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Effects of nitrogen fertilization and dried distillers grains supplementation: Nitrogen use efficiency¹

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ABSTRACT: In a 3-yr study, 135 crossbred steers (330 ± 10 kg) were used in a randomized complete block design to evaluate corn dried distillers grains plus solubles (DDGS) fed to yearling steers as a substitute for forage and N fertilizer and its effect on N use efficiency in yearling steers grazing smooth brome grass pastures. Steers were initially stocked at 6.8 animal unit months (AUM)/ha on nonfertilized smooth brome grass pastures (CONT), at 9.9 AUM/ha on smooth brome grass pastures fertilized with 90 kg of N/ha (FERT), or at 9.9 AUM/ha on nonfertilized smooth brome grass pastures with 2.3 kg (DM) of DDGS supplemented daily per steer (SUPP). Paddock was the experimental unit, with 3 replications per treatment per year for 3 yr. Paddocks were strip-grazed, and put-and-take cattle were used to maintain similar grazing pressure among treatment paddocks during the 160-d grazing season. Steers consumed less forage ($P < 0.01$), but total N intake for SUPP was greater ($P < 0.01$) per steer and per hectare

than for FERT, and both were greater ($P < 0.01$) than for CONT. Nitrogen retention for steers in the SUPP treatment was increased ($P < 0.01$) by 31% compared with N retention in the CONT and FERT treatments. Nitrogen retention per hectare for SUPP was 30 and 98% greater ($P < 0.01$) than N retention per hectare for FERT and CONT, respectively. Nitrogen excretion per steer and per hectare were also greater ($P < 0.01$) for SUPP than FERT, and both were increased ($P < 0.01$) compared with CONT. Animal N use efficiency was similar ($P = 0.29$) for steers in the CONT, FERT, and SUPP treatments. However, system-based N use improved ($P < 0.01$) by 144% for SUPP compared with FERT. The DDGS increased N intake and N excretion in yearling steers. However, because of improvements in BW gain and increases in stocking rate of pastures, DDGS can be a useful tool to increase the efficiency of N use in smooth brome grass grazing systems.

Key words: beef cattle, dried distillers grains plus solubles, nitrogen fertilizer, nitrogen use efficiency

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INTRODUCTION

Research in forage quality and animal nutrition are targeting ways of improving N use in plants (Singer and Moore, 2003) and livestock (Scholefield et al., 1991). Much is known about fertilizer type, amount, and timing of application for maximizing crop yields as well as the mechanisms and pathways of N transformation and losses for grasslands and pastures (Jenkinson, 2001). The understanding of protein utilization by grazing cattle is also extensive (Klopfenstein et al., 2001). However, major gaps exist in our knowledge of the relationships between management and harvest strategies and

N pathways in farming and ranching (Mosier et al., 2001).

Smooth brome grass yields respond to increasing rates of N fertilizer, up to 100 to 504 kg of N/ha (Casler and Carlson, 1995). Relatively small fractions of the N consumed by grazing livestock are removed from the ecosystem (Jarvis and Ledgard, 2002), leading to reduced N use efficiencies with increasing rates of N fertilization (Zemenchik and Albrecht, 2002).

Nitrogen use efficiency can be improved by increasing N retention, reducing N inputs, or both. In growing animals, BW gain is the main driver in N retention, and DDGS supplementation is very effective in increasing BW gain on high-quality forages (Klopfenstein et al., 2007). Supplementing cattle on pasture with DDGS effectively acts as N fertilization because DDGS has increased N (5% DM) and excess N is excreted as urea in the urine. Supplementing cattle on pasture at 2 to 3 kg/animal daily can result in a N fertilization rate of 35 to 40 kg/ha (Greenquist et al., 2009). The greater N

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content of urine has been shown to increase forage production significantly in the vicinity of actively growing forage plants (Doak, 1952; Ball and Ryden, 1984).

Greenquist et al. (2009) reported increased cattle BW gains by supplementing 2.3 kg of DDGS/d on non-fertilized pastures, which should give increased N use efficiency. The data reported herein represent the calculated N use efficiency from the biological data reported by Greenquist et al. (2009). The objectives of this experiment were to compare the effects of N fertilization of smooth brome grass pasture and DDGS supplementation of cattle on smooth brome grass pasture in terms of the N dynamics and N use efficiency of steers and the system as a whole.

MATERIALS AND METHODS

Steers were managed in accordance with the protocols approved by the Animal Care and Use Committee at the University of Nebraska.

Experiment Site

The experiment (3 yr) was conducted (Greenquist et al., 2009) at the University of Nebraska–Lincoln Agricultural Research and Development Center near Mead, NE (96°33' W longitude, 41°11' N latitude, 315 m elevation). The area is characterized by a continental climate with average maximum daily temperatures ranging from -0.3°C in January to 30.9°C in July. Average minimum daily temperatures range from -12.4°C in January to 17.8°C in July. The 10-yr average annual precipitation for this area was 693 mm (National Climatic Data Center, 2008), of which 75% fell in the form of rain from April through September. The most prominent soil type is a Sharpsburg silty clay loam (fine, montmorillonitic, mesic, Typic, Argiudoll). The predominant parent material is loess of Peorian age (Soil Conservation Service, 1965). The study site consisted of 3 pastures of smooth brome grass, which, over the previous 10 yr, were fertilized annually with approximately 90 kg of N/ha and grazed heavily in May and October by calves and yearlings.

Treatments

Crossbred (predominantly Angus) steers (330 ± 10 kg) were used in a randomized complete block design with 3 blocks and 3 treatments. The treatments were 1) smooth brome grass paddocks fertilized with 90 kg of N/ha and initially stocked with yearling steers at 9.2 animal unit months/ha (**FERT**), 2) nonfertilized smooth brome grass paddocks initially stocked at 6.4 animal unit months/ha (**CONT**), and 3) nonfertilized smooth brome grass paddocks stocked at the same rate as the FERT with 2.3 kg of DM of corn DDGS supplemented daily per steer (**SUPP**). Previous forage production data from this site showed 69% as much forage

produced by not fertilizing; therefore, the stocking rate was adjusted to provide equal grazing pressure (kg/steer). It was assumed the DDGS would replace the reduced amount of grass available for the steers in the SUPP treatment. Morris et al. (2005, 2006) reported improvements in performance while maintaining consumption of a DDGS supplement at 0.5% BW. In this experiment, steers were supplemented with 2.3 kg of DM of DDGS daily in feed bunks for the entire treatment period. This amount was slightly greater (0.58% of average BW) than that reported by Morris et al. (2006). Water was available ad libitum. The stocking rate for the FERT treatment was based on longer term stocking rate records for the site and University of Nebraska–Lincoln extension recommendations (Rehm et al., 1971; Waller et al., 1986). For the CONT treatment, previous research on smooth brome grass pastures adjacent to the experimental pastures indicated a 30% decrease in available forage on nonfertilized compared with fertilized (90 kg of N/ha) smooth brome grass (Schlueter, 2004).

Paddock Management

Within each of the 3 blocks, treatments were assigned randomly to 1 of 3 paddocks in 2005. Allocation of treatments to the individual paddocks was the same for 2006 and 2007. Paddocks were 2.0 ha for FERT and SUPP, and 2.9 ha for CONT, and were grazed from late April through September in each of the 3 yr. Each paddock was further divided equally into 6 strips to enable intensive grazing. The cattle were rotated through all 6 strips in each of 5 grazing cycles. The period of stay was 4 d per strip in cycle 1 and 6 d per strip in cycles 2, 3, and 4. The period of stay in cycle 5 varied from 4 to 6 d based on available forage mass. Urea was used as the source of N fertilizer and was surface applied at 90 kg of N/ha to the designated paddocks 14 to 21 d before the initiation of grazing. A single-strand electric fence was used to confine steers to the strips.

In each of the 3 yr of the experiment, 45 crossbred steers (330 ± 10 kg) were blocked by BW and assigned randomly to the 9 paddocks, with 5 steers per paddock. A variable stocking density was used to maintain comparable grazing pressure among treatments and year. This was achieved with the addition and removal of put-and-take cattle. The number of put-and-take cattle varied between and within year based on the measured forage mass and visual observations. By doing so, the effects of the treatments on animal performance would be expressed as total amount of BW gain per hectare while maintaining comparable pasture conditions. Animal days were calculated as the number of test steers multiplied by the number of days in the grazing period, plus the number of put-and-take cattle multiplied by the number of days the put-and-take cattle grazed within the grazing period. Put-and-take steers were from the same pool of cattle and were grazed adjacent brome pastures when not grazing experimental pastures.

Data Collection and Analysis

Paddock measurements were made in the second, fourth, and sixth strips in paddocks of block 1, 2, and 3, respectively, in each cycle, resulting in different collection dates for each block. Blocks were sampled on different dates because of the labor and time demands associated with the intensive diet and forage measurement procedures. Diet samples were collected at the midpoint of a grazing period, with 2 steers per pasture fitted with rumen cannulas (6 steers total). Baleseng (2006) demonstrated that samples collected midpoint in the grazing period accurately represent the average diet quality of the grazing period. Briefly, steers were fasted for 12 h and ruminally evacuated at 0800 h on each sampling day. Steers were given 30 min to graze the assigned paddock. Masticate samples were removed from the rumen, samples were immediately put on ice, and rumen contents were returned to the rumen. Samples were transported on ice to the laboratory after collection and frozen at -4°C until they were lyophilized (-50°C). The dried samples were ground individually through a Wiley mill (Thomas Scientific, Swedesboro, NJ) fitted with a 2-mm screen; a subsample was ground through a 1-mm screen. Crude protein was determined for diet and DDGS samples by the combustion method (method 4.2.10; AOAC, 1996) using a combustion N analyzer (FP-528, Leco Corp., St. Joseph, MI).

Pregrazing standing crop was estimated the day before cattle were moved into a strip that was to be used for diet collection. The drop disc method was used (Sharro, 1984; Karl and Nicholson, 1987). Fifty disc (0.26 m^2) measurements were taken at randomly selected locations in each strip and correlated with actual clipped crop from quadrats (0.38 m^2) placed immediately below every eighth disc location. Standing crop at the end of the fifth cycle (i.e., end of grazing season) also was estimated by using the drop disc method in 2005. Our goal was to leave approximately 1,200 kg/ha of standing crop at the end of the fifth cycle. Postgrazing standing crop for the fifth cycle in 2005 was approximately 1,200 kg/ha and was equivalent to a 10-cm stubble height. Grass stands in all paddocks were grazed to a stubble height of approximately 10 cm in 2006 and 2007.

N Balance

Two N balances were determined to evaluate N use efficiency on an animal and a system (expressed per hectare) basis. The animal N balance inputs included N intake from forage and N intake from DDGS. Outputs for the animal N balance were calculated using N retention, with the difference equaling surplus or excreted N. Daily forage DMI were calculated according to the method of Watson et al. (2010) by using an energetic model based on the NE equations of the beef NRC (1996). The NRC (1996) model estimates

the energy (TDN) requirement for a given ADG. If the ADG and TDN values of the diet are known, then the DMI can be estimated. Total N consumed from forages was calculated by multiplying the total forage intake by the percentage of N in the forage consumed. Total N intake was the sum of the forage N and DDGS N intake with all DDGS being consumed. Nitrogen retention was calculated from total BW gains by using NRC (1996) equations. Nitrogen excretion was calculated by subtracting N retention from total N intake. Animal N use efficiency was calculated by dividing N retention by total N intake for the steer.

The system N balance inputs included N from DDGS, fertilizer, and atmospheric deposition. Nitrogen from biological fixation in monoculture smooth brome pastures is negligible. Total inorganic N wet deposition from nitrate and ammonium was considered constant across treatments and was estimated to be 6.5 kg/ha (National Atmospheric Deposition Program, 2008). Output for the system N balance was animal N retention. Nitrogen excretion was calculated by subtracting N retention from total N consumption. The balance (surplus) was calculated by the difference between the total N inputs and the amount of N retention. Apparent N recovery rates (% of N inputs) were calculated by dividing N retention by total N inputs, multiplied by 100. Nitrogen use efficiency of the system was calculated by dividing the system outputs (N retention) by the system inputs (N from DDGS and fertilizer), multiplied by 100.

Data were analyzed using mixed-model procedures (SAS Inst. Inc., Cary, NC) as a randomized complete block design, with block and year considered random effects. Paddock was the experimental unit for diet sample and N balance measurements. Least squares means were separated using the least significant difference method when a significant *F*-test ($P < 0.05$) was detected.

RESULTS AND DISCUSSION

Precipitation varied among years. The amount received in 2007 was above average and that in 2006 was slightly above average. Typically, based on average precipitation patterns within a year, monoculture smooth brome pastures in eastern Nebraska have increased DM production and quality in May and June, followed by decreased production and quality in July and August, with some increase in September (Greenquist et al., 2009). In vitro DM digestibility averaged 60.2%, as estimated by Greenquist et al. (2009), and showed a quadratic response to grazing day. Digestibility values were increased early in the season, then declined in the summer and increased in the fall. Crude protein averaged 16.2% (DM) and showed a cubic response to grazing day (Greenquist et al., 2009), with greater values in the spring. These data are similar to other reported values (Schlueter, 2004; Baleseng, 2006;

Table 1. Animal N balance for grazing management and supplementation strategies of steers grazing smooth brome grass¹

Item ²	Treatment (TRT)			SEM	TRT <i>P</i> -value
	CONT	FERT	SUPP		
DDGS intake, kg of DM/steer daily	0	0	2.3	—	—
Forage intake, ³ kg of DM/steer daily	8.60 ^a	8.57 ^a	6.55 ^b	0.062	0.01
Forage N, % of DM	2.45	2.78	2.60	—	—
N from DDGS	0	0	17.71	—	—
N from forage	33.36 ^a	37.71 ^b	26.97 ^c	0.958	<0.01
Total N intake	33.36 ^a	37.71 ^b	44.68 ^c	0.961	<0.01
N retention ³	2.92 ^a	2.89 ^a	3.81 ^b	0.741	<0.01
N excretion ⁴ (surplus)	30.44 ^a	34.83 ^b	40.87 ^c	0.930	<0.01
Animal N use efficiency, ⁵ %	8.77	7.66	8.55	0.262	0.29

^{a-c}Means within a row without a common superscript differ ($P < 0.01$).

¹Pastures were nonfertilized (CONT), fertilized with urea at 90 kg/ha of N (FERT), or nonfertilized and steers were supplemented with 2.3 kg (DM) of corn dried distillers grains plus solubles (DDGS; 30.4% CP) daily for the grazing period (SUPP; 158.3-d average).

²Expressed as kilograms of N per steer for the entire grazing period, unless otherwise noted ($n = 9$).

³Calculated from NRC (1996) equations (Watson et al., 2010).

⁴Calculated by subtracting N retention from total N intake.

⁵Calculated by dividing N retention by total N intake.

MacDonald et al., 2007) from similar pastures within the immediate area. Steers gained 0.68, 0.67, and 0.92 kg/d and 197, 302, and 404 kg/ha for CONT, FERT, and SUPP, respectively (Greenquist et al. 2009). Animal days were 288, 446, and 440 for CONT, FERT, and SUPP, respectively.

Steers supplemented with DDGS consumed less forage ($P = 0.01$) than steers in the other treatments (Table 1). Steers grazing fertilized and nonfertilized pastures consumed 2.23% of BW of forage daily. This compares with intakes of 2.06% of BW for similar cattle on brome pastures, estimated by using chromic oxide boluses (Downs 1997). Variation in forage intake using the boluses was greater throughout the grazing season. MacDonald et al. (2007) fed chromic oxide in the supplement to similar cattle on the same brome pastures and reported 2.35% of BW of forage intake. We believe the diet samples in the current study accurately represent the TDN of the diet and that cattle BW gains over the 160-d grazing period accurately represent the energy gains of the cattle. Therefore, the DMI values in Table 2 reflect the forage intakes of the cattle. The supplemented cattle had access to 69% of the grazing area the unsupplemented (CONT and FERT) cattle had. Animal days were 6% greater (using put-and-take steers), so the net effect was that forage intake of supplemented cattle was only 73% that of unsupplemented steers. The NRC (1996) model used herein estimated the forage intake to be 76% that of the unsupplemented (CONT and FERT) steers. In vitro DM digestibility was not different for the 3 treatments; however, CP was greater for FERT than for CONT or SUPP (Greenquist et al., 2009). Degradable protein deficiencies for cattle on similar-quality pastures in the immediate area have not been detected (NRC, 1996; MacDonald et al., 2007), so no performance differences were anticipated based on these diet quality measurements, and ADG

was similar for steers in the CONT and FERT treatments.

Total N intake for SUPP (44.68 kg of N) was greater ($P < 0.01$) per steer than total N intake for FERT (37.71 kg of N); total N intakes for SUPP and FERT were both greater ($P < 0.01$) than that for CONT (33.36 kg of N). Total N intake was greater for SUPP because of the addition of 17.71 kg of N/steer from DDGS. Steers in the FERT treatment had greater ($P < 0.01$) total N intake than those in the CONT treatment because of the increased N content of the forage, even though forage intakes were similar. Intake of N from forage was less for cattle in the SUPP treatment because of the reduced forage intake.

Nitrogen retention, calculated from NRC (1996) equations, was increased ($P < 0.01$) by 31% for cattle in the SUPP treatment (3.81 kg of N) compared with those in the CONT (2.92 kg of N) and FERT (2.89 kg of N) treatments. This response can be attributed to the increase in ADG that was observed for steers in the SUPP treatment over those in the CONT and FERT treatments (Greenquist et al., 2009). No differences were observed in ADG between the CONT and FERT treatments. The ADG is critically important for these calculations. Great care was taken to measure ADG accurately. Steers were fed the same diet at the same percentage of BW before and at the conclusion of the grazing periods to create equal gastrointestinal tract fill. Further, the steers were weighed on 3 consecutive days at the initiation and conclusion of grazing. Nitrogen excretion or surplus N, which was the difference in N intake and N retention per steer, was greater ($P < 0.01$) for cattle in the SUPP treatment (40.87 kg of N) compared with those in the FERT treatment (34.83 kg of N). Nitrogen excretion for cattle in the SUPP and FERT treatments was increased ($P < 0.01$) compared with those in the CONT treatment (30.44 kg of N).

Table 2. Nitrogen balance for grazing management and supplementation strategies of smooth bromegrass pastures grazed by yearling steers¹

Item ²	Treatment (TRT)			SEM	TRT <i>P</i> -value
	CONT	FERT	SUPP		
N inputs					
N from DDGS	0	0	48.94	—	—
N fertilizer	0	90	0	—	—
N atmospheric deposition ³	6.50	6.50	6.50	—	—
Total N inputs	6.50 ^a	96.50 ^b	55.44 ^c	1.594	<0.01
N consumption					
N from DDGS	0	0	48.94	—	—
N from forage	60.48 ^a	104.83 ^b	74.17 ^c	2.341	<0.01
Total N consumption	60.48 ^a	104.83 ^b	123.11 ^c	2.344	<0.01
N retention ⁴	5.28 ^a	8.04 ^a	10.46 ^b	0.169	<0.01
N excretion	55.20 ^a	96.78 ^b	112.65 ^c	2.295	<0.01
N balance ⁵ (surplus)	1.22 ^a	88.46 ^b	44.98 ^c	0.173	<0.01
Apparent N recovery rate, ⁶ %	81.18 ^a	8.33 ^b	19.12 ^c	1.646	<0.01
N use efficiency, ⁷ %	—	8.93 ^a	21.77 ^b	0.262	<0.01

^{a-c}Means within a row without a common superscript differ ($P < 0.01$).

¹Pastures were nonfertilized (CONT), fertilized with urea at 90 kg/ha of N (FERT), or nonfertilized and steers were supplemented with 2.3 kg (DM) of corn dried distillers grains plus solubles (DDGS; 30.4% CP) daily for the grazing period (SUPP; 158.3-d average).

²Expressed as kilograms of N per hectare for the grazing period, unless otherwise noted ($n = 9$).

³Data from the National Atmospheric Deposition Program (2008; <http://nadp.sws.uiuc.edu/maps/Default.aspx>, accessed Jan. 7, 2008).

⁴N retention calculated from NRC (1996) equations.

⁵Difference between total N inputs and N retention.

⁶Calculated by dividing N retention by total N inputs, multiplied by 100.

⁷Calculated by dividing system outputs (N retention) by system inputs (N from DDGS and N fertilizer), multiplied by 100.

Nitrogen excretion was driven mainly by total N intake. Yan et al. (2007) demonstrated N intake as the primary predictor for N excretion ($r^2 = 0.898$).

Animal N use efficiency (N retention per steer \div N intake per steer $\times 100$) was not affected by treatment ($P = 0.29$). This was somewhat expected because steers were not deficient in protein. Any protein fed in excess would therefore be excreted and reduce the efficiency of use. Overall N use efficiency was approximately 8% across all treatments.

Total N inputs for steers in the SUPP treatment were 48.94 kg of N/ha from 2.3 kg/animal daily of DDGS and 6.5 kg of N/ha from atmospheric deposition (Table 2). Total N inputs for steers in the FERT treatment were 90 kg of N/ha from N fertilizer and 6.5 kg of N/ha from atmospheric deposition, whereas total N inputs for steers in the CONT treatment were 6.5 kg of N/ha from atmospheric deposition. Total N consumption was 123.1 kg of N/ha for cattle in the SUPP treatment, 104.8 kg of N/ha for those in the FERT treatment, and 60.48 kg of N/ha for those in the CONT treatment. Nitrogen retention per hectare for cattle in the SUPP treatment (10.46 kg of N/ha) was 30% greater ($P < 0.01$) compared with cattle in the FERT treatment (8.04 kg of N/ha) and was 98% greater ($P < 0.01$) compared with cattle in the CONT treatment (5.28 kg of N). Nitrogen excretion is the difference in N intake and N retention and was increased ($P < 0.01$) for cattle in the SUPP treatment (112.7 kg of N/ha) compared with those in the FERT treatment (96.8 kg of N/ha). Nitrogen excretion for cattle in the SUPP and FERT treatments was increased ($P < 0.01$) compared with

that of cattle in the CONT treatment (55.2 kg of N/ha). Nitrogen excretion per hectare was driven mainly by total N intake per hectare, which was greatest for cattle in the SUPP treatment because of DDGS supplementation. The N intake and excretion were less for cattle in the CONT treatment compared with those in the FERT treatment primarily because of 30% less stocking density.

Surplus N from the system-based N balance was calculated as the difference between total N inputs and N retention (animals). Surplus N can be an indicator of the amount of N lost to the environment, if the system is in equilibrium (Oenema et al., 2003). We believe the FERT system to be close to or at equilibrium because this management system has been maintained for the last 10 to 15 yr on these specific pastures. The 90 kg/ha fertilization rate used is recommended for brome pastures in eastern Nebraska. This is less than the amount needed for the maximum response (Casler and Carlson, 1995). Therefore, by the end of the growing season, the added N would be utilized for plant growth and an increase in soil nitrate would not be expected. However, we believe that the CONT system is not sustainable long term at its current production because N losses may be greater than annual N inputs. Soil nitrate amounts may have declined over the 3 yr of the experiment. The opposite can be said for SUPP because we believe the performance and soil characteristics of these pastures will improve with the additional OM and N from DDGS. The unknown in this system is the distribution of urine and feces. Certainly, these are not distributed uniformly over the pastures. This

is true for all 3 treatments because N was recycled to the pasture through urine and feces in all grazing systems. However, with cattle supplemented with DDGS, the concentration of N in the urine was likely greater than that in the unsupplemented cattle. Haynes and Williams (1993) suggest that N additions from urine could be as great as 400 kg/ha in the "urine spot." Over the grazing season and over the 3 yr of this experiment, we assume the extra N from the DDGS was reasonably well distributed and that nitrate had not accumulated in the soil in the urine spots or that nitrate had migrated into the ground water. After 3 yr, we assume these DDGS treatment pastures have reached steady state.

Presumably, this surplus N is lost primarily as NH_3 , although a small amount may be lost as N_2O . Oenema et al. (2003) discussed the uncertainties in nutrient budgets such as those used here. Leaching of nitrate is assumed to be very small under the soil and environmental conditions of our experiment, and production of N_2O by nitrification, denitrification, or both is small. Phillips et al. (2007) estimated N_2O losses to be 0.23% of N input. Although NH_3 is not a greenhouse gas, it would have environmental implications, depending on where it is deposited.

Apparent N recovery rate was greater ($P < 0.01$) for CONT (81.18%) compared with FERT (8.33%) and SUPP (19.22%). However, the initial pool of N from CONT may have contributed to a greater apparent N recovery because of past fertilization. As N pools decrease (inputs would still stay the same), the apparent N recovery may decrease as N pools in the soil decrease. Apparent N recovery rate of SUPP was also greater ($P < 0.01$) than that of FERT. Although CONT had markedly better N recovery, more hectares were needed to obtain total animal BW gains equal to those of either FERT (53%) or SUPP (105%; Greenquist et al., 2009).

System-based N use efficiency [$(\text{N retention/ha} \div \text{N input of fertilizer and DDGS/ha}) \times 100$], which is the same as apparent N recovery rates minus N atmospheric deposition, was improved ($P < 0.01$) by 144% for SUPP (21.37%) compared with FERT (8.93%). This ultimately indicates that N from DDGS is better utilized than N from fertilizer in these management and pasture conditions.

Nitrogen use efficiency in the ruminant is an important part of grazing systems. Nitrogen intake is correlated with N excretion, and decreased animal N use efficiencies are compounded when strategies to increase forage production, such as N fertilization, result in forages that contain N that is in excess of the needs of the animals. In combination with intensively managed pastures leading to better urine distribution, DDGS supplementation has the potential to increase N content and cycling of N in the pasture. Nitrogen use efficiency is improved by decreasing N inputs and capturing more N in the form of additional BW gain and in the cycling of N in the pasture. Dried distillers grains can be used as a substitute for forage and N fertilizer by improving

performance and N use efficiency in smooth bromegrass pastures in eastern Nebraska.

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