Journal of Agricultural and Applied Economics, 44,4(November 2012):577–592

Tall Fescue Toxicosis Mitigation Strategies: Comparisons of Cow-Calf Returns in Spring- and Fall-Calving Herds

Stephen A. Smith, James D. Caldwell, Michael P. Popp, Kenneth P. Coffey, John A. Jennings, Mary C. Savin, and Charles F. Rosenkrans, Jr.

Tall fescue toxicosis adversely affects calving rate and weight gains reducing returns to cow-calf producers in the south–central United States. This grazing study estimated animal and economic performance implications of endophyte-infected fescue and calving season. Establishing novel endophyte-infected tall fescue on 25% of pasture acres resulted in improved calving rates (87% vs. 70%), weaning weights (532 lbs vs. 513 lbs), and partial returns per acre ($257 vs. $217). Additionally, fall-calving cows had higher calving rates (91% vs. 67%), weaning weights (550 lbs vs. 496 lbs), and partial returns per acre ($269 vs. $199) than spring calving cows.

Key Words: calving rates, calving season, endophyte-infected tall fescue, novel endophyte-infected tall fescue, and partial returns analysis

JEL Classifications: Q10, Q15, Q19

Tall fescue (*Lolium arundinaceum* [Schreb.] Darbysh) is a common cool-season grass grown in temperate climates and is one of the most abundant forage crops in the United States with over 8.5 million cattle grazing tall fescue pastures (Hoveland, 1993). Tall fescue is desirable to cow-calf producers as a result of ease of establishment, persistence, range of adaptation, length of grazing season, pest resistance, and tolerance to poor management (Stuedemann and Hoveland, 1988). Although tall fescue's agronomic characteristics are excellent, animal performance, based on nutritional analysis, has not been as great as expected and can result in symptoms of toxicity (often called summer syndrome or fescue toxicosis; Buckner, Powell, and Frakes, 1979). Toxicosis, for cow-calf operations, results in two primary adverse affects,

Stephen A. Smith is a Ph.D. student and Michael P. Popp is a professor, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, Arkansas. James D. Caldwell is an assistant professor, Department of Agriculture, Lincoln University, Jefferson City, Missouri. Kenneth P. Coffey and Charles F. Rosenkrans, Jr. are professors, Department of Animal Science at the University of Arkansas, Fayetteville, Arkansas. John A. Jennings is a professor, Animal Science, University of Arkansas Cooperative Extension Service in Little Rock, Arkansas. Mary C. Savin is a professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, Arkansas.

This project was supported by the National Research Initiative of the National Institute of Food and Agriculture, USDA, grant #2006-55618-17114.

We appreciate the efforts of D. Philipp, A.N. Young, J.D. Tucker, D.S. Hubbell III, T. Hess, M.L. Looper, C.P. West, D.L. Kreider, and D. Hallford who were involved with the biological experiment.

reduced weight gain in calves and decreased calving rate (defined as the number of calves weaned per cow exposed to a bull), which adversely impact producer net returns. Losses to producers in the United States resulting from fescue toxicosis have been estimated to be $1 billion annually (Strickland et al., 2011).

Toxicosis has been attributed to tall fescue pastures being infected with *Neotyphodium coenophilalum*, a microscopic fungus, often referred to as an endophyte because it grows within the tall fescue plant (Roberts and Andrae, 2004). Ergot alkaloids such as clavine alkaloids, lysergic acid amides, and ergopeptines (Bacon et al., 1977) produced by this endophytic fungus are believed to be the cause of toxicosis with ergopeptine alkaloids generally considered the primary agent. These ergot alkaloids are highly concentrated in the seed; however, they are also present in the leaves and stems (Rottinghaus et al., 1991). Concentrations of ergovaline are greatest in late spring and early fall (when seed heads are present; Rottinghaus et al., 1991). Cattle can retain ergot alkaloids in fat tissues (Realini et al., 2005). Fat reservoirs containing toxic alkaloids may partially explain (along with higher temperatures) why visual symptoms of toxicosis in the summer and fall do not coincide with ingestion of tall fescue containing the highest concentrations of ergovaline in the spring. A more detailed description of symptoms is described in Gay et al. (1988), Porter and Thompson (1992), and Strickland, Oliver, and Cross (1993).

Eradicating E+ from pastures and replacing it with endophyte-free tall fescue (E–), nontoxic, novel-endophyte tall fescue (NE+), or alternative cool-season grasses are considered viable options for addressing toxicosis. Although E– fescue eliminates toxicosis in cattle, improves weight gain, and reproductive performance, it comes at the cost of more difficult pasture establishment, weaker stand resistance to drought, insects and overgrazing as well as poor competition with other forages and weeds (Malinowski and Belesky, 2000). Novel endophyte cultivars were thus developed by removing the common endophyte and replacing it with a new beneficial endophyte, producing no ergot alkaloids to remove deleterious toxicosis effects on cattle while at the same time attempting to maintain the beneficial agronomic traits (Bouton et al., 2002; Vibart et al., 2008). Still, replacement of E+ pastures with nontoxic forages can be challenging in pastures with shallow soils that are prone to erosion and have poor water-holding capacity and may thus not be economically feasible in some locations (Coblentz et al., 2006a, 2006b). Management techniques such as livestock rotations at key times in the year, dilution of tall fescue by interseeding perennials such as legumes, fertilizing pastures with low rates of nitrogen, ammonization of toxic fescue hay, and controlling seed heads in the field have been shown to lessen the impacts of toxicosis in cattle (Roberts and Andrae, 2004). Vaccinations or supplements to counter the effects of fescue toxicosis continue to be researched; however, at present, no such solution has been found.

With approximately 35 million acres of primarily E+ tall fescue in the southeastern region of the United States, the impact of fescue toxicosis on breeding rate (Beers and Piper, 1987; Boling, 1985; Coblentz et al., 2006a, 2006b; Coffey et al., 2007; Gay et al., 1988; Peters et al., 1992; Schmidt et al., 1986; Washburn and Green, 1991) and animal performance (Coffey et al., 1990, 2008; Cole et al., 1987; Hoveland et al., 1983; Peters et al., 1992; Schmidt and Osborn, 1993) has been well established in the literature (Table 1). Economic analyses to date have been predominantly limited to net returns from stocker animals (Beck et al., 2008; Burton et al., 1994) and cost of NE+ or E– establishment (Gunter and Beck, 2004; Zhuang et al., 2005). Gunter and Beck (2004) estimated net returns to producers for E+ pastures to be $53.93 per acre, compared with $80.41 per acre for NE+ pastures for steer stocker calves. Additionally, Gunter and Beck (2004) estimated eradication of E+ pastures and establishment of NE+ tall fescue pastures to cost $150.29 per acre, which would be prorated over an as yet unknown useful life of NE+. Zhuang et al. (2005) found that cow-calf producer gross revenue diminished from $198 per acre to $92.66 per acre as infestation level increased from 0–100%. Additionally, they estimated re-establishment benefits

Table 1. Calving Rates from Studies Comparing Endophyte-Infected Tall Fescue to Other Pastures

	Calving Rate[a]			
Source	E+	Other	Other Pasture Type[b]	Animal Type
Boling, 1985	67%	86%	Low endophyte	Cows
Schmidt et al., 1986	55%	96%	Low endophyte	Heifers
Beers and Piper, 1987	80%	90%	Low endophyte	Heifers
Gay et al., 1988	55%	95%	Endophyte-free	Cows
Washburn and Green, 1991	39%	65%	Low endophyte	Heifers
Peters et al., 1992	72%	91% and 75%	Orchardgrass and endophyte-free	Cows
Coblentz et al., 2006b	83%	81.7–92.5%	Orchardgrass and endophyte-free[c]	Cows

[a] Calving rate includes pregnancy rates depending on the methodology for determining open cows for each study (pregnancy testing or observed calving).
[b] Low endophyte-infected fescue are stands that have less than 5% infection rates.
[c] All cool-season forages were overseeded into bermudagrass pastures and contained 28 to 58% bermudagrass.

ranging from $6.84 to $105.94 per acre as infestation increased from 0–100%. As such they concluded that E+ infestation levels greater than 74% (at a stocking rate of two head per acre) should prompt pasture improvement to nontoxic species, although that threshold infestation level was indirectly, and mostly so, affected by stocking rates.

Because cow-calf producer returns are largely determined by reproductive performance of cows, calf weight gain, and forage production, this study was conducted to estimate economic effects of modifying the timing of exposure to E+ fescue. In essence, this was done by modifying calving season such that ergovaline exposure occurs at different stages in the annual cow-calf production cycle. In addition, an alternative to complete replacement of E+ with NE+ pastures was analyzed to determine the tradeoff of improved cattle performance (greatest with 100% NE+ vs. 25% NE+ vs. least with 0% NE+) with forage benefits that would be greatest with 0% NE+ and least with 100% NE+. In particular, this analysis provides estimates of changes in partial returns (PR) per head and per acre producers could anticipate when changing calving season (spring or fall) and/or adopting NE+ at varying levels holding all other practices like cattle genetics and rotational grazing management constant. Treatment effects were monitored by tracking treatment differences in 1) calf weights valued at 10-year average cash market prices at time of weaning; 2) reproductive performance tracked through calving rate and associated replacement costs of culled cows and replacement pairs; 3) net hay production (hay produced less hay fed); and 4) differences in treatment specific pasture fertilizer cost. Results provide estimates of the maximum amount a producer can spend annually on NE+ establishment and maintenance for their cow-calf operation.

Materials and Methods

Data in this analysis were based on the results of an empirical study conducted at the University of Arkansas' Livestock and Forestry Research and Extension Station (35°50′ N, 91°48′ W) located near Batesville, AR. The experimental site was 390 acres, divided into 14 pastures ranging in size from 23.0–25.5 acres. The soils were primarily silt loam to very cherty silt loam and of moderate to steep grade (3–40%). Although too data-intensive to test empirically, these pastures are considered representative of pastures in the study area. Furthermore, pasture paddocks were randomized within soil type to the different treatments so that soil type and slope would lead to no treatment differences. The study was initiated in January 2007 for both the spring- and fall-calving herd and included three complete production cycles from breeding through weaning. Both herds were rotationally grazed and cows were randomly selected from the University of Arkansas' commercial Gelbvieh × Angus beef herd and exposed to herd sires of similar genetics for a 63-day breeding period starting the second week of May and the fourth week of November for spring and fall calving herds, respectively.

Three types of tall fescue pasture management were targeted for spring and fall calving cows. The base case scenarios for spring (S0NE) and fall (F0NE) were no pasture improvement, which is common for current producer practice. The first letter in the treatment acronym represents calving season and the remainder details the percentage of NE+ adoption. By default, the remaining portion of each pasture that was not NE+ was a toxic, wild-type E+ pasture. There were three pasture replicates of S0NE, S25NE, F0NE, and F25NE and two replicates of S100NE. A positive control of F100NE was not possible given space and cost limitations. The 25% NE+ options for the fall and spring calving herds involved establishment of separately fenced areas of 100% NE+ on one-fourth of the pasture acres for those treatments to allow selective grazing of 100% NE+ to avoid toxicosis effects at critical times of the year (4 weeks before breeding and 4 weeks before weaning). A secondary benefit of this strategy is that not only animal performance could be improved, but also that grazing stress on more susceptible NE+ stands during the summer would be avoided to enhance agronomic performance of the NE+. The interested reader is referred to Caldwell et al. (2012) regarding details on experimental design, animal herd/health characteristics, pasture establishment, and animal performance pertaining to this study.

With these five treatments, partial returns analysis consisted of three revenue/cost differences as follows: 1) calf weaning weights at attendant seasonal beef value to capture animal performance; 2) cow culling/replacement costs as a result of anticipated differences in calving rate (open cows or cows that lost calves were replaced with cow/calf pairs to maintain stocking rate or grazing pressure); and 3) hay production, hay feed use, and fertilizer cost to summarize agronomic performance.

For purposes of this analysis, fescue toxicosis-related replacement costs included only those animals replaced as a result of breeding failures and those exhibiting fescue foot (Gay et al., 1988; Porter and Thompson, 1992; Strickland, Oliver, and Cross, 1993). Animals replaced as a result of calving difficulties, death losses, or other animal health issues were not considered, because these events were minimal, not related to treatments, and could be affected by many additional factors not tracked in this experiment. Culled cows were weighed in the spring or fall (W_F or W_S) at the time culling occurred (May for the spring herd, November for the fall herds) and adjusted for 3% shrink (S) (United States Department of Agriculture [USDA], 2011c). Transportation, auction, and other sale costs (TC) were estimated to be $20 per head (UACES, 2002). A 10-year average, inflation-adjusted, seasonal sale price for May and November for boning cows in Arkansas was used to estimate cull cow revenue (November $46.89/cwt [$P_F$], May $54.83/cwt [$P_S$]; UACES, 2011). A long run average seasonal price based on anticipated sale time was used to mitigate the effects of cyclically high or low cattle prices that may unduly influence the outcome of this study. Equations 1 and 2 estimate the average revenue per culled cow (CR) in dollars per head for the fall and spring treatments.

$$(1) \qquad CR_F = \frac{\sum_{n=20} W_F*(1-S)*P_F - TC}{n}$$

$$(2) \qquad CR_S = \frac{\sum_{n=83} W_S*(1-S)*P_S - TC}{n}$$

Cow-calf pair prices (PP_F and PP_S) were estimated using 10-year average prices for large and medium frame cows with 100–200 lb calves at foot (November $854.86 per pair, May $924.92 per pair; UACES, 2011). Subtracting PP_F and PP_S from Equations 1 and 2, a cost of replacement cows (RC_F or RC_S) in dollars per head was determined for both fall and spring-calving herds.

$$(3) \qquad RC_F = CR_F - PP_F$$

$$(4) \qquad RC_S = CR_S - PP_S$$

Using this method, fall-calving herd replacement costs were estimated at $341 per head compared with spring-calving costs of $283 per head. This average cost was assigned back to individual pasture treatments on the basis of the number of observed fescue toxicosis-related replacements. Hence, total replacement costs for the spring- and fall-calving herds over the 3-year period were allocated across the total production of calves for each herd to arrive at average replacement cost per weaned calf or per acre of pasture. In essence this removed the annual variation of reproductive effects from the calf performance data because that information was analyzed separately as described subsequently.

Hay costs for each pasture were calculated based on the amount of additional nitrogen (N) fertilizer ($0.20/lb of urea) each pasture received to ensure sufficient yield to allow for hay production. A standard application cost of $2.37 per acre was charged for these fertilizer applications. Furthermore, hay production in excess of the amount fed was valued at a price of $30 per bale for E+ hay with a 25% price premium added for NE+ hay (USDA, 2011b). This later premium hay was only available on S100NE pastures because hay was harvested from E+ stands in the other treatments given the focus of toxicosis mitigation with NE+ grazing. All other costs for the pastures were assumed to be nontreatment-related and as such were not included. These costs were assigned to pasture treatments on an annual basis, but per-head charges for calf performance analysis were again averaged across years to remove annual variation of agronomic effects. Hence, both annual variation resulting from reproductive performance of the cows and annual variation resulting from agronomic performance of the pasture were removed to concentrate on production year effects of annual calf performance when analyzing partial per-head returns of calves sold from the pastures.

Calf weights were based on actual observed weaning weights. Prices for calves were a 10-year average, real price for Arkansas as reported in 50-lb weight increments for both steers and heifers (Table 2). Combining the two cost differences (replacement cow and hay/pasture) with differences in calf revenue as described previously determined partial returns per calf sold (CPR) for each treatment. Differences in partial returns per unit area of pasture (PPR) between E+ and NE+ pastures could also be generated from this analysis. These PPRs were used to estimate a breakeven cost for replacing E+ pastures with NE+ pastures.

Finally, risk analyses were performed by visual comparison of cumulative distribution functions (CDFs) of CPR and weaning weights to determine differences in return and production risk. This provides insights about uncertainties of CPR and calf weaning weight across treatments because steeper CDF curves indicate a lesser range or variability in CPR or

Table 2. Inflation-Adjusted 10-Year Average Seasonal Prices ($/cwt) for Heifers and Steers (2001–2010) in Fifty Pound Weight Classes, Arkansas

	Heifers[a]		Steers[a]	
Weight Class in lbs	May	November	May	November
300–349	125.19	120.21	140.75	141.45
350–399	120.93	115.73	135.40	134.80
400–449	117.34	110.52	130.43	127.80
450–499	113.61	106.20	125.18	121.08
500–549	110.35	102.03	120.83	113.59
550–599	106.86	99.66	116.11	109.42
600–649	103.32	97.00	111.80	105.37
650–699	101.62	96.53	109.55	104.11
700–749	97.64	94.46	104.18	101.79
750–799	96.22	93.43	102.48	101.18

[a] Heifer and steer prices are from the USDA livestock marketing and information release and have been inflation adjusted using the USDA producer price index (PPI) for steers and heifers with a base year equal to 2008.The base year of 2008 was chosen as it represents the midpoint of the 3-year study.

weaning weight and hence less producer risk. Additionally, CDFs further to the right exhibit either lower likelihoods of achieving at least a threshold level of CPR or weaning weight or, alternatively, greater CPR or weaning weight at a particular likelihood level. Hence, because more CPR or weaning weight is preferred to less, treatments with CDFs further to the right tend to be preferred by producers and are judged using first-degree stochastic dominance (FSD) or second-degree stochastic dominance (SSD) where the former implies no intersection of CDFs and the later entails measurement of the overlaps between CDFs to determine preference on the basis of a risk averse decision-maker (Anderson, Dillon, and Hardaker, 1977).

Environmental Factors

In part, results were expected to be influenced by environmental factors, precipitation, and average daily temperature (Table 3). Overall, average precipitation for the 3 years was greater and temperature was less than 30-year averages (1971–2000). Temperatures in excess of 90°F have been implicated to influence the severity of some symptoms of fescue toxicosis (Peters et al., 1992; Spiers, Evans, and Rottinghaus, 2005). In 2007, 2008, and 2009, 36, 23, and 24 days, respectively, recorded mean daily temperatures in excess of 90°F (NOAA, 2011) indicating that 2007 should have had the greatest toxicosis effect of the 3 years. Environmental factors were thus only used to explain potential annual performance deviations from the base year. Nonetheless, because the pasture treatments were subject to the same environmental factors each year, they were not a source of variability among treatments and hence were summarized using annual dummy variables.

Statistics and Regression

The objective of the analysis was to estimate the effects of complete or partial introduction of NE fescue on animal and pasture performance. To that end, economic returns needed to be estimated on both a per-head and per-acre basis. Calf partial returns were analyzed using multiple linear regression in EViews version 6.0 (Startz, 2007). Zero/one dummy variables

Table 3. Precipitation (inches) and Temperature (°F) Starting with January 2007 (year 1) through December 2009 (year 3) at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

	Precipitation (inches)				Temperature (°F)			
	Year				Year			
	1	2	3	Average[a]	1	2	3	Average[b]
January	7.4	1.0	3.2	3.2	36.2	35.1	33.3	37.1
February	2.6	4.2	2.6	3.4	36.0	37.8	43.5	42.2
March	1.6	13.9	3.9	4.6	57.7	47.5	49.8	51.3
April	3.5	8.0	7.0	4.5	55.5	55.1	56.8	61.3
May	1.5	2.4	8.6	4.9	70.0	66.4	64.2	68.4
June	9.3	3.2	3.0	3.4	74.8[(1)]	75.7[(5)]	77.5[(12)]	76.4
July	2.8	4.7	5.9	3.2	75.3[(3)]	78.0[(11)]	75.7[(7)]	80.6
August	0.4	7.8	3.1	3.2	84.4[(29)]	76.0[(7)]	74.0[(5)]	78.6
September	4.8	7.0	8.2	3.8	71.3[(3)]	68.2[(0)]	68.2[(0)]	72.4
October	5.8	4.9	13.2	4.0	61.3	56.9	54.2	62.4
November	2.0	2.0	1.0	5.4	49.3	46.7	52.9	51.3
December	7.5	3.8	7.2	4.0	38.9	36.9	34.4	41.1
Total	49.0	62.8	66.9	47.5	59.3	56.8	57.1	60.2

[()] Denotes the number of days in a month that had daily temperature means exceeding 90°F.
[a] Average rainfall from 1971 to 2000 (NOAA, 2003).
[b] Average monthly temperature 1971 to 2000 (NOAA, 2003).

were used to determine the impacts of production year with 2007 as the base case and years 2 and 3 denoted by d02 and d03. Pasture improvement dummy variables for 25% and 100% NE+ were labeled d25NE and d100NE, respectively. The calving season effect was captured using a seasonal dummy variable (dFall = one for fall-calving with spring-calving as the base case). Calf gender effects with steers as the base (dHeifer = one for heifers) were also captured along with two- and three-way interaction terms for calving season, year of production, and NE+ level. The CPR equation was thus specified as:

$$\begin{aligned} \text{CPR} = {} & \beta_0 + \beta_1 \cdot \text{d02} + \beta_2 \cdot \text{d03} \\ & + \beta_3 \cdot \text{d25NE} + \beta_4 \cdot \text{d100NE} \\ & + \beta_5 \cdot \text{dFall} + \beta_6 \cdot \text{dFall} \times \text{d25NE} \\ & + \beta_7 \cdot \text{dFall} \times \text{d02} + \beta_8 \cdot \text{dFall} \times \text{d03} \\ & + \beta_9 \cdot \text{dFall} \times \text{d25NE} \times \text{d02} \\ & + \beta_{10} \cdot \text{dFall} \times \text{d25NE} \times \text{d03} \\ & + \beta_{11} \cdot \text{dHeifer} + \varepsilon \end{aligned} \tag{5}$$

where β_0 is the constant terms, the $\beta_{1\ldots11}$ are the coefficient estimates with standard errors calculated using the White's heteroscedasticity consistent estimation option in EViews 6.0, and the ε is the error term.

To examine reproductive and agronomic performance differences by treatment, the same specification as for Equation 5 was used with the exception that fewer observations were available because only one observation related to net hay production and fertilizer amount and the open rate for pasture treatment-specific herds were available. Hay cost (HC) per pasture treatment, capturing hay production, amount fed with excess sold, and fertilizer cost would thus capture agronomic effects of production year, calving season, and NE+ improvement as follows:

$$\begin{aligned} \text{HC} = {} & \beta_0 + \beta_1 \cdot \text{d02} + \beta_2 \cdot \text{d03} + \beta_3 \cdot \text{d25NE} \\ & + \beta_4 \cdot \text{d100NE} + \beta_5 \cdot \text{dFall} \\ & + \beta_6 \cdot \text{dFall} \times \text{d25NE} \\ & + \beta_7 \cdot \text{dFall} \times \text{d02} + \beta_8 \cdot \text{dFall} \times \text{d03} \\ & + \beta_9 \cdot \text{dFall} \times \text{d25NE} \times \text{d02} \\ & + \beta_{10} \cdot \text{dFall} \times \text{d25NE} \times \text{d03} + \gamma \end{aligned} \tag{6}$$

with variables as described previously and with γ as the error term.

Cow replacement costs, mainly as a function of breeding failures (only one instance of fescue foot was observed), were modeled by regressing open rates (OR) against the same variables as in Equation 6 to determine reproductive performance implications of pasture improvement along with calving season and production year effects as follows:

$$\begin{aligned} \text{OR} = {} & \beta_0 + \beta_1 \cdot \text{d02} + \beta_2 \cdot \text{d03} + \beta_3 \cdot \text{d25NE} \\ & + \beta_4 \cdot \text{d100NE} + \beta_5 \cdot \text{dFall} \\ & + \beta_6 \cdot \text{dFall} \times \text{d25NE} \\ & + \beta_7 \cdot \text{dFall} \times \text{d02} + \beta_8 \cdot \text{dFall} \times \text{d03} \\ & + \beta_9 \cdot \text{dFall} \times \text{d25NE} \times \text{d02} \\ & + \beta_{10} \cdot \text{dFall} \times \text{d25NE} \times \text{d03} + \zeta \end{aligned} \tag{7}$$

with variables as described previously and with ζ as the error term.

Finally per acre or PPR, calculated by summing annual CPR by treatment and dividing by treatment acres, was specified as follows:

$$\begin{aligned} \text{PPR} = {} & \beta_0 + \beta_1 \cdot \text{d02} + \beta_2 \cdot \text{d03} + \beta_3 \cdot \text{d25NE} \\ & + \beta_4 \cdot \text{d100NE} + \beta_5 \cdot \text{dFall} \\ & + \beta_6 \cdot \text{dFall} \times \text{d25NE} \\ & + \beta_7 \cdot \text{dFall} \times \text{d02} + \beta_8 \cdot \text{dFall} \times \text{d03} \\ & + \beta_9 \cdot \text{dFall} \times \text{d25NE} \times \text{d02} \\ & + \beta_{10} \cdot \text{dFall} \times \text{d25NE} \times \text{d03} + \eta \end{aligned} \tag{8}$$

with variables as described previously and with η as the error term.

To summarize, the CPR equation evaluates primarily calf performance but does include average reproductive and agronomic effects, the OR equation concentrates on reproductive performance, the HC equation analyzes agronomic performance, and the PPR equation summarizes combined effects of calf, reproductive, and agronomic performance without gender effects. Adjusted R^2, F-statistic, and probability of F-statistic were used to measure goodness of fit for each regression.

Results

Results are discussed in three sections: 1) a brief summary of animal performance; 2) hay and pasture costs/revenue; and 3) partial return implications ($ per head and $ per acre). A detailed analysis of cow-calf performance and pasture characteristics such as species composition and ergovaline concentrations related to this study are provided in Caldwell et al. (2012). To recap, S0NE and F0NE were considered as the baseline treatments given current practice in the study area. Improved pastures would be the S25NE, F25NE, and S100NE treatments.

Summary of Animal Performance

Table 4 provides a summary of calf weights (average calf birth weights, weaning weights and average daily gain [ADG]) for each treatment. Birth weights for fall-born calves were 2.7–5.0 lbs per head less than those for spring-born calves (p value < 0.05, Caldwell et al., 2012). A possible explanation is the concurrence of mid- to late gestation in fall-calving cows with grazing E+ pastures in the late spring and summer when the greatest concentrations of ergovaline occur in combination with seasonally highest ambient temperatures. Birth weights of calves on S100NE pastures were less than 1.5 lbs heavier on average than calves on S0NE or S25NE treatments, suggesting spring

Table 4. Treatment Averages of Open Rates, Calf Birth and Weaning Weight, Average Daily Gain, Gender, Revenue by Head and per Acre, Stocking Rate, Toxicosis Related Cull Cost, Net Hay Returns, and Partial Returns for Five Tall Fescue Treatments of a 3-Year[a] Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

Calving Season	Spring			Fall	
NE+ %	0	25	100	0	25
	Treatment Averages				
Open rates (%)[b]	48	19	21	12	6
Birth weight (lbs/head)	82.3	83.7	83.8	79.5	78.7
Weaning Weight (lbs/head)	489.7	501.8	601.4	536.5	564.0
Average daily gain (lbs/head)[c]	1.79	1.85	2.25	1.96	2.07
No. of steers	48	59	33	54	57
No. of heifers	42	65	27	46	68
Calf revenue ($/head)[d]	546.50	550.86	624.19	611.92	627.44
Weighted avg. sale price ($/lb)[e]	1.12	1.10	1.04	1.14	1.11
Acres/calf	2.37	2.17	2.57	2.22	2.15
Calf revenue ($/acre)	230.59	253.85	242.88	275.64	291.83
Net hay revenue ($/acre)[f]	6.01	4.79	3.28	6.01	-0.94
Cull cost ($/acre)[g]	60.07	25.54	24.11	18.57	9.75
Fertilizer cost ($/acre)[h]	2.79	0	2.79	2.79	0
Average partial returns ($/acre)[i]	173.74	233.10	219.25	260.29	281.14

[a] The study represents three production cycles for both fall and spring (January 2007–2010) calving herds.

[b] Open rates were determined at time of calving and not through pregnancy testing after breeding. Open rates are shown as the percentage of cows open per cows exposed to the herd sire per treatment each production year.

[c] Average daily gains are the weight difference from birth to weaning divided by the number of days between birth and weaning.

[d] Average revenue per head was estimated by multiplying each calf's weight by the 10-year average inflation adjusted calf sale price for November (spring-calving herd) and May (fall-calving herd) for the appropriate 50-lb increment and gender.

[e] The weighted average sale price in $/lb is affected by weaning weight and gender.

[f] Net hay revenue is a function of hay production less hay fed valued at $30 per #1,110 bale for E+ hay that was used for the 0 and 25% NE+ treatments and $37.50 per bale for NE+ hay available only in the 100% NE+ treatment. Negative numbers indicate the need for purchased hay. Per-acre hay production and feeding costs are excluded as they were the same across treatment.

[g] Cull cost represents the net of sale of cull animal less the cost of replacement with a cow-calf pair. Fescue toxicosis-related replacement costs included only those animals replaced resulting from breeding failures and those exhibiting fescue foot. Shown is the 3-year average prorated to annual pasture acres.

[h] Urea cost difference as a result of different fertilization of pasture paddocks used for hay production. These costs thus do not reflect total fertilizer cost per treatment.

[i] Total of calf revenue per acre less cull, fertilizer, and net hay cost. Differences are the result of rounding errors.

calf growth rates from conception to birth were not greatly affected by the E+ pastures; however, this difference was not statistically significant (Caldwell et al., 2012). At the time of weaning, average weights for fall calves were 47 (F0NE) and 62 (F25NE) lbs greater than spring calves (S0NE and S25NE, respectively), indicating that spring-born calves experience greater negative effects from dams grazing E+ pastures than those in the fall. Differences in weaning weights were significant (p value < 0.05) between fall- and spring-calving herds and percentage of NE across treatments (Caldwell et al., 2012). This is likely the result of reductions in milk production in late spring and summer. Also, calves on S100NE pastures were 62 and 37 lbs heavier than calves on F0NE and F25NE pastures, respectively, potentially indicating a seasonal difference in forage quality and/or greater impacts of fescue toxicosis. Differences in weaning weights by treatment are shown in the CDFs in Figure 1. S100NE is FSD to all other treatments. Additionally, fall treatments (F0NE and F25NE) are FSD to spring treatments with the same percentage of NE+. From simple visual analysis, it can be determined that production risk does not seem to be affected as curves merely shift (increased average weaning weights) but do not appreciably show changes in slope across treatments. Both F25NE and S25NE are SSD to their toxic counterparts, F0NE and S0NE, respectively.

Treatment effects on open rates were dependent on year, NE+ percentage, season, and interactions between explanatory variables (Tables 5 and 6). For the fall-calving herds, a total of 20 cows over the 3-year study period were culled compared with 83 for the spring-calving herds. Part of this difference is the result of the smaller fall calving herd (75 cow observations with no F100NE treatment) compared with 103 spring-calving cow observations. Nonetheless, the main difference in cull rates for spring and fall is attributed to the seasonal effect of the toxicosis on breeding/calving rates. For example, cows calving in year 2, grazing 25% NE+ pastures, and calving in the fall had an open rate of only 2%, whereas much higher open rates were observed for spring calving (S0NE) cows in the same year (39%). On average, fall open rates were found to be 45% lower across treatments than spring ($p < 0.001$), indicating a substantial difference in open rates resulting from choice of calving season. Differences in open rates resulting from pasture improvement (S0NE → S100NE) were evident ($p < 0.02$) and as expected. However, differences between partial and full adoption of NE+ (S25NE → S100NE) showed S25NE pastures to have a numerically lower open rate. This was counter to expectations but not

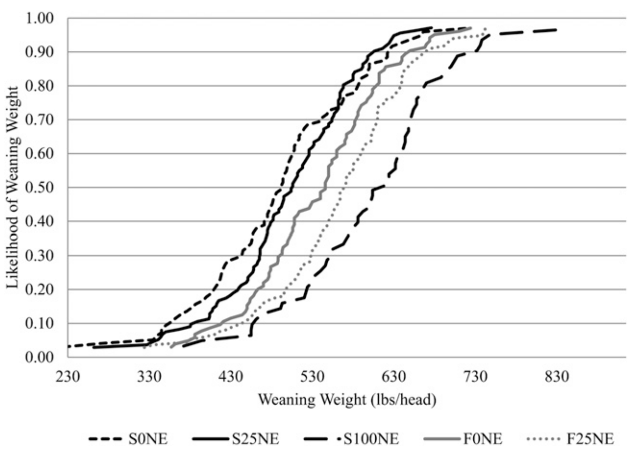

Figure 1. Treatment Differences in the Likelihood of Weaning Weight on Tall Fescue with Different Levels of NE+ Inclusion from a 3-Year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

Table 5. Partial Returns, Open Rates, and Hay Cost Regression Statistics for Tall Fescue Treatments from a 3-year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

		Calf Partial Returns (CPR in $/head)[b]		Open Rates (OR in %)[c]		Hay Cost (HC)[d]		Combined Partial Returns (PR)[e]	
Variable[a]		Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Constant term	β_0	405.42***[f]	10.46	50.96***	6.97	–3.39	1.80	143.17***	11.63
d02	β_1	61.64***	9.55	–11.63	7.96	16.19***	2.47	44.37*	18.00
d03	β_2	40.27***	9.92	1.75	6.90	3.63	2.07	37.48*	16.46
d25NE	β_3	96.38***	9.40	–28.44***	6.89	1.57	2.23	61.28***	16.49
d100NE	β_4	154.05***	11.93	–26.67*	9.92	–2.73	2.06	48.31**	15.08
dFall	β_5	177.68***	14.99	–44.96***	7.53	11.42	6.19	104.88***	13.66
dFall × d25NE	β_6	–77.36***	17.94	27.11**	7.78	–8.81	6.79	–54.47	28.39
dFall × d02	β_7	–27.94	17.17	11.63	10.20	–22.61	11.76	–38.51	19.51
dFall × d03	β_8	–4.52	17.43	15.92	9.50	–11.67	9.29	–17.49	20.75
dFall × d25NE × d02	β_9	37.73*	18.72	–2.33	7.10	7.02	13.53	26.40	21.12
dFall × d25NE × d03	β_{10}	27.73	18.71	–10.67	7.24	2.25	9.52	23.69	28.02
DHeifer[g]	β_{11}	-76.92***	5.36						
R^2 in %		67.40		68.62		44.44		72.85	
Adjusted R^2 in %		66.70		58.49		26.52		64.10	
F-Statistic		91.64***		6.78***		2.48**		8.32***	
No. of observations		499		42		42		42	

[a] Variables are as follows: β_0 is a constant and represents the base case scenario of no NE+ fescue for a spring born steer calf in 2007 or year 1; d02 and d03 are zero-one dummy variables for the second and third production year; d25NE and d100NE are zero-one dummy variables for the 25% and 100% NE+ pasture improvement treatments, respectively; dFall is a calving season dummy variable (1 = fall, 0 = spring); dHeifer is a dummy variable for calf gender (1 = heifer, 0 = steer). The × represents interaction terms or the product of previously described variables.

[b] Calf partial returns were based on replacement costs, differences in calf weights and hay cost calculated in $/head using average treatment-specific replacement and hay cost across years. See the specification of Equation 5 in the Materials and Methods section for more detail.

[c] Open rates were determined at time of calving and not by way of pregnancy testing after breeding to remove pregnancy test errors. Open rates are shown as the percentage of cows open per cows exposed to the herd sire per treatment each production year. Refer to Equation 6 for more detail.

[d] Hay costs are partial returns by accounting for excess hay revenue and added fertilizer cost by pasture treatment in $/acre per year. Refer to Equation 7 for more detail.

[e] The sum of calf partial returns per pasture treatment divided by the number of acres per treatment jointly capturing open rate, hay cost, and calf performance. Refer to Equation 8 for more detail.

[f] Statistically significant at * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

[g] dHeifer × year, NE+ % and calving season interaction variables were estimated in separate regressions with only the dHeifer × d02 interaction significant and all other interactions $p < 0.15$. Regression output is available from the authors on request.

Table 6. Net Hay[a] Production for Five Treatments of Tall Fescue from a 3-Year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

		Net Hay (bales per pasture)[a]					
Calving Season	NE+ %	Year 1	Year 2	Year 3	Average[b]	Acres[c]	Average (lbs/acre)
Spring	0	–1.0	22.0	4.7	8.6	71.2	132.3
	25	–2.3	23.5	2.7	7.9	89.7	97.4
	100	–6.0	18.3	0.0	4.1	51.4	87.4
Fall	0	16.7	7.3	4.7	9.6	74.1	141.9
	25	1.3	0.7	–9.0	–2.3	89.7	–28.6

[a] Net bales per acre hay production was determined by the total number of bales (1,100 lbs per bale) produced from each pasture treatment less the number of bales fed to the cow-calf pairs on that treatment. Hay produced by each pasture treatment was averaged across pastures to attempt to smooth site-dependent variables influencing hay production. The excess hay produced by each treatment was assumed to be sold at current market prices.

[b] Three-year average net bales (hay baled less hay fed) by treatment.

[c] Acres is the average annual acres in pasture and hay for each treatment in the study. Note that the spring-calving herd on 100 NE+ had only two replicates, whereas the other treatments were replicated three times.

statistically significant ($p = 0.82$). These findings suggest that partial conversion of pasture (F25NE and S25NE) with access to 100% NE+ pastures during critical times of the year only may be sufficient to lower incidence of breeding failures. Year and year × treatment interaction variables were found to be insignificant (Table 5). Calving rate results are within the range of other calving rate studies (Table 1).

Hay/Pasture Costs

Reduction in forage consumption by cow-calf pairs grazing toxic pastures resulted in additional net hay (harvested less fed) being produced from E+ pastures (Tables 4 and 6). However, there were no statistical differences in net hay costs between treatments ($p > 0.05$; Table 5). Net hay cost in year 2 was greater ($p < 0.001$) with a marginally significant interaction with calving season ($\beta_7 <> $ zero at $p = 0.06$). This was likely a result of seasonally abnormal rainfall favoring fall-calving herds with greater stockpiled forage resulting from July and August rains as well as higher March and April rains leading to forage availability that could be used better by fall-calving cows with heavier calves at foot (Tables 3 and 4). Because hay production was only measured in increments of 1,100-lb bales, harvested once in the spring, the lack of more statistically significant findings is not surprising.

Partial Returns

Partial returns are presented in both returns per calf (CPR in dollars per head) primarily for risk analysis and estimation of gender effects and as returns per unit of land (PPR in dollars per acre) for determination of breakeven cost of establishment for conversion of E+ to NE+ pastures. As such, the analysis of CPR showed calving season, NE+ pasture concentration, year, and gender effects that were all significant by themselves or as interactions ($p < 0.001$ level of significance; Table 5). The overriding effect for partial returns per head was calving season. An additional \$177.68 per head (β_5) in returns for fall-calving treatments was estimated compared with spring-calving treatments ($p < 0.001$). Increasing the amount of NE+ pastures in the spring from 0–25% and 25–100% increased revenue by \$96.38 head (β_3) and \$57.67 head ($\beta_4 - \beta_3$) in year 1 ($p < 0.001$), respectively, suggesting partial adoption to be superior to full adoption on a per-head basis in year 1. A similar and yet smaller result is observed in year 1 for fall-calving herds (F0NE → F25NE in year 1 results in an estimated \$19.02 gain [$\beta_3 + \beta_5 + \beta_6 - \beta_5$]). Comparing year 1 S25NE with year 1 F25NE improved returns by \$100.32 per head ($\beta_5 + \beta_6$). Higher returns to fall-calving are primarily a function of better reproductive performance and greater revenue given heavier weight and seasonal prices (Figures 1–3; Table 4). Gender effects are primarily a function of lower female weaning weight and sale price compared with their male counterparts. Figure 2 shows the treatment CDFs of CPR assigning each observation equal likelihood of occurrence across years. Greater CPRs are shown for F25NE, F0NE, and S100NE compared with S25NE and S0NE. F25NE and S25NE were FSD of F0NE and S0NE, respectively, and S100NE was FSD of S25NE. Additionally, the CDFs for S25NE and S0NE treatments show a flatter slope, indicating increased producer risk to cow-calf production or alternatively a benefit to NE+ and fall-calving.

Partial returns per acre (Tables 6 and 7) were calculated to provide an estimate of breakeven pasture establishment costs for converting E+ acres to NE+. Figure 3 shows the treatment CDFs of PPR. Fall treatments are FSD to spring treatments. Additionally, pastures with NE+ are FSD to pastures with no NE+ that use the same calving season. Of note, S25NE is SSD to S100NE, which was not the case for CPR CDFs; this was the result of stocking rates (Table 7). Table 7 shows the differences in estimated returns between treatments using Equation 8 and averaging across years. Conversion of 25% of pasture acres had the potential to increase returns for fall- and spring-calving cows by \$27.26 per acre and \$60.13 per acre, respectively. However, to achieve these additional returns, only 25% of pasture area is needed to be converted from E+ to NE+ (using controlled access to 100% NE+ acres for one-fourth of the grazing acres). So increased per-acre returns occur on all acres while improvement would only be required on 25% of acres. As an example, assume a 100-acre pasture using spring-calving: changing 25% of pasture acres to NE+ results in an estimated increase in net returns of \$60.13/acre or \$6,013 total benefit for 100 acres; to achieve this total benefit, only 25 acres need to be improved, so \$6,013/25 acres results in \$240.52 per acre that could be incurred to improve the 25 acres, whereas the remaining 75 acres would be left unimproved. The implication is that a producer would see increased returns if he or she were to spend less on annual pasture improvement costs for spring- and fall-calving herds than \$240.52 and \$109.02 per acre (\$60.13 $\times$ 4 and \$27.26 $\times$ 4), respectively. Notably, these partial return increases are larger than the estimated returns for converting all pasture to NE+ in the spring at \$46.99 per acre.

Discussions and Conclusions

This analysis provided an estimation of the effects of calving season and percentage NE+ used

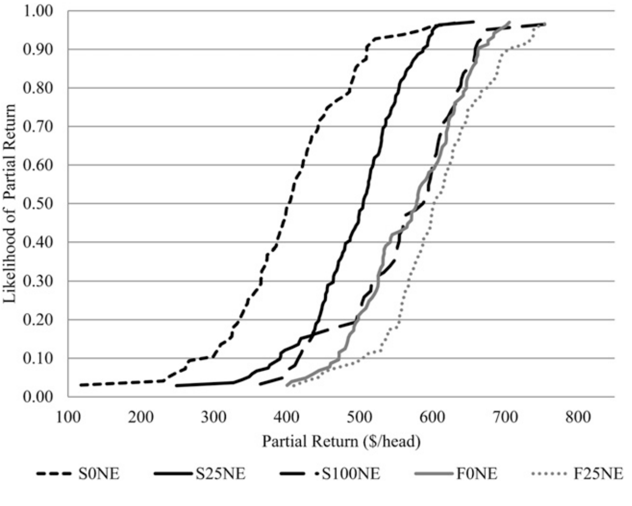

Figure 2. Treatment Differences in the Likelihood of Partial Return per Head on Tall Fescue with Different Levels of NE+ Inclusion from a 3-Year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

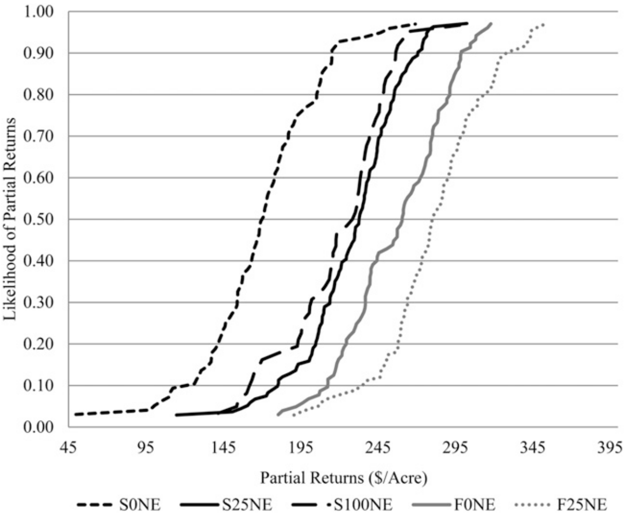

Figure 3. Treatment Differences in the Likelihood of Partial Return per Acre on Tall Fescue with Different Levels of NE+ Inclusion from a 3-Year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

in pasture rotations on open rates, hay costs, and partial returns to producers based on a 3-year empirical study using production methods that could be implemented by Arkansas producers. Results have revealed that the practice of fall-calving has the potential to provide greater returns to producers than spring-calving given seasonally different prices and significant reductions in breeding failures. Also, incorporating NE+ pastures into grazing rotations at specific times in the year limits the effects of fescue toxicosis to the same extent as if all pasture was converted from E+ to NE+. Additional producer returns to cover establishment

Table 7. Estimated Average Partial Returns ($/acre) for Five Treatments and Differences in Returns between Treatments of Tall Fescue from a 3-Year Study Conducted at the University of Arkansas Livestock and Forestry Research and Extension Station near Batesville, Arkansas

Calving Season	NE+ %	Treatment	Estimated Partial Returns[a] ($/acre)	Acres/Calf
Spring	0	S0NE	169.05	2.37
	25	S25NE	229.18	2.17
	100	S100NE	215.94	2.57
Fall	0	F0NE	255.55	2.22
	25	F25NE	282.81	2.15
Treatment Comparisons			**Estimated Gain ($/acre)[b]**	**NE+ Breakeven ($/acre)[c]**
S0NE → S25NE			60.13	240.52
S0NE → S100NE			46.99	46.99
F0NE → F25NE			27.26	109.02

[a] Estimated partial returns were determined by averaging partial returns per head by treatment and dividing by the average number of acres per calf per treatment.

[b] A positive/negative number implies an improvement/loss when switching from the first treatment to the second.

[c] Estimated maximum annual establishment and maintenance costs for NE+. For example, to convert S0NE treatment to S25NE treatment a total cost of $60.13 per acre for all acres could be incurred. However, because only one-fourth of the acres need be converted, the total cost per acre of NE+ to break even is estimated at $240.52 per acre for spring-calving herds.

and maintenance costs of NE+ improvement are achieved through lower open rates and greater calf weights at weaning. Estimated breakeven cost of establishment to convert 25% of pasture acres to NE+ was determined to be $241 and $109 per acre per year for spring- and fall-calving herds, respectively. These results compare favorably to conversion costs estimated in previous studies. The results also fortify the results of Zhuang et al. (2005) in the sense that complete conversion of pasture to pure NE+ showed lesser potential in comparison with partial conversion. Producer return risk implications were also observed in the study in the sense that introduction of NE+ and fall-calving would lower producer return risk when compared with spring-calving without and with 25% NE+.

Addition of a fall 100% NE+ treatment in the analysis—not possible as a result of limited available acreage at the experiment station—as well as uncontrolled calving season as an alternative to the treatments described within may have enhanced estimates of how much a producer could spend on improving pasture as Arkansas producers predominantly implement a year-round calving strategy (Popp, Doye, and West, 2008). Also not considered in this study were the potential impacts on seasonal prices as a result of changes in producer behavior. For example, if all producers were to switch to fall-calving, seasonal sale price differentials for calves and replacement animals may change affecting producer returns. These issues are subject to further study.

[Received October 2011; Accepted July 2012.]

References

Anderson, J.R., J.L. Dillon, and J.B. Hardaker. *Agricultural Decision Analysis*. Ames, IA: Iowa State University Press, 1977.

Bacon, C.W., J.K. Porter, J.D. Robbins, and E.S. Luttrell. "*Epichole typhina* from Tall Fescue Grasses." *Journal of Applied and Environmental Microbiology* 35(1977):576–81.

Beck, P.A., S.A. Gunter, K.S. Lusby, C.P. West, K.B. Watkins, and D.S. Hubbell, III. "Animal Performance and Economic Comparison of Novel and Toxic Endophyte Tall Fescues to Cool-Season Annuals." *Journal of Animal Science* 86(2008):2043–55.

Beers, K.W., and E.L. Piper. "Effects of Grazing Endophyte Infected Fescue on Heifers Growth, Calving Rate and Calf Birth Weight of First Calf Heifers." *Arkansas Farm Research*. 36(1987):7.

Boling, J.A. "Endophytic Fungus and Tall Fescue Utilization by Ruminants." *The Professional Animal Scientist* 1(1985):19.

Bouton, J.H., G.C.M. Latch, N.S. Hill, C.S. Hoveland, M.A. McCann, R.H. Watson, J.A. Parish, L.L. Hawkins, and F.N. Thompson. "Reinfection of Tall Fescue Cultivars with Non-Ergot Alkaloid-Producing Endophytes." *Agronomy Journal* 94(2002):567–74.

Buckner, R.C., J.B. Powell, and R.V. Frakes. *Historical Development in Tall Fescue Monograph*. Madison, WI: American Society of Agronomy, 1979, pp. 1–8.

Burton, R.O., Jr., P.T. Berends, J.L. Moyer, K.P. Coffey, and L.W. Lomas. "Economic Analysis of Grazing and Subsequent Feeding of Steers from Three Fescue Pasture Alternatives." *Journal of Production Agriculture* 7(1994):482–89.

Caldwell, J.D., K.P. Coffey, J.A. Jennings, D. Phillip, A.N. Young, J.D. Tucker, D.S. Hubbell, III, T. Hess, M.L. Looper, C.P. West, M.C. Saving, M.P. Popp, D.L. Kreider, D. Halford, and C.F. Rosenkrans, Jr. "Performance by Spring and Fall-Calving Cows Grazing with Full Access, Limited Access, or No Access to *Neotyphodium Coenophialum*-Infected Fescue." *Journal of Animal Science* (2012):doi:10.2527/jas.2011-4603 [Epub ahead of print July 10, 2012].

Coblentz, W.K., K.P. Coffey, T.F. Smith, D.S. Hubbell, III, D.A. Scarbrough, J.B. Humphry, B.C. McGinley, J.E. Turner, J.A. Jennings, C.P. West, M.P. Popp, D.H. Hellwig, D.L. Kreider, and C.F. Rosenkrans, Jr. "Using Orchardgrass and Endophyte-Free Fescue versus Endophyte-Infected Fescue Overseeded on Bermudagrass for Cow Herds: I. Four-Year Summary of Forage Characteristics." Crop Science 46,5(2006a): 1919–28.

———. "Using Orchardgrass and Endophyte-Free Fescue versus Endophyte-Infected Fescue Overseeded on Bermudagrass for Cow Herds: II. Four-Year Summary of Cow-Calf Performance." Crop Science 46(2006b):1929–38.

Coffey, K.P., W.K. Coblentz, J.D. Caldwell, C.P. West, R.K. Ogden, T. Hess, D.S. Hubbell, III, M.S. Akins, and C.F. Rosenkrans, Jr. "Cow and Calf Performance While Grazing Tall Fescue

Pastures with Either the Wild-Type Toxic Endophyte or a Non-Toxic Novel Endophyte." *Arkansas Animal Science Report Series* 553(2007): 67–69.

Coffey, K.P., W.K. Coblentz, D.H. Hellwig, M.P. Popp, T.F. Smith, D.S. Hubbell, III, D.A. Scarbrough, J.B. Humphry, J.E. Turner, Z.B. Johnson, and C.F. Rosenkrans, Jr. "Weaning and Post-Weaning Performance by Fall-Born Calves Weaned on Different Dates from Endophyte-Infected Tall Fescue Pastures Managed with Two Different Rotation Frequencies." *Livestock Science* 118(2008):183–94.

Coffey, K.P., L.W. Lomas, and J.L. Moyer. "Grazing and Subsequent Feedlot Performance by Steers That Grazed Different Types of Fescue Pasture." *Journal of Production Agriculture* 3(1990):415.

Cole, N.A., J.A. Stuedemann, C.W. Purdy, and D.P. Hutcheson. "Influence of Endophyte in Tall Fescue Pastures on the Feedlot Performance of Feeder Steers." *Journal of Animal Science* 65,Suppl1(1987):331 (Abstract).

Gay, N., J.A. Boling, R. Dew, and D.E. Miksch. "Effects of Endophyte-Infected Tall Fescue on Beef Cow Performance." *Applied Agricultural Research* 3(1988):183–86.

Gunter, S.A., and P.A. Beck. "Novel Endophyte-Infected Tall Fescue for Growing Beef Cattle." Journal of Animal Science 82,ESuppl(2004):E75–82.

Hoveland, C.S. "Economic Importance of Acremonium Endophytes." *Agriculture Ecosystems & Environment* 44(1993):3–12.

Hoveland, C.S., S.P. Schmidt, C.C. King, Jr., J.W. Odom, E.M. Clark, J.A. McGuire, L.A. Smith, H.W. Grimes, and J.L. Holliman. "Steer Performance and Association of *Acremonium Coenophialum* Fungal Endophyte on Tall Fescue Pasture." *Agronomy Journal* 75(1983):821–24.

Malinowski, D.P., and D.P. Belesky. "Adaptations of Endophyte-Infected Cool-Season Grasses to Environmental Stresses: Mechanisms of Drought and Mineral Stress Tolerance." *Crop Science* 40(2000):923–40.

National Oceanic and Atmospheric Administration (NOAA 2003). United States Department of Commerce. Internet site: http://www1.ncdc.noaa.gov/pub/orders/2870104981922dat.txt (Accessed June 15, 2011).

Peters, C.W., K.N. Grigsby, C.G. Aldrich, J.A. Paterson, R.J. Lipsey, M.S. Kerley, and G.B. Garner. "Performance, Forage Utilization, and Ergovaline Consumption by Beef Cows Grazing Endophyte Fungus-Infected Tall Fescue, Endophyte Fungus-Free Tall Fescue, or Orchardgrass Pastures." *Journal of Animal Science* 70(1992):1550–61.

Popp, M., D. Doye, and C. West. "Controlled vs Continuous Calving Seasons in the South: What's at Stake?" *Journal of Farm Managers and Rural Appraisals* 90(2008):60–73.

Porter, J.K., and F.N. Thompson, Jr. "Effects of Fescue Toxicosis on Reproduction Livestock." *Journal of Animal Science* 70(1992):1594–603.

Realini, C.E., S.K. Duckett, N.S. Hill, C.S. Hoveland, B.G. Lyon, J.R. Sackmann, and M.H. Gillis. "Effect of Endophyte Type on Carcass Traits, Meat Quality, and Fatty Acid Composition of Beef Cattle Grazing Tall Fescue." *Journal of Animal Science* 83(2005): 430–39.

Roberts, C., and J. Andrae. 2004. "Tall Fescue Toxicosis and Management." *Crop Management* April(2004):doi:10.1094/CM-2004-0427-01-MG. Internet site: www.plantmanagementnetwork.org/pub/em/management/2004/toxicosis (Accessed July 26, 2012).

Rottinghaus, G.E., G.B. Garner, C.N. Cornell, and J.L. Ellis. "HPLC Method for Quantitating Ergovaline in Endophyte-Infested Tall Fescue: Seasonal Variation of Ergovaline Levels in Stems with Leaf Sheaths, Leaf Blades, and Seed Heads." *Journal of Agricultural and Food Chemistry* 39(1991):112–15.

Schmidt, S.P., D.A. Danielson, J.A. Holliman, H.W. Grimes, and W.B. Webster. "Fescue Fungus Suppresses Growth and Reproduction in Replacement Beef Heifers. Alabama Agricultural Experiment Station, Auburn University." *Highlights of Agricultural Research* 33(1986):15.

Schmidt, S.P., and T.G. Osborn. "Effects of Endophyte-Infected Tall Fescue on Animal Performance." *Agriculture Ecosystems & Environment* 44(1993):233–62.

Spiers, D.E., T.J. Evans, and G.E. Rottinghaus. "Interaction between Thermal Stress and Fescue Toxicosis: Animal Models." *Neotyphodium in Cool-Season Grasses*. C.A. Roberts, C.P. West, and D.E. Spiers, eds. Ames, IA: Blackwell Publishing, 2005.

Startz, R. *EViews Illustrated for Version 6*. Irvine, CA: Quantitative Micro Software, 2007.

Strickland, J.R., M.L. Looper, J.C. Matthews, C.F. Rosenkrans, Jr., M.D. Flythe, and K.R. Brown. "St. Anthony's Fire in Livestock: Causes, Mechanisms, and Potential Solutions." *Journal of Animal Science* 89(2011):1603–26.

Strickland, J.R., J.W. Oliver, and D.L. Cross. "Fescue Toxicosis and Its Impact on Animal

Agriculture." *Veterinary and Human Toxicology* 35(1993):454–64.

Stuedemann, J.A., and C.S. Hoveland. "Fescue Endophyte: History and Impact on Animal Agriculture." *Journal of Production Agriculture* 1(1988):39–44.

United States Department of Agriculture. *Agricultural Marketing Service, Livestock and Seed Division Market*. Detailed Quotations, Arkansas: Livestock Weighted Average Monthly Prices for, 2010.

———. *Natural Resource Conservation Service, Web Soil Survey*. Internet site: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (Accessed June 8, 2011a).

———. *Hay Market Report, Kansas, Texas, and Missouri, 2011*. Internet site: http://ams.usda.gov/mnreports/jc_gr310.txt (Accessed June 15, 2011b).

———. *A Report from the Economic Research Service. Cattle Sector Production Practices and Regional Price Differences*. Internet site: http://www.ers.usda.gov/Publications/LDP/2011/04Apr/LDPM2021/LDPM2021.pdf (Accessed June 21, 2011c).

University of Arkansas Cooperative Extension Services (UACES). *Arkansas Livestock and Grain Market News Service of the University of Arkansas Division of Agriculture*. Internet site: http://www.uaex.edu/Other_Areas/publications/PDF/MP-413.pdf (Accessed May 20, 2011).

———. *Cow-calf Budget, 2002*. Internet site: http://www.uaex.edu/Other_Areas/publications/PDF/MP-413.pdf (Accessed June 6, 2011).

Vibart, R.E., M.E. Drewnoski, M.H. Poore, and J.E. Green, Jr. "Persistence and Botanical Composition of Jesup Tall Fescue with Varying Endophyte Status after Five Years of Stockpiling and Intensive Winter Grazing." *Forage and Grazinglands* April(2008):doi:10.1094/FS-2008-0421-01-RS. Internet site: www.plantmanagementnetwork.org/pub/fg/research/2008/jesup. (Accessed July 26, 2012).

Washburn, S.P., and J.T. Green, Jr. *Performance of Replacement Beef Heifers on Endophyte-Infected Fescue Pastures.* In: Proc. 40th Annu. Conf. North Carolina Cattlemen's Assoc. February 25–28, 1991. North Carolina State Univ., Raleigh, NC. 1991.

Zhuang, J., M.A. Marchant, C.L. Schardl, and C.M. Butler. "Economic Analysis of Replacing Endophyte-Infected with Endophyte-Free Tall Fescue Pastures." *Agronomy Journal* 97(2005):711–16.