# Tall Fescue Endophyte Toxicosis in Beef Cattle:
## Clinical Mode of Action and Potential Mitigation through Cattle Genetics

***Richard Browning, Jr., Ph.D.***
***Cooperative Agricultural Research Program***
***Tennessee State University***
***Nashville, TN 37209-1561***

## INTRODUCTION

Tall fescue (***Festuca arundinacea*** Schreb.) is the most commonly used cultivated grass in the United States to feed beef cattle. Tall fescue is a cool-season perennial grass that many cattle producers 'can't live with, but can't live without' because of its hardiness and good forage yields, but adverse effects on cattle well-being and yields. The history of this forage and its effects on animal performance have been extensively reviewed (Hemken et al., 1984; Bacon et al., 1986; Stuedemann and Hoveland, 1988; Porter and Thompson, 1992; Stuedemann and Thompson, 1993; Porter, 1994; Bacon, 1995; Paterson et al., 1995). Tall fescue was unintentionally introduced from Europe sometime in the 1800s. Early university research on growing tall fescue in the U.S. began between 1907 and 1918 in Oregon and in Kentucky in 1931 (Alderson and Sharp, 1993). Tall fescue, primarily the Kentucky-31 variety, was planted across the U.S. throughout the 1940s and 1950s because of its excellent growth under various environmental stressors. Tall fescue may be found across the eastern half of the U.S. and the Pacific Northwest covering an estimated 25 to 40 million acres of pasture and hayland. It has been estimated that over 90% of tall fescue pastures in the U.S. are infected with the fungal endophyte ***Neotyphodium coenophialum*** (Bacon and Siegel, 1988; Glenn et al., 1996). Tall fescue and the endophyte share a natural, symbiotic relationship. The endophyte protects the host plant from environmental stressors such as drought, insects, nematodes, disease pathogens, and grazing by herbivores such as cattle.

After widespread adoption of tall fescue in the 1940s, managers started to notice problems with the well-being and performance of their cattle. These problems began to be documented during the 1950s (Walls et al., 1970; Stuedemann and Hoveland, 1988). The three general problems associated with endophyte-infected tall fescue consumption by cattle are fescue foot, fat necrosis, and fescue toxicosis. Fescue foot is a condition in which cattle become lame with potential sloughing off of the hoof. The tips of the tail and ears may also be lost. Insufficient blood flow to the extremities results in fescue foot and generally occurs during winter months. Fat necrosis is the development of hard fat deposits in the abdomen that can interfere with digestion or parturition. Fescue foot and fat necrosis are relatively infrequent occurrences. Fescue toxicosis is a multifaceted syndrome that is pervasive in tall fescue-based beef production systems across the Southeast and Midwest, extending west to eastern regions of the southern Great Plains. Cattle experiencing fescue toxicosis may exhibit rough hair coats, heat stress, suppressed appetite, poor growth, or reduced calving rates.

Fescue toxicosis is not a lethal condition and may be subclinical with the only sign being poor growth or low pregnancy rates. Although endophyte infection of tall fescue was first recognized in the early 1940s (Neill, 1941), it was not until the late 1970s that the link was made between poor animal performance and presence of the endophyte in tall fescue (Bacon et al., 1977). Numerous studies have since demonstrated the adverse effects that endophyte-infected tall fescue can have on beef cattle performance (Table 1; Paterson et al., 1995; Ball, 1997). The nutritional quality of endophyte-infected tall fescue is comparable to other similar forages and is not an influential factor in most studies. Fescue toxicosis costs the U.S. beef industry an estimated $500 million to $1 billion annually in lost revenue because of reduced reproductive and growth rates in cattle herds.

Table 1. Post-weaning growth and pregnancy rates for beef cattle on high endophyte-infected tall fescue versus low endophyte-infected forage[a] averaged across studies.

| Reference | Studies reviewed | Low Infection | High infection |
|---|---|---|---|
| | | Growth Rate, pounds per day | |
| Thompson et al., 1993 | 12 | 1.52 | 1.11 |
| Paterson et al., 1995 | 12 | 1.63 | 0.92 |
| Multiple reports[b] | 8 | 1.69 | 0.81 |
| | | Pregnancy Rate, % | |
| Paterson et al., 1995 | 4 | 87 | 59 |
| Burke et al., 2001 | 16 | 78 | 60 |
| Multiple reports[c] | 3 | 83 | 64 |

[a] Low-infected forage = low endophyte-infected tall fescue, endophyte-free tall fescue, or alternative forage.

[b] Cole et al., 2001; Bouton, 2002; Andrae, 2003.

[c] Fanning et al., 1992; Peters et al., 1992; Best et al., 2002.

## CLINICAL MODE OF ACTION

The search for the causative agent(s) of tall fescue toxicosis has been ongoing since animal disorders were first recognized. These efforts preceded identification of the fescue endophyte as a key component of the toxicosis scenario (Jacobson et al., 1963; Walls et al., 1970). It is now understood the endophyte produces numerous chemical compounds responsible for the hardiness of tall fescue under environmental stress (TePaske et al., 1993; Porter, 1994, 1995). Various compounds isolated from endophytic fescue have been tested over the years to determine their likely contribution to toxicoses in cattle (Thompson and Porter, 1990; Strickland et al., 1993). Ergot alkaloids have emerged as the generally accepted toxic agents of the tall fescue endophyte. Of the ergot alkaloids, ergopeptides and lysergic acid amides have received the most research attention, primarily the ergopeptides.

The basic chemical structure of ergot alkaloids is very similar to dopamine, noradrenaline, and serotonin (Berde and Strumer, 1978; Muller-Schweinitzer and Weidmann, 1978). These three compounds are neurotransmitters normally found in the body that regulate a myriad of physiological traits such as appetite, cardiovascular function, endocrine activity, gastrointestinal motility, muscle contraction, and temperature regulation. Ergot alkaloids have diverse pharmacological properties because they are able to interact with dopaminergic, alpha-adrenergic, and serotonergic receptors in the body (Berde and Strumer, 1978; Muller-Schweinitzer and Weidmann, 1978; Pertz and Eich, 1999). Some neurotransmitter-regulated physiological traits are altered after grazing endophyte-infected tall fescue because of the pharmacological activities of ergot alkaloids consumed (Oliver, 1997).

Ergovaline is the most abundant ergopeptide detected in endophyte-infected tall fescue (Belesky et al., 1988). As such, testing of fescue samples for ergovaline concentration is done in an attempt to indicate the toxic potential of tall fescue pasture or hay (Schnitzius et al., 2001). In the laboratory, ergovaline caused vasoconstriction in isolated bovine tissue (Dyer, 1993). Vasoconstriction is considered the reason animals suffering from fescue toxicosis experience lowered peripheral skin temperature. Peripheral vasoconstriction reduces blood flow to the skin, thus lowering skin temperature. Reduced blood flow to the extremities can also result in fescue foot. Purified ergovaline, administered intravenously, altered cardiovascular function, reduced skin temperature, and induced heat stress in sheep wethers and horse geldings (Bony et al., 2001; McLeay et al., 2002). Similar studies of purified ergovaline effects on cattle have not been published.

Ergotamine is an ergopeptide found in endophyte-infected tall fescue at lower levels than ergovaline (Yates et al., 1985). Ergotamine and ergovaline have similar structures and pharmacodynamic properties (Porter, 1994; Larson et al., 1999; Schoning et al., 2001). McLeay and co-workers (2002) found that ergotamine and ergovaline had similar effects on cardiovascular and thermoregulatory function in sheep. Several studies have been conducted where cattle have been treated with purified ergotamine. Ergotamine administered to cattle intramuscularly lowered tail skin temperature (Carr and Jacobson, 1969). In the lab, ergotamine caused vasoconstriction in isolated bovine tissue (Solomons et al, 1989). Vasoconstriction would explain lowered tail skin temperature. Osborn et al. (1992) demonstrated that consumption of ergotamine by steers induced physiological changes that were similar to responses in steers that consumed endophyte-infected tall fescue. These changes included decreased feed intake and peripheral skin temperature, increased rectal temperatures and respiration rates, and reduced weight gain (Table 2). In a series of studies where cattle were administered ergotamine intravenously, the ergopeptine alkaloid significantly altered vital signs (e.g., increased blood pressure and respiration rates, reduced tail skin temperature; Browning and Leite-Browning, 1997; Browning, 2000) and plasma concentrations of metabolic hormones (e.g., increased thyroid hormone, reduced insulin; Browning et al., 1998a, 2000) and reproductive hormones (e.g., increased prostaglandin $F_2$alpha, reduced luteinizing hormone; Browning et al., 1998b, 2001).

Table 2. Signs of fescue toxicosis induced in steers fed endophyte-free tall fescue with ergotamine added to the diet.[a]

| Traits[b] | Ergotamine in the diet | |
| --- | --- | --- |
| | No | Yes |
| Skin temperature (tail tip), EF | 96.1 | 91.4 |
| Rectal temperature, EF | 103.1 | 104.5 |
| Respiration rate, breaths per minute[c] | 72 | 90 |
| Feed intake, pounds per day | 12.5 | 6.4 |
| Weight gain, pounds per day | 1.23 | -1.03 |

[a] Adapted from Osborn et al., 1992.
[b] Difference between diets for each trait was statistically significant (***P*** < 0.05).
[c] At high ambient temperature (89.6EF).

The effects of purified ergovaline and ergotamine on cattle physiological status are generally consistent with the performance problems observed in cattle grazing endophyte-infected tall fecsue. These research finding help to justify the monitoring of ergovaline levels in tall fescue intended for use in cattle diets. The ability of dietary ergovaline or any other ergot alkaloid in endophyte-infected tall fescue to affect an animal is dependent on the alkaloid crossing the gastrointestinal tract after ingestion and entering the bloodstream. One of the frustrations in the area of bovine fescue toxicosis research has been the inability to detect ergovaline or similar ergot alkaloids in the blood of cattle grazing endophytic fescue. Recent work suggests that very little ergopeptide crosses the gastrointestinal tract and the primary ergot alkaloids transported across gastrointestinal tissue are lysergic acid and lysergic acid amides (Hill et al., 2001). Lysergic acid amides (ergine, ergonovine) elicit similar physiological responses as ergopeptides in terms of vasoconstriction in isolated bovine tissue (Oliver et al., 1993) and altered vital signs and hormone profiles in cattle (Browning and Leite-Browning, 1997, Browning et al., 1997, 1998a,b). The results of Hill and coworkers (2001) have caused some to question the validity of a commonly held position that ergovaline is the primary toxin of endophyte-infected tall fescue. Data showing that orally administered ergotamine induced signs of fescue toxicosis (Osborn et al., 1992; Table 2) suggest that dietary ergopeptides or bioactive ergopeptide metabolites enter the bloodstream and tend to support the view that ergovaline is a significant toxin of endophyte-infected tall fescue to contend with.

CONTROL THROUGH CATTLE GENETICS

Direct economic impact of fescue toxicosis is generally limited to cow-calf and stocker operations. Cattle from endophyte-infected tall fescue grazing systems do not exhibit poor performance when moved to the feedlot (Beconi et al., 1995; Drouillard and Kuhl, 1999; Cole et al., 2001). Some fescue-grazed cattle exhibit compensatory gains that are economically beneficial to feedlot operators. Thus, the seedstock, commercial cow-calf, and yearling/stocker segments have a financial incentive to seek ways of minimizing or eliminating the problem. Researchers have sought to devise methods of alleviating fescue toxicosis on two fronts, forage management and animal management.

***Forage Management***.
The pasture management approach is aimed at reducing or eliminating dietary ergot alkaloids. Suggested forage management strategies used by producers to combat fescue toxicosis include: 1) replacing endophyte-infected tall fescue with low-endophyte tall fescue, endophyte-free tall fescue or other grass species for grazing or hay, 2) diluting endophyte-infected tall fescue with other grasses or legumes, 3) ammoniating fescue hay, and 4) increasing stocking rates on endophytic fescue pastures to prevent plant maturation and seedhead formation (Stuedemann and Thompson, 1993; Ball, 1997). Ergot alkaloids are found throughout the tall fescue plant, but are highly concentrated in seed. These approaches have had limited success. The alkaloid-producing fungus makes endophyte-infected tall fescue a robust grass species that is highly competitive and hard to replace successfully for grazing in many geographic locations.

The current focus of many plant scientists studying tall fescue is on genetic strains of endophyte with altered profiles of alkaloid production (Panaccione et al., 2001; Bouton et al., 2002). These ‘non-toxic’ or ‘novel’ endophytes would produce alkaloids that provide pest and drought resistance to the host grass, but not produce ergot alkaloids responsible for fescue toxicosis in livestock. Recently, tall fescue infected with a novel endophyte was commercially introduced that shows promise as a pasture management option for producers (Bouton, 2002; Andrae, 2003). Pasture management strategies, including the planting of tall fescue with novel endophytes, will each be used to some extent in beef cattle operations across the country. However, the time and expense involved in pasture renovation, the vast number of acres covered in endophyte-infected tall fescue, and the general reluctance of some managers to eradicate long-established, vigorous stands of tall fescue in cattle pastures may limit widespread implementation of any one practice.

***Animal Management***.
A lessor research focus has been on animal management procedures to help alleviate fescue toxicosis. Recent efforts to address the problem through cattle management have explored various options such as ivermectin treatment, feed additives or supplements, estrogen implantation, and vaccine development (Stuedemann and Thompson, 1993; Beconi et al., 1995). Research on these techniques has not progressed to the point of expecting any impending practical applications on an appreciable scale. Unlike endophyte-free tall fescue or the recent emergence of novel endophytes on the plant side of the problem, there have not been developments of similar magnitude on the animal side. However, like in the plant research effort where recent advancements were made by exploiting genetic variability in endophyte populations for alkaloid production, genetic

variation in cattle populations may be utilized to manage against fescue toxicosis.

Within-Breed Genetic Selection. One animal genetics approach is to identify and select animals within a herd or breed that may be less responsive to the toxic effects of the endophyte-infected tall fescue. In one study, Angus cows that had been managed on endophyte-infected tall fescue for the better part of 10+ years were screened for susceptibility to fescue toxicosis (Hohenboken et al., 1991). Results were inconclusive. A second study conducted by Gould and Hohenboken (1993) attempted to validate a producer contention that a particular Hereford bull sired calves that were resistant to fescue toxicosis. The producer claim was not supported by the controlled study. More recently, researchers have worked to select and develop inbred lines of mice that would be susceptible or resistant to fescue toxicosis. Indications are that the growth and reproductive rates of 'resistant' mice were affected to a lesser degree compared to the 'susceptible' line after eight to twelve generations of selection (Hohenboken and Blodgett, 1997; Wagner et al., 2000). However, the differences between the lines were not dramatic and post-weaning growth across diets was generally higher for the 'susceptible' mice. An apparent reduction in genetic merit for post-weaning growth in the 'resistant' animals tended to erase any weight advantage gained through their increased tolerance of an endophytic fescue diet. The mouse work did show that modest genetic changes for animal responsiveness to endophyte-infected tall fescue can be achieved.

A limitation of within-breed or within-herd selection for beef cattle improvement and fescue toxicosis resistance, aside from a possible reduction in genetic merit for growth in a resistant line, is the time required to reach eight to twelve generations. There are probably cows herds today that have been managed and selected on fescue pastures for several generations. Individual animals in those herds may have acquired some tolerance to the fescue endophyte indirectly through the selection of replacement breeding stock with desired levels of production within a fescue-based production environment. Identifying those animals would be difficult since no simple diagnostic test is available to meet that objective, but it may be possible. A preliminary report describes the screening of eight-month-old Angus bulls for rectal temperature responses to high ambient temperature and dietary endophyte-infected tall fescue seed (Lipsey et al., 1994). The bulls classified as being most 'sensitive' or most 'tolerant' based on rectal temperature responses were later used in a controlled breeding program. A diet containing ergovaline caused higher rectal temperatures in calves sired by the 'sensitive' bull compared to calves sired by the 'tolerant' bull. The history of the Angus sires used in the trial was not disclosed in the published abstract (Lipsey et al., 1994). Identifying and selecting cattle for resistance to fescue toxicosis is a challenging proposition for the producer and researcher alike, but should not be discounted. Indirect selection is likely occurring on farms using endophyte-infected tall fescue as the primary forage.

Breed Differences on Endophyte-Infected Tall Fescue. Heat stress is a well-documented consequence of fescue toxicosis, especially during summer. Cattle suffering from fescue toxicosis often exhibit elevated respiration rates and open-mouth panting, increased time spent under shade, creation of and lying in mud wallows, and decreased daytime grazing. These behaviors are attempts to dissipate excess body heat. Peripheral vasoconstriction hinders the loss of body heat through the skin, thus creating a build-up of internal body heat resulting in increased internal body temperature (Al-Haidary et al., 2001). Hyperthermia in cattle experiencing fescue toxicosis has led to experimentation on the potential of heat-tolerant germplasm for cattle on endophyte-infected tall fescue.

Research on differences between heat-tolerant and heat-sensitive cattle breeds for responses to the tall fescue endophyte has been limited. The few studies conducted have involved stocker steers (Table 3). Goetsch et al. (1988) tested British breed crosses and Brahman crosses from April to July and from August to November. Reductions in steer growth rates over 12 weeks by endophyte-infection were deemed similar for both breeds in the spring and fall as breed H diet interactions were not significant. An exception was during the first six weeks of the fall season when a breed H diet interaction was noted as the growth of Brahman crosses was statistically less affected by the endophytic forage. Angus, Brahman H Angus, and Simmental H (Brahman H Angus) steers were examined from November to May by McMurphy et al. (1990). A breed H diet interaction was detected for post-weaning growth rates as half-blood Brahman steers were less affected by high endophyte levels than straight Angus or quarter-blood Brahman steers. Cole and coworkers (2001) did not detect a statistically significant breed H diet interaction for the growth of Brahman-cross and Angus steers when grazing fescue pastures with high or low endophyte infection levels from April to August. Numerical differences between the two genotypes for responsiveness to high endophyte diet in the work of Cole et al. (2001) were conspicuous (Table 3). Two preliminary studies comparing Angus H Brahman versus Angus or Hereford H Angus steers on high endophyte versus low endophyte or endophyte-free fescue from winter to summer did not find breed H diet interactions (Stuedemann et al., 1989; Greene et al., 1994). Unfortunately, post-weaning growth rates for each experimental steer group were not provided in the published abstracts.

Table 3. Reduced post-weaning growth for ***Bos taurus*** and ***Bos indicus***-crossbred steers fed tall fescue with high endophyte infection compared to low or no infection.

| | ***Bos taurus*** | | ***Bos indicus*** cross | |
|---|---|---|---|---|
| Reference | lb/d | % | lb/d | % |
| Goetsch et al., 1988[a] | - 0.46 | - 38 | - 0.42 | - 22 |
| Goetsch et al., 1988[b] | - 0.20 | - 16 | - 0.09 | - 06 |
| McMurphy et al., 1990[c] | - 0.72 | - 39 | - 0.29 | - 14 |
| McMurphy et al., 1990[d] | - 0.72 | - 39 | - 0.44 | - 26 |
| Cole et al., 2001 | - 0.55 | - 86 | - 0.26 | - 21 |

[a] Spring
[b] Fall
[c] ***Bos indicus*** cross = Brahman x Angus
[d] ***Bos indicus*** cross = Simmental x (Brahman x Angus)

The lack of statistically significant breed H diet interactions in most individual studies with Brahman crossbred steers implies that high endophyte-infected tall fescue adversely affected the growth of Brahman-crossbred steers the same as in steers without Brahman influence. However, a consistent trend is apparent if individual breed evaluation studies are assessed collectively (Table 3). High endophyte infestation invariably reduced growth rates of Brahman-cross steers to a lesser degree than it did in steers without Brahman influence. Brahman genetics reduced the adverse effects of endophyte-infected tall fescue on steer growth by an average of 26% (range = 10 to 65%). The actual growth rates of Brahman-cross steers on high endophyte pastures were equal to or greater than steers without Brahman influence that grazed low or noninfected pastures, with one exception for the quarter-blood Brahman steers (Goetsch et al., 1988; McMurphy et al., 1990; Cole et al., 2001). A summary of Table 3 leads to a reasonable conclusion that heat tolerant genetics, Brahman germplasm in particular, would be a useful animal management option to lessen the impact of fescue toxicosis in beef cattle herds.

Rectal temperatures were measured by McMurphy et al. (1990) and Cole et al. (2001). In both reports, Angus steers on high endophyte-infected tall fescue diets had elevated rectal temperatures at the end of the grazing period, whereas rectal temperatures Brahman H Angus steers were unaffected by diet. McMurphy and coworkers (1990) also noted that rectal temperatures in steers with lower Brahman influence, (i.e., Simmental H [Brahman H Angus]), did have elevated respiration rates on high endophyte fescue. Rectal temperatures were not affected by diet in any breed during cooler intermediate measurement periods between December and April, although breed H diet interactions showed the weight gain of Brahman H Angus to be less inhibited by high endophyte tall fescue during some of those same intermediate time intervals (McMurphy et al., 1990).

The studies cited in Table 3 encompass every month of the year, suggesting that the benefits of Brahman germplasm for reducing the problem of poor growth on endophyte-infected tall fescue may not be limited to the summer months. These reports led to work to assess the comparative responsiveness of Brahman to ergopeptides. In one experiment, fullblood Brahman and Hereford steers were similar in immediate cardiovascular and peripheral skin temperature responses to ergotamine administered intravenously (Browning, 2000). The same steers were observed for a slightly longer period of time in a second study of ergotamine treatment (Browning and Thompson, 2002). Over a four-hour period, Brahman steers appeared more sensitive than Hereford steers in terms of several hormones and metabolites (Figure 1). Most notable were the respiratory and thyroid hormone response in which ergotamine increased respiration rates and plasma triiodothyronine concentrations in the Hereford but not the Brahman (Browning and Thompson, 2002). The ergotamine studies involving Brahman steers and the data of Table 3 agree in suggesting that Brahman and their crosses differ in their responsiveness to ergot alkaloids when compared to cattle not carrying Brahman genetics.

Figure 1. Plasma triglyceride concentrations in Brahman (n = 7) and Hereford (n = 7) steers before and after i.v. treatment with ergotamine tartrate (ET). Minute 0 represents the time immediately before treatment. Breed H time affected (***P*** < 0.01) triglyceride concentrations. Solid symbols (M, 0) represent post-treatment means within breed that differ from pretreatment means (***P*** < 0.01). Ergotamine elicited a bi-phasic triglyceride response in Brahman, but did not significantly alter Hereford triglyceride levels. Divergent breed triglyceride responses to ergotamine agree with other plasma profiles for these steers (Browning and Thompson, 2002).

Recent studies evaluated the performance of another heat-tolerant breed on endophyte-infected tall fescue (Table 4; Browning, 2002a,b). In one experiment, purebred Senepol and Hereford yearling steers were fed high endophyte-infected tall fescue or orchardgrass (hay + seed) from July to October. Both breeds showed clinical signs of heat stress when consuming tall fescue as respiration rates and time spent under the shade were increased by the fescue diet. The growth rate in Hereford steers dropped by 50% on tall fescue. Considering the heat stress exhibited by Senepol steers on fescue, it was remarkable that their 12-week weight gain was not significantly affected (Table 4). In a second experiment, the same Senepol and Hereford steers, as two-year-olds, were fed high endophyte-infected tall fescue or orchardgrass (hay) from mid-July to early September. In this second test, neither breed showed clinical signs of heat stress when consuming tall fescue. Respiration rates and time spent under the shade did not differ between the diets. Nevertheless, six-week weight gain in the Hereford steers was reduced by over 80% on tall fescue hay, whereas six-week weight gain in the Senepol steers was unaffected (Table 4). In both experiments, breed H diet interactions were clearly evident for daily weight gain. Two points should be noted regarding Senepol responses to fescue immediately after introduction of seed to the diets. First, yearling Senepol steers in Experiment 1 had reduced weight gain during the first month when the fescue seed and hay were introduced, although not as dramatic as seen in the Hereford steers. The Senepol compensated for lost early growth by the end of the four-month fescue toxicosis study. Second, seed was added to the diets of two-year-old steers after the conclusion of Experiment 2 for an additional six-week fall observation period and both breeds had a subsequent cessation of growth during that interval.

Research data on Senepol and Hereford cattle do not indicate that Senepol are resistant of fescue toxicosis. To the contrary, indicator traits in Experiment 1 distinctly show that tall fescue caused the Senepol steers to ‘lose their cool’ as they appeared heat stressed. Additionally, the growth rates of Senepol dropped immediately after introduction of fescue seed to the diet. Remember that ergot alkaloids are highly concentrated in the endophyte-infected tall fescue seed. Nevertheless, this work does suggest that Senepol are resilient under an endophytic fescue challenge. Basic physiological reasons for this expression in the Senepol steers are currently being investigated. There are a number of unique physiological characteristic of heat tolerance in cattle that may come into play, but an examination of these adaptive traits is beyond the scope of this discussion. What is germane to this discussion is the general conclusion drawn when the fescue toxicosis experiments involving Senepol purebreds is added to the body of information on Brahman crossbred steer responses to endophyte-infected tall fescue. The use of heat tolerant breeds does appear to be a viable animal management option for cattle managers to consider when developing strategies to overcome fescue toxicosis. Moreover, the benefits do not appear to be limited to the summer months.

Table 4. Thermoregulatory traits and weight gain for Hereford (H) and Senepol (S) steers fed endophyte-infected tall fescue (TF) or orchardgrass (OG).[a]

| | HOG | HTF | SOG | STF |
|---|---|---|---|---|
| Experiment 1[b] | | | | |
| Respiration Rate, breaths per minute | 77 [f] | 96 [d] | 50 [g] | 87 [e] |
| Daytime Shade Use, % of observations | 53 [f] | 91 [d] | 5 [g] | 77 [e] |
| Growth Rate, pound per day | 1.28 [d] | 0.64 [e] | 1.22 [d] | 1.16 [d] |
| Experiment 2[c] | | | | |
| Respiration Rate, breaths per minute | 83 [d] | 88 [d] | 46 [e] | 52 [e] |
| Daytime Shade Use, % of observations | 41 [d] | 44 [d] | 7 [e] | 7 [e] |

| | | | | |
|---|---|---|---|---|
| Growth Rate, pounds per day | 1.12 [d] | 0.20 [e] | 1.25 [d] | 1.22 [d] |

[a] Adapted from Browning, 2002a,b.
[b] Yearling steers fed hay + seed diets from July to October.
[c] Two-year-old steers fed hay diets from July to September.
[d,e,f,g] Group averages with different letters within a row differ (***P*** < 0.01).

One caveat to recommending the use of heat-tolerant cattle in breeding programs is that practically all of the fescue toxicosis research published to date involving tropically-adapted breeds has focused on post-weaning, stocker steers. These data could have some relevance for replacement heifer development. Comparable studies have not been published that indicate the potential benefits of heat-tolerant genetics for reducing the negative effects of fescue toxicosis on cow reproductive rates or preweaning calf growth. Fescue toxicosis research evaluating heat tolerant genetics for cow-calf production is needed. Additional studies of post-weaning cattle growth and behavior on high endophyte-infected tall fescue that consider various purebred and crossbred presentations of heat-tolerant beef cattle genetics would also be useful.

## CONCLUSION

Cattle performance is generally dependent on two primary factors: the production environment and the genetic composition of the animal. Tall fescue, as a forage widely used to provide nutrients to a large number of cattle, is a major environmental component of many beef production systems. Most tall fescue is infected with an endophyte that has adverse effects on cattle. Poor cattle well-being and performance on endophyte-infected tall fescue, independent of nutrient content, is usually a consequence of the condition known as fescue toxicosis. Fescue ‘endophyte’ toxicosis is probably a more appropriate term since it is the endophyte, not the fescue, that is primarily responsible for the condition. Cattle managers can address this economically significant problem by altering the environmental input through consideration of various forage management options.

Alternatively, cattle managers may consider dealing with the problem of fescue toxicosis through the manipulation of animal genetic composition. Evaluating and selecting animals, breeds, breed-crosses, or biological types that perform best in a particular production environment is not a new concept in the beef cattle industry. This report does highlight the potential to exploit beef cattle genetic diversity, especially through tropically-adapted cattle, as a means of enhancing cattle performance in a challenging production environment, the high endophyte-infected tall fescue pasture. Any genetic management decision-making process for beef cattle should, of course, include assessing the general merits of any breed or breed-cross for reproductive, growth and carcass traits, independent of tall fescue considerations. Beyond that, the use of tropically-adapted breeds shows promise as a management option to mitigate problems of fescue toxicosis and improve cattle performance. Additional experimentation will help to further explore the benefits of heat-tolerant bovine germplasm for beef cattle production on endophyte-infected tall fescue. Producers can assist in this endeavor by providing encouragement and support to researchers engaged in this effort and lobbying for additional resources to sustain and possibly expand fescue endophyte toxicosis research activities.

## LITERATURE CITED

Al-Haidary, A., D.E. Spiers, G.E. Rottinghaus, G.B. Garner, M.R. Ellersieck. 2001. Thermoregulatory ability of beef heifers following intake of endophyte-infected tall fescue during controlled heat challenge. J. Anim. Sci. 79:1780-1788.

Alderson, J. and W.C. Sharp. 1993. Grass varieties in the United States. Agricultural Handbook No. 170. United States Department of Agriculture, Washington, DC.

Andrae, J. 2003. Novel endophyte-infected tall fescue. Cooperative Extension Service, University of Georgia, Athens. Circular 861.

Bacon, C.W. 1995. Toxic endophyte-infected tall fescue and range grasses: historic perspectives. J. Anim. Sci. 73:861-870.

Bacon, C.W. and M.R. Siegel. 1988. Endophyte parasitism of tall fescue. J. Prod. Agric. 1:45-55.

Bacon, C.W., J.K. Porter, J.D. Robbins, E.S. Luttrell. 1977. Epichloe typhina from toxic tall fescue grasses. Appl. Environ. Microbiol. 34:576-581.

Bacon, C.W., P.C. Lyons, J.K. Porter, J.D. Robbins. 1986. Ergot toxicity from endophyte-infected grasses: a review. Agron. J. 78:106-116.

Ball, D.M. 1997. Significance of endophyte toxicosis and current practices in dealing with the problem in the United States. In: C.W. Bacon and N.S. Hill (ed.) ***Neotyphodium***/Grass Interactions. pp 395-410. Plenum Press, New York.

Beconi, M.G., M.D. Howard, T.D.A. Forbes, R.B. Muntifering, N.W. Bradley, M.J. Ford. 1995. Growth and subsequent feedlot performance of estradiol-implanted vs nonimplanted steers grazing fall-accumulated endophyte-infected or low-endophyte tall fescue. J. Anim. Sci. 73:1576-1584.

Belesky, D.P., J.A. Studemann, R.D. Plattner, S.R. Wilkinson. 1988. Ergopeptine alkaloids in grazed tall fescue. Agron. J. 80:209-212.

Berde, B. and E. Sturmer. 1978. Introduction to the pharmacology of ergot alkaloids and related compounds as a basis of their therapeutic application. In: B. Berde and H.O. Schild (ed.) Handbook of Experimental Pharmacology, Vol. 49, Ergot Alkaloids and Related Compounds. pp 1-28. Springer-Verlag, Berlin.

Best, T.G., J.L. Howell, J.E. Huston, R.R. Evans. 2002. Evaluation of fungus infected, fungus free and novel endophyte fescues as roughage sources for developing replacement heifers. In: Proc. Tall Fescue Toxicosis Workshop. Oct. 27-29, Wildersville, TN. pp 57-59.

Bony, S., A. Durix, A. Leblond, P. Jaussaud. 2001. Toxicokinetics of ergovaline in the horse after an intravenous administration. Vet. Res. 32:509-513.

Bouton, J. 2002. Tall fescue toxicity leads to the development of ‘Max Q’. NF Ag News & Views, August. The Samuel R. Noble Foundation, Ardmore, OK. Available: http://www.noble.org/ag/Research/Articles/TallFescueToxicity/Index.html.

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, F.N. Thompson. 2002. Reinfection of tall fescue cultivars with non-ergot alkaloid-producing endophytes. Agron. J. 94:567-574.

Browning, R. Jr. 2000. Physiological responses of Brahman and Hereford steers to an acute ergotamine challenge. J. Anim. Sci. 78:124-130.

Browning, R. Jr. 2002a. Interactive effects of forage and breed on steer performance involving endophyte-infected tall fescue and Senepol cattle. In: Proc. 7th World Cong. on Genetics Applied to Lives. Prod. Aug. 19-23, Montpellier, FRANCE. 33:441-443.

Browning, R. Jr. 2002b. Performance of purebred Senepol and Hereford steers on endophyte-infected tall fescue in Tennessee. In: Proc. Senepol - Cattle for the New Millennium. Nov. 8-9, University of the Virgin Islands, St. Croix, USVI. Available: http://rps.uvi.edu/AES/Senepol/Main_Page.html.

Browning, R. Jr. and M.L. Leite-Browning. 1997. Effect of ergotamine and ergonovine on thermal regulation and cardiovascular function in cattle. J. Anim. Sci. 75:176-181.

Browning, R. Jr. and F.N. Thompson. 2002. Endocrine and respiratory responses to ergotamine in Brahman and Hereford steers. Vet. Hum. Toxicol. 44:149-154.

Browning, R., Jr., F.N. Thompson, J.L. Sartin, M.L. Leite-Browning. 1997. Plasma concentrations of prolactin, growth hormone, and luteinizing hormone in steers administered ergotamine or ergonovine. J. Anim. Sci. 75:796-802.

Browning, R. Jr., M.L. Leite-Browning, H.M. Smith, T. Wakefield Jr. 1998a. Effect of ergotamine and ergonovine on plasma concentrations of thyroid hormones and cortisol in cattle. J. Anim. Sci. 76:1644-1650.

Browning R. Jr., F.N. Schrick, F.N. Thompson, T. Wakefield Jr. 1998b. Reproductive hormonal responses to ergotamine and ergonovine in cows during the luteal phase of the estrous cycle. J. Anim. Sci. 76:1448-1454.

Browning, R. Jr., S.J. Gissendanner, T. Wakefield Jr. 2000. Ergotamine alters plasma concentrations of glucagon, insulin, cortisol, and triiodothyronine in cows. J. Anim. Sci. 78:690-698.
Browning, R. Jr., F.N. Schrick, F.N. Thompson, T. Wakefield Jr. 2001. Effect of an acute ergotamine challenge on reproductive hormones in follicular phase heifers and progestin-treated cows. Anim. Reprod. Sci. 66:135-149.
Burke, J.M., R.W. Rorie, E.L. Piper, W.G. Jackson. 2001. Reproductive responses to grazing endophyte-infected tall fescue by postpartum beef cows. Theriogenology 56:357-369.
Carr, S.B. and D.R. Jacobson. 1969. Bovine physiological responses to toxic tall fescue and related conditions for application in a bioassay. J. Dairy Sci. 52:1792-1799.
Cole, N.A., J.A. Stuedemann, F.N. Thompson. 2001. Influence of both endophyte infestation in fescue pastures and calf genotype on subsequent feedlot performance of steers. Prof. Anim. Sci. 17:174-182.
Drouillard, J.S. and G.L. Kuhl. 1999. Effects of previous grazing nutrition and management on feedlot performance of cattle. J. Anim. Sci. 77(Suppl. 2):136-146.
Dyer, D.C. 1993. Evidence that ergovaline acts on serotonin receptors. Life Sci. 53:PL223-228.
Fanning, M.D., J.C. Spitzer, D.L. Cross, F.N. Thompson. 1992. A preliminary study of growth, serum prolactin and reproductive performance of beef heifers grazing ***Acremonium coenophialum*** infected tall fescue. Theriogenology 38:275-384.
Glenn, A.E., C.W. Bacon, R. Price, R.T. Hanlin. 1996. Molecular phylogeny of ***Acremonium*** and its taxonomic implications. Mycologia 88:369-383.
Goetsch, A.L., K.L. Landis, G.E. Murphy, B.L. Morrison, Z.B. Johnson, E.L. Piper, A.C. Hardin, K.L. Hall. 1988. Supplements, parasite treatments and growth implants for Brahman or English crossbred steers grazing endophyte-infected or noninfected fescue in the spring and fall. Prof. Anim. Sci. 4:32-38.
Gould, L.S. and W.D. Hohenboken. 1993. Differences between progeny of beef sires in susceptibility to fescue toxicosis. J. Anim. Sci. 71:3025-3032.
Greene, B.B., C.C. King Jr., J.C. Ligon. 1994. Performance of Angus-Hereford crossbred and Brangus steers grazing endophyte-infected and endophyte-free tall fescue pastures. J. Anim. Sci. 72(Suppl. 2):30 (abstr.).
Hemken, R.W., J.A. Jackson, Jr., J.A. Boling. 1984. Toxic factors in tall fescue. J. Anim. Sci. 58:1011-1016.
Hill, N.S., F.N. Thompson, J.A. Stuedemann, G.W. Rottinghaus, H.J. Ju, D.L. Dawe, E.E. Hiatt 3rd. 2001. Ergot alkaloid transport across ruminant gastric tissues. J. Anim. Sci. 79:542-549.
Hohenboken, W.D. and D.J. Blodgett. 1997. Growth and physiological responses to toxicosis in lines of mice selected for resistance or susceptibility to endophyte-infected tall fescue in the diet. J. Anim. Sci. 75:2165-2173.
Hohenboken, W.D., P.L. Berggren-Thomas, W.E. Beal, W.H. McClure. 1991. Variation among Angus cows in response to endophyte-infected fescue seed in the diet, as related to their past calf production. J. Anim. Sci. 69:85-90.
Jacobson, D.R., W.M. Miller, D.M. Seath, S.G. Yates, H.L. Tookey, I.A. Wolff. 1963. Nature of fescue toxicity and progress toward identification of the toxic entity. J. Dairy Sci. 46:416-422.
Larson, B.T., D.L. Harmon, E.L. Piper, L.M. Griffis, L.P. Bush. 1999. Alkaloid binding and activation of D2 dopamine receptors in cell culture. J. Anim. Sci. 77:942-947.

Lipsey, R.J., D.W. Vogt, G.B. Garner, L.L. Miles, C.N. Cornell. 1992. Rectal temperature changes of heat and endophyte stressed calves produced by tolerant or susceptible sires. J. Anim. Sci. 70(Suppl. 1):188 (abstr.).

McLeay, L.M., B.L. Smith, G.W. Reynolds. 2002. Cardiovascular, respiratory, and body temperature responses of sheep to the ergopeptides ergotamine and ergovaline. Am. J. Vet. Res. 63:387-393.

McMurphy, W.F., K.S. Lusby, S.C. Smith, S.H. Montz, C.A. Strasia. 1990. Steer performance on tall fescue pasture. J. Prod. Agric. 3:100-102.

Muller-Schweinitzer, E. and H. Weidmann. 1978. Basic pharmacological properties. In: B. Berde and H.O. Schild HO (ed.) Handbook of Experimental Pharmacology, Vol. 49, Ergot Alkaloids and Related Compounds. pp 87-232. Springer-Verlag, Berlin.

Neill, J.C. 1941. The endophytes of ***Lolium*** and ***Festuca***. N. Z. J. Sci. Technol. 23A:185-195.

Oliver, J.W. 1997. Physiological manifestations of endophyte toxicosis in ruminant and laboratory species. In: C.W. Bacon and N.S. Hill (ed.) ***Neotyphodium***/Grass Interactions. pp 311-346. Plenum Press, New York.

Oliver, J.W., L.K. Abney, J.R. Strickland, R.D. Linnabary. 1993. Vasoconstriction in bovine vasculature induced by the tall fescue alkaloid lysergamide. J. Anim. Sci. 71:2708-2713.

Osborn, T.G., S.P. Schmidt, D.N. Marple, C.H. Rahe, J.R. Steenstra. 1992. Effect of consuming fungus-infected and fungus-free tall fescue and ergotamine tartrate on selected physiological variables of cattle in environmentally controlled conditions. J. Anim. Sci. 70:2501-2509.

Panaccione, D.G., R.D. Johnson, J. Wang, C.A. Young, P. Damrongkool, B. Scott, C.L. Schardl. 2001. Elimination of ergovaline from a grass-Neotyphodium endophyte symbiosis by genetic modification of the endophyte. Proc. Natl. Acad. Sci. USA 98:12820-12825.

Paterson, J., C. Forcherio, B. Larson, M. Samford, M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889-898.

Pertz, H. and E. Eich. 1999. Ergot alkaloids and their derivatives as ligands for serotonergic, dopaminergic, and adrenergic receptors. In: V. Kren and L. Cvak (ed.) Medicinal and Aromatic Plants - Industrial Profiles, Vol. 6, Ergot. pp 411-440. Harwood Academic Publishers, Amsterdam.

Peters, C.W., K.N. Grigsby, C.G. Aldrich, J.A. Paterson, R.J. Lipsey, M.S. Kerley, G.B. Garner. 1992. Performance, forage utilization, and ergovaline consumption by beef cows grazing endophyte fungus-infected tall fescue, endophyte fungus-free tall fescue, or orchardgrass pastures. J. Anim. Sci. 70:1550-1561.

Porter, J.K. 1994. Chemical constituents of grass endophytes. In: C.W. Bacon and J.F. White, Jr. (ed.) Biotechnology of Endophytic Fungi of Grasses. pp 103-123. CRC Press, Boca Raton, FL.

Porter, J.K. 1995. Analysis of endophyte toxins: fescue and other grasses toxic to livestock. J. Anim. Sci. 73:871-880.

Porter, J.K. and F.N. Thompson, Jr. 1992. Effects of fescue toxicosis on reproduction in livestock. J. Anim. Sci. 70:1594-1603.

Schnitzius, J.M., N.S. Hill, C.S. Thompson, A.M. Craig. 2001. Semiquantitative determination of ergot alkaloids in seed, straw, and digesta samples using a competitive enzyme-linked immunosorbent assay. J. Vet. Diagn. Invest. 13:230-237.

Schoning, C., M. Flieger, H.H. Pertz. 2001. Complex interaction of ergovaline with 5-HT2A, 5-HT1B/1D, and alpha1 receptors in isolated arteries of rat and guinea pig. J. Anim. Sci. 79:2202-2209.

Solomons, R.N., J.W. Oliver, R.D. Linnabary. 1989. Reactivity of dorsal pedal vein of cattle to selected alkaloids associated with Acremonium coenophialum-infected fescue grass. Am. J. Vet. Res. 50:235-238.

Strickland, J.R., J.W. Oliver, D.L. Cross. 1993. Fescue toxicosis and its impact on animal agriculture. Vet. Hum. Toxicol. 35:454-464.

Stuedemann, J.A. and C.S. Hoveland. 1988. Fescue endophyte: history and impact on animal agriculture. J. Prod. Agric. 1:39-44.

Stuedemann, J.A. and F.N. Thompson. 1993. Management strategies and potential opportunities to reduce the effects of endophyte-infested tall fescue on animal performance. In: D.E. Hume, G.C.M. Latch, H.S. Easton (ed.) Proc. Second Int. Symp. ***Acremonium***/Grass Interactions. Plenary papers. Feb. 3-6, Palmerston North, New Zealand. pp 103-114.

Stuedemann, J.A., F.N. Thompson, S.R. Wilkerson, G.M. Hill, D.P. Belesky, D.L. Breedlove, M. Mehrban. 1989. Effect of level of fungus and nitrogen fertilization rate of fescue on performance of Angus versus Brahman cross steers. J. Anim. Sci. 67(Suppl. 2):46 (abstr.).

TePaske, M.R., R.G. Powell, S.L. Clement. 1993. Analyses of selected endophyte-infected grasses for the presence of loline-type and ergot-type alkaloids. J. Agric. Food Chem. 41:2299-2303.

Thompson, R.W., H.A. Fribourg, J.C. Waller, W.L. Sanders, J.H. Reynolds, J.M. Phillips, S.P. Schmidt, R.J. Crawford Jr., V.G. Allen, D.B. Faulkner, C.S. Hoveland, J.P. Fontenot, R.J. Carlisle, P.P. Hunter. 1993. Combined analysis of tall fescue steer grazing studies in the Eastern United States. J. Anim. Sci. 71:1940-1946.

Thompson, F.N. and J.K. Porter. 1990. Tall fescue toxicosis in cattle: could there be a public health problem here? Vet. Hum. Toxicol. 32(Suppl):51-57.

Wagner, C.R., T.M. Howell, W.D. Hohenboken, D.J. Blodgett. 2000. Impacts of an endophyte-infected fescue seed diet on traits of mouse lines divergently selected for response to that same diet. J. Anim. Sci. 78:1191-1198

Walls, J.R. and D.R. Jacobson. 1970. Skin temperature and blood flow in the tail of dairy heifers administered extracts of toxic tall fescue. J. Anim. Sci. 30:420-423.

Yates, S.G., R.D. Plattner, G.B. Garner. 1985. Detection of ergopeptine alkaloids in endophyte-infected, toxic KY-31 tall fescue by mass spectrometry/mass spectrometry. J. Agric. Food Chem. 33:719-722.