INFLUENCE OF ENDOPHYTE INFECTION OF TALL FESCUE WITH AND WITHOUT WHITE CLOVER ON PERFORMANCE, INTAKE, AND BITE SIZE IN STEERS DURING THE GRAZING SEASON AND SUBSEQUENT PERFORMANCE IN THE FEEDLOT

by

James Kevin Tully

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APPROVED

J.P. Fontenot, Chairman

V.G. Allen

H.J. Gerken, Jr.

D.E. Eversole

F.C. Gwazdauskas

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ABSTRACT

Experiments were conducted to investigate effects of endophyte (*Acremonium coenophialum* Morgan-Jones and Gams) infection of tall fescue (*Festuca arundinacea* Schreb.) on grazing cattle and subsequent feedlot performance, serum minerals and prolactin, intake, digestibility, bite size, and biting rate. Grazing animal performance was measured April to October, 1989 and 1990, at two locations in VA. Effects of grazing low (<5%) and high (>70%) endophyte infected tall fescue, with and without white clover (*Trifolium repens* L.), were studied with yearling steers. At each location, two replicates were used with a stocking rate of .3 ha/steer (116 steers/yr). At the end of grazing, all animals were finished on a high corn silage diet and slaughtered. Daily gains of steers grazing low endophyte-infected pastures were higher (P<.01) than for those grazing high endophyte-infected pastures. Cattle grazing high endophyte-infected tall fescue with clover at Glade Spring gained at the same rate as those grazing the low endophyte-infected tall fescue without clover during Summer, 1989.

During 1990, cattle at Glade Spring had higher ($P<.05$) daily gains than did those at Blackstone.

Rectal temperatures were .5 to 1 °C higher ($P<.05$) for steers grazing infected pastures by June of each year at both locations. Prolactin concentrations were lower ($P<.01$) in cattle grazing endophyte-infected fescue within 28 d of initiation of grazing at both locations. Visual evaluation indicated that steers grazing high-endophyte pastures had rough hair coats compared to those grazing low endophyte pastures ($P<.01$), showing evidence of tall fescue toxicosis. Serum mineral analyses indicated no consistent influence of the endophyte. During feedlot finishing, there were no detrimental effects from previously grazing endophyte-infected tall fescue on animal performance.

Forage DM yield, and CP in 1990, and IVDMD in 1989 and 1990 from Glade Spring were higher ($P<.05$) compared to Blackstone. Forage from Blackstone was typically higher in NDF, ADF, and lignin compared to Glade Spring. Forage from Glade Spring was higher in Ca, Mg, P, and Cu, compared to Blackstone.

Diet selection, digestibility, biting size, and biting rate were measured with esophageally-fistulated steers grazing low (<5%) and high (>70%) endophyte-infected tall fescue, with and without white clover. Bite size was smaller ($P<.05$) in July compared to May, corresponding to decreased quantity of forage available. Bite size and biting rate were not affected by endophyte infection or inclusion of clover. In vitro DM digestibility was higher (P<.05) for high endophyte-infected tall fescue in July. Animals consumed a higher percentage of clover than was available in the sward.

Intake and digestibility were estimated using 48 experimental animals and four esophageally-fistulated steers. Chromic oxide sustained-release boluses and forage IVDMD were used to estimate intake. The chromic oxide boluses were determined to be reliable for predicting intake of steers during a 21 d trial involving total fecal collection. Intake was higher (P<.01) in cattle grazing low endophyte-infected tall fescue compared to animals grazing high endophyte-infected fescue.

Twenty-one Angus steers (256 kg) were used to compare the effect of 0 and 40% endophyte-infected tall fescue and orchardgrass hay on DM intake, daily gain, body temperature, serum minerals, and prolactin concentrations during an 8 wk study. Quality of the diets was low, as indicated by low CP (8.1 to 10.3%), and IVDMD (41.3 to 47.1%). Daily DM intake and daily gain were higher (P<.05) for animals consuming the noninfected tall fescue compared to animals fed the other hays. Body temperature and serum prolactin were not affected by diet. These data suggest that other factors, besides endophyte infection, are important in the etiology of tall fescue toxicosis. Some of the decreased performance of steers grazing endophyte-infected tall fescue was related to lower intake. Additional research is needed to evaluate higher levels of clover to possibly ameliorate some of the problems of tall fescue toxicosis.

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CHAPTER I.

INTRODUCTION

Tall fescue (*Festuca arundinacea* Schreb.) is utilized as a forage crop throughout the Southern and Mid-Atlantic states. Approximately 14 million ha are grown in the United States. Tall fescue is a widely adapted, high yielding, cool-season grass. When properly managed, the quality of tall fescue is good.

The desirable agronomic characteristics of tall fescue are often overshadowed by reduced performance of animals consuming the forage. This reduced performance is characterized by reduced daily gain, decreased reproductive performance, reduced circulation to the extremities, rough hair coats, and altered hormone concentrations. The association of an endophytic fungus (*Acremonium coenophialum* Morgan-Jones and Gams) and increased ergopeptide alkaloids with tall fescue has been linked to the reduced animal performance.

Plant growth and composition are affected by soil fertility and moisture as well as environmental conditions. The complex interaction of soil, plant and animal under the constraints of the environment has not been addressed concerning endophyte-infection of tall fescue. Moisture stress may cause an increase in alkaloid content of endophyte-infected tall fescue. The influence of temperature on the toxic factors of tall fescue is less clear.

Climatic differences exist in the area of adaptation of tall fescue. Animal performance is affected by environment. Ambient temperature outside the thermoneutral zone of the animal results in reduced intake and therefore a reduction in overall animal performance. Animals are able to cope with some high-temperature stress if they are able to maintain comfort during the nighttime hours. Information is needed concerning the reduction in intake of animals grazing endophyte-infected tall fescue and to what extent the reduction in intake accounts for the reduced performance. Experiments have not been conducted to evaluate the effects of grazing endophyte-infected tall fescue in different environments on animal performance.

Tall fescue, with little or no endophyte infection, offers potential for reducing the impact on animal performance. However, the limited information on endophyte-free tall fescue indicates that stand persistence is compromised in these cultivars. More intense management may be required to extend the longevity of the stand. Introduction of legumes may offer some benefit, possibly by diluting the intake of toxic tall fescue.

Given the limited information available on environmental and forage effects on cattle grazing endophyte-infected tall fescue, experiments were designed to address these issues. Animal performance, blood parameters, hair coat scores, body temperatures, and forage yield and composition were monitored during 2 yr of a long-term experiment with cattle grazing low and high-endophyte-infected tall fescue, with and without white clover, at two locations in Virginia. In addition, the effect of the endophyte on bite size, biting rate, and DM intake was examined at one of the locations. The effect of grazing high endophyte fescue on subsequent feedlot performance was studied also.

CHAPTER II.

REVIEW OF LITERATURE

Tall fescue was first identified in the U.S. at Suiter's farm in Kentucky (Fergus, 1972). 'Kentucky-31', the most extensively grown cultivar of tall fescue, was released in 1942, as noted by Stuedemann and Hoveland (1988). The excellent growth, quality, and ease of establishment of tall fescue resulted in wide acceptance. There are approximately 14 million ha of tall fescue in the United States, primarily in the transition zone between the north and south in the east (Siegel et al., 1985).

Animal performance was not always as high as expected, given the composition of the forage. Animals grazing tall fescue developed various symptoms, that became synonymous with "fescue toxicosis" (Pulsford, 1950; Goodman, 1952; Stuedemann and Hoveland, 1988). Signs of these problems included depressed gains, elevated body temperatures, depressed serum prolactin concentrations, rough and dirty hair coats, and gangrene of the extremities.

The identification of higher alkaloid content in certain strains of tall fescue provided evidence concerning the causes of fescue toxicosis (Robbins et al., 1972; Bush and Jeffreys, 1975). Separation of alkaloids by gas chromatography revealed pyrrolizidine alkaloids, especially

N-formyl-loline in toxic tall fescue. Kennedy and Bush (1983) reported an increase in N-acetyl- and N-formyl-loline content in water stressed endophyte-infected tall fescue grown in a greenhouse subjected to low, medium or control water treatments for 12 wk. Porter et al. (1981) and Yates et al. (1985) identified ergopeptine alkaloids in endophyte-infected tall fescue. Signs of fescue toxicosis were identified in cattle grazing 'KY-31' tall fescue (95% infected) with .4 μg/g ergopeptine alkaloids in the forage (Yates et al., 1985).

The identification of an endophytic fungus (*Epichloe typhina*, later reclassified as *Acremonium coenophialum* Morgan-Jones and Gams) infecting tall fescue resulted in additional insight about the causes of fescue toxicosis (Morgan-Jones and Gams, 1982). Hill and Stringer (1985) reported that 75% of the fescue samples submitted from SC were more than 60% infected. In VA, 75% of the fields sampled for the endophyte had greater than 50% infection (Gerken et al., 1986). An analysis of 4,500 samples from 30 states and several foreign countries tested at Auburn University indicated that 90% of the samples had some level of infection (avg infection=60%; Ball et al., 1991).

Acremonium coenophialum exists in a symbiotic relationship with tall fescue (Clay, 1987; Cheplick et al., 1989). The grass provides the endophyte with a suitable environment and the endophyte confers resistance to insect predation (Clay et al., 1985; Buttrey, 1989), drought tolerance (Read and Camp, 1986), and altered metabolism (West et al., 1990) on the host grass which would result in competitive advantage over non-infected plants.

Yates et al. (1985) reported the presence of ergot alkaloids in infected 'KY-31' tall fescue from Missouri but none were located in noninfected plants from Georgia. High levels of N fertilizer have been reported to aggravate the symptoms of fescue toxicosis (Stuedemann et al., 1975; Garner and Cornell, 1985). This may be explained, at least partly, by the increased ergot alkaloids detected in leaf sheath and blade from N-fertilized, infected tall fescue, compared to nonfertilized, infected fescue (Lyons et al., 1986).

Symptoms in animals consuming endophyte-infected tall fescue are similar to those observed in animals suffering from ergot alkaloid poisoning (Burns, 1978; Bacon et al., 1986; Ensminger et al., 1990). Ergovaline constituted the greatest percent of total ergot alkaloids in tall fescue (Lyons et al., 1986). Garner (1989) reported that as little as 200 ppb ergovaline resulted in classical fescue toxicosis signs. More recently, Cornell et al. (1990) reported that as little as 50 ppb ergovaline supplied through endophyte-infected seed caused measurable physiological effects in 180 to 250 kg Angus calves.

<u>Agronomic Description</u>

Endophyte-infected plants were larger and had more tiller growth compared to endophyte-free plants in the greenhouse (Clay, 1984). Buttrey (1989), in Virginia, reported a numerical increase in tiller number of endophyte-infected 'Kenhy' tall fescue compared to endophyte-free fescue of the same cultivar. In Texas, high (>90%) infected tall fescue of the cultivar 'Kenhy' consistently had more forage available per animal than low endophyte-infected tall fescue (Read and Camp, 1986). In addition, two of three replicates of the low infected pastures were lost, possibly due to drought. Under field conditions endophyte-infected tall fescue consistently out yielded noninfected tall fescue (Bouton et al., 1988; Hill, 1988; Joost, 1988; West et al., 1988).

Buttrey (1989) reported an increase in DM yield of 'Kenhy' tall fescue infected with the endophyte compared to endophyte-free 'Kenhy' when maintained in the greenhouse with adequate moisture. However, Hill et al. (1990) and Chestnut et al. (1991) reported that for tall fescue grown in the greenhouse, DM yield was not affected by the endophyte.

Forage analysis identified few differences between infected and noninfected tall fescue. Endophyte infection did not affect NDF or ADF of seed (Jackson et al., 1984) or hay (Straham et al., 1987). Bond et al. (1984) examined composition of four varieties of tall fescue of varying levels of endophyte infection. No differences were detected for ADF, NDF, and CP. Crude protein in forage from infected and noninfected tall fescue was not different (Hemken et al., 1981).

Buttrey (1990) reported few differences in mineral composition between endophyte-infected 'Kenhy' tall fescue and endophyte-free 'Kenhy' when grown in the greenhouse. When grown under field conditions, the only consistent result observed was a lower Cu concentration in high endophyte-infected tall fescue compared to tall fescue with no infection. Tall fescue forage from plants with 9 to 97% infection from 7 farms in VA indicated no excesses or imbalances in mineral content (Fontenot et al., 1988).

Total non-structural carbohydrates (TNC) of endophyte-free tall fescue plants tended to be greater than endophyte-infected plants (Hill et al., 1990). However, no difference was detected for TNC between the varieties 'KY-31', 'Kenhy', and the experimental lines 'G1-306' and 'G1-307' examined by Bond et al. (1984b). Similar results were reported by Buttrey (1989) when comparing TNC of endophyte-infected

'Kenhy' tall fescue compared to endophyte-free 'Kenhy'. Hemken et al. (1981) reported that ether extract and ash were not different between infected and noninfected tall fescue forage.

Altered N metabolism was proposed by Lyons (1985) who reported that endophyte-infected tall fescue plants had increased glutamine synthetase activity. Belesky et al. (1985) examined amino acid composition of tall fescue seed because pyrrolizidine alkaloids are secondary metabolites of amino acids. The amino acid composition of varieties, 'Fawn', 'Kenhy', 'KY-31', and an experimental line of tall fescue, each infected and non-infected, were not different. It is interesting to note that glutamate/ glutamine accounted for the greatest amount of amino acids recovered. The metabolism of endophyte-infected tall fescue compared to non-infected plants deserves additional research.

The influence of environmental conditions on tall fescue composition is important, given the impact on animal performance during different seasons. A higher perloline content of tall fescue analyzed in July compared to tall fescue collected in winter may have been due to decreased photosynthesis associated with decreased hours of light in winter (Gentry et al., 1969). At that time infection with the endophyte was not known.

Animal Response to Endophyte Infection of Tall Fescue

Nutritive value of tall fescue is high (Jacobson, 1957; Buckner et al., 1967); however, animal performance is often compromised when endophyte-infected tall fescue is fed or grazed. Hoveland et al. (1980) reported a reduction of .23 kg in daily gains of crossbred steers in Alabama grazing high (>60%) endophyte-infected tall fescue compared to those grazing fescue of <20% infection.

Read and Camp (1986) reported that grazing endophyte-infected tall fescue reduced daily gains of half-sibling steers (.97 kg vs .46 kg). Levels of infection were >90% compared to <25%. Crawford et al. (1989) examined the influence of endophyte infection of tall fescue on daily gains of Holstein steers. Their results and those of Stuedemann et al. (1985d), indicated that for each 10% infection rate of tall fescue, there was a concomitant decrease of .045 kg in daily gain. Angus and Holstein steers had lower daily gains when grazing 100% infected 'G1-307' compared to those grazing non-infected 'KY-31' or 'Kenhy' (Bond et al., 1984b). From these data, it was easy to conclude that endophyte infection of tall fescue adversely affected animal performance.

A reduction in intake could account for some of the poor performance observed. Consumption of endophyte-infected seed and hay was reduced in steers by 2.3 and .39

kg/d, respectively (Schmidt et al., 1982). Intake of DM by sheep was reduced by 50% when fed endophyte-infected tall fescue hay compared to endophyte-free hay (Spears et al., 1984). A 20% reduction in intake was reported for cattle fed endophyte-infected (71%) tall fescue hay compared to animals fed fescue of less than 20% infection (Chestnut et al., 1991). Crossbred wethers (avg wt 30 kg) fed endophyte-infected ('G1-307', >95%) tall fescue hay consumed less forage and required more time to consume the entire meal than lambs fed low-endophyte (<1%) 'KY-31' tall fescue (Fiorito et al., 1991).

The reduction in intake would appear to be temperature related from the results of Hemken et al. (1981). Holstein calves were housed at 10 , 21, and 34 °C and fed 'G1-307' or 'G1-306' tall fescue. At the low temperatures there was no difference in performance or intake, but as the temperature increased from 21 to 34 °C DM intake decreased 20% with a concomitant loss of body weight. Hannah et al. (1990) fed sheep (avg initial wt, 26.8 kg) 0 or 1.5 ppm ergovaline ,through infected tall fescue seed, when housed at 27 and 34 °C. Feed was offered at 100 g of diet per kg of $BW^{.75}$. Intake was not changed by temperature in lambs fed either 0 or 1.5 ppm ergovaline.

Reduction of intake in animals grazing endophyte-infected tall fescue has been reported (Stuedemann et al., 1989; Aldrich et al., 1990; Howard et al., 1990). The magnitude of the reduction varied from 24 to 44% in steers. These experiments have been conducted with different cultivars representing the different infection levels. Research is needed comparing endophyte infection of one cultivar.

The reduction in intake may be explained, at least partly, by an alteration in grazing behavior. Steers grazing tall fescue have been observed to frequent mud holes, stand in water and spend less time grazing (Bowman et al., 1973; Stuedemann et al., 1985b). Grazing time was reduced and more time was spent in the shade by Angus and Holstein steers grazing toxic 'G1-307' compared to animals grazing 'G1-306' (nontoxic), 'KY-31', or 'Kenhy' tall fescue (Bond et al., 1984a). This grazing behavior is typical of steers under heat stress (Low et al., 1981). During the hot afternoon hours, steers grazing low endophyte-infected fescue grazed more than 40% of the time, while steers on infected fescue pastures grazed less than 25% of the time (Stuedemann et al., 1985b). Howard et al. (1990) reported that more time (537 vs 507 min/d) was spent standing without grazing by steers on endophyte-infected pastures compared to those on endophyte-free pastures.

<u>Effect of Endophyte Infection on Digestibility</u>

Total tract digestion of DM, NDF, and ADF was depressed in wethers consuming endophyte-infected (>95%) tall fescue compared to noninfected tall fescue hay (Fiorito et al., 1991). Sheep fed high and low endophyte-infected tall fescue silage had similar apparent digestibilities of DM, NDF, and ADF (Zylka, 1989). Ergovaline, supplied through tall fescue seed at 3 or 6 ppm, reduced OM digestibility in sheep fed at 10% less than the voluntary consumption of the animal that consumed the least amount of diet (Hannah et al., 1990). A minimum of 1.5 ppm was required to decrease digestibility especially at elevated temperatures.

Barth et al. (1989) and Fiorito et al. (1991) reported that N digestibility was reduced in lambs fed infected vs. noninfected tall fescue. Urinary N excretion was not affected (Barth et al., 1989). Nitrogen retention tended to be higher for sheep fed low infected tall fescue silage compared to animals fed high infected silage (Zylka, 1989).

Retention of minerals in sheep was not affected by endophyte status of tall fescue silages, with the exception that K retention decreased with increasing endophyte level (Zylka, 1989). Buttrey (1989) reported little difference in serum mineral concentrations of 200 kg steers fed endophyte-infected 'Kenhy' tall fescue hay or silage compared to animals fed orchardgrass/alfalfa hay. However, K was lower in steers fed the orchardgrass/alfalfa hay (Buttrey, 1989).

In a comprehensive survey from seven farms in VA, Fontenot et al. (1988) were unable to identify any consistent differences in serum minerals of cattle grazing tall fescue with endophyte infection levels of 9 to 97%.

Physiological Response to Consumption of Endophyte-Infected Tall Fescue

Hemken et al. (1979) reported higher rectal temperatures in Holstein cows fed toxic 'G1-307' hay with high loline and low perloline alkaloid content, compared to cows fed nontoxic 'G1-306' with low loline and high perloline alkaloid content, and 'KY-31' with intermediate perloline concentration. Elevated body temperatures were reported in Angus and Holstein steers grazing 'G1-307' tall fescue (Bond et al., 1984b). Body temperature was elevated in Angus heifers and steers fed endophyte-infected tall fescue hay compared to those fed low endophyte-infected hay (Boling et al., 1989). This temperature increase has been suggested to be related to the vasoconstrictive action of the ergot alkaloids (Turner et al., 1985).

Rhodes et al. (1991) reported decreased blood flow to skin of the inner hind leg and to the adrenals of wethers (avg BW 41 kg) consuming endophyte-infected tall fescue. Dietary treatments included high (1.18 ppm ergovaline) and low (<.05 ppm ergovaline) endophyte-infected tall fescue.

In 188 kg Holstein steers, blood flow was slightly reduced to the front hoof coronary band of animals fed 2.63 ppm ergovaline compared to those consuming less than .05 ppm ergovaline through tall fescue (Rhodes et al., 1991). The early observations of Pulsford (1950) and Goodman (1952) concerning lameness of cattle grazing tall fescue may have been the first indications of poor circulation to the extremities of animals grazing endophyte-infected tall fescue.

The results of Bond et al. (1984b) indicated that Angus and Holstein steers grazing toxic 'G1-307' were emaciated and had rough hair coats. Cattle grazing infected tall fescue were observed to have rough, dirty hair coats (Read and Camp, 1986). Recently, controlled, statistically correct studies have been conducted concerning the endophyte and hair coat scores. Fribourg et al. (1990) reported a tendency for rough, long hair coats in steers grazing infected vs. smooth hair coats in steers grazing noninfected tall fescue. Steers had more rough, dirty hair coats when grazing endophyte-infected tall fescue compared to those grazing endophyte-free fescue from April to September in Tennessee (Chestnut et al., 1991).

Reduced serum prolactin is a sign of fescue toxicosis in cattle (Bacon and Siegel, 1988; Studemann and Hoveland, 1988). Serum prolactin was increased in 3-mo-old Holstein heifers when ambient temperature was increased from 21 °C to 27 °C (Wetteman and Tucker, 1974). When exposed to 10 °C, serum prolactin was reduced. Lambs housed at 30 C had higher serum prolactin concentrations than lambs housed at 10 or 20 C (Hahn et al., 1987). The response to increasing temperature has been attributed to a decrease in the activity of dopaminergic neurons which mediated acute temperature induced changes in prolactin release from the pituitary (Tucker et al., 1991). Hahn et al. (1987) reported an increase in serum prolactin in lambs housed at 16 h of light compared to those maintained with 8 h light. Holstein bull calves exposed to 16 h of light had 8-fold higher serum prolactin compared to calves exposed to 8 h of light (Zinn et al., 1991).

Ergot peptides inhibit prolactin secretion in cattle (Karg and Schams, 1974). Lactating Holstein cows were injected with 80 mg of 2-bromo-α-ergocryptine. Serum prolactin was reduced within 2 h after injection and lasted for at least 5 d. In addition, ergocryptine decreased prolactin produced by pituitary cells in vitro (Smith et al., 1974). Tall fescue toxicosis is characterized by low serum prolactin (Hurley et al., 1981; Bacon and Seigel, 1988). This reduction may be due in part to the effect of ergot alkaloids (Berde and Schield, 1978).

There is evidence to indicate the role of prolactin in temperature regulation (Faichney and Barry, 1986). Injection of 2-bromo-α-ergocryptine suppressed prolactin secretion in anestrous ewes. Ewes exposed to mild heat stress responded by increasing respiration rate and were able to maintain body temperature. However, ewes with reduced serum prolactin had impaired thermoregulation when exposed to mild heat stress. These results have important application to tall fescue toxicosis research. The feeding of toxic 'G1-307' tall fescue to cattle appeared to block the normal increase of prolactin associated with increased temperature (Hurley et al., 1981). However, Ghorbani et al. (1989) reported that tall fescue with 7.5 and 15% infection did not alter serum prolactin of Holstein calves.

Sergent et al. (1988) used ergocryptine to artificially reduce serum prolactin in male goats. After ergocryptin injection rectal temperatures were elevated even though respiration rate increased. Perera et al. (1986) reported that Holstein cows exposed to 22 °C increased respiration rates compared to cows at -.6 °C.

At moderate temperatures, water intake was similar for cattle (Hemken et al., 1981) fed equivalent amounts of endophyte-infected or noninfected tall fescue. Similar results have been reported for sheep (Barth et al., 1989). The feeding of toxic 'G1-307' tall fescue to anestrous ewes under conditions of moderate heat stress resulted in reduced water intake compared to those fed nontoxic 'G1-306' (Faichney and Barry, 1986). Fiorito et al. (1991) reported that voluntary water consumption of wethers in metabolism stalls was dramatically lower in lambs fed high endophyte-infected tall fescue compared to lambs receiving low-infected tall fescue. Consumption of 'G1-307' by Holstein cows resulted in 173% greater urine output compared to cows consuming 'KY-31' tall fescue of moderate alkaloid content (Hemken et al., 1979). It is clear that water balance of animals consuming infected tall fescue is altered, however, the magnitude of the problem has not been defined.

Numerous other physiological traits have been investigated regarding endophyte infection of tall fescue. Hurley et al. (1981) reported no effect of feeding freshly cut toxic 'G1-307' tall fescue on bovine triiodothyronine (T_3), thyroxine (T_4), and thyrotropin. However, prolactin was lower in calves fed the 'G1-307' compared to those fed 'G1-306' tall fescue hybrid. Thyroxine in lambs was not affected by endophyte infection of tall fescue hay (Fiorito et al., 1991). This study also reported no increase in body temperature of the sheep. Thyroxine, triiodothyronine, and cortisol, hormones associated with metabolic rate and thermoregulation, were not changed in ewes or heifers fed endophyte-infected tall fescue compared to controls fed noninfected tall fescue (Aldrich et al., 1990). It appears increased body temperature in cattle consuming endophyte-infected tall fescue is not related to altered thyroid and adrenal cortex function.

Porter et al. (1990) investigated the effect of feeding infected 'KY-31' tall fescue to Angus steers on pituitary and pineal function. Two treatment regimens were imposed in which animals received either endophyte-free or endophyte-infected tall fescue. After 6 wk one-half of the animals from each treatment were switched to the other diet. Two notable differences were detected in the animals that consumed the endophyte-infected fescue for the entire 12 wk. These animals had increased pituitary dihydroxyphenylacetic acid which is a major metabolite of dopamine. In addition the animals fed the infected fescue had increased pineal 5-hydroxytryptophan, a precursor to serotonin, compared to animals fed noninfected fescue for 12 wk.

Strategies to Ameliorate Effects of Endophyte Infection

Numerous strategies have been proposed to reduce the impact that endophyte infection of tall fescue has on animal performance. The most drastic method would be destruction of the stand and seeding with a noninfected grass. Fribourg et al. (1988) recommended replacement of stands containing more than 30% infection. In stands of less than 30%

infection Fribourg et al. (1988) and Chestnut et al. (1991) stated that seeding a legume into the existing sod may be a more appropriate alternative.

Ladino clover has been successfully fall-seeded into tall fescue stands, however, no infection level was reported (Rogers et al., 1983). Treatment of the tall fescue included close clipping with removal of the forage. Sod suppression and insecticide were required for establishment of the clover. Chestnut et al. (1991) reported that inclusion of clover in both high (71%) and low (20%) endophyte-infected tall fescue pastures improved daily gains of steers, while N fertilizer offered no improvement to animal performance.

Fungicides and herbicides have been investigated as methods of destroying the endophyte or selectively eliminating tall fescue from the stand. Chlorsulfuron and metsulfuron applied at .14 or .28 and .07 or .14 kg/ha, respectively, were equally effective at controlling tall fescue in bluegrass sod, indicating that pastures being invaded by tall fescue may be renovated successfully without total destruction (Dernoeden, 1990). Endophyte status of the 'KY-31' tall fescue was not reported. The author speculated that lower rates may offer effective control. Diclofop application did not suppress tall fescue in bluegrass sod when applied at levels as high as 4.48 kg/ha.

Fungicide treatment of seed was generally effective in destroying the endophyte, but level and duration of treatment have not been clearly defined (Williams et al., 1984). Aqueous application of triadimefon (Bayleton 50 WP) resulted in complete control of the endophyte with a reduction in germination rate of 14%. Aqueous application of triademenol (Baytan 150 FS) did not eliminate the endophyte from tall fescue seed. Siegel et al. (1984) reported that dust application of triadimenol just prior to seeding was effective at controlling the endophyte.

Heat treatment (57 °C) for 40 min resulted in reduced viability of the endophyte in fescue seed but decreased germination by 16% (Siegel et al., 1984). Hot water treatment of perennial ryegrass (*Lolium perenne*) seed infected with *Acremonium lolii* eliminated the endophyte, but resulted in decreased germination (Latch and Christensen, 1982). Similar results were reported for hot water treatment of tall fescue seed (Williams et al., 1984). Seed stored for 3 mo was subjected to a hot water soak (55 °C for 10 min) with and without a cold-water presoak (5 °C for 6 h). Viability of the endophyte was reduced but seed germination was adversely affected.

Long-term storage of the endophyte-infected tall fescue seed has been the easiest, most cost effective method of removing the endophyte. After 12 mo of storage in an enclosed barn in Alabama the level of infection of tall fescue seed decreased from 90% to 0% (Williams et al., 1984). No attempt was made to control normal temperature and humidity.

Mefluidide treatment of pastures has resulted in suppressed seed head production (Elkins and Suttner, 1974). The use of mefluidide to control tall fescue seed head (location of the fungus) development resulted in increased intake as a percent of body weight in Hereford heifers (Turner et al., 1990). The suppression of flowering in endophyte-infected (90%) fescue increased daily gains of Angus X Hereford heifers by 20%. Cost effectiveness of mefluidide treatment was not reported.

The effectiveness of certain chemicals has been investigated to reduce the impact of the endophyte on animal response. Phenothiazine acts as a dopamine antagonist (Finding and Tyrell, 1986), which could potentially stimulate prolactin secretion in animals consuming endophyte-infected tall fescue. Phenothiazine supplemented at 2 g/d to grazing steers resulted in less reduction in serum prolactin resulting from consuming endophyte-infected (>57%) tall fescue (Boling et al., 1989), indicating possible ability to reduce some of the impact of reduced prolactin on related physiological functions. However, prolactin concentration of Angus heifers at elevated environmental temperatures did not respond to phenothiazine supplementation (Boling et al., 1989).

Thiamin supplements increased grazing time of dry, open cows on alfalfa pastures supplemented with 1 kg/d of 70% infected 'KY-31' tall fescue seed when the cows were exposed to heat stress (Dougherty et al., 1991). However, in this study the cows were on restricted grazing episodes. Grazing time and daily gains of steers consuming endophyte-infected tall fescue were increased with the addition of metoclopramide (Lipham et al., 1989). Metoclopramide did not affect daily gains or improve serum prolactin when dosed 3 times per week to steers grazing endophyte-infected tall fescue (Stuedemann et al., 1990).

Removal of livestock from endophyte-infected diets at critical times in the production cycle may be an alternative. In horses, the removal of the pregnant mare from infected pastures at d 300 of gestation resulted in alleviation of problems observed in mares remaining on infected tall fescue pastures (Putnam et al., 1990). Rhodes et al. (1991) reported that blood flow to the coronary band of steers returned to normal within 8 d after switching from an endophyte-infected diet to an endophyte-free diet. Piper et al. (1987) reported no detrimental effects in performance of steers after removal from endophyte-infected pastures.

Animal genetics may offer some insight into control of the poor animal performance. Brahman cattle in Oklahoma maintained body temperature near normal when grazed on infected tall fescue pastures compared to Angus cattle, which exhibited elevated body temperatures (McMurphy et al., 1990). Grazing was conducted from November through May. Brahman heifer calves had dramatically higher serum cholesterol than Angus heifer calves in AR (Tolley et al., 1990). Previously, Stuedemann and coworkers (1985a) reported that Angus cows had lower serum cholesterol when fed endophyte-infected tall fescue. The results of McMurphy et al. (1990) and Tolley et al. (1990) indicate that Brahman breeding may offer some physiological advantage to cattle consuming endophyte-infected tall fescue.

Subsequent Performance of Cattle which Grazed Endophyte-Infected Tall Fescue

There is little doubt that grazing endophyte-infected tall fescue reduces animal performance, but data concerning long-term effects on the finishing animal are limited. Stuedemann et al. (1985c) reported that steers grazing highly infected tall fescue exhibited residual effects for as long as 8 wk after switching to noninfected pastures. Results of cattle through the finishing phase have been variable. Lusby et al. (1990) investigated the effect of endophyte infection of tall fescue pasture and subsequent high concentrate finishing of Brahman, Angus and Simmental breeding in Oklahoma. Steers from infected (76%) pastures were 46 kg lighter compared to the animals that grazed low (<1%) infected fescue. These animals exhibited larger weight gains through the first 48 d in the feedlot compared to steers that had previously grazed low infected pastures. However, carcasses from steers that grazed the infected tall fescue were 22 kg lighter. Cole et al. (1987) reported that Angus steers that had previously grazed highly infected tall fescue in Georgia had higher daily gains and gain:feed ratio in the feedlot than did animals that had grazed low or medium infected tall fescue. Animals were finished on a 93% concentrate ration in Texas.

Piper et al. (1987) examined feedlot performance of 48 crossbred steers after grazing high (<80%) or low (<5%) endophyte-infected tall fescue in Arkansas. Animals were placed in the feedlot either in July or October. Animals that grazed the highly infected tall fescue gained at a faster rate when started in October compared to those that had previously grazed the low endophyte-infected fescue. However, no difference was detected when the animals were finished starting in July.

Coffey et al. (1990) reported little or no gain advantage in steers that previously grazed infected (65%)

tall fescue. However, the cattle that previously grazed infected tall fescue were more efficient in the feedlot. These results indicate no adverse effects during finishing from grazing endophyte-infected tall fescue, and in some cases compensatory gain has been reported. The results of Piper et al. (1987) indicate that environmental conditions may influence feedlot performance of cattle that had previously grazed tall fescue.

Esophageal Fistulation and Cannulae

Selection and intake by grazing ruminants are important in evaluation of forage quality. Numerous techniques and procedures have been developed to estimate grazing animal selection and intake. Mayland and Lesperance (1977), using the rumen evacuation technique reported that rumen samples had higher Na, P, Co and Zn concentrations than the diet offered to steers. This technique is labor intensive and the effects of an empty rumen on grazing behavior may bias the sample. Clipping, grab samples and mowing could be utilized, however, accuracy of these methods is questioned as grazing animals will typically select forage higher in quality than samples obtained mechanically (Weir and Torrell, 1959; Van Dyne et al., 1980).

Weir and Torrell (1959) compared esophageal samples with hand-clipped samples. The study involved esophageal fistulated Corriedale wethers grazing mixed pastures that had not been grazed and pastures which had been grazed. Crude protein was higher and crude fiber was lower in esophageal samples compared to clipped forage. Hoehne et al. (1967) reported that esophageal masticates were lower in CP, water soluble carbohydrates, and total sugars than available forage. Lignin and ADF were not changed. Gross (1985) reported that content of hand-plucked samples was different than esophageal masticate samples. These results indicated that it is difficult to mimic animal selectivity. The use of esophageally-fistulated animals is recommended as they more closely approximate natural grazing animals (Breen and Hunter, 1976; Theurer et al., 1976; Holechek et al., 1982).

Use of esophageally-fistulated animals is not without problem. Initial cannulae were constructed of rigid materials that often irritated the lumen of the esophagus (Van Dyne and Torrell, 1964; Ellis et al., 1984). The development of silicone rubber resulted in design of a lightweight cannula that reduced irritation (Ellis et al., 1984).

Additional problems of esophageal sampling include contamination through salivation, rumination or soil particles. The primary effect of salivation was reported to be increased ash content of samples (Mayland and Lesperance, 1977). Rumination resulted in contaminated samples, such that accurate chemical analysis was impossible (Holechek et al., 1982). The use of mesh collection bags and squeezing the masticate has been suggested as an alternative to reduce salivation contamination (Hoehne et al., 1967). In a comparison of random grab samples, squeezed masticate and nonsqueezed masticate from steers, Hoehne et al. (1987) reported that squeezing the sample resulted in higher P and lower Ca content in the masticate. Soil and saliva contamination can be corrected for, at least partly, through reporting composition on an ash-free basis (Holechek et al., 1982).

Composition of Extrusa Samples. Visual appraisal of extrusa samples is usually inaccurate because mastication typically renders the species unidentifiable (Cook et al., 1958). Hand separation of samples is also difficult for this reason (Marshall and Squires, 1979). The microscope point technique requires passing an extrusa sample under a low power microscope and species are identified at 100 to 400 points. Composition is related to the percent occurrence of each species (Holechek et al., 1982). The technique proved more accurate than hand separation. A higher power microscope can be used to identify species by cuticles in the sample (Sparks and Malechek, 1968; Holechek and Gross, 1982). Both of the microscope techniques are accurate, but have a high time requirement (Holechek and Gross, 1982).

Calcium is typically higher in legumes compared to grasses (NRC, 1984), indicating usefulness at estimating selection in ruminants. Playne et al. (1978) reported that Ca content of extrusa was suitable for estimating ingesta composition of cattle grazing grass-stylo (*Stylosanthes humilis* L.) pasture in Australia. Calcium was suitable for differential estimation of extrusa composition because it was not affected by mastication or oven drying. However, caution must be used in interpretation of data because Ca content may vary within a plant.

Pigurina (1986) utilized Ca and NDF as predictors for grass and legume percent in extrusa of cattle. Calcium was sufficiently different between tall fescue and red clover to be used as an accurate predictor of diet composition. Neutral detergent fiber did not improve the accuracy of prediction above that of Ca alone.

Estimating Intake and Digestibility in Grazing Animals

Estimation of intake by grazing animals can be accomplished indirectly using inert reference markers. Estimation of forage digestibility can be done using internal markers. Lignin was reported to be a fairly reliable internal marker (Kotb and Luckey, 1972); however, advances in methodology indicated that lignin use per se was invalid (Fahey and Jung, 1983). Muntifering (1982) used 30 kg lambs to investigate the efficacy of lignin as a digestion marker for 'Kenhy' tall fescue, corn cobs, or cottonseed hulls. Analysis of lignin by spectrophotometric and gravimetric methods indicated high variability, thus accuracy of prediction was low. Cochran et al. (1986) reported that acid detergent lignin (ADL) was a poor internal marker for cubed alfalfa hay, direct cut tall fescue, tall wheatgrass hay plus .9 kg/d of SBM, and prairie hay diets. The poor results using lignin may be explained from soluble lignin-carbohydrate complexes found in the rumen of sheep (Conchie et al., 1988) and cattle (Nielson and Richards, 1982).

The indigestible fractions of NDF and ADF have been used to estimate digestibility with inconsistent results (Galyean et al., 1987). Orchardgrass hay digestibility was predicted accurately using indigestible NDF and indigestible ADF (Hunt et al., 1984). Judkins et al. (1990) reported that efficacy of indigestible NDF and indigestible ADF as markers generally underestimated digestibility of forage diets fed to rams. However, indigestible ADF using a 96 h in vitro incubation was accurate for estimating digestibility of soybean meal supplemented diets. These results indicate that fiber related internal markers must be carefully evaluated before application across diets.

In vitro digestibility as estimated using the procedure of Tilley and Terry (1963) has been used as the digestibility estimate for subsequent prediction of intake. Accuracy of results have been dependent on diet. Steers hand fed direct-cut grass were used to compare total fecal collection with in vitro indigestibility to measure intake (Holechek et al., 1986). The use of in vitro OM digestibility was an acceptable technique with 72 h incubations. In a comparison of 11 techniques, Judkins et al. (1990) reported that intake of fescue or alfalfa hay fed ad libitum was accurately predicted using IVDMD. However, intake of supplemented diets was not accurately predicted by this method (Judkins et al., 1990).

Acid insoluble ash has been successfully used as an internal marker in mature sheep (Van Keulen and Young, 1977), swine (McCarthy et al., 1974), and chickens (Vogtmann et al., 1975). Van Keulen and Young (1977) reported recoveries of 86 to 102% of acid insoluble ash in sheep feces using 2N HCl. Advantages of acid insoluble ash over total collection include no need for crates, single feed and fecal samples, and ease of procedure (Van Keulen and Young, 1977). However, the technique is poor for estimating digestibility of diets low in acid insoluble ash (Van Keulen and Young, 1977).

Estimation of fecal output in conjunction with digestibility can be used to estimate feed intake. Total fecal output can be calculated by the following formula:

Total feces, kg/d = (indicator dose,mg/d)/
(indicator concentration in feces,mg/kg).

Chromium sesquioxide (chromic oxide) has been used as an external indicator for fecal output determinations (Lambourne, 1957; Hopper et al., 1978). Chromic oxide accurately predicted fecal output of mature Angus cows during lactation (Hopper et al., 1978). Pastures investigated were low quality tall fescue and high quality tall fescue plus red clover pastures in early summer in Tennessee.

Results of trials utilizing chromic oxide indicated that collection of a representative sample requires calibration of dosing time and fecal collection time techniques to account for cyclic fluctuations in excretion (Hopper et al. 1978). Mathematical models have been developed to predict optimum time of fecal collection (Hopper et al., 1978). Prigge et al. (1981) reported that twice daily dosing of chromic oxide and morning grab samples accurately predicted fecal output of cows fed alfalfa or orchardgrass hay.

Ytterbium, a rare earth metal, has received attention as an alternative to chromic oxide (Coleman, 1979; Teeter et al., 1979). An advantage of Yb over chromic oxide is the association of Yb with the particulate phase of the digesta (Ellis and Huston, 1968). A single daily dose of Yb more accurately predicted fecal output of cows compared to prediction by chromic oxide (Prigge et al., 1981). Teeter et al. (1984) reported suitability of Yb, mordanted to feedstuffs, as a particulate marker in the rumen. However, the association of Yb with cracked corn, prairie hay, and chopped alfalfa hay resulted in a depression in in vitro digestibility of 20, 49, and 46%, respectively. Chromic oxide and Yb have required daily dosing, which can be difficult in pasture situations. The process of mordanting feeds with Yb has been laborious (Teeter et al., 1984).

Sustained-release chromic oxide boluses have been recently introduced (Captec chrome, Quad Five, Rygate, MT). The boluses have proved successful as digesta markers in cattle (Momont et al., 1990). Results indicated fecal output could be accurately predicted in cows. Accuracy was also verified in sheep (Parker et al., 1989; Momont et al., 1990).

Advantages have been identified concerning the sustained release boluses (Parker et al., 1989). They included complete recovery (97-101%) of the Cr, and one time administration. In addition, the bolus reduced the impact of diurnal variation compared to a single daily dosing of chromium sesquioxide (Langlands et al., 1963; Parker et al., 1989). The boluses have been easily administered with little resistance from the animals (K.R. Pond, personal communication).

CHAPTER III.

INFLUENCE OF ENDOPHYTE INFECTION OF TALL FESCUE AND WHITE CLOVER ON PERFORMANCE OF STEERS DURING THE GRAZING AND SUBSEQUENT FEEDLOT PERIOD, AND FORAGE COMPOSITION AND YIELD

ABSTRACT: Effects of grazing low (<5%) and high endophyte-infected tall fescue, with and without white clover at two locations in Virginia were studied with yearling steers. At each location, two replicates were used with a stocking rate of .3 ha/steer (116 steers/yr). At termination of grazing, all animals were finished on a high corn silage diet and slaughtered. Daily gains of steers grazing low endophyte-infected pastures were higher ($P<.01$) than for those grazing high endophyte-infected pastures. Rectal temperatures were .5 to 1 °C higher ($P<.05$) for steers grazing infected pastures by June of each year at both locations. Prolactin concentrations were lower ($P<.01$) in cattle grazing endophyte-infected fescue within 28 d of initiation of grazing at both locations. Visual evaluation indicated that steers grazing highly infected pastures had "rough" hair coats compared to those grazing low endophyte-infected pastures ($P<.01$), showing evidence of heat stress. Inclusion of clover at the levels achieved (7% or less) in the present study had little effect on animal performance. Average forage yield and composition were not affected by the endophyte. Forage was more ($P<.05$) digestible at Glade Spring than at Blackstone during both years. During feedlot finishing, there were no detrimental effects

of previous grazing the endophyte-infected tall fescue on animal performance.

Introduction

Tall fescue (*Festuca arundinacea* Shreb.) is adapted to a wide range of climatic conditions, tolerant to drought, over-grazing, and cold temperatures (Buckner, 1985). The adaptability of tall fescue has resulted in cultivation on 14 million ha in the US (Siegel et al., 1985). Beef cattle performance is affected by environment (NRC, 1984). Temperatures above the animals' thermoneutral zone result in reduced performance. Animals consuming endophyte-infected tall fescue have reduced blood flow to the extremities (Rhodes et al., 1991) and the animal may be unable to dissipate heat effectively. There is little information concerning the interaction of endophyte infection of tall fescue and grazing animal performance in different physiographic locations.

Performance is lower in animals grazing tall fescue infected with the endophytic fungus *Acremonium coenophialum* Morgan-Jones and Gams (Hoveland et al., 1984; Read and Camp, 1986). Animals consuming endophyte-infected tall fescue show reduced daily gains, rough hair coats, elevated body temperatures, and depressed serum prolactin concentrations (Stuedemann and Hoveland, 1988). The reduction in gain was reported to amount to a loss of $26,500,000 in Arkansas alone (Daniels, 1989).

Numerous strategies, including diet dilution, have been investigated for potential to eliminate the impact of the endophyte on animal performance. For each 10% infection rate of tall fescue there was a reduction of 68 g in daily gain of animals during spring through summer grazing (Stuedemann et al., 1985c; Crawford et al., 1989). The benefits of the endophyte on the host plant include drought tolerance and insect resistance (Clay et al., 1985; Read and Camp, 1986). Therefore, utilization of endophyte-free fescue may not be warranted. The inclusion of legumes may offer a means to reduce the impact of endophyte infection of tall fescue by diluting the diet (Fribourg et al, 1988).

The effect of the endophyte infection on grazing animals is well documented, while the subsequent performance of the animal has received limited attention. Cole et al. (1987) and Lusby et al. (1990) reported compensatory gain during finishing in cattle that had previously gained at a reduce rate on endophyte-infected tall fescue pastures. Others have reported no effect on gain in cattle that previously grazed endophyte-infected tall fescue (Piper et al., 1987; Coffey et al., 1990).

The objectives of this research were 1) to compare performance of cattle grazing low and high endophyte-infected tall fescue, with and without white clover (*Trifolium repens* L.) at two different physiographic locations, 2) to investigate composition and yield of low and high endophyte-infected fescue, and 3) to examine the effects of previous grazing treatment on finishing performance and carcass traits.

Materials and Methods

Grazing Period

Low (<5%) and high (>70%) endophyte-infected 'KY-31' tall fescue, with and without 'Ladino' white clover, was established in two replications at each of two locations in Virginia. Soil samples were collected initially and each spring thereafter in an attempt to maintain equal soil fertility between locations. Fertilizer and lime were applied according to soil test recommendations, except that the pastures with clover received no N fertilizer.

The tall fescue was sod-seeded at the rate of 22.5 kg/ha in October of 1985 in eight pastures at each location. White clover was broadcast seeded at the rate of 2.25 kg/ha in four of the pastures at each location in Spring 1988, 1989, and 1990, and in Fall 1989 (2 X 2 factorial arrangement of treatments). Tall fescue tiller samples were obtained in the Spring of each year for endophyte detection. Tillers were wrapped in dampened paper towels, and overnight mailed to the Auburn University Fescue Diagnostic Laboratory where they were stained for the endophyte. Low and high levels of endophyte contamination were 4% and 72% at Glade Spring, and 4% and 80% at Blackstone, respectively.

Location 1 (Glade Spring) was in the Mountain-Valley Region of Southwest Virginia, with soil types of Frederick (Silt loam, mixed, mesic, Typic Paleudult) and Hagerstown (fine, mixed, mesic, Typic Hapludalf). Location 2 (Blackstone) was in the Southern Piedmont where soils were predominantly Appling (fine sandy loam, mixed, mesic, Typic

Hapludult), Colfax (sandy loam, mixed, mesic, Typic Hapludult), and Cecil (fined sandy loam, mixed, mesic, Typic Hapludult). Less than 10% of the soils at Blackstone were Durham (fine sandy loam, mixed, mesic, Typic Hapludult), or Worsham (sandy loam, mixed, mesic, Typic Hapludult). These locations were selected as two distinct geographical and climatic regions (350 km between locations).

Stocking rate was .3 steers/ha at both locations. A total of 116 Angus and Angus X Hereford steers were used each year (avg initial weight 246.8 and 233.3 kg in 1989 and 1990, respectively). At location 1, 48 steers were used (1989, 48 Angus and 1990, 40 Angus + 8 Angus X Hereford) and at location 2, 68 steers were used (1989, 48 Angus + 20 Angus X Hereford and 1990, 68 Angus). Animals were blocked by weight and breeding and allotted at random to location, and pastures within location. Animals were implanted with zeranol (Ralgro, Pittman-Moore, Inc., Terre Haute, IN), treated with Ivermectin (Ivomec, Merck & Co, Inc., Rahway, NJ), and vaccinated for IBR-PI3 (Nasalgen, Coopers Animal Health Inc., Kansas City, KS) and seven-way clostridium (Ultrabac CD, SmithKline Beecham, Bristol, TN) at the beginning of the grazing trial and 2 wk before termination of grazing in 1989 and 1990, except that implanting of animals at Blackstone occurred on day of shipping in 1990. At both locations, steers were reimplanted after about 90 d during the grazing period. Trace mineralized salt blocks were provided in each pasture.

Weights, rectal temperatures (Digital thermometer No. 271, Nelkin Piper, Kansas City, MO), and blood samples were obtained and hair coat scores were placed on each animal at 28 d intervals during the grazing season. Hair coats were subjectively scored on a scale of 1 to 5, with 1-normal, shiny hair; 2-25 to 50% of body covered with old, unshed hair; 3-50 to 75% of the body covered with old, unshed hair; 4-75 to 100% of body covered with old, unshed hair; and 5-100% of body covered with rough, unshed, and dirty hair coats. Blood samples were placed on ice, allowed to coagulate, centrifuged at 2200 rpm for 20 min, and serum was separated into two separate 7 ml tubes, and frozen for subsequent analysis. One tube was used for mineral analysis and the other for prolactin determinations.

Serum for Ca and Mg determinations was diluted 1:50 with lanthanum oxide to prevent P interference. Copper was measured on serum that had been diluted 1:2 with deionized water. Calcium, Mg, and Cu were measured by atomic absorption spectrophotometry. Inorganic P was detected colorimetrically as unreduced phosphomolybdate complex which can be detected at 340 nm (Daly and Ertinghausen, 1972; Sigma Diagnostics, St. Louis, MO). Serum prolactin was measured using a double-antibody radioimmunoassay (Koprowski and Tucker, 1971) except the stock solution of prolactin was iodinated as described by Akers and Keys (1984).

Estimates of DM yield were obtained on the dates of weighing the animals. Two strips (100 cm x 6.1 m) were mowed with a sickle-bar mower (5000 Series, Gravely, Clemmons, NC) in each pasture, the clipped forage was harvested, and dried in cloth bags at 80°C for a minimum of 48 h. Hand clipped samples for quality analysis were collected by walking in the pastures diagonally in an 'X' pattern, and a sample ("handful") was collected every 30 paces at location 1 and 20 paces at location 2. Care was taken to avoid fence lines, traffic paths, and areas contaminated with feces and urine. Samples were transported on ice to the laboratory, dried at 60°C, allowed to air equilibrate, and were ground in Wiley mill to pass a 1 mm screen.

Forage samples were analyzed for ash (A.O.A.C., 1990), NDF (Van Soest and Wine, 1968) with the exception that decalin and sodium sulfite were not used, ADF (Van Soest, 1963), lignin and cellulose (Van Soest and Wine, 1968). Crude protein was determined from Kjeldahl N X 6.25 (A.O.A.C., 1990). Serum and forage samples, after sequential digestion with nitric and perchloric acids, were analyzed for Ca, Mg, and Cu by atomic absorption spectrophotometry (A.O.A.C., 1990). Inorganic P content of forage was measured by the colorimetric method of Fiske and Subbarow (1925). In vitro DM digestibility was determined according to the method of Tilley and Terry (1963) with the modifications of Barnes (1969). For IVDMD, ruminal digesta was obtained from a cannulated steer fed tall fescue hay with 40% infection. Samples were analyzed in duplicate with four blank and two alfalfa reference samples included during each incubation.

At the time of pasture sampling, two or three experienced individuals visually evaluated the pastures, for percent of ground area covered by vegetation, percent grass, percent legume, percent weed in the stand, and DM yield. Abundance of individual species was evaluated using a modification of the dominant, abundant, frequent, occasional and rare scale (DAFOR) of Brodie (1985). The modification involved using a double-DAFOR evaluation. The first DAFOR was used for the desirable grass, legume, and weed species, and the second DAFOR scale was used to separate species of weeds. For statistical analysis of the data values of 5 to 1 were assigned to the scale to identify the relative abundance of the species.

Subsequent Performance

After termination of grazing, the cattle were transported 160 km from location 1 and 240 km from location 2 to a research feedlot facility. In yr 1, animals were used in a supplement feeding experiment, which was included in the statistical analysis. Animals were blocked by weight and previous location and randomly assigned to 15 pens. No treatments were imposed in yr 2 during the feedlot period allowing pen feed efficiency to be measured. Four additional animals were included to provide eight animals/pen. A common receiving diet of corn silage, and soybean meal was fed for 2 wk. In 1989, a blood sample was collected at the start of the feeding period to measure serum prolactin concentration.

Full weights were obtained 1-d prior to the beginning and end of the trials and at 28 d intervals throughout the finishing phase. Shrunk weights (16 h without feed and water) were obtained at the beginning and end of the trials. Daily feed amounts were recorded for each pen and consumption was measured for each 28 d period of the trial.

Animals were finished on a balanced diet of a full-feed corn silage, corn grain fed at 1% of BW, and .9 kg soybean meal. The diet was supplemented with vitamin A to provide 24,000 IU per day and 350 mg of monensin sodium (Rumensin, Elanco, Indianapolis, IN). Block iodized salt was provided. Steers were implanted with zeranol at the beginning of the trial.

Statistical Analysis

Pasture data were analyzed as a randomized complete block design. Pasture was the experimental unit for all forage measurements. Animal was the experimental unit for daily gain, temperature, haircoat score, serum analysis, and carcass traits. Within each year the final model used included the effects of location, endophyte, clover, all two-way interactions, the three-way interation, and replicate nested within location as the error term to test location effects. Generalized linear models procedure of SAS (1985) were conducted including analysis of repeated measures.

Feedlot gain and carcass data were analyzed with the effects of previous location, endophyte, clover, endophyte*clover, and location*endophyte tested with the residual error term. Analysis of variance was conducted using the general linear method (SAS, 1985). Pen was the experimental unit for determination of feed intake and feed conversion as affected by level of endophyte in 1990.

Results

Animal Performance

Druing the first 56 d period in 1989, cattle grazing the endophyte-infected tall fescue had lower (P<.01) daily gains than those grazing the low endophyte-infected pastures (Table 1). From June to August in 1989 the animals at Blackstone had higher (P<.01) daily gains than those at Glade Spring. The interaction of location with endophyte was present during the middle grazing period (June to August; P<.05). The decrease in gain with infection of tall fescue was greater at Blackstone than at Glade Spring. During the middle grazing period clover improved (P<.05) daily gain in cattle grazing both the low and high endophyte-infected tall fescue. The cattle grazing the high endophyte-infected tall fescue with white clover at Glade Spring gained at the same rate as those grazing low endophyte-infected tall fescue without clover. The difference (P<.01) in daily gain between cattle grazing low compared to high endophyte-infected tall fescue during the grazing season resulted in a 40 to 50 kg difference (P<.01) in final weight.

Cattle grazing the low endophyte-infected tall fescue had higher (P<.01) daily gains compared to those grazing high endophyte-infected tall fescue in all periods of 1990 except August to October (Table 2). Cattle grazing at Blackstone gained at a slower (P<.05) rate compared to those at Glade Spring during all periods except from August to October when the trend was reversed (P<.05). The lower daily gain (P<.05) for the entire grazing season for cattle at Blackstone resulted in a difference (P<.05) in final weight.

Serum prolactin concentration was lower (P<.01) in steers grazing the high endophyte-infected tall fescue at both locations (Table 3). Prolactin concentration was reduced within 28 d of initiation of grazing

TABLE 1. PERFORMANCE OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Initial wt., kg	247.1	247.2	247.1	249.2	247.6	246.0	247.4	245.5	245.2	246.0	2.4
Final wt., kg[a]	359.6	365.1	323.2	335.5	345.8	373.3	366.3	323.4	315.4	344.6	6.9
Daily gain, kg											
April-June[a]	1.17	1.15	.76	.82	.98	1.15	1.13	.86	.65	.95	.07
June-August[abcd]	.28	.40	.16	.28	.28	.49	.52	.21	.25	.37	.05
August-October[a]	.46	.46	.33	.36	.40	.56	.42	.30	.31	.40	.06
April-October[a]	.62	.65	.42	.48	.54	.71	.66	.44	.39	.55	.04

[a]Effect of endophyte (P<.01)
[b]Effect of location (P<.01)
[c]Effect of clover (P<.05)
[d]Location X endophyte interaction (P<.05)

TABLE 2. PERFORMANCE OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Initial wt., kg[a]	239.7	242.3	237.4	240.2	239.9	224.4	227.1	228.4	227.1	226.8	2.4
Final wt., kg[abc]	357.5	371.7	332.9	344.9	351.8	339.2	326.6	316.8	306.6	322.3	6.9
Daily gain, kg											
April-June[ab]	1.25	1.26	.95	1.05	1.13	1.19	1.09	.84	.86	1.00	.07
June-August[ab]	.36	.47	.32	.30	.36	.10	.13	.15	.10	.12	.04
August-October[ac]	.40	.46	.36	.43	.41	.73	.47	.52	.51	.56	.06
April-October[abc]	.65	.71	.52	.58	.62	.63	.55	.47	.44	.52	.04

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.01$)
[c]Location X clover interaction ($P<.05$)

TABLE 3. SERUM PROLACTIN (NG/ML) AND RECTAL TEMPERATURES (°C) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
1989											
Prolactin											
Initial	48.8	58.1	80.8	73.2	65.2	59.4	54.0	73.3	63.6	62.4	17.1
Average[ab]	95.6	80.9	5.0	9.2	47.7	109.4	104.8	6.7	11.8	58.2	11.0
Rectal temperature											
Initial	39.7	39.2	39.6	39.4	39.5	39.7	39.4	39.4	39.6	39.5	.15
Average[ab]	39.2	39.2	40.0	39.9	39.6	39.5	39.4	39.7	40.0	39.6	.11
1990											
Prolactin											
Initial	97.2	85.4	111.0	97.5	97.8	56.7	66.7	58.8	72.9	63.8	17.8
Average[ab]	104.0	108.5	8.9	10.5	57.9	82.3	102.3	14.7	10.8	52.5	10.5
Rectal temperature											
Initial	39.0	39.1	39.2	38.8	39.0	39.1	39.0	39.2	38.8	39.0	.17
Average[ab]	39.3	39.4	40.0	39.8	39.6	40.1	39.8	40.3	40.3	40.1	.11

[a]Average of 28 d periods
[b]Effect of endophyte (P<.01)

in both 1989 (P<.05) and 1990 (P<.01) (Appendix Tables 1 and 2). Prolactin concentration was not influenced by location or clover in 1989. In steers grazing the endophyte-infected fescue, prolactin tended to be higher when clover was seeded. In August and October of 1990 prolactin concentrations were lower (P<.05) in steers grazing at Blackstone compared to the level present in steers at Glade Spring.

Body temperature of steers grazing the high endophyte-infected tall fescue was higher (P<.01) throughout the grazing season compared to those grazing low endophyte-infected tall fescue during 1989 and 1990 (Table 3). This difference was significant within 28 d of initiation of grazing (Appendix Tables 3 and 4). The interaction of location with endophyte was seen in May, July, August, and September in 1989 (P<.05)(Appendix Table 3). During these months, the influence of the endophyte resulted in a greater (P<.05) increase in body temperature in cattle grazing at Glade Spring compared to those grazing at Blackstone. The main effect of location was not significant (P>.20) during 1989 or 1990 (Table 3).

Hair coats for both years were rougher (P<.01) in steers grazing the endophyte-infected forage compared to those grazing low infected fescue when averaged from May to October (Table 4). Hair coat scores were higher (P<.01) from July to October in cattle grazing the high endophyte-infected tall fescue compared to those grazing low endophyte-infected tall fescue in 1989 and 1990 (Appendix Tables 5 and 6). In June of 1990, the hair coat scores were higher for cattle grazing the high endophyte-infected fescue at Blackstone, but the difference was not

TABLE 4. HAIR COAT SCORES[a] OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
1989											
Initial	3.8	3.8	3.8	3.5	3.7	3.8	3.8	3.5	3.6	3.7	.15
Average[bc]	2.9	2.7	3.5	3.4	3.1	2.7	2.5	2.9	3.4	3.5	.17
1990											
Initial	3.3	3.4	3.5	3.2	3.3	3.5	3.6	3.6	3.7	3.6	.15
Average[bc]	2.2	2.2	3.5	3.1	2.8	2.5	2.4	3.7	3.8	3.1	.20

[a]Code: 1=smooth, shiny to 5=rough, dirty
[b]Average of 28 d periods
[c]Effect of endophyte ($P<.01$)

TABLE 5. SERUM MINERAL CONCENTRATION OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE WITH, AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
1989											
Ca, mg/dl,											
Initial[a]	9.56	9.66	9.45	9.73	9.62	9.10	9.26	9.46	9.43	9.34	.22
Average[b]	9.73	9.68	9.60	9.73	9.68	9.74	9.65	9.54	9.65	9.65	.11
Mg, mg/dl,											
Initial	1.84	1.89	1.93	1.92	1.89	1.83	1.85	1.91	1.88	1.88	.06
Average[ab]	1.99	2.03	2.04	2.06	2.03	2.09	2.07	2.13	2.12	2.11	.03
P, mg/dl,											
Initial	7.24	7.51	6.94	7.33	7.27	7.45	7.29	7.24	7.41	7.36	.39
Average[b]	7.08	7.04	7.00	7.14	7.07	7.24	7.22	7.21	7.40	7.27	.15
Cu, µg/dl,											
Initial[c]	70.3	65.5	77.2	72.5	71.5	70.5	63.8	72.6	66.8	68.3	3.6
Average[bcd]	64.1	55.1	65.4	59.4	61.0	63.0	62.9	59.5	61.7	61.8	2.6

[a]Effect of location ($P<.01$)
[b]Average of 28 d periods
[c]Effect of clover ($P<.05$)
[d]Location X clover interaction ($P<.01$)

significant at Glade Spring (location X endophyte interaction, P<.01). The amount of clover in this experiment did not affect hair coats of the steers.

Serum Ca, Mg, P, and Cu were not affected by endophyte infection of tall fescue in 1989 or 1990 (Tables 5 and 6, respectively). Serum Mg was lower (P<.01) during July and October of 1989 in steers grazing at Glade Spring compared to those at Blackstone (Appendix Table 9). During June, September, and October of 1990, serum Mg was lower (P<.05) in cattle grazing at Blackstone compared to those grazing at Glade Spring (Appendix Table 10).

The three-way interaction of location X endophyte X clover was seen for serum P during August of 1989 (P<.05). At Glade Spring the addition of clover to low endophyte-infected tall fescue·resulted in an increase in serum P content but serum P decreased in animals grazing high endophyte-infected tall fescue overseeded with clover compared to animals grazing forage without clover. At Blackstone the addition of clover to the low endophyte-infected fescue reduced serum P compared to serum P in animals grazing fescue alone. No consistent pattern was identified regarding the influence of location, endophyte infection level, and clover content on serum Cu concentration (Appendix Tables 13 and 14). Endophyte infection of tall fescue reduced (P<.05) serum Cu in October of 1990. Serum Cu was higher in animals grazing at Blackstone during July, and October, 1989 (P<.05), and October, 1990 (P<.01) and lower P<.05) in August, 1989, and July, 1990 compared to those at Glade Spring.

TABLE 6. SERUM MINERAL CONCENTRATION OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
1990											
Ca, mg/dl,											
Initial	9.92	9.83	10.19	9.82	9.94	9.93	10.17	9.93	9.96	9.95	.19
Average[ab]	9.56	9.82	9.43	9.53	9.58	9.51	9.51	9.43	9.24	9.42	.11
Mg, mg/dl,											
Initial	1.86	1.97	2.00	1.92	1.96	1.92	1.86	1.95	1.96	1.93	.06
Average[b]	2.08	2.16	2.11	2.21	2.14	2.10	2.12	2.19	2.14	2.14	.04
P, mg/dl,											
Initial	6.61	7.35	6.70	6.98	6.97	7.16	6.79	7.10	7.93	7.24	.30
Average[b]	6.99	7.50	7.23	7.18	7.23	7.40	7.29	7.42	7.25	7.34	.17
Cu, µg/dl,											
Initial	65.5	69.2	65.3	62.0	65.6	62.6	60.9	67.6	64.7	63.5	3.6
Average[b]	57.5	54.5	57.2	58.8	57.0	58.4	58.6	58.9	54.1	57.5	1.9

[a]Effect of location ($P<.01$)
[b]Average of 28 d periods

Subsequent Performance and Carcass Quality

During the first 28 d in the feedlot of 1989 no compensatory gain was observed in animals that had previously grazed high endophyte-infected tall fescue (Table 7). Cattle that had grazed the high endophyte-infected tall fescue at Blackstone gained more rapidly (P<.01) during the entire feedlot period than those that grazed the low endophyte-infected tall fescue from the same station, but the opposite trend was seen for Glade Spring cattle (location X endophyte interaction, P<.01). The average difference (P<.01) in initial feedlot weight was maintained throughout the finishing phase. During the first 28 d in the feedlot during 1990 the cattle that had previously grazed high endophyte-infected tall fescue had higher (P<.01) daily gains than those that had grazed low endophyte-infected tall fescue (Table 7), but no difference was seen for the entire feeding period. Serum prolactin concentration was not different between cattle that previously grazed the endophyte-infected fescue compared to those that grazed the low endophyte-infected fescue (36 vs 53 ng/ml, respectively).

Daily DM consumption during finishing was not different (P>.20) between steers that previously grazed low or high endophyte-infected tall fescue in 1990 (Table 8). During the first 28 (P<.01) and 56 (P<.05) d of the finishing trial steers that previously grazed the high endophyte-infected tall fescue had lower feed to gain ratios compared to steers that grazed the low endophyte-infected tall fescue. The difference was not observed over the entire finishing period (P>.20).

TABLE 7. FEEDLOT PERFORMANCE OF STEERS THAT HAD PREVIOUSLY GRAZED LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	kg										
1989											
Initial wt.,[a]	355.4	353.4	321.7	335.7	341.6	362.8	363.4	325.6	322.2	343.5	8.8
Final wt.,[a]	499.8	502.2	451.0	478.8	483.0	488.6	507.9	476.4	473.8	486.7	10.4
Daily gain,											
28 d	1.18	1.13	1.21	1.14	1.16	1.26	1.25	1.21	1.18	1.22	.09
118 d[d]	1.22	1.26	1.10	1.21	1.20	1.07	1.22	1.28	1.28	1.21	.06
1990											
Initial wt.,[ad]	340.4	349.4	318.0	331.8	334.9	319.5	314.1	301.8	296.2	307.9	7.9
Final wt.,[c]	511.2	528.9	483.0	502.3	506.4	487.6	508.1	487.3	483.8	491.7	15.1
Daily gain,											
28 d[a]	.83	.66	.95	1.04	.87	.61	.85	1.10	1.15	.93	.12
140 d	1.25	1.29	1.19	1.23	1.24	1.18	1.40	1.34	1.35	1.32	.09

[a]Effect of endophyte ($P<.01$)
[b]Effect of location ($P<.01$)
[c]Effect of endophyte ($P<.10$)
[d]Location X endophyte interaction ($P<.01$)

TABLE 8. DAILY FEED INTAKE (DM) AND FEED TO GAIN RATIO OF STEERS DURING FINISHING THAT PREVIOUSLY GRAZED LOW OR HIGH ENDOPHYTE INFECTED TALL FESCUE, 1990

Period	Item	Low endophyte	High endophyte	SE
28 d	Intake,kg	6.36	6.34	.07
	Feed:gain[a]	4.94	4.09	.16
56 d	Intake,kg	9.03	8.89	.07
	Feed:gain[b]	6.37	5.76	.15
140 d	Intake,kg	10.64	10.61	.06
	Feed:gain	8.41	8.29	.26

[a]Effect of endophyte level ($P<.01$)
[b]Effect of endophyte level ($P<.05$)

In 1989, the animals that had grazed high endophyte-infected tall fescue produced lighter carcasses, with lower dressing percentages, marbling scores, and kidney-pelvic-heart fat percentages ($P<.01$; Table 9). Carcasses from cattle that grazed at Blackstone were heavier ($P<.01$) than those from Glade Spring, but no other major differences were identified. No differences due to level of endophyte were detected for any carcass variable examined in 1990 (Table 10). The inclusion of clover in the grazing mixture resulted in a higher ($P<.05$) dressing percent compared to carcasses from animals that had not grazed tall fescue with clover in the mixture.

Forage Mass and Composition

Forage mass (DM basis) was not affected by location, endophyte infection or inclusion of clover in 1989 (Table 11). However, DM yield was higher ($P<.05$) at Glade Spring in 1990 compared to Blackstone (Table 12). Forage DM mass was higher ($P<.05$) at Blackstone in April and September of 1989 when compared to Glade Spring (Appendix Table 15). However, forage mass was higher ($P<.05$) at Glade Spring in May, June and July of 1989 compared to Blackstone. The inclusion of clover in the mixture resulted in higher ($P<.05$) yield in April, 1989.

The presence of the endophyte reduced the DM mass at Glade Spring in April, 1990 but had no influence at Blackstone (location X endophyte interaction, $P<.05$; Appendix Table 16). There was no consistent pattern observed for influence of endophyte infection of tall fescue or the inclusion of clover on DM mass the remainder of the grazing season. In April, May, and June 1990, no differences were detected between

TABLE 9. CARCASS QUALITY FROM STEERS THAT HAD PREVIOUSLY GRAZED LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Carcass wt.,kg[ab]	304.0	300.3	275.0	281.5	290.2	312.7	318.5	295.8	289.0	304.0	8.5
Dressing percent[a]	61.3	58.6	59.4	56.7	59.0	60.4	60.4	59.4	59.2	59.9	1.1
Quality grade[c]	12.5	12.9	11.8	12.5	12.4	12.5	12.0	12.3	11.9	12.2	.4
Back fat,cm	1.30	.98	.88	1.12	1.07	1.20	1.12	1.23	.97	1.13	.12
Ribeye area,cm^2	75.4	71.0	70.1	73.8	72.6	73.2	76.1	70.4	73.2	73.2	2.3
Marbling score[ad]	4.4	4.8	3.8	4.4	4.4	4.5	4.5	4.4	3.9	4.3	.3
KPH,%[ae]	2.25	2.00	1.53	1.54	1.83	1.95	2.02	1.94	1.72	1.91	.18
Yield grade	2.5	2.3	2.0	2.1	2.2	2.5	2.3	2.6	2.2	2.4	.2

[a]Effect of endophyte ($P<.01$)
[b]Effect of location ($P<.01$)
[c]Code: 11=high select, 12=low choice, 13=avg choice, etc.
[d]Code: 3=slight, 4=small, 5=modest, etc.
[e]Kidney, pelvic, heart fat %

TABLE 10. CARCASS QUALITY FROM STEERS THAT HAD PREVIOUSLY GRAZED LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Carcass wt.,kg	309.7	322.9	295.7	311.6	310.0	297.2	296.1	297.6	294.1	296.2	7.7
Dressing percent[a]	59.7	60.2	59.8	60.6	60.1	59.7	60.5	59.4	59.5	59.8	.4
Quality grade[b]	9.4	11.5	10.8	10.9	10.7	10.3	11.0	11.3	11.0	10.9	.7
Back fat,cm	.97	1.14	.88	1.08	1.02	1.06	.86	.86	.93	.93	.09
Ribeye area,cm^2	75.3	75.0	72.9	77.9	75.3	75.9	74.3	71.9	72.7	73.7	2.1
Marbling score[c]	4.4	3.8	4.2	4.2	4.2	3.7	3.9	4.1	3.8	3.9	.3
KPH,%[d]	2.31	2.09	2.12	2.12	2.16	2.17	2.17	2.17	2.18	2.17	.16
Yield grade	2.2	2.5	2.1	2.2	2.2	2.2	2.0	2.2	2.2	2.1	.2

[a]Effect of clover ($P<.05$)
[b]Code: 9=low select, 11=high select, 12=low choice, etc.
[c]Code: 3=slight, 4=small, 5=modest, etc.
[d]Kidney, pelvic, heart fat %

TABLE 11. FORAGE DM MASS AND COMPOSITION FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989[a]

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Mass,kg/ha	1729	1720	1624	1875	1737	1486	1313	1442	1847	1530	119.2
CP,%	14.4	13.3	14.3	13.9	14.0	14.1	15.8	13.4	13.5	14.2	.93
IVDMD,%[b]	62.9	60.6	64.7	62.2	62.6	54.6	57.2	53.9	54.2	54.7	2.39
NDF,%[b]	63.0	64.2	62.2	62.9	63.1	66.3	64.6	66.5	66.0	65.8	1.67
ADF,%	33.0	34.3	32.3	32.9	33.1	34.1	32.3	34.0	34.1	33.6	1.07
Lignin,%[b]	3.76	4.14	3.80	3.72	3.86	4.82	4.12	4.44	4.59	4.49	.37
Cellulose,%	27.0	27.6	26.4	26.7	26.9	27.8	26.9	28.1	28.0	27.7	.70

[a]DM basis
[b]Effect of location ($P<.05$)

TABLE 12. FORAGE DM MASS AND COMPOSITION FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990[a]

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Mass, kg/ha[a]	1502	1416	1450	2064	1608	1156	758	919	1235	1018	282.1
CP, %[b]	14.0	14.8	13.7	14.7	14.3	11.1	11.6	11.5	11.2	11.4	.71
IVDMD, %[b]	56.4	56.7	57.4	58.0	57.1	49.4	51.8	50.9	49.4	50.4	2.78
NDF, %[b]	65.6	63.8	64.7	61.5	63.9	68.0	67.8	66.0	67.2	67.3	1.69
ADF, %[b]	34.8	34.5	34.4	34.0	34.4	36.9	36.5	36.3	36.7	36.6	1.01
Lignin, %	3.73	3.93	3.66	3.79	3.78	4.37	4.63	4.45	4.40	4.46	.33
Cellulose, %[b]	28.6	28.1	28.2	27.7	28.1	30.4	29.9	29.6	30.2	30.0	.78

[a]DM basis
[b]Effect of location ($P<.05$)

locations for forage DM mass. However, the forage mass was greater (P<.05) at Blackstone compared to Glade Spring during July, August, September, and October.

Crude protein content was not affected by location in 1989 (Table 11) but was higher (P<.05) in forage from Glade Spring compared to Blackstone in 1990 (Table 12). Forage from Blackstone was higher (P<.05) in crude protein in April and May, compared to forage from Glade Spring (Appendix Table 17). In August, forage from Glade Spring was higher (P<.05) in CP than forage from Blackstone. Addition of white clover increased CP in the high endophyte-infected tall fescue but decreased it in low endophyte-infected forage at Glade Spring in June. At Blackstone the inclusion of clover increased CP in low endophyte-infected forage but resulted in lower CP in high endophyte-infected tall fescue forage. Interactions of location with endophyte (P<.05) and with clover (P<.01) were present.

In July, forage from the low endophyte-infected fescue treatment was lower (P<.05) in CP concentration at Glade Spring but at Blackstone, endophyte infection reduced CP concentration (location X endophyte interaction, P<.05). During August clover increased (P<.01) CP content of forage collected at Blackstone, but forage from Glade Spring had lower CP concentration (location X clover interaction, P<.01). There was no influence of location or endophyte level on CP concentration after the August sampling.

In 1990 few differences were observed in CP content between locations at different times (Appendix Table 18). Forage harvested in

June and October from Glade Spring had higher (P<.05) CP than forage from Blackstone. In September an interaction of location with endophyte indicated that at Glade Spring CP concentration was higher (P<.05) in low endophyte-infected tall fescue forage compared to infected forage, but at Blackstone the infected fescue pastures were higher in CP concentration.

In vitro digestibility of the forage from Glade Spring was higher (P<.05) than forage from Blackstone during 1989 and 1990 (Tables 11 and 12, respectively). In vitro DM digestibility of tall fescue was influenced (P<.05) by location in April, May, June, August and September of 1989 (Appendix Table 19). Forage harvested from Glade Spring was consistently (5 to 10 percentage units) higher (P<.05) in IVDMD than forage harvested from Blackstone. A location by endophyte level interaction was detected for samples collected in July (P<.05). At Glade Spring digestibility of the forage was higher for the endophyte-infected tall fescue, while at Blackstone digestibility was lower for the endophyte-infected fescue.

In vitro digestibility of forage from Blackstone was higher (P<.05) during May and September, 1990, when compared to forage from Glade Spring (Appendix Table 20). Forage collected during June, July, August, and October in 1990 from Blackstone was lower (P<.05) in IVDMD compared to forage collected at Glade Spring. In July, forage with the endophyte was higher in IVDMD than low endophyte-infected tall fescue at Glade Spring, but values were lower for the endophyte-infected fescue at Blackstone (location X endophyte interaction, P<.05).

Neutral detergent fiber was slightly higher (P<.05) in forage from Blackstone compared to Glade Spring in both years (Table 11 and 12). Neutral detergent fiber content of forage from Glade Spring was lower (P<.01) than forage from Blackstone in April and August of 1989 (Appendix Table 21). In April an interaction of endophyte level with clover was seen (P<.05). Values were higher for forage with clover for high endophyte fescue and were lower for forage with clover for low endophyte-infected fescue. The location by clover interaction present in August and October indicated that at Glade Spring the pastures seeded with clover produced forage higher in NDF content, whereas the fields with clover at Blackstone were lower in NDF.

Forage harvested from Glade Spring was lower (P<.05) in NDF content in June, July, and October of 1990 when compared to Blackstone forage (Appendix Table 22). The inclusion of clover in the pasture resulted in lower (P<.05) NDF content of forage harvested in July and September compared to the fields that had no clover. There was no influence of endophyte on NDF content at any sampling date in 1990.

Acid detergent fiber content of forage in 1989 was not affected by location, endophyte level, or clover (Table 11), but was higher (P<.05) at Blackstone than at Glade Spring in 1990 (Table 12). Acid detergent fiber content of the forage was only influenced by location in April, 1989 (Appendix Table 23). Forage at Blackstone was higher (P<.01) in ADF content. Clover resulted in higher ADF content in August at Glade Spring but a lower ADF content at Blackstone (location X clover interaction, P<.01). Endophyte infection of the tall fescue resulted in forage with higher ADF content in August at Blackstone, but produced a small decrease in ADF content of forage harvested from Glade Spring (location X endophyte interaction, P<.01).

Although differences were small, in April of 1990, forage harvested from the endophyte-infected pastures was lower (P<.05) in ADF than forage harvested from low endophyte-infected tall fescue pastures (Appendix Table 24). In May and September, forage from Blackstone was lower (P<.05) in ADF content than forage harvested at Glade Spring, but in October forage harvested at Blackstone was higher (P<.05) in ADF than forage from Glade Spring.

Lignin content of forage from Blackstone was higher (P<.05) compared to Glade Spring in 1989 (Table 11). Although not significant, similar trends were obtained in 1990 (Table 12). High endophyte-infected fescue forage harvested in May of 1989 from Glade Spring was higher (P<.05) in lignin than the forage from low endophyte-infected forage (Appendix Table 25), but endophyte infection of tall fescue at Blackstone resulted in forage of lower lignin content than forage from low endophyte-infected tall fescue (location X endophyte interaction, P<.05). In July opposite trends were seen (location X endophyte interaction, P<.05).

Endophyte infection decreased (P<.05) lignin content of forage harvested in June, 1989. At Glade Spring, forage from low endophyte-infected tall fescue pastures with clover was higher (P<.05) in lignin content than low endophyte-infected tall fescue pastures, but the inclusion of clover with high endophyte-infected tall fescue pastures resulted in forage of lower lignin content. At Blackstone, the inclusion of clover resulted in decreased lignin content in low endophyte-infected tall fescue forage but resulted in forage of higher lignin content from high endophyte-infected tall fescue pastures (location X endophyte X clover interaction, P<.01). Forage harvested at Blackstone in August was lower in lignin content for clover seeded pastures, but at Glade Spring, clover increased lignin (location X clover interaction, P<.05).

In May of 1990, lignin content was lower (P<.01) in forage harvested at Blackstone compared to samples obtained at Glade Spring (Appendix Table 26). However, in July and October lignin content was higher (P<.01) in forage from Blackstone compared to forage from Glade Spring. Endophyte infection of tall fescue did not affect lignin content of forage harvested in 1990.

Cellulose content of forage was not different between locations in 1989 (Table 11), but was higher (P<.05) at Blackstone compared to Glade Spring in 1990 (Table 12). Cellulose content of tall fescue with and without white clover was higher in forage harvested at Blackstone compared to forage from Glade Spring in April, 1989 (Appendix Table 27). The forage from high endophyte-infected tall fescue pastures was lower in cellulose compared to low endophyte-infected tall fescue pastures at Glade Spring in July and August, but endophyte infection resulted in forage of higher cellulose content compared to low endophyte-infected tall fescue at Blackstone (location X endophyte interaction, P<.01). The inclusion of clover resulted in little effect on cellulose content at Glade Spring but decreased cellulose content at Blackstone in August (location X clover interaction, P<.01).

Cellulose content of forage from Blackstone was lower (P<.05) when compared to forage harvested from Glade Spring in May of 1990; however, in July, August, and October cellulose content was higher (P<.05) in forage harvested from Blackstone compared to forage from Glade Spring (Appendix Table 28).

Mineral analysis indicated higher (P<.05) ash content of forage from Glade Spring in both years (Table 13). Location influenced ash concentration of forage from June to October in 1989 (P<.05; Appendix Table 29). Forage from Blackstone was usually lower in ash content. In August, the presence of the endophyte resulted in increased ash content of the forage at Blackstone, but a slight decrease in ash content was observed at Glade Spring (location X endophyte interaction, P<.05). From May to October of 1990, forage at Blackstone was lower (P<.01) in ash content than forage from Glade Spring (Appendix Table 30).

Forage from endophyte-infected pastures was higher (P<.05) in Ca than low endophyte-infected forage in 1989 and 1990 (Table 13). Forage from Glade Spring was higher (P<.05) in Ca compared to Blackstone in 1989. Inclusion of clover increased Ca in forage from Glade Spring, but not at Blackstone (location X clover interaction, P<.05). Calcium concentration in forage harvested in April, July, September, and October at Glade Spring was higher (P<.05) than in forage from Blackstone in 1989 (Appendix Table 31). The presence of the endophyte resulted in forage with higher (P<.05) Ca content in April, June, and August to

TABLE 13. MINERAL CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	- - - - - - - - - - - - - - - - - DM basis - - - - - - - - - - - - - - - - -										
1989											
Ash,%[a]	6.28	6.10	5.91	6.57	6.22	5.77	4.92	4.82	4.74	5.06	.30
Ca,%[ab]	.43	.45	.46	.50	.46	.32	.32	.38	.38	.35	.01
Mg,%[ab]	.30	.30	.31	.33	.31	.24	.24	.25	.26	.25	.01
P,%	.30	.32	.33	.34	.32	.31	.33	.30	.34	.32	.01
Cu,mg/kg[a]	4.75	4.94	5.05	5.33	5.02	4.13	4.17	3.81	3.90	4.00	.30
1990											
Ash,%[a]	9.30	9.45	9.61	9.63	9.50	7.26	7.26	7.52	7.34	7.34	.33
Ca,%[bcd]	.30	.36	.35	.40	.35	.34	.35	.41	.39	.37	.02
Mg,%[a]	.26	.28	.27	.29	.28	.25	.25	.25	.25	.25	.01
P,%[ab]	.39	.40	.42	.43	.41	.32	.31	.35	.32	.32	.01
Cu,mg/kg	4.81	4.64	4.57	4.44	4.62	4.66	4.33	3.88	3.70	4.14	.48

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)
[c]Effect of clover ($P<.05$)
[d]Location X clover interaction ($P<.05$)

October of 1989. The inclusion of clover did not influence Ca concentration of forage harvested in 1989.

In 1990, forage from Blackstone was higher (P<.05) in Ca than forage from Glade Spring during May, June, and August (Appendix Table 32). This does not agree with the results from 1989. The presence of the endophyte resulted in increased (P<.05) Ca content during April, June, August, and October of 1990. The inclusion of clover resulted in increased (P<.05) Ca content of forage during April and September at both locations. Calcium content was increased by addition of clover at Glade Spring in May and July but no increase was observed at Blackstone at these sampling times (location X clover interaction, P<.05).

Magnesium content was higher (P<.05) at Glade Spring compared to Blackstone in 1989 and 1990 (Table 13). Endophyte infection of tall fescue resulted in forage with higher (P<.05) Mg content in 1989. Magnesium concentration in the forage from Glade Spring was generally higher than in the forage harvested at Blackstone in 1989 and 1990 (Appendix Tables 33 and 34, respectively). The difference was significant (P<.05) throughout 1989 and during July, August and October of 1990. Endophyte infection of tall fescue resulted in an increase (P<.05) in Mg content of forage during July and August of 1989 compared to the forage from low endophyte-infected tall fescue pastures.

No difference was observed in P concentration of the forage harvested during 1989 (Table 13). The addition of clover to the pastures resulted in an increase (P<.05) in P content of forage during August and September with the magnitude being greater (P<.05) at

Blackstone than at Glade Spring (Appendix Table 35). The presence of the endophyte had no influence on P concentration of the forage in 1989.

Endophyte infection resulted in forage with higher ($P<.05$) P content in 1990 (Table 13). Forage from Glade Spring was higher ($P<.05$) in P than forage from Blackstone in 1990. The forage harvested from Blackstone was lower ($P<.05$) in P during May, June, July, and October in 1990 compared to forage from Glade Spring (Appendix Table 36). The forage from endophyte-infected tall fescue pastures was higher ($P<.05$) in P content at Glade Spring in May, at Blackstone in August and from both locations in June compared to the low endophyte-infected tall fescue forage. The inclusion of clover in the mixture resulted in a reduction in P content during August ($P<.01$).

Copper content was higher ($P<.05$) in forage from Glade Spring compared to Blackstone in 1989, but no difference was observed in 1990 (Table 13). In April, May, and September of 1989, the forage from Blackstone was lower ($P<.05$) in Cu content than forage from Glade Spring (Appendix Table 37). The interaction of location with clover was present in May ($P<.01$). At Glade Spring, the inclusion of clover resulted in forage of higher ($P<.05$) Cu concentration; however, the forage from fields overseeded with clover at Blackstone was lower in Cu content than forage from fields without clover.

The forage from endophyte-infected tall fescue pastures was lower ($P<.05$) in Cu content in June and October of 1990 than forage from low endophyte-infected fescue (Appendix Table 38). Forage harvested at

Blackstone in July and September was lower (P<.05) in Cu concentration than forage harvested at Glade Spring.

Visual Evaluation of Pastures

The three-way interaction (P<.01) between location, endophyte infection level, and inclusion of clover as well as the interaction of location with inclusion of clover (P<.05) were present for percent ground cover in 1989 (Table 14). At Glade Spring, the inclusion of clover in the mixture increased (P<.05) the ground cover percent compared to fields not overseeded with clover. At Blackstone, where ground cover was lower (P<.08) than at Glade Spring, the inclusion of clover decreased ground cover in low endophyte-infected tall fescue but caused a slight numerical increase in high endophyte-infected tall fescue (95.0 vs 96.2%). However, there was essentially no clover at Blackstone. The presence of the endophyte increased (P<.05) the ground cover percent compared to the ground cover in fields of low endophyte-infected tall fescue.

The interaction of location with inclusion of clover was present for percent grass and percent legume in the stand during 1989 (P<.05). This is due to no significant amount of legume at Blackstone. Thus, at Glade Spring, there was less (P<.08) grass and more (P<.08) legume present than was observed at Blackstone. Percent weeds was not different between locations (P>.10). The inclusion of clover increased (P<.01) the percent of weeds, but values were small.

Red clover (*Trifolium pratense* L.), lespedeza (*Lespedeza cuneata* G. Don), bluegrass (*Poa pretensis* L.), bromegrass (*Bromus* spp. L.),

TABLE 14. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[abcd]											
	95.8	97.1	97.9	98.1	97.2	94.4	91.3	95.0	96.2	94.2	.64
Grass,%[ace]	98.5	95.6	99.4	95.6	97.3	100.0	99.8	99.8	99.3	99.7	.42
Legume,%[ace]	.62	3.38	.25	3.50	1.94	.00	.00	.00	.00	.00	.32
Weed,%[e]	.62	1.00	.38	1.10	.78	.00	.15	.15	.74	.26	.27
Prevalent plants[f]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[ace]	.8	2.8	.6	2.6	1.7	.1	.2	.4	.3	.3	.12
Crabgrass[abg]	.1	.1	.1	.1	.1	2.0	2.3	1.6	1.2	1.8	.16
Bermudagrass[ab]	.4	.1	.1	.0	.2	1.4	.9	.6	.8	.9	.14
Hairy vetch[abf]	.0	.0	.0	.0	.0	.1	.0	.2	.2	.1	.04
Weeds	1.3	1.5	1.4	1.6	1.4	.9	1.2	1.3	1.3	1.2	.13
Thistle[a]	2.1	2.6	2.4	2.6	2.4	.1	.0	.1	.0	.1	.25
Horse nettle	3.4	3.3	3.2	3.4	3.3	3.2	4.0	3.6	4.0	3.7	.36

[a]Effect of location (P<.08)
[b]Effect of endophyte (P<.05)
[c]Location X clover interaction (P<.05)
[d]Location X endophyte X clover interaction (P<.01)
[e]Effect of clover (P<.01)
[f]Code: 5=dominant, 3=frequent, 1=rare
[g]Location X endophyte interaction (P<.05)

orchardgrass (*Dactylis glomerata* L.), paspalum (*Paspalum* spp. L.), redtop (*Agrostis gigantea* L.), and purpletop (*Tridens flavus* L.), appeared rarely and were not affected by location, endophyte infection level or inclusion of clover. Fescue was the dominant species at both locations in 1989. At Glade Spring, white clover was found more frequently (P<.01) in fields that were overseeded with clover compared to fields that were not overseeded. Clover was observed only rarely at Blackstone. Crabgrass (*Digitaria sanguinalis* L.) was observed more frequently (P<.08) at Blackstone than at Glade Spring. Higher endophyte infection level of tall fescue resulted in a decrease (P<.05) in the relative abundance of crabgrass and bermudagrass (*Cynodon dactylon* Per.) compared to fields of low endophyte-infected tall fescue. Hairy vetch (*Vicia villosa* L.) was found rarely at Blackstone (P<.08) and was not observed at Glade Spring. Thistle (*Cirsium* spp.) was observed more frequently at Glade Spring than at Blackstone in both years. Horse nettle (*Solanum carolinense*) was the predominant weed at both locations and was observed more frequently at Blackstone in 1990.

The percent of vegetative ground cover was greater (P<.05) at Glade Spring compared to Blackstone in 1990 (Table 15). At Blackstone, the high endophyte-infected tall fescue produced stands that covered more of the area compared to the low endophyte-infected tall fescue, whereas, the presence of the endophyte did not affect ground cover at Glade Spring (location X endophyte interaction, P<.01).

The inclusion of clover in the mixture increased (P<.05) percent legume in 1990. Weeds were less than 2% of the observed forage at Glade

TABLE 15. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[abc]	99.2	99.6	99.9	99.6	99.5	95.5	92.2	96.8	96.5	95.2	.71
Grass,%[def]	99.7	92.8	98.6	95.6	96.7	99.7	96.5	99.7	98.7	98.6	.76
Legume,%[bdef]	.14	6.94	.00	4.30	2.84	.16	3.50	.33	1.33	1.33	.72
Weed,%[acdfg]	.14	.28	1.39	.14	.49	.16	.00	.00	.00	.05	.23
Prevalent plants[h]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[bdgi]	1.7	3.7	1.0	3.1	2.4	1.4	3.7	1.3	2.7	2.3	.16
Crabgrass[abcd]	.2	.0	.0	.0	.1	2.6	2.1	1.5	1.2	1.8	.16
Bermudagrass[abc]	.0	.0	.0	.0	.0	1.5	1.1	.9	.6	1.0	.14
Hairy vetch[a]	.0	.0	.0	.0	.0	.2	.2	.4	.4	.3	.11
Weeds[e]	1.6	1.5	1.8	1.4	1.6	1.0	1.2	1.2	1.5	1.2	.15
Thistle[abc]	2.2	1.0	.6	.7	1.1	.0	.0	.0	.2	.0	.19
Horse nettle[a]	2.5	3.1	3.0	3.1	2.9	3.9	3.4	4.3	4.2	3.9	.4

[a]Effect of location (P<.05)
[b]Effect of endophyte (P<.01)
[c]Location X endophyte interaction (P<.01)
[d]Effect of clover (P<.05)
[e]Location X clover interaction (P<.05)
[f]Endophyte X clover interaction (P<.05)
[g]Location X endophyte interaction (P<.05)
[h]Code: 5=dominant, 3=frequent, 1=rare
[i]Location X endophyte X clover interaction (P<.05)

Spring and were essentially non-existent at Blackstone (P<.05). The inclusion of clover in high endophyte-infected tall fescue pastures at Glade Spring resulted in a decrease in the percent weed compared to the fields not overseeded with clover, wheras, an increase was seen at Blackstone (location X clover interaction, P<.05).

As in 1989, fescue was the dominant forage species in 1990. The three-way interaction of location, endophyte infection level, and clover was present during 1990 for the relative abundance of white clover (P<.05). The significance was in terms of magnitude rather than direction, therefore the main effects of endophyte and clover will be discussed. The overseeding of clover resulted in an increase (P<.05) in abundance of white clover compared to the fields not overseeded. Endophyte infection of tall fescue resulted in a decrease (P<.01) in relative abundance of white clover compared to low endophyte-infected tall fescue.

Crabgrass, bermudagrass, and hairy vetch were observed more often at Blackstone than at Glade Spring (P<.05). High endophyte infection of tall fescue reduced (P<.01) the abundance of crabgrass and bermudagrass compared to low endophyte infection of tall fescue, but the effect was mainly at Blackstone (location X endophyte interaction, P<.05). The location X clover interaction was present for the relative abundance of weeds (P<.05). The inclusion of clover in tall fescue at Glade Spring decreased the abundance of weeds, but increased weeds at Blackstone (location X clover interaction, P<.05).

Discussion

The effect of grazing endophyte-infected tall fescue has been well documented (Hoveland et al., 1980; Read and Camp, 1986; Crawford et al., 1989). In the present study, a reduction in daily gain in steers grazing the endophyte-infected tall fescue was observed within the first 56 d of grazing. Grazing animal performance can be dramatically affected by the environment (NRC, 1984). It was anticipated that the environment at Blackstone would result in lower animal performance. Respective yearly precipitation totals for Glade Spring and Blackstone were 140 and 122 cm in 1989 and 135 and 106 cm in 1990, indicating slightly higher rainfall amounts for Glade Spring during this time period. Buttrey (1989) reported higher (254 vs. 198 cm) precipitation at Blackstone compared to Glade Spring over a 2-yr period. Temperatures were 1.7 and 2.2 °C higher at Blackstone in 1989 and 1990, respectively, compared to Glade Spring. There was no difference in overall daily gain between locations in 1989. However, the cattle at Blackstone had lower daily gains compared to those at Glade Spring during 1990. The lower rainfall and warmer temperature at Blackstone during 1990 may partially account for this location difference.

The inclusion of clover in tall fescue has been suggested as a method to ameliorate the effects of the endophyte on animal performance (Fribourg et al., 1988). In the present study visual evaluation indicated that overseeding of clover yielded more legume (Tables 14 and 15). However, the resulting animal performance was not improved consistently. Perhaps the amounts of clover were too small for consistent effects. Fribourg et al. (1991) reported that in Tennessee animals grazing endophyte-infected tall fescue (>22%) with ladino clover had lower daily gains than those grazing clover and fescue with less than 22% infection level. The effect of greater endophyte level was curvilinear, with greatest response occurring at low and moderate levels of infection. Non-clover controls were not included.

Reduced serum prolactin has been observed in cattle suffering from tall fescue toxicosis (Hurley et al., 1981; Bacon and Siegel, 1988). In the present study, serum prolaction concentrations were lower within 28 d of initiation of grazing at both locations. The grazing season was from April to October, at which time temperature and daylength were increasing. Previous results indicated that serum prolactin increased with higher temperature (Wetteman and Tucker, 1974; Hahn et al., 1987) and increased daylength (Hahn et al., 1991; Zinn et al., 1991). These results are consistent with the observation that ergrot alkaloids depressed serum prolactin (Faichney and Barry, 1986; Sergent et al., 1988). It appears that the effect of endophyte infection of tall fescue at the two locations studied impairs the usual increase in serum prolactin associated with increasing temperature and daylength. After termination of grazing in 1989, prolactin concentrations were not affected by previous grazing treatment, indicating resumption of photoperiod and temperature control.

Elevated rectal temperatures and hair coat scores were clearly evident in the present study and are in agreement with those reported by Bond et al. (1984) and Boling et al. (1989) using similar animals. The observation of rough, dirty hair coats in cattle grazing endophyte-infected tall fescue has been reported (Read and Camp, 1986). A difference (P<.05) has been reported in hair coat score of cattle grazing tall fescue with less than 22% infection with white clover compared to those grazing fescue of greater than 35% infection plus clover (Fribourg et al., 1991). A cause for the rougher hair coats has not been identified, but is presumably related to body temperature.

The results of the present study and those of Fontenot et al. (1988) and Buttrey (1989) indicate little influence of endophyte infection of tall fescue on serum Ca, Mg, Cu, and P. Serum Ca, Mg, and Cu in the present study were within normal ranges (Underwood, 1981). These results support those of Zylka (1989) who reported no effect of endophyte infection on retention of Ca and Mg, and apparent absorption of Cu. A linear decrease in apparent absorption of P with increasing endophyte level was reported by Zylka (1989). Serum P was lower (P<.05) in steers fed tall fescue hay and silage compared to animals fed orchardgrass-alfalfa hay (Buttrey, 1989). Endophyte infection of tall fescue had little affect on serum P in the present study. In the present study, serum inorganic P was 1 to 2 mg/dl higher than the normal range of 4-7 mg/dl (Underwood, 1981).

Cattle that had grazed 76% infected tall fescue exhibited higher daily gain during the first 48 d in the feedlot compared to animals that grazed endophyte-free tall fescue (Lusby et al., 1990). Cattle were finished on a corn silage based diet in the present study, while Lusby et al. (1990) finished the animals on a high concentrate diet. Coffey et al. (1990) reported little or no gain advantage in steers that previously grazed infected tall fescue compared to those that grazed low endophyte-infected fescue. However, they reported an efficiency advantage in cattle from high endophyte-infected tall fescue pastures which was confirmed in the present study in 1990. The results of the present study and those published previously indicate no adverse, long-term effects of grazing endophyte-infected tall fescue in finishing cattle.

Crude protein content was not different between low and high endophyte-infected tall fescue collected at these same locations from November 1987 to June 1988 (Buttrey, 1989). The results of the present study confirm these results. In addition, stockpiled forage harvested from the low and high endophyte-infected tall fescue fields at Glade Spring and ensiled were not different in CP concentration (Zylka, 1989). Hemken et al. (1981) reported that CP content of infected and endophyte-free tall fescue did not differ. No differences were detected in CP of four varieties of tall fescue of varying degrees of infection (Bond et al. 1984). In the greenhouse, N concentration was higher ($P<.05$) in endophyte-free, compared to high endophyte-infected tall fescue (Buttrey, 1989).

Buttrey (1989) reported no influence of endophyte infection of tall fescue grown in the greenhouse on IVDMD. Zylka (1989) reported similar DM digestibilities in sheep fed low and high endophyte-infected, ensiled stockpiled tall fescue. More recently, Fiorito et al. (1991) reported a lower total tract digestion of DM by wethers fed endophyte-infected tall fescue compared to endophyte-free tall fescue. In the present study, forage from Glade Spring was higher in IVDMD than forage from Blackstone, but there was no influence of endophyte infection on average IVDMD.

Buttrey (1989) reported that NDF content of stockpiled, low endophyte-infected tall fescue was higher compared to high endophyte-infected fescue. Endophyte infection did not affect the NDF content of tall fescue hay (Straham et al., 1987). These results are in agreement with those of the present study, in which there were minimal effects of the endophyte on fiber components.

Previous research has indicated that the endophyte has no affect on ADF and NDF content of tall fescue forage (Bond et al., 1984; Straham et al., 1987). Buttrey (1989) reported a higher ADF concentration in low endophyte-infected tall fescue compared to high endophyte-infected tall fescue. The results of the present study support the work of Buttrey (1989) but disagree with those of Hoveland (1988) who reported accelerated maturation in endophyte-infected tall fescue, which resulted in higher fiber content. Lignin content was consistently lower in fescue that was greater than 70% infected compared to fescue with less than 2% infection level (Buttrey, 1989). Previously, Bond et al. (1984) reported similar results.

Mineral composition of tall fescue has been affected by genotype (Sleper et al., 1980). Previous research has compared low and high endophyte-infected tall fescue from different varieties (Bond et al., 1984; Aldrich et al., 1990; Howard et al., 1990). The present research offers a more valid comparison of low and high endophyte-infected tall fescue within the same variety. The presence of the endophyte resulted in forage with higher Ca content in the present study. Buttrey (1989) reported no difference in Ca between infected and endophyte-free tall fescue grown in the greenhouse or under field conditions. These results supported those of Odom and coworkers (1981) who reported no difference in Ca or Mg due to endophyte infection of tall fescue.

Magnesium concentration was not affected by endophyte infection of tall fescue harvested from these fields from November, 1987 to June, 1988 (Buttrey, 1989). However, in the greenhouse, endophyte-infected plants had lower Mg concentration compared to endophyte-free plants (Buttrey, 1989). Hoveland et al. (1984) reported increased Mg content of endophyte-infected tall fescue, compared to endophyte-free fescue.

No influence of endophyte infection of tall fescue on forage P has been reported (Hoveland et al., 1984; Buttrey, 1989; Zylka, 1989). Phosphorus content in forage from the present study was not dramatically affected by endophyte infection of tall fescue.

Copper was numerically higher in endophyte-free as compared to infected tall fescue forage grown in the greenhouse (Buttrey, 1989). In addition, stockpiled low endophyte-infected tall fescue was higher in Cu than stockpiled high endophyte-infected tall fescue (Buttrey, 1989). At only two sampling times did endophyte infection of tall fescue produce forage lower in Cu concentration in the present study.

Tillering of high endophyte-infected tall fescue was greater than tillering in low endophyte-infected fescue (Clay, 1984). Similar results were reported by Buttrey (1989). A reduction in ground cover in the present study would be indicative of stand loss. Read and Camp (1986) reported that two of three replicates of low endophyte-infected tall fescue pastures were lost compared to no loss of endophyte-infected 'Kenhy' tall fescue in a study in Texas. The more frequent occurence of crabgrass and bermudagrass in the stands of low endophyte-infected fescue may indicate a more dense sward in the endophyte-infected fescue.

The introduction of clover into tall fescue has been successful (Rogers et al., 1983). However, the authors reported no information concerning the toxicity of the tall fescue. Labandera et al. (1988) investigated the ability of white clover to persist in stands with tall fescue. No mention was made of the endophyte level of the tall fescue. Initially the sod was 37 and 63% tall fescue and white clover, respectively. During the second year, the mixture was 17% white clover and 83 % tall fescue, indicating minimal persistence of white clover. During 1990 of the present study, fields overseeded with clover were higher in legume percent compared to those fields not receiving clover seed. In addition, the presence of the endophyte decreased the observed legume percent.

Implications

Endophyte infection of tall fescue reduces grazing cattle performance, results in elevated body temperature, and rougher hair coats. The results of the present study indicated few changes in forage composition occur with endophyte infection. Forage DM yield was higher at Glade Spring during both years of the study. The inclusion of clover in the pasture offers some benefit through better performance by the animal. Further research is needed with a higher percentage of clover in the mixture. Few major differences in animal performance were detected between the locations studied during 1989 and 1990. After removal from the high endophyte-infected tall fescue, animals perform similarly to animals that previously grazed low endophyte-infected tall fescue. Differences detected in carcass measures were related to lighter body weights more than to direct effects of the endophyte.

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CHAPTER IV.

SUSTAINED-RELEASE CHROMIUM SESQUIOXIDE CAPSULES TO PREDICT FECAL OUTPUT AND INTAKE OF STEERS FED TALL FESCUE HAY

ABSTRACT: Six Angus steers (243 kg) were used to evaluate the use of a chromic oxide sustained-release bolus (Captec Chrome, Quad Five, Ryegate, MT) to estimate fecal output and intake. Chopped tall fescue hay was fed at 2.1% of body weight. Fecal samples were collected from d 1 to 21 after dosing with the bolus. In addition, once daily grab samples were collected from d 5 to 18. The release rate of Cr from the boluses was variable. Chromic oxide in the total fecal collection accurately predicted intake in five of the six steers for the period of d 5 to d 18. Dry matter intake was accurately predicted from grab sample Cr in only two of six steers. Total fecal collection Cr was accurate at predicting intake for weekly periods beginning on d 5, 7, 10, and 12. The mean difference between actual intake and intake predicted from grab sample Cr was equal to zero for the periods beginning on d 5 through d 10. The present study involved limit-fed animals which may limit application to grazing animals.

Introduction

Chromium sesquioxide (chromic oxide) has been utilized as an external marker for fecal output and intake determinations (Lambourne, 1957; Hopper et al., 1978). The use of chromic oxide in grazing situations would be difficult due to the required multiple dosing

(Prigge et al., 1981). Chromic oxide has been dosed as a powder in gelatin capsules twice daily to grazing cattle (Brisson et al., 1957) or mixed in the feed (Linnerrud and Donker, 1961; Smith and Reid, 1955). However, diurnal variation of excretion resulted in limited usefulness (Langlands et al., 1963).

Kiesling et al. (1969) examined recovery of chromic oxide administered in paper to grazing steers. The paper was used to mimic fiber passage. However, recovery of the chromic oxide from paper was not better than from chromic oxide powder. Hopper et al. (1978) added the chromic oxide to pelleted feed offered twice daily to grazing cattle. Although animals varied in Cr excretion pattern, pooled samples taken at 0800 and 1700 resulted in unbiased estimates of fecal output. Prigge et al. (1981) reported that twice daily dosing with chromic oxide appeared to reduce the amount of diurnal variation in fecal output.

Sustained-release chromic oxide capsules (SRC) have recently been released in the United States. Parker et al. (1989) reported that SRC were accurate at predicting intake of sheep fed lucerne chaff, fresh ryegrass and/or clover forage, or meadow hay indoors. In addition, diurnal variation in fecal Cr concentration was not significant. These SRC offer the advantages of one time administration and complete recovery of the chromium. The one-time dosing ensures that normal grazing behavior is not disturbed.

The SRC have been accurate in a limited number of field trials (Momont et al., 1990). Hatfield et al. (1990) reported that marker estimates of fecal output were different from total fecal collections of confinement fed sheep. They observed more accurate estimate of fecal output of grazing animals compared to estimates in the confinement fed sheep. This difference was possibly due to more consistent intake patterns of grazing animals compared to twice daily feeding in confinement. In addition, intake of the fed animals was higher than the grazing animals. The higher intake diluted the chromium in the feces. This reduced level of chromium may have resulted in detection errors.

A study was conducted to investigate the use of the capsules for accurate, indirect estimate of intake. This technology would be valuable for estimating intake of grazing animals.

Materials and Methods

Six Angus steers (243 kg) were randomly allotted to metabolism stalls, similar to those described by Nelson et al. (1954). Chopped tall fescue (*Festuca arundinacea* Shreb.) hay was fed at 2.1% of body weight at 0600 and 1800. Meals were typically consumed within 1 h. Animals were allowed free access to water the remainder of the time. The tall fescue hay used was not infected with the endophyte (*Acremonium coenophialum* Morgan-Jones and Gams). Composition of the hay used is presented in Table 16. Feed refusals, if present, were weighed and the amounts recorded at each feeding. Animals were allowed an 8 d adaptation period to the diet and stalls.

Sustained-release chromic oxide capsules were administered on d 0. Animals were dosed at 5 min intervals to allow for collection of feces at 24 h intervals on d 1 through 21. Total fecal collections were mixed

TABLE 16. COMPOSITION OF HAY FED TO STEERS

Item	Content[a]
Crude Protein, %	11.39
NDF, %	66.66
ADF, %	40.06
Lignin, %	5.28
Cellulose, %	33.36
Ash, %	6.26
Calcium, %	.52
Magnesium, %	.31
Phosphorus, %	.27
Copper, mg/kg	3.12
Digestibility, %[b]	61.7

[a]DM basis
[b]In vivo DM digestibility

thoroughly and a 5% subsample was collected. A pinch of thymol was added and sample stored at -20°C. A grab sample of feces was collected from each animal at 0800 from d 5 to 18 to test the value of a single fecal sample to predict fecal output and intake. All fecal samples were individually dried at 60°C and ground through a 1-mm screen.

Hay samples were analyzed for DM (A.O.A.C., 1990), NDF (Van Soest and Wine, 1968) with the exception that decalin and sodium sulfite were not used, ADF (Van Soest, 1963), lignin and cellulose (Van Soest and Wine, 1968). Crude protein was estimated from Kjeldahl N X 6.25 (A.O.A.C., 1990). Calcium, Mg, and Cu were measured by atomic absorption spectrophotometry following nitric and perchloric digestion (A.O.A.C., 1990). Inorganic P was measured by the colorimetric method of Fiske and Subbarow (1925). Total fecal and grab fecal samples were analyzed individually for Cr by atomic absorption spectrophotometry after sequential digestion with nitric and perchloric acid.

Total fecal output was estimated by the following equation: Total feces, kg/d = (indicator dose, mg/d)/ (indicator concentration in feces, mg/kg). Dry matter intake was predicted by the following equation: DM intake = (fecal output, kg/d)/(indigestibility) x 100.

Linear and quadratic equations for amount of Cr released from the bolus were generated from regression and generalized linear models procedures (SAS, 1985). Actual and predicted intakes were compared using t-statistics comparisons (SAS, 1985).

Results

Chromium release from the boluses was reported to be 978 mg/d in the manufacturer's literature. Prior to d 5 Cr concentration in the feces indicated that Cr had not yet equilibrated in the digestive tract. The amount of Cr released, as measured in total collection and grab samples, is plotted in Figure 1. The quadratic equation of Cr release, mg/d= 1007.4 + 33.9(day) - 2.28(day^2) was generated from the total fecal collections from d 5 to 18. This equation accounted for only 11% of the variation in amount of Cr released from the bolus. The prediction equation generated for Cr release as measured in grab samples was Cr, mg/d= 906.8 + 60.4(day) - 2.96(day^2) accounting for 5% of the variation.

The mean Cr release from the boluses as estimated from total fecal collection was 1153 and 1201 mg/d for d 5 to 11 and d 12 to 18, respectively. The equations to predict Cr release during these periods were Cr, mg/d= 943.9 + 26.9(day)(R^2=.04) and 1067.2 - 7.1(day)(R^2=.01). For the same periods, the amount of Cr released as estimated from the grab samples was 960 and 1119 mg/d, respectively. Chromium released from the bolus as measured in the grab samples was predicted by the equations Cr, mg/d= 981.8 +28.1(day)(R^2=.05) and 1340.1 - 14.7(day)(R^2=.02) for the periods d 5 to 11 and d 12 to 18, respectively.

The results of regression analysis indicated high variability in Cr release. However, the boluses may be useful to predict intake of groups of animals when fecal output is combined with digestibility. The mean DM digestibility of the diet was 61.7%. The mean difference between actual and predicted intake from chromium in the

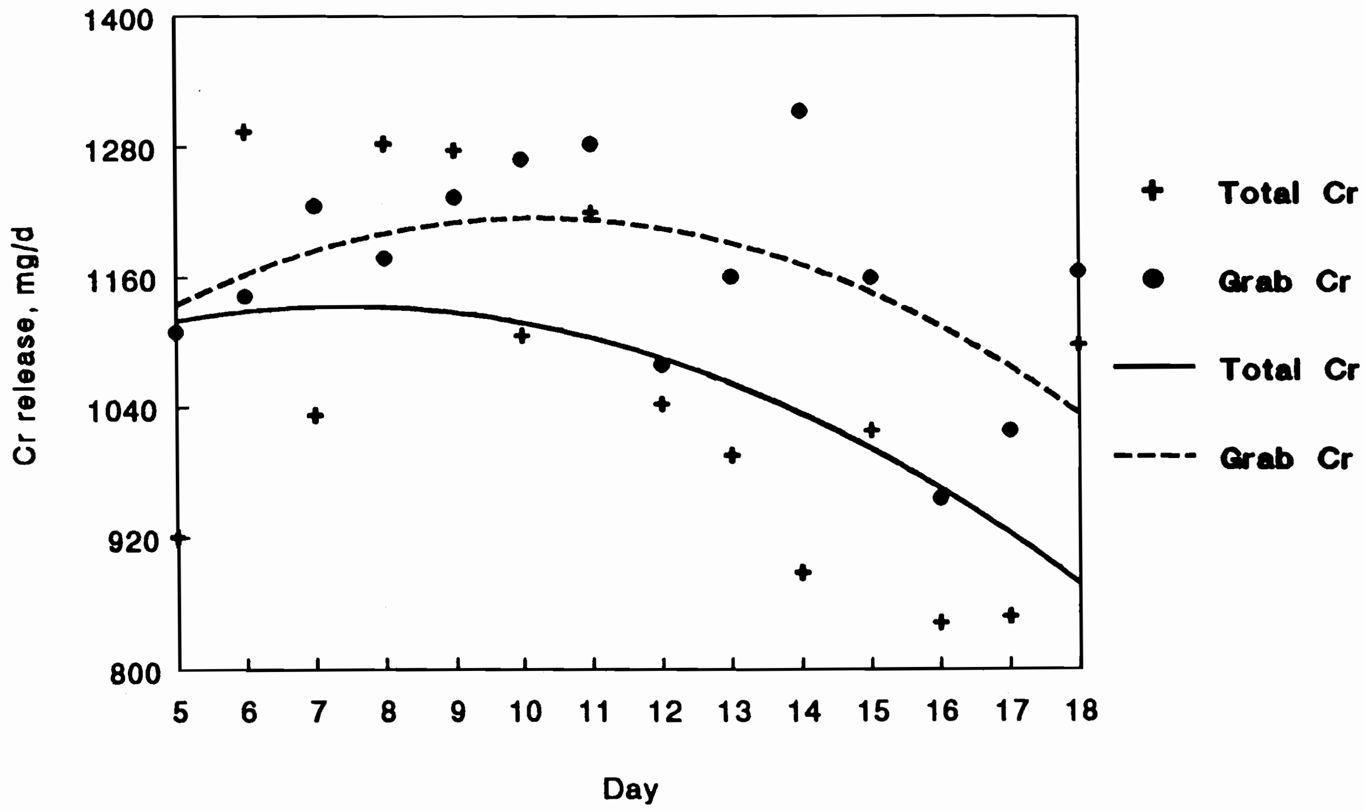

FIGURE 1. DISTRIBUTION OF CR RELEASE RATE (mg/d) ESTIMATED FROM TOTAL FECAL COLLECTIONS AND GRAB SAMPLES

total collection were not equal to zero in only one of six animals (Table 17). Intake was underestimated in four of six animals during the 14 d period. The average predicted intake for the six steers was not different (P=.34) than the actual intakes (4.65 vs. 4.76, respectively). The capsules appeared to be useful for predicting intake of steers fed twice daily.

The chromic oxide content of once daily grab samples estimated intake in two of six steers (Table 18). Chromium in once daily grab samples was not useful to predict intake when averaged over the six animals. The data in tables 17 and 18 were averaged over the 14 d collection period when chromic oxide content was consistent in all fecal samples. A more practical period of collection would be 7 d.

The mean difference between actual average intake of the six animals and intake predicted from total fecal collection chromium was equal to zero for weekly periods beginning on d 5, 7, 8, 10 and 12 ($P > .05$; Table 19). Predicted intake was much lower than actual intake for the periods when the mean difference was not equal to zero. The mean difference between actual intake and intake predicted from grab sample Cr concentration was equal to zero ($P > .10$) for the periods beginning on d 5, 6, 7, 8, 9, and 10 (Table 20). Predicted intake from grab sample chromic oxide concentration was consistently lower than actual intake (77.8 to 90.7%; Table 20).

Discussion

TABLE 17. USE OF SUSTAINED-RELEASE CHROMIC OXIDE CAPSULES TO PREDICT INTAKE OF INDIVIDUALLY FED STEERS FROM TOTAL FECAL COLLECTIONS

	Intake, kg DM/d			
Animal no.	Actual	Predicted	SE	P-value[a]
1	4.75	3.90	.42	.10
2	4.76	4.48	.28	.34
3	4.79	5.18	.28	.19
4	4.78	5.25	.28	.13
5	4.75	4.67	.19	.72
6	4.72	4.02	.27	.02
Overall	4.76	4.65	.12	.34

[a]Probability that the mean difference = 0

TABLE 18. USE OF SUSTAINED-RELEASE CHROMIC OXIDE CAPSULES TO PREDICT INTAKE OF INDIVIDUALLY FED STEERS FROM FECAL GRAB SAMPLES

	Intake, kg DM/d			
Animal no.	Actual	Predicted	SE	P-value[a]
1	4.75	3.63	.42	.04
2	4.76	3.96	.23	.004
3	4.79	4.61	.14	.23
4	4.78	4.68	.17	.58
5	4.75	4.26	.10	.0005
6	4.72	3.66	.20	.0002
Overall	4.76	4.18	.09	.0001

[a]Probability that the mean difference = 0

TABLE 19. USE OF SUSTAINED-RELEASE CHROMIC OXIDE CAPSULES TO PREDICT INTAKE OF SIX STEERS BY PERIOD FROM TOTAL FECAL COLLECTIONS

Days	Intake, kg DM/d		SE	P-value[a]
	Actual	Predicted		
5 to 11	4.75	5.19	.40	.32
6 to 12	4.80	3.69	.21	.003
7 to 13	4.71	4.39	.62	.63
8 to 14	4.78	3.94	.33	.07
9 to 15	4.67	3.60	.12	.003
10 to 16	4.72	4.83	.60	.86
11 to 17	4.78	3.86	.20	.02
12 to 18	4.77	5.01	.15	.11

[a]Probability that the mean difference = 0

TABLE 20. USE OF SUSTAINED-RELEASE CHROMIC OXIDE CAPSULES TO PREDICT INTAKE OF SIX STEERS BY PERIOD FROM FECAL GRAB SAMPLES

	Intake, kg DM/d			
Days	Actual	Predicted	SE	P-value[a]
5 to 11	4.75	4.31	.33	.25
6 to 12	4.80	4.26	.39	.22
7 to 13	4.71	3.84	.42	.11
8 to 14	4.78	4.24	.42	.27
9 to 15	4.67	3.82	.39	.12
10 to 16	4.72	4.04	.46	.21
11 to 17	4.78	3.72	.30	.04
12 to 18	4.77	4.28	.11	.0001

[a]Probability that the mean difference = 0

Chromic oxide in gelatin capsules accurately predicted intake of lactating cows (Hopper et al., 1978). However, once or twice daily dosings of chromic oxide requires development of dosing time and fecal collection time techniques to account for cyclic fluctuations in excretion (Langlands et al., 1963; Hopper et al., 1978; Prigge et al., 1981). Ytterbium has an advantage over chromic oxide as an external marker because it is associated more closely with the particulate phase of the digesta (Ellis and Huston, 1968). The labor requirement of dosing with gelatin capsules or mordanting of feeds with Yb is substantial (Prigge et al., 1981; Teeter et al., 1984).

Sustained-release chromic oxide boluses reportedly provide a constant supply of Cr in the rumen, offering a labor savings alternative to gelatin capsules (Parker et al., 1989). Administration of the boluses in the present study was not difficult, as indicated by K.R. Pond (personal communication).

Parker et al. (1989) reported that the bolus reduced the impact of diurnal variation associated with once daily dosing in sheep. In addition, once daily grab samples were effective in predicting intake of sheep offered fresh or dried forage. However, release of Cr was extremely variable in their study (52 to 70 mg/d). The results of the present study indicated nonuniform release rate of Cr. Grab samples consistently underestimated intake in cattle fed twice daily. Buntinx et al. (1990) report that the sustained-release bolus consistently overestimated fecal output in free grazing sheep. Momont et al. (1990) investigated the use of the bolus to predict intake of cows and ram lambs fed mature grass hay. Accurate predictions of intake were obtained from estimated fecal output and alkaline peroxide lignin marker.

Kattnig et al. (1990) reported that fecal output of range cows was reasonably predicted using the sustained-release boluses. A reasonable prediction was defined as one that results in a biologically reasonable level of fecal output. Hatfield et al. (1990) indicated more accurate prediction of intake in grazing sheep compared to those fed in confinement. Although the boluses had limited accuracy in the present study, they do appear promising to estimate intake of free, grazing ruminants.

Implications

Some differences were observed between marker estimates of individual intake and actual intake in the present study. Estimates of grazing animal intake are typically measured over a 5 or 7 d period. The data from the present study indicated potential of the boluses for predicting DM intake over 5 to 7 d periods. Total fecal Cr concentration offered no advantage over fecal grab sample Cr concentration at predicting DM intake. The data of the present study were obtained from limit fed animals which may limit application for ad libitum fed or grazing animals.

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CHAPTER V.

DIET SELECTION, DIGESTIBILITY, AND INTAKE OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE WITH AND WITHOUT WHITE CLOVER

ABSTRACT: Two separate trials were conducted to measure selectivity, bite size, biting rate, intake, and forage digestibility of steers grazing low (<5%) and high (>70%) endophyte (*Acremonium coenophialum* Morgan-Jones and Gams)-infected tall fescue (*Festuca arundinacea* Schreb.), with and without white clover (*Trifolium repens* L.). Four steers equipped with esophageal cannulae were used to estimate diet composition, bite size, and biting rate. Intake and digestibility were estimated using 48 experimental animals and four esophageally-fistulated steers. Chromic oxide sustained-release boluses and forage IVDMD were used to estimate intake. Bite size was smaller (P<.05) in July than May, corresponding to decreased quantity available. Bite size and biting rate were not affected by endophyte infection or clover. In vitro DM digestibility was higher (P<.05) for high endophyte-infected tall fescue in July. Animals consumed a higher percentage of clover than was available in the sward. Intake was higher (P<.01) in cattle grazing low endophyte-infected tall fescue compared to animals grazing high endophyte-infected fescue. These data indicated an ability of animals to selectively graze clover in mixed tall fescue/white clover pastures. Some of the decreased performance of steers grazing endophyte-infected tall fescue is related to lower intake. Additional research, involving higher levels of clover in the pasture, is needed to

evaluate the effectiveness of clover to ameliorate the toxic factors of tall fescue.

Introduction

The impact of infection of tall fescue with the endophytic fungus on animal agriculture is well documented (Stuedemann and Hoveland, 1988). The reduction in performance observed in cattle consuming endophyte-infected tall fescue has been attributed to the presence of ergopeptine alkaloids (Bacon et al., 1986; Garner, 1989). Evidence that indicated a reduction in intake in animals consuming endophyte-infected tall fescue compared to animals consuming noninfected tall fescue of different varieties has been presented (Aldrich et al., 1990; Howard et al., 1990). Animals grazing endophyte-infected tall fescue spent less time grazing and more time standing compared to animals on endophyte-free pastures (Stuedemann et al., 1985; Howard et al., 1990), which may partially explain the reduction in intake.

The endophyte benefits the host plant through increased insect resistance (Clay et al., 1985) and drought tolerance (Read and Camp, 1986; Buttrey, 1989). Therefore, removal of the endophyte as a strategy for reducing the impact of the endophyte on animal performance may not be beneficial. Certain feed additives may have the ability to reduce the impact of the endophyte. Phenothiazine, acting as a dopamine agonist, may stimulate prolactin secretion in animals consuming endophyte-infected tall fescue (Boling et al., 1989). Thiamin supplements increased grazing time of cows that were supplemented with

70% infected tall fescue seed while grazing alfalfa. Metoclopramide has produced inconsistent results concerning reduction of tall fescue toxicosis (Lipham et al., 1989; Stuedemann et al., 1990). The inclusion of legumes in mixtures with endophyte-infected tall fescue may be a more feasible option (Fribourg et al., 1988).

In order to utilize overseeded legumes in tall fescue pastures successful establishment is required. Endophyte-infected tall fescue has been characterized as being capable of greater growth and persistence compared to low endophyte-infected tall fescue (Read and Camp, 1986; Buttrey, 1989). The introduction of ladino clover in tall fescue has been successful; however, no level of infection was reported (Rogers et al., 1983). Inclusion of clover in low and high endophyte-infected tall fescue increased daily gains of steers (Chestnut et al., 1991).

Diet composition was accurately predicted in steers using Ca as an indicator of percent tall fescue and red clover ingested (Pigurina, 1986). Selectivity of steers can be dramatic. Moore et al. (1987) reported a quadratic increase in legume percent of extrusa as legume percent in the upper canopy level increased. Limpograss (*Hemarthria altissima*) and American jointvetch (*Aeschynomene americana*) were grazed by 350 to 450 kg esophageally-fistulated steers. When the canopy contained 40% or more legume, the extrusa contained about 80% legume. Data were not available concerning selectivity of cattle grazing low and high endophyte-infected tall fescue with and without white clover.

The objectives of this study were 1) to compare selectivity, bite size, and biting rate of steers grazing low and high endophyte-infected tall fescue with and without white clover, and 2) to investigate the effects of endophyte infection of tall fescue and inclusion of white clover on intake and digestibility of forage by grazing steers.

Materials and Methods

Two separate trials were conducted to measure bite size, biting rate, selectivity (Trial 1), intake and forage digestibility (Trial 2) of steers grazing low (<5%) or high (>70%) endophyte-infected tall fescue, with and without white clover. A 2 X 2 factorial arrangement of treatments was utilized in a randomized complete block design with two replications of pastures.

The trials were conducted at the Southwest Virginia Agricultural Experiment Station at Glade Spring. The trials were conducted concurrently with the grazing experiments described in Chapter III. In pasture block 1 the soil was Frederick (silt loam, mixed, mesic, Typic Paleudult). Soil in pasture block 2 was Hagerstown (fine, mixed, mesic, Typic Hapludalf). Soil fertility was maintained according to soil test recommendations, except that fields with white clover received no N fertilizer.

'Kentucky-31' tall fescue was no-till seeded on September 22 and 23, 1986. Tall fescue tillers from all pastures in both years of the present trial were microscopically screened for the presence of the endophyte at the Fescue Diagnostic Laboratory, Auburn University.

'Ladino' white clover was broadcast seeded into one-half of the pastures in Spring of 1989, and 1990, and in Fall of 1989.

Trial 1. Four tamed yearling steers (290 kg) equipped with esophageal cannulae were used to estimate bite size, and diet composition. Observations were made from May 17 to June 8 and again July 16 to August 6, 1989. A latin-square design was used in order for each steer to graze each pasture in the two blocks. After sample collection, animals were moved to the new pasture allowing a minimum of 72 h to adjust to the new pasture.

Esophageal extrusa samples were collected between 0600 and 0900. For collection, the solid plug of the cannula was replaced with a hollow tube and a polyethylene bag was attached. Small holes were placed in the bags to allow saliva to drain. A subjective evaluation of grazing vigor was made during each collection on a scale of 1 to 10, with 1 being an animal not interested in grazing (0% of time grazing), 5 indicating an animal that grazed 50% of the sampling time, and 10 being an aggressive grazer with no pauses during sample collection. The animals were carefully observed to detect swallowing of the entire sample before bag removal. Steers being collected were allowed to graze with the other animals during collection. Pastures were sampled one at a time, with collections usually completed within 20 min.

Extrusa samples were frozen at -20°C until analyzed. Samples were dried in a forced air oven at 50°C for 48 h to determine DM and subsequently ground in a Cyclone mill to pass a 1-mm screen. Ground samples were analyzed for N by Kjeldahl procedure (A.O.A.C., 1990), and

NDF (Van Soest and Wine, 1968) except decalin and sodium sulfite were not used. In vitro dry matter digestibility was estimated using procedures of Tilley and Terry (1963) as modified by Barnes (1969). For the IVDMD, ruminal digesta was obtained from a cannulated steer fed tall fescue hay with 40% infection. Samples were analyzed in duplicate with four blank and two alfalfa reference samples included during each incubation.

Extrusa samples were wet ashed in nitric and perchloric acids for Ca analysis (A.O.A.C., 1990). Samples were analyzed for Ca by atomic absorption spectrophotometry using a Perkin-Elmer Zeeman 500 PC. Lanthanum oxide was used to prevent interference by P in detecting Ca. Calcium content was used to predict clover content of the collected extrusa (Pigurina, 1986). Tall fescue and white clover samples from low and high endophyte-infected pastures were collected during each sampling period. Individual tillers were cut at a height of 3 cm. These samples were individually dried at 60 °C and ground to pass a 1-mm screen. Tall fescue and white clover were analyzed in ratios of 0:100, 20:80, 40:60, 60:40, 80:20, and 100:0 for Ca by atomic absorption. Clover content of the extrusa was estimated from the equations generated from the mixtures (Table 21; Harker et al., 1964; Pigurina, 1986).

Trial 2. Intake and digestibility were estimated in May and July of 1990 using 24 experimental steers and 4 yearling steers with esophageal cannulae at each time. Actually the entire 48 steers on the grazing study (Chapter III) were used. One half of the steers were used in May, and the other half were used in July. Chromic oxide sustained-

TABLE 21. EQUATIONS USED TO PREDICT CLOVER CONTENT OF EXTRUSA FROM CALCIUM CONTENT OF TALL FESCUE[a] AND WHITE CLOVER[b]

Infection level	Month	Equation	R^2
Low[c]	May	102.2*Ca% - 27.86	.97
	July	107.5*Ca% - 25.60	.96
High[d]	May	100.1*Ca% - 22.08	.97
	July	101.7*Ca% - 20.35	.98

[a]Tall fescue Ca, DM = .22 %
[b]White clover Ca, DM = 1.19 %
[c]Low: <5% infected with *Acremonium coenophialum*
[d]High: >70% infected with *Acremonium coenophialum*

release boluses (Captec chrome, Quad Five, Rygate, MT) were administered on d 0 to the experimental animals. Fresh fecal samples were obtained in the field from d 9 to 16 between 0630 and 0930 after the animals were observed to defacate. Samples were frozen at -20°C until analyzed. Equal quantities of wet feces were combined from each day for each experimental animal. Samples were dried at 60°C for 48 h for DM determination and subsequently ground in a Wiley mill to pass a 1-mm screen. Samples were sequentially wet ashed with nitric and perchloric acid for detection of Cr by atomic absorption spectrophotometry.

Fistulated steers were randomly assigned to pastures on d 6 providing a 3-d adjustment period as esophageal extrusa was collected from d-9 to d-16. Extrusa samples were collected as described in trial 1. Samples were stored at -20°C until dried at 60°C for about 48 h and ground to pass a 1-mm screen. In vitro dry matter digestibility was estimated using procedures of Tilley and Terry (1963) as modified by Barnes (1969). Details are given in trial 1. Dry matter intake was estimated from fecal output and indigestibility of the extrusa samples.

The complete statistical model for the trials included the main effects of pasture replication, time, endophyte level, and inclusion of clover with all two and three-way interactions. There were no significant interactions, therefore, the final model for both trials included endophyte, clover, and time effects. Analysis of variance was conducted using the general linear method of SAS (1985).

Results and Discussion

Trial 1. There was a difference (P<.05) between May and July for bite size, CP content, IVDMD, and clover content of the extrusa (Table 22). When forage was less available in July, bite size was smaller (P<.05; Table 23). In general, a decrease in quantity of temperate grass available will result in a decrease in bite size and an increase in rate of biting (Allden and Whittaker, 1970; Jamieson and Hodgson, 1979). Bite size in cattle decreased as yield of Asiatic bluestem (*Bothriocloa* spp.) decreased (Forbes and Coleman, 1987). In the present study, although not significant (P>.15), vigor was slightly higher during July compared to May. This was interpretted to indicate an increase in biting rate to attempt to compensate for the decrease in bite size. There was no influence of endophyte infection or clover on vigor, or bite size during either time period investigated.

Crude protein of the forage available in May and July was 12.4 and 12.6%, respectively (Table 23). Extrusa contained 13.4 and 14.5% CP in May and July, respectively, indicating a slight ability to select forage higher in CP than was available (Table 22). Crude protein content of the extrusa was higher (P<.05) in July compared to May and was not affected by endophyte infection or inclusion of clover.

In vitro DM digestibility was higher for clipped high endophyte-infected tall fescue compared to clipped low endophyte-infected tall fescue in July (Table 23). However, in vitro DM digestibility of the extrusa was not affected by endophyte level or clover at either time studied. Animals generally select forage of higher quality than forage on offer (Barth et al., 1989; Milne et al., 1982). Buttrey (1989)

TABLE 22. BITE SIZE, AND COMPOSITION OF EXTRUSA COLLECTED FROM STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE WITH AND WITHOUT WHITE CLOVER IN 1989

Item	Low endophyte		High endophyte		SE
	No clover	Clover	No clover	Clover	
May					
Vigor[a]	4.5	3.8	4.6	5.0	.84
Bite size[bc]	.48	.58	.47	.51	.08
CP, % DM[c]	12.74	12.79	12.83	15.25	.81
NDF, % DM	68.43	69.18	67.76	66.26	1.48
IVDMD, % DM[c]	61.77	60.19	65.34	63.26	2.05
Ca, % DM[d]	.32	.34	.29	.38	.03
Clover, % DM[cd]	4.40	6.60	7.31	16.02	3.66
July					
Vigor	5.3	5.8	4.8	5.2	.84
Bite size[c]	.29	.39	.39	.45	.08
CP, % DM[c]	13.83	15.55	14.21	14.62	.81
NDF, % DM	66.50	66.14	67.60	68.31	1.39
IVDMD, % DM[c]	56.28	57.07	58.13	55.77	1.92
Ca, % DM[d]	.31	.39	.35	.47	.06
Clover, % DM[cd]	8.20	16.06	15.50	27.83	4.89

[a]Code: Subjective score, 1=no interest to 10=very aggressive biting rate
[b]Bite size expressed as g/bite
[c]Effect of time (P<.05)
[d]Effect of clover (P<.07)

TABLE 23. FORAGE YIELD AND COMPOSITION FROM TALL FESCUE PASTURES WITH AND WITHOUT CLOVER IN MAY AND JULY OF 1989

Item[a]	Low endophyte		High endophyte		
	No clover	Clover	No clover	Clover	SE
May					
Yield, kg/ha	2618.4	2860.1	2803.0	1972.7	285.1
CP, %	11.50	12.18	12.88	13.00	.75
IVDMD, %	69.18	62.76	68.56	66.12	2.28
NDF, %	59.52	61.72	59.58	58.02	1.16
Ca, %	.40	.43	.45	.44	.04
Clover, %[bc]	.31	2.76	.23	3.47	.42
July					
Yield, kg/ha	2241.7	2033.1	1651.5	1995.9	273.8
CP, %	11.72	12.14	13.66	12.98	1.03
IVDMD, %[d]	50.44	51.90	64.60	60.75	4.53
NDF, %	68.08	67.63	67.08	66.50	1.78
Ca, %	.43	.44	.43	.49	.03
Clover, %[c]	.43	3.43	.28	3.55	.41

[a]All items expressed on a DM basis
[b]Estimated clover percent from visual evaluation
[c]Effect of clover ($P<.05$)
[d]Effect of endophyte ($P<.05$)

reported no influence of endophyte infection of tall fescue on IVDMD of tall fescue when grown in the greenhouse. Goetsch et al. (1987) reported an increased in vivo digestibility of infected tall fescue compared to noninfected fescue. Sheep fed the same quantity of high and low endophyte-infected tall fescue silage had similar apparent DM digestibilities (Zylka, 1989). The animals in the present study selected forage of similar quality to that on offer. The lack of nutritional selection may have been due to management practices or too infrequent sampling, hence, deserves further study.

Clover has been introduced as a possible method of ameliorating the toxic effects of the endophyte. Animals are able to select legumes of high quality compared to grasses of lower quality (Moore et al., 1987). Calcium content of forage available was not affected by inclusion of clover in either May or July (Table 23). Visual estimates indicated that clover in the mixture was increased (P<.05) through overseeding of clover (Table 23). Calcium content in the extrusa was higher for cattle grazing fescue-clover pastures in May (P<.05) and July (P<.07) (Table 22), hence, more clover in the extrusa. Moore et al. (1987) reported that percentage of legume (American jointvetch) in the extrusa of steers increased quadratically as the legume percentage in the upper canopy increased. In the present study, for both low and high endophyte-infected tall fescue with clover, the increase in clover intake was roughly twice the intake of clover observed in the low and high endophyte-infected stands alone.

Trial 2. Fecal output, DM intake (kg/d and percent of BW), and daily gain were higher (P<.01) in cattle grazing low endophyte-infected tall fescue compared to animals grazing high endophyte-infected tall fescue (Table 24). Spears et al. (1984) reported that DM intake of sheep was reduced by 50% when fed endophyte-infected tall fescue hay compared to intake of endophyte-free fescue hay. A 20% reduction in intake was reported for cattle fed endophyte-infected (71%) tall fescue hay compared to animals fed fescue of less than 20% infection (Chestnut et al., 1991).

Howard et al. (1990) recently reported that steers grazing 'Johnstone' tall fescue with less than 1% infection level had higher intake than steers grazing 60% endophyte-infected 'KY-31' tall fescue. Daily intake was estimated from bites/d and bite size. Aldrich et al. (1990) used sustained-release chromic oxide capsules and IVOMD of extrusa to estimate intake of steers grazing 'Martin' (low infection) or 'KY-31' (high infection) tall fescue. Intake, as a percentage of body weight, was higher in steers grazing the 'Martin' tall fescue. In the present study, endophyte infection of tall fescue reduced intake of steers by 30% compared to animals grazing the low endophyte-infected forage.

In vitro DM digestibility of the extrusa was not affected by endophyte infection level, inclusion of clover, or time in the present study. Aldrich et al. (1990) reported that in vitro OM digestibility of extrusa from steers grazing low endophyte-infected tall fescue was slightly lower than digestibility of extrusa from high endophyte-

TABLE 24. BODY WEIGHT, FECAL OUTPUT, DM INTAKE, AND DAILY GAIN, OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE WITH AND WITHOUT WHITE CLOVER IN 1990

Item	Low endophyte		High endophyte		SE
	No clover	Clover	No clover	Clover	
May[a]					
BW,kg	288.9	278.4	273.4	271.7	12.5
Feces,kg DM/d[b]	2.56	2.37	1.71	1.97	.18
DM intake,kg/d[b]	5.81	5.11	3.48	4.13	.45
DM intake,%BW[b]	2.00	1.82	1.31	1.54	.14
IVDMD,%DM	52.73	54.87	50.71	51.68	3.57
Daily gain, kg/d, April to June[b]	1.25	1.26	.95	1.05	.07
July[a]					
BW,kg	316.7	322.2	297.4	310.6	16.0
Feces,kg DM/d[b]	2.67	2.75	2.40	2.12	.18
DM intake,kg/d[b]	5.10	6.22	4.85	4.94	.45
DM intake,%BW[b]	1.61	1.95	1.60	1.56	.14
IVDMD,%DM	48.57	48.12	51.85	52.78	3.57
Daily gain, kg/d, June to August[b]	.36	.47	.32	.30	.04

[a]Differences due to time for BW, feces, and DM intake, kg/d (P<.05)
[b]Effect of endophyte infection of tall fescue (P<.01)

infected pastures. Total tract digestion of DM was depressed in wethers fed endophyte-infected (>95%) tall fescue compared to noninfected (<1%) tall fescue hay (Fiorito et al., 1991). Dry matter digestibility was not affected by endophyte infection when sheep were fed similar quantities of forage (Zylka, 1989).

Fecal output, and DM intake (kg/d) were higher (P<.05) in July compared to May. However, DM intake as a percent of BW was not affected by time. The effect of clover on DM intake was not significant at any time studied.

Implications

These data suggest that cattle are able to selectively graze white clover from pastures of high endophyte-infected tall fescue that has been overseeded with clover. The digestibility and protein content of diet samples were not affected by endophyte level or clover content of the pastures. Although the intake reduction in steers grazing endophyte-infected tall fescue would account for some of the reduction in performance, other factors also are of importance. Future research involving higher levels of white clover in the pasture will be important to evaluate the effectiveness of clover for ameliorating the toxic factors of tall fescue.

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CHAPTER VI.

INFLUENCE OF ENDOPHYTE INFECTION OF TALL FESCUE HAY ON INTAKE, PERFORMANCE, RECTAL TEMPERATURES, SERUM MINERALS AND PROLACTIN OF STEERS

ABSTRACT: Twenty-one Angus steers (256 kg) were utilized to compare the effect of feeding 0 and 40% endophyte-infected tall fescue and orchardgrass hay on DM intake, daily gain, body temperature, serum minerals, and serum prolactin during an 8 wk study. Quality of the diets was low, as indictated by low CP (8.1 to 10.3%), and IVDMD (41.3 to 47.1%). Daily DM intake, and daily gain were higher ($P<.05$) for animals consuming the noninfected tall fescue compared to animals fed the other hays. Body temperature and serum prolactin were not affected by diet. These data suggest that other factors, besides endophyte infection, are important in the etiology of tall fescue toxicosis.

Introduction

The association of the endophytic fungus, *Acremonium coenophialum*, Morgan-Jones and Gams, with tall fescue (*Festuca arundinacea*, Schreb.) has been linked to tall fescue toxicosis (Bacon et al., 1986; Stuedemann and Hoveland, 1988). Symptoms of tall fescue toxicosis include reduced animal performance (Read and Camp, 1986; Stuedemann et al., 1985), elevated temperature, more rough hair coats (Bond et al., 1984), and depressed serum prolactin (Daniels et al., 1983).

Crawford et al., (1989) combined their results and previous data and identified a relationship between infection level and daily gain.

They reported a reduction of 45 g in daily gain for each 10% increase in infection level. Hemken et al. (1979) reported higher rectal temperatures in Holstein cows fed toxic 'G1-307' and 'KY-31' tall fescue hay compared to cows fed nontoxic 'G1-306' tall fescue/ryegrass hybrid. Read and Camp (1986) observed rough, dirty hair coats in cattle grazing endophyte-infected tall fescue. Fribourg et al. (1990) reported rough, long hair coats in steers grazing infected tall fescue compared to those grazing noninfected tall fescue. Serum prolactin has been shown to be depressed in cattle consuming endophyte-infected tall fescue (Bolt et al., 1983; Thompson et al., 1987).

Bacon et al. (1986) suggested the presence of ergopeptine alkaloids as the causative agent for depressed serum prolactin in animals fed endophyte-infected tall fescue. Buttrey (1989) investigated the effect of ensiling and drying (hay) of endophyte-infected tall fescue on tall fescue toxicosis in steers. Serum prolactin and cholesterol concentration among steers fed orchardgrass/alfalfa hay was generally, but not always significantly, greater than concentration in steers fed the endophyte-infected silage or hay. The ergot alkaloids are found in greater quantity in infected tall fescue compared to noninfected forage (Yates et al., 1985) and symptoms of tall fescue toxicosis are similar to ergot poisoning (Bacon et al., 1975). Furthermore, ergot alkaloids stimulate dopamine receptors in rats (Porter et al., 1985) and dopamine inhibits prolactin secretion from the pituitary (Macleod and Lehmeyer, 1974). The direct link of endophyte infection of tall fescue to reduced prolactin is unresolved.

The present study was conducted to further evaluate the effects of moderate endophyte levels in tall fescue hay on toxicosis in beef steers.

Materials and Methods

Twenty-one Angus steers (256 kg) were utilized to compare the effect of 0 and 40% infected tall fescue hay and orchardgrass (*Dactylis glomerata* L.) hay on DM intake, daily gain, body temperature, serum minerals and prolactin during an 8 wk study. The trial consisted of four 2-wk periods. Steers were blocked by weight and randomly assigned to three hay diets. Orchardgrass hay was fed during a 5-d adjustment period. Animals were individually fed long hay in an open shed. Feed was offered ad libitum from 1600 to 0800 h. Animals had access to water and an open lot the remaining time. Feed offered and refusals were weighed daily.

Animals were weighed, rectal temperatures measured, and blood samples were collected at 14 d intervals. Blood samples were centrifuged at 2,400 rpm for 20 min and serum was frozen for mineral and prolactin concentration determinations. Calcium, Mg, and Cu of serum were measured by atomic absorption spectrophotometry. Lanthanum oxide was used to reduce interference of P in samples for Ca and Mg determination. Serum inorganic P was determined colorimetrically after reaction with ammonium molybdate and sulfuric acid. The unreduced phosphomolybdate complex was detected at 340 nm (Sigma Diagnostics, ST. Louis, MO; Daly and Ertingshausen, 1972). Serum prolactin was measured using a double-antibody radioimmunoassay (Koprowski and Tucker, 1971) except the stock solution of prolactin was iodinated as described by Akers and Keys (1984).

Every third bale of hay was sampled and composited weekly. Composites were dried at 60 °C and ground to pass a 1-mm screen. Forage samples were analyzed for DM, ash (A.O.A.C., 1990), NDF (Van Soest and Wine, 1968), with the exception that decalin and sodium sulfite were not used, ADF (Van Soest, 1963), lignin and cellulose (Van Soest and Wine, 1968). Crude protein was estimated from Kjeldahl N X 6.25 (A.O.A.C., 1990). In vitro dry matter digestibility was estimated using procedures of Tilley and Terry (1963) as modified by Barnes (1969). For IVDMD ruminal digesta was obtained from a cannulated steer fed tall fescue hay with 40% endophyte infection. Determinations on duplicate samples (16/treatment), four blank, and two alfalfa reference samples were included during each incubation. Forage samples were analyzed for Ca, Mg, and Cu by atomic absorption spectrophotmetry after sequential digestion with nitric and perchloric acid. Inorganic P of forage was measured by the colorimetric method of Fiske and Subbarow (1925).

Data were analyzed by the general linear method (SAS, 1985). The experimental design was a randomized complete block design. Residual error was used to test the main effects of treatment and animal block. Tukey's procedure was used for mean separation (Steele and Torrie, 1980).

Results

Crude protein content of hay was highest (P<.05) in the noninfected fescue and lowest in the orchardgrass hay (Table 25). The orchardgrass hay was higher (P<.01) in ADF, cellulose, and lignin compared to the tall fescue hays. Cell wall (NDF) content of the noninfected tall fescue hay was lower (P<.05) when compared to moderately endophyte-infected tall fescue hay and orchardgrass hay. No difference was detected in NDF between the moderately-infected tall fescue and orchardgrass hays.

In vitro DM digestibility was higher (P<.05) for the noninfected tall fescue compared to either the moderately infected tall fescue or the orchardgrass hay. There was no difference (P>.05) in IVDMD between the moderately infected tall fescue and orchardgrass hay.

Ash content of the orchardgrass hay was higher (P<.05) than ash content of either tall fescue hay which were not different (P>.05). However, this did not result in higher Ca, Mg, P, or Cu concentrations of the forage. The moderately endophyte-infected tall fescue hay was higher (P<.05) in Ca and Mg compared to the endophyte-free tall fescue and orchardgrass hay.

Daily DM intake was higher (P<.05) for animals consuming the noninfected tall fescue hay compared to animals fed moderately-infected tall fescue hay or orchardgrass hay (Table 26). Intake was similar for the cattle fed orchardgrass and endophyte-infected tall fescue hay. Daily gain was highest (P<.05) for animals fed the noninfected fescue hay during the initial 2 wk of the trial compared to endophyte-infected fescue and the orchardgrass hay. During the rest of the trial the

TABLE 25. COMPOSITION OF HAYS FED TO STEERS DURING 8 WEEK TRIAL

Item[a]	Tall fescue Noninfected	Tall fescue Infected	Orchardgrass	SE
Crude protein,%	10.34[b]	9.13[bc]	8.14[c]	.34
NDF,%	70.09[b]	73.04[c]	73.36[c]	.50
ADF,%	40.06[b]	40.49[b]	44.09[c]	.42
Cellulose,%	33.36[b]	33.39[b]	36.06[c]	.34
Lignin,%	5.28[b]	5.44[b]	7.24[c]	.25
IVDMD,%	47.09[b]	41.34[c]	44.14[c]	.83
Ash,%	6.26[b]	6.24[b]	7.10[c]	.20
Ca,g/kg	5.18[b]	6.46[c]	5.31[b]	.32
Mg,g/kg	3.11[b]	4.30[c]	3.08[b]	.11
P,g/kg	2.72	2.60	2.64	.07
Cu,mg/kg	3.12[b]	2.68[c]	2.18[d]	.11

[a]Values expressed on a DM basis

[bcd]Means within a row with different superscripts differ (P<.05)

TABLE 26. INTAKE AND DAILY GAIN OF STEERS FED TALL FESCUE OR ORCHARDGRASS HAY

Item	Tall fescue: Noninfected	Tall fescue: Infected	Orchardgrass	SE
	- - - - - - - - - - kg	- - - - - - - - - -		
Daily DM intake				
Period 1	5.03^{a}	3.83^{b}	3.82^{b}	.24
Period 2	5.36^{a}	3.34^{b}	4.43^{ab}	.42
Period 3	7.78^{a}	4.87^{b}	5.60^{b}	.52
Period 4	8.56^{a}	4.50^{b}	5.61^{b}	.76
Overall	6.68^{a}	4.14^{b}	4.86^{b}	.43
Daily gain				
Period 1	$.45^{a}$	$-.09^{b}$	$-.38^{b}$	.15
Period 2	.44	.35	.09	.19
Period 3	.58	.15	.28	.15
Period 4	$.51^{a}$	$-.02^{b}$	$-.02^{b}$	.20
Overall	$.50^{a}$	$.10^{b}$	$-.01^{b}$	.06

[ab]Means within a row with different superscripts differ ($P<.05$)

animals fed the noninfected tall fescue hay gained at a numerically higher rate of gain. For the entire 8-wk trial the animals fed noninfected tall fescue hay gained more rapidly (P<.05) than the animals fed the other hays. There was no difference (P>.05) in daily gain between animals fed the endophyte-infected tall fescue hay and orchardgrass hay.

No differences (P>.05) were detected in body temperature (Table 27). Although not significantly different, serum prolactin in steers fed the noninfected tall fescue was approximately twice the amount found in steers fed the moderately-infected fescue hay (Table 27). No differences were detected for serum Ca and Mg (Table 28). All values were within normal ranges (Church, 1979). Serum P was highest (P<.05) in animals consuming the noninfected tall fescue hay compared to the animals fed moderately infected tall fescue hay and orchardgrass hay after 4 wk of the trial. No other differences were detected in serum P concentration. Serum obtained at the middle of the trial from animals fed noninfected tall fescue was higher (P<.05) in Cu compared to animals fed orchardgrass hay. Serum Cu from animals fed moderately infected tall fescue hay was intermediate at that sample time.

Discussion

The NDF and ADF contents of all the diets were high, indicating advanced maturity. Forage analysis identified few differences between endophyte- infected and noninfected tall fescue. Endophyte infection did not affect NDF or ADF content of tall fescue hay (Bond et al., 1984;

TABLE 27. RECTAL TEMPERATURE (°C) AND SERUM PROLACTIN CONCENTRATION (ng/ml) OF STEERS FED TALL FESCUE OR ORCHARDGRASS HAY

	Tall fescue			
Time	Noninfected	Infected	Orchardgrass	SE
Temperature				
Initial	38.42	38.16	38.05	.20
Middle	38.86	38.45	38.45	.20
Final	38.88	38.52	38.35	.19
Prolactin				
Initial	9.27	8.34	12.34	3.32
Middle	9.84	5.18	2.94	2.15
Final	10.56	4.78	9.61	3.25

TABLE 28. SERUM MINERAL CONCENTRATIONS OF STEERS FED TALL FESCUE OR ORCHARDGRASS HAY

Mineral	Time	Tall fescue		Orchardgrass	SE
		Noninfected	Infected		
Ca,mg/dl	Initial	9.43	9.68	9.14	.63
	Middle	8.64	8.31	8.58	.49
	Final	8.63	8.58	8.81	.37
Mg,mg/dl	Initial	1.86	1.71	1.82	.11
	Middle	2.01	1.84	1.93	.12
	Final	1.74	1.69	1.70	.06
P,mg/dl	Initial	5.86	6.01	6.09	.34
	Middle	9.08[a]	8.05[b]	8.29[b]	.31
	Final	8.87	8.31	8.32	.41
Cu,μg/dl	Initial	59.12	63.19	64.42	3.83
	Middle	62.31[a]	60.81[ab]	58.37[b]	4.62
	Final	71.62	68.43	68.82	3.77

[ab]Means within a row with different superscripts differ ($P<.05$)

Straham et al., 1987). Likewise, CP in tall fescue hay was not affected by endophyte infection (Hemken et al., 1981; Bond et al., 1984). Fontenot et al. (1988) reported no excesses or imbalances in mineral content from tall fescue with 9 to 97% infection levels. Copper was consistently higher in high endophyte-infected tall fescue compared to tall fescue with low infection levels (Buttrey, 1989). However, the Cu content of the noninfected tall fescue hay in the present study was greater ($P<.05$) than the Cu content of the moderately-infected hay.

Dry matter intake of steers fed the experimental diets was low during the first period. Intake of the noninfected hay was higher ($P<.05$) than intake of of moderately-infected fescue hay during all time periods. Consumption of endophyte-infected seed and hay reduced intake of steers by 2.3 and .39 kg/d, respectively (Schmidt et al., 1982). More recently, Chestnut et al. (1991) reported a 20% reduction in DM intake of infected tall fescue hay compared to noninfected tall fescue.

Endophye infection levels were 0 and 40% in the present study. Daily gains were severely depressed in steers fed the 40% infected tall fescue hay compared to the 0% infected hay over the entire feeding trial. Ghorbani et al. (1989) reported no reduction in gain of Holstein calves fed tall fescue with 7.5% and 15% infection levels. A depression in daily gain has been associated with consumption of endophyte-infected tall fescue forage (Hoveland et al., 1980; Read and Camp, 1986; Crawford et al., 1989). The results of the present study are similar to previous results as reviewed by Stuedemann and Hoveland (1988).

The present trial was conducted from September 25 to November 20, 1990. Ambient temperature was moderate during this time and animals did not exhibit signs of heat stress. Hemken et al. (1981) reported an interaction of environmental temperature with tall fescue toxicosis. When ambient temperature was less than 13 °C, cattle exhibited no symptoms of toxicosis. However, at temperatures greater than 34°C increased rectal temperatures were reported. Consumption of toxic tall fescue resulted in elevated body temperatures of cows and steers (Hemken et al., 1979; Bond et al., 1984). The cattle in the present study did not differ in rectal temperature due to diet, in agreement with results of Hemken et al. (1981). No increase in body temperature was reported in sheep fed infected tall fescue hay (Fiorito et al., 1991). The present data and other reported data are inconclusive regarding elevated temperatures in steers fed endophyte-infected tall fescue hay.

Reduced serum prolactin has been a common sign of tall fescue toxicosis (Bacon and Siegel, 1988; Stuedemann and Hoveland, 1988). In the present study, prolactin concentrations were low for the entire study and were not affected by diet. Prolactin concentration was reduced by low ambient temperature (Wetteman and Tucker, 1974) and short photoperiod (Hahn et al., 1987), accounting partially for the results of the present study. Buttrey (1989) reported decreased serum prolactin in steers fed endophyte-infected tall fescue hay or silage.

Very few differences have been reported concerning mineral status of animals consuming endophyte-infected tall fescue. Zylka (1989) reported decreased K retention in sheep with increasing endophyte level.

In a comprehensive survey of seven farms in VA, Fontenot and coworkers (1988) did not find any consistent differences in serum minerals of cattle grazing tall fescue with endophyte infection levels of 9 to 97%.

Implications

These data suggest that other factors, besides endophyte infection, are important in the etiology of tall fescue toxicosis. Moderate infection levels (40%) reduced intake and daily gains of steers. However, rectal temperatures and serum prolactin were not significantly affected. Further research is needed concerning the cause of elevated body temperature and the impact of elevated body temperature on the animal. At the present time insufficient data are available concerning the multitude of factors that affect the symptoms of tall fescue toxicosis.

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CHAPTER VII.

GENERAL DISCUSSION

The continued use of tall fescue will require more understanding of the soil-plant-animal interface. With adequate soil fertility, tall fescue is a high yielding, good quality forage. However, performance is often reduced in animals consuming tall fescue. The association of the endophytic fungus *Acremonium coenophialum* with tall fescue has been related to the low animal performance. The problem therefore involves understanding the impact of the fungus on the interrelationships.

The endophyte benefits the host grass through drought tolerance and insect resistance (Clay et al, 1985; Read and Camp, 1986; Buttrey, 1989). These benefits appear to result in increased yield (Joost, 1988; Buttrey, 1989). This may be a result of increased tillering (Clay, 1984). Data from the present study indicate that the high endophyte-infected fescue at both locations had higher DM production compared to low endophyte-infected tall fescue.

From the present study and previous data it appears that tall fescue forage composition is not consistently affected by endophyte infection. Endophyte infection did not affect NDF or ADF content of seed (Jackson et al., 1984) or hay (Straham et al., 1987). Crude protein content in forage from infected and noninfected tall fescue was not different (Hemken et al., 1981; Bond et al., 1984). Buttrey (1989) reported that N concentration was higher in noninfected as compared to high endophyte-infected tall fescue grown in the greenhouse, but under field conditions, no difference was detected.

Tall fescue toxicosis is characterized by rough, uneven hair coats, elevated body temperatures, and decreased serum prolactin concentrations in cattle (Stuedemann and Hoveland, 1988). This may be due to the presence of ergot alkaloids found in higher quantities in endophyte-infected tall fescue (Robbins et al., 1972; Bush and Jeffreys, 1975; Lyons et al., 1986). Ergot alkaloids result in decreased blood flow to the extremities (Ensminger et al., 1990) and reduced serum prolactin (Berde and Schield, 1978). The signs of tall fescue toxicosis were clearly evident during the present study. Steers had elevated rectal temperatures, rough hair coats, and reduced serum prolactin within 8 wk of initiation of grazing.

Performance is severely restricted in animals consuming endophyte-infected tall fescue (Bush et al., 1979; Read and Camp, 1986). Tall fescue is adapted to a variety of climates. The data available have indicated reduced animal performance across many states, but no data were available that involved a direct comparison of different locations. Cattle grazing highly infected tall fescue at the two locations studied gained less than those grazing the low endophyte-infected tall fescue. The results obtained from this study indicate that grazing steer performance was depressed to a similar degree at both locations.

During 1989, the selectivity of steers was examined. Percentage clover of the ingesta was estimated indirectly from Ca content (Pigurina, 1986). The data indicated that the ability of steers to selectively graze clover in tall fescue/white clover mixtures was high. However, the presence of clover at the low levels in the present study failed to improve performance. The testing of the benefits of clover will require additional amounts in the mixture. The additional clover may serve to dilute the diet as the animals are able to selectively graze the clover.

A decrease in DM intake of animals fed endophyte-infected tall fescue hay has been observed (Schmidt et al., 1982; Spears et al., 1984). Cattle grazing infected tall fescue have been observed to spend less time grazing when compared to animals grazing noninfected tall fescue (Bond et al., 1984a; Stuedemann et al., 1985b). Total intake was reduced in animals grazing the high endophyte-infected tall fescue compared to animals consuming low endophyte-infected tall fescue. However, bite size and biting rate were not different between the cattle grazing these forages. The evidence is conclusive that grazing endophyte-infected tall fescue will result in reduced animal performance and intake.

Previous treatment may influence subsequent performance of stocker/finishing cattle. In the present study, the detrimental effects of the endophyte observed in grazing cattle did not affect performance during the feedlot period. Steers that had previously grazed highly infected tall fescue had higher daily gains and gain:feed ratio than did animals from low or medium infected tall fescue when finished on a 93% concentrate ration in TX (Cole et al., 1987). Lusby et al. (1990) reported compensatory gains during the first 48 d in the feedlot in steers from infected (76%) pastures. During 1989 and 1990, the steers from high endophyte-infected tall fescue experienced daily gains similar to those that previously grazed low endophyte-infected tall fescue. In all instances, cattle that were lighter when entering the feedlot failed to attain similar finishing weights, after similar days on feed. These results have important application to the industry.

Steers from infected tall fescue pastures may have rough, uneven, and dirty hair coats and may appear emaciated (Bond et al., 1984b; Fribourg et al., 1990). These types of cattle are typically purchased at a lower price than cattle with short, shiny hair coats (B.R. McKinnon, personal communication). The benefit of the normal feedlot performance is therefore received by the finishing segment of the industry. The seller of feeder calves raised on endophyte-infected tall fescue forage may experience a benefit from retained ownership or by developing a sound reputation with various feedlot operators.

Additional data on tall fescue toxicosis contributes to our understanding, but the endophyte remains a problem. Tall fescue continues to be the dominant forage grass in the Mid-Atlantic region, and the majority of the grass is endophyte-infected. Therefore, management strategies capable of partially, or totally, ameliorating the toxicity need to be developed.

Do certain breeds or strains of livestock tolerate the effects of the endophyte more easily than others? Will maintenance of clover in the mixture dilute the diet enough to ameliorate the toxicosis? Do compounds exist that can economically "detoxify" the chemicals responsible for the depressed prolactin? It is obvious that there is room for agronomists, nutritionists, physiologists, geneticists (plant and animal), and members of many other disciplines in the study of tall fescue toxicosis. Only through combined efforts will we be able to develop recommendations concerning optimum utilization of the 14,000,000 ha of tall fescue in the United States.

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APPENDIX TABLE 1. SERUM PROLACTIN CONCENTRATION (NG/ML) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	48.8	58.1	80.8	73.2	65.2	59.4	54.0	73.3	63.6	62.4	17.1
May[a]	139.7	119.8	6.4	10.7	69.2	154.2	131.8	6.5	6.0	74.6	9.1
June[a]	123.9	106.7	16.9	10.3	64.4	180.8	148.7	15.6	17.5	90.7	11.6
July[a]	119.0	105.8	14.0	14.2	63.3	109.1	114.8	26.1	28.4	69.7	14.0
August[a]	124.8	114.3	15.2	17.6	68.0	141.7	124.1	19.7	20.6	76.4	12.0
September[a]	58.8	42.0	2.0	2.0	25.6	102.1	68.8	2.0	3.2	43.8	11.3
October[a]	35.8	35.7	2.0	2.0	18.1	76.8	54.4	2.0	2.0	33.0	9.5
Average[a]	95.6	80.9	5.0	9.2	47.7	109.4	104.8	6.7	11.8	58.2	11.0

[a]Effect of endophyte ($P<.01$)

APPENDIX TABLE 2. SERUM PROLACTIN CONCENTRATION (NG/ML) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	97.2	85.4	111.0	97.5	97.8	56.7	66.7	58.8	72.9	63.8	17.8
May[ab]	148.1	136.6	13.8	13.9	78.1	.	.	.	.	.	13.5
June[a]	150.0	158.1	9.8	24.2	85.5	99.0	110.7	14.1	16.0	60.0	10.3
July[a]	104.1	145.8	17.9	17.1	71.3	131.9	179.2	49.5	30.2	97.8	13.6
August[ac]	124.0	120.1	11.8	6.6	65.6	67.9	75.6	3.9	3.8	37.8	11.3
September[a]	47.1	53.5	2.6	2.2	26.4	63.2	69.8	2.8	2.6	34.5	9.5
October[ac]	94.9	64.8	2.2	2.1	41.0	41.7	64.5	2.4	2.1	27.7	8.0
Average[a]	104.0	108.5	8.9	10.5	57.9	82.3	102.3	14.7	10.8	52.5	10.5

[a]Effect of endophyte ($P<.01$)
[b]No sample obtained at Blackstone at this date
[c]Effect of location ($P<.05$)

APPENDIX TABLE 3. RECTAL TEMPERATURE (°C) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	39.7	39.2	39.6	39.4	39.5	39.7	39.4	39.4	39.6	39.5	.15
May[abc]	39.4	39.3	40.4	39.6	39.7	39.6	39.4	39.5	40.0	39.6	.13
June[ad]	39.2	39.2	39.9	40.1	39.6	39.4	39.7	39.8	40.4	39.8	.13
July[ab]	40.0	39.6	40.9	40.7	40.3	39.8	39.8	40.2	40.3	40.0	.13
August[abe]	38.6	38.8	39.3	39.2	39.0	39.6	39.2	39.4	39.8	39.5	.12
September[abe]	39.3	39.3	40.4	40.4	39.8	39.4	39.2	39.4	40.0	39.5	.13
October[ae]	38.8	39.0	39.7	39.1	39.1	39.2	38.9	39.7	39.7	39.4	.13
Average[a]	39.2	39.2	40.0	39.9	39.6	39.5	39.4	39.7	40.0	39.6	.11

[a]Effect of endophyte ($P<.01$)
[b]Location X endophyte interaction ($P<.05$)
[c]Location X clover interaction ($P<.05$)
[d]Effect of clover ($P<.05$)
[e]Location X endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 4. RECTAL TEMPERATURE (°C) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	39.0	39.1	39.2	38.8	39.0	39.1	39.0	39.2	38.8	39.0	.17
May[ab]	39.5	39.9	40.4	40.1	40.0	.	.	.	.		.15
June[c]	39.1	39.0	39.5	39.3	39.2	40.2	40.4	40.6	40.2	40.4	.13
July[ad]	39.6	39.8	40.5	40.2	40.0	40.4	39.8	40.3	40.5	40.3	.15
August[a]	39.3	39.6	40.2	40.2	39.8	39.9	39.6	40.2	40.2	40.0	.13
September[ad]	39.2	39.6	40.3	40.1	39.7	40.0	39.6	40.4	40.3	40.1	.14
October[a]	39.2	39.2	39.4	39.4	39.3	39.9	39.6	40.1	40.2	40.0	.13
Average[a]	39.3	39.4	40.0	39.8	39.6	40.1	39.8	40.3	40.3	40.1	.11

[a]Effect of endophyte ($P<.01$)
[b]No temperature measured at Blackstone at this date
[c]Effect of endophyte ($P<.05$)
[d]Location X endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 5. HAIR COAT SCORES[a] OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
April	3.8	3.8	3.8	3.5	3.7	3.8	3.8	3.5	3.6	3.7	.15
May	3.7	3.5	3.5	3.2	3.5	3.6	3.4	3.1	3.6	3.4	.20
June	3.0	2.9	3.0	3.1	3.0	3.0	2.7	2.7	3.1	2.9	.24
July[b]	2.6	2.4	2.9	3.1	2.7	2.4	2.0	2.6	3.3	2.6	.24
August[b]	2.3	2.1	3.7	3.4	2.8	2.0	1.8	2.4	3.2	2.4	.23
September[b]	2.3	2.0	3.6	3.9	3.0	1.8	1.5	2.8	3.6	2.5	.22
October[b]	2.5	2.5	3.8	3.8	3.1	2.1	1.9	3.4	3.6	2.8	.21
Average[b]	2.9	2.7	3.5	3.4	3.1	2.7	2.5	2.9	3.4	3.5	.17

[a]Code: 1=smooth, shiny 5=rough, dirty
[b]Effect of endophyte ($P<.01$)

APPENDIX TABLE 6. HAIR COAT SCORES[a] OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
April	3.3	3.4	3.5	3.2	3.3	3.5	3.6	3.6	3.7	3.6	.15
May[b]	3.0	3.2	3.2	2.8	3.0	.	.	.	.		.22
June[cd]	2.8	2.9	2.9	2.7	2.8	3.1	3.1	3.4	3.5	3.3	.24
July[c]	2.1	2.1	3.3	2.8	2.6	2.5	2.5	3.5	3.3	3.0	.24
August[c]	1.7	1.6	3.7	3.2	2.6	2.2	2.1	3.6	3.6	2.9	.23
September[c]	1.6	1.7	3.8	3.5	2.6	2.2	2.0	4.0	4.2	3.1	.22
October[c]	1.9	2.0	3.9	3.7	2.9	2.4	2.2	4.1	4.2	3.2	.21
Average[c]	2.2	2.2	3.5	3.1	2.8	2.5	2.4	3.7	3.8	3.1	.20

[a]Code: 1=smooth, shiny 5=rough, dirty
[b]Hair coat not evaluated at Blackstone on this date
[c]Effect of endophyte ($P<.01$)
[d]Location X endophyte interaction ($P<.01$)

APPENDIX TABLE 7. SERUM CALCIUM CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE WITH, AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April[a]	9.56	9.66	9.45	9.73	9.62	9.10	9.26	9.46	9.43	9.34	.22
May	9.63	9.58	9.72	9.41	9.58	9.64	9.69	9.80	9.69	9.70	.21
June[b]	9.74	9.64	9.46	9.87	9.68	9.82	9.66	9.50	9.67	9.67	.17
July[c]	9.61	9.89	9.40	9.61	9.63	9.71	9.74	9.42	9.43	9.52	.12
August	9.73	9.45	9.89	9.63	9.66	9.66	9.60	9.67	9.79	9.71	.19
September	9.44	9.24	9.55	9.46	9.42	9.71	9.57	9.57	9.80	9.67	.21
October[ac]	10.12	10.18	9.84	9.96	9.99	9.70	9.84	9.46	9.52	9.63	.14
Average	9.73	9.68	9.60	9.73	9.68	9.74	9.65	9.54	9.65	9.65	.11

[a]Effect of location ($P<.01$)
[b]Endophyte X clover interaction ($P<.05$)
[c]Effect of endophyte ($P<.05$)

APPENDIX TABLE 8. SERUM CALCIUM CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	9.92	9.83	10.19	9.82	9.94	9.93	10.17	9.93	9.96	9.95	.19
May[a]	9.73	9.86	9.61	9.54	9.68	.	.	.	.	.	.23
June[bc]	9.50	9.90	9.29	9.13	9.46	9.46	9.20	8.97	8.84	9.12	.24
July[bcde]	9.60	9.92	9.32	9.60	9.61	9.27	9.29	9.34	9.13	9.24	.10
August[f]	9.63	9.94	9.67	9.64	9.72	9.46	9.84	9.61	9.24	9.50	.18
September	9.34	9.65	9.54	9.68	9.55	9.74	9.51	9.60	9.44	9.52	.21
October	9.71	9.67	9.32	9.53	9.56	9.69	9.69	9.69	9.63	9.66	.12
Average[bc]	9.56	9.82	9.43	9.53	9.58	9.51	9.51	9.43	9.24	9.42	.11

[a]No sample obtained at Blackstone at this date
[b]Effect of location ($P<.01$)
[c]Effect of endophyte ($P<.05$)
[d]Location X endophyte interaction ($P<.05$)
[e]Location X clover interaction ($P<.01$)
[f]Endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 9. SERUM MAGNESIUM CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	1.84	1.89	1.93	1.92	1.89	1.83	1.85	1.91	1.88	1.88	.06
May	2.03	1.98	1.86	1.93	1.95	1.94	1.88	1.47	2.06	1.84	.06
June	1.95	2.02	2.05	2.03	2.01	2.04	1.99	2.06	2.00	2.03	.05
July[ab]	2.01	1.97	1.86	2.07	1.98	2.10	2.12	2.19	2.18	2.15	.05
August	1.91	1.96	1.98	1.96	1.95	1.97	1.94	2.00	1.95	1.97	.05
September[b]	2.15	2.31	2.43	2.23	2.28	2.26	2.25	2.30	2.35	2.29	.07
October[a]	1.95	1.96	1.86	1.98	1.94	2.05	2.05	2.10	2.11	2.08	.05
Average	1.99	2.03	2.04	2.06	2.03	2.09	2.07	2.13	2.12	2.11	.03

[a]Effect of location ($P<.01$)
[b]Location X endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 10. SERUM MAGNESIUM CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	1.86	1.97	2.00	1.92	1.96	1.92	1.86	1.95	1.96	1.93	.06
May[a]	1.93	2.10	1.87	1.92	1.96	.	.	.	.	.	.06
June[b]	2.15	2.04	2.26	2.25	2.18	2.24	2.31	2.33	2.28	2.28	.08
July[bcde]	1.96	2.08	1.88	2.19	2.03	1.88	1.89	1.96	1.86	1.89	.05
August	2.05	2.26	2.06	2.10	2.11	2.14	2.10	2.15	2.19	2.14	.05
September[bf]	2.16	2.17	2.24	2.26	2.21	2.25	2.27	2.41	2.34	2.32	.06
October[bc]	2.10	2.22	2.10	2.25	2.17	1.98	2.08	2.06	2.03	2.04	.05
Average	2.08	2.16	2.11	2.21	2.14	2.10	2.12	2.19	2.14	2.14	.04

[a]No sample obtained at Blackstone at this time
[b]Effect of location ($P<.01$)
[c]Effect of clover ($P<.05$)
[d]Location X clover interaction ($P<.01$)
[e]Location X endophyte X clover interaction ($P<.05$)
[f]Effect of endophyte ($P<.05$)

APPENDIX TABLE 11. SERUM PHOSPHORUS CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	7.24	7.51	6.94	7.33	7.27	7.45	7.29	7.24	7.41	7.36	.39
May	7.31	7.61	7.52	7.49	7.26	7.68	7.41	7.38	7.52	7.50	.36
June	7.80	7.92	7.63	7.38	7.70	7.77	7.67	7.45	7.66	7.66	.35
July[a]	6.57	6.25	6.17	6.52	6.39	7.51	7.64	7.87	7.59	7.69	.21
August[b]	6.88	7.60	7.44	7.38	7.35	7.57	7.14	7.23	8.20	7.55	.35
September	7.07	6.54	6.76	7.24	6.90	6.64	6.54	6.74	6.47	6.61	.37
October[a]	7.00	6.88	7.09	6.96	6.98	6.73	6.70	6.50	6.40	6.61	.25
Average	7.08	7.04	7.00	7.14	7.07	7.24	7.22	7.21	7.40	7.27	.15

[a]Effect of location ($P<.05$)
[b]Location X endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 12. SERUM PHOSPHORUS CONCENTRATION (MG/DL) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	6.61	7.35	6.70	6.98	6.97	7.16	6.79	7.10	7.93	7.24	.30
May[a]	6.80	7.18	7.20	7.08	7.06	.	.	.	.	.	.30
June	7.74	8.16	7.92	7.92	7.87	8.28	7.55	8.63	7.89	8.10	.34
July	7.19	7.48	7.24	7.64	7.40	7.44	7.07	7.22	7.29	7.21	.26
August	7.52	7.42	7.69	7.24	7.47	7.56	7.22	7.70	7.39	7.48	.26
September	6.30	7.05	6.50	6.61	6.61	6.65	6.97	6.53	6.53	6.64	.30
October	6.36	7.24	7.02	6.85	6.88	7.02	7.34	7.10	7.19	7.21	.34
Average	6.99	7.50	7.23	7.18	7.23	7.40	7.29	7.42	7.25	7.34	.17

[a]No sample obtained at Blackstone at this time

APPENDIX TABLE 13. SERUM COPPER CONCENTRATIONS (μg/100ml) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April[a]	70.3	65.5	77.2	72.5	71.5	70.5	63.8	72.6	66.8	68.3	3.6
May	66.8	70.2	69.1	66.9	68.2	68.4	60.2	68.7	63.3	65.2	3.8
June	65.5	61.3	71.3	66.2	66.1	64.2	58.2	64.6	61.1	61.8	3.5
July[b]	53.0	50.5	56.1	44.5	51.0	62.7	60.6	55.0	56.5	58.5	3.0
August[b]	65.7	61.8	68.9	68.2	66.0	62.6	58.6	59.2	63.2	60.9	3.8
September[c]	78.5	68.5	70.0	71.3	72.1	69.6	77.3	66.2	77.9	73.0	3.3
October[abcd]	48.3	53.3	53.7	46.8	45.4	56.5	60.2	52.9	48.5	54.6	3.4
Average[ac]	64.1	55.1	65.4	59.4	61.0	63.0	62.9	59.5	61.7	61.8	2.6

[a]Effect of clover ($P<.05$)
[b]Effect of location ($P<.05$)
[c]Location X clover interaction ($P<.01$)
[d]Location X endophyte interaction ($P<.05$)

APPENDIX TABLE 14. SERUM COPPER CONCENTRATIONS (μg/100ml) OF STEERS GRAZING LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
April	65.5	69.2	65.3	62.0	65.6	62.6	60.9	67.6	64.7	63.5	3.6
May[a]	51.8	45.4	41.8	42.6	45.4	.	.	.	.	.	3.4
June	55.3	54.5	62.8	58.9	58.0	57.7	63.6	58.6	57.8	59.5	4.3
July[b]	54.7	51.7	51.8	47.0	51.3	44.8	45.4	44.2	41.7	44.1	3.4
August	61.8	57.2	58.5	64.8	60.6	56.3	55.9	56.2	55.6	56.3	3.8
September[cde]	65.0	69.0	70.5	72.3	69.2	70.6	71.6	72.7	63.7	70.0	2.9
October[bfg]	50.5	40.3	40.3	41.8	43.2	62.3	56.1	56.0	50.3	56.4	3.4
Average	57.5	54.5	57.2	58.8	57.0	58.4	58.6	58.9	54.1	57.5	1.9

[a]No sample obtained at Blackstone at this date
[b]Effect of location ($P<.05$)
[c]Location X endophyte interaction ($P<.05$)
[d]Location X clover interaction ($P<.01$)
[e]Endophyte X clover interaction ($P<.05$)
[f]Effect of endophyte ($P<.05$)
[g]Effect of clover ($P<.05$)

APPENDIX TABLE 15. FORAGE DM MASS (KG/HA) FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
April[abc]	1579	1182	632	1200	1148	1220	1722	1301	1803	1511	135.3
May[a]	2618	2860	2803	1973	2563	1770	1649	1735	2223	1844	285.1
June[a]	3426	3754	2896	4781	3714	1646	1532	1871	2402	1862	647.0
July[a]	2242	2033	1652	1996	1980	1640	1125	1292	1287	1336	273.8
August[d]	1339	1107	1765	1368	1395	1272	1784	1366	2260	1670	206.1
September[a]	642	899	1240	1113	974	1815	1119	1814	1862	1652	317.1
October	263	209	379	696	387	1036	263	717	1090	777	255.0
Average	1729	1720	1624	1875	1737	1486	1313	1442	1847	1530	119.2

[a]Effect of location ($P<.05$)
[b]Effect of clover ($P<.05$)
[c]Location X endophyte interaction ($P<.05$)
[d]Location X clover interaction ($P<.05$)

APPENDIX TABLE 16. FORAGE DM MASS (KG/HA) FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, AT TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
April	1622	1485	1847	1659	1653	1600	1622	1825	1764	1703	208.6
May	2635	2667	2402	2494	2550	2175	1363	1688	2000	1806	549.2
June[a]	2509	1747	1753	2235	2061	1973	1113	1030	2005	1530	376.1
July[bc]	1235	1339	1429	2300	1576	869	417	732	1070	772	286.1
August[b]	947	1056	1047	1628	1170	283	425	102	856	416	426.0
September[bc]	932	905	916	1940	1173	480	147	708	583	482	325.8
October[bdef]	634	712	757	2201	1076	730	216	345	365	414	299.0
Average[b]	1502	1416	1450	2064	1608	1156	758	919	1235	1018	282.1

[a]Endophyte X clover interaction ($P<.10$)
[b]Effect of location ($P<.05$)
[c]Effect of endophtye ($P<.10$)
[d]Location X endophyte interaction ($P<.10$)
[e]Location X clover interaction ($P<.10$)
[f]Endophyte X clover interaction ($P<.10$)

APPENDIX TABLE 17. CRUDE PROTEIN CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April[a]	18.0	15.9	18.3	16.8	17.2	22.6	24.3	22.8	20.5	22.5	1.81
May[a]	11.5	12.2	12.9	13.0	12.4	13.7	13.8	13.8	14.4	13.9	.75
June[bc]	10.3	9.0	9.4	11.6	10.1	9.9	11.0	11.0	9.3	10.3	.26
July[b]	11.7	12.1	13.7	13.0	12.6	14.0	14.8	9.9	10.0	12.2	1.03
August[ade]	15.0	14.3	15.0	14.0	14.6	11.7	14.8	10.0	13.3	12.5	.66
September	16.4	14.6	14.8	13.9	14.9	12.9	15.9	13.4	13.3	13.9	1.41
October	18.2	15.0	15.8	15.4	16.1	13.5	16.0	12.6	13.5	13.9	1.27
Average	14.4	13.3	14.3	13.9	14.0	14.1	15.8	13.4	13.5	14.2	.93

[a]Effect of location ($P<.05$)
[b]Location X endophyte interaction ($P<.05$)
[c]Location X endophyte X clover interaction ($P<.01$)
[d]Effect of clover ($P<.05$)
[e]Location X clover interaction ($P<.01$)

APPENDIX TABLE 18. CRUDE PROTEIN CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April	15.8	17.0	16.5	18.3	16.9	17.3	18.1	16.9	18.0	17.6	.71
May	10.9	12.4	11.9	12.8	12.0	10.7	10.0	10.6	11.1	10.6	.35
June	11.8	13.4	12.4	13.5	12.8	9.72	12.1	11.3	11.8	11.2	1.34
July[a]	12.6	14.0	13.4	14.0	13.5	7.38	8.22	7.51	7.33	7.59	1.01
August	12.9	13.3	12.5	13.2	13.0	12.2	11.2	12.6	10.7	11.7	.97
September[bc]	14.4	16.1	13.9	14.6	14.8	13.6	14.5	14.7	14.5	14.3	.32
October[ab]	19.7	17.6	15.6	16.1	17.2	13.2	13.6	12.1	11.8	12.6	1.16
Average[a]	14.0	14.8	13.7	14.7	14.3	11.1	11.6	11.5	11.2	11.4	.71

[a]Effect of location ($P<.05$)
[b]Effect of clover ($P<.05$)
[c]Location X endophyte interaction ($P<.05$)
[d]Effect of endophyte ($P<.05$)

APPENDIX TABLE 19. IN VITRO DRY MATTER DIGESTIBILITY OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	%, DM basis										
April[a]	75.8	78.7	77.1	74.9	76.6	71.0	67.2	70.0	61.0	67.3	2.61
May[a]	69.2	62.8	68.6	66.1	66.7	60.7	62.6	66.1	59.7	62.3	2.28
June[a]	52.5	50.8	53.2	52.8	52.3	42.9	46.2	47.5	45.8	45.6	1.99
July[b]	50.4	51.9	64.6	60.8	56.9	49.5	56.1	44.3	51.8	50.4	4.53
August[ac]	65.6	67.0	68.3	63.6	66.1	44.5	54.2	45.6	51.2	48.9	1.88
September[a]	59.0	60.0	60.0	55.4	58.6	49.6	56.7	51.4	55.5	53.3	3.01
October	67.7	52.8	61.4	61.5	60.8	57.5	57.3	52.5	54.4	55.4	5.26
Average[a]	62.9	60.6	64.7	62.2	62.6	54.6	57.2	53.9	54.2	54.7	2.39

[a]Effect of location ($P<.05$)
[b]Location X endophyte ($P<.05$)
[c]Location X clover ($P<.05$)

APPENDIX TABLE 20. IN VITRO DRY MATTER DIGESTIBILITY OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	%, DM basis										
April	74.3	75.6	74.2	75.4	74.9	72.8	73.7	74.6	74.8	74.0	2.29
May[a]	55.9	56.1	59.6	59.3	57.7	62.3	63.4	62.9	60.5	62.2	3.25
June	53.3	52.1	54.7	54.7	53.7	49.5	51.3	51.5	51.2	50.9	2.85
July[ab]	44.3	47.0	50.9	50.4	48.2	41.2	46.3	41.4	40.1	42.3	1.41
August[a]	52.0	49.6	46.8	47.7	49.0	39.6	36.2	41.0	37.3	38.5	2.04
September[a]	49.5	54.6	54.1	54.9	53.3	57.6	57.0	59.0	61.5	58.8	2.52
October[a]	65.3	61.9	61.6	63.4	63.0	46.2	56.7	49.9	46.0	50.0	3.49
Average[a]	56.4	56.7	57.4	58.0	57.1	49.4	51.8	50.9	49.4	50.4	2.78

[a]Effect of location ($P<.05$)
[b]Location X endophyte ($P<.05$)

APPENDIX TABLE 21. NEUTRAL DETERGENT FIBER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	- - - - - - - - - - - - - - - -				%, DM basis	- - - - - - - - - - - - - - - -					
April[ab]	51.6	49.0	46.4	49.6	49.2	56.8	56.3	54.4	61.3	57.2	1.71
May[c]	59.5	61.7	59.6	58.0	59.7	62.0	61.4	59.2	63.2	61.4	1.16
June	68.5	69.6	67.3	67.3	68.2	71.0	70.2	70.4	70.6	70.6	1.75
July	68.1	67.6	67.1	66.5	67.3	65.6	65.3	72.4	71.7	68.7	1.78
August[ad]	60.4	64.7	60.6	63.1	62.2	70.7	64.0	71.2	67.0	68.2	1.48
September	68.1	68.2	67.7	67.0	67.8	68.8	67.6	69.1	62.8	67.0	1.71
October[d]	64.8	68.3	66.7	68.8	67.2	69.0	67.1	68.9	65.8	67.7	.80
Average[a]	63.0	64.2	62.2	62.9	63.1	66.3	64.6	66.5	66.0	65.8	1.67

[a]Effect of location ($P<.01$)
[b]Endophyte X clover interaction ($P<.05$)
[c]Location X endophyte X clover interaction ($P<.05$)
[d]Location X clover interaction ($P<.01$)

APPENDIX TABLE 22. NEUTRAL DETERGENT FIBER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	%, DM basis										
April	53.6	52.6	53.2	53.6	53.2	54.8	56.2	54.3	55.1	55.1	1.11
May	68.0	63.9	67.4	64.7	66.0	64.0	63.3	61.1	64.5	63.2	1.40
June[a]	66.2	64.2	66.1	61.8	64.7	72.6	68.1	68.6	67.0	69.0	1.89
July[ab]	73.2	67.1	70.3	65.2	69.0	74.4	72.2	72.4	72.5	72.9	1.55
August	74.2	74.2	70.9	67.8	71.8	69.5	72.4	68.4	72.4	70.7	2.56
September[b]	65.7	61.9	64.5	60.5	63.1	64.8	62.6	60.1	60.3	62.0	1.42
October[a]	58.2	61.8	60.6	57.2	59.4	62.9	68.3	65.5	66.7	65.8	2.84
Average[a]	65.6	63.8	64.7	61.5	63.9	68.0	67.8	66.0	67.2	67.3	1.69

[a]Effect of location ($P<.05$)
[b]Effect of clover ($P<.05$)

APPENDIX TABLE 23. ACID DETERGENT FIBER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April[a]	25.0	25.2	23.0	24.3	24.4	27.7	27.3	26.3	30.5	28.0	1.18
May	33.1	34.6	32.2	32.2	33.0	34.7	33.5	31.6	33.6	33.3	1.02
June	36.8	39.6	37.8	36.4	37.6	37.3	36.5	35.5	36.6	36.5	1.03
July[b]	38.4	37.4	34.3	35.2	36.3	34.2	33.2	38.7	30.6	36.2	1.38
August[bcd]	33.2	33.3	31.7	32.2	32.6	36.0	30.7	37.6	33.2	34.4	.74
September	33.5	35.5	34.3	35.9	34.8	34.5	32.5	34.8	33.0	33.7	1.80
October	31.2	34.5	33.3	33.9	33.2	34.2	32.6	33.8	33.0	33.4	1.06
Average	33.0	34.3	32.3	32.9	33.1	34.1	32.3	34.0	34.1	33.6	1.07

[a]Effect of location (P<.01)
[b]Location X endophyte interaction (P<.01)
[c]Effect of clover (P<.05)
[d]Location X clover interaction (P<.01)

APPENDIX TABLE 24. ACID DETERGENT FIBER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	-%, DM basis										
April[a]	27.6	27.5	27.2	26.5	27.2	27.2	27.6	26.9	27.1	27.2	.18
May[b]	37.4	36.1	36.5	36.0	36.5	33.6	34.1	33.5	34.2	33.8	.58
June	37.5	36.7	36.8	35.2	36.6	38.8	36.1	35.6	36.8	36.8	1.98
July	37.5	36.8	35.9	35.8	36.5	41.7	39.4	40.7	40.0	40.4	.62
August[b]	36.4	36.6	36.2	38.3	36.9	38.5	39.8	38.8	40.0	39.2	.83
September[b]	35.5	33.8	35.3	34.6	34.8	33.1	32.9	32.2	32.2	32.6	.54
October	31.7	33.8	33.0	31.5	32.5	35.9	36.9	37.3	37.4	36.9	1.65
Average[b]	34.8	34.5	34.4	34.0	34.4	36.9	36.5	36.3	36.7	36.6	1.01

[a]Effect of endophyte ($P<.05$)
[b]Effect of location ($P<.05$)

APPENDIX TABLE 25. LIGNIN CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	- - - - - - - - - - - - - - - - - % DM basis -										
April	1.82	2.57	1.42	1.72	1.89	2.18	2.68	1.68	3.78	2.58	.67
May[ab]	3.16	3.33	3.40	3.47	3.34	5.12	4.10	2.74	3.40	3.84	.34
June[ac]	4.66	5.93	5.60	4.30	5.12	5.54	4.72	4.30	4.44	4.75	.24
July[b]	6.06	5.17	4.05	3.97	4.81	5.24	4.72	6.00	6.41	5.59	.45
August[d]	3.37	3.88	3.82	4.84	3.97	5.67	3.19	6.62	5.07	5.14	.60
September	3.70	3.86	4.24	4.45	4.06	5.02	4.88	5.63	4.50	5.01	.86
October[ce]	3.14	4.28	4.11	3.31	3.71	4.98	4.54	4.07	4.51	4.53	.36
Average[e]	3.76	4.14	3.80	3.72	3.86	4.82	4.12	4.44	4.59	4.49	.37

[a]Effect of endophyte ($P<.05$)
[b]Location X endophyte interaction ($P<.05$)
[c]Location X endophyte X clover interaction ($P<.01$)
[d]Location X clover interaction ($P<.05$)
[e]Effect of location ($P<.05$)

APPENDIX TABLE 26. LIGNIN CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	- - - - - - - - - - - - - - - - %, DM basis - - - - - - - - - - - - - - - -										
April	1.42	1.42	1.68	1.92	1.61	1.56	1.39	1.84	1.83	1.66	.18
May[a]	3.96	3.35	3.63	3.68	3.66	2.16	2.74	2.50	2.74	2.54	.23
June	4.00	4.30	3.88	3.99	4.05	4.84	4.58	4.10	4.63	4.54	.42
July[a]	4.70	5.00	3.70	4.51	4.48	5.24	5.52	5.85	4.57	5.29	.42
August	4.20	4.62	4.34	4.13	4.33	4.54	5.44	4.76	4.54	4.82	.30
September	4.66	4.61	4.90	4.80	4.75	4.18	4.50	3.61	4.29	4.15	.38
October[a]	3.14	4.19	3.48	3.57	3.60	5.24	5.01	5.89	5.60	5.44	.64
Average	3.73	3.93	3.66	3.79	3.78	4.37	4.63	4.45	4.40	4.46	.33

[a]Effect of location ($P<.01$)

APPENDIX TABLE 27. CELLULOSE CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	%, DM basis										
April[a]	21.6	21.0	20.5	21.0	21.0	24.0	23.3	23.0	24.8	23.8	.66
May	28.0	29.1	27.2	26.9	27.8	28.3	28.6	27.6	29.2	28.4	.85
June	29.6	30.9	29.9	29.3	29.9	30.0	29.5	30.1	30.4	30.0	.56
July[b]	29.0	29.4	27.6	27.7	28.4	27.6	26.8	31.4	30.2	29.0	.89
August[bcd]	27.0	26.8	26.0	25.3	26.3	29.0	26.6	29.1	26.8	27.9	.29
September	27.9	28.9	27.5	28.7	28.2	28.0	26.8	27.4	27.2	27.4	.78
October[d]	25.9	27.3	26.5	28.1	26.9	27.8	26.8	28.2	27.1	27.5	.70
Average	27.0	27.6	26.4	26.7	26.9	27.8	26.9	28.1	28.0	27.7	.70

[a]Effect of location (P<.01)
[b]Location X endophyte interaction (P<.01)
[c]Effect of clover (P<.01)
[d]Location X clover interaction (P<.01)

APPENDIX TABLE 28. CELLULOSE CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	- - - - - - - - - - - - - - - - %, DM basis - - - - - - - - - - - - - - - -										
April	24.4	24.2	23.5	22.8	23.7	25.4	24.8	26.2	24.3	25.2	.28
May[a]	31.9	30.9	31.8	30.8	31.3	29.8	29.9	29.1	29.4	29.6	.49
June	31.2	30.5	31.0	29.6	30.6	32.3	30.2	29.7	30.2	30.6	1.47
July[a]	29.6	28.9	29.4	28.5	29.1	33.8	32.2	32.4	32.6	32.8	.70
August[a]	29.0	28.5	28.5	30.8	29.2	31.9	32.5	31.9	33.1	32.4	1.61
September	28.0	26.4	27.4	26.4	27.0	26.5	26.1	26.0	26.6	26.3	.57
October[a]	26.0	27.2	25.8	27.0	26.5	28.2	28.3	28.6	29.0	28.5	.64
Average[a]	28.6	28.1	28.2	27.7	28.1	30.4	29.9	29.6	30.2	30.0	.78

[a]Effect of location (P<.05)

APPENDIX TABLE 29. ASH CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	-%, DM basis										
April	7.45	8.05	5.20	8.80	7.38	9.90	6.90	7.65	6.55	7.75	.98
May	7.30	8.25	7.95	8.05	7.89	7.45	6.65	7.30	7.05	7.11	.56
June[a]	8.50	7.85	8.00	8.65	8.25	6.45	3.74	3.78	3.51	4.37	.42
July[a]	4.33	3.76	4.19	3.64	3.98	4.22	4.50	3.51	4.32	4.14	.33
August[ab]	5.34	4.86	5.03	5.56	5.20	3.79	4.29	3.44	4.08	3.90	.44
September[a]	6.58	5.35	6.39	6.68	6.25	4.30	4.37	4.07	4.03	4.19	.68
October[acd]	4.44	4.59	4.62	4.55	4.55	4.28	4.03	3.97	3.66	3.98	.33
Average[a]	6.28	6.10	5.91	6.57	6.22	5.77	4.92	4.82	4.74	5.06	.30

[a]Effect of location ($P<.05$)
[b]Location X clover interaction ($P<.01$)
[c]Location X endophyte interaction ($P<.05$)
[d]Endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 30. ASH CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	- - - - - -	- - - -	- - - -	- - - -	- - - -	%, DM basis	- - - -	- - - -	- - - -	- - - -	
April	8.38	8.08	8.55	8.55	8.39	8.29	9.01	8.56	8.49	8.59	.38
May[a]	7.80	8.35	7.90	8.30	8.09	6.50	6.20	6.55	6.75	6.50	.32
June[a]	9.00	9.50	9.15	9.40	9.26	7.30	7.70	8.05	8.05	7.78	.28
July[a]	10.10	10.10	10.00	10.10	10.08	6.15	6.15	6.15	6.20	6.16	.22
August[a]	9.25	9.45	9.65	10.05	9.60	6.45	5.95	7.00	6.30	6.42	.54
September[a]	9.35	10.35	10.40	10.65	10.19	8.65	8.15	8.70	8.70	8.55	.49
October[a]	11.25	10.30	11.65	10.35	10.89	8.50	9.40	8.65	8.05	8.65	.57
Average[a]	9.30	9.45	9.61	9.63	9.50	7.26	7.26	7.52	7.34	7.34	.33

[a]Effect of location ($P<.01$)

APPENDIX TABLE 31. CALCIUM CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April[ab]	.55	.53	.55	.57	.55	.32	.34	.43	.42	.38	.02
May	.40	.43	.45	.44	.43	.27	.27	.38	.36	.32	.04
June[b]	.40	.43	.44	.52	.45	.32	.32	.38	.37	.35	.02
July[a]	.43	.44	.43	.49	.45	.38	.38	.42	.40	.39	.03
August[b]	.44	.44	.44	.48	.45	.33	.33	.39	.43	.37	.03
September[ab]	.44	.48	.51	.53	.49	.33	.32	.38	.36	.35	.02
October[ab]	.35	.41	.39	.48	.41	.26	.26	.32	.33	.29	.03
Average[ab]	.43	.45	.46	.50	.46	.32	.32	.38	.38	.35	.01

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)

APPENDIX TABLE 32. CALCIUM CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
	%, DM basis										
April[ab]	.34	.40	.41	.46	.40	.38	.41	.43	.45	.42	.02
May[cd]	.24	.36	.28	.37	.31	.38	.34	.44	.41	.39	.03
June[ac]	.29	.34	.33	.38	.34	.34	.38	.42	.39	.38	.02
July[d]	.36	.48	.39	.48	.42	.36	.36	.46	.42	.40	.03
August[ac]	.29	.30	.35	.34	.32	.33	.32	.42	.37	.36	.02
September[b]	.28	.34	.29	.35	.32	.30	.36	.34	.38	.34	.02
October[a]	.34	.33	.39	.38	.36	.34	.36	.41	.38	.37	.02
Average[abd]	.30	.36	.35	.40	.35	.34	.35	.41	.39	.37	.02

[a]Effect of endophyte ($P<.05$)
[b]Effect of clover ($P<.05$)
[c]Effect of location ($P<.05$)
[d]Location X clover interaction ($P<.05$)

APPENDIX TABLE 33. MAGNESIUM CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April[a]	.30	.26	.29	.30	.28	.23	.22	.23	.21	.22	.01
May[a]	.27	.26	.29	.28	.27	.22	.22	.24	.24	.23	.02
June[a]	.30	.29	.31	.33	.31	.22	.23	.24	.23	.23	.01
July[ab]	.28	.27	.30	.31	.29	.28	.26	.28	.28	.28	.01
August[abc]	.32	.33	.34	.36	.34	.26	.27	.25	.31	.27	.01
September[a]	.34	.35	.34	.38	.35	.26	.27	.26	.27	.26	.01
October[a]	.30	.31	.32	.36	.32	.22	.23	.24	.25	.24	.02
Average[ab]	.30	.30	.31	.33	.31	.24	.24	.25	.26	.25	.01

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)
[c]Effect of clover ($P<.01$)

APPENDIX TABLE 34. MAGNESIUM CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	- - - - - - - - - - - - - - - - - - %, DM basis - - - - - - - - - - - - - - - - - -										
April	.23	.24	.25	.25	.24	.26	.23	.23	.24	.24	.01
May	.23	.25	.23	.25	.24	.24	.22	.23	.23	.23	.01
June	.25	.27	.27	.28	.27	.26	.28	.28	.28	.28	.01
July[a]	.30	.32	.32	.31	.31	.24	.27	.22	.26	.25	.02
August[a]	.26	.26	.27	.29	.27	.18	.16	.21	.18	.18	.02
September	.26	.29	.29	.32	.29	.29	.30	.28	.31	.30	.01
October[a]	.30	.29	.30	.33	.30	.26	.25	.26	.26	.26	.02
Average[a]	.26	.28	.27	.29	.28	.25	.25	.25	.25	.25	.01

[a]Effect of location ($P<.05$)

APPENDIX TABLE 35. PHOSPHORUS CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April	.26	.33	.31	.32	.30	.32	.32	.30	.27	.30	.02
May	.27	.32	.33	.32	.31	.30	.28	.29	.28	.29	.02
June	.24	.24	.27	.30	.26	.26	.27	.26	.27	.26	.02
July	.26	.28	.30	.32	.29	.31	.34	.29	.33	.32	.02
August[ab]	.32	.34	.32	.36	.34	.32	.40	.28	.42	.35	.02
September[a]	.35	.37	.36	.41	.37	.36	.39	.34	.42	.38	.02
October[c]	.38	.38	.42	.38	.39	.31	.34	.35	.38	.34	.02
Average	.30	.32	.33	.34	.32	.31	.33	.30	.34	.32	.01

[a]Effect of clover (P<.05)
[b]Location X clover interaction (P<.05)
[c]Effect of location (P<.05)

APPENDIX TABLE 36. PHOSPHORUS CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	%, DM basis										
April	.40	.39	.41	.42	.40	.36	.36	.40	.38	.38	.01
May[abc]	.38	.38	.42	.43	.40	.27	.26	.27	.26	.27	.01
June[ab]	.41	.42	.46	.46	.44	.32	.33	.36	.33	.34	.02
July[a]	.38	.46	.44	.46	.43	.27	.28	.32	.30	.29	.04
August[bcd]	.36	.35	.36	.35	.36	.32	.25	.39	.31	.32	.01
September	.35	.40	.42	.42	.40	.40	.40	.40	.41	.40	.03
October[a]	.46	.41	.42	.47	.44	.33	.34	.35	.32	.34	.02
Average[ab]	.39	.40	.42	.43	.41	.32	.31	.35	.32	.32	.01

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)
[c]Location X endophyte interaction ($P<.05$)
[d]Effect of clover ($P<.01$)

APPENDIX TABLE 37. COPPER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1989

Item	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	- - - - - - - -	- - - -	- - - -	- - - -	mg/kg,	DM basis	- - - -	- - - -	- - - -	- - - -	
April[a]	4.63	7.36	7.25	6.31	6.39	3.89	4.33	3.84	3.79	3.96	1.12
May[abcd]	4.41	5.50	4.50	7.84	5.56	4.43	3.97	4.08	3.88	4.09	.22
June	3.50	3.58	3.18	3.84	3.52	3.99	3.74	3.78	3.51	3.76	.42
July	4.33	3.76	4.19	3.64	3.98	4.22	4.50	3.51	4.32	4.14	.33
August	5.34	4.86	5.03	5.56	5.20	3.79	4.29	3.44	4.08	3.90	.44
September[a]	6.58	5.35	6.39	6.68	6.25	4.30	4.37	4.07	4.03	4.19	.68
October	4.44	4.59	4.62	4.55	4.55	4.28	4.03	3.97	3.66	3.99	.33
Average[a]	4.75	4.94	5.05	5.33	5.02	4.13	4.17	3.81	3.90	4.00	.30

[a]Effect of location ($P<.05$)
[b]Effect of clover ($P<.05$)
[c]Location X clover interaction ($P<.01$)
[d]Endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 38. COPPER CONTENT OF FORAGE FROM LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, 1990

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
	mg/kg, DM basis										
April	2.91	3.76	2.77	3.97	3.35	3.08	3.46	2.98	3.87	3.35	.46
May	4.37	2.67	2.89	3.18	3.28	5.63	3.91	3.91	3.44	4.22	.82
June[a]	6.05	3.52	3.15	4.81	4.38	6.10	5.07	4.11	4.07	4.84	.48
July[b]	5.22	5.70	4.98	4.82	5.18	3.06	3.31	2.92	3.86	3.29	.50
August	6.13	5.02	4.48	4.55	5.04	4.48	4.19	3.96	3.61	4.06	.75
September[b]	5.50	5.99	7.50	7.28	6.57	5.14	5.01	4.66	4.06	4.72	.91
October[a]	4.75	4.34	4.16	4.15	4.35	4.15	4.47	3.74	3.18	3.89	.32
Average	4.81	4.64	4.57	4.44	4.62	4.66	4.33	3.88	3.70	4.14	.48

[a]Effect of endophyte ($P<.05$)
[b]Effect of location ($P<.05$)

APPENDIX TABLE 39. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, APRIL 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%	99.3	100.0	100.0	100.0	99.8	99.4	99.2	100.0	100.0	99.6	1.6
Grass,%[abc]	99.2	95.3	100.0	97.2	97.9	100.0	99.0	100.0	98.8	99.4	2.1
Legume,%[abcd]	.8	4.7	.0	2.8	2.1	.0	1.0	.0	1.2	.6	1.1
Weed,%	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[b]	.0	1.5	.0	2.3	1.0	.0	.3	.2	1.9	.6	.19
Crabgrass	.0	.0	.2	.0	.0	.0	.0	.4	.0	.1	.27
Bermudagrass	.0	.0	.0	.0	.0	.0	.2	.0	.4	.2	.11
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds	1.0	.6	.3	.5	.6	.0	.0	.7	.4	.3	.22
Thistle[c]	2.8	3.2	4.8	4.3	3.8	.0	.0	.0	.0	.0	.47
Horse nettle[c]	2.2	3.2	1.2	3.8	2.6	2.6	3.8	3.4	3.4	3.3	.81

[a]Effect of endophyte ($P<.05$)
[b]Effect of clover ($P<.01$)
[c]Effect of location ($P<.05$)
[d]Location X endophyte clover interaction ($P<.05$)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare

APPENDIX TABLE 40. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, MAY 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[ab]											
	95.8	96.7	96.7	96.7	96.5	94.2	88.3	93.3	91.7	91.8	1.40
Grass,%	100.0	96.7	100.0	95.8	98.1	100.0	100.0	100.0	100.0	100.0	.92
Legume,%[cd]	.0	3.3	.0	3.3	1.6	.0	.0	.0	.0	.00	.84
Weed,%	.0	.0	.0	.8	.2	.0	.0	.0	.0	.0	.29
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[acdf]	.8	2.5	.8	2.7	1.7	.2	.2	.3	.3	.2	.33
Crabgrass[a]	.0	.0	.0	.0	.0	.7	.5	.3	.3	.4	.26
Bermudagrass	.3	.0	.2	.0	.1	.0	.0	.0	.0	.0	.13
Hairy vetch[a]	.0	.0	.0	.0	.0	.5	.0	.8	1.0	.6	.16
Weeds[a]	1.2	1.8	1.0	1.7	1.4	.2	.8	1.2	.7	.7	.28
Thistle[a]	4.3	4.7	4.0	5.0	4.5	.0	.0	.0	.0	.0	.37
Horse nettle[a]	1.7	1.3	2.0	.8	1.4	.0	.0	.0	.0	.0	.56

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)
[c]Effect of clover ($P<.01$)
[d]Location X clover interaction ($P<.05$)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[f]Location X endophyte interaction ($P<.05$)

APPENDIX TABLE 41. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, JUNE 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
Ground cover,%[abc]	94.2	98.3	97.5	99.2	97.3	93.3	91.7	95.8	95.0	94.0	1.3
Grass,%[acd]	100.0	92.5	100.0	94.2	96.7	100.0	100.0	100.0	100.0	100.0	1.0
Legume,%[acd]	.0	3.3	.0	4.2	1.9	.0	.0	.0	.0	.0	.75
Weed,%[acd]	.0	4.2	.0	1.6	1.4	.0	.0	.0	.0	.0	.44
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[acd]	.5	2.7	.5	2.7	1.6	.0	.2	.2	.2	.2	.19
Crabgrass[a]	.0	.3	.0	.0	.1	1.2	1.0	.8	.8	1.0	.29
Bermudagrass	.8	.0	.0	.0	.2	1.0	.5	1.0	.8	.8	.30
Hairy vetch[a]	.0	.0	.0	.0	.0	.0	.0	.0	.3	.1	.08
Weeds	1.0	1.5	1.0	1.5	1.2	.5	.8	1.2	.8	.8	.23
Thistle[a]	2.5	2.5	2.5	2.7	2.5	.0	.0	.0	.0	.0	.67
Horse nettle[a]	4.3	2.7	2.7	2.5	3.0	2.5	4.7	4.7	4.7	4.2	.73

[a]Effect of location ($P<.05$)
[b]Effect of endophyte ($P<.05$)
[c]Location X clover interaction ($P<.05$)
[d]Effect of clover ($P<.01$)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare

APPENDIX TABLE 42. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, JULY 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]	98.3	100.0	100.0	100.0	99.6	95.0	93.3	95.0	98.3	95.4	.88
Grass,%[abc]	98.3	95.8	100.0	95.8	97.5	100.0	100.0	100.0	99.2	99.8	1.0
Legume,%[abc]	.0	4.2	.0	3.3	1.9	.0	.0	.0	.0	.0	.75
Weed,%	1.7	.0	.0	.9	.6	.0	.0	.0	.8	.2	.44
Prevalent plants[d]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[abc]	.0	2.0	.3	2.2	1.6	.0	.0	.0	.0	.0	.19
Crabgrass[a]	.3	.2	.0	.0	.1	1.8	2.7	1.8	1.7	2.0	.29
Bermudagrass[a]	.0	.0	.0	.0	.0	1.0	.7	.2	.8	.7	.30
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.08
Weeds	1.2	1.3	1.7	1.7	1.5	1.2	1.2	1.7	1.0	1.3	.23
Thistle[abc]	1.2	3.3	1.2	3.5	2.3	.0	.0	.0	.0	.0	.37
Horse nettle	5.0	3.3	5.0	4.5	4.4	2.5	5.0	2.5	4.8	3.7	.51

[a]Effect of location (P<.05)
[b]Effect of clover (P<.05)
[c]Location X clover interaction (P<.01)
[d]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare

APPENDIX TABLE 43. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, AUGUST 1989

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]	96.7	97.5	98.3	98.3	97.7	96.7	92.5	95.0	97.5	95.4	1.3
Grass,%[abc]	100.0	96.7	100.0	97.5	98.6	100.0	100.0	100.0	100.0	100.0	.4
Legume,%[abc]	.0	3.3	.0	2.5	1.4	.0	.0	.0	.0	.00	.44
Weed,%	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Prevalent plants[d]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[abc]	.0	2.8	.2	2.5	1.4	.0	.0	.2	.5	.2	.18
Crabgrass[aef]	.0	.0	.0	.0	.0	3.0	3.5	2.7	1.5	2.7	.29
Bermudagrass[ae]	.3	.3	.0	.0	.2	2.2	1.5	1.0	1.0	1.4	.35
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Weeds	1.5	1.3	1.8	1.7	1.6	1.3	1.5	1.3	1.7	1.4	.26
Thistle[a]	1.7	1.3	.8	2.7	1.6	.0	.2	.2	.0	.1	.39
Horse nettle[abcfg]	5.0	5.0	5.0	2.5	4.4	4.8	4.8	5.0	5.0	4.9	.36

[a]Effect of location (P<.05)
[b]Effect of clover (P<.05)
[c]Location X clover interaction (P<.05)
[d]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[e]Effect of endophyte (P<.05)
[f]Location X endophyte (P<.01)
[g]Endophyte X clover interaction (P<.05)

APPENDIX TABLE 44. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, SEPTEMBER 1989

Item	Glade Spring					Blackstone					SE
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	
Ground cover,%[a]	95.8	97.5	99.2	100.0	98.1	95.0	94.2	98.3	98.3	96.4	1.2
Grass,%[bc]	97.5	95.8	97.5	94.2	96.2	100.0	99.2	100.0	96.7	99.0	1.1
Legume,%[bcd]	.0	2.5	.0	3.3	1.4	.0	.0	.0	.0	.0	.7
Weed,%	2.5	1.7	2.5	2.5	2.3	.0	.8	.0	3.3	1.0	.9
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[bcd]	.8	3.2	.3	2.8	1.8	.5	.7	.8	.5	.6	.30
Crabgrass[abf]	.5	.0	.2	.3	.0	2.8	3.3	2.5	1.7	2.6	.33
Bermudagrass	1.2	.3	.5	.0	.5	1.7	1.2	1.2	.7	1.2	.42
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds	2.2	2.0	2.3	2.0	2.1	1.3	1.8	1.3	2.0	1.6	.27
Thistle[ebg]	.8	1.7	2.3	.7	1.4	.5	.0	.0	.0	.1	.35
Horse nettle[bcd]	3.2	4.2	3.2	5.0	3.9	5.0	5.0	4.7	5.0	4.9	.29

[a]Effect of endophyte (P<.05)
[b]Effect of location (P<.05)
[c]Effect of clover (P<.01)
[d]Location X clover interaction (P<.01)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[f]Location X endophyte interaction (P<.05)
[g]Location X endophyte X clover interaction (P<.01)

APPENDIX TABLE 45. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, OCTOBER 1989

Item	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[ab]	96.2	97.5	100.0	100.0	98.4	91.2	86.2	91.2	96.2	91.2	1.4
Grass,%[ac]	97.5	95.0	100.0	96.2	97.2	100.0	100.0	100.0	98.8	99.7	1.0
Legume,%[acd]	.0	3.8	.0	3.8	1.9	.0	.0	.0	.0	.0	.7
Weed,%	2.5	1.2	.0	.0	.9	.0	.0	.0	1.2	.3	.7
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[acd]	1.0	3.2	.0	2.8	1.8	.0	.5	.8	.2	.4	.28
Crabgrass[abf]	.0	.0	.2	.0	.0	2.5	3.0	1.2	1.2	2.0	.39
Bermudagrass[abf]	.2	.2	.0	.0	.1	3.0	2.2	.5	1.5	1.8	.35
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds	1.8	1.8	1.5	2.2	1.8	.8	.8	1.2	1.5	1.1	.33
Thistle[a]	1.0	1.0	.8	.2	.8	.2	.0	.2	.0	.1	.23
Horse nettle[ac]	2.8	3.2	3.0	5.0	3.5	4.8	5.0	5.0	5.0	5.0	.40

[a]Effect of location (P<.05)
[b]Effect of endophyte (P<.05)
[c]Effect of clover (P<.05)
[d]Location X clover interaction (P<.01)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[f]Location X endophyte interaction (P<.05)

APPENDIX TABLE 46. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, APRIL 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%	98.3	100.0	100.0	100.0	99.6	98.2	99.2	98.2	100.0	98.9	1.2
Grass,%[abcd]	99.2	83.3	100.0	94.2	94.2	100.0	100.0	100.0	98.8	99.7	1.9
Legume,%[ab]	.8	16.7	.0	5.8	5.8	.0	.0	.0	1.2	.3	1.1
Weed,%	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Prevalent plants[e]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[b]	2.5	3.7	2.0	2.8	2.8	.0	.7	.2	2.6	.9	.29
Crabgrass	.5	.0	.2	.0	.2	.5	.0	.2	.3	.2	.21
Bermudagrass	.2	.0	.0	.0	.0	1.0	.2	.0	.4	.4	.14
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds	1.0	.8	.5	.7	.8	.6	.8	1.7	1.5	1.2	.27
Thistle[abcf]	4.8	.0	.0	.8	1.4	.0	.0	.0	.0	.0	.42
Horse nettle	.0	.0	.0	.2	.0	.4	.2	.2	.5	.4	.21

[a]Effect of endophyte ($P<.05$)
[b]Effect of clover ($P<.05$)
[c]Effect of location ($P<.05$)
[d]Location X endophyte interaction ($P<.05$)
[e]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[f]Endophyte X clover interaction ($P<.05$)

APPENDIX TABLE 47. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, MAY 1990

Item	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[ab]	99.2	98.3	99.2	99.2	99.0	96.2	93.8	98.8	97.5	96.6	1.3
Grass,%[c]	100.0	93.3	100.0	93.3	96.6	98.8	97.5	97.5	97.5	97.8	2.6
Legume,%[c]	.0	6.7	.0	6.7	3.4	1.2	2.5	2.5	2.5	2.2	2.6
Weed,%	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Prevalent plants[d]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[bce]	1.7	3.8	.8	3.5	2.4	2.5	3.8	2.5	2.0	2.7	.35
Crabgrass[ab]	.2	.0	.0	.0	.0	.8	.8	.2	.2	.5	.21
Bermudagrass[a]	.0	.0	.0	.0	.0	.2	.0	.0	.2	.1	.11
Hairy vetch[abf]	.0	.0	.0	.0	.0	1.8	1.5	2.8	3.0	2.3	.35
Weeds[abf]	.8	.8	1.0	.8	.8	1.0	1.0	2.2	1.8	1.5	.20
Thistle	.3	.3	.0	.0	.2	.0	.0	.0	.0	.0	.14
Horse nettle	.3	.2	.2	.2	.2	.0	.2	.5	.5	.3	.22

[a]Effect of location (P<.05)
[b]Effect of endophyte (P<.05)
[c]Effect of clover (P<.05)
[d]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[e]Location X clover interaction (P<.05)
[f]Location X endophyte interaction (P<.05)

APPENDIX TABLE 48. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, JUNE 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]	100.0	100.0	100.0	100.0	100.0	95.0	96.2	98.8	98.8	97.2	1.5
Grass,%[abcde]	100.0	88.8	100.0	92.5	95.3	100.0	96.2	100.0	100.0	99.1	1.2
Legume,%[abcde]	.0	11.2	.0	7.5	4.7	.0	3.8	.0	.0	1.0	1.2
Weed,%	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Prevalent plants[f]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[bc]	1.5	4.0	1.0	3.5	2.5	1.2	3.5	1.2	2.8	2.2	.30
Crabgrass[acdeg]	.0	.0	.0	.0	.0	1.8	.0	.2	.2	.6	.26
Bermudagrass[acd]	.0	.0	.0	.0	.0	1.0	.0	.8	.0	.4	.28
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds	1.2	1.0	.8	1.0	1.0	1.0	1.5	1.8	1.5	1.4	.31
Thistle[abh]	4.8	2.2	1.2	.8	2.2	.0	.0	.0	.0	.0	.6
Horse nettle[abcdh]	.2	2.8	2.5	3.5	2.2	5.0	5.0	5.0	5.0	5.0	.49

[a]Effect of location (P<.05)
[b]Effect of endophyte (P<.05)
[c]Effect of clover (P<.05)
[d]Location X clover interaction (P<.05)
[e]Endophyte X clover clover interaction (P<.05)
[f]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[g]Location X endophyte X clover interaction (P<.05)
[h]Location X endophyte interaction (P<.05)

APPENDIX TABLE 49. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, JULY 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]	99.2	100.0	100.0	99.2	99.6	93.3	86.7	93.3	94.2	91.9	2.3
Grass,%[abc]	100.0	95.0	99.2	93.3	96.9	100.0	100.0	100.0	100.0	100.0	1.1
Legume,%[abc]	.0	5.0	.0	5.8	2.7	.0	.0	.0	.0	.0	.9
Weed,%[a]	.0	.0	.8	.8	.4	.0	.0	.0	.0	.0	.4
Prevalent plants[d]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[be]	1.3	3.8	.3	2.8	2.1	.7	4.0	.8	3.0	2.1	.28
Crabgrass[aef]	.0	.0	.0	.0	.0	2.5	2.0	1.0	1.3	1.7	.24
Bermudagrass[ae]	.0	.0	.0	.0	.0	1.8	1.8	1.5	.3	1.4	.31
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds[e]	2.2	1.5	2.5	1.8	2.0	.8	.8	1.0	1.3	1.0	.22
Thistle[aef]	2.3	1.2	1.2	.7	1.4	.2	.0	.0	.2	.1	.39
Horse nettle[eg]	2.5	5.0	4.7	4.7	4.2	4.8	2.5	4.7	4.2	4.0	.53

[a]Effect of location (P<.05)
[b]Effect of clover (P<.05)
[c]Location X clover interaction (P<.05)
[d]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[e]Effect of endophyte (P<.05)
[f]Location X endophyte interaction (P<.05)
[g]Location X endophyte X clover interaction (P<.05)

APPENDIX TABLE 50. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, AUGUST 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]	100.0	100.0	100.0	100.0	100.0	96.7	94.2	95.8	97.5	96.0	2.2
Grass,%[b]	100.0	97.5	97.5	97.5	98.1	100.0	95.0	100.0	97.5	98.1	1.3
Legume,%[b]	.0	2.5	.0	2.5	1.2	.0	5.0	.0	2.5	1.9	1.2
Weed,%[a]	.0	.0	2.5	.0	.6	.0	.0	.0	.0	.0	.4
Prevalent plants[c]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[bd]	2.0	4.0	.8	3.2	2.5	2.0	4.0	2.0	3.7	2.9	.32
Crabgrass[ade]	.0	.0	.0	.0	.0	3.2	3.0	2.3	1.5	2.5	.31
Bermudagrass[a]	.0	.0	.0	.0	.0	2.3	1.5	1.2	1.0	1.5	.51
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds[ad]	2.2	2.0	3.0	2.2	2.4	1.0	.7	1.2	1.3	1.0	.33
Thistle[a]	1.2	.8	1.2	.5	.9	.0	.0	.0	.2	.0	.15
Horse nettle[f]	5.0	5.0	5.0	5.0	5.0	5.0	2.5	4.8	5.0	4.3	.48

[a]Effect of location (P<.05)
[b]Effect of clover (P<.05)
[c]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[d]Effect of endophyte (P<.05)
[e]Location X endophyte interaction (P<.05)
[f]Location X endophyte X clover interaction (P<.05)

APPENDIX TABLE 51. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, SEPTEMBER 1990

Item	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]											
	99.2	99.2	100.0	100.0	99.6	96.7	92.5	97.5	95.8	95.6	1.4
Grass,%[bcd]	99.2	95.8	96.7	99.2	97.7	99.2	91.7	100.0	97.5	97.1	1.4
Legume,%[bcde]	.0	3.3	.0	.8	1.0	.0	8.3	.0	2.5	2.7	1.1
Weed,%	.8	.8	3.3	.0	1.3	.8	.0	.0	.0	.2	.8
Prevalent plants[f]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[be]	.7	3.0	.8	2.5	1.8	1.3	3.8	.8	2.8	2.2	.29
Crabgrass[aeg]	.5	.0	.0	.0	.1	3.7	3.8	3.0	2.3	3.2	.28
Bermudagrass[a]	.0	.2	.0	.0	.0	1.5	1.7	.8	1.0	1.2	.43
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds[a]	2.0	2.5	2.5	1.8	2.2	1.7	2.0	1.2	1.5	1.6	.35
Thistle[a]	1.5	1.7	1.7	1.7	1.7	.0	.0	.0	.7	.2	.19
Horse nettle	5.0	4.8	4.8	5.0	4.9	4.7	5.0	5.0	5.0	5.0	.11

[a]Effect of location (P<.05)
[b]Effect of clover (P<.05)
[c]Location X clover interaction (P<.05)
[d]Endophyte X clover interaction (P<.05)
[e]Effect of endophyte (P<.05)
[f]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[g]Location X endophyte interaction (P<.05)

APPENDIX TABLE 52. VISUAL ESTIMATES OF LOW AND HIGH ENDOPHYTE-INFECTED TALL FESCUE PASTURES, WITH AND WITHOUT WHITE CLOVER, FROM TWO LOCATIONS IN VIRGINIA, OCTOBER 1990

	Glade Spring					Blackstone					
	Low endophyte		High endophyte			Low endophyte		High endophyte			
Item	No clover	Clover	No clover	Clover	Avg	No clover	Clover	No clover	Clover	Avg	SE
Ground cover,%[a]											
	98.8	100.0	100.0	98.8	99.4	93.8	91.2	98.8	96.2	95.0	2.4
Grass,%[a]	100.0	97.5	96.2	100.0	98.4	100.0	100.0	100.0	100.0	100.0	1.0
Legume,%	.0	1.3	.0	.0	.4	.0	.0	.0	.0	.0	.4
Weed,%[a]	.0	1.2	3.8	.0	1.2	.0	.0	.0	.0	.0	1.0
Prevalent plants[b]											
Fescue	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	.
Clover[acde]	2.8	3.8	1.0	3.2	2.7	.5	3.0	.2	1.2	1.2	.33
Crabgrass[acf]	.0	.0	.0	.0	.0	3.0	1.5	1.2	.5	1.6	.44
Bermudagrass[a]	.0	.0	.0	.0	.0	1.2	1.0	.5	.5	.8	.42
Hairy vetch	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.
Weeds[a]	1.8	2.2	2.5	1.5	2.0	.5	1.0	1.0	1.5	1.0	.34
Thistle[acf]	.8	1.8	.2	.0	.7	.0	.0	.2	.0	.0	.30
Horse nettle[d]	5.0	5.0	4.8	4.8	4.9	2.2	5.0	4.8	4.8	4.2	.43

[a]Effect of location (P<.05)
[b]Code: 5=dominant, 4=abundant, 3=frequent, 2=occassional, 1=rare
[c]Effect of endophyte (P<.05)
[d]Effect of clover (P<.05)
[e]Location X endophyte X clover interaction (P<.05)
[f]Location X endophyte interaction (P<.05)

VITA

James Kevin Tully was born May 8, 1964, in Argentia, Newfoundland, Canada, the son of John and the late Mary Claire. He was reared in Gettysburg, Pennsylvania, and graduated from high school there in 1982. He received his BS in Biology from East Stroudsburg University in May, 1985. In August of 1988, the author received his MS in Animal Science from The Pennsylvania State University. He entered the Ph.D. program in Animal Science at Virginia Polytechnic Institute and State University in August of 1988. The author is a member of the American Society of Animal Science, American Society of Agronomy, and American Forage and Grassland Council. The author married the former Wendi Blair Miller on January 25, 1992.