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Research Article

Exposure to Toxic Fescue during Late Gestation on Beef Cows: Effects on Cow Performance and Offspring Performance from Birth to Weaning

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Abstract

To examine the effects of endophyte-infected tall fescue during late gestation on maternal and offspring performance, multiparous Angus cows (n = 40) were bred via AI and allocated into grazing treatments: toxic (E+) or nontoxic (E-) endophyte tall fescue. Cows body weight (BW), body temperature, body condition score (BCS), and respiration rate were recorded and blood samples collected on 180, 210 and 240 days of gestation. Calf's BW were recorded at birth and weaning. Cow/calf pairs were managed as one group on nontoxic pasture from calving until weaning (180 days of age). Body weight decreased ($P = 0.022$) and body temperature increased ($P < 0.0001$) at day 240 in E+ compared to E- cows. BCS did not differ ($P = 0.891$) between treatments. Respiratory frequency increased ($P = 0.003$) in E+ compared to E- cows. Ergovaline concentration of urine increased ($P = 0.003$) at day 210 and 240 in E+ compared to E- cows. Prolactin concentrations decreased ($P < 0.0001$) at day 210 in E+ compared to E- cows. Birth and weaning weight decreased ($P < 0.05$) in calves from E+ cows compared to E- cows. Overall, grazing endophyte-infected tall fescue reduced maternal and subsequent offspring BW.

Keywords: *Beef Cattle; Calf Development; Tall Fescue; Endophyte; Fescue Toxicity*

Introduction

Tall fescue *(Lolium arundinaceum)* is the most widely grown perennial grass in Argentina, with 3.5 million hectares (30% total cultivated pasture area), predominantly in the Humid and Sub-humid Pampas [1]. It is also a major forage species in the Southeastern United States, covering approximately 14 million hectares of [2]. A majority of tall fescue contains the endophyte *Neotyphodium coenophialum,* which produces ergot alkaloids (ergovaline, ergovalinine, etc). Ingestion of toxic endophyte-infected tall fescue by grazing livestock results in a condition known as fescue toxicosis, which has been known to reduce animal growth and weight gain [3,4], conception rate [5,6], milk production [7] and blood components [8,9].

To reduce the effects of ergot alkaloids on reproductive performance, fescue pastures are traditionally grazing during autumn and winter. This period of time often corresponds to the second half of gestation in cattle. Little is known about how ergot alkaloids impacts bovine fetal growth. It has been observed that ergovaline induces constriction of blood vessels pertinent to fetal growth and development

[10-14]. Other factors potentially attributed to reduced fetal growth include decreased volatile fatty acid (VFA) absorption due to increased ruminal ergot alkaloid concentrations [15] which have the potential to decrease metabolic rate, and overall, reduce feed intake and weight gain [16].

Objective of the Study

The objective of this study was to determine the effect of grazing toxic endophyte-infected tall fescue during late gestation on maternal performance and pre-weaning performance of subsequent offspring.

Materials and Methods

Ethical consideration

The institutional Animal Care and Use Committee of INTA-CERBAS approved all animal procedures used in this study (Approval No 107). The experiment was conducted and maintained in Cuenca del Salado Experimental Station (Buenos Aires, Argentina).

Animals

One hundred twenty two (122) Angus multiparous cows were synchronized using a controlled internal drug-realizing device (Cronipres®, Biogénesis-Bago, Argentina) for 7 days, and upon removal of the device, 500 µg of cloprostenol (Ciclase DL®, Syntex, Argentina) and 1 mg of estradiol benzoate (Benzoato de Estradiol Syntex®, Argentina) were administrated intramuscularly. Artificial insemination (AI) was performed 48 hours later using semen from a single Angus sire. At 30 days post AI, 40 pregnant cows were identified pregnant to AI via transrectal ultrasonography and selected for the study.

Experimental design

Cows were managed on a common pasture during early to mid-gestation. At 180 days of gestation, cows were blocked by parity and body weight (BW) and randomly allocated into one of two grazing treatments: toxic endophyte tall fescue (`Kentucky-31´; E+) or nontoxic endophyte tall fescue (`BarOptima´; E-). Cows (*n* = 20 per treatment) remained on grazing treatments until calving. The E+ pastures consisted of a long-established ‘Kentucky-31’ cultivar. The E- pasture was stablished in March of 2013 using a nontoxic `BarOptima´ tall fescue. Both pastures were closed (no grazing) from October 1, 2013 to May 7, 2014 when the trial was initiated.

Forage quantification

Forage availability was quantified in both pastures and surfaces assigned to both treatments were adjusted to provide similar DM forage availability between treatments. Pasture composition and analysis are depicted in table 1. Pastures were sampled at 3 different locations within each pasture using a 0.093m square every 16 days, and forage was cut at ground level using shears. The samples were frozen at -20°C until sent for analysis. Forage samples chemically analyzed for dry matter, organic matter, and crude protein using procedures by the Association of Official Analytical Chemists [17] and dry matter digestibility and neutral detergent fiber were determined using the methods outlined by Van Soest [18].

Treatment	Day[1]	DM[2]	Organic matter, %DM	DM digestibility, %DM	Crude protein, %DM	NDF[3], %DM
E+	0	38.2	89.6	61	11	59.4
	16	38	92.3	56.6	10.5	63.9
	32	38.9	91.7	61.8	12.4	52.7
	48	45.2	91.7	46	7	70.3
	64	39.4	89.3	54.7	9.4	61.7
	80	31.1	89.8	62.5	11.6	56.3
E-	0	29.1	89.3	66.4	22.4	51.6
	16	27.2	89.5	68	22.9	52.3
	32	35.6	88.5	58.8	16.7	55.2
	48	30	89.2	63.7	17.1	53.7
	64	35.2	88.5	54.4	13.8	61.7
	80	34.1	90.5	64.8	17.7	53.6

Table 1: *Chemical composition of forage consumed by cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation until parturition.*

[1]: Day relative to start of experiment.

[2]: Dry matter (DM). [3]: Neutral detergent fiber (NDF).

Maternal measurements

Cows BW, body condition score (BCS), body temperature, respiration rate, and cotyledon diameter were recorded at 180, 210 and 240 days of gestation. Cotyledon diameter was measured in five cotyledons per cow using transrectal ultrasonography (Aquila pro, Esaote Europe B.V. Maastricht, NL; 6 MHz probe). Cotyledon diameter was measured by averaging diameters of both the widest and narrowest portion of each cotyledon. All cows were allowed to calve naturally, and after calving, calves and their dams were managed as one group endophyte free pasture until weaning of calves at ~180 days of age.

Body weights and BCS of cows were recorded at calving (less than 12h after calving) and at weaning. Bull calves were castrated at 5 month of age. Calf BW was recorded at birth and at weaning. Adjusted 205-day weaning weight was computed using Beef Improvement Federation guidelines without the age of dam or sex of calf adjustments [19]. Calves removed or lost from the E-treatment group of the study consisted of one stillborn calf, one dam (death post parturition), and four cows did not calve in designated time interval (± 10 days from expected parturition to AI date). Data from these associated calves were removed from statistical analysis. Final number of calves after statistical removal were: E- (n = 14) and E+ (n = 20).

Milk sample collection

Milk production was assessed with a portable milking machine equipped with a milk meter in line (TrueTest, Auckland, New Zealand) at day 30, 60, 120 and 200 ± 10 of lactation on the same 4 E- and 6 E+ chosen at random. At ~12:00 p.m. cows were separated from calves and each cow was injected intramuscularly with 10 IU of oxytocin (Over®, Argentina) to facilitate milk letdown. Cows were milked 5 min after injection and calves were fitted with strong nose plates and remained with their dams in the same paddock. The following day, at ~06:00 a.m., cows were milked again with the same protocol [20]. Homogenized milk samples were collected from each cow at each milking to determine milk protein, fat, lactose, total solid (IDF 141C:2000 Bentley Instruments, Chaska, MN, USA) and urea (Chemspec 150, Bentley Instruments, Chaska, MN, USA) in Dairy Laboratory LABVIMA, Buenos Aires, Argentina.

Blood collection and assay

Cow blood samples were collected at 180, 210 and 240 days of gestation using a 12 ml syringe via the jugular vein. For prolactin analysis, blood was stored in a 7.5 ml glass tube and allowed to clot at room temperature before being centrifuged at 1,500 rpm for 15 minutes. Serum was stored at -20°C for subsequent analysis. Cow serum was analyzed for prolactin via a double anti-body RIA [21]. Intra-assay and interassay CV was 8.4% and 7.8% respectively. For hematologic analysis, blood samples were stored in room temperature (approximately 20°C) and analyzed within 8 hours after blood collection. Hematologic parameters were measured using the Mindray™ BC5150 hematology analyzer (Mindray Medical International Limited, Mahwah, NJ, USA). Blood smears were stained using May-Grünwald Giemsa (microscopy 100X).

Presuckled glucose blood concentrations were determined in calves at birth. Glucose concentration was determined in whole blood with a hand-held electronic glucometer (Abbott©, UK) immediately after blood samples were taken [22].

Urine collection and assay

Cow urine samples were collected at 180, 210 and 240 days of gestation. Approximately 25 ml of urine was collected in sterile plastic containers and immediately refrigerated for further analysis. Urination was induced through massages in the comb region. Urinary alkaloid and creatinine concentrations were determined using commercially available kits (Phytoscreen urine alkaloid kit, Agrinostics, Inc., Watkinsville, GA) following the manufacturer's instructions [23].

Placental collection

Immediately after calving, five whole placentas from E- cows and four whole placentas from E+ cows were collected. Placentas were weighed and all cotyledons were counted.

Offspring measurements

Less than 12 hours postpartum, calf sex, birth weight, and the following measurements on the calf were recorded: head circumference (measurement collected around parietal bone and mandible just posterior to eye orbits), body length (linear distance along the vertebral column from the occipital bone to the first coccygeal vertebra), abdominal girth (circumference around the abdominal cavity at the umbilicus), hip height (linear distance from the trochanter major of the femur to the floor), femur length (linear distance from the head of the femur to the stifle), heart girth (posterior to foreleg), and cannon bone circumference (narrowest point of metacarpus). All body measurements were collected when the animal was standing naturally; head raised and weight on all four feet. Head measurements were collected while the animal was restrained. Body mass index (BMI) of newborn calves was calculated by dividing the birth weight of each calf by the square of body length.

Statistical analyses

Cow/calf was considered the experimental unit. Maternal prolactin and ergovaline on each day of collection, maternal BW and BCS at calving and weaning were analyzed as an ANOVA using the GLM procedure of SAS (SAS Institute Inc., Cary, NC, USA) with treatment as a fixed effect in the model statement. Gestation length, calf BW at parturition and morphometrics were analyzed as an ANOVA using the MIXED procedure of SAS with treatment as a fixed effect and calf sex as a random effect in the model. Maternal BW, BCS body temperature, respiration rates, cotyledonary diameter and blood measurements and serum prolactin concentrations during gestation along with maternal milk yield and composition were analyzed as a repeated measure analysis using the MIXED procedure of SAS with treatment, day, and their interaction in the model statement as fixed effects. The covariance structure selected based on the fit of statistical parameters in the model was autoregressive. Mean separation was determined using LSMEANS with PDIFF in SAS following a significant ($P \leq 0.10$) preliminary F-test. Data are presented as least squares means ± standard error of the mean and considered significantly different when $P \leq 0.05$, and a tendency was indicated when statistical probability was between $P = 0.051$ and $P \leq 0.10$.

Results

Maternal measurements

Maternal BW and BCS results during gestation are depicted in table 2. Cow BW exhibited a treatment by day interaction ($P = 0.030$) where E+ cows were decreased ($P = 0.022$) at day 240 compared to E- cows. Cow BCS decreased ($P = 0.029$) as gestational day increased but was not different ($P = 0.891$) between treatments. Body temperature exhibited a treatment by day interaction ($P = 0.013$) where E+ cows temperature was greater ($P < 0.0001$) at day 240 compared to E- cows. Respiratory frequency was increased ($P = 0.003$) in E+ cows compared to E- cows. Cotyledon diameter measured by ultrasound increased ($P < 0.0001$) as gestational day increased but was not different ($P = 0.627$) between treatments.

Gestation length was decreased ($P = 0.038$) in E+ cows (273.54 ± 1.1 days) compared to E- cows (277.35 ± 1.3 days). Maternal body condition at calving was not different ($P = 0.731$) between treatments and averaged 2.79 ± 0.54 BCS. Maternal BW at calving was not different ($P = 0.324$) between treatments and averaged 442.57 ± 13.56 kg. Maternal body condition at weaning was not different ($P = 0.983$) between treatments and averaged 2.57 ± 0.13 BCS. Maternal BW at weaning was not different ($P = 0.250$) between treatments and averaged 443.75 ± 13.08 kg.

	Treatment									
	E-			E+				P-value		
Item	180	210	240	180	210	240	SEM	Trt	Day	Trt x Day
Cow, n	20	20	20	20	20	20	-	-	-	-
Body weight, kg	511.64	532.57	550.43[a]	510.94	505.80	502.75[b]	18.34	0.1808	0.2194	0.0304
Body condition scores[1], 1 - 5	3.04	3.26	3.09	3.17	3.17	2.99	0.08	0.8906	0.0287	0.2904
Body temperature, °C	37.67	-	38.51[a]	37.79	-	39.22[b]	0.11	0.0006	<.0001	0.0129
Respiratory frequency, beats/min	43.71	37.43	32.86	46.04	46.20	45.40	1.72	0.0027	0.1150	0.1718
Cotyledon diameter, mm	312.57	365.50	387.43	300.19	377.15	393.15	6.71	0.6270	<.0001	0.3512

Table 2: *Body weight, body condition scores, body temperature, and respiratory frequency of multiparous cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation. Data presented LSM ± SEM. [a,b]: Means differ by P value reported for that item.*

[1]: Body condition scoring system based on the findings of Wagner., et al. 1988.

Milk analysis

Milk analysis results of samples from lactating cows are depicted in table 3. Milk yield increased (P = 0.003) day 60 of lactation but was not different (P = 0.291) between treatments. Percent fat was not different (P = 0.371) between treatments. Percent protein increased (P < 0.0001) at day 60 of lactation but was not different (P = 0.709) between treatments. Percent lactose increased (P = 0.038) at day 60 of lactation but was not different (P = 0.419) between treatments. Total solids were not different (P > 0.100) between treatments or day of lactation. Milk urea nitrogen increased (P < 0.0001) at day 60 of lactation but was not different (P = 0.674) between treatments. For all milk variables, there was a non-significant treatment by day interaction (P > 0.46).

	Treatment										
	E-				E+				P-value		
Item	30	60	120	200	30	60	120	200	SEM	Trt	Day
Cow, n	4	4	4	4	6	6	6	6	-		
Milk yield, kg/d	4.57	7.22	4.55	4.37	5.80	8.28	5.36	5.10	0.88	0.2908	0.0003
Fat, %	2.6	2.94	2.99	3.47	2.29	3.13	2.54	2.71	0.39	0.3711	0.1881
Protein, %	3.00	3.42	3.47	3.30	2.90	3.44	3.43	3.26	0.09	0.7091	<.0001
Lactose, %	4.75	4.97	4.76	4.45	4.58	4.63	4.78	4.35	0.17	0.4193	0.0378
Total solids, %	11.79	11.94	12.01	12.23	10.59	12.01	11.49	11.41	0.52	0.2560	0.2894
MUN[1], %	10.83	10.30	12.29	10.16	10.71	10.34	12.53	10.48	0.37	0.6737	<.0001

Table 3: *Milk analysis during lactation of multiparous cows that grazed either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation. Data presented LSM ± SEM. [a,b]: means differ by P value reported for that item.*

[1]: Milk urea nitrogen (MUN).

Blood analysis

Prolactin concentrations exhibited a treatment by day interaction (P < 0.0001) where prolactin of E+ cows was decreased (P < 0.0001) at day 210 and tended to increase (P = 0.0873) at day 240 compared to E- cows (Figure 1).

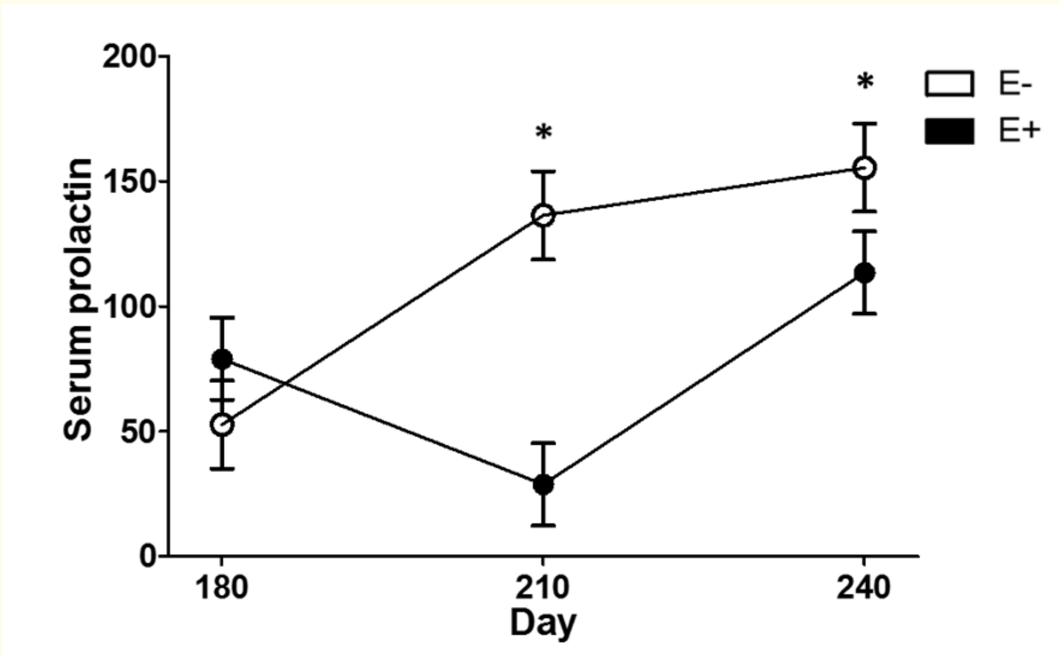

Figure 1: *Serum prolactin concentrations (ng/ml) of multiparous cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation. An asterisk (*) signifies a significant difference at P ≤ 0.05.*

Hematologic results of blood samples from gestating cows are depicted in table 4. Leucocytes exhibited a treatment by day interaction (P = 0.011) where E+ cows were increased (P = 0.021) at day 240 compared to E- cows. Erythrocytes exhibited a treatment by day interaction (P = 0.019) where E- cows decreased (P < 0.0001) from day 180 to 210, followed by an increase (P = 0.014) from day 210 to 240 of gestation. Similarly, erythrocytes of E+ cows decreased (P = 0.005) from day 180 to 210, however, tended to increase (P = 0.096) from day 210 to 240 of gestation. Hemoglobin and hematocrit was decreased (P < 0.0001) as gestational day increased, but were not different (P > 0.050) between treatments. Volume corpuscular mean (VCM) tended to exhibit a treatment by day interaction (P = 0.061) where E+ cows were increased (P = 0.090) at day 240 compared to E- cows. Hemoglobin corpuscular mean (HCM) exhibited a treatment x day interaction (P = 0.020) where E+ cows were increased (P = 0.049) at day 240 compared to E- cows. Mean corpuscular hemoglobin concentration (MCHC) and platelet count were not different (P > 0.100) between treatments or gestational day.

Glucose concentrations of pre-suckled calves was decreased (P = 0.0003) in calves from E+ cows (90.29 ± 4.27 mmol/L) compared to calves from E- cows (117.23 ± 5.06 mmol/L).

	Treatment									
	E-			E+			P-value			
Item	180	210	240	180	210	240	SEM	Trt	Day	Trt x Day
Cow, n	20	20	20	20	20	20	-	-	-	-
Leucocytes, mm[3]	8268.36	7922.87	7708.76[a]	8257.90	7529.25	8984.69[b]	362.12	0.4805	0.0346	0.0112
Erythrocytes, mil/mm[3]	6.67	6.06	6.37	6.74	6.34	6.08	0.15	0.9125	<.0001	0.0193
Hemoglobin, g/dL	11.30	10.31	10.52	11.38	10.72	10.46	0.24	0.6336	<.0001	0.2750
Hematocrit, %	34.34	31.28	32.16	34.74	32.66	31.81	0.71	0.5770	<.0001	0.1527
VCM[1], fl	51.45	51.40	50.66	51.70	51.56	52.30	0.66	0.4258	0.9433	0.0610
HCM[2], pg	16.92	16.97	16.49[a]	16.86	16.94	17.15[b]	0.23	0.5058	0.5621	0.0199
MCHC[3], g/L	32.82	32.92	32.74	32.77	32.70	32.75	0.13	0.4436	0.8630	0.6266
Platelets, mm[3]	265330	265306	216841	276649	218601	201246	28923	0.4949	0.1210	0.5656

Table 4: *Blood analysis of multiparous cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation.*
Data presented LSM ± SEM. [a,b]: means differ by P value reported for that item.
[1]: Volume corpuscular mean (VCM).
[2]: Hemoglobin corpuscular mean (HCM).
[3]: Mean corpuscular hemoglobin concentration (MCHC).

Urine analysis

Ergovaline concentration was increased at day 210 (P = 0.017) and day 240 (P = 0.002) in E+ cows compared to E- cows (Figure 2).

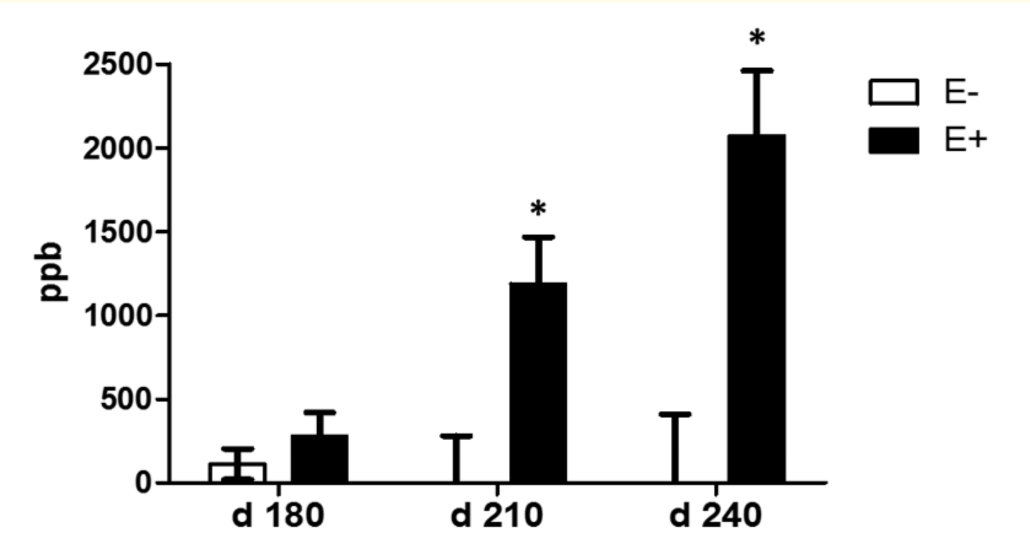

Figure 2: *Urine Ergovaline concentrations of multiparous cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) during gestation. An asterisk (*) signifies a significant difference at P ≤ 0.05.*

Placental measurements

Placental weight was not different (P = 0.247) between treatments and averaged 4.06 ± 0.53 kg in E- cows and 3.23 ± 0.74 kg in E+ cows. Placental efficiency tended to be increased (P = 0.094) in E+ cows (14.61 ± 2.42) compared to E- cows (9.05 ± 1.35).

Offspring measurements

Morphometric measurements of subsequent offspring at birth are depicted in table 5. Birth weight was decreased (P = 0.021) in calves from E+ compared to E- cows. Birth weight of male offspring was increased (P = 0.039) compared to female offspring. Body length, abdominal girth, hip height, and femur length were not different (P > 0.050) between treatments or sex. Body mass index was decreased (P = 0.044) in calves from E+ compared to E- cows, additionally, female offspring were leaner (P = 0.020) than male offspring. Weaning weight was decreased (P = 0.055) in calves from E+ compared to E- cows, but not different (P = 0.482) between calf sex was observed.

	Treatment					
	E-		E+		P-value	
Item	Male	Female	Male	Female	Trt	Sex
Calf, n	8	6	8	12	-	-
Birth weight, kg	35.6 ± 1.3	34.0 ± 1.0	33.6 ± 1.3	29.8 ± 1.0	0.0205	0.0387
Head circumference, cm	48.9 ± 0.6	47.3 ± 0.7	48.9 ± 0.6	47.6 ± 0.5	0.7340	0.0150
Body length, cm	72.0 ± 2.0	72.0 ± 2.3	74.5 ± 2.0	70.9 ± 1.6	0.7225	0.3717
Abdominal girth, cm	73.3 ± 1.8	73.3 ± 2.1	75.1 ± 1.8	71.4 ± 1.5	0.9688	0.3212
Hip height, cm	64.8 ± 1.0	65.2 ±1.2	65.1 ± 1.0	62.9 ± 0.8	0.3714	0.3927
Femur length, cm	21.1 ± 0.6	20.5 ± 0.7	21.1 ± 0.6	21.1 ± 0.5	0.6552	0.6047
Heart girth, cm	75.6 ± 1.6	77.7 ±1.8	72.3 ± 1.6	73.2 ± 1.3	0.0246	0.4187
Cannon bone circumference, cm	12.5 ± 0.3	12.4 ± 0.4	12.4 ± 0.3	11.4 ± 0.3	0.0878	0.0770
BMI[1], kg/cm^2	0.49 ± 0.01	0.46 ± 0.02	0.47 ± 0.01	0.43 ± 0.01	0.0441	0.0200
Weaning weight, kg	218.7 ± 13.5	217.2± 14.8	200.63 ± 11.7	183.9 ± 10.5	0.0549	0.4820

Table 5: *Morphometric measurements of calves born to multiparous cows grazing either a toxic endophyte tall fescue (E+) or nontoxic endophyte tall fescue (E-) at birth.*
Data presented LSM ± SEM. [a,b]: Means differ by P value reported for that item.
[1]: Body mass index (BMI) calculated by birth BW (kg) / body length (cm)^2.
[2]: Adjusted 205-day weaning weight was computed using Beef Improvement Federation guidelines without the age of dam or sex of calf adjustments.

Discussion

Maternal conditions

In the current study, maternal BW was decreased, in cows grazing toxic endophyte-infected tall fescue compared to cows grazing non-toxic tall fescue by late gestation. However, even though maternal BCW decreased as gestation progressed, there was no effect of grazing treatment. Additionally, body temperature and respiratory frequency were increased in cows grazing toxic endophyte-infected tall fescue.

Similar results were observed in beef cows grazing endophyte-infected tall fescue observed decreased BCS (3.8 ± 0.15), increased body temperature (39.6 ± 0.12°C) and increased respiratory frequency (52.0 ± 1.4 breathes/minute) [5].

Traditionally, as gestation progresses, the size of the placentome increases [24], which is supported by the data in the current study in which cotyledon diameter as measured by ultrasound increased as gestation progressed. However, limited research has been performed on cotyledon growth during fescue supplementation and in the current study, cotyledon diameter was not impacted by treatment.

Cows grazing toxic endophyte-infected tall fescue observed longer periods of gestation, which contrasts observations in mares grazing endophyte-infected tall fescue in which they may have a prolonged gestation up to a month [25,26]. Maternal BCS and BW at calving and at weaning did not differ between treatments in the current study. Both Fanning [27] and Watson [28] observed similarities in heifers and cows fed endophyte-infected tall fescue. However, studies by Watson [28] observed reduced BW and BCS of dams on infected fescue, which contrasts with current findings.

Milk analysis

Altered milk yield, percent fat, percent protein, percent lactose, and milk urea nitrogen were observed in the current study due to the day of lactation rather than any impact of treatment. Previous research has observed decreased milk yield in dams on endophyte-infected fescue compared to endophyte free forage [29,30]. For example, Baldwin [30] observed reduced milk yield in Holstein heifers fed endophyte-infected fescue seed during late lactation and the dry period, however, no differences were observed in subsequent lactations. Additionally, reduced milk yield and fat percentages were observed in Angus and Brahman cows fed endophyte-infected fescue year round at 100% infection rate [31]. Initial studies in dairy cows observed reduced milk production as well [32]. However, the current study observed no difference due to grazing endophyte-infected tall fescue. Similar results were observed in lactating ewes fed endophyte-infected hay where no negative impacts on milk quantity or quality occurred [33]. This may be due to prolactin being involved in both lactogenesis and mammogenesis in cattle, but does not participate in galactopoiesis [34]. The impact on milk production may be due to the vasoconstrictive action of ergot alkaloids on reproductive vessels rather than the suppression of prolactin concentrations [35,36]. Additionally, cows were all on an endophyte-free fescue during lactation, thus, may have recovered from the negative impacts of fescue toxicity prior to milk production.

Blood analysis

Prolactin concentrations decreased during mid-gestation and increased by late gestation in cows grazing toxic endophyte-infected tall fescue. Similar results of reduced prolactin concentrations were observed in postpartum beef cows [5], beef steers [9], lactating ewes [33,37,38], and horses [39-41]. Ergot peptide alkaloids, produced by the ingested endophyte, are contributing factors to fescue toxicity and have been observed to decrease prolactin concentrations in livestock species [39,42]. Thus, prolactin serves as the primary biomarker for evaluating the onset of fescue toxicities. Ergot peptide alkaloids function as a dopamine agonist, whereas dopamine functions as an inhibitory regulator for prolactin secretion [43].

In the current study, leucocytes and HCM were increased in cows grazing toxic endophyte-infected tall fescue compared to cows grazing non-toxic tall fescue during late gestation. Whereas erythrocytes observed depressed levels from early to mid gestation then increased by parturition in cows grazing non-toxic endophyte-infected tall fescue. While hemoglobin, hematocrit, MCHC, and platelet count were unaffected by treatment. Varying results have been observed in cattle for increasing, decreasing, or no difference in leukocyte counts [8,9,44]. Experiments by Oliver [9] evaluated the blood components of Angus steers grazing endophyte infected pastures and observed similar results: increased erythrocyte count, no difference in hemoglobin or hematocrit, and decreased mean corpuscular hemoglobin and mean corpuscular volume. In the same study, the mean corpuscular hemoglobin concentration was decreased which contrasts from the results of the current experiment [9].

Glucose concentrations of pre-suckled calves were decreased in calves born to cows grazing toxic endophyte-infected tall fescue compared to calves born to cows grazing non-toxic tall fescue. Similar observations have been reported in studies of late gestation nutrient restriction in beef cattle, calves from nutrient restricted dams, regardless of protein supplementation, observed reduced glucose concentrations compared to control fed dams [45]. This may be due to the limited amount of nutrients and resources received by the fetus closer to term due to restricted blood flow.

Urine analysis

Since ergovaline concentration was increased at day 210 and 240 of gestation in cows grazing ergot alkaloids compared to cows on a control forage, the treated cows have been determined as receiving infected-tall fescue in order to induce the effects of fescue toxicosis.

Placental measurements

Placental weight did not differ between treatments, while placental efficiency tended to increased in cows grazing toxic endophyte-infected tall fescue compared to cows grazing non-toxic tall fescue. Mares fed endophyte seed experienced heavier and thicker placentas then those on control seed [46]. Additionally, in mares grazing endophyte-infected fescue, placentas were observed to be a reddish color, thickened, and heavier than those of mares grazing endophyte-free fescue [40]. Similar findings in sheep and cow models determined that compromised pregnancies alter placental blood flow and vascularity in late gestation [47]. In models of early gestation maternal undernutrition of beef cows, placental vascularity did not differ by mid gestation, however, nutrient restricted cows observed a placental programming effect in late gestation [48].

Offspring measurements

In the current study, birth weight was decreased in calves born to cows grazing toxic endophyte-infected tall fescue compared to calves born to cows grazing non-toxic tall fescue. However, an effect of sex was observed in which the birth weight of male offspring was increased compared to female offspring. Similar results were observed in [28], beef calves from cows fed endophyte-infected tall fescue observed decreased birth weights by 5 kg and reduced average daily gain when raised on the same pasture. As well as Bolt and Bond [49] where pregnant heifers grazing endophyte-infected tall fescue from d 155 of gestation until parturition gave birth to lighter calves than heifers grazing endophyte-free tall fescue. However, Schmidt [50] did not observe any difference in birth weight of calves from heifers grazing endophyte-infected or endophyte-free fescue.

In the current study, while body length, abdominal girth, hip height, and femur length did not differ between treatments, BMI was decreased in calves born to cows grazing toxic endophyte-infected tall fescue compared to calves born to cows grazing non-toxic tall fescue. Interestingly, female offspring were also leaner than male offspring. Moresca., *et al*. [51] observed similar results of asymmetrical fetal development in cows under conditions of protein restriction. Limited research has been performed comparing the differences in body composition and growth of males and females. However, in female rats, as the level of endophyte infected seed increased, average daily feed intake and average daily weight gain [52].

In the current study, weaning weight was decreased in calves born to cows grazing toxic endophyte-infected tall fescue compared to calves born to cows grazing non-toxic tall fescue. Similar results were observed in adjusted weaning weights of calves from postpartum beef cows fed infected fescue at 195.8 ± 4.5 kg [5]. Additionally, during that time in the 1990s, livestock economic loss due to fescue resulted in approximately $354 million due to reduced calf numbers and $255 million in reduced weaning weights in the US [3]. More recently, Strickland [53] estimated that approximately $1 billion are lost annually.

Similar results have been observed in calves from cows that experienced nutrient restriction during late gestation. However, rather than a decrease in the amount of nutrients readily available for the developing fetus, it may be due to a decrease in blood flow due to the vasoconstrictive characteristics of ergot alkaloids. Ergovaline has been observed to exhibit vasoactive effects in both reproductive and non-reproductive vessels [10-14]. For example, in the bovine ruminal artery, ruminal vein, and saphenous vein, ergovaline induced local vasoconstriction on vasculature [54]. In equine medial palmer artery and vein, ergovaline was the most vasoactive alkaloid tested, but did not alter activity in the uterine artery [35]. Ergovaline induced persistent vasoconstriction on vasculature through serotonin receptors due to its similar ring structure [11,55,56]. Serotonin activates S_2- serotonergic receptors on vascular smooth muscle to induce vasoconstriction directly [57]. However, Foote [58] has reported that the constriction leads to a reduction in epithelial blood flow. Thus, the true mechanism in which ergot alkaloids work is still being investigated. Additionally, as ergot alkaloids induce vasoconstriction, they may activate nitric oxide, a known vasodilator. Nitric oxide functions to regulate blood flow due to vasorelaxation of vascular smooth muscle cells [59]. The disruption of blood flow in both reproductive and non-reproductive vessels due to the consumption of ergovaline and other ergot alkaloids remains unclear.

Calves indirectly impacted by ergot alkaloids due to maternal consumption during gestation are not the only concern for producers when evaluating fescue management practices. In fescue grazing studies, steers would exhibit a decrement of 0.045 kg in average daily gain for every 10% increase in ergovaline level [25], which may be due to reduced feed intake [60]. However, when grazing endophyte-free tall fescue, steer weight is increased by gains of 30 to over 100% [3]. Grazing studies in stocker cattle observed decreased average daily gain and dry matter intake on endophyte-infected tall fescue, effects that were alleviated upon grazing endophyte-free tall fescue pastures [61]. Additionally, beef steers averaged a 70% or greater rate of gain and gain per hectare of pasture compared to the endophyte-infected tall fescue grazers [61]. Recently, Mote [62] evaluated Angus steers grazing toxic fescue pastures and determined the primary consequences to endophyte consumption were tryptophan and lipid metabolism disruption. However, the presence of the endophyte enhances persistence of the plant, competitiveness, and prevalence of endophyte-infected tall fescue versus the endophyte-free tall fescue [63,64].

Conclusion

Exposure to E+ forage during late gestation results in decreased maternal semen prolactin and BW during late gestation compared to cows consuming E- forage. Exposure to E+ forage resulted in calves with reduced weight and BMI at birth and a tendency for reduced BW at weaning compared to calves from E-dams. Exposure to E+ forage did not affect locational performance of dams. Additionally, further work is needed to determine the exact amount of ergot consumption that effects calf development in utero. This amount is probably dependent on maternal BCS and possible maternal age. This could be important to the cow calf industry since we know that dilution with other forages or supplements may be one of the most important management options in managing fescue toxicosis.

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Conflicts of Interest

There is no conflict of interest to report for this work with any of the authors.

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