The effects of endophyte-infected tall fescue on production and reproductive performance parameters of beef cattle and calves

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ABSTRACT

Beef cattle production records from two Virginia Department of Corrections herds from 2012-2019 were analyzed to determine how the cultivar of tall fescue – toxic endophyte-infected or novel endophyte-infected – impacted cattle productivity metrics. Parameters compared were artificial insemination pregnancy rates, calving rates, body weights, and body condition scores of cows and birth weights and weaning weights of calves. The experimental design was a randomized completed block design with year as the replication. Samples of tall fescue were collected from the farm locations and tested for total ergot alkaloid concentrations. The samples from the farm with toxic endophyte-infected tall fescue all contained toxic levels of ergot alkaloids while the samples from the farm with novel endophyte-infected tall fescue indicated that half of the pastures at this location did not have toxic levels of total ergot alkaloids. Artificial insemination pregnancy rates were greater (P = 0.0011) for cows on novel endophyte-infected tall fescue (52 ± 1%) than for cows on toxic endophyte-infected tall fescue (43 ± 1%). Cows on novel endophyte-infected tall fescue had greater calving rates (94 ± 1%) than cows on toxic endophyte-infected tall fescue (89 ± 1%; P=0.0243). Body condition scores and body weights at pre-breeding were greater for the cows on novel endophyte-infected tall fescue (P=0.0153 and P = 0.0456, respectively). Birthweights were reduced for calves on toxic endophyte-infected tall fescue (34 ± 0.9 kg.) than for calves on novel endophyte-infected tall fescue (38 ± 1.4 kg.; P = 0.0257). Calves on novel endophyte-infected tall fescue had greater weaning weights (278 ± 5.9 kg.) than calves on the toxic endophyte-infected tall fescue (254 ± 5.9 kg.; P = 0.0217). Cattle production was improved on the farm with novel endophyte-infected tall fescue compared to cattle production on the farm with only toxic endophyte-infected tall fescue.

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Introduction:

Tall fescue, (*Schedonorus arundinaceus* (Schreb.) Dumont., syn. *Lolium arundinaceum* (Schreb.) Darbysh., formerly *Festuca arundinacea* Schreb), is the predominant cool season forage for cow-calf producers in Virginia and the Southeastern United States. Tall fescue is grown on approximately 14 million hectares of pasture and hay land. Tall fescue has a mutualistic symbiosis with a fungus, *Neotyphodium coenophialum* (Benner, Booher, and Fike, 2018). The relationship between the fungal endophyte and the grass allows the forage to resist and tolerate insects, drought, low soil fertility, competition from other plants, and overgrazing (Stuedemann and Hoveland, 1988; Patterson et al., 1995).

Although the fungus benefits the grass, it also causes negative effects to livestock that consume it (Bacon et al., 1977; Nihsen et al., 2004; Caldwell et al., 2013). The endophyte produces ergot alkaloids, toxic compounds that cause a suite of symptoms in livestock collectively known as fescue toxicosis. Bovine fat necrosis, fescue foot, and summer slump are the three syndromes typical for livestock grazing infected fescue. More generally, ergot alkaloids cause a reduction in production and reproductive performance. Along with decreased reproductive efficiency, consumption of ergot alkaloids causes reductions in birth weight, weaning weight (WW), conception and pregnancy rates, body weight, calving rate (CR), and body condition score (BCS) (Stuedemann and Hoveland, 1988; Peters et al. 1992; Porter and Thompson, 1992; Paterson et al., 1995; Nihsen et al., 2004; Watson et al., 2004; Kallenbach, 2013). Fescue toxicosis costs the United States beef industry approximately $2 billion each year (Strickland et al, 2011; Caldwell et al., 2013; Kallenbach, 2015; Wilson, 2018). Much of this price is paid in the Southeastern United States which contains a significant portion of the “fescue belt” and which is home to 12 million head of cattle (Kallenbach 2015). Much of the loss can be

attributed to decreased calving rates (Caldwell et al., 2013). Reduced conception rates and weaning weight alone constitute a loss of $609 million each year (Hoveland, 1993).

In this study, records from 2012-2019 of two spring-calving beef herds of the Virginia Department of Corrections (VADOC) Agribusiness sector were analyzed to compare the performance of animals which grazed toxic endophyte-infected tall fescue (E+) with those that grazed novel endophyte-infected tall fescue (NE+). Farms at Coffeewood stocked cattle on E+, while the farm at Jarratt stocked cattle on NE+. Pregnancy Rate (PR), CR, birth weight, WW, body weights, BCS, and average daily gain (ADG) were compared for both forage types to determine the effect of forage type on production and reproductive performance parameters between cattle consuming E+ versus NE+ tall fescue types. This study is unique in the fact that 2300 head of cattle were analyzed over the course of eight years. Many other research-based studies have a smaller number of cattle and the trials are completed over a one to three-year period. The cattle used for this study were all a part of the same agribusiness system within Virginia.

For this study it was hypothesized that cattle consuming E+ tall fescue will have decreased reproductive and production performance compared to cattle that consume NE+. To test this hypothesis, forage samples from each farm location were collected to determine the difference in total ergot alkaloid concentrations in the forage. Cattle production records were analyzed to compare differences between E+ tall fescue and NE+ tall fescue in reproductive performance parameters, including pregnancy rate, calving rate and birthweight, cow condition, including BCS and pre-breeding body weight, and calf growth, including WW and ADG.

Literature Review:

Tall Fescue:

Tall fescue is the predominant cool-season forage in Virginia and throughout the Southeastern United States. The forage was likely introduced to the United States from Europe without particular intention in the 1800s and became increasingly popular after 1930 when the most popular cultivar, Kentucky 31, was first introduced (Stuedemann and Hoveland, 1988). Tall became one of the best options for forage producers in the Southeastern United States due to its ability to establish in and tolerate many environmental conditions (Hoveland, 1993). However, over time, producers began to notice poor production performance and growth efficiency in cattle consuming the forage (Beers and Piper, 1987; Stuedemann and Hoveland, 1988).

Fescue Toxicosis:

Tall fescue shares a mutualistic relationship with a fungus known as *Neotyphodium coenophialum* (Bacon, Porter, Robbins, and Luttrell, 1977). This fungus is often referred to as an endophyte, simply meaning "within the plant" (Fike, 2018). The fungus helps the plant survive droughts, predatory insects, diseases, nematodes, and other pest and environmental conditions (Stuedemann and Hoveland, 1988; Paterson et al., 1995). The endophyte present in tall fescue produces ergot alkaloids, including ergovaline. Research suggests ergovaline is the leading cause of the toxic effects in beef cattle (Strickland et al. 2011).

Cattle consuming E+ tall fescue may exhibit one or more of the following characteristic symptoms: reductions in weight gain, feed intake, milk production, serum prolactin and reproductive performance, and corresponding increases in respiration rates, body temperatures, and salivation, along with a rough hair coat (Paterson et al., 1995; Strickland et al., 2011; Fike and Pent, 2018; Poole et al., 2019). Fescue toxicosis is a collective set of syndromes, including fescue foot, summer slump, and bovine fat necrosis. Fescue foot occurs due to reduced blood

flow to the hooves, resulting in altered vessel architecture. This syndrome is most common during cold weather, and animals often display a characteristic limp. In extreme cases, vessel damage and corresponding infection can result in gangrene and the sloughing of the hoof. This condition occurs due to vasoconstriction of blood vessels. This reduces blood flow to the extremities of the animal causing swelling in the feet, loss of tips of ears and tail switch (Fike and Pent, 2018). Another condition is known as summer slump (Fike and Pent, 2018). Summer slump is characterized by poor animal performance in summer and can be recognized by the rough hair coats on cattle. Fat necrosis, the third toxicosis syndrome, describes the death and hardening of fat depots, particularly in the digestive tract. These hard, necrotic tissues can reduce flow through the digestive tract in cattle (Fike and Pent, 2018).

Reproduction:

The effects of ergot alkaloids on reproductive performance in cattle have proven variable in the many studies conducted to further understand the mechanisms behind the toxicity. Several studies found no change in calving rate, calving interval, and pregnancy and embryonic losses in cattle grazing E+ tall fescue (Watson et al., 2004; Burke et al., 2001a). Other research has shown a difference in reproductive performance (Gay et al., 1988; Porter & Thompson, 1992). Watson et al. (2004) concluded that reduced temperatures during spring breeding, decreased alkaloid concentrations, and good body condition present on cows may have caused there to be little-to-no difference in reproductive performance in cattle grazing toxic E+ or NE+ tall fescue. Gay et al. (1988) suggested that the increased body temperatures and respiration rates associated with consuming E+ tall fescue alkaloids may reductions in conception rates and embryo viability in cattle.

Pregnancy Rates Cattle grazing E+ tall fescue often have reduced conception and/or pregnancy rates compared with those consuming non-toxic forages (i.e. NE+ tall fescue, orchardgrass, common bermudagrass). The ability for a cow to conceive and maintain a viable pregnancy is the most important aspect of production for cow-calf operations (Eversole, 2009). Hazlett (1999) indicated that reproductive losses do not occur until after the second week of pregnancy. Burke et al. (2001b) similarly found that most pregnancy losses for cattle grazing E+ tall fescue occurred between 30-60 days of gestation, the greatest losses occurring during the first 30-45 days of gestation. Burke et al (2001b) also noted that all of the losses occurred after the environmental temperature rose above 37.8˚C (100.04˚F) for an extended period of time. These results suggest that environmental conditions play a role in reproductive performance of cattle grazing E+ tall fescue.

Pregnancy rates and conception rates are two different metrics used to analyze the effectiveness of reproduction in a cow herd. Conception rate is calculated as the number of conceptions at the time of natural mating or artificial insemination (Javic & Conroy, 2001). Pregnancy rate is calculated as the total number of services given to a specific herd of animals over a period of time (breeding season) and thus, presented as the percentage of animals pregnant out of the total number services (AHDB, undated). Burke et al. (2001b) concluded that differences in environmental temperatures may be a leading cause for the variation in responses of pregnancy rates in the studies they analyzed. Poole et al. (2018) found that the consumption of E+ tall fescue seed led to a decrease in uterine and ovarian vessel area which restricted blood flow to necessary reproductive organs. This decreased blood flow has the potential to reduce the function of the ovaries and follicles along with reducing conception and pregnancy rates (Poole et al., 2018). Schmidt et al. (1986) noted that for every 10% increase in percent of infection in E+

tall fescue, there is a 3.5% decrease in conception rates. First-calf heifers grazing low E+ tall fescue had a conception rate of 93% while heifers grazing high E+ tall fescue had a conception rate of 33% (Schmitt et al., 1986)

Calving rates. Schmitt et al. (1986) reported a linear decrease in calving rates for cattle grazing increasing levels of E+ tall fescue. Gay et al. (1988) also reported similar findings, with calving rates being greater for cattle grazing pastures with low levels of E+ infection compared to cattle grazing highly infected tall fescue.

Caldwell et al. (2013) studied the difference between fall-calving cattle and spring-calving cattle grazing E+ and NE+ tall fescue. The authors found that calving rates increased 36% by converting 25% (75% E+ tall fescue) of the spring-calving pasture to NE+ tall fescue (Caldwell et al., 2013). For spring calving herds, calving rates did not differ between 25% NE+ and 100% NE+ tall fescue treatments. However, calving interval was extended for the 25% NE+ tall fescue herd (Caldwell et. al., 2013). Fall-calving herds grazing E+ tall fescue pastures had greater calving rates than spring-calving herds grazing E+ tall fescue. The conversion of pasture to 25% NE+ tall fescue can increase calving rates of spring-calving herds, but the best option to increase calving rates is to convert pastures to NE+ tall fescue and/or switch to a fall-calving season.

Looper et al. (2010) found that calving rates were reduced for cattle grazing E+ tall fescue (79%) compared with those grazing common bermudagrass (84%), despite good body condition. In the same study, cattle with marginal body condition pre-breeding had a decreased calving rate (61%) because these cattle were not able to gain the necessary body condition to conceive (Looper et al., 2010).

Growth

Birth Weight, Weaning Weight, Average Daily Gain. Many studies have determined that cows grazing E+ tall fescue gave birth to calves with reduced birth weights, first-calf heifers, and weaned calves have a reduction in growth when consuming E+ tall fescue. Patterson (2012) found that cows grazed on E+ tall fescue gave birth to calves with decreased birth weights compared to cows grazing common bermudagrass. These results are similar to other studies (Watson, 2004; Burke et al., 2010). Beers and Piper (1987) found that cows grazing E+ tall fescue had reductions in ADG and reductions in calving rate and calf birth weights. Similarly, Schmidt et al. (1986) concluded that heifers grazing E+ tall fescue had decreased conception rates, milk production, and ADG compared to heifers grazing endophyte-free (E-) tall fescue.

Cattle grazing E+ tall fescue have exhibited a decrease in milk production (Schmidt et al., 1986; Beers and Piper, 1987; Peters, 1992; Paterson et al., 1995) Peters et al. (1992) found that cattle produced 25% less milk when grazing E+ tall fescue than cattle grazing other types of forages. For every 10% increase in infection of E+ tall fescue, daily milk production decreased by 1.04 kg. (Schmidt et al., 1986). Therefore, WW and ADG of calves are reduced. Peters et al. (1992) also mentions that WW of calves consuming E+ tall fescue are reduced when compared to other forage types. The reduction in WW can be linked to reductions in forage intake (Beers and Piper, 1987). Schmidt et al., (1986) found that by 100 days of age, calves on pastured on and grazing E+ tall fescue were beginning to show signs of fungal infection levels in the forage.

Body Condition Scores and Body weight. BCS is a common method used to assess the nutritional status of cattle (Eversole et al., 2009). BCS is completed through visual observation, then assigning a number corresponding to the visual assessment of the animal. A BCS of 1 means the animal is emaciated with no visible fat and a BCS of 9 means the animal is extremely

fat and is considered obese with no visible bone structures (Eversole et al., 2009). DeRouen et al. (1994) studied first-calf heifers to determine a relationship between third trimester of pregnancy BCS and the nutritional needs of heifers to ensure optimum reproductive performance. By analyzing pre-partum BCS, the amount of energy needs can be determined to ensure adequate reproductive performance. DeRouen concluded that cows with diminished BCS at calving had a longer calving interval and decreased pregnancy rates. Cows that maintain an optimal BCS in the last trimester and at calving can prevent reductions in growth and development for heifers being used as replacements (Patterson, 2012).

A BCS, between 5 and 7 is preferred for optimal reproductive performance (Eversole et al., 2009). Hess et al. (2005) noted that cows with a BCS < 5 at calving had a negative energy balance in the last trimester of gestation. DeRouen et al. (1994) found that heifers need to be provided with adequate nutrition to maintain a BCS of ≥ 6 to increase pregnancy rates in spring-calving herds. Cows with marginal body condition grazing E+ tall fescue during a 60-day breeding season did not gain any condition throughout the breeding season and therefore had reduced calving rates (Looper et al., 2010). In the same study, Looper et al. (2010) found that cows grazing E+ tall fescue had a reduction in BCS at the end of the breeding season compared to those consuming alternate forages. Weight loss for cattle consuming E+ tall fescue can be significant. Peters et al. (1992) found that cows grazing E+ tall fescue lost an average of 35 kg. more than cows grazing E- tall fescue. In some situations, losing 45-91 kg. can be a difference in a BCS for an animal (Eversole et al., 2009).

Management Strategies for Toxicosis Mitigation

Animal Management and Genetics. Producers in Virginia and the Southeast United States may benefit from converting from spring-calving systems to a fall-calving system (Campbell et

al., 2013). In fall-calving systems, cattle perform better because they are not subjected to heat stress during breeding as occurs in spring-calving systems. Calves will have greater ADG, thus a greater WW and market weight price. This has the potential to increase profits for producers (Caldwell et al., 2013). Another option for spring-calving systems is removeing cattle from E+ tall fescue 30 days prior and post breeding (Caldwell et al., 2013)

Whether intentional or not, over time many farmers have selected cattle based on traits of interest such as slick hair coat, weight gain reproductive success which are associated with a greater ability to tolerate alkaloids in E+ tall fescue. Producers typically select for traits that associated with greater productive and reproductive success (e.g., reproductive success, weight gain, slick hair coat) and such cattle may possess genes that mitigate the effects of fescue toxicosis. Crossbreeding also may be used to introduce traits associated with greater resistance to tall fescue toxicosis (Browning, 2013). An example of this would be introducing Senepol genetics to an Angus herd. Senepol cattle possess a genetic mutation that causes slick hair coats which prevents the rough hair coat commonly associated with fescue toxicosis (Poole et al., 2019).

Stockpiling. Stockpiling E+ tall fescue for consumption during winter can benefit cattle and producers due to increased nutritional quality of the stockpiled fescue, the reduction of hay needed for winter feeding, and the reduction of ergot alkaloid concentrations in stockpiled fescue (Poore and Drewnoski, 2010). Ergot alkaloid concentrations decline during the winter. Booher, Benner and Fiske (2017) discuss the methods of creating a stockpile system to use for winter grazing. In late summer, begin to strip graze the summer stockpile and apply fertilizers to other resting pastures to ignite fall growth for winter grazing (Booher, Benner, and Fiske, 2017). Using this stockpiling system has the potential to extend the grazing season approximately ninety days

when compared to conventional systems (Booher, Benner, and Fiske, 2017). Stuedemann and Hoveland (1988) mentioned that increased nitrogen fertilization caused an increase in ergot alkaloid concentrations in E+ tall fescue pastures. It is important that producers remain mindful of this fact and do not over fertilize. Splitting up the total amount of fertilizer needed between spring and fall applications will help prevent ergot alkaloid concentrations from increasing to harmful levels.

Seed head control and dilution. Kallenbach (2015) discusses another method to control ergovaline concentrations by controlling the amount of seed heads present in pastures as the levels of ergot alkaloids are typically greatest in the seed heads. This can be done by using chemical and mechanical treatments. Chaparral ® is a newer chemical technology that uses a growth regulator to suppress seed head growth. When using growth regulators, producers need to keep in mind that they can also suppress the growth of pasture forages altogether (Kallenbach, 2015). Mowing is a common mechanical technique that is used to control seed heads without the expense of chemical treatments. Kallenbach (2015) also mentions increasing stocking rates on E+ tall fescue pastures for a period of time to prevent plant maturation and seed head formation, being careful not to overstock the pastures for overgrazing. When E+ tall fescue is kept in the vegetative growth stages ergovaline concentrations are the lowest in the spring and increases throughout the summer months, with the largest increase in the fall (Rogers et al. 2011). Diluting pastures with clover can help to increase the nutritional plane of cattle grazing E+ tall fescue. Pastures can also be interseeded with other non-toxic forages such as orchardgrass, bermudagrass, legumes, and warm season grasses (Kallenbach, 2015).

Renovation. The extensive cost associated with conversion to NE+ tall fescue hinders the conversion on cow-calf operations. Many farms in Virginia and the Southeastern United States

are small family farms that rely on other occupations for primary income. Renovation breakeven cost for spring-calving producers can be estimated at $98 per hectare (Smith et al., 2012). It is not beneficial for producers to plant E- tall fescue seed that does not have the fungus to allow the fescue to survive the climate of Virginia and the Southeastern United States (Hoveland, 1993; Browning, 2003). Producers could also benefit from supplementing NE+ tall fescue in their pasture rotations during the grazing season when ergot alkaloids are greatest in E+ tall fescue pastures and cattle are more sensitive to ergot alkaloids. (Caldwell et al., 2013). Benefits of NE+ over E+ tall fescue includes improved pregnancy and conception rates, increased gains from cattle and stockers, increased weaning weights, and increased herd longevity (NRCS.gov, 2007). Other methods of renovation include using various options of such as dilution by interseeding legumes, or partial kill with herbicide treatment, or seeding small sections with NE+ tall fescue (Strickland et al., 2001).

Materials and Methods:

Locations:

This project utilized cattle production data from the VADOC Agribusiness program. VADOC cattle were ideal for this project because there are approximately 2,300 head managed on an annual basis across the state according to similar protocols and veterinary programs, have similar genetic backgrounds, and are stocked on similar forage types.

Two of the agribusiness operations were selected based on their breeding season and dominant forage type. The agribusiness operation located at Coffeewood Correctional Center has been termed "Coffeewood" for the purposes of this project. Coffeewood is located at 38˚ 21'53.28" N, 78˚ 1'13.08" W in Culpeper County. This farm is approximately 263 hectares with 101 hectares used for permanent pasture and 162 hectares used for hay production. In addition to the farm located at the Coffeewood Correctional Center, there is a separate group of cattle kept at Sky Meadows State Park (38˚ 59'27.6" N, 77˚ 57'52.56" W). This group consists of cattle mostly over the age of 5. The cattle remain at the State Park from April to November and are then brought back to Coffeewood Correctional Center to calve from December to March. Breeding and all other management for the Sky Meadows herd is completed at the State Park location. In both locations, Coffeewood and Sky Meadows, the main forage source is E+ tall fescue. These two farms were treated as a single farm because the cattle are managed together during the calving season and are only separated seasonally.

The agribusiness operation at Greensville Correctional Center (termed "Jarratt" for the purposes of this project) is located at 36˚ 47'52.188" N, 77˚ 28'57.41" W in Greensville County. This farm is approximately 179 total hectares with 141 hectares used for pasture and 38 hectares used for hay production. Originally, only non-toxic forages were available on this farm,

including novel endophyte-infected tall fescue and bermudagrass. The bermudagrass is used predominately for hay production.

Both farms have a spring-calving season that extends from late January to March and cattle are rebred from late April to early May. Pregnancy checks are performed at approximately 60 days and again at approximately 120 days after breeding. During each pregnancy check, BCS are estimated for all of the cattle. Weaning is completed in early to mid-October, totaling approximately 230 days from birth to weaning. Cows are weighed pre-breeding and calves are weighed at weaning.

Data Collection:

The information and data provided in these records were collected by veterinary students from the Virginia-Maryland College of Veterinary Medicine (VMCVM). All data and information gathering activities are overseen by DVM instructors. The data used for this project were retrieved from the recordkeeper for the VADOC and included breeding and weaning records from years 2012-2019. The records were formatted in a Microsoft Excel spreadsheet with multiple tabs for each farm.

Visits were coordinated with each farm in April 2019 to collect tall fescue for ergot alkaloid analysis. At least 30 leaf samples were collected from each grazing field at each farm. Samples were randomly collected in multiple locations throughout the fields. Samples were collected in a random manner throughout the field. Spots in the field were hay was fed were avoided during sampling. The samples were lyophilized at the Southern Piedmont Agriculture Research and Extension Center. These samples were analyzed for total ergot alkaloids by a commercial lab (Agrinostics Ltd., Watkinsville, GA) using an ELISA-based system. Samples

from Sky Meadows were colleted by the Coffeewood farm manager and frozen until they were shipped to Agrinostics for analysis. Only leaf samples were submitted at the time of this study.

Reproductive data manipulation:

The cattle used for data analysis can be found in Appendix A. The data were summarized using the Pivot Tables function in MS Excel®. Tables were created based on calving rate, artificial insemination pregnancy rate, BCS, and pre-breeding weight. Cows at each farm were pregnancy checked twice during the season and BCS were taken at three different periods: pre-breeding, at first pregnancy check, and at second pregnancy check. BCS is used to analyze the changes in body condition throughout calving, pregnancy, summer grazing season, and to compare the effect of endophyte status on cow pregnancy and cow and calf production measures.

Some cattle were removed from the data set (Appendix B) based on the following criteria:

- No identification or data entry present in the data set
- The cow was brought to the farm mid-season as already bred
- The cow was not exposed via artificial insemination or natural service

Calving rate was not provided in the original records, but was calculated for each farm based on the number of calves born (alive or dead) divided by the number of cows exposed to breeding. Differences in live and dead births by pasture treatment also was recorded; calves were recorded as dead if they died within two weeks of calving. Cows that did not calve were labeled as open.

Weaning weight data manipulation:

Weaning weight data were gathered from separate records and (compiled in Appendix C). Some calves had to be removed from the data set and can be (referenced in Appendix D). Based on the following criteria:

- Died prior to weaning
- No identification or data entry present
- Sold prior to weaning
- Bottle-fed
- No weaning weight available

The data were summarized using the Pivot Tables function in MS Excel®. Tables were created based on the weaning weight and average daily gain. Average daily gain was calculated by subtracting weaning weight from birth weight getting the total gain then dividing by 230 days.

Climatology Data:

Climate data was gathered from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. Local climatological data was selected from Richmond International Airport (37˚ 30'17.28" N, 77˚ 19'19.56" W) in Richmond, VA. Richmond was the only centralized weather station location that was close to all three locations. Richmond is located 90.6 kilometers from Jarratt, VA, 133.9 kilometers from Mitchells, VA (Coffeewood), and 188.3 kilometers from Sky Meadows State Park. At the time of this manuscript, 2019 climate data was not available). The average maximum temperature was analyzed between the months of April through October to determine the average maximum temperature between the months of breeding, conception, and into the second trimester

Statistical Analysis:

A mixed ANOVA of birth weight, BCS, pre-breeding body weight, CR, AI pregnancy rate, WW, and ADG between forage type was conducted using the PROC MIXED procedure in SAS Studio, v. 3.8 (SAS Inst., Cary, NC). Experimental design was treated as a randomized complete block design with year as the replication and forage type as the treatment. Differences between treatments were considered significant when $P < 0.05$.

Results:

Ergot Alkaloid Concentrations:

Ergot alkaloid concentrations in the samples collected from Jarratt did not reflect the ergot alkaloid levels that correspond with the levels understood to be present in NE+. This may be explained by not managing the NE+ tall fescue to persist under intense grazing. At times E+ tall fescue may have been over-seeded leading to the NE+ tall fescue pastures to be contaminated over time with E+ tall fescue.

Table 1: Total ergot alkaloid concentrations (ppb) present in toxic endophyte-infected (E+) or novel endophyte-infected (NE+) pastures at Coffeewood, Jarratt, and Sky Meadows in April of 2019

Location	Pasture	Endophyte Status	Total ergot alkaloids	Cattle group[1]
Sky Meadows	1	E+	389	
Sky Meadows	2	E+	2526	
Coffeewood	1	E+	952	
Coffeewood	2	E+	677	
Jarratt	1	NE+	236	Heifers
Jarratt	2	NE+	0	4+ yr. old (AI)
Jarratt	3	NE+	1284	Bull-bred
Jarratt	4	NE+	2187	3-4 yr. old (AI)

[1] : Cattle at Jarratt are organized in pastures based on age/breeding groups

Climatological Data:

Climate data was based on data collected from the NOAA weather station in Richmond, VA (Figure 1). 2018 had the greatest temperature between April and October of 27.61ºC. The average minimum temperature was also analyzed. From 2012-2018, the year with the lowest minimum temperature was 2014 with 9.1ºC.

Extreme temperatures were analyzed from the climatology data. The year with the greatest number of days over 32.2ºC, was 2015 with 47 days. The years with the second largest number of days over 32.2ºC, were 2012, 2013, and 2018 at 46 days.

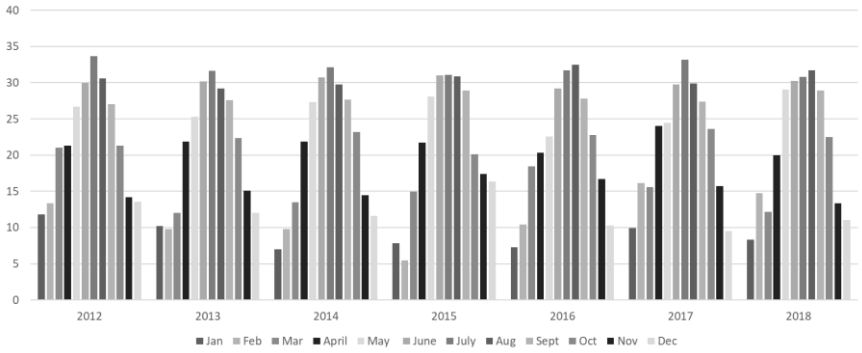


Figure 1: Average maximum temperatures for Richmond, VA for each month organized by year for the years of 2012-2018 (˚C).

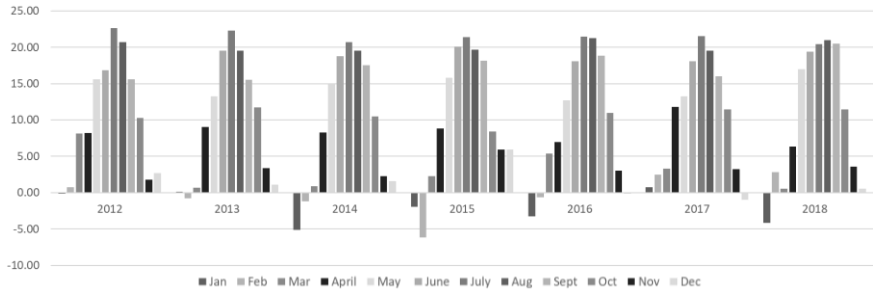


Figure 2: Average minimum temperatures for Richmond, VA for each month organized by year for the years of 2012-2018 (˚C).

Birth Weight:

Average birth weights from 2012 to 2019 was about 4 kg. greater (p = 0.0257) for animals on NE+ fescue (Table 2). Birth weights over time also were more variable with E+ tall fescue pastures.

Table 2: Average birth weight (kg.) of calves birthed from cows grazing either toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue for 2012-2019.

Year	Forage type	
	E+	**NE+**
	----- kg. -----	
2012	35	35
2013	34	36
2014	35	38
2015	31	40
2016	27	39
2017	37	n/a
2018	32	37
2019	36	38
Overall	**----- kg. -----**	
LSMeans	34	38
SE	3	2
*P*value	0.0257	

Body Condition Score and Body Weight:

BCS was (p = 0.0153) decreased for cattle on E+ tall fescue than for cows on NE+ tall fescue at the pre-breeding period. No differences in BCS were observed at subsequent measurement periods. Cows on E+ tall fescue had decreased (p = 0.0456) body weights at pre-breeding than cows on NE+ tall fescue.

Table 3: Average body condition score given pre-breeding, at first pregnancy check, and at second pregnancy check to cows consuming toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue for 2012- 2019.

Year	Forage type					
	E+	**NE+**	**E+**	**NE+**	**E+**	**NE+**
	Pre-Breeding		**First Preg. Ck**		**Second Preg. Ck**	
2012	5.3	5.3	6.1	5.2	6.1	5.3
2013	5.5	5.7	5.4	n/a	n/a	n/a
2014	5.0	4.9	5.2	4.8	4.9	4.8
2015	4.9	5.5	5.4	5.7	5.3	5.6
2016	5.4	6.0	5.3	5.3	5.4	5.4
2017	5.0	5.9	5.5	5.9	5.4	5.9
2018	5.1	5.5	5.2	5.9	5.6	6.5
2019	4.9	5.3	5.2	6.0	5.3	6.2
Overall	**----- BCS -----**		**----- BCS -----**		**----- BCS -----**	
LSMeans	5	6	5	6	5	6
SE	0.1	0.1	0.2	0.2	0.2	0.2
*P*value	0.0153		0.5974		0.3292	

Table 4: Average pre-breeding body weight (kg.) of cows grazing toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012-2019

Year	Forage type	
	E+	**NE+**
	----- kg. -----	
2012	525	500
2013	561	572
2014	499	508
2015	483	535
2016	498	599
2017	503	586
2018	527	619
2019	515	n/a
Overall	**----- kg. -----**	
LSMeans	514	560
SE	27	30
*P*value	0.0456	

Calving Rate (CR):

Cattle grazing NE+ tall fescue had the greatest ($p \leq 0.0243$) CR, but there were no differences ($p \leq 0.1553$) between treatments for the percentage of dead calves.

Table 5: Calving rate (%) of live calves born from cows grazing toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012-2019.

Year	Forage type	
	E+	**NE+**
	-----%-----	
2012	94	93
2013	89	89
2014	79	92
2015	93	96
2016	85	93
2017	92	93
2018	90	96
2019	89	95
Overall	**----- %-----**	
LSMeans	89	94
SE	1	1
*P*value	0.0243	

Table 6: Calving rate (%) of dead calves born to cows grazing toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012-2019.

Year	Forage type	
	E+	**NE+**
	-----%-----	
2012	4	5
2013	4	7
2014	18	3
2015	1	0
2016	3	2
2017	3	1
2018	3	1
2019	9	4
Overall	**----- %-----**	
LSMeans	5	2
SE	1	1
*P*value	0.1553	

Pregnancy Rate:

Animals on NE+ had 20% greater (p = 0.0011) pregnancy rates than those on E+ tall fescue.

Table 7: Artificial insemination pregnancy rate (%) for cows grazing toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012- 2019.

Year	Forage type	
	E+	**NE+**
	-----%-----	
2012	35	46
2013	55	56
2014	49	60
2015	31	37
2016	43	58
2017	42	49
2018	50	56
2019	42	49
Overall	**----- %-----**	
LSMeans	43	52
SE	1	1
*P*value	0.0011	

Weaning Weight:

Calves grazing E+ tall fescue weighed less (p = 0.0217) at weaning than calves grazing NE+. ADG was decreased for calves consuming E+ tall fescue than NE+ tall fescue (p = 0.0203).

Table 8: Average weaning weight of calves grazing or pastured on toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012-2019.

Year	Forage type	
	E+	**NE+**
	----- kg. -----	
2012	273	263
2013	255	251
2014	229	236
2015	242	285
2016	246	280
2017	252	296
2018	271	298
2019	273	263
Overall	**----- kg. -----**	
LSMeans	254	278
SE	13	13
*P*value	0.0217	

Table 9: Average daily gain (kg.) of calves grazing toxic endophyte-infected (E+) or novel endophyte-infected (NE+) tall fescue from 2012-2019.

Year	Forage type	
	E+	**NE+**
	----- kg. -----	
2012	1.04	1.0
2013	n/a	n/a
2014	0.86	0.86
2015	0.91	1.04
2016	0.95	1.13
2017	0.95	1.32
2018	1.04	1.18
2019	1.0	
Overall	**----- kg. -----**	
LSMeans	0.95	1.09
SE	0.1	0.1
*P*value	0.0203	

Discussion:

The goal of this study was to determine if cattle grazing E+ tall fescue had decreased reproductive and weight gain performance compared to cattle grazing NE+ tall fescue. Birth weight, body condition score (BCS), body weight, calving rate, pregnancy rate, weaning weights, climate data, and ergot alkaloid concentrations were compared for each forage type. Cows and calves on E+ tall fescue had decreased reproductive and growth performance than cows and calves on NE+ tall fescue at two farms in Virginia. Decreased birth weights, weaning weights, and average daily gain were observed in calves. Decreases in BCS of cows at pre-breeding and during pregnancy checks were observed in herds grazing E+ tall fescue. Although, with a small amount of the NE+ pastures contaminated with E+, cattle stocked on these pastures still performed better than cattle on E+ tall fescue. Similar results can be found in a study completed by Caldwell et al. (2013) on the differences in spring- and fall-calving systems and a 25% pasture conversion to NE+ tall fescue. Caldwell et al. (2013) found that by converting pastures to 25% NE+, calving rates increased 36% compared calving rates on 100% E+ pastures.

Birth Weight:

Calves produced from cows grazing E+ tall fescue collectively had decreased birth weight when compared to calves of cows consuming NE+ tall fescue. Dryer (1993) studied vasoconstriction of uterine and umbilical arteries in ewes and found that ergovaline (most common ergopeptide) constricted uterine and umbilical arteries. This constriction caused reduced fetal growth in livestock (Dryer, 1993). Watson et al. (2004) similarly found that cows grazing the wild-type tall fescue had calves with reduced birth weights when compared to other fescue types.

Weaning Weight:

WW also followed the same pattern as birth weights. Calves raised on E+ tall fescue weighed less at weaning than calves grazing NE+ tall fescue. The effects of fescue toxicosis can be passed from the cow to the calf through decreased birth weights and WW (Miller, 2009). Decreased prolactin production leads to decreased milk production (Peters et al, 1992) in cattle grazing E+ tall fescue and nursing calves. Due to these decreases, calves exhibit reduced WW when compared to cattle grazing alternative forages, such as NE+ tall fescue. Other studies also suggest that the decrease in serum prolactin production of cows grazing E+ tall fescue has an effect on milk production, thus resulting in reduced weaning weights of calves (Schmidt et al., 1986; Koltz, 2015). Steers grazing E+ tall fescue were shown to have a reduction in ADG compared those grazing endophyte-free or forage types (Paterson et al, 1995). Cattle have increased toxicity effects when grazing E+ tall fescue and exposed to stressful environmental conditions (extreme heat or cold) (Peters et al, 1992). Settivari et al. (2007) found that ADG was reduced in calves due to a reduction in feed intake.

Body Condition Score and Body Weight:

Cattle grazing E+ tall fescue exhibited decreased BCS at pre-breeding when compared to cattle grazing NE+ tall fescue. Schmitt et al (1986) found that a decrease in weight loss and BCS occur in cows consuming E+ tall fescue. DeRouen et al. (1994) found that when BCS are given at calving for first-calf heifers, it is a more reliable indicator of the reproductive performance at breeding. Hess et al. (2005) found that cattle that have nutritional deficiencies pre-partum, will have a decreased BCS post-partum resulting in decreased weight gain in calves (Paputungan and Makarechian, 2000). The third trimester of pregnancy for spring-calving herds typically occurs in the middle of winter when their forage is least nutritious. (Paputungan and Makarechian,

2000). Calves from herds lacking sufficient nutrition will ultimately weigh less and gain less than other calves from herds with sufficient nutrition during the third trimester. The comparison between forages showed cows grazing E+ tall fescue weighed less than NE+ tall fescue.

Pregnancy Rate:

Schmidt et al. (1986) also found that for every increase in ergot alkaloid concentrations (5%, 60%, 99%), the number heifers that conceived and maintained a pregnancy (96%, 82%, 55%) decreased. Gay et al. (1988) noted a decrease in pregnancy rates for cattle grazing E+ tall fescue. A decrease in conception and pregnancy rates can be attributed to a decrease in feed intake, weight gain and body condition in cattle consuming E+ tall fescue (Paterson et al., 1995). DeRouen et al. (1994) found that cows with a BCS of 5-6 had greater pregnancy rates and reduced postpartum intervals than cows that had a lesser BCS (4-5). Poole et al. (2018) conclude that the reduction in pregnancy rates could be due to the lack of blood flow to the reproductive system in cattle consuming E+ tall fescue.

Calving Rate:

Cows grazing E+ tall fescue had a larger percentage of open cows when compared to cattle grazing NE+ tall fescue. Many studies have reported decreases in calving rates due to the consumption of E+ tall fescue (Hazlett, 1999, Looper et al, 2010). Research is still being conducted to determine the cause of this decrease (Miller, 2009). Beers and Piper (1987) cited that cows consuming E+ tall fescue had decreased conception rates than cows consuming endophyte free (E-) tall fescue. Caldwell et al. (2013) suggests that cattle have increased calving rates when utilizing a fall-calving system or by converting a percentage of the pasture to NE+ tall fescue. In a fall-calving system, cattle are not subjected to increased ergot alkaloid concentrations and heat stress while breeding. By converting a portion of the pasture to NE+ tall

fescue, cattle are not consuming solely E+ tall fescue which helps to mitigate the effects of the ergot alkaloids.

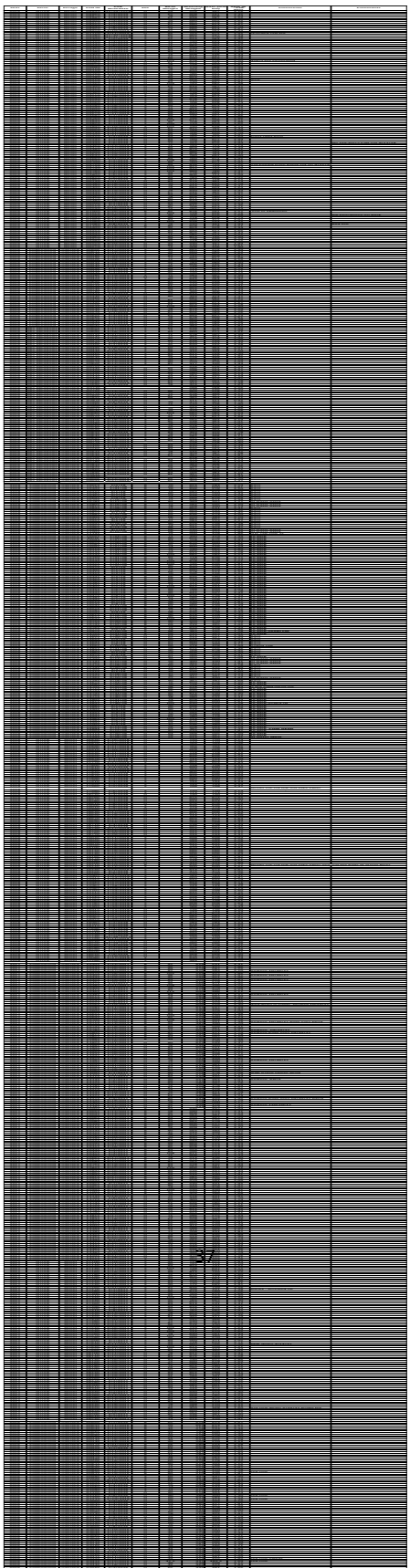
Climatological Data:

The goal of analyzing climatology data was to determine a correlation between extreme temperatures and decreased reproductive performance. It is understood that environmental factors, such as heat stress, play a role in the severity of fescue toxicosis and are linked to decreased production (Burke et al., 2001b). Reductions in body weight and conception rates were found in 2015. This could be because this was the year with the most days over 90˚. 2014 had the most days (86) where the minimum temperature was below 0˚ C. 2013 followed next with a total of 77 days below 0˚ C. There are changes in birth weight, WW, ADG, body weights, CR, and PR data for E+ and NE+ tall fescue, but it is not apparent that these fluctuations are caused by temperatures below freezing.

Implications:

It was found that reductions in birth weights occur in calves produced from cows that graze E+ tall fescue. Lactating cows had reduced body weight and condition when grazing E+ tall fescue and exposed to heat stress. A.I. conception rates and calving rates were also reduced for cattle grazing E+ tall fescue. Growth traits in calves, such as weaning weights and ADG were reduced due to the consumption of E+ tall fescue. Further research should be conducted on the ergot alkaloid types and concentration, reinfection rates, and management of E+ and NE+ tall fescue. An economic analysis is needed that compares the costs renovation of E+ pastures and hay land to NE+ tall fescue. The cost of reduced production efficiency in cattle should also be included, such as the loss of pregnancy, WW, and ADG, this will help determine how feasible conversion is for the commercial cow-calf producer.

Appendix A:



Appendix B

Appendix C

Appendix D

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