled stocking rates of NFERT, NPFERT, and DDGS compared to CONT. These data along with the improved gains (Table 8) continue to support the use of DDGS as a way to increase stocking rate and replace N fertilizer in a grazing program. Date of collection also affected ($P < 0.05$) CP content (Table 11). CP decreased ($P < 0.05$; Table 11, Figure 8) for each clipping as time elapsed (15.04, 7.4, and 5.89% CP; respectively). Date also affected ($P < 0.05$) NDF and ADF content (Table 11, Figures 9 and 10). Neutral detergent fiber increased ($P < 0.05$) throughout the trial (60.49, 67.77, and 70.71 % NDF) as did acid detergent (29.76, 34.01, and 37.81; respectively). The increase in NDF and ADF content is consistent with data reported by Dabo et al. (1988) for changes in forage components in Old World bluestem as forage maturity increased. Date of collection also affected ($P < 0.05$) mineral concentrations (Table 11) for phosphorus (P), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) or sulfur (S) concentrations. For each sampling period concentrations of all measured minerals decreased. Treatment means for each sampling period are included in Appendix Table 2.

Year: 2010 vs. 2011

These two years are difficult to compare due to the large difference in precipitation (Table 1). In year 1 heavier weight (274 ± 33 kg) heifers grazed for 133 days. In year 2 lighter weight steers (238 ± 23 kg) only grazed for 63 days before the pastures had to be destocked. However, some generalizations can be made between the two years. In each year CONT was not fertilized and had a targeted stocking rate of 336 kg of BW/ha, NFERT was fertilized with 90 kg/ha of N and had a targeted stocking rate of 672 kg of BW/ha, NPFERT was fertilized with 90 kg of N/ha and 39 kg of P/ha and had a targeted stocking rate of 672 kg of BW/ha, and DDGS was not fertilized and was supplemented with DDGS at 0.75 % of BW/day and had a targeted stocking rate of 672 kg of BW/ha. Actual stocking rates (kg/ha) for both years were higher than the targeted rate due to differences in actual BW of the cattle compared to estimated BW when allotment occurred. Year 2 stocking rates were greater than year 1. Period 1 for year 1 is a nearly identical representation of the dates of the entire trial in year 2. For these periods gain/ha was increased in year two compared to year 1 across all treatments which is consistent with the findings of Ackerman et al. (2001) that lighter weight cattle had greater gains/ha on Old World bluestem compared to heavier weight cattle at three different stocking rates (392, 504, and 840 kg of live weight/ha). In each year DDGS cattle had the highest BW gains per head and per hectare at every period of measurement, but the ranking of treatments behind DDGS differed slightly between year 1 and year 2. Nitrogen recovery was highest for CONT in each year due to the low N inputs for that treatment, but N recovery by steers supplemented with DDGS was greatly improved compared to fertilized treatments. The DDGS treatment also improved economic returns in both years of the study.

Conclusion

Fertilizing Old World bluestem pastures with N or N and P or feeding DDGS at 0.75% of BW/day were found to be effective strategies for increasing stocking rates 2-fold without decreasing cattle performance or forage mass. In each year fertilized pastures increased ($P < 0.05$) BW gain/ha compared with the control, and DDGS increased gain/ha over the fertilized treatments except for NPFERT which had similar gains to DDGS in year 2. Nitrogen recovery for CONT was highest ($P < 0.05$) in both years reflecting the low levels of N inputs to the system. However, when comparing the more intensive grazing programs (NFERT, NPFERT, and DDGS) with higher N inputs, DDGS increased ($P < 0.05$) N recovery by 3.0-fold in year 1 and by about 5-fold in year 2. In each year supplementing DDGS also proved to be effective in increasing profitability compared to the other grazing programs. It is possible to have a year such as the one described by Greenquist et al. (2009a) in which the added BW gain from DDGS supplementation could negatively affect profitability due to the negative price slide of heavier cattle being worth less $/pound. However, in today's cattle markets additional weight gain is typically rewarded to an extent and if that weight was added at a low price then profitability is generally increased. Forage mass was highest for CONT in year 1. However, forage mass was similar between treatments in year 2 of the pastures being subjected to the same treatments. This could be a result of residual fertilizer applied in previous years before initiation of this trial affecting forage mass in year 1 or potentially a result of the the drought in year 2 affecting forage mass to the point that forage mass of all treatments became limited.

In summary supplementing growing beef cattle with DDGS was an effective strategy to increase stocking rates, improve BW gains, improve N recovery, and increase profitability of an Old World bluestem grazing program.

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Table 1. Marena Mesonet Station Rainfall near Crosstimbers Bluestem Stocker Range, cm

	Year		
Item	2010	2011	14 yr Avg (2000-2014)
Month			
March	3.56	1.19	6.35
April	8.69	3.91	8.23
May	17.40	11.71	10.13
June	14.48	6.22	13.91
July	7.04	1.09	8.41
August	6.71	6.58	8.36
September	8.05	6.27	6.32
Total	65.91	36.98	61.72

Table 2. Two year summary of DDGS & protein supplement composition

	Year		
	2010		2011
Ingredient, % as-fed	DDGS	Protein	DDGS
Cottonseed meal	-	80.5	-
Soybean meal	-	11.85	-
Wheat middlings	-	7.5	-
Rumensin 80	-	0.15	-
DDGS	100	0	100
Chemical, % DM			
DM[1]	88.54	90.27	93.36
Ash	5.02	7.34	4.33
CP, % DM	28.25	42.50	26.48
NDF	39.43	29.81	37.22
ADF	14.57	12.75	10.68
P, % DM	1.05	1.16	0.93
Ca, % DM	0.05	0.13	0.03
K, % DM	1.33	1.83	1.15
Mg, % DM	0.41	0.66	0.34
Na, % DM	0.21	0.19	0.15
S, % DM	0.93	0.47	0.62

Table 3. Effect of treatment on heifer performance (2010)

	Treatment[1]					
Item	CONT	NFERT	NPFERT	DDGS	SEM	P-value
Number of heifers	31	63	66	71		
Initial stocking rate, heifers/ha	1.27	2.42	2.51	2.53		
Initial stocking rate, kg/ha	355	659	683	695		
BW, kg						
Initial (May 18, d 0)	279	272	272	275	3.50	0.52
Mid (July 20, d 63)	345	335	341	348	4.40	0.25
Final (Sept 28, d 133)	407^{a}	386^{b}	389^{b}	412^{a}	5.40	0.02
Gain, kg/hd						
Period 1 (63 d)	67^{a}	63^{a}	68^{ab}	73^{b}	1.80	0.03
Period 2 (70 d)	62^{a}	51^{b}	48^{b}	64^{a}	3.40	0.01
Total (133 d)	128^{a}	114^{b}	117^{b}	136^{a}	3.50	0.01
ADG, kg						
Period 1 (63 d)	1.06^{a}	1.00^{a}	1.09^{ab}	1.15^{b}	0.03	0.03
Period 2 (70 d)	0.89^{a}	0.73^{b}	0.69^{b}	0.91^{a}	0.05	0.01
Total (133 d)	0.96^{a}	0.85^{b}	0.87^{b}	1.02^{a}	0.03	0.01
Gain, kg/ha						
Period 1 (63 d)	84^{a}	164^{b}	170^{bc}	183^{c}	5.5	<.0001
Period 2 (70 d)	78^{a}	120^{b}	120^{b}	160^{c}	8.8	<.0001
Total (133 d)	162^{a}	284^{b}	291^{b}	344^{c}	7.2	<.0001

^{abc} Within a row, means without a common superscript differ ($P < 0.05$).

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

Table 4. Effect of treatment on nitrogen use and efficiency (2010)

Item	Treatment[1] CONT	NFERT	NPFERT	DDGS	SEM	P-value
N inputs, kg/ha						
N from feed	2.4	4.4	4.6	33.0	-	-
N from fertilizer	0.0	90.0	90.0	0.0	-	-
N atmospheric deposition	5.0	5.0	5.0	5.0	-	-
Total N inputs	7.4[a]	99.4[b]	99.6[b]	38.0[c]	0.26	<.0001
N retention[2], kg/ha	4.0[a]	7.4[b]	7.5[b]	8.6[c]	0.16	<.0001
N recovery, %	51.7[a]	7.4[b]	7.5[b]	22.5[c]	0.01	<.0001

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

[2] N retention is a calculated value measured as N retained in BW gain of cattle.

Table 5. Effect of treatment on forage mass and nutritive value (2010)

Item	Treatment[1]				SEM	P-Value	
	CONT	NFERT	NPFERT	DDGS		Trt	Cattle Req[2]
Forge DM, %	40.29	42.53	40.13	40.53	1.46	0.46	-
Forage mass, kg/ha[3]	6290[a]	5192[b]	5656[ab]	5563[ab]	385	0.02	-
Forage yield, kg/ha[4]	13,797	10,717	12,627	10,731	1834	0.17	-
OM, %	93.83	93.78	93.64	93.74	0.26	0.73	-
CP, % DM	9.25[a]	10.23[b]	10.36[b]	9.38[a]	0.38	0.04	-
NDF, % DM	66.13	66.80	66.20	66.70	0.79	0.74	-
ADF, % DM	33.67	33.14	33.48	34.27	0.54	0.26	-
P, % DM	0.15	0.15	0.16	0.16	0.01	0.57	0.18
Ca, % DM	0.31	0.29	0.29	0.28	0.02	0.60	0.33
K, % DM	1.27	1.34	1.23	1.40	0.05	0.14	0.60
Mg, % DM	0.167[a]	0.169[a]	0.187[b]	0.164[a]	0.01	0.04	0.10
Na, % DM	0.06	0.06	0.08	0.05	0.03	0.43	0.07
S, % DM	0.20	0.21	0.20	0.20	0.03	0.96	0.15

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and targeted stocking rate of 672 kg/ha (DDGS).

[2]Reqiurements based on NRC (2000) recommendations for 300 kg growing cattle gaining 0.89 kg ADG. Tables 5-1 and 9-2.

[3]Forage mass is the standing crop clipping data collected monthly of forage available for consumption.

[4]Forage yield is represented as clipping data of total yield collected at the conclusion of the trial from fenced exclosures within each trial pasture.

Table 6. Effect of time on forage mass and nutritive value (2010)

Item	Date				SEM	P-Value		Cattle Req[1]
	June 9 (d 22)	July 13 (d 56)	August 19 (d 93)	September 21 (d 126)		Time	Trt*Time	
Forge DM, %	37.87[a]	39.39[ab]	41.59[bc]	44.63[c]	1.46	<0.01	0.01	-
Forage Mass, kg/ha	4432[a]	5594[b]	6776[c]	5824[b]	385	<0.01	0.15	-
OM, %	93.74[a]	93.31[b]	93.83[ac]	94.11[c]	0.26	<0.01	0.07	-
CP, % DM	12.46[a]	9.46[b]	8.39[c]	8.91[c]	0.37	<0.01	0.01	-
NDF, % DM	64.24[a]	68.26[b]	65.19[a]	68.13[b]	0.77	<0.01	0.02	-
ADF, % DM	32.70[a]	32.33[a]	32.97[a]	36.55[b]	0.52	<0.01	<0.01	-
P, % DM	0.17[a]	0.16[a]	0.13[b]	0.15[a]	0.01	0.03	0.54	0.18
Ca, % DM	0.31[a]	0.31[a]	0.30[a]	0.25[b]	0.02	<0.01	0.48	0.33
K, % DM	1.28[a]	1.47[b]	1.28[a]	1.28[a]	0.05	<0.01	0.18	0.60
Mg, % DM	0.164[a]	0.172[ab]	0.185[b]	0.166[a]	0.01	0.06	0.38	0.10
Na, % DM	0.08[a]	0.11[a]	0.04[b]	0.02[b]	0.03	<0.01	<0.01	0.07
S, % DM	0.205[a]	0.253[b]	0.170[c]	0.175[ac]	0.03	<0.01	0.10	0.15

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

[1]Reqiurements based on NRC (2000) recommendations for 300 kg growing cattle gaining 0.89 kg ADG. Tables 5-1 and 9-2.

Table 7. Effect of treatment on grazing economics (2010)

Item	Treatment[1]				SEM	P-value
	CONT	NFERT	NPFERT	DDGS		
Number of heifers	31	63	66	71		
U.S. dollars / head						
Revenue[2]	873	837	848	878	-	-
Expenses[3]	763	799	812	809	-	-
Returns[4]	110[a]	39[b]	36[b]	68[c]	6	< 0.05
U.S. dollars / hectare						
Revenue[2]	1102	1998	2119	2208	-	-
Expenses[3]	963	1905	2029	2036	-	-
Returns[4]	139[a]	93[b]	90[b]	172[c]	13	< 0.05

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

[2]Revenue = cattle sale value from OKC National Stockyards market reports at the most nearby date to trial conclusion.

[3]Expenses = initial cattle purchase price from OKC National Stockyards market reports at the most nearby date to trial initiation as well as actual local prices paid for fertilizer, DDGS, and protein supplement.

[4]Returns = difference of revenue and expenses. Represented as returns to land, management, labor, transportation, etc.

Table 8. Effect of treatment on steer performance (2011)

Item	Treatment[1]				SEM	*P*-value
	CONT	NFERT	NPFERT	DDGS		
Number of steers	40	78	79	84		
Initial stocking rate, steers/ha	1.64	3.00	3.01	2.99		
Initial stocking rate, kg/ha	389	716	718	706		
BW, kg						
Initial (May 17, d 0)	237	239	239	236	1.60	0.38
Final (July 19, d 63)	306[a]	306[a]	320[b]	321[b]	2.50	< 0.01
Gain, kg/hd						
Total (63 d)	69[a]	67[a]	80[b]	86[a]	2.20	< 0.01
ADG, kg						
Total (63 d)	1.10[a]	1.07[a]	1.28[b]	1.37[b]	0.05	< 0.01
Gain, kg/ha						
Total (63 d)	97[a]	187[b]	224[c]	239[c]	5.3	<.0001

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

Table 9. Effect of treatment on nitrogen use and efficiency (2011)

Item	Treatment[1]				SEM	*P*-value
	CONT	NFERT	NPFERT	DDGS		
N inputs, kg/ha						
N from feed	-	-	-	16.0	-	-
N from fertilizer	0.0	90.0	90.0	0.0	-	-
N atmospheric deposition	6.0	6.0	6.0	6.0	-	-
Total N inputs	6.0[a]	96.0[b]	96.0[b]	22.0[c]	0.08	<.0001
N retention[2], kg/ha	2.4[a]	4.6[b]	5.4[c]	5.8[c]	0.13	<.0001
N recovery, %	48.3[a]	5.4[b]	6.4[b]	30.0[c]	0.56	<.0001

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

[2] N retention is a calculated value measured as N retained in BW gain of cattle.

Table 10. Effect of treatment on forage mass and nutritive value (2011)

Item	Treatment[1]				SEM	P-Value	
	CONT	NFERT	NPFERT	DDGS		Trt	Cattle Req[2]
Forge DM, %	50.75	52.38	51.38	53.99	1.08	0.18	-
Forage mass, kg/ha[3]	3931	3278	3559	3315	325	0.15	-
Forage yield, kg/ha[4]	6306	6664	8980	4753	1444	0.11	-
OM, %	94.07	94.04	94.23	93.92	0.22	0.79	-
CP, % DM	8.33[a]	10.27[b]	10.68[b]	8.48[a]	0.60	< 0.01	-
NDF, % DM	66.68	66.41	65.39	66.81	0.55	0.27	-
ADF, % DM	34.11	33.99	33.38	34.03	0.92	0.92	-
P, % DM	0.12[a]	0.12[a]	0.19[b]	0.14[a]	0.02	< 0.01	0.18
Ca, % DM	0.32	0.30	0.30	0.30	0.02	0.92	0.33
K, % DM	1.43	1.43	1.45	1.38	0.06	0.82	0.60
Mg, % DM	0.154[a]	0.164[abc]	0.192[c]	0.153[ab]	0.01	0.11	0.10
Na, % DM	0.019[a]	0.053[b]	0.053[b]	0.026[ab]	0.02	0.06	0.07
S, % DM	0.17	0.19	0.17	0.17	0.03	0.84	0.15

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and targeted stocking rate of 672 kg/ha (DDGS).

[2]Reqiurements based on NRC (2000) recommendations for 300 kg growing cattle gaining 0.89 kg ADG. Tables 5-1 and 9-2.

[3]Forage mass is the standing crop clipping data collected monthly of forage available for consumption.

[4]Forage yield is represented as clipping data of total yield collected at the conclusion of the trial from fenced exclosures within each trial pasture.

Table 11. Effect of time on forage mass and nutritive value (2011)

Item	Date			SEM	P-Value		Cattle Req[1]
	June 3 (d 17)	July 6 (d 50)	July 19 (d 63)		Time	Trt*Time	
Forge DM, %	38.65[a]	55.09[b]	62.64[c]	0.95	<0.01	0.53	-
Forage Mass, kg/ha	4182[a]	3325[b]	3058[b]	306	<0.01	0.80	-
OM, %	93.14[a]	94.32[b]	94.73[b]	0.19	<0.01	0.99	-
CP, % DM	15.04[a]	7.40[b]	5.89[c]	0.53	<0.01	0.24	-
NDF, % DM	60.49[a]	67.77[b]	70.71[c]	0.48	<0.01	0.36	-
ADF, % DM	29.76[a]	34.01[b]	37.81[c]	0.92	<0.01	0.82	-
P, % DM	0.21[a]	0.12[b]	0.10[b]	0.01	<0.01	0.56	0.18
Ca, % DM	0.38[a]	0.29[b]	0.25[b]	0.02	<0.01	0.70	0.33
K, % DM	1.60[a]	1.37[b]	1.31[b]	0.06	<0.01	0.93	0.60
Mg, % DM	0.196[a]	0.164[b]	0.136[c]	0.01	<0.01	0.70	0.10
Na, % DM	0.054[a]	0.033[ab]	0.026[b]	0.02	0.12	0.98	0.07
S, % DM	0.25[a]	0.15[b]	0.12[b]	0.03	<0.01	0.99	0.15

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

[1]Reqiurements based on NRC (2000) recommendations for 300 kg growing cattle gaining 0.89 kg ADG. Tables 5-1 and 9-2.

Table 12. Effect of treatment on grazing economics (2011)

Item	Treatment[1]				SEM	P-value
	CONT	NFERT	NPFERT	DDGS		
Number of steers	40	78	79	84		
U.S. dollars / head						
Revenue[2]	944	943	985	990	-	-
Expenses[3]	790	822	836	825	-	-
Returns[4]	154[ab]	121[a]	149[ab]	165[b]	8.4	< 0.05
U.S. dollars / hectare						
Revenue[2]	1518	2806	2928	2945	-	-
Expenses[3]	1269	2455	2488	2455	-	-
Returns[4]	249[a]	361[b]	440[c]	490[c]	22	< 0.05

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

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

[2]Revenue = cattle sale value from OKC National Stockyards market reports at the most nearby date to trial conclusion.

[3]Expenses = initial cattle purchase price from OKC National Stockyards market reports at the most nearby date to trial initiation as well as actual local prices paid for fertilizer, DDGS, and protein supplement.

[4]Returns = difference of revenue and expenses. Represented as returns to land, management, labor, transportation, etc.

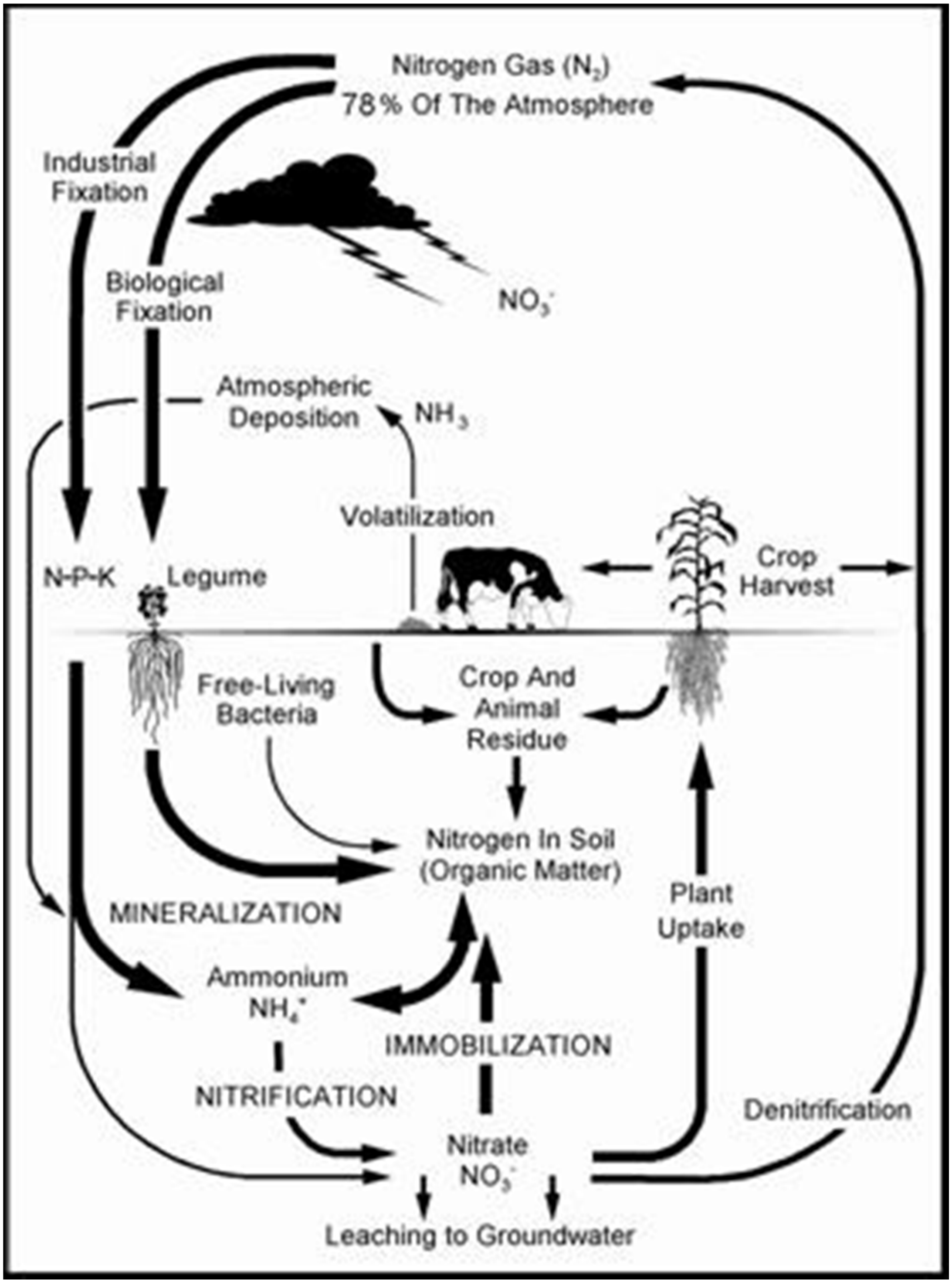

Figure 1. Nitrogen pathways within agricultural systems
Image from Ontario Ministry of Agriculture, Food, and Rural Affairs (McMcKague et al., 2005)

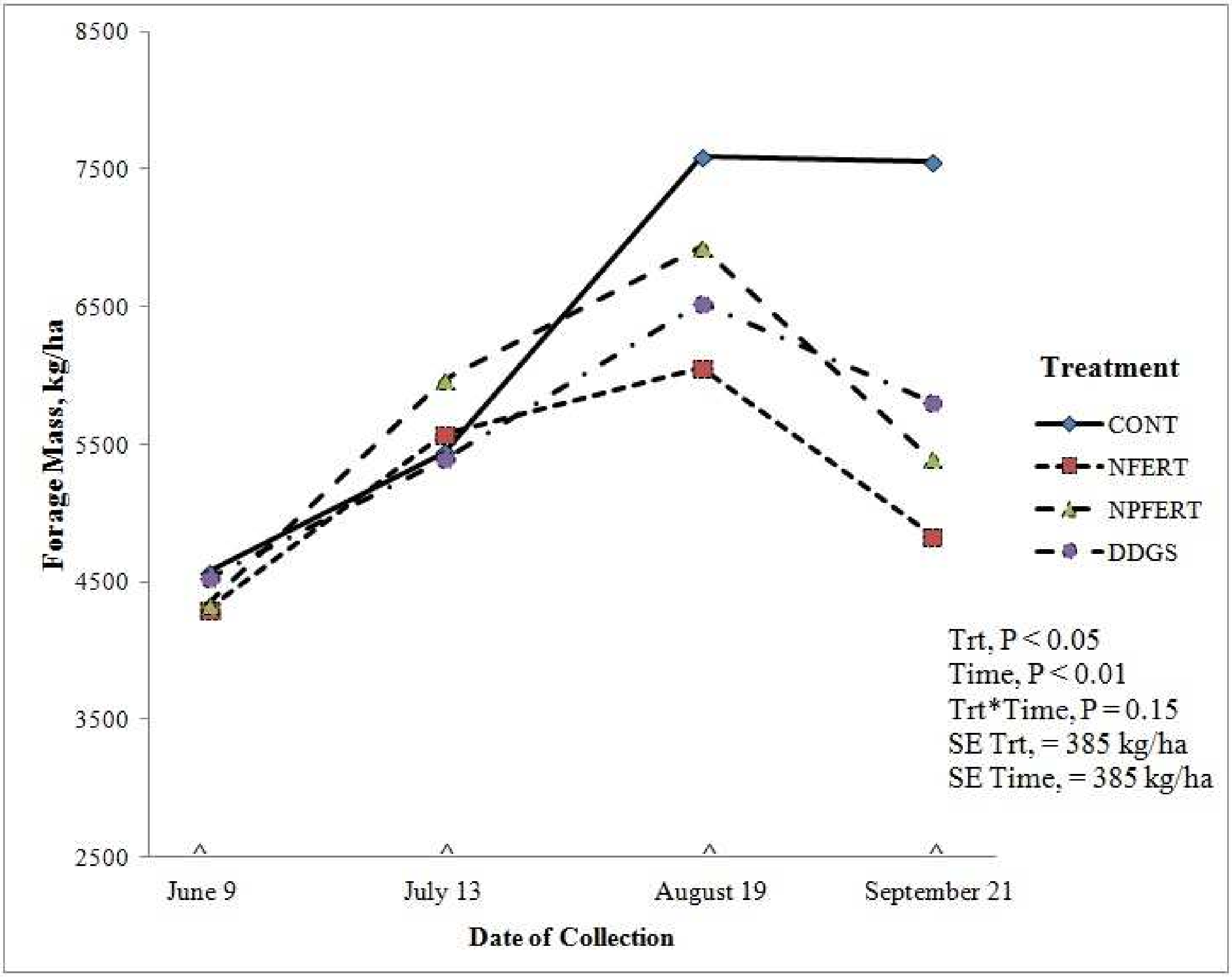

Figure 2. Effect of treatment on forage mass across collection dates, 2010.

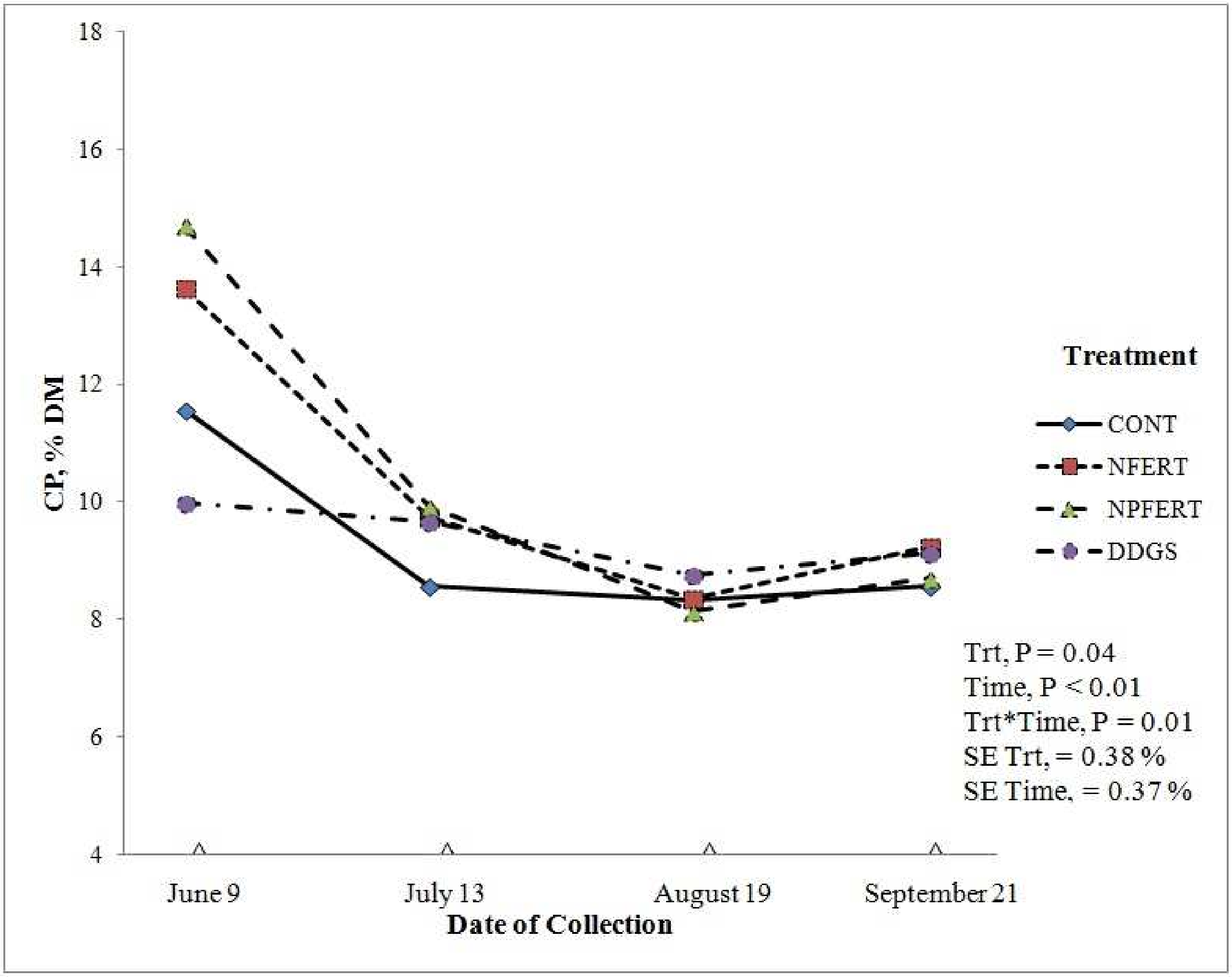

Figure 3. Effect of treatment on forage crude protein across collection dates, 2010.

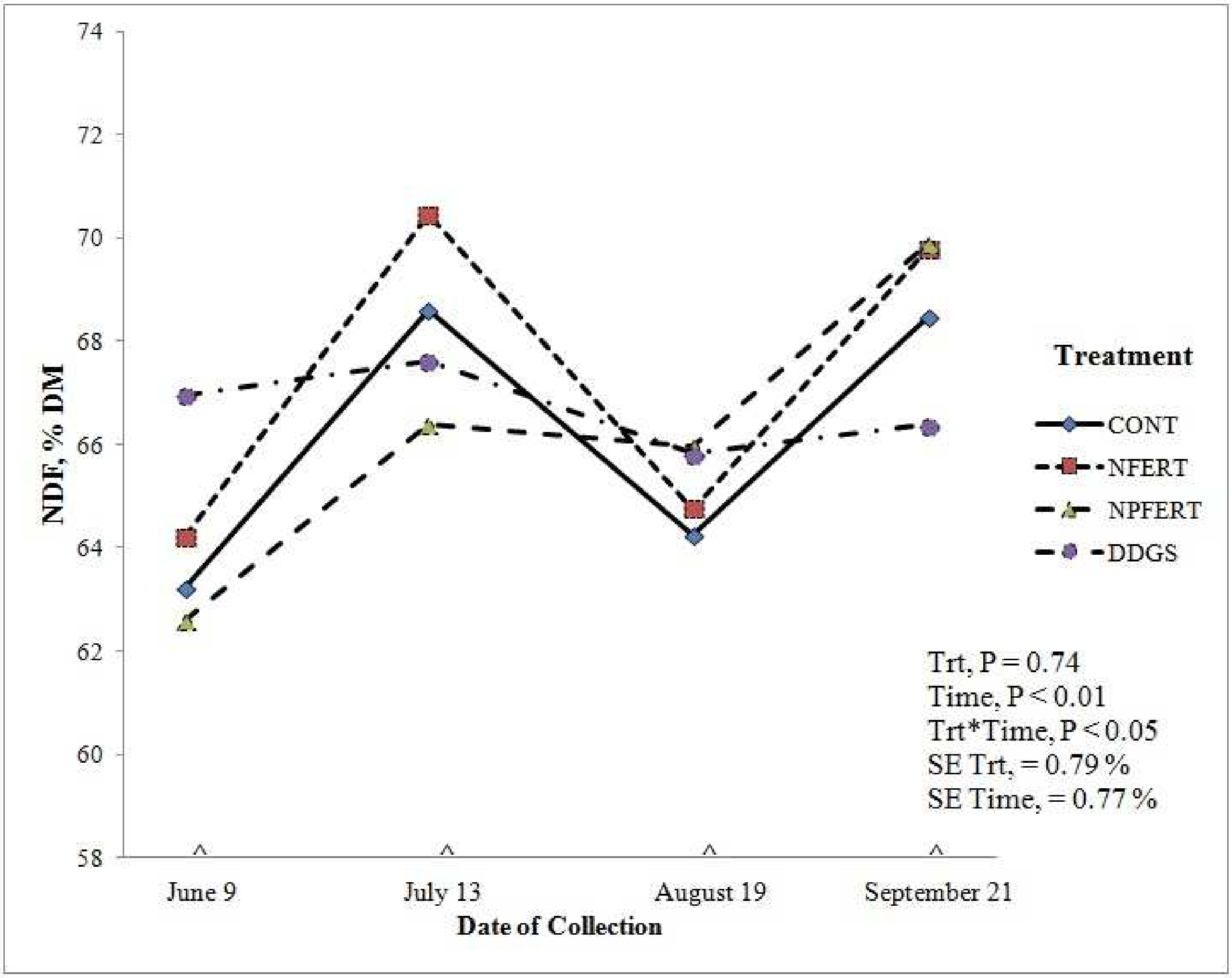

Figure 4. Effect of treatment on forage neutral detergent fiber across collection dates, 2010.

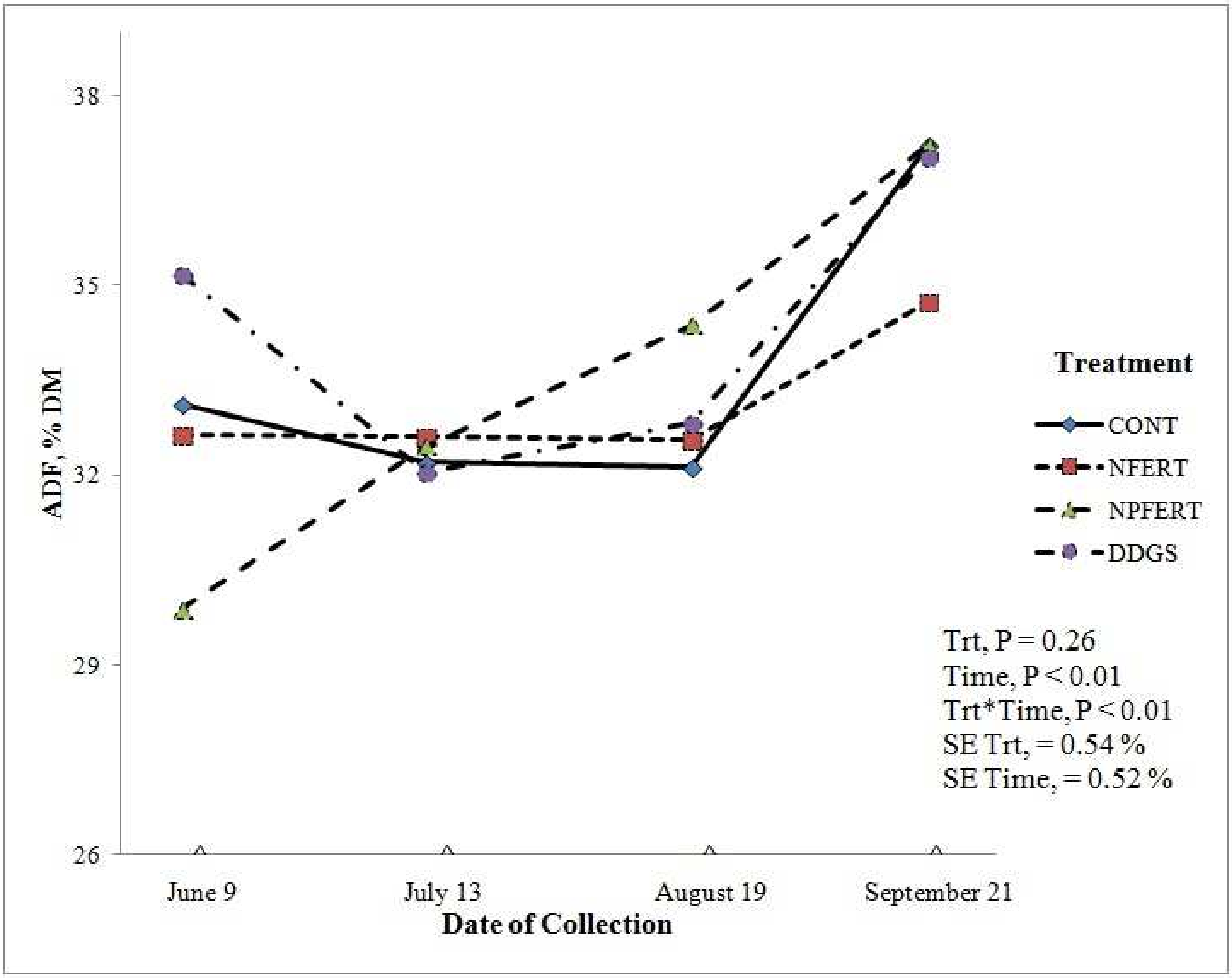

Figure 5. Effect of treatment on forage acid detergent fiber across collection dates, 2010.

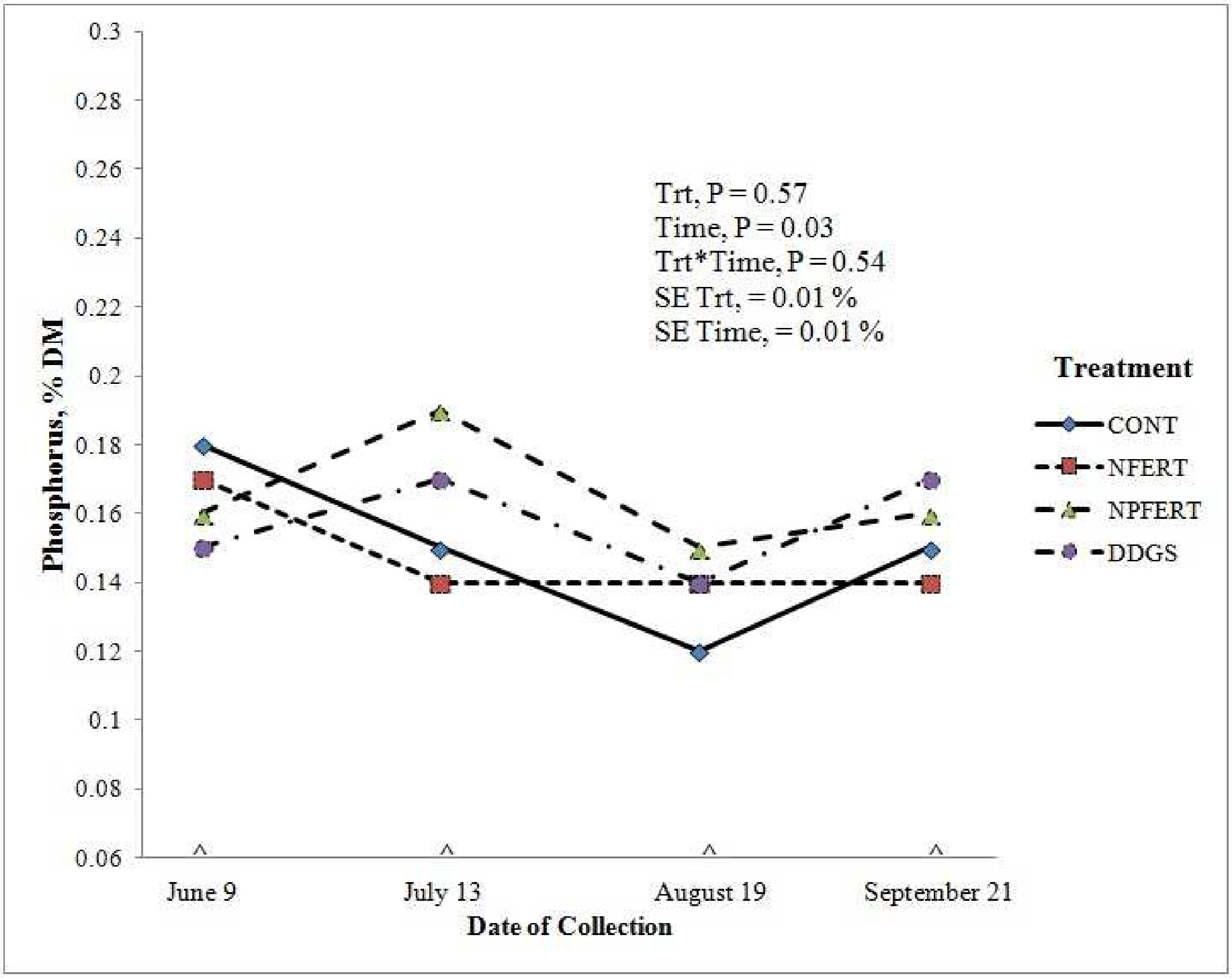

Figure 6. Effect of treatment on forage phosphorus across collection dates, 2010.

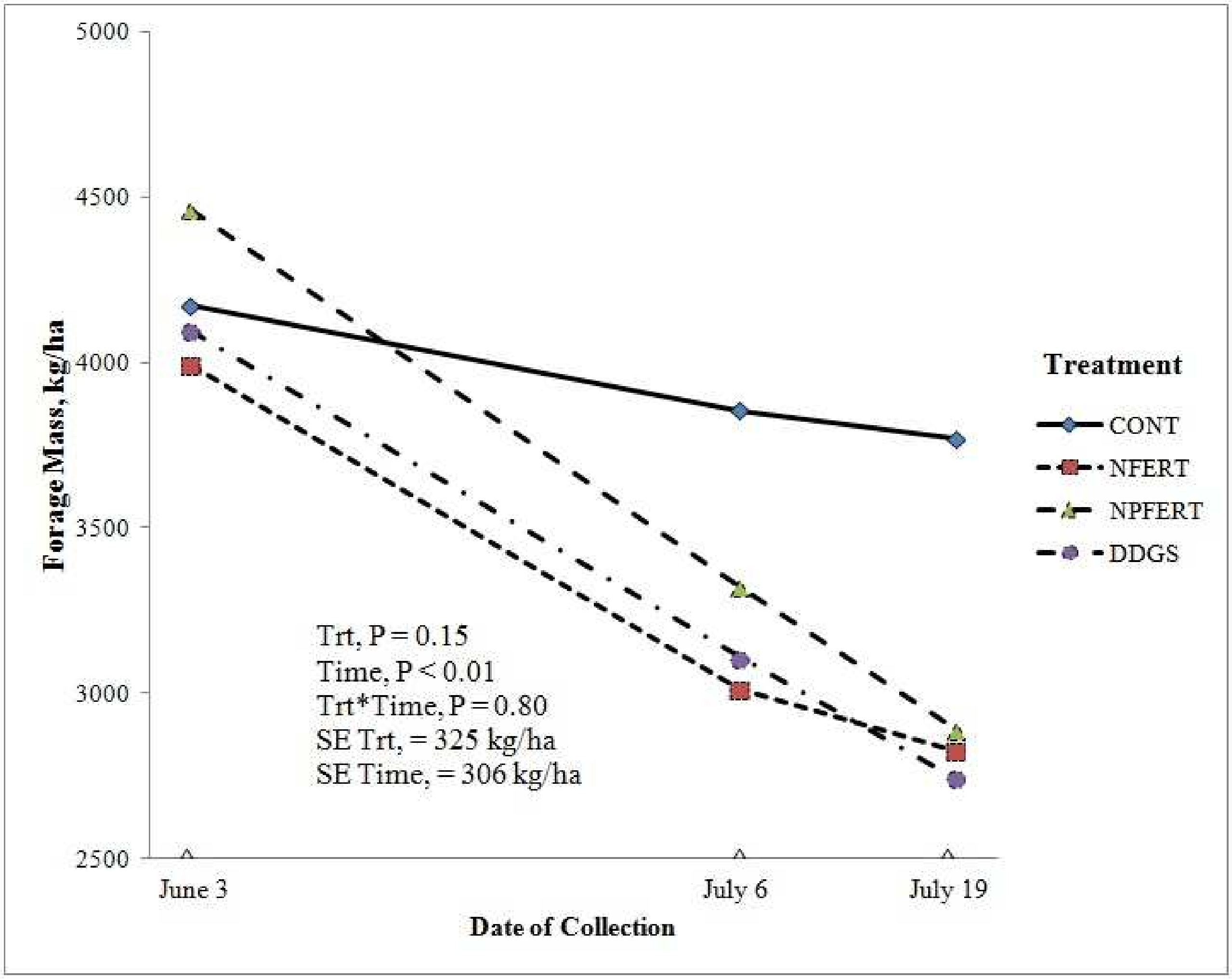

Figure 7. Effect of treatment on forage mass across collection dates, 2011.

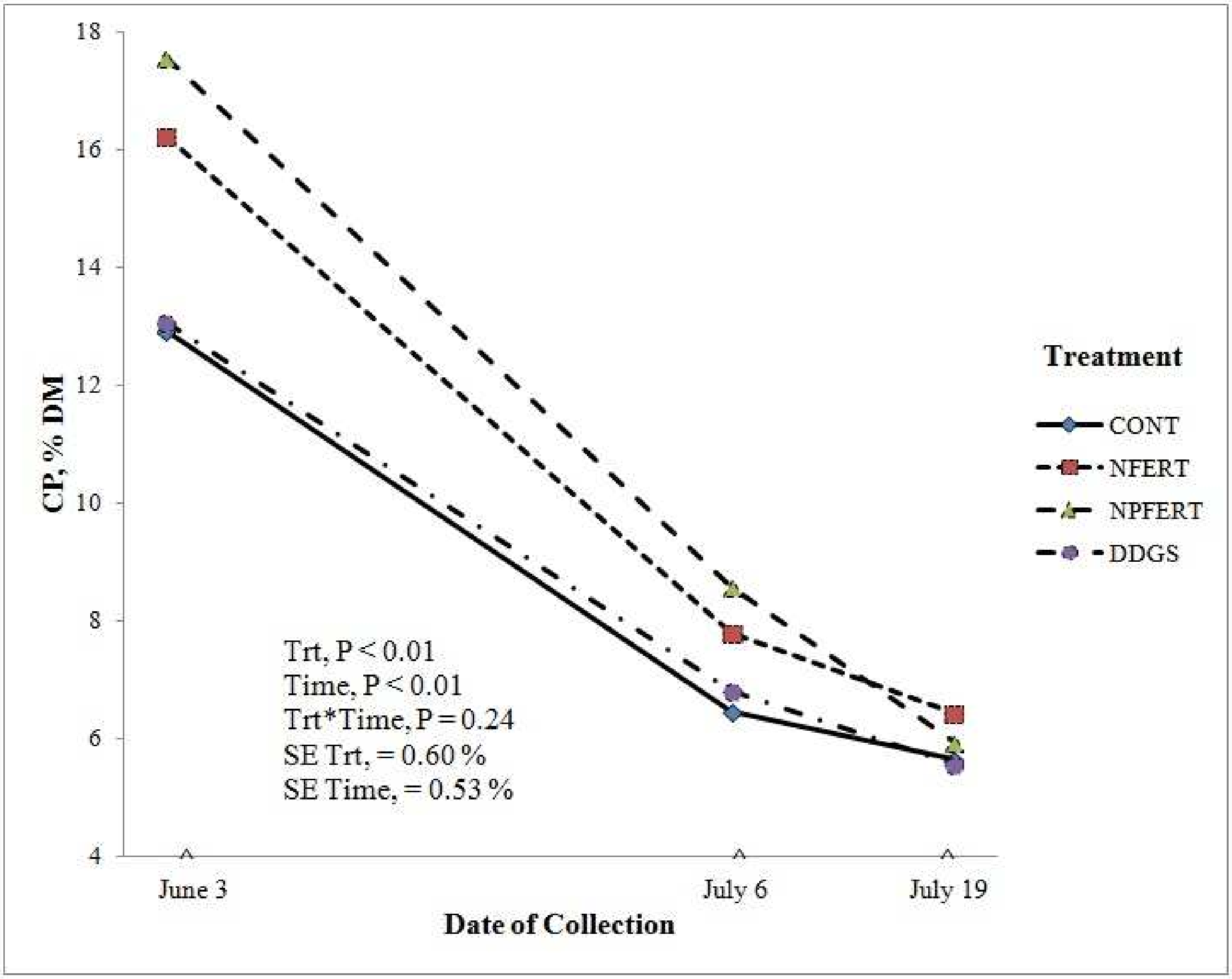

Figure 8. Effect of treatment on forage crude protein across collection dates, 2011.

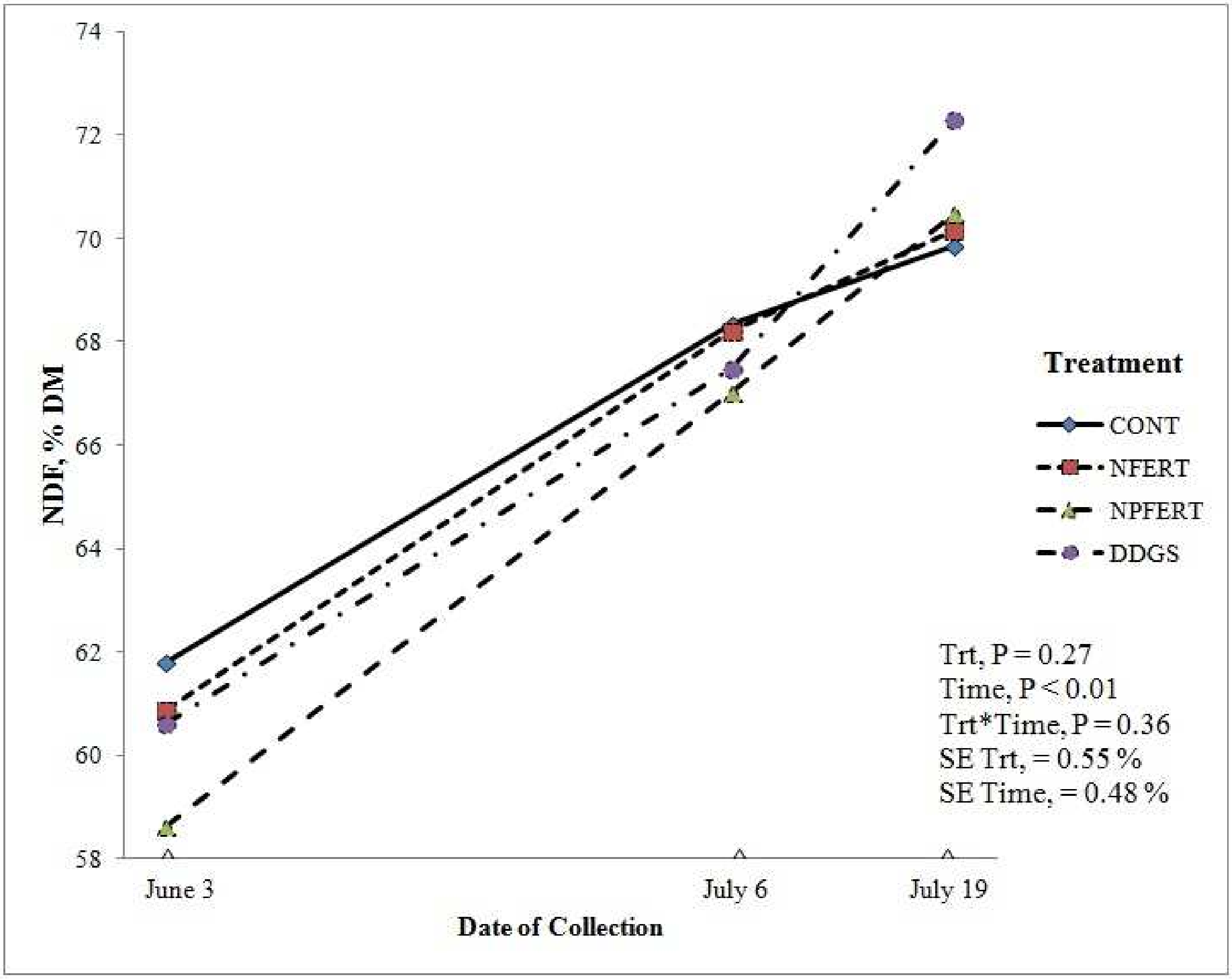

Figure 9. Effect of treatment on forage neutral detergent fiber across collection dates, 2011.

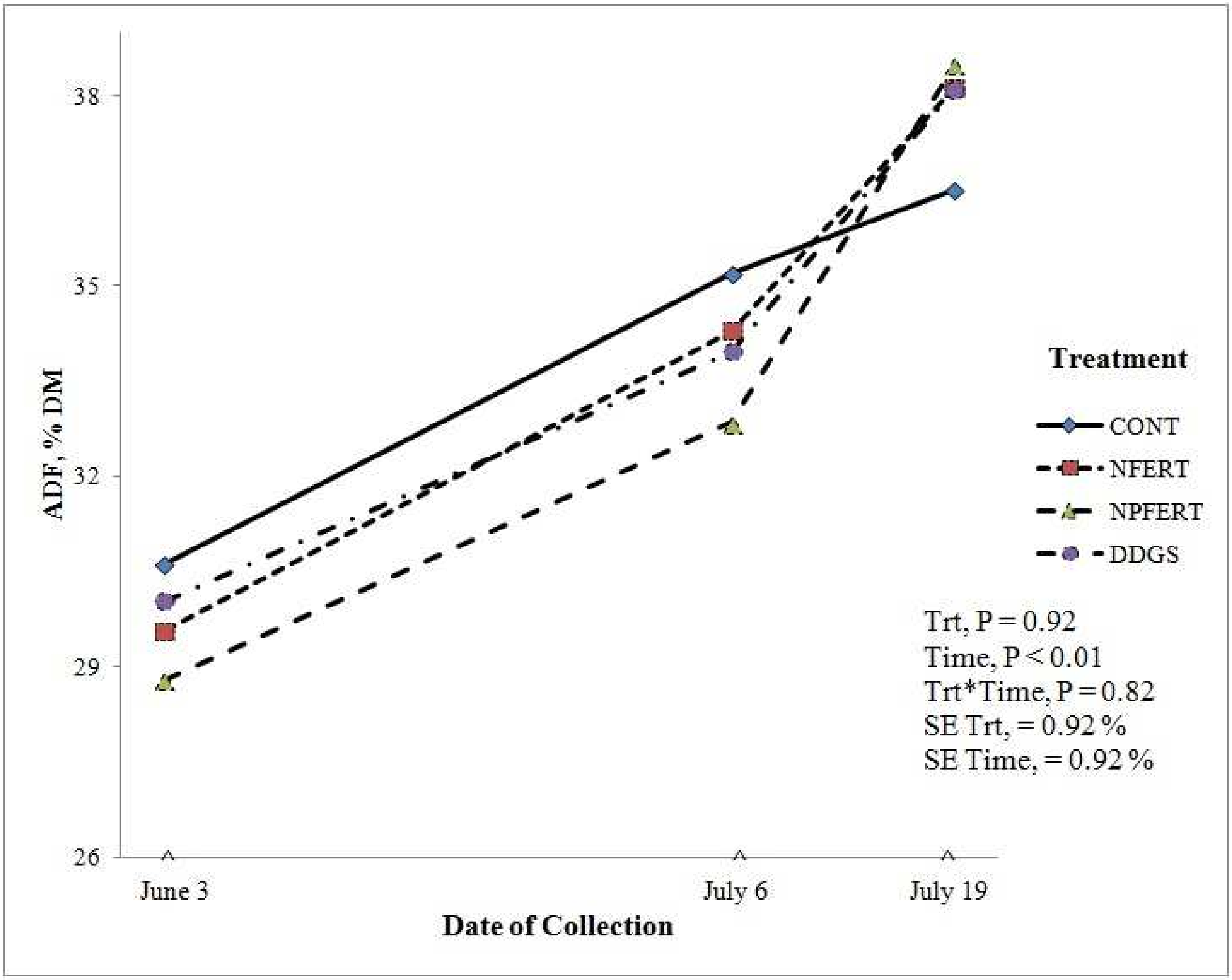

Figure 10. Effect of treatment on forage acid detergent fiber mass across collection dates, 2011.

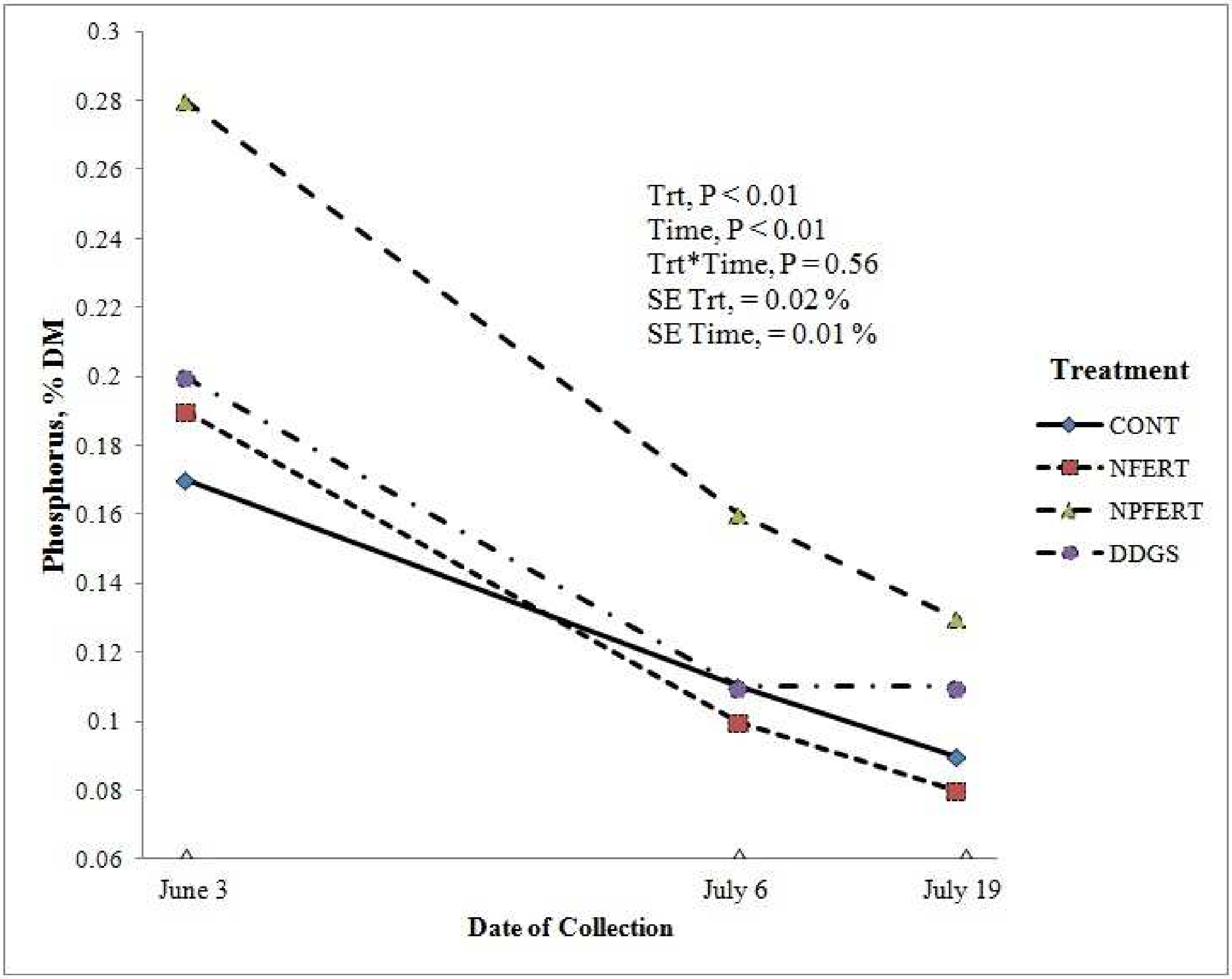

Figure 11. Effect of treatment on forage phosphorus across collection dates, 2011.

APPENDICES

Appendix Table 1. Effect of treatment and time on forage mass and nutritive value (2010)

	Treatment[1]					P-Value		
Item	CONT	NFERT	NPFERT	DDGS	SEM	Trt	Time	Trt*Time
Forage DM, %								
June 9	38.40	36.34	33.98	42.77	1.46	0.46	<0. 01	0.01
July 13	39.59	42.31	36.88	38.80	1.46	0.46	<0. 01	0.01
August 19	40.82	43.82	42.26	39.45	1.46	0.46	<0. 01	0.01
September 21	42.39	47.65	47.39	41.08	1.46	0.46	<0. 01	0.01
Forage Mass, kg/ha								
June 9	4574	4297	4331	4527	385	< 0.05	<0.01	0.15
July 13	5443	5576	5966	5393	385	< 0.05	<0.01	0.15
August 19	7590	6059	6933	6523	385	< 0.05	<0.01	0.15
September 21	6290	4838	5393	5807	385	< 0.05	<0.01	0.15
Forage OM, %								
June 9	93.72	93.76	93.27	94.20	0.26	0.73	<0.01	0.07
July 13	93.39	93.68	93.16	93.01	0.26	0.73	<0.01	0.07
August 19	93.78	93.96	94.06	93.52	0.26	0.73	<0.01	0.07
September 21	94.42	93.72	94.08	94.23	0.26	0.73	<0.01	0.07
CP, %								
June 9	11.55	13.63	14.70	9.97	0.38	0.38	<0.01	0.01
July 13	8.56	9.73	9.92	9.65	0.38	0.38	<0.01	0.01
August 19	8.33	8.35	8.13	8.76	0.38	0.38	<0.01	0.01
September 21	8.56	9.23	8.71	9.14	0.38	0.38	<0.01	0.01
NDF,%								
June 9	63.21	64.21	62.59	66.97	0.79	0.74	<0.01	0.01
July 13	68.60	70.44	66.39	67.62	0.79	0.74	<0.01	0.01
August 19	64.25	64.75	65.95	65.82	0.79	0.74	<0.01	0.01
September 21	68.48	69.78	69.88	66.38	0.79	0.74	<0.01	0.01

ADF, %								
June 9	33.12	32.63	29.89	35.17	0.54	0.26	<0.01	<0.01
July 13	32.20	32.62	32.46	32.04	0.54	0.26	<0.01	<0.01
August 19	32.13	32.56	34.37	32.82	0.54	0.26	<0.01	<0.01
September 21	37.22	34.74	37.21	37.03	0.54	0.26	<0.01	<0.01
P, % DM								
June 9	0.18	0.17	0.16	0.15	0.01	0.57	0.03	0.54
July 13	0.15	0.14	0.19	0.17	0.01	0.57	0.03	0.54
August 19	0.12	0.14	0.15	0.14	0.01	0.57	0.03	0.54
September 21	0.15	0.14	0.16	0.17	0.01	0.57	0.03	0.54
Ca, % DM								
June 9	0.35	0.29	0.30	0.31	0.02	0.60	<0.01	0.48
July 13	0.33	0.28	0.33	0.30	0.02	0.60	<0.01	0.48
August 19	0.31	0.30	0.27	0.30	0.02	0.60	<0.01	0.48
September 21	0.23	0.28	0.25	0.22	0.02	0.60	<0.01	0.48
K, % DM								
June 9	1.23	1.49	1.08	1.31	0.05	0.14	<0.01	0.18
July 13	1.40	1.38	1.63	1.50	0.05	0.14	<0.01	0.18
August 19	1.28	1.26	1.16	1.43	0.05	0.14	<0.01	0.18
September 21	1.17	1.24	1.07	1.34	0.05	0.14	<0.01	0.18
Mg, % DM								
June 9	0.17	0.16	0.16	0.16	0.01	0.04	0.06	0.38
July 13	0.17	0.16	0.20	0.15	0.01	0.04	0.06	0.38
August 19	0.16	0.19	0.20	0.18	0.01	0.04	0.06	0.38
September 21	0.16	0.17	0.18	0.16	0.01	0.04	0.06	0.38
Na, %DM								
June 9	0.08	0.10	0.10	0.04	0.03	0.43	<0.01	0.93
July 13	0.11	0.09	0.11	0.11	0.03	0.43	<0.01	0.93
August 19	0.03	0.03	0.06	0.04	0.03	0.43	<0.01	0.93
September 21	0.01	0.02	0.04	0.00	0.03	0.43	<0.01	0.93
S, % DM								
June 9	0.22	0.22	0.18	0.20	0.03	0.96	<0.01	0.10
July 13	0.25	0.22	0.27	0.27	0.03	0.96	<0.01	0.10
August 19	0.16	0.17	0.17	0.19	0.03	0.96	<0.01	0.10
September 21	0.17	0.22	0.17	0.13	0.03	0.96	<0.01	0.10

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

Appendix Table 2. Effect of treatment and time on forage mass and nutritive value (2011)

	Treatment[1]					P-Value		
Item	CONT	NFERT	NPFERT	DDGS	SEM	Trt	Time	Trt*Time
Forage DM, %								
June 3	38.35	39.16	35.75	41.33	1.08	0.18	<0.01	0.53
July 6	51.71	55.25	56.71	56.70	1.08	0.18	<0.01	0.53
July 19	62.20	62.75	61.68	63.94	1.08	0.18	<0.01	0.53
Forage Mass, kg/ha								
June 3	4171	3994	4464	4097	325	0.15	<0.01	0.15
July 6	3855	3012	3324	3108	325	0.15	<0.01	0.15
July 19	3769	2828	2892	2743	325	0.15	<0.01	0.15
Forage OM, %								
June 3	93.20	93.12	93.41	92.84	0.22	0.79	<0.01	0.99
July 6	94.30	94.35	94.49	94.15	0.22	0.79	<0.01	0.99
July 19	94.70	94.65	94.81	94.78	0.22	0.79	<0.01	0.99
CP, %								
June 3	12.91	16.23	17.56	13.07	0.60	<0.01	<0.01	0.24
July 6	6.46	7.79	8.57	6.80	0.60	<0.01	<0.01	0.24
July 19	5.64	6.42	5.93	5.56	0.60	<0.01	<0.01	0.24
NDF,%								
June 3	61.81	60.87	58.65	60.63	0.55	0.27	<0.01	0.36
July 6	68.35	68.21	67.03	67.49	0.55	0.27	<0.01	0.36
July 19	69.87	70.16	70.49	72.32	0.55	0.27	<0.01	0.36
ADF, %								
June 3	30.62	29.57	28.80	30.04	0.92	0.92	<0.01	0.82
July 6	35.20	34.29	32.85	33.97	0.92	0.92	<0.01	0.82
July 19	36.51	38.12	38.49	38.10	0.92	0.92	<0.01	0.82
P, % DM								
June 3	0.17	0.19	0.28	0.20	0.02	<0.01	<0.01	0.56
July 6	0.11	0.10	0.16	0.11	0.02	<0.01	<0.01	0.56
July 19	0.09	0.08	0.13	0.11	0.02	<0.01	<0.01	0.56
Ca, % DM								
June 3	0.40	0.37	0.36	0.39	0.02	0.92	<0.01	0.70
July 6	0.28	0.27	0.33	0.29	0.02	0.92	<0.01	0.70
July 19	0.27	0.27	0.21	0.23	0.02	0.92	<0.01	0.70
K, % DM								
June 3	1.53	1.65	1.66	1.55	0.06	0.82	<0.01	0.93
July 6	1.44	1.33	1.38	1.32	0.06	0.82	<0.01	0.93
July 19	1.32	1.31	1.32	1.27	0.06	0.82	<0.01	0.93
Mg, % DM								
June 3	0.18	0.20	0.22	0.18	0.01	0.11	<0.01	0.70
July 6	0.14	0.15	0.21	0.16	0.01	0.11	<0.01	0.70

July 19	0.14	0.15	0.14	0.12	0.01	0.11	<0.01	0.70
Na, %DM								
June 3	0.03	0.07	0.07	0.04	002	0.06	0.12	0.98
July 6	0.01	0.05	0.06	0.01	002	0.06	0.12	0.98
July 19	0.00	0.04	0.03	0.02	002	0.06	0.12	0.98
S, % DM								
June 3	0.24	0.27	0.29	0.24	0.03	0.84	<0.01	0.99
July 6	0.14	0.15	0.15	0.18	0.03	0.84	<0.01	0.99
July 19	0.22	0.14	0.12	0.12	0.03	0.84	<0.01	0.99

[1]Treatments include 1) no fertilizer or DDGS with targeted stocking rate of 336 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and targeted stocking rate of 672 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and targeted stocking rate of 672 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and a targeted stocking rate of 672 kg/ha (DDGS).

VITA

Brody Donovan Wallis

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Master of Science

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