Productivity of cow–calf pairs grazing tall fescue pastures infected with either the wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542[1,2]

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ABSTRACT: The nonergot alkaloid-producing endophyte, AR542, has been shown to improve the persistence and yield of tall fescue pastures without causing the animal disorders commonly associated with tall fescue toxicosis. A 3-yr grazing study was conducted to compare effects of AR542-infected tall fescue pastures with wild type endophyte-infected (E+) tall fescue pastures on cow–calf performance. Replicated 7.3-ha pastures of each treatment were grazed by cow–calf pairs (16 pairs per pasture replication) each year from March to weaning in September. The cows were exposed to breeding on their respective pasture treatments from April 1 through June 15. The treatment groups were compared for reproductive performance, ADG, BCS, calf growth rate, and weaning weight. Blood samples were also collected for serum prolactin (PRL) analysis. There were no significant differences in calving rate ($P = 0.98$) or calving interval ($P = 0.62$) between pasture treatments. Cows that grazed the AR542 pastures subsequently gave birth to calves that were heavier ($P < 0.05$) than calves from cows that had grazed the E+ pastures. Cows grazing the AR542 pastures had higher ($P < 0.05$) BCS at the end of the grazing period, and had higher ADG during the grazing period. Calves raised on the AR542 pasture had higher ($P < 0.05$) ADG and weaning weights than calves of the same sex raised on the E+ pastures. Serum PRL concentrations were decreased ($P < 0.05$) in both cows and calves on the E+ pastures compared with serum PRL concentrations in cows and calves grazing the AR542 pastures. The results indicate that grazing tall fescue pastures infected with the AR542 endophyte may give significant advantages in cow–calf growth rates and BCS over grazing E+ pastures. However, there did not seem to be any benefit in reproductive performance in this trial. There was a small, but significant increase in birth weight in cows grazing AR542 pasture.

Key Words: Beef Cattle, Cow–Calf, Endophytes, Ergot Alkaloids, *Festuca arundinacea*, Grazing

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Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is a cool-season perennial grass that is well adapted for grazing, and is one of the most widely grown introduced forage grass species in the United States. Most tall fescue pastures are infected with the fungal endophyte, *Neotyphodium coenophialum*, which produces metabolites that are toxic to grazing animals. Cow-calf pairs grazing wild-type endophyte-infected (**E+**) tall fescue often exhibit signs of toxicosis, including decreased calf growth rate and milk production (Peters et al., 1992), reduced pregnancy rate (Gay et al., 1988), hypothermia, and reduced serum prolactin (**PRL**; Oliver, 1997). The use of endophyte-free (**E**–) tall fescue avoids toxicosis problems; however, E– plant persistence, and hence DM yields, are often inferior to E+ pastures, and they often will not survive under grazing in the southeastern United States (Bouton et al., 1993).

Naturally occurring endophyte strains have been found that do not produce ergot alkaloids, which are thought to be the major compounds responsible for fes-

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cue toxicosis, but have retained the ability to foster improved plant persistence. It is possible that these endophyte strains offer a solution to the tall fescue problem. One endophyte strain, AR542, has been incorporated into Jesup and Georgia-5 tall fescue cultivars and found to give similar plant yield and persistence to E+ plants (Bouton et al., 2002). It has also been shown that the performance by sheep and stocker cattle grazing AR542-infected pastures is similar to that of animals grazing E– pastures, and that these animals show no signs of fescue toxicosis (Parish et al., 2003a,b). Given the importance of tall fescue-based pastures to cow–calf production in the southeastern United States, the next step was to evaluate the AR542 endophyte/tall fescue association in cow–calf production systems. The current study aims to compare performance of cow–calf pairs grazing either wild-type or AR542-infected tall fescue pastures.

Materials and Methods

Treatment Pastures

Two pasture treatments, Georgia-5 AR542 endophyte-infected tall fescue (AR542) and Georgia-5 wild-type endophyte-infected tall fescue (E+) were compared for the performance of cow–calf pairs each year for 3 yr. Two 7.3-ha paddock replicates of each treatment were sown in the fall of 1999 at the Northwest Georgia Research and Education Center, near Calhoun, GA (lat 34.5577°N; long 84.8158°W; elevation 209 m). The seed was no-till drilled at a rate of 33.6 kg/ha into a herbicide-treated (2.5 L/ha 41% glyphosate (Roundup, Monsanto, St. Louis, MO) pasture that had been sown in successive crops of cotton, corn, and soybean until 1996, followed by bermudagrass (*Cynodon dactylon*) and E– tall fescue pasture until the year of treatment pasture establishment. The soil type was a Sequatchie loam, and soil tests indicated medium to high fertility (pH was 5.9, and extractable levels of, P, K, Ca, and Mg were 47, 210, 1,662, and 214 kg/ha, respectively). All pastures were fertilized with 67 kg of N/ha 1 wk after sowing and subsequently each year in two 67 kg of N/ha applications in February and July.

Animals and Grazing Management

The cattle in these studies were managed under protocol A2000-10092 approved by the University of Georgia Animal Care and Use Committee. Cow–calf pairs used in the trial were selected each year from the Northwest Georgia Research Station purebred Angus cow herd. The herd had no previous exposure to toxic tall fescue. In yr 1, 64 cow–calf pairs were selected and allocated to four even groups that were balanced for cow age (average age = 6.5 yr, range 3 to 10 yr), weight (average = 470 kg), BCS (average = 5.8), calving date, calf sex, and calf weight. The average age structure, initial BW, and BCS of the treatment groups were not significantly different between years so means reported for these variables are pooled across years. In yr 2, the cow–calf groups consisted of eight pairs that had grazed the same treatment/replicate in yr 1, and eight pairs that had not previously been in the trial. The eight pairs that were on their respective treatment/replicates for yr 1 and 2 were included to look at possible effects of long-term exposure to the endophyte treatments, with the intention that similar animals grazing the endophyte treatments in yr 3 would be carried over into a fourth year. However, the grazing study was terminated after yr 3, preventing the completion of the long-term exposure component. Therefore, animals that received 2 yr of treatment exposure were excluded from the analysis in this study. In yr 3, cow–calf pairs were selected in the same manner as yr 1, with no previous exposure to treatment pastures or toxic tall fescue. In addition to the 16 tester animals in each group, other cow–calf pairs were designated as grazers to be added or removed under put-and-take grazing management to ensure forage supply was equal between groups. Pregrazing forage availability was similar between reps and treatments each year, so an additional four cow–calf grazer pairs were included with each rep from the end of March through June 15th (removal of the bull) each year to control excess spring forage production.

Each group was randomly allocated and introduced to a pasture treatment/replicate at the end of March. Angus bulls that had passed a recent breeding soundness evaluation were introduced to each group (one bull per group) on April 1 and remained with the group until June 15 each year. It was not determined whether all cows were cyclic at the start of mating.

The calves were weaned at the end of August each year and removed from the treatment pastures. The groups were given free access to water and a mineral supplement block (Vigortone 35S, Madison Farm Supply, Madison, GA) at all times (Table 1). Cows were tagged (two per cow) with a Patriot insecticidal (active ingredient 40% Diazinon) fly tag (Boehringer Ingelheim, St. Joseph, MO) and dosed with Eprinex pour-on (active ingredient eprinomectin per milliliter; Merial, Duluth, GA) at a rate of 1 mL/10 kg BW for internal parasite control in late May each year. The calves were also treated at approximately 120 d of age with Eprinex pour-on at a rate of 1 mL/10 kg BW, and vaccinated with 2 mL (s.c.) Alpha-7, 7-way clostridial vaccine (Boehringer Ingelheim). All cows were given Vibrio-Lepto vaccinations (5mL, i.m.) 3 wk before breeding (Vibrio-Lepto5, Agrilabs, St. Joseph, MO). All the cows were grouped together during calving on E– tall fescue pasture and supplemented with E– tall fescue hay.

Data Collection

Available forage and forage growth rate were determined by 0.09-m^2 quadrat cuts taken before grazing and subsequently each month from grazed areas (n =

Table 1. Composition of mineral block supplement[a]

Item	As-fed basis
Calcium, minimum, %	12.00
Calcium, maximum, %	14.00
Phosphorus, minimum, %	8.00
NaCl, minimum, %	12.00
NaCl, maximum, %	14.00
Magnesium, minimum, %	0
Potassium, minimum, %	1.60
Sulfur, minimum, %	1.50
Fluorine, maximum, %	0.08
Cobalt, minimum, ppm	60
Iodine, minimum, ppm	50
Iron, minimum, ppm	6,000
Manganese, minimum, ppm	1,900
Selenium, minimum, ppm	20
Zinc, minimum, ppm	2,800
Vitamin A, minimum, IU/kg	661,387
Vitamin D3, minimum, IU/kg	220,462
Vitamin E, minimum, IU/kg	220

[a]Blocks supplied by Madison Farm Supply, Madison, GA.

Table 2. Forage endophyte infection rates, mean ergot alkaloid concentration, mean available forage, and mean forage growth rate in the wild-type endophyte-infected (E+) and AR542-infected tall fescue pastures

	Pasture treatment		
Item	E+	AR542	SEM
Endophyte infection, %[c]	70[a]	85[b]	5
Ergot alkaloid concentration, ppb[cd]	448[a]	0[b]	—
Available forage, kg DM/ha[e]	1395	1353	126
Forage growth rate, kg DM·ha^{-1}·d^{-1} [e]	29.7	27.4	10.1

[a,b]Row means with different superscripts differ, $P < 0.05$.
[c]Represents 3,600 tall fescue tiller samples pooled within treatment and across years.
[d]Data were subjected to root transformation for statistical analysis. Untransformed means are reported.
[e]Represents 360 pasture quadrate samples pooled within treatment and across years.

15) and under grazing exclusion cages (n = 5) in each pasture. The forage samples were oven dried at 60°C, and weighed to determine kilograms of DM per hectare. Monthly tall fescue tiller samples (n = 10) were taken randomly from the grazed area in each pasture to determine endophyte infection rate using the immunoblot procedure of Hiatt et al. (1997), and ergot alkaloid concentration using ELISA procedures described by Adcock et al. (1997).

Each year, all cows and calves were weighed the day before introduction to the treatment pastures, and subsequently at the end of mating, and at calf weaning. On each weigh date, cows were visually assessed for BCS using a 1-to-9 scale (1 = emaciated, 9 = extremely fat; Richards et al., 1986) using the same trained observers each time to maintain consistency, and 5 mL of blood was drawn from cows and calves via caudal venipuncture for serum PRL analysis. Calves were not bled on pretreatment weigh dates due to their small size and the stress associated with handling. Blood samples were centrifuged at 3,000 × g for 20 min. The serum was then harvested and stored at –20°C before PRL analysis using the procedure described by Lipham et al. (1992). The intraassay and interassay CV were 11 and 9%, respectively. The cows were examined by rectal palpation by a trained veterinarian each year in September to determine pregnancy rate and then monitored at calving for calving date, calving rate, and calf birth weight.

Statistical Analyses

Forage and animal data, except calving rate and BCS, were analyzed using PROC GLM/LSMEANS procedures of SAS (SAS Inst., Inc., Cary, NC). A complete randomized experimental design was used, with paddock as the experimental unit. Available forage, alkaloid concentrations, cow BW, and serum PRL concentrations were analyzed with endophyte treatment, year, replication, and their interactions included in the model. Means of pasture alkaloid concentrations showed nonhomogenity among their variances due to near zero values in one treatment being compared with values in the hundreds for the other treatment. These data were subjected to square-root transformation before analyses were performed. Calving rate and BCS were analyzed by χ^2 test using the GENMOD function of SAS, with endophyte treatment, year, and replication in the model. Calf weight, ADG, and serum PRL concentrations were analyzed with endophyte treatment, year, replication, sex, and their interaction included in the model.

Results

Year and replication were not significant sources of variation in any of the forage variables measured. Therefore, least squares means presented are pooled within treatment across years and replications. Endophyte infection rate did not differ (P = 0.79) within treatment during the three trial years. Infection rate was lower (P < 0.05) in the E+ pasture than the AR542 pasture. Total ergot alkaloid concentrations during the grazing period (March to September) were greater (P < 0.05) in the E+ pasture than in the AR542 pasture. Ergot alkaloid concentrations in the AR542 pasture were below assay detection concentrations on all but two occasions when trace concentrations were detected. Under the put-and-take grazing system, available forage (P = 0.75) and forage growth rate (P = 0.68) did not differ between treatment pastures (Table 2).

Year and replication did not affect any of the cow variables measured. Pasture treatments did not differ for calving rate (P = 0.98) or calving interval (length of time in d from the birth of one calf to the birth of the subsequent calf) (P = 0.76). Calves born to cows that had been grazing the AR542 pasture were heavier (P < 0.05) at birth than calves born to cows that had been

Table 3. Calving rate, calving interval, calf birth weight, ADG, and change in body condition score of cows that grazed either wild-type endophyte-infected (E+) or AR542-infected tall fescue pasture

	Pasture treatment		
Item	E+	AR542	SEM
No. of cows[c]	96	96	—
Calving rate, %	94	94	2.0
Calving interval, d	341	350	21
Birth weight, kg	32.7[a]	38.6[b]	1.9
ADG, kg	0.12[a]	0.29[b]	0.02
Change in BCS	0[a]	0.4[b]	0.1

[a,b]Row means with different superscripts differ, $P < 0.05$.
[c]Represents total number of cows within each treatment across the 3-yr trial.

grazing the E+ treatment. All cows either maintained or gained weight and BCS during the grazing period; however, weight and BCS gain were greater ($P < 0.05$) in cows grazing the AR542 pasture (Table 3).

Year and replication were not significant sources of variation in calf ADG or weaning weight (adjusted to 205 d of age). Calf sex affected ADG and weaning weight, with steer calves growing faster ($P < 0.05$) and weighing more at weaning ($P < 0.05$) than heifer calves within the same treatment group. Calves on the AR542 pasture treatment had greater ($P < 0.05$) growth rate and weaning weight compared with calves of the same sex on the E+ pasture treatment. There was no interaction ($P = 0.50$) between calf sex and treatment (Table 4).

Serum PRL in the cows was not affected by year ($P = 0.44$) or replication ($P = 0.74$). Pretreatment PRL concentrations were similar between cows in the E+ group and cows in the AR542 group. During the treatment grazing period, PRL concentrations were lower ($P < 0.05$) in the E+ group (Table 5). Serum PRL in the calves was not affected by replication ($P = 0.67$) or calf sex ($P = 0.34$), but it was affected by year and treatment. Calf PRL concentrations were greater ($P < 0.05$) in yr 2 and 3 than in yr 1 within a treatment group, and were greater ($P < 0.05$) in AR542 calves than in E+ calves in all years. There was no interaction ($P = 0.67$) between year and treatment (Table 6).

Table 5. Serum prolactin (PRL) concentrations in cows at pre-treatment and while grazing either wild-type endophyte-infected (E+) or AR542-infected tall fescue pasture

	Pasture treatment		
Serum PRL, ng/mL	E+	AR542	SEM
No. of cows[c]	96	96	—
Pretreatment	67	54	11
During treatment grazing	40[a]	142[b]	16

[a,b]Row means with different superscripts differ, $P < 0.05$.
[c]Represents the total number of cows within each treatment across the 3-yr trial.

Discussion

The objective of the present trial was to compare the performance of cow–calf pairs grazing either E+ or AR542-infected tall fescue pastures to determine the efficacy of using a nonergot alkaloid-producing endophyte (AR542) to alleviate the poor animal performance associated with grazing E+ tall fescue. This trial was limited by the exclusion of an E– tall fescue treatment, which would have set an animal performance benchmark against which the AR542 treatment and E+ treatment could be compared. However, recent studies have already demonstrated that animal performance in lambs and stocker cattle grazing AR542-infected tall fescue is not significantly different from E- tall fescue, and that there was no evidence of toxicosis (Parish et al., 2003a,b). Therefore, rather than consider a cow–calf trial from a toxicosis standpoint, which would necessitate an E– treatment, the current study was designed to determine to what extent cow–calf performance is improved by using the AR542 endophyte relative to the wild-type endophyte.

The major mechanism for improving animal performance using the nonergot alkaloid-producing endophytes is likely a combination of increased persistence (Bouton et al., 2002) and increased forage DMI (Parish et al., 2003b). Although neither stand persistence nor animal intake data were collected in this trial, DM production suggested that the AR542 treatments were as productive during the 3-yr trial period as E+ treatments, indicating no stand loss relative to the E+. Over-

Table 4. Average daily gain and weaning weight of steer and heifer suckling calves grazing either wild-type endophyte-infected (E+) or AR542-infected tall fescue pasture

	Steer calves		Heifer calves		
Item	E+	AR542	E+	AR542	SEM
No. of calves[d]	44	44	52	52	—
ADG, kg	0.97[a]	1.15[b]	0.9[c]	1.03[a]	0.02
Weaning weight, kg[e]	227.3[a]	255.5[b]	217.0[c]	236.8[a]	6.2

[a,b,c]Row means with different superscripts differ, $P < 0.05$.
[d]Represents the total number of calves within each treatment across the 3-yr trial.
[e]Weaning weight was adjusted to an average calf age of 205 d.

Table 6. Serum prolactin (PRL) concentrations in suckling-calves grazing either wild-type endophyte-infected (E+) or AR542-infected tall fescue pasture in each of the three trial years

	Posttreatment serum PRL concentration, ng/mL		
	Pasture treatment		
Year	E+	AR542	SEM
No. of calves each year[c]	32	32	—
1[d]	16[a]	50[b]	8
2	31[a]	119[b]	15
3	55[a]	165[b]	21

[a,b]Row means with different superscripts differ, $P < 0.05$.
[c]Represents the total number of calves within each treatment each year.
[d]Serum PRL concentrations were lower ($P < 0.05$) within a treatment group in yr 1.

all available forage levels and DM growth rates were also similar to other cattle studies using the nonergot alkaloid-producing endophyte (Parish et al., 2003b).

Nonetheless, it should be noted that the greater palatability of tall fescue infected with the nonergot alkaloid-producing endophytes compared with E+ tall fescue could lead to overgrazing when animals are stocked under continuous grazing during periods of low growth rate, such as the summer. Where overgrazing occurs, the long-term benefits of using these nonergot alkaloid-producing endophytes strains may be decreased.

Reproductive performance was not affected by treatment in the present trial, with the exception of a small reduction in birth weight in the E+ cows. There are conflicting reports on the effect of grazing E+ tall fescue on reproductive performance of the beef cow. Although some studies have observed moderate to severe reductions in pregnancy and calving rates (Gay et al., 1988; Brown et al., 1992; Porter and Thompson, 1992), others have failed to observe any reduction (Mahmood et al., 1994; Rorie et al., 1998; Burke et al., 2001). It seems that reproductive dysfunction may only be evident when a certain set of conditions prevail, which may include factors such as climate, cow genetics, alkaloid concentrations, and nutritional management. It is possible that the reproductive system of the cow is often robust enough to withstand the effects of grazing E+ tall fescue even when other symptoms such as decreased PRL and BW gain are evident. Fanning et al. (1992) observed this in a study with heifers fed E+ tall fescue, which exhibited decreased serum PRL and weight gain without any negative effect on reproductive performance. This also seemed to be the case in the current study, as reproductive performance was generally good in both the E+ and AR542 groups despite lower BW gain, condition score, and serum PRL in the E+ group, indicating that toxicosis was present. The potential for reproductive performance to be adversely affected in the E+ cows may have been decreased by mating in the cooler spring period, by relatively low endophyte infection rates and alkaloid concentrations in the E+ pastures, and by the fact that the E+ cows were generally in good condition and gained weight over the trial period. The cows used in the trial were also sourced from a herd that had no previous exposure to endophyte toxins, which would eliminate any possible adverse effects on reproduction as a result of chronic exposure to E+ tall fescue. Therefore, it is likely that this trial did not demonstrate the full potential benefit of using tall fescue infected with nonergot alkaloid-producing endophyte strains to improve reproductive performance in cattle that would otherwise be grazing E+ tall fescue. Many cow–calf producers in the southeastern United States are faced with higher endophyte levels in their E+ fescue pastures, practice autumn mating and calving after exposure to higher alkaloid levels during the summer, and have herds that have suffered chronic exposure to E+ tall fescue, all of which could greatly increase the severity and likelihood of reproductive dysfunction.

One aspect of cow reproductive performance that was affected by pasture treatment was the birth weight of their calves. Cows that grazed the E+ treatment gave birth to calves that were 5 kg lighter than calves born to cows that grazed the AR542 treatment. This is consistent with the findings of Bolt and Bond (1989), who reported that pregnant heifers grazing E+ tall fescue from d 155 of gestation through to parturition gave birth to lighter calves than heifers grazing E– tall fescue. Cows in the current study were removed from the treatment pastures as early as 90 d before parturition, excluding them from exposure to the treatments during the period of greatest fetal growth; however, it seems that there was significant enough exposure during gestation to affect the subsequent birth weight of the calf. This lower birth weight may be linked to the poorer weight gains and BCS in the E+ cows. Lower birth weights in livestock may also be linked to a decrease in uterine blood flow caused by the ergot alkaloids present in the E+ tall fescue (Porter and Thompson, 1992). From a production standpoint, lower birth weights may be desirable for reducing dystocia within a herd, as long as negative effects on calf viability and growth rate are not large.

The greatest benefit of grazing the AR542-infected pasture was the improvement in calf growth rate and subsequent weaning weight. After reproductive performance, live weight gain by calves and ultimate weaning weight are the most important economic factors to cow–calf producers. The higher weaning weights of the calves would provide a significant increase in income generated per cow, and across the whole herd, and more than offset the cost of establishing new pastures.

Lower growth rate in the calves on the E+ treatment may have been due to lower milk production in the cow, lower forage intake in the calf, or a combination of these two factors. Neither milk production nor DMI were measured in this trial; however, these two factors are often decreased in cattle grazing E+ tall fescue (Howard et al., 1992; Peters et al., 1992; Brown et al., 1993). Although this offers the most plausible explanation for the reduction in calf growth rate, possible direct effects of ergot alkaloids on calf growth cannot be ruled out.

Serum PRL concentrations in the calves grazing the E+ pasture were significantly lower than concentrations in the AR542 calves. This indicates that some degree of fescue toxicosis was evident in the E+ calves, and that significant concentrations of ergot alkaloids were being ingested. It is likely that the major source of ergot alkaloids was through the direct consumption of forage, although alkaloid concentrations were not measured in the milk and this cannot be ruled out as another potential source for ergot alkaloid ingestion by the calf.

Serum PRL and growth rate data show that calves may suffer the effects of grazing E+ pasture from very early in life. Possible long-term and carryover effects of grazing toxic fescue have not been clearly identified or quantified. However, it is possible that this early exposure to endophyte toxins may permanently impair development of calves later in life. It has been shown that stocker cattle moved to the feed lot and fed a grain diet after grazing toxic fescue did not recover production losses (Duckett et al., 2001). This finding indicates a possible carryover effect associated with grazing toxic fescue. Such carryover effects in calves could compound production losses associated with stocker cattle phase of the production system, or decrease the subsequent performance of replacement heifers.

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