FERTILIZATION AND DRIED DISTILLERS GRAINS SUPPLEMENTATION EFFECTS ON PERFORMANCE AND N RECOVERY BY STOCKER CATTLE GRAZING OLD WORLD BLUESTEM

By

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Abstract: A 2-yr study evaluated the efficacy of using dried distillers grains plus solubles (DDGS) as a substitute for nitrogen (N) or N and phosphorus (P) fertilizer in stocker cattle grazing Plains Old World bluestem. Cattle were allotted to one of 4 treatments:1) Old World bluestem pastures with no N or P fertilizer and low stocking rate of 325 kg/ha (**CONT**), 2) Old World bluestem pastures fertilized with 90 kg/ha of N and no P with high stocking rate of 650 kg/ha (**NFERT**), 3) Old World bluestem pastures fertilized with 90 kg/ha of N and 40 kg/ha of P with high stocking rate of 650 kg/ha (**NPFERT**), and 4) unfertilized Old World bluestem pastures with the same stocking rate as NFERT and NPFERT with cattle receiving 0.75% BW of corn DDGS per day for a 5 day / week feeding schedule (**DDGS**). Average forage mass in yr 1 was 3,170 kg and yr 2 was 6,051 kg. In yr 1 final BW ($P < 0.05$), total BW gain ($P < 0.05$), overall ADG ($P < 0.05$), and gain/ha ($P < 0.05$) were greater for DDGS compared to CONT, NFERT, and NPFERT. Nitrogen recovery as cattle weight gain was greatest ($P < 0.05$) for CONT, and DDGS was greater than NFERT and NPFERT. In yr 2 there were no differences ($P > 0.05$) between final BW, total BW gain, or overall ADG between treatments. This may be due to greater forage mass in yr 2 from increased rainfall. Gain per ha was greater ($P < 0.05$) for DDGS, NFERT, and NPFERT compared to CONT and is due to increased stocking rates for those treatments. Nitrogen recovery was greater ($P < 0.05$) for CONT, intermediate for DDGS, and lowest for NFERT and NPFERT. Dried distillers grains can be used as a substitute for forage and N fertilizer by improving performance and N recovery by stocker cattle grazing Old World bluestem.

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CHAPTER I

Introduction

Increasing costs of land and inputs are currently major challenges facing the beef cattle industry. To be profitable beef production relies on the ability of cattle to consume and efficiently use forage to gain weight. This is reliant upon an abundance of high quality forage available for the cattle to graze. In the southern Great Plains this includes native and introduced grasses and small grains forages. Old World bluestem is a warm-season introduced perennial grass that has been planted in large areas of the southern Great Plains to assist in arresting soil erosion on marginal farmland and as a high quality summer forage for cattle (Dewald et al., 1985). Like many warm season grasses, Old World bluestem contains high nutrient levels early in the growing season, but these levels decline as the season advances and are quite low when bluestem is dormant.

Producers may implement management strategies to either take advantage of the high nutritive value of Old World bluestem early in the growing season or balance out the reduced quality later in the growing season. These strategies can include fertilization of the pasture early in the growing season to enhance forage growth and nutrient content (Dubeux et al., 2006), increased stocking rates to better utilize available forage and prevent forage maturation (Teague et al., 1996), or provide supplements to cattle to meet nutrient deficiencies. Nitrogen fertilizer costs have steadily risen since the mid-1990s.

This increase in cost has incentivized beef producers to look for alternate methods of supplying N to the system, such as supplementing DDGS.

Early in the growing season when crude protein levels are adequate in forage energy supplements may need to be incorporated to improve protein utilization. However, if grain supplements are provided and protein levels are not adequate fiber digestion may be reduced and result in decreased cattle performance (Chase and Hibberd, 1987). As the growing season advances protein becomes the first-limiting nutrient which would necessitate the use of a protein supplement to ensure adequate cattle gains. In addition, undegradable protein may be necessary if forage protein is highly degradable (Hafley et al., 1993). Distillers grains plus solubles is a byproduct of the ethanol industry and a source of energy and both degradable and undegradable protein. These characteristics allow DDGS to be fed throughout the grazing period and provide energy and protein when needed based on what is limited in the forage (Creighton et al., 2003).

Animal manure is an excellent source of micro- and macronutrients for forages. About three-fourths of nitrogen, four-fifths of phosphorus, and nine-tenths of potassium ingested by animals is excreted (Brady and Weil, 2002). Greenquist et al. (2011) reported that excretion of N was increased when steers were supplemented with DDGS at 0.5 % of BW compared with steers that grazed unfertilized smooth bromegrass (112.65 and 55.20 kg N/ha; respectively).

The objective of this study was to evaluate the effect of N or N+P fertilizer application to pasture or feeding DDGS to growing beef cattle on cattle performance, beef production/hectare, and recovery of fertilizer and feed N while grazing Old World bluestem pasture.

CHAPTER II

Literature Review

Old World Bluestem Grasses

History

Old World bluestems (*Bothriochola ischaemum* L.) were first noted in the Western Hemisphere in the late 19th and early 20th century. These introduced bluestems drew interest due to their superiority in quality, production, persistence to grazing, and response to elevated fertility levels over the American species of bluestem grasses (Celarier and Harlan, 1955). In 1917, a specimen of *Bothriochloa ishaemum* was brought to California from Amoy, China. Samples were sent to locations throughout the country including Stillwater, Ok and College Station, Tx. In Texas the bluestem samples were released as Texas Yellow Beardgrass and King Ranch bluestem. Through international collaboration the largest collection of Old World bluestems in the Western Hemisphere were acquired, grown, and studied in Stillwater, Ok (Celarier and Harlan, 1955).

Hodges and Bidwell (1993) reported that the majority of Old World bluestems used in Oklahoma were Caucasian, Granada, King Ranch, WW-Spar, WW-Iron Master, and Plains. Plains bluestem (*Bothriochloa ischaemum* (L.) Keng. var. *ischaemum*) was developed as a composite of thirty selected seed sources that were morphologically similar. The source material for Plains bluestem can be traced back to specimens from Pakistan, Iran, Iraq, India, Turkey, and Afghanistan (Taliaferro et al., 1972).   Plains bluestem was cooperatively released in 1972 by the Oklahoma Agricultural Experiment Station and the Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture. Plains bluestem is winter hardy, drought tolerant, and has the ability to resist leaf rust (Taliaferro and Harlan, 1973).

Dewald et al. (1985) noted that Old World bluestems were being included in establishment programs to arrest soil erosion of marginal farmland in Oklahoma and Texas. This use resulted from the increased ease of establishment, seed acquisition, and high production levels of both forage and grazing cattle (Dewald et al., 1985). Berg and Sims (1995) stated that an estimated 2 million hectares (ha) of Old World bluestem had been established in Texas and Oklahoma by 1995. With its inclusion in grassland reestablishment programs and increased production levels it is important to fully understand the management and usage of Old World bluestems in the Southern Great Plains. However, Old World bluestem may be considered an invasive species with respect to native habitats (Weir et al. 2009).

Growth Characteristics, Productivity, and Management

Taliaferro et al. (1972) described Plains bluestem as an erect, tufted perennial with high productivity and persistence that has the potential to produce between 4 and 6 tons of dry forage per acre under adequate conditions. Plains bluestem can be grown throughout Oklahoma due to its winterhardiness and ability to grow in a variety of soil types from acidic to alkali. Dewald et al. (1985) reported that growth of Plains bluestem begins in April and grazing can commence in late May or early June. Taliaferro et al. (1972) indicated that while Plains bluestem starts growth later in the spring than other warm season grasses when under optimum growing conditions it can provide high forage yields throughout the growing season. The greatest growth rate for Plains bluestem is achieved in late summer and fall and this may enable producers to devise management strategies to take advantage of this growth pattern for improved animal performance.

Old World bluestems are principally a secondary succession rather than a climax species (Dewald et al., 1985). Eck and Sims (1984) confirmed this in a 36 year assessment of forages grown in Dallam County, Texas. Thirty-six years after establishment Yellow and Caucasian bluestems were the dominant forages in the fields where they were planted as well as in fields where other species of forages had been planted and subsequently died out. The authors determined that Caucasian and Yellow bluestems had the highest forage yields in pastures that were ungrazed while galleta grass had the highest forage yield in grazed pastures where it was present. Between the two Old World bluestem species, Caucasian bluestem was more abundant in ungrazed areas while Yellow bluestem was more abundant in grazed areas.

Taliaferro et al. (1984) reported that Caucasian and Plains bluestems have increased dry matter yields when clipping interval increased from 3 to 7 weeks but did not note any changes from 7 to 11 week clipping intervals. Dabo et al. (1987) described an increase in dry matter yields among four Old World bluestems as weekly harvest dates increased. The authors attributed the increased yields to overall forage accumulation and noted that as accumulation increased forage quality declined, similar trends in other warm season forages were noted by the authors.

Dewald et al. (1985) recommended fertilizing Old World bluestems especially on marginal farmland. The authors suggested that 25 to 40 pounds of high quality forage can be produced for each pound of nitrogen when 30 to 60 pounds per acre of nitrogen was applied to Old World bluestems with adequate rainfall. Berg (1990) evaluated the response of Old World bluestem to increased levels of nitrogen fertilization. Nitrogen was applied at rates of 0, 35, 70, 70 split application, and a single application of 105 kg nitrogen / ha. An average of 800 kg / ha of forage was produced with no nitrogen application. A linear increase in forage production was noted when nitrogen levels increased from 35 to 70 kg / ha. In years with high precipitation levels the trend continued up to the 105 kg / ha application rate. However, in years with limited precipitation there was no increased forage production when nitrogen levels increased from 70 to 105 kg. The author noted that at the 30 and 70 kg nitrogen application rates an increase of 30 kg of forage was produced from each kg of nitrogen applied. No advantage was observed for the split application of 70 kg of nitrogen over the single 70 kg application. Berg (1990) concluded that under average conditions 70 kg of nitrogen was adequate for Old World bluestem production and that 105 kg was only advantageous when precipitation levels were above normal.

Dewald et al. (1985) suggested that Old World bluestem should only be burned when excessive old growth remains in the spring. A report by Berg (1993) agreed that burning Old World bluestem should only be done when excessive old growth is present or to manage unwanted plant species. Berg and Sims (2000) reported that forage production and cattle gains were increased in Old World bluestem pastures that had been fertilized with ammonium nitrate over the previous 5 years. The authors speculated that this was due to residual nitrogen in the soil which increased forage production and elevated crude protein levels in the forage.

<u>Nutrient Characteristics and Animal Performance</u>

Taliaferro et al. (1972) reported that Plains bluestem was preferentially grazed by cattle when compared with Caucasian bluestem. Along with this, in vitro digestibility was greater for Plains compared with Caucasian bluestem. Dabo et al. (1988) evaluated chemical composition of four Old World bluestem cultivars as affected by level of maturity. The Old World bluestems consisted of Caucasian, Ganada, Plains, and WW-Spar and subplots were harvested weekly for 10 weeks to evaluate maturation differences. As level of maturation increased, the levels of NDF, ADF, and ADL increased across the 10 week time period. Small differences in NDF based on cultivar were noted, with Ganada having increased levels and WW-Spar having decreased levels as compared to Caucasian and Plains. Acid detergent fiber and ADL levels were higher in Caucasian and Plains when compared with Ganada and WW-Spar. Crude protein levels decreased as level of maturity increased and Caucasian had lower levels of CP than the other cultivars. Dabo et al. (1988) further noted that level of maturity had a greater impact on chemical composition than did cultivar. They indicated that with increased fiber levels and decreased protein levels, management practices would have to be employed to ensure continued animal performance. Dabo et al. (1987) noted that in vitro dry matter disappearance (IVDMD) declined as maturity increased. They also reported that Ganada bluestem had higher IVDMD and Caucasian had lower IVDMD than the other bluestem cultivars.

Taliaferro et al. (1972) indicated that cattle would readily consume Plains bluestem. Gunter et al. (1995) conducted a diet quality analysis of midgrass prairie and Plains bluestem with esophageally or ruminally fistulated cattle. It was found that cattle grazing Plains bluestem had greater in vitro organic matter disappearance that did cattle that grazed midgrass prairie, while fiber content increased for both forage types as the forage matured. In situ organic matter and nitrogen disappearance was greater in cattle grazing bluestem over those that grazed midgrass prairie. Forbes and Coleman (1993) reported that Plains bluestem was more digestible than Caucasian bluestem and cattle consumed more Plains bluestem.

Berg and Sims (1995) evaluated the effect of Old World bluestem pastures fertilized with ammonium nitrate, on cattle gains. Cattle gained an average of 3.3 kg BW/per kg of nitrogen applied at a rate of 34 kg of nitrogen per ha. An additional one kg of steer gain per kg of applied nitrogen was found when the application rate was increased to 68 kg of nitrogen per ha. Above the 68 kg application rate steer gains were negligible as the application rate increased to 102 kg of nitrogen per ha. Berg and Sims (2000) found that residual nitrogen in the soil can impact steer gains after cessation of fertilization. Steer weight gain averaged 0.63 kg per kg of applied nitrogen in the three year study when nitrogen fertilizer had been applied over the preceding five years.

Factors Influencing Grazing Cattle Performance

Stocking Rate

Stocking rate is a major factor that can impact rate of gain of grazing cattle. Dubeux et al. (2006) reported that as stocking rate increased levels of extractable soil N, P, K, and Mg increased on fertilized bahiagrass pastures. Phillips and Coleman (1995) compared three grazing strategies consisting of tallgrass native range with an average stocking rate of 0.23 steers / acre, bermudagrass stocked at 1.63 steers / acre, and Old World bluestem stocked at 2.07 steers / acre. Individual animal gains were not different between the strategies, but gain per acre was greater in the bermudagrass and Old World bluestem pastures when compared with the native range pastures. Coleman and Forbes (1998) stated that as stocking rate increased from 3 to 8 steers / ha that individual animal gains decreased while gain / ha increased for cattle grazing Old World bluestem. McCollum et al. (1999) also found that individual gain declined and gain / ha increased when stocking rate increased from 50 to 90 animal-unit-days / ha for cattle grazing Old World bluestem under both continuous and rotational stocking strategies. Teague et al. (1996) reported a similar decrease in individual animal gain with increased stocking rate but gain / ha did not change. In this study stocking rates were adjusted weekly to maintain forage heights at either 35-40, 41-45, or 46-55 mm forage height. The authors noted that under the heaviest stocking (35-40mm) rate forage quality was improved but availability was limited and this would explain the lack of improved gain / ha. In a study on grazing dallisgrass a reduction in ADG for steers was observed as stocking rate increased from 3.7 to 11.1 head / ha (Gunter et al. 2005). Similar to the other studies Ackerman et al. (2001) reported a reduction in ADG as stocking rates increased from 329 kg to 840 kg live weight / ha and that gain / ha increased as stocking rate increased for cattle grazing Old World bluestem. The authors attributed the reduced ADG as stocking rate increased to a decrease in forage intake, increased time grazing, and reduced availability of forage. Stocking rate tends to decrease individual animal performance by reducing intake and forage availability but performance is increased on a per unit land basis since more cattle are stocked on the same amount of land. This is achieved by improving utilization of forage and providing less mature, more leafy forage for the cattle to consume.

Fertilization

Another factor that can affect cattle gains is forage availability and nutrient content. These factors can be enhanced by fertilization to encourage increased forage growth and alter nutrient content of the forage. As stated above Dubeux et al. (2006) reported increased levels of plant available N, P, K, and Mg in bahiagrass pastures that had high stocking rates and fertilization levels (360 kg N / ha and 4.2 animal units / ha) over pastures with low and medium stocking rates and fertilization levels (low: 40 kg N fertilizer / ha and 1.4 animal units / ha, medium: 120 kg N fertilizer / ha and 2.8 animal units / ha). Forage accumulation was increased in the pastures that received high and medium amounts of fertilization over those that received low amounts of fertilization. Carryover effect from previous years may have played a role in the increased forage levels. Further, Dubeux et al. (2006) indicated that increased fertilization increased forage concentrations of N, P, and in vitro digestible organic matter (IVDOM). Apart from increased fertilization the authors noted that increased forage N and P could result from increased stocking rate due to increased nutrient availability from urine and feces of the animals. Krysl et al. (1987) observed increased selectivity by steers that grazed fertilized blue grama rangeland over those that grazed nonfertilized rangeland. Increased selectivity increased the CP content of the diet and reduced the fiber components of the diet which led to increased digestibility. However, digestibility was only increased during the growing season and was reduced during dormancy when compared with nonfertilized rangeland. Rumen pH was reduced and NH_3 concentrations where increased throughout the year for steers that grazed fertilized rangeland but little effect was noted for rumen VFA proportions (Krysl et al., 1987). Berg and Sims (1995) reported that steer weight gains increased quadratically as N fertilization rates increased from 0 to 102 kg N/ha. A response of 3.3 kg of gain / kg of N applied at an application rate of 34 kg / ha per year was noted. An increase of one additional kg of steer gain / kg of N fertilizer was seen when the application rate increased to from 34 kg / ha to 68 kg / ha each year. Berg and Sims (2000) indicated that residual N levels may remain elevated for a number of years after cessation of fertilization to Old World bluestem pasture. A 2- to 4- fold increase was noted in forage yields for pastures that had been fertilized over those that had not been fertilized. Steer gains were increased by 0.63 kg / kg of N applied over the previous 5 years. Total weight gain per steer increased linearly with increasing levels of N fertilizer application. Based on these studies fertilization of pastures is a viable option for improving cattle weight gain through increased forage availability and improved forage quality. However, cost of the additional N inputs must be considered.

Supplementation of Growing Cattle on Pasture

Supplementation is a common practice in grazing programs. However, due to costs incurred from the purchasing and distribution of supplements, goals must be set to ensure production and economic benefit are realized. Supplementation can provide a number of benefits including: correction of specific nutrient deficiencies, conservation of forage, improved utilization of forage, improved animal performance, increased economic returns, provide a carrier for feed additives, or assist in animal behavior management (Kunkle et al., 2000). A meta-analysis (Moore et al., 1999) evaluated ADG and feed intake responses of cattle fed forage based diets while being fed supplements. The authors reported that when forage was fed alone energy and protein levels may not be adequate to achieve desired performance. Energy and protein supplements can be fed to achieve desired performance. However, the amount and type of supplement fed may impact animal gains and result in gains that are greater or less than expected. This occurs from interactions of the nutrients provided by the forage and supplement that can result in adequate energy but low protein or vice versa.

Protein

Metabolizable protein (MP) is defined by the NRC (2000) as true protein absorbed by the small intestine that is supplied by microbial protein and undegradable intake protein (UIP). Microbial protein is derived from the breakdown of degradable intake protein (DIP) and nonprotein nitrogen (NPN; such as urea) sources by microbes and used for protein production in the rumen. Degradable intake protein is feed protein that is degraded in the rumen. Undegradable intake protein is supplied either by forage or supplements provided to the animal and passes through the rumen for use by the animal. Degradable intake protein requirements must be met by the diet if a response to UIP is to be observed (Klopfenstein, 1996). Creighton et al. (2003) reported that cattle grazing smooth bromegrass respond to UIP supplementation (corn gluten feed) due to a MP deficiency resulting from high concentrations of forage DIP.

A digestibility trial (Donaldson et al., 1991) examined the effects of level of UIP fed to cattle grazing annual ryegrass. Supplements included a corn supplement (control), low UIP, and high UIP supplements composed of fish meal and distillers grains that provided 0.125 and 0.25 kg of estimated UIP respectively. As UIP level increased a quadratic increase in total DMI and forage DMI was observed. UIP supplementation increased total tract DM digestibility, determined by in vitro digestion of abomasal and fecal samples taken from the cannulated animals. The authors concluded that supplementing cattle grazing high quality forage with UIP allowed for increased protein flow and nutrient intake without negatively affecting fiber digestion (Donaldson et al. 1991). These data agree with that of Anderson et al. (1988) where steers grazing smooth brome pasture were supplemented with increasing levels of UIP consisting of bloodmeal and corn gluten meal. Average daily gain increased as supplementation level (0, 0.11, 0.23, and 0.34 kg / head) increased during both spring and fall grazing. Crude protein degradation of the forage was between 80 and 90% after 12 hours of in situ incubation. The authors speculated that the steers were deficient in MP based on the increased gains with UIP supplementation and the highly degradable protein in the forage.

An experiment (Hafley et al., 1993) was conducted to evaluate the effect of protein supplements that varied in ruminal degradation on growth of cattle grazing mixed warm season grass pastures that were primarily big bluestem and switchgrass. The supplements included a control (cornstarch and molasses), UIP (control plus soybean meal and feather meal), ruminally degradable protein (control plus corn steep liquor and urea), and a combination of UIP and ruminally degradable protein (control plus soybean meal, feather meal, corn steep liquor, and urea) . Weight gains of cattle fed UIP were not increased compared to cattle fed the control diet. However, cattle fed the degradable protein tended to increase gains compared with those fed the control diets. Cattle fed the combination supplement had improved gains over those fed the control diet and showed a numerical increase (0.05 kg/d) over those fed the degradable protein supplement. In situ degradation of the forage protein showed that about 50% escaped ruminal degradation. The authors concluded that performance of cattle grazing warm-season forage may be improved by supplementation of ruminally degradable protein. However, they also suggested that in certain instances UIP supplementation along with degradable protein may be necessary to realize maximum gains.

Energy

Chase and Hibberd (1987) evaluated the effects of increasing levels of corn supplemented to cows fed native grass hay. Corn levels included 0, 1, 2,or 3 kg/d with cottonseed meal substituted for corn to maintain 256 g/d of supplemental protein. Digestibility of hay was obtained via in situ incubation of hay samples for 6 to 96 hours. As level of corn supplementation increased digestibility of hemicellulose, cellulose, and hay OM decreased, while total DM and OM digestibility increased. Corn supplementation reduced rumen pH along with rumen ammonia levels. When 3 kg of corn were fed pH dropped below 6.3. The authors concluded that without the adequate amount of DIP in the diet cattle fed grain supplements will have inadequate fiber digestion. This results from reduced rumen pH that inhibits microbial degradation of forage and inadequate ammonia concentrations.

Horn et al. (1995) conducted an experiment to evaluate the effect of supplementing cattle grazing wheat pasture with either high-starch or high-fiber energy supplements. Cattle received about 0.70% BW of the supplement six days per week.

Average daily gains were improved by 0.15 kg when energy supplements were provided to cattle. Type of supplement did not affect gains. The authors attributed this to the relatively low level of supplementation and to the fact that wheat contained adequate protein so that animal performance was not restricted by N deficiency.

Associative effects of supplementation have been observed for grazing animals (Moore et al. 1999). This is in agreement with Garces-Yepez et al. (1997) who evaluated the effect of type of energy supplement on steer performance. Three energy supplements consisting of corn and soybean meal, wheat middlings, and soybean hulls were offered at either 25 or 50% of the estimated TDN intake along with bermudagrass hay. Steer ADG was greater for supplemented than non-supplemented animals. Steers fed soybean hulls had greater ADG than those fed corn and soybean meal at high supplementation level. While no differences in ADG were observed at the low supplementation level. The authors attributed the lower performance of cattle consuming the corn and soybean meal supplement to altered intake due to increased starch content in the diet. However, hay intake was lower for cattle that were fed the high level of supplement but intake was not altered by type of supplement. These data indicate that energy supplements can enhance grazing cattle performance. However, when protein levels in the forage are not adequate energy supplements can inhibit fiber digestion and cause a reduction in cattle performance. This is especially of concern when high grain supplements are fed.

Distillers Grains

Background

Distillers grains are a by-product of the dry-milling industry. Davis (2001) and Stock et al. (1999) provided detailed accounts of the dry-milling process. Briefly, the dry-milling process involves the production of alcohol by the fermentative action of yeast on the starch of cereal grain. After fermentation is complete the alcohol is removed via distillation and the remaining slurry is called whole stillage. Coarse grain particles from the whole stillage are removed by centrifugation to yield distillers grains, which may be sold as wet distillers grains (WDG) or dried and sold as dried distillers grains (DDG). The liquid remaining after the coarse particles are removed is called thin stillage and may contain up to 40% of the total residual DM. Condensed distillers solubles (CDS) is a syrup-like by-product that is produced from the thin stillage via evaporation. The CDS can be sold as a feedstuff or a portion can be added back to the DDG to produce dried distillers grains plus solubles (DDGS) or the WDG to produce wet distillers grains plus solubles (WDGS). The amount of solubles added back to the distillers grains there is one factor that affects the nutritive value of DDGS or WDGS.

Nutritive Value

The nutrient value in distillers grains can also be affected by the plant where they are produced and the processing method used, as discussed by Buckner et al. (2011) and Holt and Pritchard (2004). Despite this plant to plant variation some general distinctions can be made about distillers grains. On a DM basis roughly two-thirds of the original grain is starch. After removal of starch during fermentation the remaining nutrients in the grain become more concentrated. Since the whole grain is two-thirds starch the remaining nutrients will increase approximately three-fold in the whole stillage and distillers grains solids.

Buckner et al. (2011) evaluated DDGS from six ethanol plants in Nebraska and reported an average of 31% CP (DM basis) among the plants with a range of 30.1 to 32.2%. Fat averaged 11.9 % (DM basis) with a range of 10.9 to 13.0 %, P content averaged 0.84% (DM basis) with a range of 0.78 to 0.91%, and an average S content of 0.77% (DM basis) with a range of 0.71 to 0.84%. These values are higher than those reported in the NRC (2000). The NRC (2000) reported that DDGS contained 29.5% CP (DM basis), 10.3% fat (DM basis), 0.83 % P (DM basis), and 0.4 % S (DM basis).

Corrigan et al. (2009) conducted an experiment that included both varying levels of DDG supplement (0.25 to 1.0% of BW) along with varying amounts of CDS in the distillers grains (0.0 to 22.1% of DM) fed to growing calves. Protein and fat levels increased while NDF and ADIN levels decreased in the DDG as CDS inclusion increased. Final BW increased quadratically as DDG supplementation level increased. Similar final BW was noted for steers fed DDG at 0.75 and 1.0 % of BW and both were greater than final BW of steers fed DDG at 0.25 and 0.50 % of BW. A cubic response was reported as DDG supplementation level increased when CDS was included at 0.0, 14.5, and 19.1 %. When CDS was included at 19.1 and 22.1 % steers supplemented with DDG at 0.75 and 0.50 % BW had the greatest ADG. The authors speculated that the gain response was due to increased fat intake as the level of DDG supplementation and CDS levels increase, which may have resulted in the inhibition of NDF digestion (Pavan et al., 2007).

Cattle Performance

As stated above, Kunkle et al. (2000) suggested that supplements can be included in forage based diets to ensure adequate nutrient supply to cattle throughout the grazing season. Creighton et al. (2003) reported cattle grazing growing smooth bromegrass may experience a potential UIP deficiency due to the highly degradable protein content of the forage. This deficiency may be alleviated by the inclusion of DDGS in the diet of grazing animal due to a high UIP (53.8 % of CP) (NRC, 2000). Distillers grains are also an appropriate choice for use in grazing programs due to the removal of the starch during fermentation and the elimination of potential negative associative effects of starch on fiber digestion. Horn and McCollum (1987) suggested that high fiber energy supplements can be supplemented to increase energy content of the diet without resulting in negative effects associated with starch. These properties of distillers grains may allow for increased gains for cattle grazing growing forage due to the inclusion of UIP in the supplement without the negative effects on forage digestion that are seen with high-starch supplements.

MacDonald et al. (2007) compared supplementing heifers grazing smooth bromegrass with either DDG, an amount equivalent to that supplied by DDG of UIP supplied as corn gluten meal (CGM), or fat supplied as corn oil (OIL). Supplements were fed on a daily basis individually to heifers with DDG being fed at 750, 1,500, and 2,250 g/d while CGM and OIL were offered at 375, 750, and 1,125 g/d. CGM and OIL supplements were fed at half the rate of DDG but provided the same amount of UIP and fat as the DDG. Average daily gain was increased when DDG was supplemented as compared with the control. Daily gain tended to be greater in heifers provided DDG when compared with heifers supplied CGM or OIL. Heifers supplemented with CGM had an increase in ADG over heifers fed OIL that may mirror the effect of meeting a MP deficiency similar to DDG supplementation.   Corn oil did not increase ADG (P = 0.25) of the heifers which indicates that added energy from the ether extract did not have a great role in improving ADG. The authors speculated that this may show that MP was the first-limiting nutrient in the heifers. A forage substitution rate for DDG of -0.45 was reported. Forage substitution rate is the unit forage intake reduction per unit of supplement consumed. Supplementing OIL up to 1,125 g per day resulted in a forage substitution rate similar to that of DDG. However, CGM supplementation reduced forage intake compared with DDG supplemented heifers potentially due to UIP, though the authors noted this was unlikely since DDG and OIL intake rates were not different. They theorize that the reduced intake may be caused by an endocrine response, in the form of cholecystokinin release, to the UIP because there was no difference between DDG and OIL on forage intake. It was postulated that the improved ADG for the DDG supplemented heifers may have been due to an associative effect between the UIP and fat that was not realized when each component was fed separately.

Loy et al. (2008) conducted a trial with heifers fed grass hay that evaluated the effects of either daily or three times weekly supplementation of DDGS, dried rolled corn (DRC), or DRC plus corn gluten meal (DRC+CGM). The supplements were individually fed at either 0.21 % of BW (LOW) or 0.81 % of BW (HIGH). Dry rolled corn and DRC+CGM were supplemented at rates that equaled the energy and UIP supplied by DDGS, respectively. At LOW supplementation heifers provided DDGS had improved gain and G:F efficiency 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 in relation to DRC at the HIGH supplementation level. It was speculated that a UIP response may have been the cause of the DDGS and DRC+CGM improvements at the HIGH supplementation level. The authors note that all supplements were formulated to exceed MP requirements of the heifers, and that an MP deficiency would be more likely at the LOW supplementation concentration. The authors suggested that a reduction in starch content of the DDGS and DRC+CGM may have reduced the negative associative effect experienced by the HIGH DRC group.

Leupp et al. (2009) investigated the metabolic effects of increasing DDGS levels fed to steers that received a basal diet of smooth bromegrass hay. Steers were fed DDGS at 0.0, 0.30, 0.60, 0.90, and 1.2 % of BW. Rumen degradation characteristics were determined in situ by incubating samples in the rumen for 0, 2, 5, 9, 14, 24, 36, 48, 72, and 96 hours. A cubic response was noted for hay DM disappearance with the greatest disappearance occurring at the 0.9% DDGS and the least occurring at the 1.2% DDGS level. Hay OM intake decreased while total OM intake increased as supplement level increased. Apparent and true ruminal OM digestion along with total tract OM digestibility increased linearly as level of DDGS supplementation increased. Neutral detergent fiber intake was not affected by supplementation level, but NDF digestibility increased linearly with increasing levels of supplementation. Neither ruminal pH or total VFA concentrations were affected by DDGS supplementation level. However, the molar proportion of acetate linearly decreased and the molar proportion of butyrate linearly increased as DDGS level increased. There was a quadratic increase in the molar proportion of propionate and the acetate: propionate ratio decreased linearly as DDGS supplementation level increased. The authors speculated that the reduction in acetate: propionate ratio may have resulted from either increased levels of fat in the diet as DDGS levels increased or increased carbohydrate fermentation in the DDGS compared with the basal forage diet.

A metabolism study (Loy et al., 2007) compared DRC and DDGS effects on forage DMI and digestibility. Heifers fed grass hay were supplemented with either DRC or DDGS at 0.40 % of BW daily or 0.80 % of BW on alternate days. Kinetics of hay disappearance were determined by in situ incubation in the rumen. Samples were placed in dacron bags and incubated in the rumen for 0, 12, 24, 48, or 96 hours to determine degradation. Heifers that received supplement had reduced DMI compared with control heifers, but there was no difference between cattle supplemented with DRC and DDGS groups. There was no difference between supplement type on rumen pH, but both were lower than the pH of control heifers that received only hay. Distillers grains increased NDF disappearance rate compared with DRC fed heifers, but there was no corresponding increase in forage intake. Volatile fatty acid concentrations were decreased in control heifers compared with supplemented heifers. Acetate:propionate ratios of distillers grains supplemented heifers were reduced compared with those fed DRC. It is clear that DDGS and DRC impacted rumen degradation kinetics when compared to the control heifers. Dry rolled corn had a greater impact on VFA concentrations than DDGS. This may be the result of negative effects of starch in DRC.

Greenquist et al. (2009) compared the effects of applying N fertilizer to smooth bromegrass pastures or providing DDGS to steers. Fertilized pastures were fertilized with 90 kg of N / ha and initially stocked at 9.2 animal unit month (AUM) / ha (FERT), non-fertilized pastures were stocked at 6.4 AUM / ha (CONT), and non-fertilized pastures were stocked at the same rate as the fertilized pastures and steers received 2.3 kg DDGS daily / steer (SUPP). Higher CP levels were reported for bromegrass that received fertilizer over those pastures that did not. Average daily gain and total BW gain were greater for steers that were fed DDGS over those that only grazed bromegrass. There was no difference in ADG or total BW gain between steers that grazed fertilized or non-fertilized pastures. Body weight gain / ha was increased for steers that were fed DDGS and that grazed fertilized bromegrass over steers that grazed non-fertilized bromegrass. Also, supplemented steers had greater BW gain / ha than steers that grazed fertilized bromegrass. The authors attributed these results to the fact that both the supplemented steers and steers that grazed fertilized bromegrass had greater stocking rates than did the steers that grazed the non-fertilized pastures, and the supplemented steers were receiving additional energy and protein compared to the steers grazing fertilized bromegrass. The authors concluded that DDGS can be used as a substitute for N fertilizer due to increased steer performance.

Jenkins et al. (2009) evaluated the effect feeding varying levels of DDG to steers grazing dormant rangeland. Steers were fed DDG at 0.0, 0.25, 0.5, or 0.75 % BW / day. Average daily gain increased linearly as level of DDG supplementation increased. Final BW and total BW gain both linearly increased as DDG supplementation increased.

Research conducted by MacDonald et al. (2007) and Loy et al. (2008) illustrate the associative effects of UIP and energy found in distillers grains. Both reports examined distillers grains plus equivalent amounts of UIP and energy provided by CGM, corn oil, or DRC. A consistent response in gain was observed in both studies from supplementation of CGM and DRC+CGM (UIP equivalents), though not as great as the distillers grains, and there was less response to the energy equivalents (corn oil and DRC). These data indicate that while there was a potential MP deficiency that was addressed there was a clear positive associative effect from the combination of UIP and energy in the distillers grains. Greenquist et al. (2009) reported steers fed DDGS had improved ADG over steers that grazed fertilized bromegrass pastures. The authors attributed this to the addition of both energy and protein from the DDGS as opposed to just additional protein that the fertilized bromegrass provided. The metabolism trials conducted by Leupp et al. (2009) and Loy et al. (2007) showed that DDGS altered rumen kinetics by increasing degradation rate as well as decreasing the acetate: propionate ratio. Loy et at. (2007) reported less alteration in rumen digestion kinetics, compared with control, from DDGS compared with DRC which they attributed to the lower starch levels found in DDGS compared with DRC. Loy et al. (2008) also reported that the improved gain and feed efficiency observed were possibly a result of reduced starch in the HIGH diets of DDGS and DRC+CGM over the DRC diet. In summary, these data indicate that distillers grains are a suitable supplement for cattle on forage based diets due to the supply of UIP and energy and because of reduced negative associative effects as compared with higher starch, cereal grain-based supplements.

Nutrient Cycling

Nitrogen is extremely important in agriculture, from its use as a fertilizer to enhance plant growth to the need for proper handling and disposal of animal waste in confinement operations. An understanding of the Nitrogen Cycle allows for proper management and usage of this important element. Briefly, atmospheric N deposition occurs primarily from either lightning strikes that form nitrate in the soil, by being borne into the soil by rain, snow, dust, and gaseous absorption, or biological N fixation. Typically atmospheric N is introduced into the soil as either ammonium (NH_4^+) or nitrate (NO_3^-), inorganic forms of N. Nitrogen can also be introduced in organic form from human, plant, and animal sources. For inorganic N ammonium undergoes nitrification to produce NO_3^-, which can then be absorbed by plants for protein production. Nitrogen from organic compounds usually is first mineralized by enzymes produced by soil microbes, but plants are able to take up soluble organic nitrogen. This involves breaking down amine groups into amino groups. These can then be hydrolyzed to produce ammonium, which then undergoes nitrification. Certain plants, mainly legumes, are able to fix gaseous N (N_2) to reactive forms that the plant can use with the help of symbiotic bacteria that live mainly in root nodules (Brady and Weil, 2008).

However, N is lost from the cycle through a variety of ways including: volatilization, leaching, erosion, and runoff. These losses occur more with inorganic N since it is soluble in water and ammonium can escape as ammonia gas easily. Organic sources of N are less likely to be lost due to leaching and runoff as they are insoluble (Brady and Weil, 2008).

Grazing cattle obtain N from forage and any supplemental feeds that are fed. As stated above, forage concentrations of N and P were increased when bahiagrass pastures were fertilized (Dubeux et al., 2006), and digestibility was improved during the growing season in blue grama rangeland when fertilized (Krysl et al., 1987). Protein supplementation has been shown to improve growth performance of grazing cattle (Anderson et al.,1988; Donaldson et al., 1991; Hafley et al., 1993).

Degradable protein that enters the rumen is broken down by proteases produced by rumen microbes to smaller amine groups and ammonia. The microbes then use these N containing compound to produce microbial crude protein (MCP). This, along with UIP, supplies the protein that cattle require. Microbial protein ranges from 20 to 60% DM with an average of 50% for bacteria and 40% for protozoa with a biological value of 66 to 87. Ammonia is the main source of N for ruminal bacteria along with amino acids and peptides. There are several sources for the ammonia that ruminal microbes use for protein production including: degradation of feed protein and MCP, NPN, and hydrolysis of recycled urea entering the rumen from the blood (Owens and Zinn, 1993).

Microbial protein and UIP pass through the rumen to the abomasum for digestion and into the small intestine where amino acid and peptide absorption takes place. If amino acids are not used for synthesis of body tissue they are catabolized with the amino-N being removed and converted to urea. Urea is absorbed into the blood stream where it can be excreted in urine or be recycled for use as ammonia in the rumen. Urea can be recycled to the rumen either in saliva or attenuated diffusion through the rumen wall. From 15 to 50% of urea can be reintroduced into the rumen through saliva in forage diets. When urea diffuses into the rumen urease, produced by bacteria that adhere to the rumen wall, convert the urea to ammonia. The ammonia is converted to ammonium ions by the lower ruminal pH. This allows for the N to be incorporated into MCP. About 10-15% of dietary N intake will be recycled to the rumen.

Nitrogen is excreted from animals as urine and feces. Animal manure is an excellent source of micro- and macronutrients for forages. About three-fourths of nitrogen, four-fifths of phosphorus, and nine-tenths of potassium ingested by animals is excreted (Brady and Weil, 2002). Greenquist et al. (2011) reported that excretion of N was increased when steers were supplemented with DDGS at 0.5 % of BW compared with steers that grazed unfertilized smooth bromegrass (112.65 and 55.20 kg N/ha; respectively). Smith and Frost (2000) stated that animal size, productivity, diet and water intake, and seasonal weather conditions are all factors that affect quantity and nutrient content of waste (feces and urine). Smith (1973) reported that beef cattle feces contained 3% nitrogen on a dry matter basis. Langmeier et al. (2002) evaluated the use of manure, slurry (manure and urine), and mineral N fertilizer on growth rates of ryegrass grown in pots. N sources were labeled with ^{15}N. Plant total N uptake was greatest for mineral fertilized plants and least for plants fertilized with feces. Nitrogen uptake from the soil was increased for mineral N suggesting mineral N increased mineralization of soil N. However, manure reduced N uptake from the soil suggesting soil N was immobilized. Ryegrass was clipped six times at 19, 366, 64, 96, 134, and 162 days after seeds were sown. After the first clipping 80% of available mineral N was present in the ryegrass, while 50% of available fecal N was present. This suggests that N excreted in feces are available for a longer time period than mineral N but had lower N release rates. After the final clipping only 11% of mineral N remained in the soil while N remaining from feces was 60% and slurry was 55%.

Literature Review Summary

Proper management of grazing cattle is important to ensure adequate gains are realized for the producer to be profitable. Old World bluestem is a viable option for use in grazing strategies in the Southern Great Plains. Proper management of the forage is needed to maintain forage growth and nutrient levels through the grazing season.

These management variables can include fertilization, altering stocking rates, and supplementation. Altering stocking rates and fertilization of forage can enhance utilization of the forage and ensure that adequate forage levels are available throughout the grazing period. Supplementation can also improve cattle performance by providing additional protein or energy or both to enhance growth and allow the animal to more efficiently utilize forage. With Old World bluestem's response to fertilization and increased stocking rates, many options are available to improve cattle performance and increase the productivity of the enterprise.

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CHAPTER III

FERTILIZATION AND DRIED DISTILLERS GRAINS SUPPLEMENTATION EFFECTS ON PERFORMANCE AND N RECOVERY BY STOCKER CATTLE GRAZING OLD WORLD BLUESTEM

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ABSTRACT: A 2-yr study evaluated the efficacy of using dried distillers grains plus solubles (DDGS) as a substitute for nitrogen (N) or N and phosphorus (P) fertilizer in stocker cattle grazing Plains Old World bluestem. Cattle were allotted to one of 4 treatments:1) Old World bluestem pastures with no N or P fertilizer and low stocking rate of 325 kg/ha (**CONT**), 2) Old World bluestem pastures fertilized with 90 kg/ha of N and no P with high stocking rate of 650 kg/ha (**NFERT**), 3) Old World bluestem pastures fertilized with 90 kg/ha of N and 40 kg/ha of P with high stocking rate of 650 kg/ha (**NPFERT**), and 4) unfertilized Old World bluestem pastures with the same stocking rate as NFERT and NPFERT with cattle receiving 0.75% BW of corn DDGS per day for a 5 day / week feeding schedule (**DDGS**). Average forage mass in yr 1 and 2 was 3,170 and 6,051 kg/ha, respectively. In yr 1 final BW ($P < 0.05$), total BW gain ($P < 0.05$), overall ADG ($P < 0.05$), and gain/ha ($P < 0.05$) were greater for DDGS compared to CONT, NFERT, and NPFERT. Nitrogen recovery as cattle weight gain was greatest ($P < 0.05$) for CONT, and DDGS was greater than NFERT and NPFERT. In yr 2 there were no differences ($P > 0.05$) between final BW, total BW gain, or overall ADG between treatments. This may have been due to greater forage mass in yr 2. . Gain per ha was greater ($P < 0.05$) for DDGS, NFERT, and NPFERT compared to CONT and may be due to increased stocking rates for those treatments. Nitrogen recovery was greater ($P < 0.05$) for CONT, intermediate for DDGS, and lowest for NFERT, NPFERT. Dried distillers grains can be used as a substitute for forage and N fertilizer by improving performance and N recovery by stocker cattle grazing Old World bluestem.

Key Words: Stocker Cattle, Old World Bluestem, Weight Gain, Nitrogen Recovery

Introduction

Increasing costs of land and inputs are currently major challenges facing the beef cattle industry. To be profitable beef production relies on the ability of cattle to consume and efficiently use forage to gain weight. This is reliant upon an abundance of high quality forage available for the cattle to graze. In the southern Great Plains this includes native and introduced grasses and small grains forages. Old World bluestem is a warm-season introduced perennial grass that has been planted in large areas of the southern Great Plains to assist in arresting soil erosion on marginal farmland and as a high quality summer forage for cattle (Dewald et al., 1985). Like many warm season grasses, Old World bluestem contains high nutrient levels early in the growing season, but these levels decline as the season advances and are quite low when bluestem is dormant.

Producers may implement management strategies to either take advantage of the high nutritive value of Old World bluestem early in the growing season or balance out the reduced quality later in the growing season. These strategies can include fertilization of the pasture early in the growing season to enhance forage growth and nutrient content (Dubeux et al., 2006), increased stocking rates to better utilize available forage and prevent forage maturation (Teague et al., 1996), or provide supplements to cattle to meet nutrient deficiencies. Nitrogen fertilizer costs have steadily risen since the mid-1990s. This increase in cost has incentivized beef producers to look for alternate methods of supplying N to the system, such as supplementing DDGS.

Early in the growing season when crude protein levels are adequate in forage energy supplements may need to be incorporated to improve protein utilization. However, if grain supplements are provided and protein levels are not adequate fiber digestion may be reduced and result in decreased cattle performance (Chase and Hibberd, 1987). As the growing season advances protein becomes the first-limiting nutrient which would necessitate the use of a protein supplement to ensure adequate cattle gains. In addition, undegradable protein may be necessary if forage protein is highly degradable (Hafley et al., 1993). Distillers grains plus solubles is a byproduct of the ethanol industry and a source of energy and both degradable and undegradable protein. These characteristics allow DDGS to be fed throughout the grazing period and provide energy and protein when needed based on what is limited in the forage (Creighton et al., 2003).

Animal manure is an excellent source of micro- and macronutrients for forages. About three-fourths of nitrogen, four-fifths of phosphorus, and nine-tenths of potassium ingested by animals is excreted (Brady and Weil, 2002). Greenquist et al. (2011) reported that excretion of N was increased when steers were supplemented with DDGS at 0.5 % of BW compared with steers that grazed unfertilized smooth bromegrass (112.65 and 55.20 kg N/ha; respectively).

The objective of this study was to evaluate the effect of N or N+P fertilizer application to Old World bluestem pasture or feeding DDGS to growing beef cattle on cattle performance, beef production / hectare, and N recovery in cattle weight gain.

Material and Methods

All experimental protocols were approved by the Oklahoma State University Animal Care and Use Committee.

Research Site

This study was part of a four year study that began in 2010. Treatments were assigned to pasture in 2010 and maintained throughout the study. The study was conducted at the Crosstimbers Bluestem Stocker Range 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. Plains Old World bluestem (*Bothriochloa ischaemum* (L.) Keng. var *ischaemum*) was seeded and established at this site in 1989. Total precipitation for the months of April, May, June, July, August, and September was 36.73 cm during 2012, and 65.60 cm during 2013. The 29-yr average (1981-2010) precipitation for these months was 59.37 cm (Table 1).

Cattle

During both years (2012 and 2013) cattle were received in the spring. In yr 1, mix breed *Bos taurus* short yearling heifers (n = 266) arrived on April 3. Heifers were implanted with a combination Estradiol Trenbolone acetate implant that contained

Tylosin tartrate (Component TEG, Elanco Animal Health, Greenfield, IN), vaccinated with a modified-live virus, respiratory vaccine (Titanium 3, Agrislabs, St. Joseph, MO), and an injectable dewormer (Dectomax Injectable, Zoetis, Florham Park, NJ) at a commercial feedlot where they were fed a low-energy growing diet for about 30 days, before delivery to the Crosstimbers Bluestem Stocker Range. Two-hundred and thirty heifers (average initial wt: 286 ± 2 kg) were used during year one. In yr 2, fall-born angus steer calves (n = 275) arrived on May 1 and May 8. Before arrival at the Crosstimbers Bluestem Stocker Range the cattle were vaccinated as suckling calves with a preventative killed virus, respiratory vaccine (Triangle 9 + PH-k, Boehringer Ingelheim Pharmaceuticals Inc., Ridgefield, CT), a Clostridial vaccine (Covexin 8, Merck Animal Health, Millsboro, DE), a modified live virus, respiratory vaccine (Vista Once SQ, Intervet, Millsboro, DE), and a zeranol anabolic implant (Ralgro, Merck Animal Health, Millsboro, DE). Two-hundred and sixty-eight steer calves (average initial wt: 226 ± 16 kg) were used during year two. At time of trial initiation steers were vaccinated with Vista Once SQ to prevent respiratory disease.

Experimental Design and Treatments

A randomized complete block design with 3 blocks and 4 treatments was used. The treatments were 1) Old World bluestem pastures with no N or P fertilizer and low stocking rate of 325 kg/ha (**CONT**), 2) Old World bluestem pastures fertilized with 90 kg/ha of N and no P with high stocking rate of 650 kg/ha (**NFERT**), 3) Old World bluestem pastures fertilized with 90 kg/ha of N and 40 kg/ha of P with high stocking rate of 650 kg/ha (**NPFERT**), and 4) unfertilized Old World bluestem pastures with the same stocking rate as NFERT and NPFERT with cattle receiving approximately 0.75% BW of corn dried distillers grains plus solubles per day for a 5 day / week feeding schedule (**DDGS**; Table 2). Both years cattle were stratified by initial BW and assigned to one of twelve pastures. A total of 104 ha of Old World bluestem were fenced into 12 pastures ranging in size from 4 to 10 ha. Due to variations in cattle weights and the number of cattle used during each year the actual stocking rates were different than the targeted stocking rates (CONT 333 and 302, NFERT 632 and 610, NPFERT 655 and 622, DDGS 651 and 614 kg/ha; 2012 and 2013 respectively). Similarly actual amounts of DDGS fed were different (0.71 % BW for 2012 and 2013) from the calculated 0.75 % BW. Fertilizer was applied to appropriate pastures on May 2 in 2012 and May 16, 17, and 18 in 2013. Cattle had free-choice access to plain salt and water from ponds and improved water sources. At the midpoint of each grazing season (July 17, 2012 and July 18, 2013) when it was determined that forage CP levels were declining cattle that were not fed DDGS were provided daily 0.45 kg / head of a 40% CP supplement (cottonseed meal, soybean meal, wheat middlings, and Rumensin 90; Table 2) to ensure cattle received adequate protein throughout the grazing period.

Data Collection and Analysis

During both years cattle were weighed at the beginning, midpoint, and end of summer grazing (May 17, July 17, and September 13, 2012; May 21, July 18, and September 19, 2013, respectively). Before each weigh day cattle were placed in holding pens overnight without access to food or water in an attempt to minimize rumen fill .

Nitrogen retention was calculated for cattle each year. Briefly, net nitrogen was calculated from equations in Ch. 3, Growth and Body Reserves, in the NRC (2000).

Abbreviations are as follows: EBG is empty body gain, kg; EQSBW is equivalent shrunk body weight, kg; SRW is standard reference weight for the expected final body fat, and the value used was 478 kg for animals finishing at small marbling (28 % body fat); FSBW is actual final shrunk body weight at the body fat endpoint, 591 kg was used; EQEBW is equivalent empty body weight, kg; RE is retained energy, Mcal/day; NPg is net protein requirement, g/day; NN is net nitrogen, g/day.

EBG, kg = 0.956*SWG	Eq. 3-4/3-5 using constants
EQSBW, kg = SBW*(SRW/FSBW)	Eq. 3-9
EQEBW, kg = 0.891*EQSBW	Eq. 3-4/3-5 using constants
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	

Then N retention, kg/ha, of BW gain was calculated on a pasture basis by multiplying net nitrogen by the number of grazing days and stocking rate of the pasture. Nitrogen recovery was calculated by dividing nitrogen retention (kg/ha) by nitrogen inputs (kg/ha) for each pasture and then multiplied by 100, for a percentage basis.

Forage diet quality and forage mass samples were collected each month (June, July, August, and September) of the grazing season for both years. In yr 1, 104 forage mass samples (1 sample / ha) per month were clipped from known locations using a GPS device along with 3 diet quality samples per pasture. Sampling sites were selected in an attempt to obtain representative samples of each pasture. Forage mass samples were clipped from a 0.09 m^2 quadrant to ground level. Diet quality samples were hand clipped in an attempt to match forage selection by the cattle. In yr 2, 64 forge mass samples (approximately 1 sample / 2 ha) were clipped from known locations using a GPS device. The number of forge mass samples were reduced in yr 2 due to a lack of available labor on collection days. Sample collection methods were the same in yr 2 as in yr 1 for forage mass and diet quality. Dry matter (oven drying at 55^{o} C to a constant weight) was determined immediately following collection, and after drying samples were ground through a 2-mm screen using a Wiley Mill (Thomas Scientific, Philadelphia, PA) and stored for later analysis. Supplement samples were collected weekly and composited by month.

Forage and supplement samples were analyzed for laboratory DM (oven drying at 105^{o} C), NDF and ADF (Ankom Tech Corp., Fairport, NY), ash (combusted 6 h in a muffle furnace at 500^{o} C), and CP (% N x 6.25; Truspec-CN LECO Corporation, St. Joseph, MI).

Degradable intake protein (DIP) of the diet quality forage samples and supplements was analyzed using a *Streptomyces griseus* protease (Type XIV Bacterial; Sigma-Aldrich, Co., St. Louis, MO) as described by Mathis et al. (2001). Briefly, forage sample amounts equivalent to 15 mg of N were placed into 125-mL Erlenmeyer flasks. Forty milliliters of a borate-phosphate buffer was added to each flask and the flasks were incubated for 1 h at 39^{o}C in a shaker water bath. After incubating in the buffer, 10 mL of the protease solution was added to each flask and incubated for 48 h at 39^{o}C in a shaker water bath. After the incubation period the samples were filtered through Whatman #541 filter paper using a cone-shaped funnel. Samples were rinsed with 400 mL of distilled water to remove any incubation media, and then dried for 48 h at 90^{o}C to obtain residue DM weight. The samples were analyzed for N content using the Kjeldahl assay with a

2400 Kjeltec Analyzer Unit Foss Tecator (Hoganas, Sweden). The undegradable intake protein (UIP) percentage was calculated by dividing the milligrams of residual N by milligrams of total N from the sample and multiplying by 100. The result was then subtracted from 100 to determine the percent DIP in each sample.

Mineral analysis of the forage diet quality samples and supplement samples was conducted by Oklahoma State University Soil, Water, and Forage Analytical Laboratory. Samples were prepped for analysis by grinding through a 1-mm screen using a Cyclone Sample Mill (Udi Corp., Fort Collins, CO). Then 0.5 g of sample were digested with 10 mL of trace-metal-grade nitric acid (67-70 % NHO_3) in a vessel and allowed to sit for 1 h. After the hour the samples were 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 screw top tubes for delivery and 40 mL of distilled water was added to dilute the samples. Minerals were analyzed by ICP for mineral concentrations.

Statistical Analysis

All data, cattle performance and forage mass and quality, were analyzed for a randomized complete block design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Pasture was the experimental unit and treatment was considered a fixed effect. Block was considered a random effect. The model included treatment for cattle performance and treatment, time, and treatment*time for forage data and used Kenward-Rogers degree of freedom procedure. Least square means and the P-DIFF procedure, with Tukey-Kramer adjustment, were used to separate treatment means when a significant (P < 0.05) F-Test was detected.

Results and Discussion

Year 1

Forage Mass and Forage Nutritive Value. Forage mass averaged 3,170 kg/ha and was affected by treatment (P < 0.05; Table 3, Figure 1). Forage mass was greatest for NPFERT (3,671 kg/ha) while CONT, NFERT, and DDGS did not differ (3,018, 3,053, and 2,939; respectively). Forage mass declined (P < 0.05) as the grazing season progressed (Table 4). Forage mass was greatest in July (3,926 kg/ha) and did not differ between June, August, and September (2,855, 3,199, and 2,701 kg/ha; respectively). The increase in forage mass in July can be explained by the fact that 5.49 cm of rain fell in June (Table 1) which would boost forage growth. Berg (1990) reported that near Woodward, OK Old World bluestem responded linearly to N fertilization up to 70 kg/ha in a year of normal precipitation. Forage production increased by 30 kg of forage per kg of N applied at 35 and 70 kg N/ha application rates. The fact that no additional response was noted when N was applied at 90 kg/ha but forage mass increased when 90 kg N/ha and 30 kg P/ha was applied may suggest that the soil required extra P.

Treatment did not affect (P > 0.05) CP (Figure 2), NDF (Figure 3), or ADF (Figure 4). However, DIP (Figure 5) was affected (P < 0.05) by treatment. Degradable intake protein (Table 3) was greater for CONT and DDGS (73.51 and 73.13 % CP; respectively), intermediate for NFERT (67.55 % CP), and lowest for NPFERT (65.99 % CP). Month (P < 0.05) affected CP, NDF, ADF, and DIP. Crude protein (Table 4) was greatest in June (16.41 %), intermediate in July (11.58%) and September (13.73 %), and lowest in August (8.57 %). Neutral detergent fiber (Table 4) was lowest in June (79.44 %), intermediate in July (82.57 %) and September (83.92 %), and highest in August (86.25 %). Acid detergent fiber (Table 4) followed a similar pattern as NDF with the lowest level in June (38.33 %), intermediate levels in July (43.68 %) and September (44.65 %), and highest in August (47.68 %). Degradable intake protein (Table 4) was lowest in June (66.63 % CP), highest in August (72.77 % CP), while July (69.41 % CP) and September (71.36 % CP) did not differ. A similar trend was reported by Dabo et al. (1988) for changes in CP, NDF, and ADF in Old World bluestem, near Stillwater, OK, as maturation increased. They reported that as the season progressed NDF and ADF increased, while CP levels decreased. They attributed the increased fiber levels to maturity and elevated temperatures during the summer months.

Forage mineral concentrations (Table 3) were not affected ($P > 0.05$) by treatment. When compared to NRC requirements for a 300 kg growing/finishing animal gaining 0.89 kg/d, the concentrations of all minerals, except Zn, were adequate for each treatment. Concentration of Zn requirements were 26.01, 28.78, 26.34, and 28.33 ppm for CONT, NFERT, NPFERT, and DDGS; respectively and close to the requirement of 30 ppm. Calcium, Na, and Zn were not affected ($P > 0.05$; Table 4) by month, but P, K, Mg, S, and Cu were affected ($P < 0.05$). Phosphorus change across sampling periods is shown in Figure 6. Apart from Zn, mineral requirements were met for P, Ca, K, Mg, Na, S, and Cu. In June Zn requirements were met (30.68 ppm), but Zn concentrations declined below requirements in July, August, and September (26.08, 27.72, and 24.98

ppm; respectively). The treatment means for each sampling month are shown in Appendix Table 1.

Cattle Performance. It has been previously shown that feeding dried distillers grains plus solubles improves performance of grazing cattle (Greenquist et al. 2009, McMurphy et al. 2011, and Watson et al. 2012). Supplementation increased ($P < 0.05$) overall ADG and total gain of heifers during the grazing season (Table 5) compared to heifers in CONT, NFERT, and NPFERT grazing groups. During Period 1 supplemented heifers had improved ($P < 0.05$) ADG compared to heifers in CONT and NFERT treatments but not over heifers in NPFERT groups. This may be due to the fact that forage mass (Table 3) was greater (3,351 kg/ha) for NPFERT than CONT (2,484 kg/ha), NFERT (2,975 kg/ha), and DDGS (2,591 kg/ha). Heifers that were fed DDGS had improved gain/ha ($P < 0.05$) compared to heifers that grazed fertilized and unfertilized pasture. While, heifers that grazed the NFERT and NPFERT pastures had greater gain/ha than the CONT groups. Gain per hectare was improved because of the increased stocking rate (650 vs. 325 kg/ha) for heifers grazing fertilized pastures and heifers supplemented with DDGS. This suggests that stocking rates can be increased with supplementation of DDGS. Final BW was improved for DDGS supplemented heifers compared to CONT, NFERT, and NPFERT heifers. These results are to be expected since forage quality (Table 4) declined as the grazing season advanced, but the DDGS provided additional CP and energy compared to the other treatments. Nitrogen recovery (Table 5) was greatest ($P < 0.05$) for CONT, intermediate for DDGS, and lowest for NFERT and NPFERT. This would occur since N inputs for NFERT (100.03 kg/ha) and

NPFERT (100.32 kg/ha) were higher than for CONT (8.13 kg/ha) and DDGS (41.12 kg/ha).

Greenquist et al. (2009) evaluated the effect of fertilizing smooth bromegrass with 90 kg/ha of N or supplementing steers daily with DDGS at 0.5% of BW. Steers fed DDGS had improved ADG, final BW, total BW gain, and gain/ha over steers that grazed either fertilized or unfertilized smooth bromegrass. The authors attributed these improvements to the supply of additional CP and energy to steers fed DDGS. Our results are in agreement with those of Greenquist et al. (2009) where feeding DDGS improved cattle performance over fertilization of pasture. A report by MacDonald et al (2007) supports the idea that DDG improves gains by providing CP and energy. They reported that supplementing heifers that grazed smooth bromegrass pasture with DDG improved heifer gains compared with corn gluten meal (amount of UIP equivalent to that provided by DDG) or corn oil (amount of energy equivalent to that provided by DDG). The authors attributed the improved gains to the combination of UIP and energy provided by the DDG since neither of the individual components (UIP or energy) had gains similar to those of the DDG.

Year 2

Forage Mass and Forage Nutritive Value. Forage mass averaged 6,051 kg/ha and was affected ($P < 0.05$) by treatment (Table 6, Figure 7). Forage mass was least for DDGS (5,007 kg/ha), did not differ for CONT (6,141 kg/ha), NFERT (6,055 kg/ha), and NPFERT (7,001 kg/ha). Month also affected ($P < 0.05$) forage mass (Table 7). Forage mass was greatest in August (8,126 kg/ha) and did not differ between June (5,371 kg/ha), July (4,690 kg/ha), and September (6,018 kg/ha). Rainfall during 2013 (Table 1) was greater (65.60 cm) than the 29 year average (59.37 cm), which increased forage growth.

Crude protein (Table 6; Figure 8) was affected ($P < 0.05$) by treatment with the CONT having the lowest concentration (15.05 %), DDGS was intermediate (17.43 %), and NFERT and NPFERT being highest (18.44 and 18.45 %; respectively). Treatment did not affect ($P > 0.05$) NDF (Figure 9), ADF (Figure 10), or DIP (Figure 11). Month affected ($P < 0.05$) CP, NDF, ADF, and DIP. Crude protein (Table 7) was least for July (14.74 %), intermediate for June (16.81 %) and September (18.24 %), and greatest for August (19.50 %). Neutral detergent fiber (Table 7) was least in June (73.06 %) intermediate in July (75.99 %) and August (76.00 %), and greatest in September (79.16 %). Acid detergent fiber (Table 7) was least in June (36.44 %), intermediate in July (39.91 %) and August (38.89 %), and greatest in September (41.71 %). Degradable intake protein (Table 7) was least in July (70.39 % CP), intermediate in June (74.34 % CP) and August (77.52 % CP), and greatest in September (82.91 % CP).

Treatment did not affect ($P > 0.05$) Ca, K, or S, but did affect ($P < 0.05$) P, Mg, Na, and Cu. When compared to the NRC (2000) requirements for a 300 kg growing animal gaining 0.89 kg/d forage mineral concentrations were adequate for Ca, P, Mg, S, and Cu. The NRC (2000) requirement for P is 0.18 % DM and NPFERT (0.24 % DM) was the only treatment that provided adequate P (Table 6; Figure 12), while CONT, NFERT, and DDGS (0.15, 0.14, and 0.18 % DM; respectively) were inadequate. Sodium requirements (0.07 % DM; Table 6) were met for NFERT (0.10 % DM), NPFERT (0.17 % DM), and DDGS (0.09 % DM), while CONT was not adequate (0.06 % DM). Zinc requirements (30.00 ppm; Table 6) were met by NFERT (32.91 ppm), while CONT

(29.69), NPFERT (23.31), and DDGS (26.47) were below the recommended levels. Month did not affect (P > 0.05) Na, but did affect (P < 0.05) P, Ca, K, Mg, S, and Ca. Calcium, K, Mg, Na, S, and Cu concentrations were above the NRC (2000) recommendations for all months during Year 2. Phosphorus concentrations (Table 7) were adequate in June (0.20 % DM), July (0.19 % DM), and August (0.18 %DM), but were inadequate in September (0.14 % DM). Zinc concentrations (Table 7) ranged from 28 to 34 ppm and were slightly below or above the NRC (2000) requirement of 30 ppm. The treatment means for each sampling month are shown in Appendix Table 1.

Cattle Performance. There were no differences (P > 0.05) in steer final BW, overall ADG, or total BW gain, between treatments during the grazing season (Table 8). Gain per hectare was greater (P < 0.05) for NFERT, NPFERT, and DDGS steers than CONT steers. This is due to the fact that the CONT group had a lower stocking rate (325 kg/ha) than NFERT, NPFERT, and DDGS groups (650 kg/ha). Supplementing DDGS did not increase gain/ha as compared to the NFERT and NPFERT treatments as it did in yr 1. This may have been due to the fact that forage mass (Table 6) was elevated throughout the grazing season as compared to yr 1 and nutrient requirements of the cattle may have been met by the forage. Nitrogen retention was greatest (P < 0.05) for CONT, intermediate for DDGS, and lowest for NFERT, and NPFERT. Higher N inputs in the NFERT (102.05 kg/ha) and NPFERT (102.17 kg/ha) treatments would reduce the N use efficiency compared with CONT (9.07 kg/ha) and DDGS (41.69 kg/ha).

Rainfall (Table 1) was much higher in 2013 than the previous few years. This led to improved forage mass and forage quality (Table 6) throughout the grazing season, along with residual N from previous years that did not get utilized due to the drought conditions in the area. Crude protein levels were elevated with a dip in July and increased in August and September. Neutral detergent fiber and ADF levels rose as the grazing season progressed but no to the same extent as the previous year. Degradable intake protein levels were above 65% throughout the grazing season. These indicate that forage quality was improved throughout the season compared with yr 1. This is potentially why no differences between treatments for final BW, ADG, or total gain were observed. These results differ from Greenquist et al. (2009) who reported improved gains for steers grazing smooth bromegrass that received DDGS. They attributed the additional gains of steers fed DDGS over those that grazed fertilized or nonfertilized bromegrass to the additional protein and energy provided in the DDGS. However, the discrepancies between the current study and Greenquist et al. (2009) could be due to the fact that forage CP levels in the current study were much higher, while bromegrass CP ranged from 13 to 18 %.

Year: 2012 vs. 2013 Cattle in yr 1 were larger and older than those in yr 2. This resulted in greater final BW (339 kg) of cattle in yr 1 compared to yr 2 (317 kg). However, ADG was greater in yr 2 (0.76 kg/d) than yr 1 (0.62 kg/d). Stocking rate (head/ha) was greater in yr 2 than yr 1, whereas stocking rate (kg/ha) was similar between years. These data agree with those reported by Ackerman et al. (2001) who reported that setting stocking rate at a kg/ha basis allowed for greater gain/ha for light weight steers despite lower rates of gain per animal.

Greenquiest et al. (2009) reported that steers that received DDGS when grazing smooth bromegrass had improved performance over steers that grazed fertilized or unfertilized pasture. Year 1 of the current study agreed with this where DDGS-fed heifers had improved final BW, overall ADG, total gain, and gain/ha over heifers that grazed fertilized or unfertilized Old World bluestem. However, yr 2 did not follow a similar pattern with no difference between final BW, overall ADG, or total gain, while gain/ha was improved for NFERT, NPFERT, and DDGS treatments. In both years N recovery was greatest for CONT due to low N input, and DDGS had improved N recovery during both years over NFERT and NPFERT.

Conclusion

Fertilization of Old World bluestem pasture with N or N+P or feeding DDGS at about 0.75% of BW allowed for stocking rate (BW/ha) to be doubled without a decrease in cattle growth performance during two season-long, summer grazing programs. Beef gain/ha for the fertilized pastures was increased by 2- and 1.7-fold during the first and second year of the study compared with the control. In yr 1, gain/ha for the DDGS treatment was increased an additional 50 kg ($P < 0.05$) compared with the fertilized treatments. However, during yr 2 DDGS supplementation did not increase ($P > 0.05$) gain/ha compared to the fertilized treatments. The lack of difference in yr 2 between the DDGS and fertilized treatments may have been due to the increased rainfall during yr 2 that allowed for increased forage growth throughout the grazing season, forage mass averaged 3,170 kg/ha in yr 1 and 6,051 kg/ha in yr 2. The increased forage mass may have supplied enough nutrients as to mitigate the benefit of feeding DDGS. Nitrogen recovery as cattle weight gain was low (5 to 7 %) for the fertilized pastures in yr 1 and 2. Supplementation with DDGS improved N recovery in yr 1 to about 14 % ($P < 0.05$) and 18 % in yr 2 ($P < 0.05$). Nitrogen recovery for control, non-fertilized pastures was 28 and 45 % in years 1 and 2, respectively. Dried distillers gains can be used as a substitute for forage and N fertilizer by improving performance and N recovery by stocker cattle grazing Old World bluestem.

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Table 1. 2012 / 2013 Rainfall near Crosstimbers Bluestem Stocker Range, cm

	Year		
Item	2012	2013	10 yr Avg
Month			
April	15.65	13.54	8.92
May	2.84	15.80	13.46
June	5.49	10.03	12.24
July	0.18	14.15	7.67
August	6.71	6.45	7.59
September	2.79	4.29	10.11
Total	33.66	64.26	59.99

Table 2. Chemical composition of DDGS and Protein Supplement

	Year			
	2012		2013	
Item	DDGS	Protein	DDGS	Protein
Number of samples	3	3	4	3
CP, % DM	37.21	46.15	38.99	51.72
DIP, % CP	73.13	88.07	63.4	88.87
P, % DM	0.962	1.222	1.13	1.228
Ca, % DM	0.028	0.277	0.053	0.322
K, % DM	1.212	1.86	1.43	1.876
Mg, % DM	0.345	0.657	0.414	0.675
Na, % DM	0.278	0.105	0.392	0.205
S, % DM	0.575	0.446	0.555	0.523
Fe, ppm	93.96	905.91	133.49	196.72
Zn, ppm	62.87	70.65	82.54	76.56
Cu, ppm	5.49	21.01	9.36	16.49
Mn, ppm	18.17	39.93	21.25	42.33

Table 3. Effect of treatment on forage mass and nutritive value (2012)

Item	Treatment[1]				SEM	P-Value		Cattle Req[2]
	CONT	NFERT	NPFERT	DDGS		Trt	Trt*Time	
Forge DM, %	63.2	64.5	62.6	66.2	1.870	0.22	0.56	-
Forage Mass, kg/ha	3018[a]	3053[a]	3671[b]	2,939[a]	305	0.005	0.20	-
OM, %	94.39	94.75	94.18	94.15	0.238	0.24	0.80	-
CP, % DM	11.67	12.58	13.30	12.74	0.706	0.42	0.55	-
NDF, % DM	82.92	83.95	82.63	82.67	0.732	0.33	0.62	-
ADF, % DM	44.52	43.49	43.51	42.83	1.009	0.47	0.05	-
DIP, % CP	73.51[a]	67.55[ab]	65.99[b]	73.13[a]	2.537	0.002	0.50	-
P, % DM	0.26	0.28	0.27	0.28	0.018	0.85	0.76	0.18
Ca, % DM	0.52	0.65	0.39	0.54	0.134	0.57	0.53	0.33
K, % DM	2.09	2.17	2.15	2.33	0.170	0.45	0.98	0.60
Mg, % DM	0.20	0.22	0.43	0.23	0.124	0.47	0.59	0.10
Na, % DM	0.09	0.09	0.10	0.07	0.033	0.90	0.26	0.07
S, % DM	0.30	0.32	0.31	0.33	0.024	0.83	0.51	0.15
Zn, ppm	26.01	28.78	26.34	28.33	2.033	0.51	0.37	30.00
Cu, ppm	29.97	29.61	37.54	30.82	4.195	0.42	0.07	10.00

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 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.

Table 4. Effect of month on forage mass and nutritive value (2012)

Item	Month				SEM	P-Value		Cattle Req[1]
	June	July	August	September		Time	Trt*Time	
Forge DM, %	46.59	53.97	84.09	71.85	1.870	<0.0001	0.56	-
Forage Mass, kg/ha	2855[a]	3926[b]	3199[a]	2701[a]	305	<0.0001	0.20	-
OM, %	94.29	94.01	94.80	94.38	0.238	0.12	0.80	-
CP, % DM	16.41[a]	11.58[b]	8.57[c]	13.73[b]	0.706	<0.0001	0.55	-
NDF, % DM	79.44[a]	82.57[b]	86.25[c]	83.92[b]	0.732	<0.0001	0.62	-
ADF, % DM	38.33[a]	43.68[b]	47.68[c]	44.65[b]	1.009	<0.0001	0.05	-
DIP, % CP	66.63[a]	69.41[ab]	72.77[b]	71.36[ab]	2.537	0.05	0.50	-
P, % DM	0.18[a]	0.22[a]	0.30[b]	0.32[c]	0.018	<0.0001	0.76	0.18
Ca, % DM	0.44	0.55	0.53	0.57	0.134	0.91	0.53	0.33
K, % DM	1.31[a]	1.81[b]	2.98[c]	2.62[c]	0.170	<0.0001	0.98	0.60
Mg, % DM	0.44	0.21	0.25	0.17	0.124	0.39	0.59	0.10
Na, % DM	0.09	0.08	0.10	0.08	0.033	0.95	0.26	0.07
S, % DM	0.24[a]	0.26[a]	0.43[b]	0.33[a]	0.024	<0.0001	0.51	0.15
Zn, ppm	30.68	26.08	27.72	24.98	2.033	0.09	0.37	30.00
Cu, ppm	26.89[abc]	25.56[b]	41.78[c]	33.70[abc]	4.195	0.02	0.07	10.00

[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 5. Heifer growth performance, gain/ha, and N use efficiency (2012)

	Treatment[1]					
Item	CONT	NFERT	NPFERT	DDGS	SEM	P-value
Pastures	3	3	3	3		
Number of Heifers	31	65	65	69		
Stocking Rate (heifers/ha)	1.27	2.43	2.47	2.45		
Stocking Rate (kg/ha)	332	632	655	651		
Initial BW, kg (5/17)	264	267	265	266	2.24	0.7500
Midpoint BW, kg (7/17)	306	310	313	320	3.03	0.0739
Final BW, kg (9/13)	331^{a}	333^{a}	336^{a}	355^{b}	3.21	0.0027
Gain, kg/heifer						
Period 1 (61 d)	41.5^{a}	43.3^{a}	47.6^{ab}	54.1^{b}	1.69	0.0077
Period 2 (58 d)	25.1	23.3	23.2	35.0	2.56	0.0472
Total (119 d)	66.7^{a}	66.5^{a}	70.7^{a}	89.0^{b}	1.80	0.0002
ADG, kg/d						
Period 1	0.67^{a}	0.7^{a}	0.77^{ab}	0.87^{b}	0.027	0.0077
Period 2	0.44	0.41	0.41	0.61	0.045	0.0472
Overall	0.56^{a}	0.56^{a}	0.59^{a}	0.75^{b}	0.02	0.0002
Gain/ha, kg	84^{a}	160^{b}	175^{b}	218^{c}	5.05	<0.0001
N Inputs, kg/ha	8.13^{a}	100.03^{b}	100.32^{b}	41.12^{c}	0.307	<0.0001
N retention, kg/ha	2.30^{a}	4.42^{b}	4.79^{b}	5.85^{c}	0.126	<0.0001
N Recovery, %	28.32^{a}	4.42^{b}	4.77^{b}	14.22^{c}	0.50	<0.0001

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 30 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 kg/ha (DDGS).

Table 6. Effect of treatment on forage mass and nutritive value (2013)

Item	Treatment[1]				SEM	P-Value		Cattle Req[2]
	CONT	NFERT	NPFERT	DDGS		Trt	Trt*Time	
Forge DM, %	45.77	44.95	45.71	45.34	1.248	0.96	0.36	-
Forage Mass, kg/ha	6141[ab]	6055[ab]	7001[a]	5007[b]	457	0.01	0.05	-
OM, %	94.10	94.24	93.94	93.94	0.204	0.58	0.52	-
CP, % DM	15.05[a]	18.44[b]	18.45[b]	17.34[ab]	0.886	0.003	0.35	-
NDF, % DM	75.65	76.07	75.42	77.07	0.765	0.45	0.25	-
ADF, % DM	39.68	39.38	37.97	39.91	0.924	0.21	0.39	-
DIP, % CP	76.05	76.88	73.92	78.31	1.904	0.11	0.36	-
P, % DM	0.15[a]	0.14[b]	0.24[c]	0.18[d]	0.013	<0.0001	0.67	0.18
Ca, % DM	0.40	0.37	0.41	0.37	0.018	0.17	0.53	0.33
K, % DM	1.32	1.38	1.36	1.47	0.058	0.25	0.85	0.60
Mg, % DM	0.20[a]	0.21[a]	0.24[b]	0.21[a]	0.008	0.0007	0.63	0.10
Na, % DM	0.06[a]	0.10[a]	0.17[b]	0.09[a]	0.030	<0.0001	0.78	0.07
S, % DM	0.23	0.24	0.27	0.27	0.036	0.053	0.67	0.15
Zn, ppm	29.69[abc]	32.91[b]	27.23[c]	29.50[abc]	1.582	0.03	0.28	30.00
Cu, ppm	28.34[a]	25.12[ab]	23.31[b]	26.47[ab]	0.959	0.006	0.13	10.00

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 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.

Table 7. Effect of month on forage mass and nutritive value (2013)

Item	Month				SEM	P-Value		Cattle Req[1]
	June	July	August	September		Time	Trt*Time	
Forge DM, %	43.22[a]	43.43[a]	41.89[a]	53.22[b]	1.248	<0.0001	0.36	-
Forage Mass, kg/ha	5371[a]	4690[a]	8126[b]	6018[a]	457	<0.0001	0.05	-
OM, %	93.83[a]	93.84[a]	93.79[a]	94.75[b]	0.204	0.001	0.52	-
CP, % DM	16.81[ab]	14.74[b]	19.50[c]	18.24[ac]	0.886	0.0001	0.35	-
NDF, % DM	73.06[a]	75.99[ab]	76.00[b]	79.16[c]	0.765	<0.0001	0.25	-
ADF, % DM	36.44[a]	39.91[bc]	38.89[c]	41.71[b]	0.924	<0.0001	0.39	-
DIP, % CP	74.34[abc]	70.39[b]	77.52[c]	82.91[d]	1.904	<0.0001	0.36	-
P, % DM	0.20[a]	0.19[a]	0.18[a]	0.14[b]	0.013	<0.0001	0.67	0.18
Ca, % DM	0.41[ab]	0.45[b]	0.33[c]	0.36[ac]	0.018	<0.0001	0.53	0.33
K, % DM	1.63[a]	1.35[b]	1.50[ab]	1.01[c]	0.058	<0.0001	0.85	0.60
Mg, % DM	0.22[ab]	0.25[a]	0.20[bc]	0.19[c]	0.0008	<0.0001	0.63	0.10
Na, % DM	0.11	0.13	0.10	0.08	0.030	0.10	0.78	0.07
S, % DM	0.27[a]	0.29[a]	0.24[ab]	0.22[b]	0.036	0.0023	0.67	0.15
Zn, ppm	28.89[a]	34.04[b]	28.83[a]	27.55[a]	1.582	0.004	0.28	30.00
Cu, ppm	27.42[a]	27.77[a]	27.94[a]	20.10[b]	0.959	<0.0001	0.13	10.00

[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 8. Steer growth performance, gain/ha, and N use efficiency (2013)

	Treatment[1]					
Item	CONT	NFERT	NPFERT	DDGS	SEM	P-value
Pastures	3	3	3	3		
Number of Steers	36	77	75	80		
Stocking Rate (steers/ha)	1.48	2.87	2.85	2.84		
Stocking Rate (kg/ha)	302	610	622	614		
Initial BW, kg (5/21)	224	226	227	226	16.58	0.5500
Midpoint BW, kg (7/18)	259	262	262	265	12.90	0.5200
Final BW, kg (9/19)	322	312	312	321	12.26	0.2800
Gain, kg/steer						
Period 1 (58 d)	35.9	35.6	35.4	39.5	4.49	0.5800
Period 2 (69 d)	63.1	50.7	50.2	55.4	2.84	0.0577
Total (121 d)	99.0	86.2	85.6	94.9	6.22	0.1200
ADG, kg/d						
Period 1	0.60	0.59	0.59	0.66	0.075	0.5767
Period 2	1.24	0.99	0.98	1.09	0.056	0.0577
Overall	0.82	0.71	0.71	0.78	0.05	0.1200
Gain/ha, kg	146[a]	247[b]	244[b]	269[b]	16.41	0.0003
N Inputs, kg/ha	9.07[a]	102.05[b]	102.17[b]	41.69[c]	0.777	<0.0001
N retention, kg/ha	4.11[a]	7.06[b]	6.97[b]	7.60[b]	0.55	0.0003
N Recovery, %	45.45[a]	6.91[b]	6.81[b]	18.20[b]	2.00	0.001

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 30 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 kg/ha (DDGS).

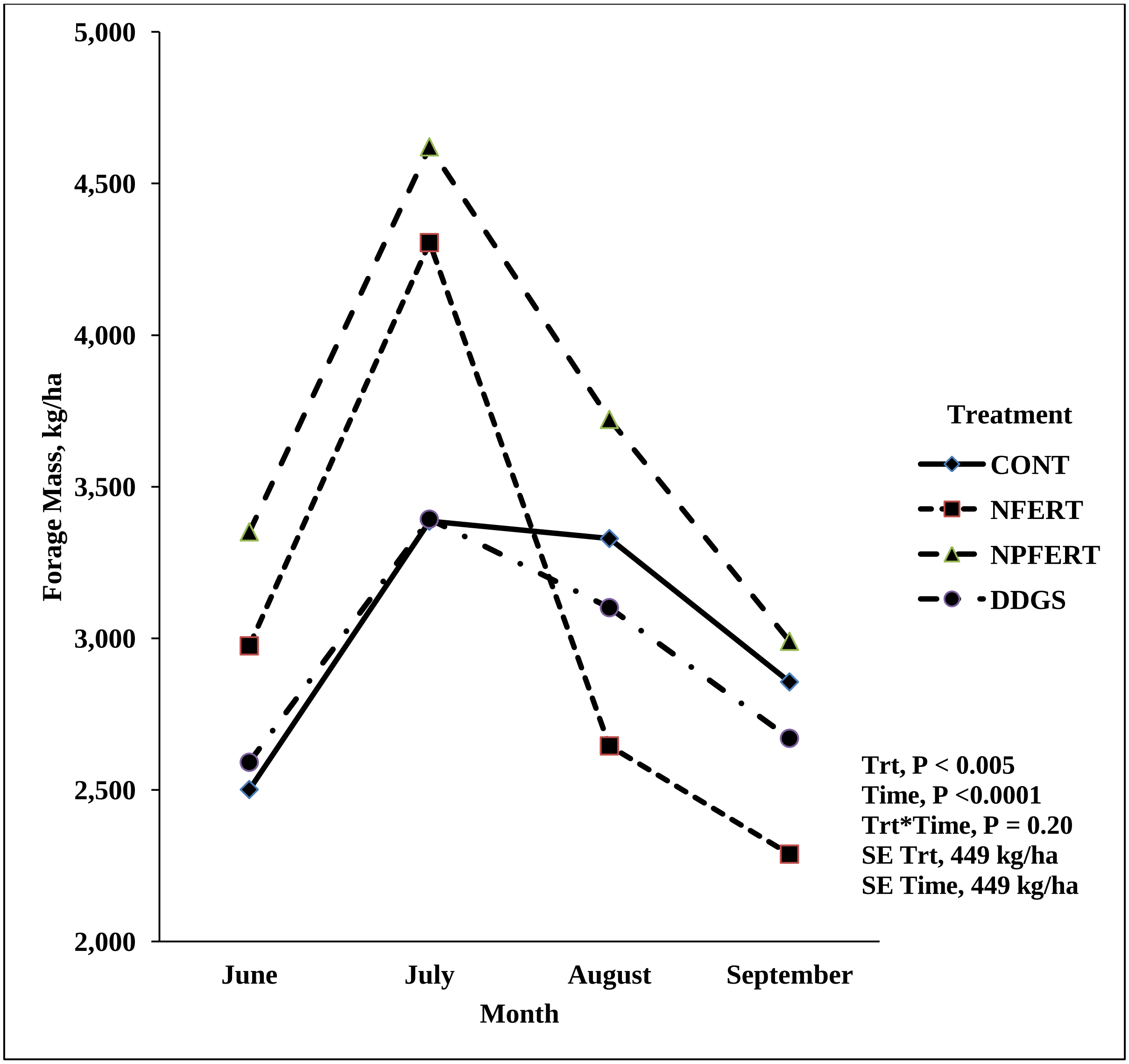

Figure 1. Forage mass change by treatment across sampling periods, 2012.

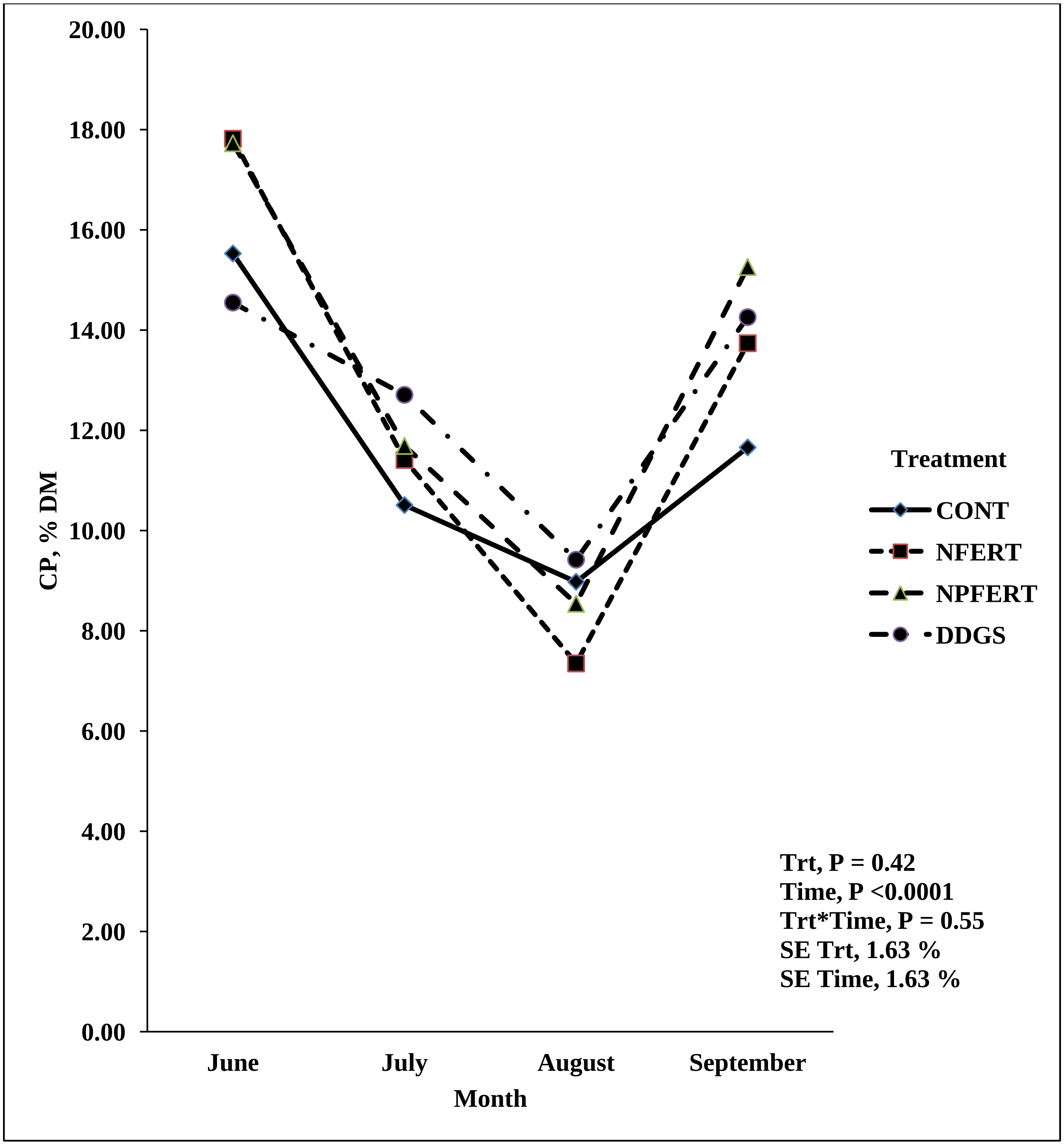

Figure 2. Crude protein change by treatment across sampling periods, 2012.

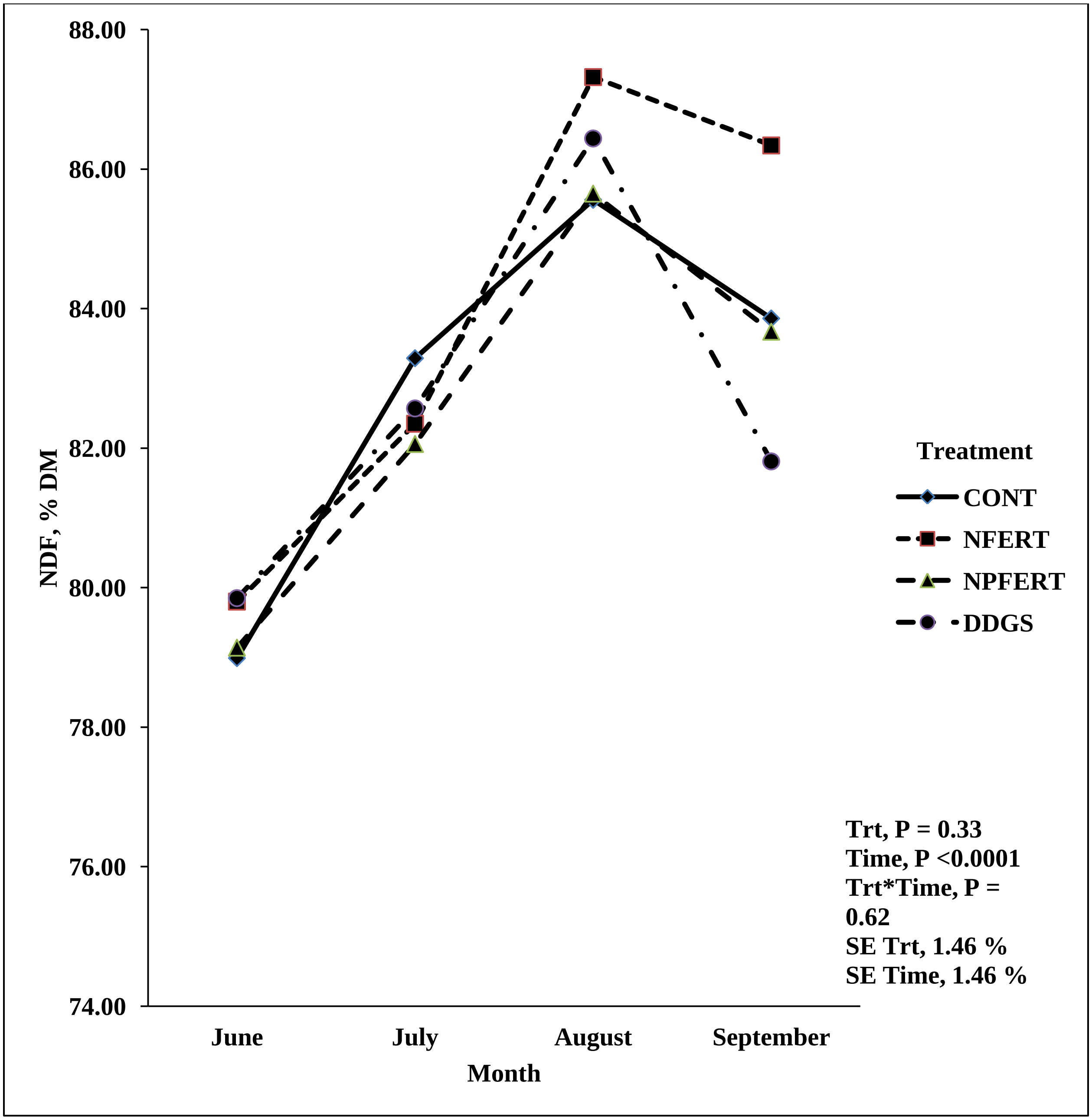

Figure 3. Neutral detergent fiber change by treatment across sampling periods, 2012.

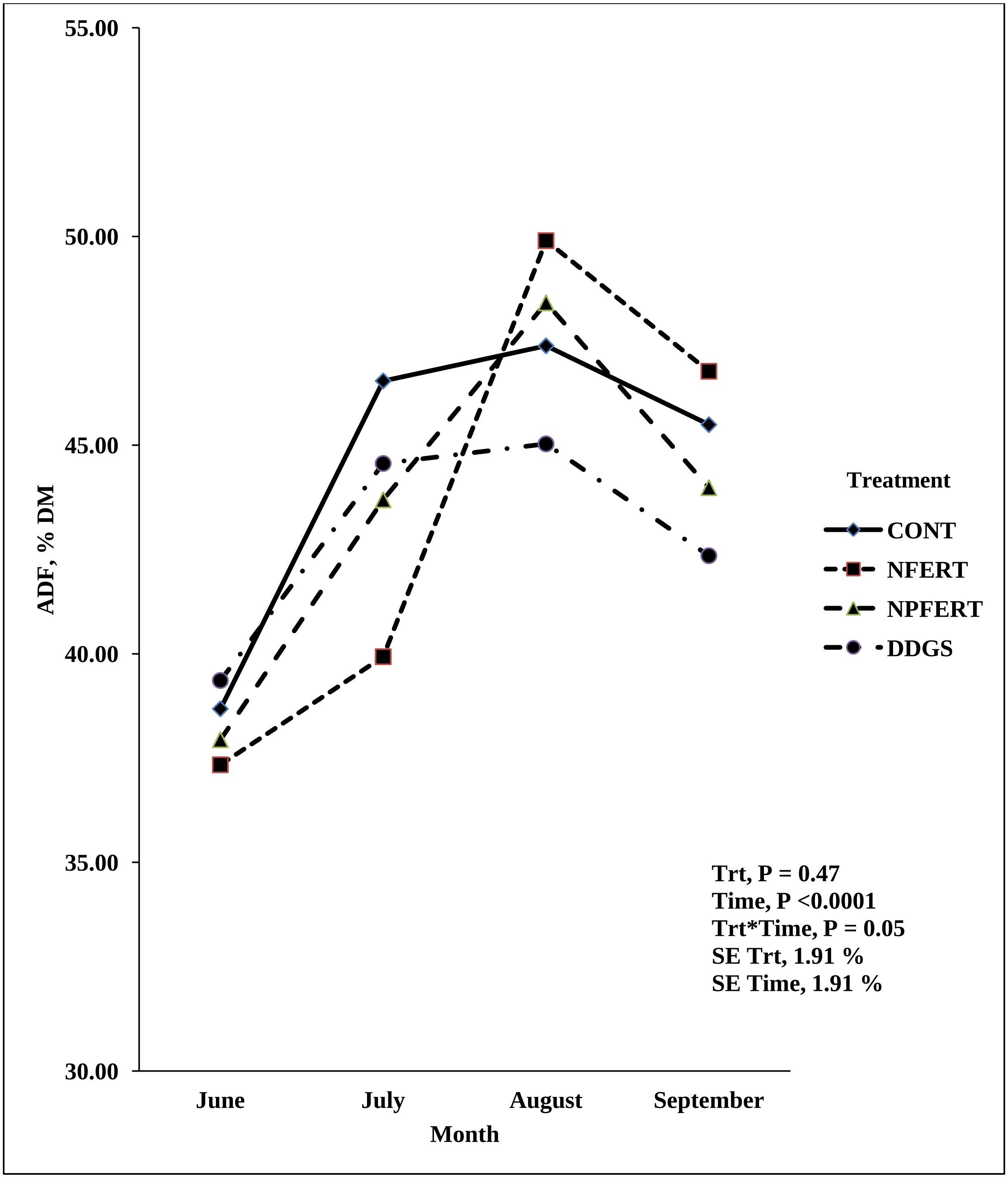

Figure 4. Acid detergent fiber change by treatment across sampling periods, 2012.

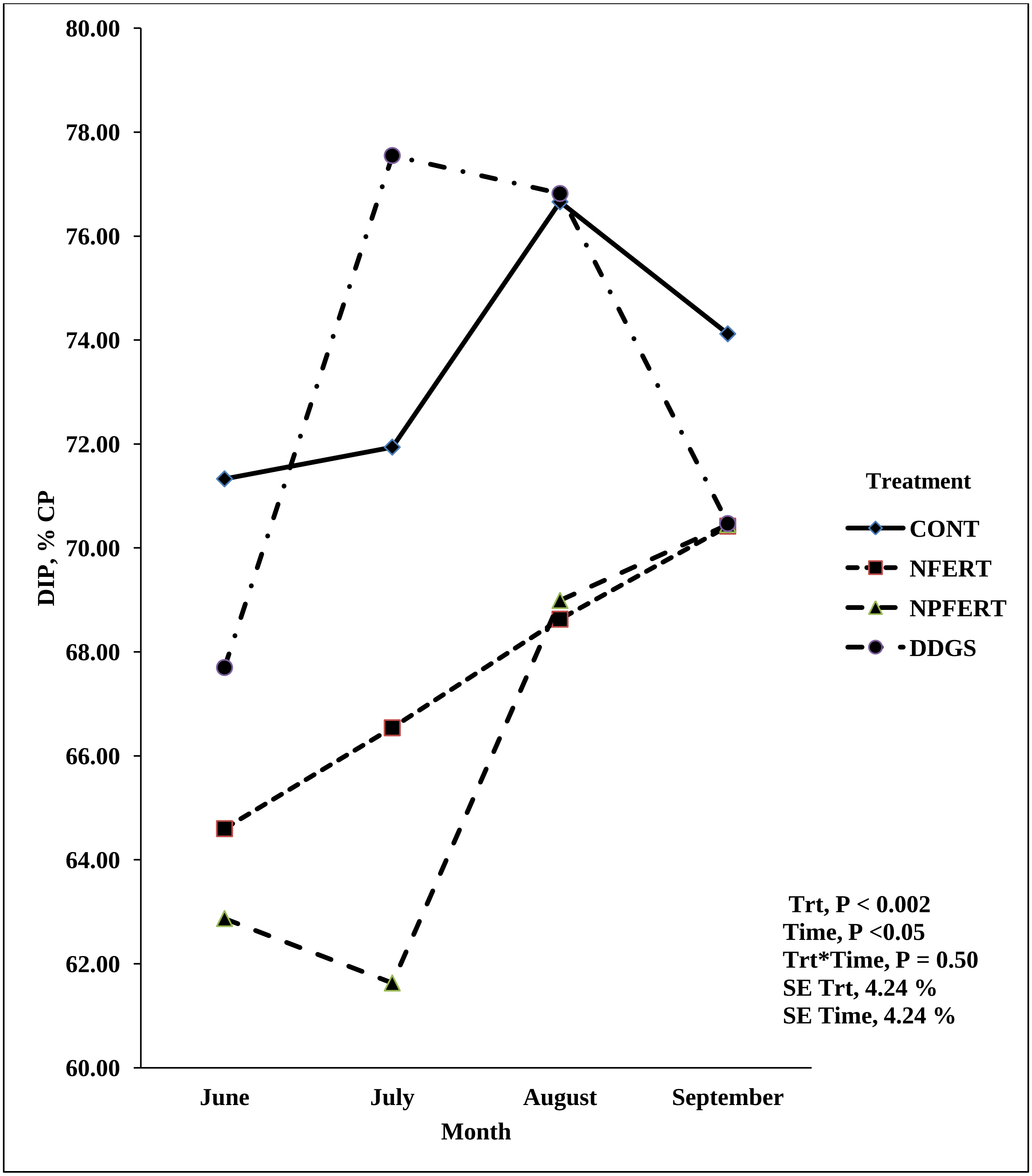

Figure 5. Degradable intake protein change by treatment across sampling periods, 2012.

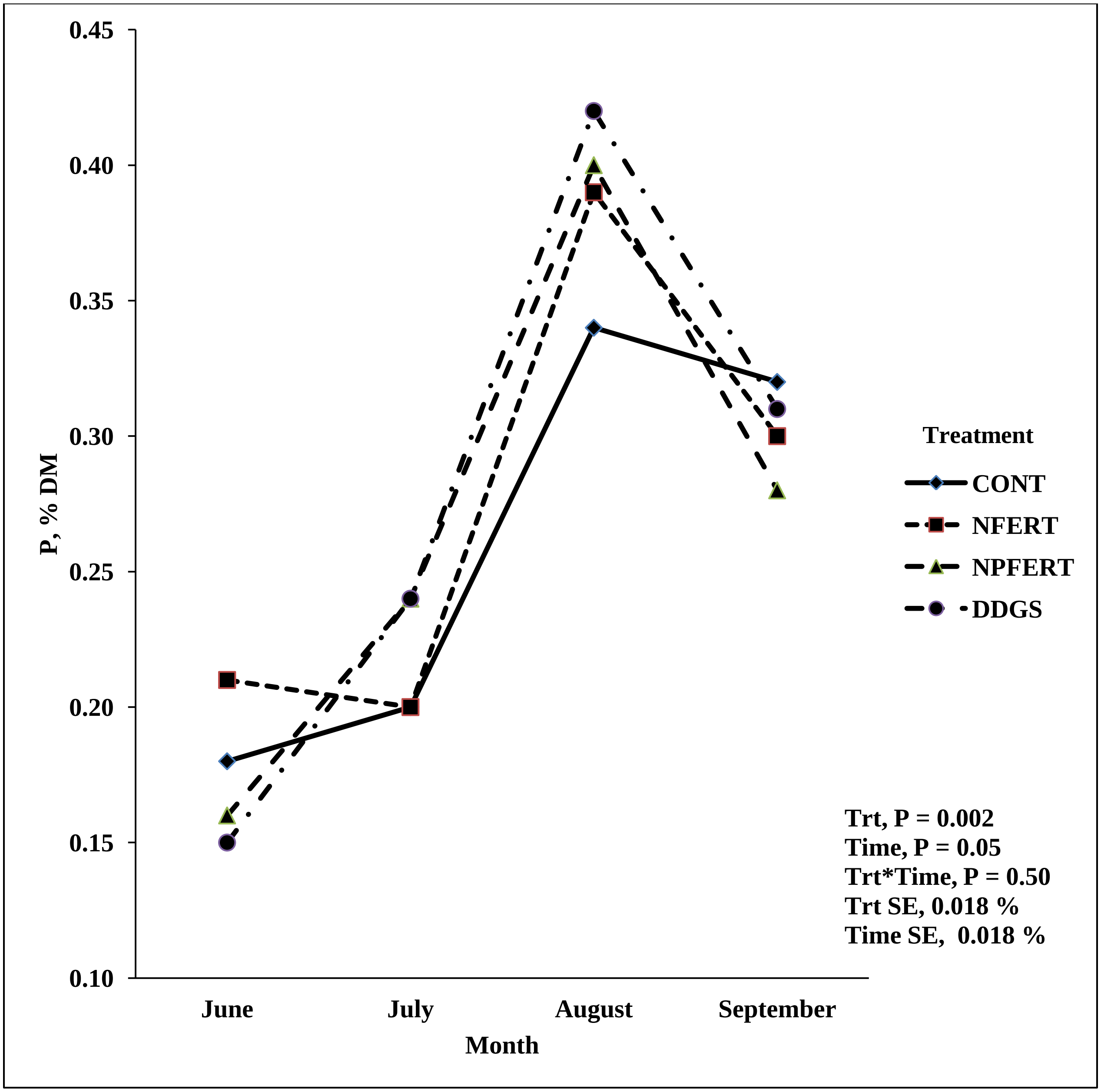

Figure 6. Phosphorus change by treatment across sampling periods, 2012.

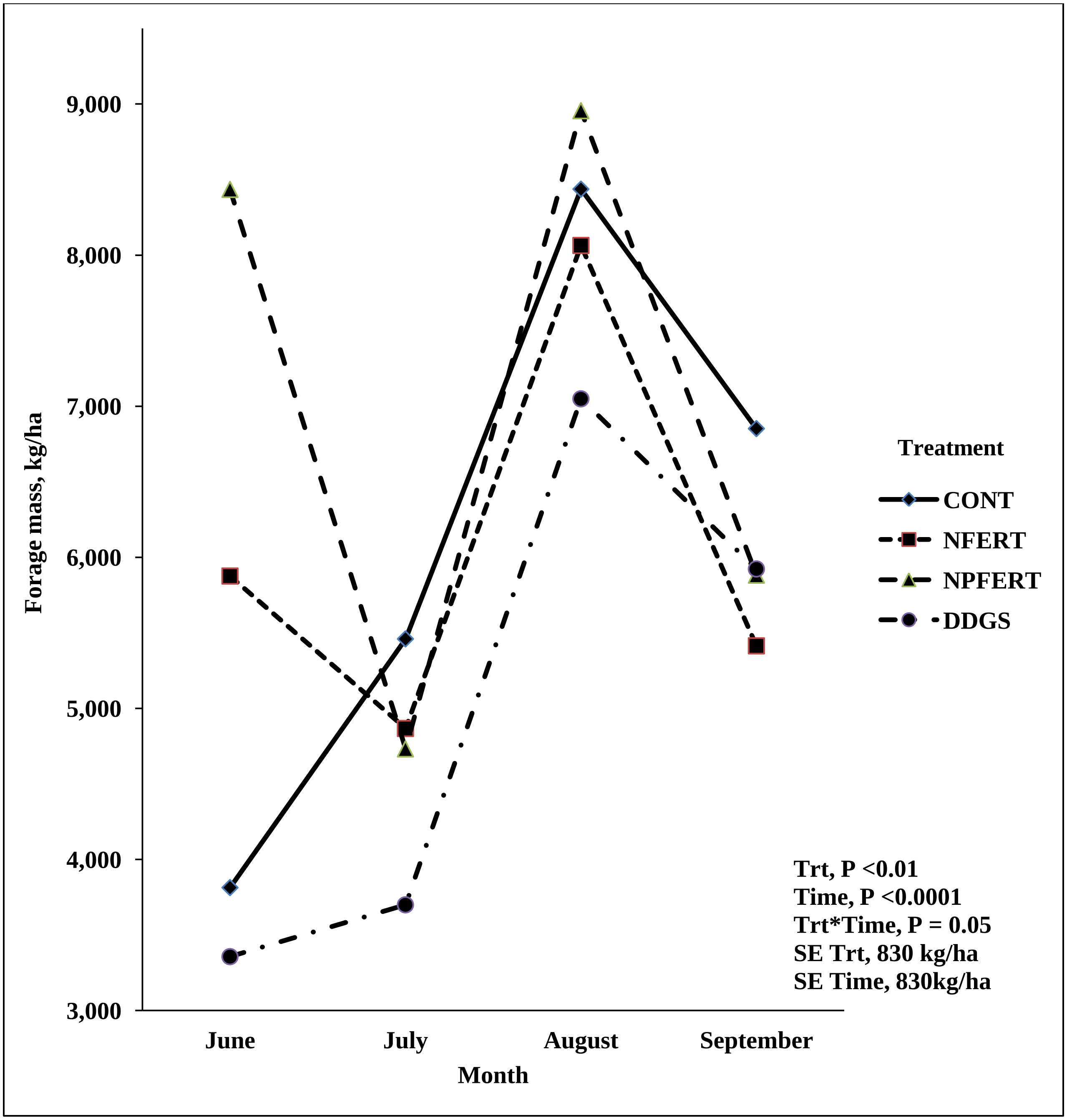

Figure 7. Forage mass change by treatment across sampling periods, 2013.

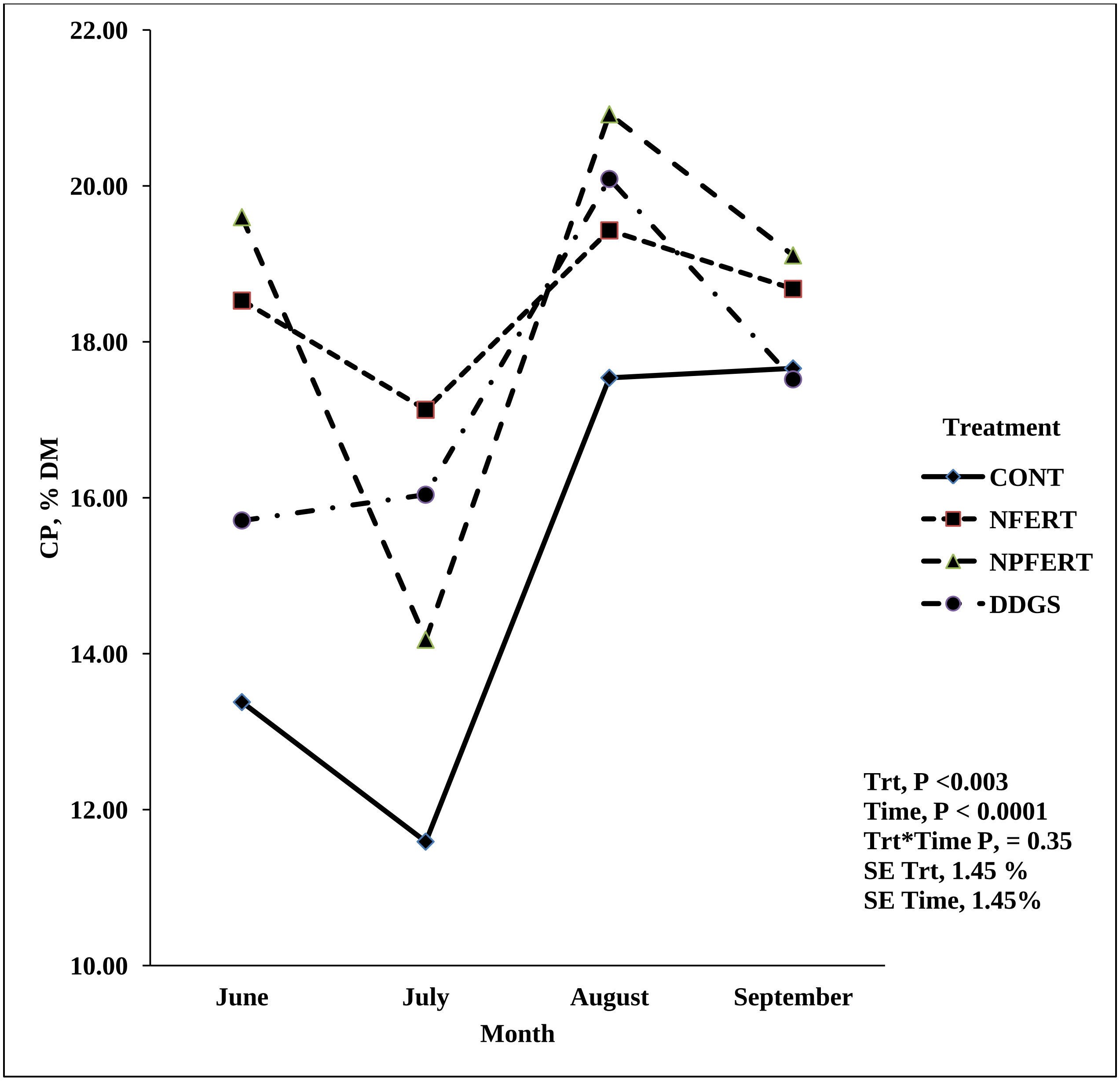

Figure 8. Crude protein change by treatment across sampling periods, 2013.

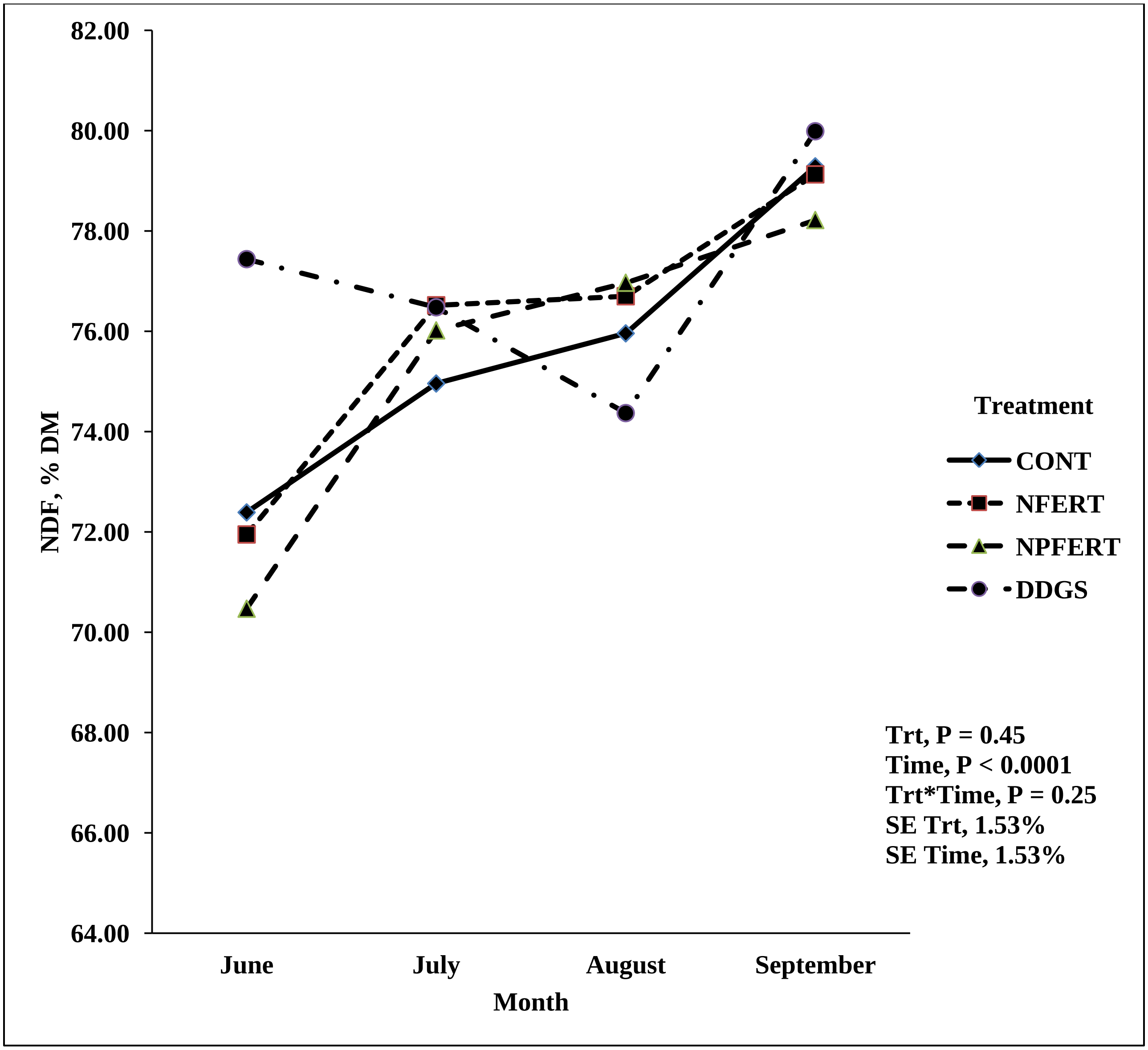

Figure 9. Neutral detergent fiber change by treatment across sampling periods, 2013.

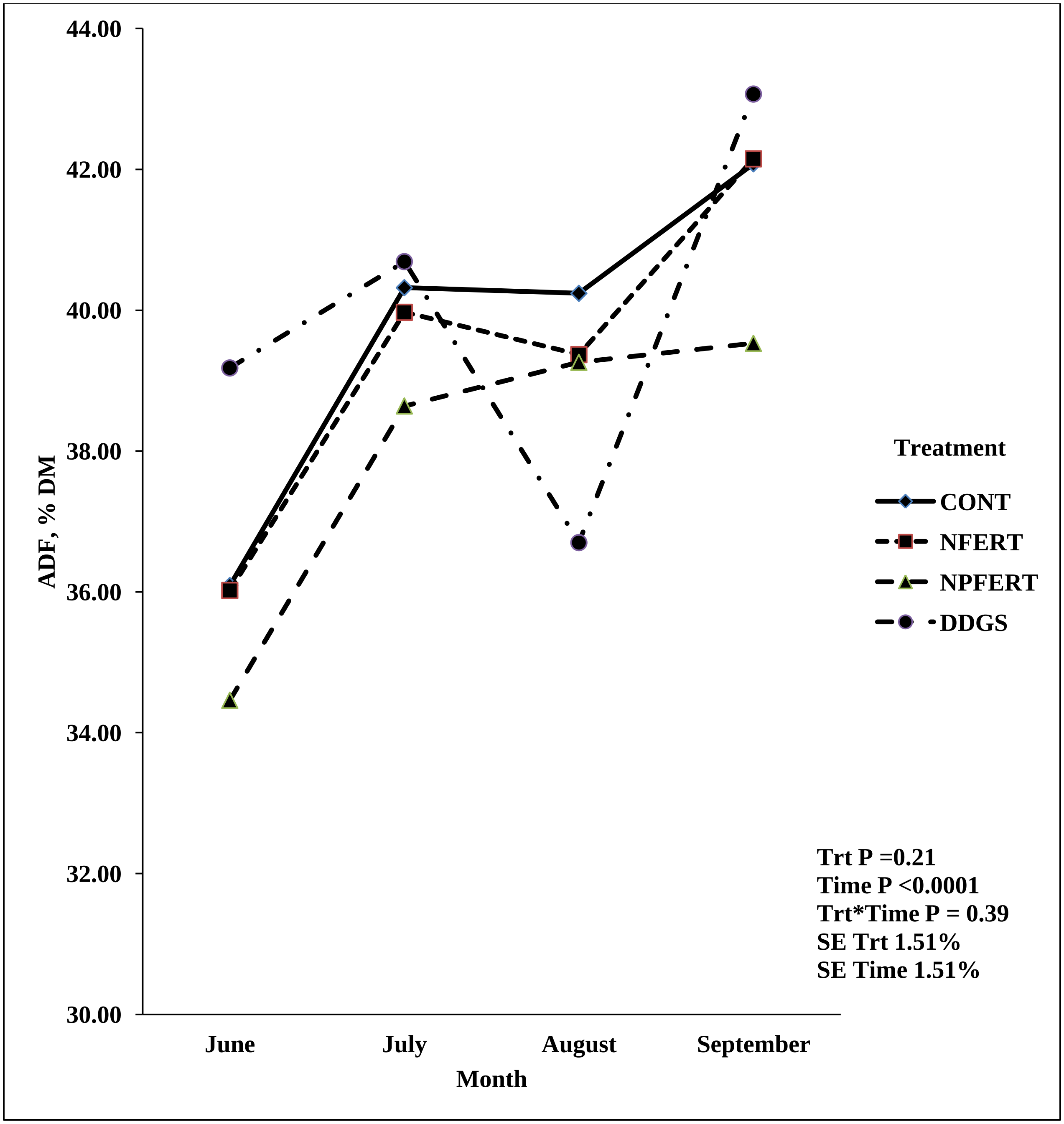

Figure 10. Acid detergent fiber change by treatment across sampling periods, 2013.

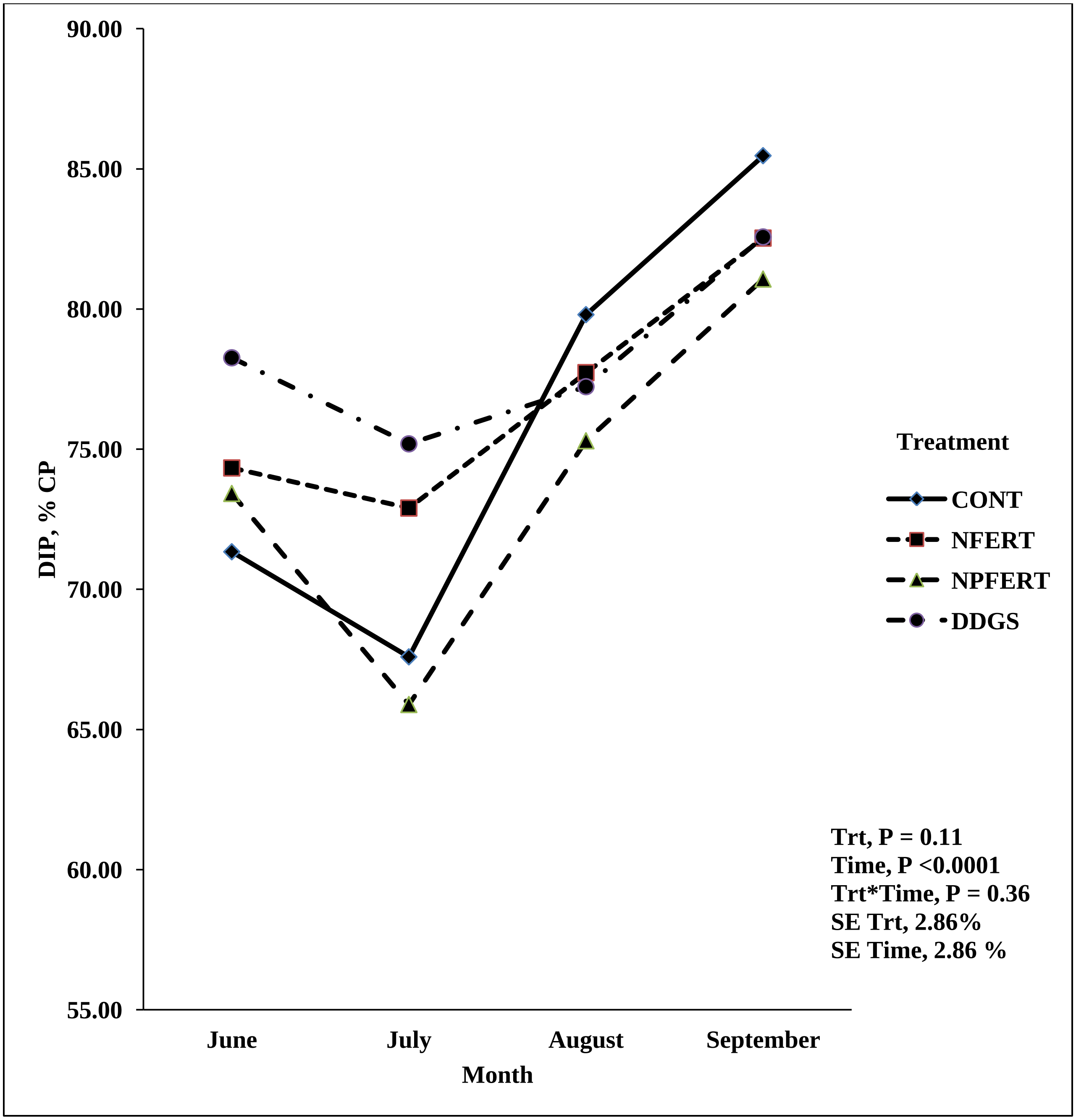

Figure 11. Degradable intake protein change by treatment across sampling periods, 2013.

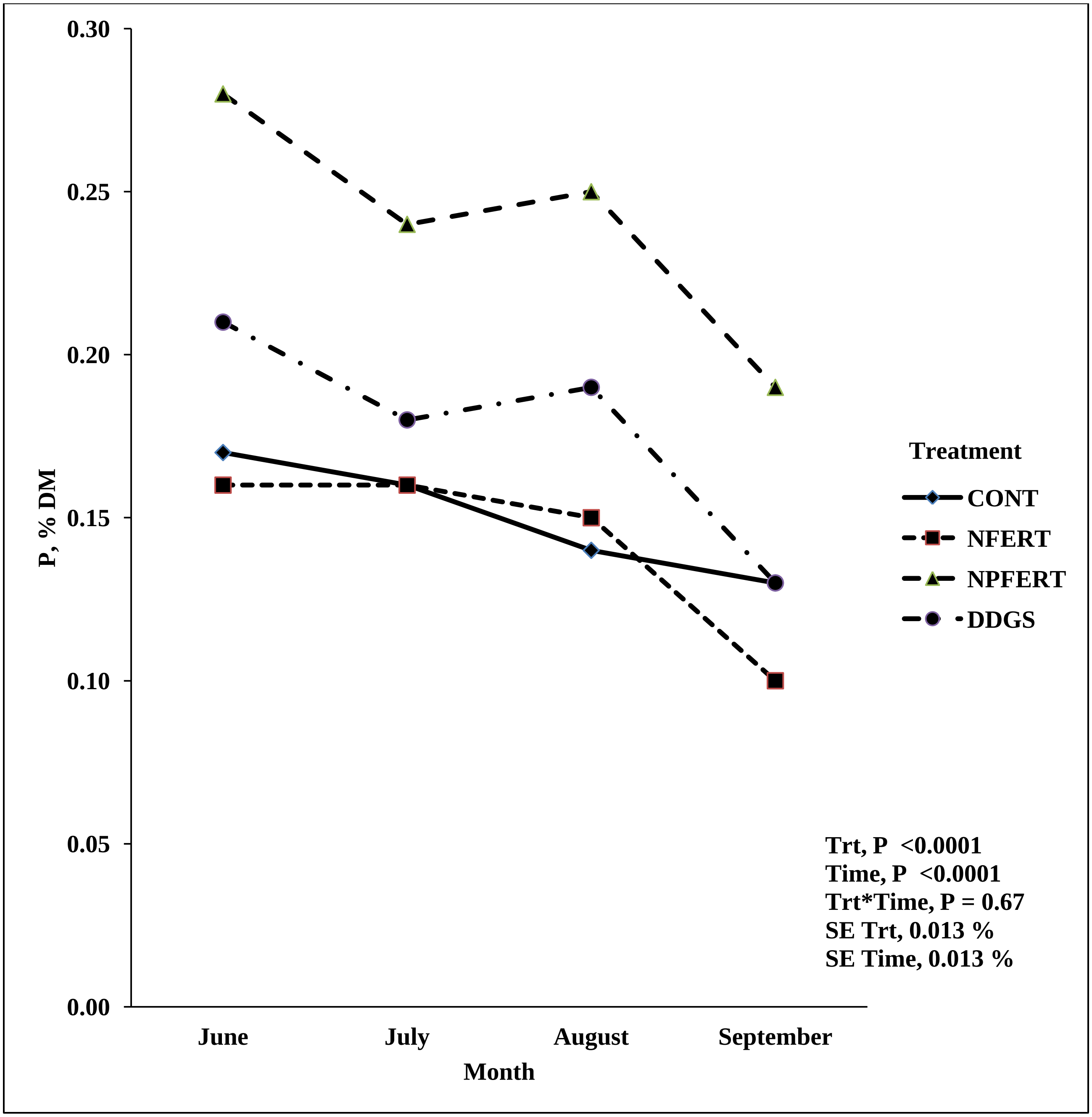

Figure 12. Phosphorus change by treatment across sampling periods, 2013.

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APPENDICES

Appendix Table 1. Effect of treatment and time on forage mass and nutritive value (2012)

	Treatment[1]					P-Value		
Item	CONT	NFERT	NPFERT	DDGS	SEM	Trt	Time	Trt*Time
Forage DM, %								
June	43.5	45.5	48.1	49.3	3.40	0.22	<0.0001	0.56
July	54.6	52.3	51.2	57.8	3.40	0.22	<0.0001	0.56
August	81.3	86.4	83.2	85.4	3.40	0.22	<0.0001	0.56
September	73.2	73.8	67.9	72.4	3.40	0.22	<0.0001	0.56
Forage Mass, kg/ha								
June	2,501	2,975	3,351	2,591	449	0.005	<0.0001	0.20
July	3,386	4,305	4,621	3,393	449	0.005	<0.0001	0.20
August	3,329	2,645	3,722	3,101	449	0.005	<0.0001	0.20
September	2,856	2,288	2,990	2,670	449	0.005	<0.0001	0.20
Forage OM, %								
June	94.20	94.37	93.86	94.71	0.551	0.24	0.12	0.80
July	94.03	94.52	93.79	93.68	0.551	0.24	0.12	0.80
August	94.55	95.39	94.89	94.36	0.551	0.24	0.12	0.80
September	94.76	94.70	94.19	93.86	0.551	0.24	0.12	0.80
CP, %								
June	15.53	17.82	17.73	14.55	1.630	0.42	<0.0001	0.55
July	10.51	11.41	11.69	12.71	1.630	0.42	<0.0001	0.55
August	8.98	7.35	8.54	9.42	1.630	0.42	<0.0001	0.55
September	11.66	13.74	15.26	14.26	1.630	0.42	<0.0001	0.55
NDF,%								
June	78.99	79.80	79.14	79.85	1.463	0.33	<0.0001	0.62
July	83.29	82.35	82.06	82.57	1.463	0.33	<0.0001	0.62
August	85.56	87.32	85.65	86.44	1.463	0.33	<0.0001	0.62
September	83.86	86.34	83.67	81.81	1.463	0.33	<0.0001	0.62

ADF, %								
June	38.68	37.34	37.94	39.36	1.910	0.47	<0.0001	0.05
July	46.54	39.93	43.69	44.56	1.910	0.47	<0.0001	0.05
August	47.38	49.90	48.41	45.03	1.910	0.47	<0.0001	0.05
September	45.49	46.77	43.98	42.35	1.910	0.47	<0.0001	0.05
DIP, % CP								
June	71.33	64.60	62.87	67.70	4.238	0.002	0.05	0.50
July	71.94	66.54	61.63	77.55	4.238	0.002	0.05	0.50
August	76.66	68.63	68.99	76.82	4.238	0.002	0.05	0.50
September	74.12	70.42	70.45	70.47	4.238	0.002	0.05	0.50
P, % DM								
June	0.18	0.21	0.16	0.15	0.041	0.85	<0.0001	0.76
July	0.20	0.20	0.24	0.24	0.041	0.85	<0.0001	0.76
August	0.34	0.39	0.40	0.42	0.041	0.85	<0.0001	0.76
September	0.32	0.30	0.28	0.31	0.041	0.85	<0.0001	0.76
Ca, % DM								
June	0.47	0.48	0.40	0.42	0.308	0.57	0.91	0.53
July	0.39	1.02	0.37	0.41	0.308	0.57	0.91	0.53
August	0.40	0.75	0.51	0.48	0.308	0.57	0.91	0.53
September	0.83	0.34	0.28	0.84	0.308	0.57	0.91	0.53
K, % DM								
June	1.23	1.34	1.36	1.31	0.291	0.45	<0.0001	0.98
July	1.77	1.70	1.77	2.00	0.291	0.45	<0.0001	0.98
August	2.72	3.00	2.98	3.23	0.291	0.45	<0.0001	0.98
September	2.63	2.64	2.48	2.77	0.291	0.45	<0.0001	0.98
Mg, % DM								
June	0.22	0.26	1.06	0.22	0.283	0.47	0.39	0.59
July	0.20	0.21	0.24	0.20	0.283	0.47	0.39	0.59
August	0.22	0.22	0.25	0.32	0.283	0.47	0.39	0.59
September	0.15	0.18	0.16	0.19	0.283	0.47	0.39	0.59
Na, %DM								
June	0.07	0.10	0.09	0.09	0.076	0.90	0.95	0.26
July	0.05	0.04	0.21	0.04	0.076	0.90	0.95	0.26
August	0.22	0.09	0.05	0.06	0.076	0.90	0.95	0.26
September	0.02	0.13	0.06	0.10	0.076	0.90	0.95	0.26
S, % DM								
June	0.26	0.27	0.23	0.21	0.055	0.83	<0.0001	0.51
July	0.28	0.24	0.27	0.25	0.055	0.83	<0.0001	0.51
August	0.35	0.42	0.45	0.51	0.055	0.83	<0.0001	0.51
September	0.31	0.35	0.31	0.35	0.055	0.83	<0.0001	0.51

Fe, ppm								
June	157.2	213.2	129.4	138.9	133.84	0.34	<0.0001	0.39
July	317.1	132.8	335.5	234.5	133.84	0.34	<0.0001	0.39
August	729.4	580.2	918.4	902.4	133.84	0.34	<0.0001	0.39
September	436.0	688.8	742.6	576.8	133.84	0.34	<0.0001	0.39
Zn, ppm								
June	27.50	37.15	30.20	26.86	4.021	0.52	0.09	0.37
July	27.77	24.04	24.94	27.58	4.021	0.52	0.09	0.37
August	27.53	27.07	26.23	30.05	4.021	0.52	0.09	0.37
September	21.25	26.84	22.98	28.83	4.021	0.52	0.09	0.37
Cu, ppm								
June	29.12	28.99	24.73	24.73	9.509	0.42	0.02	0.07
July	30.99	19.16	28.99	23.10	9.509	0.42	0.02	0.07
August	42.55	24.75	48.45	51.36	9.509	0.42	0.02	0.07
September	17.22	45.52	47.98	24.08	9.509	0.42	0.02	0.07
Mn, ppm								
June	77.00	68.70	76.63	59.78	51.645	0.66	<0.0001	0.60
July	97.68	46.97	95.20	136.58	51.645	0.66	<0.0001	0.60
August	217.08	208.10	171.86	182.13	51.645	0.66	<0.0001	0.60
September	145.90	232.41	158.86	269.68	51.645	0.66	<0.0001	0.60

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 kg/ha (DDGS).

Appendix Table 2. Effect of treatment and time on forage mass and nutritive value (2013)

	Treatment[1]					P-Value		
Item	CONT	NFERT	NPFERT	DDGS	SEM	Trt	Time	Trt*Time
Forage DM, %								
June	47.82	41.35	39.77	43.95	2.496	0.96	<0.0001	0.36
July	40.96	41.44	45.97	45.36	2.496	0.96	<0.0001	0.36
August	41.84	42.87	42.58	40.28	2.496	0.96	<0.0001	0.36
September	52.45	54.12	54.53	51.77	2.496	0.96	<0.0001	0.36
Forage Mass, kg/ha								
June	3,814	5,876	8,435	3,357	830	0.01	<0.0001	0.05
July	5,460	4,867	4,732	3,700	830	0.01	<0.0001	0.05
August	8,437	8,064	8,956	7,049	830	0.01	<0.0001	0.05
September	6,852	5,414	5,882	5,923	830	0.01	<0.0001	0.05
Forage OM, %								
June	93.99	94.06	93.34	93.94	0.367	0.58	0.001	0.52
July	93.80	93.80	94.16	93.59	0.367	0.58	0.001	0.52
August	93.97	94.18	93.83	93.20	0.367	0.58	0.001	0.52
September	94.62	94.92	94.43	95.04	0.367	0.58	0.001	0.52
CP, %								
June	13.38	18.53	19.60	15.71	1.450	0.003	0.0001	0.35
July	11.59	17.13	14.18	16.04	1.450	0.003	0.0001	0.35
August	17.54	19.43	20.92	20.09	1.450	0.003	0.0001	0.35
September	17.66	18.68	19.11	17.52	1.450	0.003	0.0001	0.35
NDF,%								
June	72.39	71.95	70.47	77.44	1.530	0.45	<0.0001	0.25
July	74.96	76.52	76.02	76.48	1.530	0.45	<0.0001	0.25
August	75.96	76.70	76.97	74.37	1.530	0.45	<0.0001	0.25
September	79.29	79.13	78.22	79.99	1.530	0.45	<0.0001	0.25
ADF, %								
June	36.09	36.02	34.46	39.18	1.507	0.21	<0.0001	0.39
July	40.32	39.97	38.64	40.69	1.507	0.21	<0.0001	0.39
August	40.24	39.37	39.26	36.70	1.507	0.21	<0.0001	0.39
September	42.08	42.15	39.53	43.07	1.507	0.21	<0.0001	0.39
DIP, % CP								
June	71.34	74.33	73.42	78.26	2.859	0.11	<0.0001	0.36
July	67.59	72.90	65.89	75.19	2.859	0.11	<0.0001	0.36
August	79.80	77.73	75.30	77.23	2.859	0.11	<0.0001	0.36
September	85.47	82.53	81.07	82.57	2.859	0.11	<0.0001	0.36

P, % DM								
June	0.17	0.16	0.28	0.21	0.018	<0.0001	<0.0001	0.67
July	0.16	0.16	0.24	0.18	0.018	<0.0001	<0.0001	0.67
August	0.14	0.15	0.25	0.19	0.018	<0.0001	<0.0001	0.67
September	0.13	0.10	0.19	0.13	0.018	<0.0001	<0.0001	0.67
Ca, % DM								
June	0.44	0.37	0.43	0.42	0.033	0.17	<0.0001	0.53
July	0.47	0.43	0.48	0.43	0.033	0.17	<0.0001	0.53
August	0.32	0.34	0.32	0.34	0.033	0.17	<0.0001	0.53
September	0.37	0.34	0.41	0.29	0.033	0.17	<0.0001	0.53
K, % DM								
June	1.48	1.64	1.71	1.68	0.111	0.25	<0.0001	0.85
July	1.32	1.40	1.30	1.39	0.111	0.25	<0.0001	0.85
August	1.46	1.41	1.40	1.71	0.111	0.25	<0.0001	0.85
September	0.99	1.10	1.04	1.11	0.111	0.25	<0.0001	0.85
Mg, % DM								
June	0.21	0.21	0.24	0.23	0.015	0.0007	<0.0001	0.63
July	0.23	0.24	0.27	0.25	0.015	0.0007	<0.0001	0.63
August	0.19	0.18	0.24	0.20	0.015	0.0007	<0.0001	0.63
September	0.18	0.19	0.23	0.16	0.015	0.0007	<0.0001	0.63
Na, %DM								
June	0.07	0.09	0.20	0.09	0.038	<0.0001	0.10	0.78
July	0.09	0.12	0.20	0.11	0.038	<0.0001	0.10	0.78
August	0.06	0.09	0.15	0.09	0.038	<0.0001	0.10	0.78
September	0.04	0.12	0.12	0.05	0.038	<0.0001	0.10	0.78
S, % DM								
June	0.23	0.25	0.30	0.28	0.041	0.053	0.0023	0.67
July	0.27	0.25	0.30	0.32	0.041	0.053	0.0023	0.67
August	0.21	0.24	0.25	0.26	0.041	0.053	0.0023	0.67
September	0.20	0.23	0.24	0.20	0.041	0.053	0.0023	0.67
Fe, ppm								
June	189.4	176.2	136.8	177.9	21.94	0.10	0.14	0.70
July	170.3	134.2	122.6	142.0	21.94	0.10	0.14	0.70
August	144.4	126.5	138.3	179.6	21.94	0.10	0.14	0.70
September	118.2	120.8	126.2	172.6	21.94	0.10	0.14	0.70
Zn, ppm								
June	27.78	30.39	26.08	31.32	2.659	0.03	0.004	0.28
July	34.51	38.56	28.02	35.07	2.659	0.03	0.004	0.28
August	27.55	29.72	29.25	28.81	2.659	0.03	0.004	0.28
September	28.82	32.97	25.56	22.76	2.659	0.03	0.004	0.28

Cu, ppm								
June	27.88	28.57	24.04	29.19	1.918	0.006	<0.0001	0.13
July	33.84	27.37	23.28	26.56	1.918	0.006	<0.0001	0.13
August	30.42	25.14	25.11	31.10	1.918	0.006	<0.0001	0.13
September	21.21	19.36	20.79	19.03	1.918	0.006	<0.0001	0.13
Mn, ppm								
June	104.33	87.07	104.50	137.90	17.518	0.20	0.75	0.75
July	121.27	83.27	105.97	120.73	17.518	0.20	0.75	0.75
August	104.57	97.13	114.80	112.63	17.518	0.20	0.75	0.75
September	127.50	111.40	131.67	103.70	17.518	0.20	0.75	0.75

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

[1]Treatments include 1) no fertilizer or DDGS with socking rate of 325 kg/ha, 2) nitrogen fertilizer applied at 90 kg/ha and stocking rate of 650 (NFERT), 3) nitrogen and phosphorus fertilizers applied at 90 and 40 kg/ha respectively and stocking rate of 650 kg/ha (NPFERT), and 4) dried distillers grains plus solubles fed at 0.75% of BW and stocking rate of 650 kg/ha (DDGS).

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