

Effects of management system on beef heifer growth and reproductive performance

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ABSTRACT: This study evaluated the effect of heifer development system on body weight (BW), body condition score (BCS), fescue toxicosis symptoms, reproductive performance, and subsequent calf growth of fall-calving beef heifers. Angus × Simmental heifers [$n = 399$; 240 ± 20.0 kg initial BW; age = 252 ± 20 d] were stratified by BW and BCS and assigned to 1 of 12 groups in each of the two production years. The study utilized a stratified randomized design. Pens were randomly assigned to four treatments: drylot (DL) development (fed ad-libitum diet consisting of 90% hay and 10% DDGS on a dry matter basis), grazing endophyte-infected fescue supplemented daily (2.3 kg as-fed/heifer/d; 50:50 mix of soybean hulls and DDGS; E+/S), grazing endophyte-infected fescue and supplemented from the midpoint of treatment period until breeding (4.5 kg as-fed/heifer/d; 50:50 mix of soybean hulls and DDGS; E+/LS), and grazing novel endophyte-infected fescue with no supplement (NE+/NS). Treatments ceased on d 168 [time of artificial insemination (AI)] and heifers were commingled and managed as a group through second breeding season. Heifers in DL had greatest ($P \leq 0.05$) BW and BCS from d 28 until d 254. Furthermore, E+/S heifers had greater ($P \leq 0.05$) BW and BCS than both E+/LS and

NE+/NS from d 28 until d 168. On d 56 and 84, E+/LS heifers had lower ($P \leq 0.05$) BW and BCS compared to NE+/NS, but on d 148 treatments reranked and E+/LS remained at a greater ($P \leq 0.05$) BW and BCS compared to NE+/NS through the first breeding season. Drylot heifers had greatest ($P \leq 0.05$) percentage cycling and percentage of mature BW at AI (66.6%) and had greater ($P \leq 0.05$) AI and overall pregnancy rates compared to E+/LS and NE+/NS. The E+/S (55%) and E+/LS (53.7%) heifers were developed to a greater ($P < 0.01$) percentage of mature BW than NE+/NS (49.3%). A greater ($P \leq 0.02$) percentage of DL and E+/S heifers were pregnant at the end of the first breeding season (89.3 and 85.1%; respectively) compared to NE+/NS (61.5%). In summary, DL heifers had the greatest BW and BCS at AI, percentage cycling, and AI pregnancy rate. However, this strategy did not result in differing overall pregnancy rates between DL, E+/S, and E+/LS and there were no differences in milk production, rebreeding reproductive performance, and calf performance between all treatments. Finally, the poorest AI and overall pregnancy rates of the NE+/NS heifers suggests this is not a viable development strategy for fall-born heifers.

Key words: drylot, fescue, heifer development, reproduction

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INTRODUCTION

To maintain herd size and productivity, proper selection and retention of replacement

beef females is extremely important for the sustainability of an operation. In the Midwest, the lack of grazable acres is one of the major constraints on expanding the cowherd (NASEM, 2016). Land price, feed availability, equipment sharing with row crop enterprise, and manure utilization have allowed the Midwest cattlemen to explore year-round management of beef females in the drylot. However, recent studies have compared drylot heifer development with lower-quality forage grazing systems (corn residue or native winter range) and noted that drylot developed heifers had reduced efficiency and in some cases reduced longevity in the cowherd (Funston and Deutscher, 2004; Roberts et al., 2009; Mulliniks et al., 2013; Summers et al., 2014).

Considering the majority of this work was conducted in extensive rangelands in the western United States, little is known about how these systems translate to the lower Midwest where cow-calf production relies on tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort) systems (Hoveland, 1993). Tall fescue is a cool-season grass that is adaptable, easy to establish, and persistent under adverse conditions (Gunter and Beck, 2004). Unfortunately, most tall fescue contains an endophyte that produces ergot alkaloids, which can cause fescue toxicosis (Gunter and Beck, 2004). Cattle grazing toxic endophyte-infected tall fescue (E+) can suffer fescue toxicosis, which is characterized by elevated body temperature, reduced feed intake, and decreased ADG (Schmidt and Osborn, 1993; Paterson et al., 1995; Aiken et al., 2013). Fescue toxicosis can be detrimental to reproductive processes including pregnancy rates (Paterson et al., 1995). Utilizing supplementation as a strategy to alleviate fescue toxicosis has been successful at improving performance (Aiken et al., 2008; Carter et al., 2010). Whereas utilizing strategic compensatory gain prior to the breeding season has been successful at reducing labor without sacrificing reproductive performance (Freetly et al., 2001; Grings et al., 2007). However, this strategy has not been evaluated in an E+ grazing system.

The adverse effects of cattle grazing E+ led to the development of non-toxic novel endophyte-infected tall fescue (NE+; Bouton et al., 2002). Research has demonstrated cattle grazing NE+ do not exhibit signs of fescue toxicosis and show improved performance compared to cattle grazing E+ (Parish et al., 2003). Drewnoski et al. (2009) demonstrated replacement heifers grazing NE+ during spring growth had increased ADG and reduced prolactin compared to heifers grazing E+. However, no work has been done to investigate allowing heifers

to graze NE+ with no supplementation or utilizing strategic compensatory gain when heifers graze E+ as strategies to develop fall-calving beef heifers.

The objectives of this experiment were to compare the growth and reproductive performance of replacement fall-calving beef heifers developed in two common Midwest systems (drylot developed and grazing E+ with daily supplementation) with two alternative strategies (grazing E+ with daily supplementation from the midpoint of treatment period until breeding, or grazing NE+). Authors hypothesized that heifer growth performance would be greatest for drylot developed heifers but would not differ between grazing treatments. Finally, it was hypothesized that reproductive performance and calf growth would not differ between the treatments.

MATERIALS AND METHODS

All experimental procedures were approved by the Institutional Animal Care and Use Committee of the University of Illinois (IACUC #17108) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animal in Agricultural Research and Teaching (FASS, 2010).

Animals and Experimental Design

Three hundred and ninety-nine fall-born, Angus × Simmental heifers [240 ± 20.0 kg initial body weight (BW); age = 252 ± 20 d; mean \pm standard deviation] from two production years were utilized in a stratified randomized design to identify the most successful management strategy to develop fall-calving beef heifers. Heifers were housed at the Dixon Springs Agricultural Center in Simpson, IL. In both years, heifers were weaned in mid-March and grazed a common pasture with supplementation of dried distillers grains with solubles [DDGS; 2.3 kg as-fed/heifer/d; 31.5% neutral detergent fiber (NDF), 10.2% acid detergent fiber (ADF), 10.7% fat, and 28.2% crude protein (CP)] until the initiation of treatments (late May). Heifers were stratified by BW and body condition score (BCS) and assigned 1 of 12 replications (Figure 1). Treatments were randomly assigned to each replicate, resulting in 3 replications per treatment within each year. Treatments included: 1) drylot (DL) developed (ad-lib fed a diet consisting of 90% hay and 10% DDGS; 56% NDF, 36% ADF, 0.7% fat, and 12.4% CP); 2) grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S);

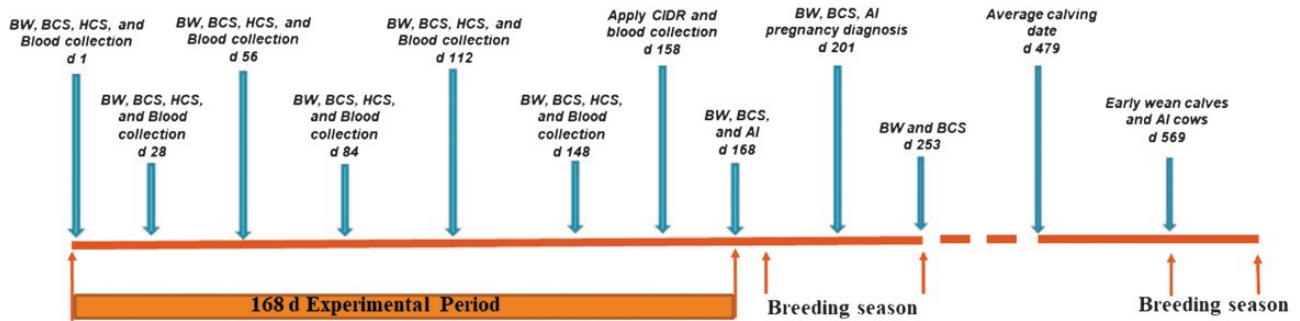


Figure 1. Experimental timeline. Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS). The exact timeline was replicated in yr 2. Hair coat score (HCS; 1 to 5, in which 1 = slick and 5 = unshed).

3) grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); or 4) grazing novel endophyte-infected fescue (NE+/NS). Composition of the supplement provided to E+/S and E+/LS was 47% NDF, 27% ADF, 5.6% fat, and 19.2% CP. Supplementation for the E+/LS heifers began 80 d after the initiation of the trial at a rate of 2.3 kg as-fed/heifer/d, then was increased to 3.4 kg as-fed/heifer/d on d 86, followed by an increase to 4.5 kg as-fed/heifer/d on d 93. This resulted in E+/S and E+/LS heifers receiving the same amount of supplement for the treatment period. Cattle on E+/S and E+/LS rotationally grazed endophyte-infected tall fescue (“Kentucky-31”; Year 1: 67% infected; total ergot alkaloid concentration: September: 2,610 $\mu\text{g/L}$; Year 2: 86.5% infected; total ergot alkaloid concentration: June: 620 $\mu\text{g/L}$; July 670 $\mu\text{g/L}$; September: 1,812 $\mu\text{g/L}$; October: 1,715 $\mu\text{g/L}$) and red clover pastures (*Tri-folium pretense*) pastures. Heifers on NE+/NS treatment rotationally grazed novel endophyte-infected tall fescue [“Jesup” (MaxQ; Madison, GA); Year 1: 63% infected; total ergot alkaloid concentration: September: 0 $\mu\text{g/L}$; Year 2: 68% infected; total ergot alkaloid concentration: June: 0 $\mu\text{g/L}$; July 215 $\mu\text{g/L}$; September: 367 $\mu\text{g/L}$; October: 256 $\mu\text{g/L}$] and red clover pastures (*Tri-folium pretense*) pastures. Cattle had free-choice access to a mineral supplement (Southern FS Services, Marion, IL; 12% Ca, 9.5% P, 17% salt, 5.9% Mg, 1.15% K, 24 mg/kg Co, 31 mg/kg I, 3,000 mg/kg Fe, 1,400 mg/kg Cu, 2,000 mg/kg Mn, 26.4 mg/kg Se, 4,000 mg/kg Zn, 550,000 IU/kg vitamin A, 3,300 IU/kg vitamin D, 220 IU/kg Vitamin E, and 6,600 mg/kg chlortetracycline).

Pasture size was 2.05 ± 0.15 ha, with an average stocking density of 7.8 heifers/ha. Groups were

rotated every 14 d. Available forage was quantified as heifers went in the pastures by using a falling plate meter (Jenquip, Fielding, New Zealand) to collect 12 random measurements. A minimum of 1,457 kg DM/ha was available to all groups throughout the study, with 2,560 kg DM/ha of forage available on average. One heifer from the DL treatment was removed at d 51 for a back injury. Three heifers (1 E+/S and 2 E+/LS) were removed at d 137 for poor BCS. An additional three heifers from the DL treatment were removed at d 166 for rectal prolapse.

Immediately following artificial insemination (AI), treatments ended and heifers were combined into 2 groups with all treatment replications being represented in each group and placed on pasture. Heifers were managed to meet or exceed the NRC requirement for protein and energy. For year 1, from 11/17/17 until 12/21/17 they were fed DDGS (2.72 kg as-fed/heifer/d; ADF 8.40%, NDF 29.4%, CP 26.80%, Fat 11.51%) and free choice mixed grass hay (53.5% NDF, 31.4% ADF, and 12.09% CP). On 12/22/17 cattle were provided a total mixed ration consisting of corn silage, mixed grass hay, DDGS, and soybean hull pellets (12.2 kg DM/heifer/d; 36% NDF, 19% ADF, 4.7% fat, and 15.9% CP). Cattle were then transitioned on 1/29/18 to a mixed grass hay, corn, DDGS, and soybean hull pellets (7.1 kg DM/heifer/d; 33% NDF, 17% ADF, 5.1% fat, and 18.4% CP) until 4/11/18. From 4/11/18 until 12/11/18 heifers grazed endophyte-infected fescue (*Festuca arundinacea*) and red clover pastures (*Tri-folium pretense*; spring = 54% NDF, 30% ADF, and 12.7% CP; summer = 56% NDF, 28% ADF, and 12.9% CP, fall = 52% NDF, 27% ADF, and 15.5% CP). For year 2, from 11/15/18 until 2/19/19 they were fed DDGS (3.63 kg as-fed/heifer/d; 33% NDF, 12% ADF, 10.3% fat, and 29.4% CP) and free choice mixed grass hay (63% NDF, 36% ADF, 1.3% fat, and 9.4% CP). On 2/19/19, heifers were

transitioned to corn silage diet (8.3 kg DM/heifer/d; 34% NDF, 17% ADF, 3.1% fat, and 8.1% CP) and DDGS (3.63 kg as-fed/heifer/d; 33% NDF, 12% ADF, 10.3% fat, and 29.4% CP) until 3/26/19. On 3/27/19, they were fed DDGS (1.81 kg as-fed/heifer/d; 37% NDF, 11% ADF, 10.8% fat, and 26.8% CP) and free choice mixed grass hay. From 5/3/19 until 12/11/19 heifers grazed endophyte-infected fescue (*Festuca arundinacea*) and red clover pastures (*Tri-folium pretense*; spring = 60% NDF, 30% ADF, and 14.5% CP; summer = 60% NDF, 31% ADF, and 10.0% CP, fall = 59% NDF, 30% ADF, and 11.3% CP). Pasture groups were rotated under the discretion of trained University of Illinois research personnel based on visual appraisal of forage availability.

As per Dixon Springs Agriculture Center cowherd's annual vaccination schedule, pregnant heifers received 2 mL Leptoform 5 (Zoetis Inc., Parsippany, NJ) via intramuscular injection, and Ivermax (Bayer, Pittsburgh, PA) pour on at 1 mL/9.98 kg BW topically. In June, heifers received 1 mL anaplasmosis vaccine (University Products L.L.C., Baton Rouge, LA), 2 mL autogenous *Moraxella bovis*/*Moraxella bovoculi* (Addison Biological Laboratory Inc., Fayette, MO), 2 mL Leptoform 5 (Zoetis Inc., Parsippany, NJ), and 2 Corathon fly tags (Bayer, Pittsburgh, PA). In August, heifers received 5 mL Bovishield Gold FP5VL5HB (Zoetis Inc. Parsippany, NJ), 2 mL Scourguard 4KC (Zoetis Inc., Parsippany, NJ), 5 mL Covexin 8 (Merck Animal Health, Madison, NJ), and 7 mL Mu-Se (Merck Animal Health, Madison, NJ).

Once heifers calved, their calves received 1 mL vitamin AD (Sparhawk Laboratories, Lenexa, KS), 1 mL Bo-Se (Merck Animal Health, Madison, NJ), 2 mL autogenous *Moraxella bovis* / *Moraxella bovoculi* (Addison Biological Laboratory Inc., Fayette, MO), and 40 mL Bovisera (Colorado Serum Company, Denver, CO) all administered subcutaneously. All bull calves were castrated at birth. Calves were early-weaned (90 ± 14 d of age).

Sample Collection and Analytical Procedures

Heifer BW and BCS [emaciated = 1; obese = 9; as described by Wagner et al. (1988)] were collected at trial initiation (252 ± 20 d of age), d 28, 56, 84, 112, 148, 168, 201, 253, and at rebreeding AI. Heifer percent of mature BW at AI was based on herd average mature cow BW (567 kg). Hair coat scores (HCS; 1 to 5, in which 1 = slick and 5 = unshed) were also recorded at trial initiation and d 28, 56, 84, and 112 by the same farm technician. Sixty

heifers (15 per treatment) per year that were most similar to average initial BW and BCS were selected for additional observation. Respiration rates were collected from these 60 heifers at d 1, 29, 57, 85, 113, and 149 of the trial. These data were collected 1 d following other measures in order to avoid the influence of animal handling on respiration rates. Ambient temperatures were 24 ± 1.4 °C on d 1, 26 ± 0.4 °C on d 29, 25 ± 1.5 °C on d 57, 20 ± 1.0 °C on d 85, 25 ± 0.6 °C on d 113, and 15 ± 1.9 °C on d 149. Milk production was estimated via the weigh-suckle-weigh technique (Boggs et al., 1980) at 84 ± 13.7 d postpartum using a representative subset of cows for each replicate ($n = 96$). Cows and calves were separated at 1200 h, allowed to nurse at 1930 h, and then were separated overnight. At 0730 h the next day, an empty calf BW was recorded, calves were allowed to nurse for 15 min or until finished, and a full calf BW was recorded. Calf BW was recorded on a scale that rounded to the nearest 0.23 kg. The BW difference between full and empty calf BW was assumed to be 12 h milk production. Estimate of 12 h milk production was multiplied by 2 to calculate 24 h milk production. Calf BW was recorded at birth and at early-weaning (84 ± 13.7 d of age).

Forage samples were collected by randomly clipping approximately 5 cm from the ground, from 12 different locations, within each pasture. At the same time, fescue stems were collected throughout each field by collecting the bottom 15.24 cm closest to the ground and were frozen at -20 °C. Stems were composited by treatment into 4 time periods. Feed and forage samples were collected every two weeks throughout the experiment. Forage and feed samples were dried at 55 °C for a minimum of 3 d, ground through a 1 mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Forage samples were composited by group into 4 time periods and feed samples were composited for the entire experiment. Ground feed and forage were analyzed for NDF and ADF using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY) as well as CP (Leco TruMac, LECO Corporation, St. Joseph, MI). Feed samples were also analyzed for crude fat using an Ankom XT10 fat extractor (Ankom Technology, Macedon, NY). Additional samples were freeze-dried and ground to pass a 1-mm screen using a Wiley mill then composited by group into 4 time periods. Frozen stems and ground forage were then packed on ice and shipped to Agrinostics Limited, Co. (Watkinsville, GA). Total ergot alkaloid analysis of forages and percent infected stems were conducted in a commercial laboratory (Agrinostics Limited, Co., Watkinsville, GA).

Prolactin Analysis

Blood samples were collected from all heifers at d 0, 28, 56, 84, and 112 for prolactin analysis. Blood was collected via jugular venipuncture into a 10-mL serum blood collection vacuum tube (Becton, Dickinson, and Co., Franklin Lakes, NJ). Blood was allowed to clot for 2 h at room temperature before being centrifuged at $1,300 \times g$ for 20 min at 5 °C. Serum was stored at -20 °C for subsequent prolactin analysis. Serum was pooled within each replication. Serum was analyzed for prolactin analysis via a radioimmunoassay as described by [Bernard et al. \(1993\)](#) at the University of Tennessee (Knoxville, TN). The intra- and inter-assay CV for all prolactin analysis were 6.6% and 8.1%, respectively.

Reproductive Development, Estrous Synchronization, and Breeding

Two blood samples from all heifers were collected 10 d apart to determine percent of heifers cycling at d 148 and d 158 (401 and 411 ± 20 d of age). Samples were collected via jugular venipuncture in 10 mL K_{2EDTA} vacuum tubes (Becton, Dickinson, and Co., Franklin Lakes, NJ) and immediately placed on ice. Samples were centrifuged at $1,300 \times g$ for 20 min at 5 °C, and plasma was stored at -20 °C until analyzed. Heifers were considered cycling when a single plasma sample contained ≥ 2 ng/mL of progesterone, or when both samples collected 10 d apart contained ≥ 1 ng/mL of progesterone as previously described by [Gunn et al. \(2015\)](#). Plasma progesterone concentration was analyzed using a chemiluminescent enzyme immunoassay (Immulite 1000; Siemens Medical Solutions Diagnostics, Los Angeles, CA). The intra- and inter-assay CV for all progesterone analysis were 2.44% and 5.63%, respectively and the sensitivity across assays was 0.46 ng/mL.

At d 158 (early November) heifers were enrolled in a 7-day CO-Synch + controlled internal drug-release (CIDR; Pfizer Animal Health, New York, NY) protocol ([Lamb et al., 2006](#)) and were artificially inseminated at a fixed time. In yr 1, Angus sires ($n = 4$) and AI technician ($n = 3$) were stratified across groups. In yr 2, Angus sires ($n = 2$) and AI technician ($n = 2$) were stratified across groups. Immediately following AI, heifers were combined into 2 groups with an equal representation of each treatment and placed on pasture. Ten d following AI, heifers were placed with 10 bulls (which passed breeding soundness exams; 5 bulls/

group) for an 85-d breeding season. The following production season, at d 559 (early December) cows were synchronized using a 7-day CoSynch + CIDR protocol ([Larson et al., 2006](#)) and were artificially inseminated at a fixed time. Both sire ($n = 8$) and AI technician ($n = 4$) were stratified across treatments. At 10 d following the rebreeding AI, heifers were placed with 8 bulls (which passed breeding soundness exams; 4 bulls/group) for a 60-d breeding season. At d 201 (mid December) and d 614 (early February), AI pregnancy rates and rebreeding AI pregnancy rates were collected by a trained technician via ultrasonography (Aloka 500 instrument, Hitachi Aloka Medical America, Inc., Wallingford, CT; 7.5 MHz general purpose transducer array). Overall pregnancy rates and rebreeding overall pregnancy rates were determined at d 300 and d 666 (respectively, late March) by a trained technician via rectal palpation or ultrasonography (Aloka 500 instrument, Hitachi Aloka Medical America, Inc., Wallingford, CT; 7.5 MHz general purpose transducer array).

Statistical Analysis

A stratified randomized design was used and group served as the experimental unit. Pasture forage classification (ADF, NDF, CP, and forage availability), BW, BCS, HCS, respiration rates and serum prolactin concentrations were analyzed with the MIXED procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). The model included the fixed effects of treatment, and time, the interaction of treatment and time, and sire. Random statements included year and group nested within treatment for BW, BCS, HCS, respiration rates and serum prolactin concentrations. Respiration rates at d 1 were significantly different, thus they were included as a covariate. The REPEATED statement of SAS 9.4 (SAS Institute Inc., Cary, NC) was used to model the repeated measurements within animal for each variable and the autoregressive covariance structure were selected after considering the Akaike and Bayesian information criteria. The SLICE statement of SAS 9.4 (SAS Institute Inc., Cary, NC) was used to separate least square means when the interaction of treatment and time was significant ($P \leq 0.05$). The residuals for serum prolactin concentrations were not normally distributed, so a log transformation was performed before analysis. Least square means were back transformed for ease of interpretation.

Heifer percentage of mature BW at AI, cow BW and BCS at time of rebreeding, milk production,

and calf birth BW and early-wean BW were analyzed with the MIXED procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). The model included the fixed effect of treatment. Calf sire and calf sex were included as fixed effects for calf birth BW. Calf sire, calf sex, and calf age were included as fixed effects for calf early-wean BW. Year and group nested within treatment was included as a random effect. Calf date of birth was included as a covariate for cow milk production. Heifer commingle group was not significant for cow BW and BCS at time of rebreeding and milk production, thus was removed from the model.

Binary data, including percent of heifers cycling, heifer reproductive success (AI and overall pregnancy rates), and cow reproductive success (rebreeding AI and overall pregnancy rates) were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). The model included the fixed effect of treatment. Year and group nested within treatment was included as a random effect. Technician and AI sire did not improve model fit for AI pregnancy rates and thus were removed from the model. Treatment effects were considered significant at $P \leq 0.05$ and tendencies were

noted at $0.05 < P \leq 0.10$. Means reported in tables are least squares means \pm SEM.

RESULTS

Treatment \times time effects were detected ($P \leq 0.05$; Table 1) for pasture ADF, NDF, and CP. The E+/S and E+/LS pastures were greater in ADF and NDF for d 1–41, d 42–83, and d 126–168 and lower in CP for d 42–83 and d 126–168 compared to NE+/NS. Treatment \times time effects were not detected ($P = 0.93$) for pasture forage availability. A time effect was detected ($P < 0.01$) for all pasture forage analysis. Pasture ADF and NDF decreased over time, whereas CP and forage availability decreased to d 84–125 then increased to d 126–168. Additionally, there was a treatment effect ($P < 0.01$) for all pasture forage analysis. The NE+/NS pastures had the lowest ADF, NDF, and forage availability, but they had the greatest CP percent.

Treatment \times time effects were detected ($P < 0.01$; Figure 2) for BW and BCS. Heifers in DL had the greatest BW from d 28 until the end of the first breeding season. Furthermore, E+/S heifers had a greater BW than both E+/LS and NE+/

Table 1. Pasture forage proximate analysis of the grazing treatments

Item	Treatment*			SEM	P-value†		
	E+/S	E+/LS	NE+/NS		Trt	Time	Trt \times Time
ADF, %					<0.01	<0.01	0.05
d 1–41	29.9 ^a	29.6 ^a	27.2 ^b	0.95	<0.01		
d 42–83	29.0 ^a	28.6 ^a	26.3 ^b	0.95	<0.01		
d 84–125	26.7	27.4	27.4	0.95	0.58		
d 126–168	25.4 ^a	25.3 ^a	23.6 ^b	0.95	0.03		
NDF, %					<0.01	<0.01	< 0.01
d 1–41	56.3 ^a	55.1 ^a	50.0 ^b	1.16	<0.01		
d 42–83	55.3 ^a	54.9 ^a	50.2 ^b	1.16	<0.01		
d 84–125	54.7	54.1	55.4	1.16	0.62		
d 126–168	51.6 ^a	51.1 ^a	48.2 ^b	1.16	0.03		
CP, %					<0.01	<0.01	0.03
d 1–41	13.3	13.1	14.7	0.76	0.20		
d 42–83	13.6 ^b	13.4 ^b	16.5 ^a	0.76	<0.01		
d 84–125	14.6	14.2	13.9	0.76	0.73		
d 126–168	16.8 ^b	17.5 ^b	19.8 ^a	0.76	<0.01		
Forage availability, kg DM/ha					<0.01	<0.01	0.93
d 1–41	2,941	3,194	2,843	288.8			
d 42–83	2,988	3,259	2,895	288.8			
d 84–125	2,272	2,353	2,209	288.7			
d 126–168	1,933	1,984	1,846	288.7			

*Grazing treatments included: grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS). This study began on June 1.

†Trt = Treatment effect; Trt \times Time = treatment by time effect.

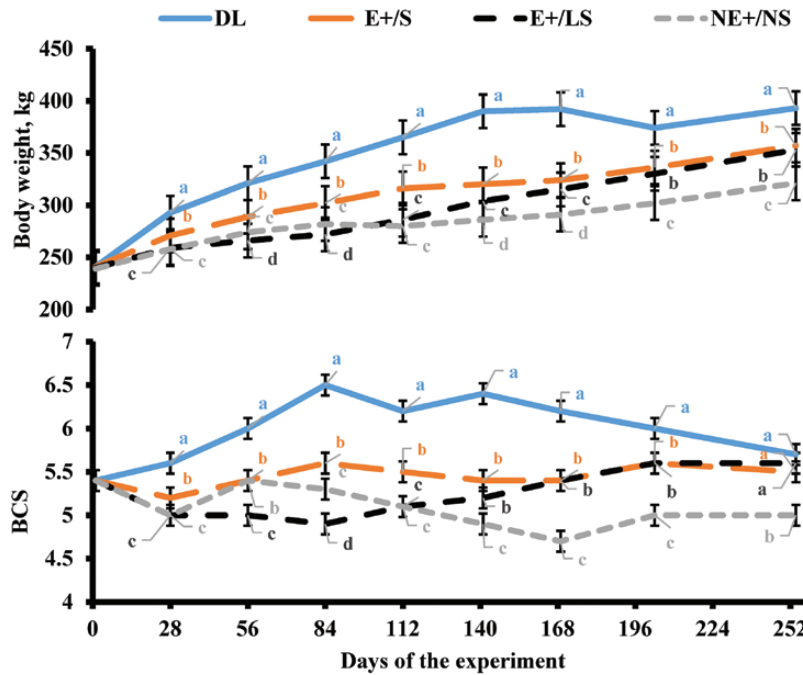


Figure 2. Effects of pre-breeding heifer development system on BW and BCS. Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS). Means at the same time point with different superscripts differ ($P \leq 0.05$). Treatment \times time, time, and treatment effects were detected ($P < 0.01$) for BW and BCS.

NS on d 28, 56, 84, 112, 148, and 168, but on d 201 and 254 E+/S and E+/LS heifers were not different. On d 56 and 84, E+/LS heifers had lower BW compared to NE+/NS, but on d 148 treatments reranked and E+/LS remained at a heavier BW compared to NE+/NS through the first breeding season. Heifers in DL had the greatest BCS from d 28 until d 254. From d 28 until the end of the first breeding season E+/S heifers had a greater BCS compared to NE+/NS excluding d 56 where they were not different. On d 28, 56, 84, and E+/S heifers had the greater BCS compared to E+/LS heifers. On d 56 and 84, E+/LS heifers had the lower BCS compared to NE+/NS, but on d 148 treatments reranked and E+/LS had the greater BCS compared to the NE+/NS through the first breeding season.

Treatment \times time effects were detected ($P < 0.01$; Figure 3) for HCS. On d 28, E+/S and E+/LS heifers had the greater HCS compared to DL and NE+/NS. On d 56, E+/LS heifers had the greatest HCS; DL had a greater HCS compared to NE+/NS but E+/S was intermediate and not different from either. On d 84, E+/LS heifers had the greatest HCS compared to E+/S, E+/LS, and NE+/NS. On d 112 E+/LS heifers had a greater HCS compared to DL which were also greater than NE+/NS; E+/S heifers were intermediate and not different from either E+/LS or DL but were greater than NE+/NS. On d 148

E+/LS heifers had the greatest HCS; E+/S and E+/LS heifers were intermediate and not different from each other but still greater than NE+/NS.

Treatment \times time effects were detected ($P < 0.01$) for respiration rate. On day 29, DL heifers had more respirations than E+/LS, but E+/S and NE+/NS females were intermediate and not different from any treatment. On day 57, E+/S and NE+/NS heifers had greater respiration rates compared to DL, but E+/LS females were intermediate and not different from any treatment. On day 113, E+/LS females had the greatest respiration rate, while the E+/S heifers were still greater than both NE+/NS and DL, which were not different from each other. Finally, on day 149, E+/S and E+/LS heifers had greater respiration rates compared to DL and NE+/NS females. A time effect was detected ($P < 0.01$) for respiration rate. Respiration rates decreased from d 29 until 85, but then sharply increased to d 113.

Treatment \times time effects were detected ($P < 0.01$) for serum prolactin. Heifers in the DL had elevated prolactin levels compared to E+/S and E+/LS at d 28, 56, 84, and 112, but E+/S and E+/LS were not different from each other at any time point. Whereas NE+/NS heifers were intermediate at d 28 and not different from DL and E+/S heifers but were greater than E+/LS females. On d 56, 84,

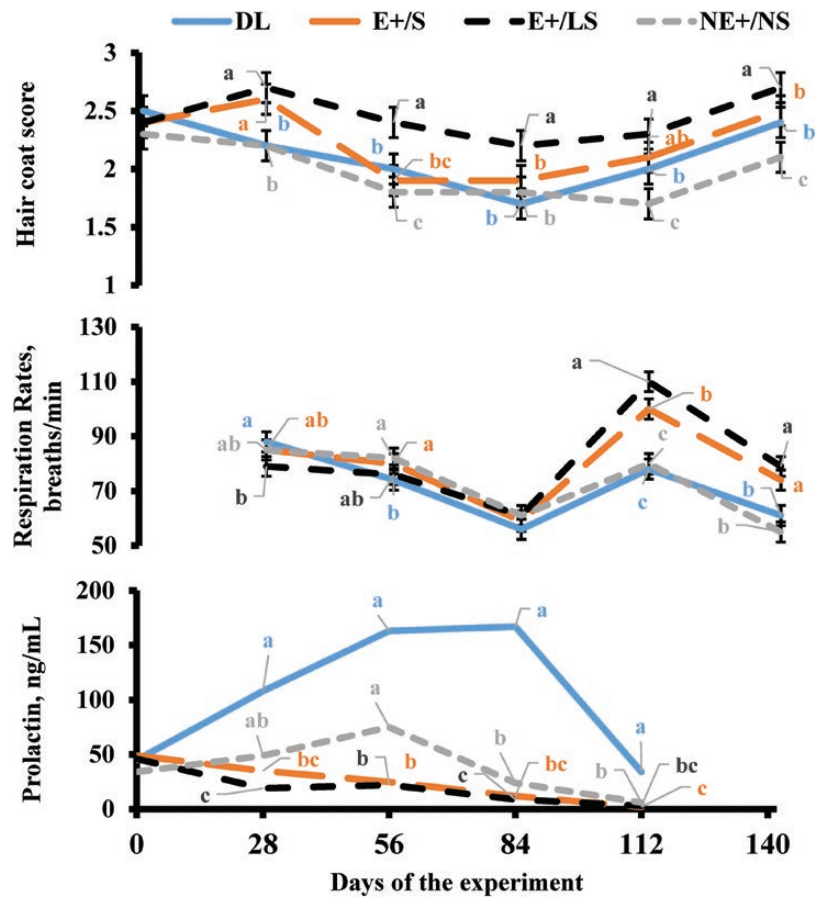


Figure 3. Effects of pre-breeding heifer development system on hair coat score (HCS; 1 to 5, in which 1 = slick and 5 = unshed), respiration rates, and prolactin concentrations. Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS). Means at the same time point with different superscripts differ ($P \leq 0.05$). Respiration rates at d 0 were significantly different, thus they were removed and included as covariate. The residuals for serum prolactin concentrations were not normally distributed, so a log transformation was performed before analysis. Least square means were back transformed for ease of interpretation. Treatment \times time, time, and treatment effects were detected ($P < 0.01$) for HCS, respiration rates, and prolactin concentration.

and 122, NE+/NS had less respirations compared to DL, but were greater than both E+/S and E+/LS on d 56, and greater than only E+/LS on d 84.

The effects of heifer development system on reproductive performance are displayed in Table 2. Treatment effects were detected ($P < 0.01$) in percent of heifers cycling prior to synchronization. Drylot heifers had the greatest (83.7%) cyclicity. Whereas E+/S females were intermediate and still greater (60.3%) than both E+/LS and NE+/NS, which were not different (32.5 and 28.2%) from each other. Treatment effects were detected ($P < 0.01$) for percentage of mature BW at AI. Drylot heifers had the greatest (66.6%), whereas, E+/S and E+/LS were intermediate and not different from each other (55.0% vs. 53.7%; respectively), but still greater than NE+/NS (49.3%). Treatment effects were detected ($P = 0.02$) for AI pregnancy rate. Drylot heifers had a greater AI pregnancy rate compared

to E+/LS and NE+/NS females and tended to be greater than E+/S females, which were not different from E+/LS and NE+/NS. Finally, treatment effects were detected ($P = 0.02$) for overall pregnancy rate. A greater percentage of DL and E+/S heifers were pregnant at the end of the first breeding season (89.3 and 85.1%; respectively) compared to NE+/NS females (61.5%). Whereas E+/LS heifers were intermediate and not different (78.0%) from any treatment.

Heifer milk production did not differ ($P \geq 0.80$; Table 3) regardless of treatment. Additionally, calf BW at birth and early-weaning did not differ ($P \geq 0.42$) for any treatment. Furthermore, cow BW and BCS at the start of the second breeding season (d 592) were not different ($P \geq 0.12$; Table 4). Finally, rebreeding AI pregnancy rate and rebreeding overall pregnancy rate did not differ ($P \geq 0.85$) regardless of treatment.

Table 2. Effect of heifer development system on reproductive performance

Item	Treatment*				SEM	P-value
	DL	E+/S	E+/LS	NE+/NS		
Cyclicity, [†] %	83.7 ^a	60.3 ^b	32.5 ^c	28.2 ^c	–	<0.01
Percent of mature BW, [‡] %	66.6 ^a	55.0 ^b	53.7 ^b	49.3 ^c	3.08	<0.01
AI pregnancy rate, %	36.9 ^a	24.5 ^{ab}	16.9 ^b	17.7 ^b	–	0.02
Overall pregnancy rate, %	89.3 ^a	85.1 ^a	78.0 ^{ab}	61.5 ^b	–	0.02

*Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS).

[†]Cyclicity was defined as when 1 plasma sample contained ≥ 2 ng/mL of progesterone or when both samples contained ≥ 1 ng/mL of progesterone. Measurements taken at d 148 and d 158 (401 and 411 \pm 20 d of age).

[‡]Percent of mature BW at breeding based on mature cow size of 567 kg.

^{a-c}Means in a row with different superscripts differ ($P \leq 0.05$).

Table 3. Effect of heifer development system on milk production and calf performance

Item	Treatment*				SEM	P-value
	DL	E+/S	E+/LS	NE+/NS		
Cow milk production, [†] kg	4.9	4.5	5.3	4.9	1.20	0.80
Calf birth BW, kg	29	28	30	29	1.3	0.42
Calf early-wean BW, [‡] kg	85	87	88	86	3.3	0.92

*Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS).

[†]24 h milk production estimated via weigh-suckle-weigh technique; 69 \pm 13.7 d postpartum

[‡]Measured at 84 \pm 13.7 d of age

Table 4. Effect of heifer development system on reproductive performance at rebreeding

Item	Treatment*				SEM	P-value
	DL	E+/S	E+/LS	NE+/NS		
Cow BW, kg	473	470	481	452	7.8	0.12
Cow BCS	4.6	4.7	5.0	4.9	0.12	0.21
AI pregnancy rate, %	64.4	57.7	54.8	53.9	–	0.59
Overall pregnancy rate, %	94.7	98.8	95.3	97.1	–	0.66

*Heifers received (for 168 d prior to AI) 1 of 4 treatments ($n = 6$ pens/treatment): drylot developed [ad-lib fed 90% hay and 10% DDGS (DL)]; grazing endophyte-infected fescue supplemented daily with a 50:50 mix of soybean hulls and DDGS (2.3 kg as-fed/heifer/d; E+/S); grazing endophyte-infected fescue and transitioned to daily supplementation from the midpoint of treatment period until breeding with a 50:50 mix of soybean hulls and DDGS (4.5 kg as-fed/heifer/d; E+/LS); grazing novel endophyte-infected fescue (NE+/NS).

DISCUSSION

There has been minimal research that has evaluated contrasting heifer development systems in Midwestern fall-calving cow-calf operations. Recommendations for developing beef heifers have changed over time and are regionally specific (Endecott et al., 2013). Previous research in spring-calving herds in the western United States indicated that heifers developed in a grazing program to a lower BW at AI can reduce input costs without impairing reproductive performance (Funston and Deutscher, 2004; Roberts

et al., 2009; Mulliniks et al., 2013; Summers et al., 2014). In contrast, Schubach et al. (2019) noted that heifers with an ADG of 0.80 kg after weaning hastened puberty attainment and date of first calving. Regionally specific and conflicting previous research led to this experiment, which was designed to evaluate post-weaning developmental systems on growth and reproductive performance of heifers.

Pasture ADF and NDF was lower and CP was higher in the present study than that of prior recent studies conducted at Dixon Springs Agricultural

Center in Simpson, IL (Shoup et al., 2016; Stokes et al., 2018; Volk et al., 2019). However, Stokes et al. (2018) noted that forage quality rapidly increased in the late fall which is similar to the present study. Furthermore, the NE+/NS pastures were higher quality than that of the E+/S and E+/LS treatments. The E+/S and E+/LS pastures consisted of a long-established “Kentucky-31” cultivar at the Dixon Springs Agricultural Center (Simpson, IL). The NE+ pastures were established in the fall of 2011 using “Jesup MaxQ” tall fescue (Pennington Seed, Inc., Madison, GA). The study by Shoup et al. (2016) also noted that NE+ pastures were lower in ADF and NDF and greater in CP compared to E+ pastures, which were similar to the pastures used in this trial. Lippke et al. (2000) deduced that 850 kg dm/ha was the minimum threshold of forage mass to support steers grazing lush spring pastures. All heifers in this study were in pastures with a forage availability of greater than 1,500 kg dm/ha. Additionally, pasture forage availability was similar to that of studies by Shoup et al. (2016) and Stokes et al. (2018) and they noted that forage availability was not limiting at similar stocking densities. The difference in forage availability between the NE+/NS and the E+ pastures (E+/S and E+/LS) may be explained by the supplementation provided to E+/S and E+/LS treatments. Krysl and Hess (1993) noted that protein supplementation affected time spent grazing: unsupplemented cattle grazed approximately 1.5 h/d more than did supplemented cattle. Additionally, DDGS supplementation to grazing cattle has been reported to replace forage at 0.27 to 0.79 kg/kg of DDGS supplemented (Griffin et al., 2009). Another explanation is that heifers grazing E+ pastures were experiencing fescue toxicosis which was limiting dry matter intake (Osborn et al., 1992). Intake was not measured in the current experiment or in previous grazing studies, so the authors can only speculate that intake may have been affected. Ultimately, NE+/NS heifers likely grazed more and kept their pastures in the early vegetative state, which is likely the reason that ADF and NDF are lower and CP is greater for those pastures.

Ergot alkaloid concentrations in the E+/S and E+/LS pastures were the lowest in the summer and the greatest in the fall (2017: September: 2,610 µg/L; 2018: June: 620 µg/L; July 670 µg/L; September: 1,812 µg/L; October: 1,715 µg/L). These results are similar to those of Volk et al. (2019) and Stokes et al. (2018) at the same station where ergot alkaloid concentrations increased 488 % from July to September. On the other hand, the NE+/NS

pastures had minor ergot alkaloid concentrations (2017: September: 0 µg/L; 2018: June: 0 µg/L; July 215 µg/L; September: 367 µg/L; October: 256 µg/L). These values are similar to those found by Shoup et al. (2016) on similar pastures at the same station.

Utilizing supplementation as a strategy to alleviate fescue toxicosis has been successful at improving ADG, prolactin level, and hair coat score (Aiken et al., 2008; Carter et al., 2010). Volk et al. (2019) and Stokes et al. (2018) demonstrated that developing heifers on E+ pastures with supplementation (2.7 kg as-fed/heifer/d; 50:50 mix of corn gluten feed and soybean hulls) can achieve 59 and 54% (respectively) of their mature BW at the start of the breeding season. Limiting gain for a period followed by a period of increased dietary intake can take advantage of compensatory gain resulting in reduced labor with similar reproductive performance when heifers are grazing winter range (Clanton et al., 1983; Lalman et al., 1993; Marston et al., 1995; Freetly et al., 2001; Cicciooli et al., 2005; Grings et al., 2007). However, no work has been done evaluating this strategy when fall-born beef heifers are grazing E+ pastures. The E+/S and E+/LS heifers were expected to reach 55% of their mature BW. In the study by Stokes et al. (2018) at the same station, heifers reached similar pre-breeding BW when they grazed E+ pastures and were supplemented with 2.7 kg/d of DDGS. The E+/LS heifers had a low ADG (0.38 kg) until d 84 followed by an improved ADG (0.51 kg) until breeding. Authors expected this change in ADG because the heifers were only supplemented from d 80 through AI. Heifers were likely benefiting from compensatory gain. Delaying gain to take advantage of compensatory gain is more economical than constant gain throughout the developmental period (Clanton et al., 1983; Lalman et al., 1993). Heifers can offset minimal post-weaning ADG through compensatory gain (Marston et al., 1995; Cicciooli et al., 2005).

Utilizing NE+ varieties in stocker cattle has been successful at improving BW (Parish et al., 2003). Drewnoski et al. (2009) demonstrated replacement heifers grazing NE+ during spring growth had increased ADG and reduced prolactin compared to heifers grazing E+. However, no work has been done to investigate allowing heifers to graze NE+ with no supplementation in a fall-calving production model. Authors had also hypothesized that NE+/NS heifers would have ADG similar to that of the E+/S heifers but, this was not observed. Johnson et al. (2012) compared growth parameters of steers grazing NE+ (Jesup-MaxQ) or KY31 E+ pastures. Results indicated

that steer ADG on MaxQ were superior to those on KY31 E+ pastures (0.84 kg/d vs. 0.63 kg/d; respectively). The fact that NE+/NS had an ADG of only 0.30 kg/d and consequently only reached 49.3% of their mature BW prior to the start of the breeding season was not expected and is difficult to explain. Heifers did not exhibit signs of fescue toxicosis and pasture forage quality would be labeled as high quality.

One common sign of fescue toxicosis is increased HCS which may be the explanation for why the E+/S and E+/LS heifers had greater HCS. In previous research, steers grazing E+ had greater HCS compared with steers grazing a NE+ (Saker et al., 2001). Increased RR in cattle grazing E+ is associated with vasoconstriction caused by ergot alkaloids (Finch, 1986). The RR for E+/S and E+/LS heifers in this experiment were consistent with other experiments utilizing heifers at this research station (Stokes et al., 2018). Furthermore, the very small standard error (3.1 breaths/min) for RR likely contribute to differences in RR for d 28 and 56 being significant, but this small difference may not be biologically relevant. However, the dramatic increase in RR on day 112 and 149 for E+/S and E+/LS heifers aligns with the greatest ergot alkaloid concentration and can be attributed to heifers grazing E+.

Prolactin concentrations are typically decreased in cattle grazing E+ (Aiken et al., 2013). Serum prolactin concentrations were not different between E+/S and E+/LS treatments. From early summer to late fall, prolactin concentrations decreased and were very low at d 112. These results are similar to Shoup et al. (2016) and Volk et al. (2019), indicating that E+/S and E+/LS heifers were experiencing fescue toxicity. Additionally, Shoup et al. (2016) noted that cows grazing E+ had reduced prolactin concentrations in July and October compared with cows grazing NE+. These results are consistent with the current experiment. Prolactin is the most responsive to changes in seasons, ambient temperature and photoperiod and is greatest in summer when ambient temperatures are highest and photoperiods are longest (Tucker 1982). Drylot heifers being housed with shade is likely the reason for serum prolactin concentrations >100 ng/mL during the summer months followed by a drop in the fall.

The differences in BW between treatments are not surprising as intake and ADG were not controlled for the grazing treatments. The DL heifers were developed to 66.6% of their mature BW and had an ADG of 0.90 kg which was slightly greater than the target of 65% of their mature BW. These

gains are similar to the high gain heifers in the study by Schubach et al. (2019). Additionally, DL heifers lost BW from d 168 to d 196, which was expected. Heifers developed in a drylot and subsequently turned out to pasture exhibited reduced ADG (Perry et al., 2013) during the first 27 d and increased activity level (Perry et al., 2015) during the first 3 d compared to their range developed counterparts. Nutrient restriction following AI negatively impacted embryo development (Kruse et al., 2017), resulted in poorer quality embryos (Kruse et al., 2017) and a subsequent reduction in AI pregnancy rates (Perry et al., 2013). Plane of nutrition before and after the breeding season has been indicated as an imperative time point for reproductive success (Mulliniks et al., 2013; Summers et al., 2014). In the present study, heifers housed in the DL, who were transitioned abruptly to pasture at time of AI, still managed to have a greater AI pregnancy rate compared to heifers that were not transitioned to a new diet.

Heifers in DL had the greatest cyclicity (83.7%) prior to the initiation of the synchronization protocol followed by the E+/S at 60.3%. Similar values were noted by Funston and Larson (2011) when they compared developing heifers in drylot vs. grazing setting (88 and 46%; respectively). Additionally, Schubach et al. (2019) who compared low, medium, and high ADG pre-breeding noted a similar response in percent heifers pubertal (56 %, 63 %, and 88 %; respectively) by breeding. Authors did not expect E+/LS and NE+/NS heifers to have so low cyclicity (32.5 and 28.2%; respectively). Delaying gain did not result in similar percent of heifers cycling. Heifers with BCS ≥ 5 had improved pregnancy rates relative to heifers assigned with a BCS of 4 or less (Rae et al., 1993). Furthermore, there was 14% difference in pregnancy rates to AI favoring heifers assigned with a BCS = 6 relative to those assigned with a BCS = 5 (Dickinson et al., 2019). At the AI in the present study, NE+/NS heifers had a mean BCS of 4.7, E+/S and E+/LS heifers had a mean BCS of 5.4, and the DL heifers had a mean BCS of 6.2. In light of the reduced BW gains and BCS achieved by the NE+/NS heifers it is reasonable to state that they were likely underdeveloped and as result had not reached puberty by the initiation of the synchronization protocol. Additionally, DL heifers had greater AI pregnancy rates compared to both E+/LS and NE+/NS heifers. Improved AI pregnancy rates for drylot developed heifers has been noted in the literature (Funston and Larson, 2011). The lack of AI pregnancy rates differences between the DL and E+/S

could be associated with the implementation of estrus synchronization protocol (Larson et al., 2006).

Authors acknowledge that in the current study AI pregnancy rates were low for all treatments. Pregnancy rates at AI have been inconsistent in studies conducted at Dixon Springs Agricultural Center, Simpson, IL. Volk et al (2019) observed AI pregnancy rates of 63.5%. However, Buskirk et al. (1995) and Stokes et al. (2018) observed low first service/AI pregnancy rates (15.1 and 33.5%; respectively). Both authors attributed the low AI pregnancy rates to heifers needing to reach a greater targeted percent of mature BW for optimal reproductive success. Another explanation could be that comingling of heifers and change of management at time of AI could have led to a decreased AI pregnancy rate. Plane of nutrition and management before and during the breeding season impacts reproductive success (Mulliniks et al., 2013; Summers et al., 2014; Kruse et al., 2017). However, the diet of the E+/S and E+/LS heifers remained very similar following AI and AI pregnancy rates remained low (25% and 17%; respectively). Despite the extremely poor AI pregnancy rates, DL, E+/S and E+/LS heifers had very acceptable overall pregnancy rates for the 85 d breeding season. In contrast, the NE+/NS heifers only achieved a 61.5% overall pregnancy rate which was 27 percentage units less than the DL heifers. Although the E+/LS and NE+/NS heifer were not statistically different, E+/LS heifers had a 16.5 percentage unit numerical advantage. Poor reproductive performance by the NE+/NS heifers was not expected. Watson et al. (2004) compared grazing cows on NE+ vs. E+ and noted no difference in overall pregnancy rates. Excluding the NE+/NS heifers, overall pregnancy of the other three treatments (84%) were similar if not greater than in previous experiments at this station and elsewhere (Lalman et al., 1993; Buskirk et al., 1995; Marston et al., 1995; Cicciooli et al., 2005; Funston and Larson, 2011; Stokes et al., 2018; Volk et al., 2019).

Endecott et al. (2013) made the recommendation based on previous studies (Funston and Deutscher, 2004; Roberts et al., 2009; Funston and Larson, 2011; Mulliniks et al., 2013) that developing heifers to 50 to 57% of mature BW at breeding compared with 60 to 65% of mature BW can result in similar reproductive performance. These studies all started the breeding season at approximately 450 d of age to target a calving date of 2 yr of age. In contrast, Schubach et al. (2019) noted improved reproductive performance for heifers that have

reached >60% of their mature BW. In the study by Schubach et al. (2019) and the current study, the breeding season began at 420 d of age, which is to target calving at 23 months of age (1 month prior to mature cows). It is common practice for producers to calve their heifers before the mature cows so they have a longer rebreeding period and can manage calving season labor (Funston and Deutscher, 2004). If a producer wants to calve their heifers prior to their cows they may want to consider an increased rate of gain to mitigate the effects of age on reproduction.

There were no differences in calf birth BW or milk production between the treatments. This is similar to the study by Schubach et al. (2019) who compared low, medium, and high ADG pre-breeding. In contrast, Buskirk et al. (1995) reported milk production was improved for heifers with 0.62 kg ADG compared to heifers with 0.43 kg ADG. As a result, there were no differences in calf early-wean BW which is similar to other heifer development studies (Funston and Larson, 2011; Schubach et al., 2019).

In summary, DL heifers had the greatest BW and BCS at AI as well as percentage of heifers cycling, and this resulted in an increase in AI pregnancy rate. Body weight and BCS of E+/LS heifer did not catch up to E+/S heifers by AI. Likely E+/LS heifers experienced greater fescue toxicosis and were never able to compensate for that. This resulted in a lower percentage of heifers that were cycling compared to E+/S and DL and lower AI pregnancy rates compared to DL. However, these vastly different developmental strategies did not result in differing overall pregnancy rates between DL, E+/S, and E+/LS and there were no differences in cow milk production, rebreeding reproductive performance, and calf performance between all treatments. Finally, NE+/NS were likely in pastures with less forage availability during the summer with out supplementation which led to lower BW, BCS, and percentage of heifers cycling at AI. This translated into the poorest AI pregnancy rate and overall pregnancy rates. This suggests NE+/NS is not a viable strategy for developing fall-born replacement beef heifers.

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Conflict of interest statement. None declared.

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