Tall fescue (Lolium arundinaceum) is a cool-season perennial grass that many producers use for grazing beef cattle in the United States. Most tall fescue is infected with the endophyte fungus (Neotyphodium coenophialum) that is essential for the plant’s survival but detrimental to cattle performance. Ergot alkaloids are the generally accepted toxic agents produced by the fescue endophyte. Cattle that consume forages infected with this endophyte can develop fescue foot, fat necrosis, or fescue toxicosis. It is estimated that the beef industry loses over US$500 million annually due to fescue toxicosis through heat stress, reduced weight gain, suppressed appetite, and decreased reproductive performance. Other symptoms include a retained or rough hair coat and increased body temperature, which can be detrimental when animals are located in hot and or humid environments. Different forages and forage systems, feed additives, and animal management strategies have been tested through the years allowing the use of tall fescue in beef production systems while minimizing the adverse effects. An animal genetics approach needs to identify and select animals less susceptible to the ergot alkaloids. Research in this area reports that different cattle within the same herd can respond differently when grazing tall fescue, and evidence exists that breed type may also play a role in genetic tolerance to the negative effects on performance. Some studies have looked at the potential of identifying genetic markers that may assist in the selection of more resistant animals. From these studies, there is evidence that genetic variation does exist for resistance to the ergot alkaloids present when grazing endophyte-infected tall fescue. Forage management coupled with animal genetic selection could allow for more efficient use of tall fescue as a significant forage source in beef cattle systems. These would allow producing more beef per hectare in the United States in response to an increasing population combined with decreasing resources.

Key words: beef cattle, ergot alkaloids, genetic resistance, tall fescue
have been looking for ways to minimize these losses through forage and animal management.

Much research has been done to search for ways to minimize fescue toxicosis through the development of new varieties and different pasture management techniques (Parish et al., 2003); however, producers are reluctant to change pasture varieties because of the expense, labor, and time to manage new forages in well-established stands (Browning, 2004). Selecting animals based on their ability to withstand greater levels of ergot alkaloids would be another way to combat the adverse effects of fescue toxicosis. Research to date has been limited in this area and some results have been contradictory. Genetic resistance or tolerance, in combination with forage management, could allow producers to be even more profitable while using tall fescue as their base forage. The objective of this paper is to summarize work evaluating genetic variation in resistance to the effects of grazing endophyte-infected tall fescue.

VARIATION WITHIN BREED

Determining genetic variation for tolerance to fescue toxicosis would allow for a producer to make keep–cull decisions on animals in their herds. Identifying sires that produce calves that are less susceptible to the effects of fescue toxicosis would be valuable to producers. In a study by Gould and Hohenboken (1993), progeny from 2 Polled Hereford sires were fed endophyte-infected tall fescue seed to measure variability in susceptibility to fescue toxicosis. One sire was reputed to produce calves that were resistant to fescue toxicosis and another was used as a control with unknown performance. A total of 15 calves from the 2 sires were measured for voluntary feed intake, serum prolactin, cholesterol, and alkaline phosphatase concentrations. They also measured the ability to maintain body temperature and heat-transfer inefficiency. There were no differences among the 2 sire groups based on symptoms associated with fescue toxicosis; however, calves from the sire that had the reputation of producing calves that were resistant to fescue toxicosis had greater feed intake and lower rectal body surface temperatures through the trial. The authors suggested that this may have been the reason for the reputation of the sire to produce calves that were less susceptible to fescue toxicosis. However, the number of sires being evaluated in this study was very small.

Another study using eighteen 12-yr-old Angus cows evaluated the variation in production from females that spent most of their productive lives on pastures dominated by endophyte-infected tall fescue (Hohenboken et al., 1991). Two groups of cows were fed endophyte-infected seed or no seed in a cross-over design. There were no differences between cow groups for serum prolactin and cholesterol concentrations as well as no differences in calf weaning weights from past records over an 11-yr period. The authors stated that variation could and probably does exist for tolerance to fescue toxicosis; however, their experiment was unable to show those differences due to several issues with their project.

RESEARCH USING MICE AS A MODEL

In multiple experiments, mice were bred from genetic lines selected for resistance or susceptibility to growth depression from eating endophyte-infected tall fescue over 8 generations (Hohenboken and Blodgett, 1997). Progeny produced from these lines were fed diets with infected or noninfected seed. Average daily gain and activity of liver enzymes were measured. In all experiments, the susceptible genetic line of mice fed the endophyte-infected fescue diet had a greater reduction in initial ADG when compared with the resistant line of mice fed the same diet; however, susceptible lines did express compensatory gain later in the trial when on the diet of noninfected seed. For glutathione-S-transferase and uridine diphosphate glucuronosyl-transferase (GRT), 2 detoxifying enzymes found in the liver, activity from the resistant lines were generally greater than those from the susceptible lines. Enzymatic activity by GRT was significantly affected by dietary treatments. These results indicated a metabolic difference between the 2 genetic lines of mice. In these same mice, reproductive traits and mature size were evaluated on the same diets as in the previous study (Wagner et al., 2000). The resistant lines of mice produced more total pups born and weaned, more total litters, and greater total litter weight weaned than the susceptible lines when fed the endophyte-infected diet. The susceptible line of mice had greater mature weights than the resistant lines of mice on both diets. In addition, the endophyte-infected diet suppressed mature weight more for the susceptible line than the resistant line. Wagner et al. (2000) also investigated line and diet effects on hepatic glutathione-S-epoxytransferase and GRT enzyme activities on reproductive traits. Across diets, glutathione-S-epoxytransferase activity was higher for the resistant dams than for the susceptible dams but was not different by diet or line × diet. In both studies, growth, reproduction, and enzymatic activity were affected by consuming endophyte-infected diets when comparing resistant and susceptible genetic lines (Hohenboken and Blodgett, 1997; Wagner et al., 2000). Males were evaluated from these same genetic lines from the previous 2 studies for their effect on litter size when mated to females after being fed a diet containing endophyte-infected tall
fescue (Ross et al., 2004). Litter size was reduced by 0.5 pups in mates of the susceptible males but increased by 1.0 in mates of resistant males. In another study using mice, Miller et al. (1994) evaluated inbred genetic lines and line crosses in several experiments for susceptibility and resistance to fescue toxicosis for growth and reproduction. They reported no differences among the genetic groups when exposed to a 50% endophyte-infected tall fescue diet. The same results were found in other studies where 2 genetic lines were compared for growth (Godfrey et al., 1994; Duringer et al., 2005).

**BEEF CATTLE BREEDS AND BREED CROSSES**

Authors of several papers have reported on the interactions of breed or breed type and grazing endophyte-infected tall fescue. Most of these reports have centered on looking at incorporating Bos indicus breeding and their subtropical adaptability in trials to evaluate their ability to withstand increased body temperature that is a common symptom of fescue toxicosis. Browning (2000) determined that there were no differences in cortisol or prolactin concentrations, respiration rate, rectal temperature, skin temperature at the tail head or tip, systolic or diastolic blood pressure, or heart rate between Hereford and Red Brahman steers injected with ergotamine. Browning (2004) compared Senepol and Hereford steers for thermal status and growth when challenged with a diet consisting of endophyte-infected tall fescue or orchardgrass (Dactylis glomerata). Senepol steers were less susceptible to heat stress when compared with Hereford steers and had greater ADG when consuming the endophyte-infected diet. In another study, no differences were found when Romosinuano (a heat-tolerant Bos taurus breed) and Angus dams were compared for milk production and milk quality when grazing endophyte-infected tall fescue (Burke et al., 2010). In 1 of 3 experiments, Cole et al. (2001b) compared Angus and Brahman × British crossbred steers on low, moderate, and high endophyte infestation pastures for ADG, feedlot, and carcass traits. They reported differences overall when comparing percentage infestation in pastures; however, there were no differences when comparing breed types.

Genotype × environment interaction was evaluated using Angus, Brahman, and reciprocal cross calves on common bermudagrass (Cynodon dactylon) and endophyte-infected tall fescue (Brown et al., 1993a,b,c, 1996, 1997, 2000). For preweaning data (Brown et al., 1993b), averaged values of heterosis for birth weight, 205-d weight, weaning hip height, and weaning weight to height ratio were similar across forage environments. Calf comparisons of the same breeding indicated a larger heterotic effect for postweaning ADG in calves managed on endophyte-infected tall fescue (Brown et al., 1993a). Daily milk yield and milk fat percentage were estimated on 60 Angus and 60 Brahman cows over a 3-yr period (Brown et al., 1993c). It was found that endophyte-infected tall fescue decreased milk yield more in Angus cows than in Brahman cows, but there were no differences in milk fat percentage. Brown et al. (1996) added reciprocal cross cows to the evaluation and measured milk yield and milk fat percentage again along with protein and somatic cell counts over a 4-yr period. Direct and maternal breed effects and heterosis were estimated for these traits. Results indicated greater levels of heterosis on common bermudagrass than on tall fescue and no effects for milk protein or somatic cell counts. Two studies evaluated reproductive and preweaning data on Angus, Brahman, and reciprocal crosses with 2- and 3-breed-cross calves (Brown et al., 1997, 2000). In both studies, it was found that Brahman-cross cows had more of an advantage over purebreds when managed on endophyte-infected tall fescue when compared with common bermudagrass. Similar results were also found by Cole et al. (2001a) for Brahman × Angus and Angus × Brahman crossbred cows.

In a sheep study, Burke et al. (2002) found that pregnancy and lambing rates were similar when comparing St. Croix, Romanov, and their crossbred ewes while grazing bermudagrass overseeded with ryegrass or endophyte-infected tall fescue. Birth weights and weaning weights of lambs were similar for suckling ewes across forages, and BCS were maintained in an acceptable range.

**GENETIC MARKERS**

With the current trend of looking for those significant genes that play a role in the expression of a phenotype, several studies have looked at identifying genetic markers that could have a large impact on tolerance to fescue toxicosis. Genes that influence control of prolactin have been explored because of the association of fescue toxicosis and decreased circulating prolactin concentrations. Looper et al. (2010) took genomic DNA samples from purebred Angus, Brahman, and their reciprocal cross cows and calves. Polymorphisms were evaluated in the enhancer region of the bovine prolactin gene. Cows were grazing either common bermudagrass or endophyte-infected tall fescue for their lifetime. Cows with the TT genotype at c1286t in the discovery population that grazed endophyte-infected tall fescue had reduced calving rates during their lifetime compared with all other genotypes. An intronic SNP was discovered within the dopamine receptor D2 gene (Campbell et al., 2014). In this study, 42 Angus-based steers were grazed on endophyte-infected tall fescue and a nontoxic fescue and genotyped for the receptor D2 gene. Genotype was associated with decreased
serum prolactin concentrations and increased hair scores (1 = short and smoother and 5 = rough, long, and shaggy) when grazing the endophyte-infected tall fescue. In addition, spring- and fall-calving Angus cows were genotyped for the same D2 SNP. Cows calving in the spring on endophyte-infected tall fescue were more susceptible to fescue toxicosis. The favorable genotype was more prevalent in the spring-calving cows, possibly indicating natural genetic selection for animals that are more resistant to fescue toxicosis. In another study, a polymorphism within the \textit{XKR4} gene located on BTA14 was examined for its association to serum prolactin levels in beef cows grazing endophyte-infected tall fescue (Bastin et al., 2014). The SNP was associated to serum prolactin concentrations with a genotypic effect in Angus and Simmental cattle.

**OTHER INDICATOR TRAITS**

There are multiple signs that indicate the occurrence of fescue toxicosis because of the many ways an animal responds to this stressor. Identifying animals with the disease frequently requires blood collection or some other extensive evaluation of the animal. For beef producers, determining a way to easily identify those animals with minimal effort and cost would be appealing. One of the signs of fescue toxicosis that can be easily detected in many breeds is a retained winter hair coat. Fescue toxicosis commonly results in a rough hair coat, due to winter hair coat retention during the summer months, with decreased tolerance to heat stress (Porter and Thompson, 1992; Aiken et al., 2001; McClanahan et al., 2008). Research has indicated that the effect of fescue toxicosis is relative to the amount of fungal endophyte in the forage consumed. Coffey et al. (2001) observed that steers consuming low endophyte-infected tall fescue had shorter and sleeker hair coats than steers consuming high endophyte-infected tall fescue.

Gray et al. (2011) made an effort to establish a hair coat shedding scale and determine its association with cattle performance. Angus cows ($n = 532$) over 3 yr of age with their calves were evaluated every 30 d from March to July for their ability to shed their winter coat over a 3-yr period. Approximately 50% of the cows were located in Mississippi and the others were located at the Upper Piedmont Research Station in North Carolina and maintained on endophyte-infected tall fescue pastures. Trained technicians used a scale of 1 to 5 with a 1 representing a cow that had completely shed her winter coat (slick) and a 5 was where no shedding had occurred. Cattle that had reached an average score of 3 or less by May first were grouped as early shedders and those after were considered late. Calf 205-d weaning weight was measured as a trait of the dam. Calves from cows that had reached a score of 3 or less by the end of May were 11.1 kg heavier for 205-d weaning weight than their contemporaries that were out of cows that began to shed after May. Variance components were also measured for shedding ability and its association to 205-d weaning weight. Heritability for shedding ability was found to be moderately heritable at 0.35 (95% confidence interval = 0.261 to 0.587). Shedding ability was moderately strong and negatively correlated with d-205 weaning weight and highly repeatable at 0.65. Similar heritability estimates and genetic correlations have been found by other methods of scoring hair coats in other breeds of cattle (Schleger and Turner, 1960; Turner and Schleger, 1960; Williams et al., 2006).

Hair coat shedding ability becomes economically important with the association of hair shedding and weaning weight of calves. Gray et al. (2011) concluded that while animals in North Carolina were on endophyte-infected tall fescue, there was still variation in shedding throughout the herd. This could indicate the possibility of using shedding ability as a way to identify animals that are genetically resistant to the effects of fescue toxicosis or more adapted to their environment. Evaluating animals for shedding would be an easy way to identify those individuals and would be an applicable selection tool for producers to use. However, further research would be needed to understand the relationship of shedding to productive traits and other measurements associated with fescue toxicosis.

**SUMMARY AND CONCLUSIONS**

With tall fescue being an important base forage for many beef operations in the United States, researchers and producers are constantly looking for ways to increase production by controlling the adverse effects of grazing endophyte-infected varieties of tall fescue. Changing forage varieties and management of the forage have proven benefits but may not be the only answer. Selecting animals that are genetically resistant to fescue toxicosis coupled with management strategies could be more profitable for producers. Less research has been done in this area compared with other methods of alleviating the effects of fescue toxicosis. Although some work has been done, for most trials, animal numbers have been an issue and looking at genetic variance usually takes considerable resources. In most cases, producers have already inadvertently selected for genetic resistance for fescue toxicosis by keeping cows that have the least symptoms of the disease, calve every year, and wean the heaviest calves. These characteristics would identify those individuals that could thrive in an environment where endophyte-infected tall fescue is the base forage. However, there
still may be opportunity to select for those individuals that have a greater threshold for tolerance and show no symptoms when ergot alkaloids levels are great.

Another problem with studying genetic resistance to fescue toxicosis has been assuring that animals consume enough of the toxin to elicit a response. This usually requires individual feeding systems to assure that this can occur, and coupling that with the needed animal numbers can be challenging. More recent and promising research has looked at identifying major genes, their variants, and the impact they have on phenotypic variation when consuming the toxins. It seems that genetic variation does exist for susceptibility or tolerance to fescue toxicosis. The goal would be to provide a producer with an easy selection tool that he or she could use to identify those individuals that would be more profitable in a tall fescue forage-based system. Research with adaptive traits, such as hair shedding, could be a good candidate. Genetic resistance to fescue toxicosis is an area that needs to be further researched to allow us to be as efficient as possible with every grazeable hectare we have while sustaining the livelihood of our U.S. beef cattle producers.

**LITERATURE CITED**


