Performance by spring and fall-calving cows grazing with full, limited, or no access to toxic Neotyphodium coenophialum-infected tall fescue

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ABSTRACT: Replacing toxic, wild-type Neotyphodium coenophialum-infected tall fescue (E+) with nontoxic, N. coenophialum-infected tall fescue (NE+) has improved cow performance, but producer acceptance of NE+ has been slow. The objective was to compare performance by spring- and fall-calving cows grazing either E+ or NE+ at different percentages of the total pasture area. Gelbvieh × Angus crossbred cows (n = 178) were stratified by BW and age within calving season and allocated randomly to 1 of 14 groups representing 5 treatments for a 3-yr study: i) Fall-calving on 100% E+ (F100); ii) Spring-calving on 100% E+ (S100); iii) Fall-calving on 75% E+ and 25% NE+ (F75); iv) Spring-calving on 75% E+ and 25% NE+ (S75); and v) Spring-calving on 100% NE+ (SNE100). Groups allocated to F75 and S75 grazed E+ until approximately 28 d before breeding and weaning, then were moved to their respective NE+ pasture area for 4 to 6 wk; those allocated to F100, S100, and SNE100 grazed their pastures throughout the entire year. Samples of tall fescue were gathered from specific cells within each pasture at the time cows were moved into that particular cell (~1 sample/mo). Blood samples were collected from the cows at the start and end of the breeding season. Stocking rate for each treatment was 1 cow/ha. Forage IVDMD, CP, and total ergot alkaloid concentrations were affected (P < 0.05) by the treatment × sampling date interaction. Hay offered, cow BW, and BCS at breeding, end of breeding, and at weaning were greater (P < 0.05) from fall-calving vs. spring-calving. Cow BW at weaning was greater (P < 0.05) from F75 and S75 vs. F100 and S100. The calving season × NE+ % interaction affected (P < 0.05) calving rates. Preweaning calf BW gain, actual and adjusted weaning BW, ADG, sale price, and calf value at weaning were greater (P < 0.05) from fall-calving vs. spring-calving and from SNE100 vs. S75 except for sale price which was greater (P < 0.05) from S75 vs. SNE100. Cow concentrations of serum prolactin at breeding and serum NEFA at the end of breeding were affected (P < 0.05) by the calving season × NE+ % interaction. Serum Zn and Cu concentrations from cows were affected (P < 0.05) by calving season. A fall-calving season may be more desirable for cows grazing E+, resulting in greater calving rates, cow performance, and calf BW at weaning, whereas limited access to NE+ may increase calving rates, serum prolactin, and NEFA concentrations during certain times in the production cycle, particularly in spring-calving cows.

Key words: calving season, cattle, novel endophyte, performance, tall fescue


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INTRODUCTION

Tall fescue [Lolium arundinaceum (Schreb.) Darbysh] is commonly used in grazing systems in the southeastern United States because of its long-term persistence and summer survival. These superior traits are attributed to the plant being infected with the fungus Neotyphodium coenophialum (Bouton et al., 1993). However, this fungus produces toxins (ergot alkaloids) that negatively impact animal growth (Nielsen et al., 2003), reproductive performance (Porter and Thompson, 1992), prolactin (Watson et al., 2004) and serum copper concentrations (Oliver et al., 2000), and may alter certain hemogram values (Oliver et al., 2000). In total, consumption of tall fescue infected with the wild-type endophyte (E+) costs U.S. livestock producers in excess of $1 billion each year (Strickland et al., 2011). Development of endophyte-free tall fescue (E−) showed promise in early grazing trials (Hoveland, 1993), but plant persistence was reduced (Bouton et al., 1993). Recently, an alternative to mitigate the negative effects from grazing E+ was developed by combining novel nontoxic endophytes that produce little, if any, measureable toxins with compatible tall fescue cultivars (Parish et al., 2003; Watson et al., 2004). Novel-endophyte-infected tall fescue (NE+) has been reported to have greater persistence and yield capabilities compared with E− (Bouton et al., 2002; Vibart et al., 2008). However, producer acceptance of NE+ has been slow, likely attributable to one or more of the following: the expense of planting, inability to use pastures during establishment, land limitations such as terrain and/or soil matrix restricting certain renovation practices, and the uncertainty of persistence of NE+ cultivars. In practical situations, producers may be able to convert only a portion of their farms to NE+ at any given time. Also, information about the impacts of calving season on performance by cows is limited. The study objective was to investigate the performance by spring- and fall-calving cows grazing either E+ or NE+ at different percentages of the total pasture area.

MATERIALS AND METHODS

The study was conducted at the University of Arkansas Livestock and Forestry Research Station near Batesville, AR. All animal procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee (protocol No. 06062).

Pasture and Treatments

A total of 178, 2- to 6-yr-old Gelbvieh × Angus crossbred, spring-calving (520 ± 7.4 kg; 5.8 ± 0.04 average initial BW and BCS, respectively) and fall-calving cows (500 ± 7.2 kg; 5.5 ± 0.06 average initial BW and BCS, respectively) were used in a 3-yr grazing study. Historically, the spring-calving cows were derived from purebred Angus cows whereas the fall-calving cows were derived from crossbred Angus cows. In the 6 yr before beginning this study, the same group of Gelbvieh bulls was mated to spring- and fall-calving cows over a 5-yr period, and the same group of Angus bulls was mated to spring- and fall-calving cows the year before using the Gelbvieh bulls. These matings resulted in the cows used in this study. Cows were stratified by BW and age within calving season and allocated randomly to 1 of 14 groups or pastures representing 5 treatments: i) Fall-calving on 100% E+ (F100; 3 replications); ii) Spring-calving on 100% E+ (S100; 3 replications); iii) Fall-calving on 75% E+ and 25% NE+ (F75; 3 replications); iv) Spring-calving on 75% E+ and 25% NE+ (S75; 3 replications); and v) Spring-calving on 100% NE+ (SNE100; 2 replications) starting January 30, 2007. All NE+ pastures were seeded to the HiMag4 cultivar. Pastures were blocked based on previous forage production and allocated randomly within block to 1 of the 5 treatments. The E+ areas for each replicate of the first 4 treatments and the NE+ area for the SNE100 treatment replicates were approximately 10 ha. Two separate 10-ha NE+ pastures were divided into three 3.2-ha pastures each. Each of these 3.2-ha NE+ pastures was assigned randomly to one of either the S75 or F75 pastures and remained with that replicate throughout the 3-yr study. This combination resulted in 10 ha of E+ and 3.2 ha of NE+ for the S75 and F75 groups (Fig. 1).

Cows assigned to S75 and F75 treatments grazed E+ until approximately 28 d before the start of the breeding season and 28 d before weaning, at which time they were moved to their respective NE+ pastures (Fig. 2). Breeding seasons began May 9, 2007; May 13, 2008; and May 12, 2009 for spring-calving cows and November 27, 2007; November 20, 2008; and November 24, 2009 for fall-calving cows. Weaning dates were October 18, 2007, October 23, 2008, and October 22, 2009 for spring-calving cows, and May 9, 2007, May 14, 2008, and May 12, 2009 for fall-calving cows. The S75 and F75 groups remained on NE+ pasture until available forage was limiting (<1000 kg/ha), and then were returned to their original E+ pastures. Cows assigned to F100, S100, or SNE100 treatments stayed on their assigned pasture throughout the year. All pastures were grazed using rotational stocking and stocked at 1 cow/ha. Each of the E+ and SNE100 pastures were subdivided into 6 1.6-ha paddocks. Each 3.2-ha portion of NE+ for F75 and S75 was divided in half and cows were rotated within those paddocks. Approximately 3.2 ha from each replicate was set aside annually in the spring for hay production. This area consisted of E+ for all treatments,
except SNE100 which was NE+. In late August, cows were rotated through the same pasture area to remove excess available forage and prepare the area for subsequent stockpiling.

Pastures were located on either Clarksville very cherty silt loam, Captina silt loam, Gepp very cherty silt loam, or Noark very cherty silt loam (Ferguson et al., 1982). The forage fertility program for the grazed areas of F100, SNE100, and S100 consisted of annual urea application (46–0–0) of 34 kg N/ha in late February or early March. The 3.2 ha harvested for hay were fertilized annually in the spring with 67 kg N/ha as urea and again in early-September of each year with 56 kg N/ha as urea to prepare these pastures for stockpiling. The NE+ pastures assigned to S75 and F75 were fertilized annually in the spring, with 67 kg N/ha as urea to enhance yield of the NE+ forage. One-half of the grazed E+ area assigned to S75 and F75 was fertilized with 34 kg N/ha as urea in the spring, and one-half was not fertilized. This was done because of limited spring grazing of the E+ portion of those pastures and to equalize the application of N on a per-hectare basis across the entire pasture area. Phosphorus, K, and lime were applied annually on a per-pasture basis in the fall to meet soil test requirements as specified by Arkansas Cooperative Extension Service soil test guidelines (Chapman, 2001).

Cattle Management

Once allocated to a treatment, cows remained in their assigned groups throughout the entire study, but were replaced only at the start of the breeding season with a primarparous heifer with a calf if they did not give birth to a live calf or if their calf died. An Angus × Gelbvieh crossbreed bull that passed a breeding soundness evaluation according to the guidelines of the Society of Theriogenology (Hopkins and Spitzer, 1997) was added to the spring and fall-calving groups during their respective 63-d breeding seasons. Bulls were allocated randomly to groups each season, but allocations were adjusted to have similar EPDs across treatments. Bulls were rotated annually across groups to remove sire effects; bulls went to different treatments in consecutive years. Cow BW and BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) were evaluated at the start of the experiment, at the start and end of each breeding season, and at weaning without prior removal from pasture or water. Approximately 28 d before the start of the breeding season, cows were vaccinated against infectious bovine rhinotraceitis (IBR), bovine virus diarrhea (BVD), parainfluenza (PI3), bovine respiratory syncytial virus (BRSV), Campylobacter fetus, and 5 strains of Leptospira (Vira Shield 6 + VL5, Novartis Animal Health, Inc., Larchwood, IA). Before calving (approximately 14 d) cows were vaccinated against 8 Clostridial strains (Coxevin 8, Schering-Plough Animal Health Limited, Upper Hatt, NZ) and treated for internal parasites with moxidectin (Cydecin, Fort Dodge Animal Health, IA). During adverse weather conditions or when available forage was limiting, cows were offered hay [11.5% CP, 45% IVDMD; 9% CP, 46% IVDMD, average for E+ and NE+, respectively (DM basis)] that was harvested from the hay area assigned to the particular replication. A random subset (approximately 20%) of the hay bales was weighed and an average weight cal-
culated before offering the hay. This weight was then applied to each bale offered to the cows. No estimates of hay wastage were made and cows were left in a particular cell where hay was offered until they had consumed the majority of the remaining hay before the initiation of grazing of another cell. No supplemental concentrate was offered to any treatment, and trace mineralized salt (79% salt, 5% Mg, 1000 mg of Fe/kg, 8000 mg of Mn/kg, 12,000 mg of Zn/kg, 4000 mg of Cu/kg, 60 mg of Se/kg, 200 mg of I/kg, and 50 mg of Co/kg) was available free choice throughout the duration of the study. Mineral feeders were checked twice weekly and fresh trace mineral supplement was weighed and added as needed throughout the study. The trace mineral supplement offered was mixed at the University of Arkansas using 79.1% salt, 10% NB Ruminant Trace Mineral, (NB-8675; Nutra Blend Corp., Neosho, MO), 8.9% magnesium-oxide, and 2% liquid molasses. Water was available free choice via automatic waterers and either natural or artificial shade was provided.

All calves were weighed at birth and at weaning, and male calves were castrated at birth. Twenty-eight days before weaning, calves were gathered at 0800 h and vaccinated against 7 Clostridial strains (Alpha 7; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO), IBR, BVD, PI3, BRSV, Haemophilus somnus, and 5 strains of Leptospira (Elite 9-HS; Boehringer Ingelheim Animal Health, Inc., MO). At weaning, calves were re-vaccinated (Elite 9-HS; Boehringer Ingelheim Animal Health, Inc.), and treated for internal parasites (Cydectin; Fort Dodge Animal Health). At this time, calves were separated from their dams, commingled, placed in a drylot away from their dams, and offered ad libitum access to bermudagrass [Cynodon dactylon (L.) Pers.] hay [15% CP, 41% IVDMD (DM basis)], water, and mineral.

Sample Collection and Analyses

In yr 1, a 1.6-ha paddock from each E+ and SNE100 pasture was evaluated for quantity and quality of available forage before cows entered that paddock. In yr 2 and yr 3, an additional 1.6-ha paddock from each E+ and SNE100 pasture was evaluated for quantity and quality of available forage before moving to that paddock. Each sampling paddock was walked in a zigzag pattern and available forage was measured at 12 locations/paddock using a disk meter (Bransby et al., 1977). Tall fescue samples were collected by clipping the forage at a 2.5-cm stubble height with hand shears at each alternate disk meter drop. Forage samples were then placed in plastic zip-lock bags, submerged in ice, and transported to a conventional freezer (−20°C) for a minimum of 2 h. Samples were then transported on ice to the University of Arkansas Animal Science Department and stored in an ultra-low freezer (−80°C) until lyophilization.

Disk meters were calibrated approximately every 14 d during the spring and every month thereafter, by clipping forage directly underneath the disk meter (0.25 m²) to a 2.5-cm stubble with hand shears at 6 locations in both E+ and NE+ pastures. Harvested samples were dried to a constant weight under forced air at 50°C, and the resulting weights were converted to kg/ha. These converted weights were then regressed against the disk meter heights to develop calibration equations.

Forage samples collected for quality and total ergot alkaloid analyses were lyophilized using a Labconco freeze dryer (Labconco Corporation, Kansas City, MO), ground through a 1-mm screen using a Wiley mill grinder (Arthur H. Thomas, Philadelphia, PA), and stored at −80°C pending laboratory analyses. Ground fescue samples were analyzed for IVDMD using the batch-culture procedures outlined by Ankom Technology Corporation (Fairport, NY) and for total N using rapid combustion (AOAC, 1998; Elementar Americas, Inc, Mt. Laurel, NJ). Crude protein was estimated by multiplying the total N concentrations by 6.25. Total ergot alkaloid concentrations were measured using an ELISA procedure outlined by Adcock et al. (1997). The within-plate CV was 6.6, but the across-plate CV was 35.0. Therefore, all standards were included on each plate and total ergot alkaloid concentrations for each sample were calculated using the standard curve for the plate on which the particular sample was placed.

Forage species frequency and basal cover were determined on November 9, 2006, before the start of the study; and then on October 30, 2007, October 31, 2008, and on November 17, 2009 by a modified step-point procedure (Owensby, 1973). Twenty-five observations/ha were recorded, and forage species were grouped as tall fescue, cool- or warm-season perennials, cool- or warm-season annuals, or other broadleaf weeds.

Blood samples (16 mL) were harvested from each cow at the start and end of the breeding season via jugular venipuncture in serum separator vacuum tubes (Vacutainer, Becton Dickinson, Inc., Franklin Lakes, NJ), and vacuum tubes (Vacutainer, Becton Dickinson, Inc.) for subsequent trace mineral analyses. Blood samples were transported on ice and stored in a conventional refrigerator (2°C) for approximately 12 h. Serum was harvested after centrifugation (1200 × g for 25 min at room temperature) and stored at −20°C. Serum samples were analyzed for NEFA concentrations with an in vitro enzymatic colorimetric procedure [NEFA-HR (2); Wako Chemicals, Inc., Richmond, VA], and for Fe, Zn, and Cu concentrations following the procedure described by Caldwell et al. (2011). Serum prolactin concentrations were determined at New Mexico State
University using a double antibody RIA procedure (Spoon and Hallford, 1989). Within-and among-assay CVs were 7.1 and 3.3%, respectively.

**Statistical Analyses**

**Forage Measurements.** A randomized complete block experimental design with a 2 × 2 factorial treatment structure and a positive control was used, with pasture considered the experimental unit and previous forage production as the blocking factor. Species composition was evaluated as 6 different treatments: F100, F75, SNE100, NE25, S100, and S75, because pastures were evaluated separately. The NE25 treatment represents the NE+ part of S75 and F75 pastures. Four orthogonal contrast statements were used to evaluate species composition: i) the mean of F100 and F75 vs. the mean of S100 and S75, ii) the mean of F75 and S75 vs. that of F100 and S100, iii) SNE100 vs. NE25, and iv) the mean of SNE100 and NE25 vs. that of F100, F75, S100, and S75. Contrast statements were selected to compare i) E+ pastures grazed by fall-calving cows with E+ pastures grazed by spring-calving cows, ii) E+ pastures grazed by fall- and spring-calving cows that have 75% of their total pasture area as E+ with those grazed by fall- and spring-calving cows that have 100% of their total pasture area as E+, iii) NE+ pastures grazed by spring-calving cows that have 100% of their total pasture area as NE+ with NE+ pastures that were only grazed during certain times during the production cycle, and iv) all NE+ pastures compared with all E+ pastures.

Forage mass and concentrations of CP, IVDMD, and total ergot alkaloids were treated as repeated measures and analyzed using mixed models (PROC MIXED procedure; SAS Inst. Inc., Cary, NC). The error term for treatment effects was pasture × treatment × year. Year was considered a random effect and sampling date was considered the repeated measurement. These measurements were analyzed with consideration given to the forage the cows were grazing on the particular sampling date. For example, NE+ forage was analyzed for the F75 treatment when cows were grazing NE+ in April, May, and October, but E+ forage was analyzed for the F75 treatment during the remaining months. Four preplanned orthogonal contrasts were used: i) mean of fall-calving with the mean of spring-calving cows, ii) mean of S75 and F75 with the mean of S100 and F100, iii) SNE100 with S75, and iv) interaction between spring- and fall-calving cows in their response to having 25% of their total pasture area as NE+. Calf weaning weights were analyzed both as actual and adjusted 205-d weaning weights. Weaning weights were adjusted for calf age but not for age of cow. Calf value was assigned by first estimating the price per unit of calf BW expressed as $/45.4 kg for each calf. The price ($/45.4 kg) was derived using a sliding price scale within calf sex based on Arkansas state average price ranges on the actual weaning date. It is possible that using actual prices could introduce marketing effects independent of the treatments. However, we considered these effects as small over a 3-yr period and felt that actual market prices accurately reflected apparent treatment differences. Price was not adjusted for calf appearance. The actual weaning weight of each calf was then multiplied by the derived market price ($/45.4 kg) at weaning to obtain calf value. Calving rates are reported as a percent of the total number of cows that calved per treatment and were analyzed by the χ² procedure of SAS, using individual analyses to represent the same contrast statements as described above. Treatment means are reported as least squares means. Differences referred to as tendencies are those having a P-value between 0.05 and 0.10.

**RESULTS AND DISCUSSION**

Monthly rainfall data for all 3 yr of the study are shown in Table 1. Monthly rainfall patterns for this 3-yr study were inconsistent, but typical for this research station. Overall annual rainfall amounts during the study were close to or greater than the 30-yr average.

**Species Composition**

Basal cover, contamination by cool-season annuals, warm-season perennials, and other broadleaf weeds did not differ (P ≥ 0.21) across treatments and averaged 17.3, 0.8, 15.7, and 2.5%, respectively (Table 2). Pastures
were dominated by tall fescue and averaged 69.9% of the vegetation frequency across all treatments. Within NE+ pastures, SNE100 had 11.2% units greater ($P < 0.05$) frequency of tall fescue compared with NE25. Within E+ pastures, contamination by cool-season perennials tended ($P \leq 0.10$) to be greater from fall-calving cows grazed with those grazed by fall-calving cows (6.2 vs. 4.5%, average, respectively). Warm-season annual contamination was greater ($P < 0.05$) from NE25 compared with SNE100 and from NE100 and NE25 compared with the mean of all the E+ pastures. Cool-season perennial contamination consisted primarily of orchardgrass (Dactylis glomerata L.) and rescuegrass (Bromus catharticus Vahl), with the cool-season annual contamination consisting primarily of cheat (Bromus secalinus L.), little barley (Hordeum pusillum Nutt.), and annual ryegrass (Lolium multiflorum L.). Bermudagrass was the primary warm-season perennial contaminant, especially in areas where hay had been offered in previous years but broomsedge (Andropogon virginicus L.) was also present. Warm-season annual forage contamination consisted primarily of crabgrass [Digitaria sanguinalis (L.) Scop.] and knotroot foxtail [Setaria geniculata (Lam.) Beauv.]. Differences detected in species composition are likely a function of forage type and grazing time, especially in NE25. Although the NE25 pastures were only grazed during certain times of the year, they were grazed at a heavier stocking density during the late spring. This removed much of the forage competition before summer, allowing encroachment of the warm-season annual forages. Continuation of this practice could reduce the stand life of the NE+ forage.

### Table 1. Precipitation (mm) at the Livestock and Forestry Research Station (LFRS) near Batesville, AR, starting with January 2007 (yr 1) through December 2009 (yr 3)

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Average$^1$</th>
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</thead>
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<tr>
<td>January</td>
<td>185</td>
<td>26</td>
<td>79</td>
<td>80</td>
</tr>
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<td>February</td>
<td>64</td>
<td>104</td>
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<td>March</td>
<td>39</td>
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<tr>
<td>May</td>
<td>37</td>
<td>61</td>
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<td>122</td>
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<tr>
<td>June</td>
<td>233</td>
<td>80</td>
<td>75</td>
<td>86</td>
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<tr>
<td>July</td>
<td>71</td>
<td>118</td>
<td>147</td>
<td>80</td>
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<td>August</td>
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<tr>
<td>October</td>
<td>144</td>
<td>122</td>
<td>330</td>
<td>99</td>
</tr>
<tr>
<td>November</td>
<td>49</td>
<td>49</td>
<td>26</td>
<td>134</td>
</tr>
<tr>
<td>December</td>
<td>187</td>
<td>94</td>
<td>181</td>
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<tr>
<td>Total</td>
<td>1225</td>
<td>1571</td>
<td>1672</td>
<td>1187</td>
</tr>
</tbody>
</table>

$^1$Average rainfall from 1971 to 2000 at the LFRS (NOAA, 2003).

### Table 2. Forage species composition from ergot-alkaloid producing N. coenophialum-infected (E+; F100, F75, S100, and S75) and non-toxic, novel-endophyte–infected (NE+; SNE100 and NE25) tall fescue pastures that were grazed by spring- or fall-calving cows

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment$^1$</th>
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<tbody>
<tr>
<td></td>
<td>F100</td>
</tr>
<tr>
<td>Basal cover, %</td>
<td>17.4</td>
</tr>
<tr>
<td>Species composition, % of plant species</td>
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<tr>
<td>Tall fescue</td>
<td>72.5</td>
</tr>
<tr>
<td>Cool-season perennials$^4$</td>
<td>3.3</td>
</tr>
<tr>
<td>Cool-season annuals$^5$</td>
<td>0.9</td>
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<tr>
<td>Warm-season perennials$^6$</td>
<td>13.6</td>
</tr>
<tr>
<td>Warm-season annuals$^7$</td>
<td>5.0</td>
</tr>
<tr>
<td>Other broadleafs$^8$</td>
<td>2.2</td>
</tr>
</tbody>
</table>

$^1$Forage species composition was measured in mid-October through early-November of each year using a modified step-point method (Owensby, 1973). Treatment designations of 100 or 75 represent the percentage of total pasture acreage that was E+. The NE25 treatment was the NE+ area of the S75 and F75 treatments.

$^2$SEM = Pooled SEM.

$^3$Contrasts: W = mean of fall-calving cows compared with the mean of spring-calving cows ($P < 0.05$); X = mean of S75 and F75 compared with the mean of S100 and F100 ($P < 0.05$); Y = SNE100 compared with NE25 ($P < 0.05$); Z = mean of SNE100 and NE25 compared with the mean of F100, F75, S100, and S75 ($P < 0.05$); lowercase letters represent statistical tendencies ($P < 0.10$); ns = no significant difference ($P > 0.10$).

$^4$Included orchardgrass (Dactylis glomerata L.), rescuegrass (Bromus catharticus Vahl), Kentucky bluegrass (Poa pratensis L.), and perennial ryegrass (Lolium perenne L.).

$^5$Included cheat (Bromus secalinus L.), little barley (Hordeum pusillum Nutt.), and annual bluegrass (Poa annua L.).

$^6$Included bermudagrass [Cynodon dactylon (L.) Pers.], quackgrass (Elytrigia repens L.), dallisgrass (Paspalum dilatatum Poir.), johnsongrass [Sorghum halepensis (L.) Pers.], broomsedge (Andropogon virginicus L.), and yellow nutsedge (Cyperus esculentus L.).

$^7$Included crabgrass [Digitaria sanguinalis (L.) Scop.] and knotroot foxtail [Setaria geniculata (Lam.) Beauv.].

$^8$Included horse nettle (Solana carolinense L.), vetch (Vicia sativa L.), hop clover (Trifolium agrarium), and henbit (Lamium amplexicaule L.).
Table 3. Forage mass and IVDMD (DM basis) concentrations from ergot-alkaloid-producing *N. coenophialum*-infected (E+) or nontoxic, novel-endophyte-infected (NE+) tall fescue pastures that were grazed by spring- or fall-calving cows.

<table>
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<tr>
<th>Item</th>
<th>F100</th>
<th>F75</th>
<th>SNE100</th>
<th>S100</th>
<th>S75</th>
<th>SEM² Contrast³</th>
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<tbody>
<tr>
<td>Forage mass, kg/ha</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>March–November</td>
<td>3771</td>
<td>3516</td>
<td>3425</td>
<td>3844</td>
<td>3713</td>
<td>340.9 ns</td>
</tr>
<tr>
<td>Forage mass: IVDMD, %</td>
<td>69</td>
<td>65</td>
<td>68</td>
<td>69</td>
<td>67</td>
<td>1.2 X</td>
</tr>
<tr>
<td>April</td>
<td>74²</td>
<td>74²</td>
<td>77¹</td>
<td>81¹</td>
<td>77²</td>
<td>4.3 –</td>
</tr>
<tr>
<td>April</td>
<td>79³b</td>
<td>74³b</td>
<td>82²a</td>
<td>82²a</td>
<td>77³ab</td>
<td>2.3 –</td>
</tr>
<tr>
<td>May</td>
<td>68²a</td>
<td>66²a</td>
<td>56²b</td>
<td>64²b</td>
<td>64²b</td>
<td>2.4 –</td>
</tr>
<tr>
<td>June</td>
<td>63³a</td>
<td>58³a</td>
<td>64³a</td>
<td>59³a</td>
<td>59³a</td>
<td>3.5 –</td>
</tr>
<tr>
<td>July</td>
<td>61³a</td>
<td>60³a</td>
<td>64³a</td>
<td>63³a</td>
<td>58³a</td>
<td>3.0 –</td>
</tr>
<tr>
<td>August</td>
<td>70³a</td>
<td>59³b</td>
<td>59³ab</td>
<td>61³a</td>
<td>70³a</td>
<td>4.0 –</td>
</tr>
<tr>
<td>September</td>
<td>65³a</td>
<td>67³a</td>
<td>68³a</td>
<td>68³a</td>
<td>64³a</td>
<td>3.0 –</td>
</tr>
<tr>
<td>October</td>
<td>69³ab</td>
<td>67³ab</td>
<td>74³a</td>
<td>74³a</td>
<td>64³b</td>
<td>2.4 –</td>
</tr>
<tr>
<td>November</td>
<td>75³a</td>
<td>63³b</td>
<td>70³a</td>
<td>70³a</td>
<td>72³a</td>
<td>3.0 –</td>
</tr>
</tbody>
</table>

³Means in a row without a common superscript differ (P < 0.05).
¹Treatments represent NE+ pasture grazed by spring-calving cows (SNE100), or E+ pastures grazed by spring- or fall-calving cows for which either all (S100 or F100) or 75% of the total pasture area (S75 or F75) was E+ and the remainder was NE+.
²SEM = Pooled SEM.
³Contrasts: X = mean of S75 and F75 compared with the mean of S100 and F100 (P < 0.05); ns = no significant difference (P > 0.05).

Available Forage, Forage Quality, and Total Ergot Alkaloids

A sampling date effect was detected (P < 0.05) for available forage, but interactions of treatment and sampling date were not detected (P = 0.13). Therefore, these data were pooled across sampling dates and years (Table 3). Available forage did not differ (P = 0.31) across treatments (3654 kg/ha, average).

Forage concentrations of IVDMD (Table 3), were greater (P < 0.05) from F100 and S100 compared with F75 and S75 when averaged across sampling dates, but the treatment × sampling date interaction affected (P < 0.05) those concentrations. When analyzed within sampling date, forage concentrations of IVDMD did not differ (P ≥ 0.27) across treatments during March, June, July, or September (Table 3). However, forage IVDMD concentrations from F75 were less (P < 0.05) than those from SNE100 and S100 in April, than those from F100, S100, and S75 in August, and those from all other treatments in November. The differences observed in April and November may be a result of forage management scenarios. In April, the F75 groups were moved to their respective NE+ paddocks. Because of limited paddock sizes, those paddocks were split into 2 cells and the cows rotated on a weekly basis. Also, the calves in the F75 groups were approximately 200 d of age (data not shown) at the time they were moved to NE+ in the spring. The extra stocking density limited forage mass to a greater degree in those cells and would therefore reduce forage quality. A similar scenario occurred in November when F75 cows remained on NE+ until the time bulls were added in late November.

In May, IVDMD concentrations from SNE100 were less than (P < 0.05) those from F100, F75, and S75, and IVDMD concentrations in October were less (P < 0.05) from S75 compared with SNE100 and S100. Forage IVDMD concentrations in the present study are comparable with those reported by Parish et al. (2003), who reported values between 63 and 73%.

Concentrations of CP were 2% units greater (P < 0.05) from SNE100 compared with S75 (Table 4), and were greater (P < 0.05) from F100 and S100 compared with F75 and S75. Forage CP concentrations in the present study were on average 5% units greater than those reported from E+ and NE+ (12.0 vs. 12.3, respectively) pastures during the spring (Drewnoski et al., 2009), but were similar to forage CP concentrations reported by Parish et al. (2003) from March through June (20.2%, average) and from September through December (16.0%, average).

When averaged across sampling dates, total ergot alkaloid concentrations were greater (P < 0.05) from F100 and S100 compared with F75 and S75 (Table 4). This is

Table 4. Crude protein (DM basis) and total ergot alkaloid concentrations from ergot-alkaloid producing *N. coenophialum*–infected (E+) or nontoxic, novel-endophyte-infected (NE+) tall fescue pastures that were grazed by spring- or fall-calving cows.

<table>
<thead>
<tr>
<th>Item</th>
<th>F100</th>
<th>F75</th>
<th>SNE100</th>
<th>S100</th>
<th>S75</th>
<th>SEM² Contrast³</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP, %</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>16</td>
<td>0.4 X,Y</td>
</tr>
<tr>
<td>Total ergot alkaloids, µg/kg</td>
<td>522</td>
<td>313</td>
<td>104</td>
<td>509</td>
<td>373</td>
<td>99.9 X,Y</td>
</tr>
</tbody>
</table>

³Means in a row without a common superscript differ (P < 0.05).
¹Treatments represent NE+ pasture grazed by spring-calving cows (SNE100), or E+ pastures grazed by spring- or fall-calving cows for which either all (S100 or F100) or 75% of the total pasture area (S75 or F75) was E+ and the remainder was NE+.
²SEM = Pooled SEM.
³Contrasts: X = mean of S75 and F75 compared with the mean of S100 and F100 (P < 0.05); ns = no significant difference (P > 0.05).
⁴Treatment × sampling date interaction (P < 0.05).
likely because F75 and S75 averages included months where cows grazed the NE+ portion of those pastures, thereby reducing the overall average ergot alkaloid concentrations. Total ergot alkaloid concentrations were greater (P < 0.05) from S75 compared with SNE100 (373 vs. 104 μg/kg, respectively), and were a function of S75 grazing E+ pastures for much of the year. However, the treatment × sampling date interaction affected (P < 0.01) total ergot alkaloid concentrations. Generally, differences in total ergot alkaloids observed within months reflected whether S75 and F75 groups were grazing E+ or NE+ pastures during the month. Total ergot alkaloid concentrations from E+ pastures in the present study were approximately 547 μg/kg less than those from a previous study at the existing site from E+ pastures that were grazed year round (1062 vs. 515 μg/kg, average, respectively; Coffey et al., 2005), but were greater than those reported in Georgia from March through September from E+ and NE+ pastures (Watson et al., 2004).

### Hay, Mineral Offered, and Cow and Calf Performance

Hay offered was greater (P < 0.05) from fall-calving cows compared with spring-calving cows. Mineral offered (kg/cow) tended (P = 0.10) to be greater from F100 and S100 compared with F75 and S75, and was greater (P < 0.05) from SNE100 compared with S75 (Table 5). The difference in the amount of hay offered from fall-calving cows compared with spring-calving cows is likely a function of fall-calving cows nursing calves during the hay feeding period. No other contrasts affected (P ≥ 0.35) hay or mineral offered.

Cow BW at the start and end of the breeding season and at weaning were greater (P < 0.05) from fall-calving cows compared with spring-calving cows. Cow BW at weaning was also greater (P < 0.05) from S75 and F75 compared with S100 and F100 and from SNE100 compared with S75. Spring-calving cows lost (P < 0.05) more BW during the breeding season compared with fall-calving cows, and S75 and F75 lost (P < 0.05) 17 kg more BW during breeding compared with S100 and F100. Cow BW at the end of the breeding season tended (P = 0.06) to be greater from SNE100 compared with S75, and cow BW loss during breeding tended (P = 0.07) to be greater from S75 compared with SNE100. Cow BCS at the start and end of the breeding season and at weaning were greater (P < 0.05) from fall-calving cows compared with spring-calving cows. Also, spring-calving cows lost (P < 0.05) body condition during the breeding season whereas fall-calving cows maintained BCS (~0.5 vs. 0.1 average, respectively). Cow BCS at the start of the breeding season and at weaning were greater (P < 0.05) from SNE100 compared with S75.

To our knowledge, this is the first published study comparing fall and spring-calving cows grazing E+. Most research studies evaluating the effects of E+ with other nontoxic forages on livestock performance used stocker cattle for the experimental model. However, a review by Paterson et al. (1995) did summarize a limited number of studies that reported cow/calf performance and concluded that cows grazing E+ lost more BW than cows grazing E−. More recently, spring-calving cows grazing E+ pastures that were diluted 50% by bermudagrass and managed using a twice-monthly rotation frequency, lost more body condition from calving to weaning, weighed 45 kg less at calving, and lost 17 kg more BW from calving to weaning compared with those managed using either a twice weekly or twice monthly grazing schedule on pastures of E− or orchardgrass mixed with bermudagrass (Coblentz et al., 2006).

Calving rates averaged 31% units greater (P < 0.05) and calving intervals were 11 d (average) shorter (P < 0.05) from fall-calving cows compared with spring-calving cows. Calving rates were greater (P < 0.05) from S75 and F75 compared with S100 and F100, and the calving season × NE+ % interaction (P < 0.05) also affected calving rates. By adding only 25% of the total pasture area as NE+, calving rates increased by 36% units from S75 compared with S100, but by only 5% units from F75 compared with F100. Calving rates were not different (P = 0.98) between S75 and SNE100, but calving interval was longer (P < 0.05) from S75 compared with SNE100. Calving rates from the spring-calving cows in the present study generally followed the same trend as previously reported by Peters et al. (1992) and Coffey et al. (2007). In those 2-yr studies, spring-calving cows grazing E+ had 19% unit (Peters et al., 1992) and 40% unit (Coffey et al., 2007) reductions in pregnancy rates compared with those grazing E− or NE+, respectively. Others have reported no difference in reproductive performance by spring-calving cows (Watson et al., 2004) or heifers (Drewnoski et al., 2009) grazing pastures with either E+ or NE+ starting in early spring. Calving rates by the fall-calving cows in the present study were similar to those reported by Coffey et al. (2005) from fall-calving cows grazing year round on E+ and managed with different rotation schedules (twice monthly or twice weekly) and weaning strategies (early or late).

No treatment by sex of calf interactions were detected (P ≥ 0.19) for any of the calf measurements evaluated in this study. Calf birth weight was greater (P < 0.05) from spring-calving cows compared with fall-calving cows, but calf weaning age, actual and adjusted weaning weight, preweaning calf BW gain, ADG, sale price, and calf value at weaning were greater (P < 0.05) from fall-born compared with spring-born calves. Calf actual and adjusted weaning weight, calf BW gain, and ADG tend-
ed to be greater ($P = 0.09$) from S75 and F75 compared with S100 and F100, whereas sale price ($$/45.4 \text{ kg}$) was greater ($P < 0.05$) from S100 and F100 compared with S75 and F75 because those calves weighed less. These factors offset each other so that calf value at weaning was not different ($P = 0.49$) from S75 and F75 compared with S100 and F100. Calf actual and adjusted weaning weight, calf BW gain, ADG, and calf value at weaning were greater ($P < 0.05$) from SNE100 compared with S75 although sale price was greater ($P < 0.05$) from S75 compared with SNE100. Daily BW gains by calves in this study were comparable across treatments with that previously reported by spring-born calves grazing E+ or NE+ (Coffey et al., 2007).

**Cow Serum Prolactin, NEFA, and Mineral Concentrations**

Serum prolactin concentrations at the start of breeding and at the end of the breeding season were greater ($P < 0.05$) from spring-calving cows compared with fall-calving cows (Table 6). Concentrations of prolactin at breeding were greater ($P < 0.05$) from S75 and F75 compared with S100 and F100 and were greater ($P < 0.05$) at end breeding from SNE100 compared with S75. The calving season × NE+ % interaction also affected ($P < 0.05$) serum prolactin concentrations at the start of breeding. Although concentrations of prolactin varied from fall-calving compared with spring-calving cows, and depressed concentrations of prolactin are usually associated with tall fescue toxicosis (Paterson et al., 1995), this observed difference between fall and spring-calving cows is more likely a function of season, because con-
centrations of prolactin increase with increasing day-
light (Stanisiewski et al., 1988). However, within calv-
ing season, allowing cows access to NE+ before breed-
ing appears to mitigate the negative effects of E+ on
concentrations of prolactin. These findings are similar
to those reported by Coblentz et al. (2006), who reported
increased concentrations of prolactin from cows grazing
bermudagrass pastures mixed with either orchardgrass
or E– compared with those grazing E+ pastures diluted
with 50% bermudagrass.

At the start of the breeding season, concentrations of NEFA were greater ($P < 0.05$) from F75 and S75 compared with F100 and S100 and were greater ($P < 0.05$) from S75 compared with SNE100. A calving sea-
son × NE+ % interaction ($P < 0.05$) affected concentra-
tions of NEFA at the end of breeding. By adding 25% NE+ to the total pasture area, an increase was observed for concentrations of NEFA from S75 compared with S100, but a decrease in concentrations of NEFA was observed from F75 compared with F100. Therefore, moving spring-calving cows back to E+ before the end of the breeding season may cause more fat to be catabo-
lized than keeping them on E+, but the inverse is true for fall-calving cows.

Serum Fe concentrations at breeding, at the end of
breeding, and change during breeding did not differ ($P 
$≥ 0.28) across treatments (Table 6). Serum Zn and Cu
concentrations at breeding, Zn concentrations at the end
of breeding, and change in serum Zn concentrations
during breeding were greater ($P < 0.05$) from spring-
calving compared with fall-calving cows. Serum Cu
concentrations at the end of breeding and change in
er serum Cu during breeding were greater ($P < 0.05$)
from fall-calving compared with spring-calving cows.
Serum Cu concentrations at the end of breeding were
also greater ($P < 0.05$) from SNE100 compared with
S75. Serum Zn and Cu concentrations across treatments
were at concentrations that would not be considered de-
cicient (Underwood and Suttle, 1999), and cows should
not be immunocompromised due to Cu deficiency
(Stabel et al., 1993).

In summary, fall-calving cows have greater perform-
ance when grazing E+ compared with spring-calving
cows grazing E+. The performance differences between fall- and spring-calving cows may be attributed to lower
environmental temperatures and (or) toxin concentra-
tions during critical times of the year when cow produc-
tion requirements are greatest. Furthermore, limited use
of NE+ during the grazing season may improve cow

| Table 6. Serum prolactin, NEFA, and mineral concentrations from spring- and fall-calving cows grazing pastures of which all of the acreage (S100 or F100), 75% of the acreage (S75 or F75), or none of the acreage (SNE100) was ergot-alkaloid producing *N. coenophialum*-infected tall fescue, and the remainder was nontoxic, novel-endophyte-infected tall fescue |
|-----------------------------------------------|-----------|
| Item                                          | Treatment |
|                                               | F100  | F75  | SNE100 | S100  | S75  | SEM\(^1\) | Contrast\(^2\) |
| Serum prolactin, ng/mL                       |        |      |        |       |      |          |              |
| Start of breeding                            | 1     | 28   | 138    | 14    | 140  | 17.6     | W, X, Z       |
| End of breeding                              | 26    | 12   | 149    | 43    | 52   | 9.2      | W, Y          |
| Serum NEFA, uEq/L                            |        |      |        |       |      |          |              |
| Start of breeding                            | 558   | 807  | 468    | 487   | 701  | 71.3     | X, Y          |
| End of breeding                              | 668   | 517  | 593    | 570   | 666  | 69.4     | Z             |
| Serum mineral, mg/L                          |        |      |        |       |      |          |              |
| Start of breeding                            |        |      |        |       |      |          |              |
| Fe                                            | 1.7   | 1.7  | 2.0    | 2.0   | 2.1  | 0.87     | ns            |
| Zn                                            | 1.6   | 1.6  | 1.9    | 1.9   | 1.9  | 0.29     | W             |
| Cu                                            | 0.48  | 0.46 | 0.67   | 0.65  | 0.62 | 0.098    | W             |
| End of breeding                              |        |      |        |       |      |          |              |
| Fe                                            | 3.3   | 3.4  | 3.9    | 3.5   | 4.3  | 1.90     | ns            |
| Zn                                            | 1.6   | 1.6  | 3.7    | 3.1   | 3.2  | 1.04     | W             |
| Cu                                            | 0.64  | 0.64 | 0.56   | 0.43  | 0.46 | 0.051    | W, Y          |
| Change during breeding\(^3\)                 |        |      |        |       |      |          |              |
| Fe                                            | 1.50  | 1.80 | 1.90   | 1.20  | 2.50 | 1.380    | ns            |
| Zn                                            | –0.04 | –0.05| 1.80   | 1.13  | 1.20 | 1.074    | W             |
| Cu                                            | 0.16  | 0.18 | –0.10  | –0.20 | –0.15| 0.140    | W             |

\(^1\)SEM = Pooled SEM.
\(^2\)Contrasts: W = mean of fall-calving cows compared with the mean of spring-calving cows ($P < 0.05$), X = mean of S75 and F75 compared with the mean of S100 and F100 ($P < 0.05$), Y = SNE100 compared with S75 ($P < 0.05$), Z = the interaction between spring- and fall-calving cows in their response to having 25% of their pasture area as nontoxic, endophyte-infected tall fescue ($P < 0.05$). Lowercase letters represent statistical tendencies ($P < 0.10$); ns = no significant difference ($P > 0.05$).

\(^3\)Change in serum mineral concentrations during their respective 63-d breeding season.
weight at weaning, calf weight through weaning, and may increase calving rates of spring-calving cows by offsetting some of the negative impacts associated with grazing E+ during times of the year when tall fescue toxicosis is more severely manifested.

Based on these results, producers with predominantly E+ pastures may benefit from using fall-calving cows rather than spring-calving cows, resulting in better cow performance and heavier calves with greater value at weaning which would benefit producers selling in a cash market. Limited use of NE+ may benefit calving rates of spring-calving cows by providing those cows with nontoxic forage at the early stages of the breeding season, thereby resulting in reduced impacts of toxins consumed previously from E+ pastures. This resulted in more calves and more BW to sell from those cows.

**LITERATURE CITED**


