Complementing and improving grazing systems for stocker and cow-calf production

by

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Abstract

Grazing management strategies have given producers the ability to both improve rangeland and grazing lands, while also the potential to destroy quality and profitable grazing prairie through overgrazing, overstocking, understocking, and improper knowledge of natural flora and cattle grazing behaviors. Overgrazing often leads to the encroachment of noxious weeds. The Flint Hills of Kansas suffers from the increasing number of infested acres of *Sericea lespedeza*, an invasive plant. Although at one time it was used for soil erosion control and as a hay crop, wild *S. lespedeza* contains high levels of tannins, thus decreasing the palatability for grazing animals. Because complete eradication is unlikely, producers use a variety of methods to decrease encroachment and plant numbers. The goals of range management remain constant, regardless of geographical location or size of operation. Improvement of rangeland does not occur instantaneously, but with dedication, advancement will occur. Grazing management also incorporates an understanding of supplementation strategies to either improve animal performance, pasture performance, or a combination of both. Four studies were conducted to evaluate of several management options that can be used to improve pasture management for grazing cattle. Study 1: The objective was to utilize cattle to manage *S. lespedeza* in pastures. Pastures (n = 8) had four treatments applied that consisted of CON (no management), spraying high *S. lespedeza* infestation areas within pasture with a molasses spray at 12.5, 25, or 50% (v/v). Plant counts and animal grazing behavior were evaluated over a 92 d grazing period on tallgrass native range. Spraying *S. lespedeza* with molasses reduced the number of plants growing as compared to CON. Specifically, the 12.5% level had greater control than the 50% with 25% being in the middle. These results could be explained by steers spending more time in the areas immediately surrounding the 12.5% than any other treatment. Even though spraying *S. lespedeza*

plants with molasses resulted in a lower number of plants at the end of the grazing period, this management option may not be practical for producers to implement. The cost for the molasses and labor made this more expensive than spraying techniques and burning. Additionally, molasses was damaging to spray equipment, thus needing replaced several times, which further increase cost. Study 2: the objective was to evaluate steer growth performance, pasture utilization, and ruminal fermentation characteristics (via *in vitro* procedures) of mineral supplements that contain either lasalocid, an ionophore (ION) or essential oils (EO), or both. Briefly, 281 steers were allowed to graze tallgrass native range for 92 d during the summer. Steer body weight gains, mineral intake, and forage intake were not different based on mineral supplemented to steers. Addition of minerals increased ruminal energetics and this was enhanced by addition of ION and EO and even further improved with the COMBO of ION and EO. Based on these results, there is potential for EO to replace the ION for cattle operations that are marketing animals in the natural and/or organic feeding programs. Study 3: Evaluation of corn silage supplementation on different varieties of fescue for cow-calf operations for cattle performance and forage utilization. Two years of data were collected on multiparous and primiparous Angus-cross beef cows (n = 45; Year 1 and n = 48; Year 2) grazing two varieties of fescue (TOX and NONTOX) in a 2 x 2 factorial arrangement where the second factor was supplementation (NOSUPP; no supplementation or SUPP; supplementing cows 1% of BW on DM basis of corn silage daily). Cow and calf growth performance were measured from mid-second trimester through weaning. Supplemented cows had greater weight gain through the entire supplementation period and had greater increase in BCS from 3rd trimester through lactation. Supplementation had no effect on calf birth weight or milk production. Supplementation tended to increase forage mass by 7.48% over NONSUPP pastures, while not impacting forage accumulation or quality. Weaning weight tended to be greater for NONTOX-SUPP as compared to TOX-SUPP and TOX-NONSUPP. Cows grazing TOX fescue had lower weight gains, more hair length, greater hair score, and lighter calf birth weights than NONTOX. TOX pastures had 12.27% greater forage mass with no differences in forage accumulation. Replacing toxic fescue with non-toxic varieties is a better option to improve productivity in cow herds than offsetting issues with supplementation. Supplementation may only have benefits during low forage years. Study 4: Evaluation of corn silage supplementation on bermudagrass pastures for cow-calf operations for cattle performance and forage utilization. Two years of data were collected on multiparous and primiparous Angus-cross beef cows (n = 24 each year) grazing bermudagrass pastures (n = 8; 3 cows per pasture) and received one of two supplementation treatments (NOSUPP; no supplementation or SUPP; supplementing cows 1% of BW on DM basis or corn silage daily). Each pasture contained a bred heifer (<2 years of age), 3-5 year old cow, and a 6+ year old cow. Cow and calf performance was measured from mid-second trimester through weaning. Supplementing had no effect on body weight, body condition score, hair length, nor hair score. Rump fat was increased with SUPP during the second trimester. Supplementation had no effect on calf birth weight and estimated milk output, but dams that were NONSUPP during gestation had greater dam adjusted 205 d weaning weight. First calf heifers had the lightest birthweight calves, lowest milk output, and lightest actual weaning weight while the OLD (>6 yr old) dams had the highest values and MID aged cows intermediate. Forage accumulation, forage mass, and forage nutrient quality were not impacted by supplementation methods. Offering corn silage to pregnant non-lactating cows grazing high quality bermudagrass could slightly improve cow condition but had no other economic benefits. Feeding 1% of corn silage daily was not a sufficient amount to result in more available forage.

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Chapter 1 - Literature Review

Introduction

Throughout Kansas and surrounding states, invasive plant species are encroaching on native prairie and grasslands, reducing the quality native tall grass range for large mammalian herbivores to graze. Through dedication and education, stewards of the land can continue to sustain the largest intact tallgrass prairie remaining in North America (2012). The Flint Hills of Kansas, which is included in the remaining intact tallgrass prairie, provides grazing for over one million cattle annually, including 500,000 grazing yearling steers and 275,000 beef cattle locally owned by ranches in the Flint Hills region (Beam, 2010).

Grazing management is both an art and a science (Robinett, 2002). Managers have both the ability to improve rangeland and increase grazing uniformity but also could destroy quality and productive rangeland through overgrazing, overstocking, and/or improper understanding of plant science and cattle grazing behaviors. Many strategies that are used today have been known for 70 years (Williams, 1954). Williams (1954) states that grazing problems have existed since the range was first stocked with ruminants. Efficient and proper grazing becomes more difficult with the increase in grazing units, class of grazing stock, distance from a water source, fencing, salt location, supplementation, and rangeland conditions. Rangeland managers are often reluctant to change strategies and management due to high cost, or an increased amount of labor involved (Bailey, 2004). The goals of rangeland management remain constant, no matter the geographic location or size of operation. Common rangeland goals include; 1) identifying optimal stocking rate, 2) identifying optimal grazing periods, 3) understanding type of grazing animal needed for optimum forage usage, and 4) undehttps://krex.k-state.edu/info/guidelines/keywords rstanding optimal grazing distributions (Vallentine, 2000). Improving rangeland will not occur instantly, but with dedication, improvement of land can be achieved. Often profitability is a turning point for producers and range managers to alter grazing systems.

Tall Grass Prairie

Tallgrass prairie is now the most endangered ecosystem in North America (Samson and Knopf, 1994). Prior to European colonization, tallgrass prairie inhabited more than 68 x 106 hectares in the North American Great Plains (Samson and Knopf, 1994; Wagle and Gowda, 2018). Once spanning 170 million acres from Texas through Canada and as far east as Indiana (Hickey and Webb, 1987), native tallgrass prairie has decreased by 99.9% since European settlement (Samson and Knopf, 1994). The remaining tall grass prairie still provides grazing opportunities for grazing livestock systems in multiple states. In some areas management is low, while others are managed well to combat decreasing tallgrass prairie range. Ultimately, tallgrass prairie is less managed than crop land (Wagle and Gowda, 2018). Through effective and inefficient management practices, remaining tallgrass prairie is subject to drought, fire, and overgrazing. Comprehension of the consequences that might occur through disturbances of the natural flora, nutrient recycling, and plant communities is necessary for conservation and economic advancement.

Sanders et al. (2002) stated that Best Management Practices, hereafter referred to as BMP, was determined through years of research of effective management practices and created effective yet practical ways to conserve soil, improve agricultural productivity, and reduce water pollutants. Best management practices can be traced back to the 1930’s, the Dust Bowl era. Following what was thought to be longest drought known to man, farmers and ranchers recognized the importance of stewardship and dedicated their lives to perseverance. The Soil

Conservation Service (SCS) was established on the 27th day of April in 1935 as a branch of the USDA to financially incentivize producers to remove unavailing production crop ground out of production in hopes to return the baron ground to its natural state. Later renamed as the Natural Resource Conservation Service, it promoted terraces, contour plowing, and crop rotation. Today, BMP is still used in both crop production and prairie preservation.

King (2016) summarized the four most dominant grasses in the Flint Hills as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Other introduced grasses utilized for grazing in Kansas include bermudagrass (*Cynodon dactylon*), old world bluestems (*Bothriochloa*), brome (*Bromus*) and tall fescue (*Festuca arundinaceus*) (Ohlenbusch and Jones, 2002).

Tallgrass prairie consists of both cool season grasses (C3) and warm season grasses (C4) grasses and C3 forbs (Wagle and Gowda, 2018). C3 grasses, also known as cool season grasses, are best grown and able to fixate CO2 in cooler environments. During events of photorespiration, cool season grasses often become dormant due to inadequate amounts of energy (Talburt, 2020). C4 grasses, also known as warm season grasses, primarily thrive in the southern United States. C4 grasses utilize a different enzyme to attach the CO2, creating a 4-carbon compound. By using a different enzyme, C4 grasses require more energy to produce carbohydrates. Compared to C3 grasses, C4 grasses do not use photorespiration and results in a larger amount of carbohydrate production (Talburt, 2020). When cool season grasses are not able to remain green in color and continue growing, warm season grasses thrive but have an increased amount of water and nitrogen usage. The recycling of nitrogen and carbon through root decay alters plant communities and forage quality of hay and pasture grazing (Tian et al., 2003). Still et al. (2003)

recognized that C3 grasses grow primarily in the spring and fall, while C4 grasses dominate during the summer months.

King (2016) states that BPM for tallgrass, shortgrass, and mixed grass prairie are all similar in the fact that they should include proper stocking rates, grazing distribution, planned rest seasons, and control of noxious invaders and brush. ‘Proper’ stocking rates, distribution of grazing and rest seasons can all be attributed to the amount of rainfall that is received through the growing season. Having the largest effect on grazing capacity and land management, the amount of rainfall that is received at the beginning of the grazing and growing season and the combined amount during the grazing season results in grazing operations and managers having different needs and practices (Redfearn et al., 2005). Not only does rainfall dictate plant growth and performance, but it can also limit cattle performance (Ohlenbusch and Jones, 2002).

Cattle Grazing Strategies

Lyons et al. (1999) recognize three different types of grazing ruminants; grazers, intermediate feeders, and browsers. Cattle and bison are known as grazers and consume grass as a large percentage of their daily forage intake, which are high in fiber and lower in readily digestible materials. Browsers, such as white-tailed deer, ingest large amounts of forbs, which are high in readily digestible materials and low in fiber. Rapidly digestible forages pass at a rapid rate through the digestive tract, which results in higher intake rates. Intermediate feeders, such as sheep and goats, consume relatively equal amounts of grass and forbs, intermediate to that of grazers and browsers. Smaller ruminants and intermediate feeders have the ability to become more selective in their browsing and grazing due to different mouth parts that grazers do not have.

Owensby et al. (2008) acknowledged that grazing systems should be created with the dominant grazing species in mind and configuring an appropriate stocking rate that will optimize livestock gain per animal unit, without decreasing gain per animal. Differences in livestock gain tend to decrease as the growing season begins to conclude due to the amount of forage regrowth slowing and plants maturing. Briske et al. (1982) and Curll et al. (1982) recognize this occurrence through two different aspects. First, with an increased number of cattle grazing a certain area, plants are often regrazed more often, decreasing their ability to produce new leaf area. Second, the area that is grazed when stocking rates are increased is not linear. A grazing study conducted in 1997 on tallgrass prairie using yearling steers found that doubling the acceptable stocking rate for the first half of the grazing season did not double the area grazed. In fact, the area grazed at 2x the stocking rate was 1.45 times that of the 1x rate. Oppositely, Owensby et al., (2008) recognized that grazing heavy early in the season and decreasing stocking rate during the second half of the grazing season tends to allow stocking rates to be increased without decreasing production rates of grazing animals. This resulted in lower animal gains due to the reduced productivity of frequently grazed tillers plus the decreased regrowth area per animal during the late season (Brock, 1997).

Owensby et al. (1978) recognized the two most common grazing practices in the Flint Hills of Kansas being season-long stocking and intensive early stocking. Both begin in late April. Season-long stocking (SLS) concludes in early October while intensive early stocking (IES) concludes in mid-June (Owensby and Smith, 1978). By utilizing an IES rate, stocking rates are able to be doubled without harmful damage to native range. Owensby et al. (2008) found that using a fixed sequence stocking rates and various grazing seasons increased the yearly return per hectare. Owensby et al. (2008) implemented a three-year, three-pasture grazing study to identify which would increase profitability for producers. Each of the two conventional grazing systems served as controls during a 9-year study and used to compare a grazing scheme known as the IES+ system. The IES+ system is a combination of three pastures. The first pasture was grazed for the entirety of the grazing season; late April through early October. The second was grazed using an intensive-early rate; late April through mid-June, while the third was grazed from late April to mid-June at twice the stocking as the season-long rate and then at the rate of season-long for the remainder of the grazing season. Each pasture rotated through each of the grazing strategies 3 times over three years to draw the conclusion of an increased return per hectare rate of $5.98 in the year 2006, compared to both conventional grazing systems used (SLS and IES). Twelve yearling steers were utilized yearly averaging an approximate starting weight of 250 kg. Owensby et al. (2008) recognized that when pasture rent is charged on a per-head basis, returns per hectare are much higher when implementing the IES+ system. This may differ if rent is charged per steer, per hectare, or if no rent is charged. Due to a multitude of factors (i.e. rainfall amounts, weights of calves, and length of grazing season, returns differ. Due to inflation of the U.S. dollar, $5.98 in 2006 is equivalent to $9.36 in 2025. According to CPI (2025), the dollar has an average inflation rate of 2.39% per year, resulting in 56.49% over 19 years.

Hart et al. (1993) summarized a list of names and characteristics of short-duration grazing. Some nomenclatures used include: Savory Grazing Method (SGM), Holistic Resource Management (HRM), planned grazing, and short-duration rotational grazing. Short-duration grazing includes multiple pastures, a high stocking rate density, and is grazed for a short amount of time so that regrowth of forage is not ingested within the grazing period. The largest benefit that is claimed to be achieved through short-duration grazing is hoof action through a heavy stocking rate and lower acres available for cattle to graze. Savory (1983) states that hoof action breaks surface crust of the grazed area, which in turn, helps with water infiltration, implements manure into the soil, thus increasing nutrient cycling. Hoof action is also known to bury seeds to increase establishment. This can be both positive and negative, depending on the seed species and their mode of action. Little research has confirmed the claimed benefits of implementing short-duration rotational grazing to animals, plants, and pasture (Hart et al., 1988; Goodloe, 2013). Although Hart et al. (1988) confirmed that stocking rates that are increased above 'government-prescribed' amounts can become profitable, Laycock (1983) stated that profitability may occur through more ways other than increasing stocking rates and the rotation of grazing cattle.

Determining the correct carrying capacity of grazing land is pertinent for all grazing managers and ranchers. Forage quality and forage intake go hand in hand when determining carrying capacity. With overstocking, overgrazing will occur, decreasing productivity and profitability of grazing land. The NRC (National Research Council. Subcommittee on Feed, 1987) reported that standing forage crop levels above 1,133.98 kilograms per acre will not limit intake for most grazing livestock. However, there is a decline in forage intake, thus reducing production, when standing forage levels decrease from 1,133.98 to 453.59 kilograms per acre. (Stuth and Sheffield, 1986; Marston et al., 1998; National Academies of Sciences et al., 2016; Lalman and Holder, 2024)

Cattle Grazing Behaviors

Landscapes across the world are naturally formed and maintained by grazing ruminants and herbivores. Numerous studies document what herbivores eat and how composition changes under different management practices, but less research has been reported on the behavior of such herbivores. Cattle are more partial to eating leaves over stems of plants and green forage over dried-brown forages (Provenza et al., 2015). Through selective foraging, associated conditioning can occur, ultimately changing the cow's grazing forever. Provenza et al. (2015) recognized that the grazing decisions that cattle make are due to two different aspects; learned behavior and or a wanting/liking of a certain plant. Often these two factors go together. "Wanting" a certain plant or plants is motivation for reward through either external stimuli or the internal state of the grazing animal, while "liking" is encouraged through responses either consciously or unconsciously (Bailey et al., 2015). Associated conditioning of grazing cattle is noticeable when cattle are placed in novel grasslands with a large number of cattle experiencing difficulties keeping adequate body condition scores than their experienced counterparts who have grazed on the grassland prior (Provenza et al., 2015).

Beef cattle grazing selection has spanned multiple generations, ultimately influenced during developmental periods in utero, early life, and during growing phase which can alter food preferences later in life (Villalba et al., 2015). Sheep exposed to saltbush (Atriplex spp.) in utero often grow at an exponential rate and are able to handle larger salt loads than those developed in sheep that were not (Longmore, 2016). Sheep and cattle that are introduced to highly fibrous forages have an increased amount of nitrogen retention and can completely digest fiber compared to those who were not developed on highly fibrous diets (Distel et al., 1994; Wiedmeier et al., 2012). A large reason grazing ruminants utilize selective grazing is to sustain an energy and protein balance in their diets which is ultimately achieved through association of flavors of feeds and nutrient feedback (Galyean and Gunter, 2016). Forage intake will often decrease with an inappropriate balance of energy related to the balance of protein but will in turn increase when the energy and protein ratios are balanced (Poppi and McLennan, 1995; Hill et al., 2009). Odadi et al. (2013) reported that cattle (BW = 301 ± 26 kg) that were grazing low-quality forage and supplemented with 500 grams per day of 32% crude protein grazed 76% less forbs than their counterparts that were not supplemented to maintain an appropriate energy to protein balance. This proves that cattle seek different dietary intakes to create a balance in their protein-to-energy intake through short-term intake of associated flavored foods. The balancing of diets will eventually impact voluntary intake due to the fact cattle will graze and search for forages that meet their internal needs of homeostasis (Gregorini et al., 2008). Overall, this implies that each grazer, disregarding species, potentially selects their diets depending on genetic and learned preferences, resulting in nutritionists experiencing difficulties properly managing grazelands.

Confined cattle are provided uniform diets to optimize growth and decrease days on feed (Leonardi and Armentano, 2003; DeVries et al., 2007). Contrarily, grazing cattle's diets differ each day due to selective grazing and learned behavior (Galyean and Gunter, 2016). Grazing diets also change after each meal due to different available forages, which is complex to understand and hard to quantify (Bohman and Lesperance, 1967; Villalba et al., 2015; Galyean and Gunter, 2016). Cattle typically graze 11.3 hours per day in May and June and decrease grazing times to 9.5 hours per day in August and September due to a decreased amount of daylight (Walker et al., 1989). Another study found that yearling steers often graze for 8.5 hours per day during daylight hours (Hepworth et al., 1991). When comparing the Walker et al. (1989) study and the Hepworth et al., (1991) study, differences in each study can potentially determine why they found different amounts of time cattle graze. Walker et al. (1989) studied the grazing habits of 125 Angus x Hereford crossbred cows grazing at the Texas Experiment Ranch on the eastern edge of the Rolling Plains resource region. These cattle were stocked at a heavy stocking rate of 3.7 hectares per cow per year. The Hepworth et al. (1991) study utilized either Hereford x Angus x Simmental or Hereford x Angus x Charolais yearling steers averaging 247 kilograms in weight. Steers were grazing the High Plains Grasslands Research Station (~10 km Northwest of Cheyenne, Wy). Two different stocking rates were used between the studies: Moderate (4 steers / 12 hectares) and Heavy (4 steers / 9 hectares).

Terrain not only plays a large role in the distance that cattle must travel to water and mineral locations, but it also plays a significant role in the utilization of herbage on grazinglands (Bailey et al., 2015; Ginane et al., 2015). Bailey et al., (2015) reported that cattle grazing homogeneous terrain altered their feeding sites more frequently than those grazing heterogeneous terrain. Slope percentages also tend to decrease grazing frequencies of grasslands. Cattle have been documented avidly avoiding grazing lands that have slopes greater than 10% (Mueggler, 1965; Cook, 1966; Gillen et al., 1984). During the same experiment, slopes between 11 and 30% resulted in a decrease in grazing by 30%. Slopes between 31 and 60% reported a 60% decrease in grazing, and slopes over 60% were avoided during grazing. Remaining on grazing areas longer results in a decreased diet diversity than cohorts that move to grazing sites more frequently (Bailey and Provenza, 2008). Walburger et al. (2009) reported that cows between the ages of 2 and 8 years often graze at higher elevations, travel greater distances between water sources and grazing areas, and roam farther from protection. This results in older cows being much more efficient in grazing due to a larger range of grazing, increased distance traveled, and diet variety. Sproul et al. (2008) reported that cattle will remain between 650 yards of self-fed supplements up to 40% of the time. But the limitations include terrain and mineral delivery methods.

Overgrazing Leads to Noxious Weed Invasion

Intensive livestock grazing pressure on native vegetation often leads to degradation of pastoral lands (Scarnecchia et al., 1995). Ibanez et al (2007) recognize that the impacts of grazing are often quantified through the density of the individual ruminant species, their dietary preferences and their grazing behaviors. Hall (1994) summarized that cattle graze differently, depending on grass height. For example, if grass stubble is greater than 3 inches, cattle will reach their tongue out of the side of their mouth, to draw in vegetation. But, when stubble height is lowered to 3 inches or smaller, they begin to ingest forage by eating in bites, taking twice as much time and effort. The thickness of a cow's lower lip is a limiting factor when grazing. When forage height is less than ¾ inch, cattle must move locations to continue grazing (Van Soest, 1982). With excessive stocking rates, Heady et al., (1995) found a reduction in plants cover, and ultimately a reduction in plant diversity. The reduction of plant cover decreases the supply of organic matter in the soil, resulting in decreased infiltration capacity, increased runoff production and soil erosion (Ibanez et al., 2007). Often, people fail to realize that plants require a growth phase before grazing occurs to help to maintain native vegetation for grazing lands (Smith, 1940). By allowing a growth phase during the Spring, before grazing, plants are able to utilize in-ground reserves, increasing plant productivity. This ultimately dictates the proper stocking rate and duration of grazing allowed without detrimental effects (Smith, 1940).

The impact of overgrazing on grasslands may be slow but has a detrimental change in botanical composition due to the plant variety's coverage, palatability, and productivity (Shankarnarayan, 1977). Smith (1940) recognized that early and continuous grazing will ultimately eliminate desirable plant populations, and in their place unpalatable and unwanted species will claim territory. Overgrazing, not only through excessive stocking rates, may also occur through hoof trampling. Shankarnarayan (1977) suggested that trampling of forages is far more detrimental than mouths, especially when cattle are congested in pastures and around watering locations.

Overgrazing and overutilization for multiple years often leads to an increase of noxious weeds that cattle are not enticed to graze. This leads to an overpopulation of noxious weeds and a decrease in native grasses. The Kansas Department of Agriculture created a list of noxious weeds, separated into three categories (A, B, C) that have become threats to the Kansas environment, as they interfere with property values, production of agricultural crops and destroy wildlife habitats (Marsh, 2024). Categories A noxious weeds are generally not found in the state of Kansas but are subject to active eradication wherever detected. Category A noxious weeds include; Hoary Cress (Lepidium Draba), Leafy Spurge (Euphorbia virgate), Quackgrass (Elymus repens), Russian Knapweed (Rhaponticum repens), Kudzu (Pueraria montana var. lobata), Pignut (Hoffmannseggia gluaca). Category B weeds are found in limited distributions throughout the state and are subject to immediate control wherever detected. The only Category B noxious weed listed on the Kansas Noxious Weed List is the Canadian Thistle (*Cirsium arvense*). Category C noxious weeds are known to be well-established and are known to be in large populations throughout the state. New populations of category C noxious weeds are subject to efforts for eradication and manipulation of populations. According to the Kansas Department of Agriculture, category C noxious weeds include Field Bindweed (*Convolvulus arvensis*), Musk Thistle (*Carduus natans*), Sericea Lespedeza (*Lespedeza cuneata*), Johnsongrass *(Sorghum halepense*), and Bur Ragweed (*Ambrosia grayii*).

Sericea Lespedeza (Lespedeza cuneata)

History and Geography

Sericea lespedeza, a perennial legume, was first introduced into the United States in 1896 by the North Carolina Agriculture Experiment Station (Schwendiman et al., 1985) from Japan to increase forage production and help to combat erosion control, increase hay production, and reseed wildlife food plots (Eddy et al., 2003; Ohlenbusch et al., 2007; Cummings et al., 2017). *Sericea lespedeza*, hereafter referred to as *S. lespedeza*, was seeded in strip-mined land in Southeast Kansas and Missouri in the 1930's and then additionally seeded land plots for wildlife habitats in Kansas federal and state reservoirs from 1940 to 1970 (Ohlenbusch and Jones, 2002). What seemed to become the perfect forage to help improve the quality of land from the detrimental effects of strip mining,began to cause concern as it threatened vegetation composition and prairie ecosystems (Eddy et al., 2003). This has resulted in widespread areas of S. lespedeza being found in Kansas (Figure 1).

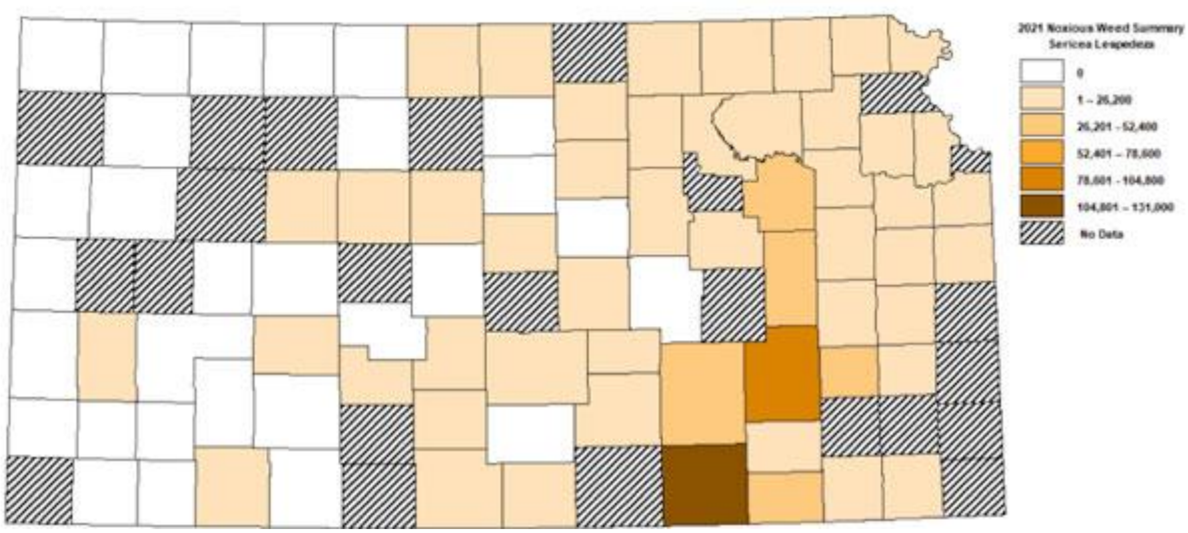

Figure 1.1 Distribution of *Sericea lespedeza* in Kansas (KNWS, 2021).

Sericea lespedeza matures to 3 feet tall with trifoliate leaves. In early August, *S. lespedeza* will begin blooming cream flowers with a purple throat. Most seed production occurs in September. Cummings et al. (2017) reported pure stands of *S. lespedeza* are extremely prolific and may produce 195-386 kilograms of seeds per hectare, with each kilogram containing 350,000 seeds, with an expected 10-20% germination rate. *Sericea lespedeza* is relatively effortless to establish, but germination and seedling growth increases with increasing daylight and temperatures ranging from 20 to 30°C (Ohlenbusch et al., 2007). Blocksome (2006) reported that *S. lespedeza* is able to reproduce through colonial formation and through seed germination. As the plant begins to mature, *S. lespedeza* restricts daylight to other plants due to a taller height and dense foliage. Due to inefficient water use, *S. lespedeza* also requires more water than most warm-season plants. Cummings et al. (2017) recognized that not only does *S. lespedeza* complete for light, nutrition, and water, it produces an allelopathic component, which negatively impacts the germination and growth of competing plants. For more than 40 years, *Sericea lespedeza* has spread through the ranges of Kansas, Missouri, Oklahoma, and eastern Texas at an expeditious rate due to its ability to withstand drouth conditions, acidic shallow and low fertility soils (Eddy et al., 2003; Ohlenbusch et al., 2007). Currently, *S. lespedeza* lespedeza infests over 650,000 acres in Kansas alone (Fick, 2022).

Although *S. lespedeza* is considered a noxious weed in the state of Kansas, *S. lespedeza* is grown in southern states as a production forage and is commonly known as ‘poor man’s alfalfa’ or ‘smart man’s alfalfa’ (Terrill and Mesjidis, 2017; Tracy et al., 2022). *Sericea lespedeza* has been grazed and used as a hay crop in the United States for ~100 years and South Africa for ~30 years due to its hardiness and ability to grow in acidic soils (Fair, 2014). *These S. lespedeza* plants are known as TAME, as they have been studied and developed to have specific qualities. For examples, in 1939, ‘Arlington’ *S. lespedeza*, and in 1944, ‘Okinawa’ *S. lespedeza*, were developed through rigorous breeding programs to have thick stems, ultimately decreasing cattle palatability, thus reducing performance (Donnelly, 1954). To increase palatability and cattle performance, 'Serala' and 'Interstate' varieties were developed and released to the public (Terrill and Mesjidis, 2017). These two varieties are still used today for hay production as they contain lower fiber content, lower tannin concentrations and tend to improve grazing selection for grazing beef cattle. Wild (invasive) *S. lespedeza* does not hold the qualities that tame S. lespedeza has. Thus, consumption of wild *S. lespedeza* continues to be a problem in tall-grass prairies.

Forage Quality

Although *Sericea lespedeza* contains high levels of crude protein, it is not considered desirable for cattle forage due to the high levels of condensed tannins (Ohlenbusch et al., 2007; Cummings et al., 2017). Tannins are polyphenolic, secondary plant compounds that affect microbial activity to affect fermentation, protein degradation and possibly mitigate food borne pathogens (Shewangraw, 2016). Tannins bind to protein, causing said proteins to become unavailable for digestion (Ohlenbusch et al., 2007). Tannins are categorized into two different groups, based on their chemical structure and properties; hydrolysable tannins and condensed tannins (Athanasiadou et al., 2001). *Sericea lespedeza* contains condensed tannins, which in turn, makes grazing ruminants avoid them due to their woody stalk and unpleasant taste. Addisu (2016) recognized three negative and positive effects to tannin containing plants. Any plant that contains tannins is said to have three major negative effects; decreased palatability, decreased digestion, and a development of aversion to certain plants. In turn, tannins will decrease animal production due to the slowed movement of dry matter in the rumen and emptying of the digestive tract, giving ruminants the false sensation of satiety (Cohen et al., 1996). Although the negatives almost always outweigh the positives, the four major positive effects of tannins in *Sericea* *lespedeza* include; rumen escape, the recycling of urea, methane mitigation and the increased efficiency of microbial survival and production (Goel and Makkar, 2011; Addisu, 2016).

Concentration of condensed tannins increase in *S. lespedeza* through maturity of plant, high air temperature, and low amounts of yearly rainfall, but will decrease through ground drying following harvest for hay production (Ohlenbusch et al., 2007; Cummings et al., 2017). Mowing matured *S. lespedeza* will not kill an established plant and will leave many seeds in the soil that will germinate when conditions are optimal, thus increasing the spread of the noxious weed. Different species of ruminants consume *S. lespedeza* more than others. For example, Ohlenbusch (2007) reported that cattle will most likely only consume *S. lespedeza* in an early growing season through management intensive grazing or intensive early stocking. Poor cattle intake results in negligible pasture pressure of beef cattle which increases encroachment of *S. lespedeza*. Sheep and goats were reported to consume *S. lespedeza* more intensely throughout the growing season, more than cattle (Wolf et al., 1987; Hart, 2001). Pacheco et al. (2012) reported that *S. lespedeza* was grazed at an increased rate when grazing pastures were stocked at full rate with cattle and goats (i.e, 0.8 AUM or AEU/ha for both species) than in pastures stocked with cattle alone.

Animal Considerations

When *Sericea lespedeza* was seeded in wildlife food plots, it was first considered a valuable foodstuff and provided cover for wildlife. But this has not been supported through recent research and practical experiences (Ohlenbusch et al., 2007). Although some wildlife colonies utilize *S. lespedeza* infestations, the ongoing overpopulation and encroachment leads to exclusion of other plants, thus reducing the diversity of plants needed to support and encourage a variety of wildlife. Ohlenbusch (2007) states that white-tailed deer will only utilize *S. lespedeza* as a feedstuff during the early growing stages of the plant and during drought conditions and some species of quail will consume the seeds, which are low in nutritional value, on occasion. Foley et al. (1995) reported that once cattle have a sense of satiety, they will ultimately stop eating until concentrations in the body decrease through either detoxification and or elimination. Another reason for a halt on grazing is when cattle eat large amounts of tannins, which can decrease bloat, increase protein usage, and immune responses (Min et al., 1999; Min and Hart, 2003; Waghorn, 2008).

The dispersal of *S. lespedeza* seed from animals is quite possibly the leader of mechanical dispersions. According to Blocksome (2006), S. lespedeza seed resembles an alfalfa seed in size and shape and is not specially designed for water, wind, animal attachment or attractant for the purpose of dispersal, although all of these are examples of transportation and possible expansion of the noxious weed colonies. Schupp (1993) recognized that the effectiveness of dispersal of seeds is dependent on both quality and quantity. Quality is summarized as the probability the seed will survive through movement and produce a new adult plant, while quantity is described as the amount consumed by a grazing animal and the number of seeds produced on a single plant.

Numerous studies have identified the effects of cattle consuming and digesting *S. lespedeza* seeds and was concluded that mammals are the most important dispersers for managing tall grass prairie range when comparing to other dispersal transport methods; water, wind, and mechanically transporting (Janzen, 1984; Blocksome, 2006). Mammals are one of the largest dispersers of *S. lespedeza* seeds and this can be attributed to an increased amount of time of seed retention in the rumen. Clauss et al. (2002) concluded that physical characteristics of ingesta, such as size and functional specific gravity, are known to influence retention time in the rumen. Dore and Raymond (1942) stated a single cow distributes over 900,000 *S. lespedeza* seeds in its manure during the growing season. Animals that have longer retention time will spread seeds farther as they travel to graze fresh foliage, spreading seeds to a larger area (Kerner, 1895). Bruun and Fitzboger (2002) summarized that within the first 48 hours of ingestion cattle will pass most seeds consumed, with a small amount being passed for another 24 hours. Cattle consuming high quality forages have a faster rate of passage than those consuming lower quality, such as *S. lespedeza* infested grasses due to a high concentration of indigestible components (Blackshaw and Rode, 1991; Scarnecchia et al., 1995; Vallentine, 2000). Due to the fact cattle are normally limited to grazing spaces through fencing, the implementations of new noxious weed communities and large populations are largely attributed to transportation of ruminants to new grazing areas, wildlife migration, wind, birds, and water run-off.

Sericea lespedeza Control

Considering the ability for *S. lespedeza* to remain a biological irritant for grassland managers and livestock producers, control has been at the forefront of most management practices. This is due to the fact that once *S. lespedeza* is established, eradication is unlikely. Eddy and Moore (1998) reported that *S. lespedeza* reduces grass production in native tall grass prairie by as much as 92%, drastically changing the biological ecology of the grassland prairie. To help combat such a dramatic reduction of native tall grass prairie, most land stewards utilize one or multiple of the following: prescribed burning, mechanical intervention, herbicide application, and intensive grazing.

Prescribed Burning

Pyric control of *S. lespedeza* during the spring is the most used technique, although it may exacerbate the problem (Gatson, 2018). As discussed in Cummings et al. (2017), fire can either increase the growth of *S. lespedeza* colonies or help to control them. Fire can scarify the seed (crack the outer coat of the seed shell) which helps to promote germination with adequate moisture or prohibit germination if exposed to high temperatures. In contrast, fire can help to control *S. lespedeza* by removing previous year's growth, kill some seedlings and improve herbicide applications and effectiveness. To examine the effects of prescribed burn timing on seed survival and germination rates, Wong et al. (2012) conducted two field studies; burning once in early November and burning once between the dates of April 21st and September 4th. It was found that prescribed burning in early November resulted in a lessened *S. lespedeza* establishment. The second field study, burning between April 21st and September 4th, resulted in a stronger *S. lespedeza* seed germination, but the authors attributed this effect partly to the rapid increase of *S. lespedeza* in the Flint Hills of Kansas. Wong et al. (2012) summarized that *S. lespedeza* seedling survival was much greater when burning occurred during the early growing season, and although early November burning resulted in an increase of germination, very few of the seedlings survived to the next growing season.

Alexander et al. (2017) compared the difference in traditional spring burning to summer burning. It was found that traditional spring burning decreased canopy coverage and seed production of *S. lespedeza*. It was stated that during the year of 2017, prescribed burning in the Flint Hills of Kansas cost less than $1 USD/acre, while the application of a common herbicide during the fall resulted in roughly $18 USD/acre.

A study conducted at Kansas State University examined the effects of growing-season prescribed burning on *Sericea lespedeza* in the Flint Hills of Kansas. Alexander et al. (2016) compared a traditional spring burning, to dormant-season burning, to burning during the summer months. This study utilized 9 units of 12-18 acres and each unit was randomly assigned to one of three prescribed burning times: early spring (April 1st; CONTROL), mid-summer (July 30;

EARLY) and late summer (September 1st; LATE). It was found that burning during the summer months reduced seed production of *S. lespedeza* significantly. Whole-plant dry matter weight (mg/plant), total seed weight (mg/plant) and number of seeds per plant were all also statistically different when comparing the CONTROL, EARLY, and LATE burning times. Similarly to their findings in 2017, prescribed burning had a cash cost of less than $1 USD/hectare, while the application of a common herbicide during the fall resulted in roughly $10-$20 USD/hectare.

A study conducted at the Bressner Research pastures near Yates Center, Kansas from the years of 2006 through 2012, evaluated whether patch burning tall-grass native prairie does or does not negatively affect stocker performance and which plant species were influenced by fire (Farney et al., 2017). This study utilized 8 pastures split into 4 pastures that consisted of a yearly spring burn (CONTROL) and 4 pastures that experienced patch burning on 1/3 of each pasture per year (PB). It was stated that for those pastures assigned to PB, each patch in the patch treatment was burned once in every 3-year interval. This resulted in cattle being able to graze 1/3 of the pasture that was burned the current year, 1/3 burned the previous year, and 1/3 burned 2 years prior. It was found that the grazing steers average daily gain was not different. Major grass species identified on the CONTROL pastures were relatively similar, but there was some year-to-year differences (Farney et al., 2017). Regarding the PB plant compositions, it was found that perennial grass populations tended to increase ($P < 0.10$), while Switchgrass declined ($P < 0.05$;Farney et al., 2017). Farney et al. (2017) also recognized that the botanical composition was similar when comparing the PB system and full-pasture burning, except for an increase in annual grasses while utilizing the PB system. Overall, this burning strategy offered a positive option for pasture management when grazing stocker cattle during the grazing season. This type of burning system also had no impact on *S. lespedeza* over that 6-year period.

Mechanical

Mechanical intervention through cutting or mowing *S. lespedeza* plants could decrease the vigor of established colonies but is not a cost effective or efficient method. To receive the best results, plants should be removed, close to the ground, each time they reach a height of 12 to 18 inches (Cummings et al., 2017; Ohlenbusch et al., 2017). Mowing *S. lespedeza* will not kill the plants and can, in some cases, damage native, advantageous plants. In addition, depending on the frequency and timing of mowing, large deposits of seeds may be deposited into the soil, creating a bank that could potentially increase the colonies in the future and create opportunities for the seeds to spread to noninfected areas.

Another method of 'mechanical' control was using animals to be attracted to the undesirable plant. In California, a trial used molasses as an attractant to increase the consumption of the noxious weed known as Medusahead (*Taeniatherum caput-medusae*). This weed infests over 5 million acres in California and has been given the name of 'the worst rangeland weed in Idaho' (Lusk et al., 1961). Doran (2008) used 4 treatments of different amounts of water and molasses. Treatment 1 was the control: 100% water at 50 gallons/acre. Treatment 2: 12.5% molasses and 87.5% water at 50 gallons/acre. Treatment 3: 25% molasses and 75% water at 50 gallons/acre. Treatment 4: 50% molasses and 50% water at 50 gallons/acre. The ewes were placed into 4 different groups for conditioning. Unfortunately, the molasses treatment did not attract the sheep to consume more Medusahead.

Herbicides

Altom et al. (1992) were pioneers in contributing to the current knowledge behind the application of herbicides as a method of controlling *S. lespedeza*. By utilizing post-emergence herbicides, they were able to evaluate each individually and with combinations when applied to

S. lespedeza from May through June in north-central Oklahoma. The herbicides that were evaluated were as follows: triclopyr, picloram, 2,4-D, metsulfuron methyl, dicamba, clopyralid, and fluroxypyr. Post application of the herbicides, *S. lespedeza* foliage was visibly diseased and decaying within one month. It was found that the only two post-emergence herbicides used, triclopyr and fluroxypyr, consistently brought necrosis to the *S. lespedeza* plants sprayed, while metsulfuron methyl was inconsistent. It was concluded with perplexity that *S. lespedeza* decayed visually after one month of treatment, but never more than 33% for any of the application rates, location, or herbicide type. It was also found that the stem density one year after treatment ranged from 0 to 67% of the control areas.

Following the gaps in knowledge reported by Altom et al. (1992), Koger et al. (2002) evaluated timing effects of the three herbicides that resulted in the best necrosis of *S. lespedeza*; triclopyr, fluroxypyr, and metsulfuron methyl. Koger et al. (2002) applied each herbicide to either the stem, branched stem, or flowering stage of *S. lespedeza* growth during the times of mid-June, mid to late-July and mid to late-September. The triclopyr and fluroxypyr were effective during the first half of the growing season when applied to the stem and branch stem stages, while metsulfuron methyl was the least effective option. In contrast, mesulfuron methyl was the most beneficial option when applied to the flowering stage of *S. lespedeza*. Koger et al (2002) found triclopyr and fluroxypyr applied to plants during the branched stem growing phase, prior to flowering, regardless of herbicide rate, provided the most efficient and consistent long-term control of *S. lespedeza*.

Whilst both studies resulted in a successful decrease of *S. lespedeza*, herbicides are not effective in eliminating *S. lespedeza* permanently due to the ability for seeds to emerge from seed banks. It is also important to note that the most common chemicals used as herbicides are also designed to repress native forbs in prairie grass ecosystems and are quite costly for yearly application (Koger et al., 2002; Crone et al., 2009).

Importance of Supplementing Cattle

To accomplish sufficient levels of production for grazing cattle, producers often supplement cattle with either harvested forages or protein. Providing nutrients often offsets nutrient deficiencies and is most utilized during summer grazing seasons and during fall and winter months. Supplementation can be economically demanding and draining to producers and is suggested to be inefficient. Inefficiency can be associated with improper timing of feeding, inaccurate understanding of supplemental requirements for various classes and physiological statuses of ruminants, and poor utilization of feedstuffs (McCollum and Horn, 1990). In contrast, it is well documented that when insufficient quantities and qualities of forages are available for grazing ruminants, supplementation of protein improves energy statuses (McCollum and Horn, 1990; Bodine et al., 2001).

To perfect energy supplementation of grazing ruminants, understanding of energy requirements and outputs is essential, and is often not adequately described. Often, estimates from pen-fed studies are used to estimate energy requirements, but these often are not accurate as grazing ruminants exert more energy. The requirement of energy for grazing cattle is a moving target due to varying production levels of ruminants, energetic outputs, years, and breeds of grazing animals (Caton and Dhuyvetter, 1997). Robbins (1994) reported that energetic costs of eating ranges from 20 kcal per animal per kg of DM ingested to 300 kcal per animal per kg of DM ingested. The range of energy used is variable due to differing amounts of time spent eating, maturity of forage ingested, and ruminating. Constant movement during grazing also significantly increases energy requirements (Caton and Dhuyvetter, 1997). Osuji (1974) reported that grazing sheep had an increase of energy expenditure of 30% compared to that of confined sheep. Krysl and Hess (1993) stated that grazing behavior and energy expenditure are closely related. Supplementing energy to grazing ruminants alters grazing behavior by altering efficiency of nutrient use (Caton and Dhuyvetter, 1997). Adams (1985) reported that supplementing concentrates decreased the time of grazing, but the degree of change in grazing time is dictated upon the time of supplementation.

Although forage intake of grazing ruminants is a moving-target, cattle have been reported to consume between 0.91 and 4.3% of their body weight per day while grazing native range (Adams, 1985; Kirby and Parman, 1986; Caton and Dhuyvetter, 1997). Depending on the time of year and the stage of plant maturity, energy supplementation is practiced maintaining adequate energy for production levels (Caton and Dhuyvetter, 1997). Reports that low levels of energy supplementation often increase residual forages seem to appear in sheep studies more often than studies of cattle. For example, Henning (1980) reported that supplementation of corn increased forage intake when fed at 7.8% of DM intake. In contrast, cattle supplemented with corn while grazing New Mexico summer pasture had reduced forage intake (Pordomingo et al., 1991). A reduction in forage intake of grazing ruminants due to supplementation of energy is termed substitution (Caton and Dhuyvetter, 1997).

The most common form of supplementation for mature cattle that producers use is a form of protein. McCollum and Horn (1990) summarized that a diet without proper amounts of protein will often decrease forage digestion and forage intake, while also decreasing metabolizable energy utilization. McCollum and Horn (1990) also reported that protein supplementation is able to alter grazing ruminants performance through the following: increasing rate of digestion through correction of nitrogen, an increase of non-ammonia nitrogen flow to the small intestine, correction of an amino acid deficiency which has the ability to stimulate forage intake and increase metabolizable energy utilization, increase the supply of glycogenic amino acids, and increase the supply of amino acids which improves tissue deposition.

Forage utilization is important for proper grazing land management. Ruminants grazing either low, medium, or high-quality forages may require different amounts of supplementation to produce uniform grazing and achieve adequate performance. Ruminants grazing high quality forages that were supplemented with less than 0.25% of body weight corn resulted in no adverse effects on the utilization of forage (Matejovsky and Sanson, 1995). Although, reduction in forage intake due to energy supplementation is dictated by the degree of quality of the basal diet, supplementing readily degradable fiber sources as supplements for grazing ruminants often leads to different responses than when supplementing with grains. For example, Martin and Hibberd (1990) supplied cattle with up to 3 kg of soybean hulls per cow per day, resulting in a slight decrease in forage intake when compared to not supplementing soybean hulls to counterparts.

Ultimately, supplementing grazing ruminants can improve efficiency, production, and forage management by reducing total feed requirements to meet nutritional requirements.

Minerals in Grazing Cattle

The mineral requirements for beef cattle have changed as science and technology have advanced. The total mineral, or ash content, in the animal's body makes up a very small amount of the total body weight (Perry, 1995). A study conducted in Missouri reported the mineral composition of steers of varying age. Characterized minerals that were reported were calcium, phosphorus, sodium, potassium, chlorine, magnesium, and sulfur. The percentage of each mineral as a percent of the total body weight of the steers were 1.33%, 0.74%, 0.16%, 0.19%, 0.11%, 0.04%, and 0.15%, respectively (Hogan and Neirman, 1927).

Mineral supplementation programs for grazing beef cattle often looks different for producers and can range from strictly salt supplementation, loose or in block form, to highly formulated free-choice mineral that contain both organic and non-organic sources of minerals. Considering several variables, designing a mineral supplementation program that provides that largest return to investment is often the most important factor producers take into consideration. Such variables include: method of supplementation, environmental conditions, management practices, forage type, and animal production level and genetics (Greene, 1999).

Mineral requirements for grazing cattle have been reported by NRC (1996) but are difficult to assess due to utilization of forages, mineral-mineral interactions, and stage and level of production (Greene, 1997). Meeting the mineral requirements of grazing cattle is challenging. Identification of minerals not supplied in adequate quantities is complicated, but essential. Depending on mineral composition of forages being consumed, producers are able to create formulated mineral packages to help overcome such challenges.

Minerals can either be provided through direct route or indirect routes (McDowell, 1996). As summarized by Greene (1999), indirect routes of mineral supplementation often include using fertilization of forages, altering the soil pH, and encouraging growth and development of certain forages that contain adequate minerals for grazers. Altering soil pH often increases uptake of Se and Mo, but decreases uptake of Cu and Co (McDowell, 1996). In addition, Greene (1999) stated that the P and K content of forages is often increased in environments that exhibit promotion of growth and uptake of soil minerals.

Direct route mineral supplementation includes adding minerals to water, oral drenching, injection to grazing animals, ruminal boluses, free-choice supplementation, and forced feeding through protein and energy feeds (Greene, 1997, 1999). Orally supplementing minerals is labor intensive and not practical as minerals pass through digestive path at rapid rates and decreases absorption. Although orally drenching multiple days would increase minerals absorbed, it is labor intensive and often expensive and not recommended as a method of providing adequate minerals to grazing cattle. Supplementing minerals with the addition of water has the ability to result in more animal-animal variation compared to any other method, as consumption of water, and in turn minerals, are varied. Black et al. (1943) reported that P supplements were successfully added to water, eliminating P deficiencies in cow herds in southern Texas. The largest downside of adding mineral supplements to water is useless if cattle have multiple sources of water available.

Providing minerals in high energy and protein supplements is variable, in regard to consumption and uniformity. Mineral consumption, much like protein supplementation, is often variable when supplied as self-fed and is frequently hard to quantify (McCollum and Horn, 1990). Greene (1999) reported that the supplementation of 1 kg of natural protein (cottonseed meal or soybean meal) has the ability to supply 25% of the cows' P requirements. Although supplementation of protein and energy is rarely used year-round, supplementation of minerals through this method is not economic in the long-term.

The most common and widely used method of direct route mineral supplementation is free-choice supplementation. Creating a palatable formulation with adequate amounts of minerals is as much of an art as it is a science (Greene, 1999). For example, formulation of a free-choice mineral with perfect amounts of each mineral is often useless if consumption is not adequate. Regulation of consumption is often hard to quantify, although absolutely necessary as some cattle will overconsume, while others will under consume. As reported by Greene (1999), target intake of free-choice minerals is generally between 56 and 114 g per animal per day. The base of free-choice mineral is often NaCl, which is a limiter for consumption. Phosphorus and Mg are often not as palatable for cattle, which tends to reduce the consumption of free-choice mineral supplements. To enhance palatability of such mineral supplements, the addition of protein, energy feeds, molasses or flavor enhancers are often used (Greene, 1999).

Formulation of free-choice supplements has the possibility of being complex. Ideally, this form of mineral supplementation should be reformulated for each different stage of production, time of year, and consumption. But due to limited resources and time producers have available, it is most common to supply the same mineral package to cattle year-round. It is recommended that producers with large herds to work closely with a nutritionist to formulate supplements to meet production needs for different times of the year. Formulation of free-choice minerals can be as complex as assessing micro and macro minerals individually to simply provide a salt/sulfur block. While it is not recommended to simply provide a salt and sulfur block, it is sometimes the most economically beneficial program. Often, free-choice minerals are often carriers for ionophores, medications, and other feed additivies.

Ionophores

Ionophores, lipid soluble compounds, were first identified in 1951 but not actively used in the United States until 1975 (Berger et al., 1951; Novilla, 2018). As summarized in Novilla (2018), ionophores are classified into two groups: neutral ionophores and carboxylic ionophores. Neutral ionophores disturb biological membranes and action potentials, causing them to be highly toxic. Carboxylic ionophores are more tolerated in organisms due to the promotion of electrically neutral cation exchange diffusion, through the creation of zwitterionic complexes. Pressman (1976) described the physiological activity of ionophores as the movement of monovalent cations (calcium and sodium) across the cell wall in exchange for potassium and hydrogen, giving the drug class the name ionophores. Spears (1990) reported that ionophores tend to increase absorption of minerals; magnesium, phosphorus, zinc and selenium, while increasing DE of the fed diet and increases digestibility of nitrogen.

The seven carboxylic ionophores that are currently approved for use in the United States for growth promotion, anticocciostatic benefits, production efficiency and disease control from the Feed Additive Compendium include: monensin (tradenames include: Coban, Rumensin, Rumensin CRC, Kexxtone), lasolocid (tradename: Bovatec), salinomycin (tradenames include: Bio-cox, Sacox), narasin (tradenames include: Maxiban, Monteban), maduramicin (tradename: Cygro), laidlomycin (tradename: Cattlyst) and semduramicin (tradename: Aviax) (Animal Health, 1966).

According to the Eighth Revised Edition of Nutrient Requirements of Beef Cattle (2016), the only four products that are currently licensed in North America for usage as a feed additive for grazing and confined cattle include: lasalocid, laidlomycin propionate, monensin, and salinomycin. Lasalocid, laidlomycin propionate, and salinomycin are also approved for usage in Canada. Lasalocid and monensin have similar ionic transport mechanisms but are not identical. Monensin has a stronger preference for sodium (Na^+) ions than potassium (K^+). In contrast, lasalocid has more resonance for potassium (K^+) and similar affinity with calcium (Ca^{2+}) and sodium ions (Na^+) (Nutrient Requirements of Beef Cattle, 2016).

Novilla (2018) recounted the dates and usages of the approved carboxylic ionophores. Monensin was first introduced into the United States market known as Coban as a coccidiostat for chicken in 1971 and then was later marketed as Rumensin and used in cattle as a growth promoting feed additive and to increase feed efficiency. Two years after the usage of monensin in cattle, lasalocid was marketed for chickens and then was approved in 1982 for usage in cattle under the trade name of Bovatec. Post 1982, laidlomycin, with the trade name of Cattlyst, was available for cattle while salinomycin, narasin, maduramicin, and semduramycin were used in chickens.

Monensin has been identified to not produce harmful effects if administered daily for long periods of time. Laudert et al. (2017) recorded no observable effect levels (NOELs) through a study using rats and dogs fed monensin at different levels for a two-year period. Hersom and Thrift (2012) reported that equine and swine should not consume ionophores or feeds contaminated with ionophores, as they are not capable of metabolizing ionophores specifically designed for cattle consumption. As for cattle, sheep, chickens and dogs, ionophores are absorbed in the small intestine, metabolized within the liver and discarded in the form of bile in feces (Hersom and Thrift, 2012).

Benefits of Ionophore Usages

The effects of feeding ionophores to grazing cattle (<75% DM) has much less research as feeding ionophores to confined cattle. Bretschneider et al. (2008) summarized studies comparing monensin and lasalocid: 46 and 15 studies respectively. It was reported that cattle consuming monensin had an increased ADG of 12.1% and the cattle consuming lasalocid had an enhanced ADG of 10.3%, when compared to no supplementation of the respective ionophores. The cattle supplemented monensin had an average daily gain of 0.66-0.74 kg per day, while those consuming lasalocid had an average daily gain of 0.78-0.86 kg per day. No difference was recorded between either monensin or lasalocid when considering dry matter intake, although a tendency was observed when monensin was fed, decreasing 2.7%. It was reported that forage quality appeared to be a limiting factor in regard to ADG in many of the studies. Bretschneider et al. (2008) recognized that when cattle are grazing high-quality forage, they experience an increased rate of gain but no additional response to monensin supplementation. Kunkle et al., (2000) reported that grazing steers and heifers supplemented with 115 mg per day of monensin will have an increased average daily gain of 0.08 kg per day (or an increase of 13.5%) as compared to those not supplemented with monensin. When monensin is supplemented at a rate of 200 mg per day, cattle will gain 0.09 kg per day (or an increase of 16%) when compared to those not supplemented with monensin (Kunkle et al., 2000).

Oliver (1975) conducted a study at North Louisiana Hill Farm Experiment Station to evaluate effects of 4 different levels of monensin (mg/hd/day) while grazing coastal bermudagrass. This grazing study lasted 140 days and each paddock was stocked with 5 steer calves (~156 kg initial body weight) and 5 yearling steers (~235 kg initial body weight). Yellow, ground and pelleted corn was used as the carrier for the different levels of monensin and was fed at a rate of 908 grams per head per day. Treatments consisted of: no corn supplementation, corn only, and corn plus 25, 50, 100, or 200 mg monensin per steer per day. Oliver (1975) reported that all levels of monensin produced larger weight gains, cattle fed corn performed better than those who were not supplemented with corn, and growth rates of steers increased as monensin supplementation increased to 100 mg/hd/ day. The grazing steer calves and yearling steers that were supplemented with 200 mg/hd/day gained only slightly more than those fed 25 mg/hd/day monensin.

USDA (2011) reported that over 90% of confined cattle operations, over 1,000 head capacities, include an ionophore as part of their daily nutritional management programs. The use of ionophores in feedlot diets promote efficiency of feedstuffs through numerous mechanisms: improved rumen fermentation by altering products for better absorption and metabolism, decrease cost of production, improve feed efficiency and animal growth (Russell and Storbel, 1989; USDA, 1994-2011; Cernicchiaro et al., 2016). Foster et al. (2023) study conducted by Texas A&M University with cattle located in Clayton, NM, evaluated the effects of monensin fed to newly-received feedlot calves. This study utilized 380 crossbred beef steers (~231 kg), which were randomly assigned to one of 20 pens. Ten of the pens were fed a control diet, consisting of a basal receiving diet and no feed additives, while the other 10 pens were fed a basal diet, including 170 mg/animal/day of Rumensin 90 (Elanco Animal Health, Greenfield, IN). The steers were fed for 56 days and weighed at days 0, 14, 28, and 56 to record average daily gain and gain:feed ratio. It was found that feeding monensin did not affect the daily feed intake ($P = 0.58$), but average daily gain was increased ($P < 0.01$) by 12.5%. This resulted in a 10.7% increase in gain:feed ratio for the steers supplemented with monensin (Foster et al., 2023).

Ionophore Toxicosis

Ionophore toxicosis is preventable when fed to target species. Toxicosis has occurred from the following: improper dosage and usage, feeding errors, and drug-drug interactions (Laudert et al., 2017). Hersom and Thrift (2012) reported that ionophores are classified as antibiotics, but not therapeutic antibiotics. With an increase of concern regarding the feeding of antibiotics and increase antibiotic resistance in beef cattle, Hersom and Thrift (2012) reported a list of reasons as to why ionophores are not increasing antibiotic resistance. Some included on the list are as follows: ionophores have never been used as antimicrobials in humans, ionophores do not have the same mode of action as therapeutic antibiotics, and ionophores have the ability to translocate across cell membranes of animals, thus limiting their use as a therapeutic antibiotic (Hersom and Thrift, 2012).

Acute toxicity (LD50), in broiler chickens occurs at 214 mg/kg and 1.4 mg/kg in horses, the most sensitive of species to ionophore toxicity (Novilla, 2018). Time and dosage are two great factors that affect the outcome of improper usages of ionophores, with the greatest risk of toxicosis being at initial exposure. This is due to the fact that after toxicosis occurs, animals will not consume highly contaminated feeds in the same capacity as they had previously consumed (Potter et al., 1984; Matsuoka et al., 1996).

Potter et al. (1984) reported clinical signs and mortality when feeding monensin on a mg/kg/day basis. They reported that anorexia was first observed 2 days after feeding 1.5 mg/kg/day and 1 day after feeding 2.3 mg/kg/day - 15.5 mg/kg/day. Diarrhea was observed 5 days after feeding monensin at a rate of 1.5 mg/kg/day, 4 days after feeding 2.3 mg/kg/day, 3 days after feeding 3.8 mg/kg/day, and 2 days after feeding monensin at a rate of 7.6-15.5 mg/kg/day. Appetite depression was witnessed after 7 days feeding monensin at a rate of 1.5 mg/kg/day, 6 days feeding monensin at a rate of 2.3 mg/kg/day, 4 days feeding monensin at rates between 3.8-7.6 mg/kg/day, and 3 days after feeding monensin at a rate of 15.5 mg/kg/day. Dyspnea was observed 5 days after feeding monensin at a rate between 7.6-15.5 mg/kg/day. Ataxia was observed 5 days after feeding 7.6 mg/kg/day of monensin and 4 days after feeding 15.5 mg/kg/day. Death was observed at the same time and feeding rates as ataxia was observed.

Essential Oils

The inclusion of ionophores in cattle diets has been suggested to improve cattle performances and mitigate metabolic diseases (Duffield et al., 2012). Due to the growing global concern of antibiotic resistance, alternatives of ionophores are being investigated. The inclusion of essential oils in diets has grown popular in the scientific community as it has shown potential of having similar animal performance benefits as ionophores and are generally recognized as safe for human health (Ferreira et al., 2024). According to Patra and Saxena (2010), essential oils are a group of secondary plant metabolites that have the potential to alter rumen fermentation through anti-bacterial activity, improve ruminal propionate proportions and mitigate ruminal methane emissions. In addition, essential oils have been reported to increase average daily gain, when hand-fed in dried distillers grains and decreased the number of engorged ticks on grazing heifers in Southeast Kansas (Farney, 2020). Typically, essential oils are obtained through plants through steam extractions (Ferreira et al., 2024). It has been reported that beef cattle are more responsive to essential oil concentrations, in comparison to small ruminants and dairy cattle (Khiaosa-ard and Zebeli, 2013).

Ferreira et al. (2024) completed a meta-analysis of 14 publications to determine the effects of essential oils on consumption, performance, and ruminal fermentation of beef cattle. The doses observed in these studies ranged from 57.1 to 1600 mg/kg of DM consumed, with an experimental timeline that averaged 71.5 days. The initial body weight of all beef cattle in the studies averaged 351.8 ± 130.3 kg. The percentage of concentrate offered to the beef cattle in all studies ranged from 0% (strictly forage diet) to 93% of total diet. It was reported that when essential oils were included in the diet, there was an increase in dry matter intake, average daily gain, and gain to feed ratio. Although, the dry matter intake was affected by supplementation of essential oils; low doses increased dry matter intake (Patra and Saxena, 2010).

In terms of methane production, there were no differences observed from those supplemented essential oils and their counterparts. The meta-analysis concluded that the addition of essential oils did improve feed intake and animal performance through increased dry matter intake, average daily gain, increased propionate concentrations and reduced N-NH3 concentrations. Ultimately, it was reported that due to limitations, other research is likely to report different findings. The limitations that were reported were as follows: different essential oils and combinations (i.e. cinnamon, orange, garlic, clove), differing dosages, different experimental conditions and methods of obtaining ruminal fermentation parameters (Ferreira et al., 2024) . In conclusion, Ferreira et al. (2024) urges further research to explore other essential oils, as well as differing doses.

Torres et al. (2021) created a meta-analysis of 10 peer-reviewed articles to determine the effects of essential oil as an alternative to monensin in diets for feedlot cattle. The essential oils used in all of the studies were a complete proprietary blend, cinnamaldehyde, anise oil, capsicum oil, thyme oil, and cinnamon oil. Supplementation of essential oils in these 10 studies ranged from 30-160 days, with inclusion rates ranging from 50-500 mg/kg DM. All studies used a total mixed ration with concentrate concentrations ranging from 700 – 900 g/kg DM. Supplementation of essential oils to replace monensin, significantly increased dry matter intake, ruminal concentration of butyrate, valerate, and isovalerate ($P < 0.0001$) (Torres et al., 2021). Consequently, there was no effect on DMI of forages, DM digestibility, nor methane concentrations. Replacing monensin with essential oils increased carcass dressing percentage, subcutaneous fat, ribeye area, and the presence of liver abbesses. On the other hand, there were no observations of an increase in body weight, carcass weight, average daily gain, nor feed efficiency.

In conclusion, Torres et al. (2021) observed through their meta-analysis that the implementation of essential oils, instead of monensin, had no impact on the performance of finishing beef cattle. They stated that this might have been influenced by little to no dietary adaptation periods, but the concept is valuable in addressing public concerns with the growing of antibiotic resistance in beef cattle.

Essential oils and spices have been found to alter rumen microbial populations (Elcoso et al., 2019) and replace feed antibiotics in feedlot diets (Araujo et al., 2019), all of which may increase cattle gains. There have been varying responses to cattle gains based on types of essential oil within feedlot diets, with a greater majority reporting similar gains as control diets. Limited other studies have reported cattle gains while grazing pastures, thus the importance of evaluating essential oils on stocker cattle gains. Studies conducted at the Southeast Research and Extension Center, Parsons, KS, where growing cattle grazed either tallgrass native range or bromegrass pastures, calves gained on average 0.10 pounds0.05 kg per day more with an essential oil mineral than their controlled minerals (ranging from 0.048 – 0.11 kg/day depending on year and animal type; Farney et al., 2017; Farney, 2020; Farney et al., 2022; Farney et al., 2023; Farney et al., 2024). Contrary to these findings, Beck et al. (2017) found no improvements in gains when either handfeeding or offering mineral as free-choice with cinnamon and garlic essential oils when compared to ionophore minerals.

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Chapter 2 - Managing *Sericea Lespedeza* in Native Pastures by Concentrated Grazing

ABSTRACT

Objective: The objective of this study was to determine if molasses would entice steers to consume areas of heavy *Sericea lespedeza* infestation in tallgrass native range.

Materials and Methods: Steers (n=281; 291 ± 5 kg) were randomly assigned to one of 8 tallgrass native range pastures to graze between May and August based on a predetermined sort order through chute. Within each pasture, four locations were identified to have heavy *S. lespedeza* infestation and were randomly assigned to one of four treatments. In all pastures, treatments were applied weekly at equal rates of 468 L/ha and consisted of 4 treatments: control (CON: nothing applied); 12.5% (v/v) molasses concentrated spray (12.5M); 25% (v/v) molasses concentrated spray (25M); and 50% (v/v) molasses concentrated spray (50M). Plant counts of *S. lespedeza* were conducted on permanent transects within spray quadrants and occurred on 0, 30, 60, and 90 d of cattle grazing pastures. Steers (n = 29; 4-5 per pasture, equal to 12.8% of total steers per pasture) were fitted with GPS and activity tracking ear tags and monitored for location to determine proportion of time spent in sprayed areas and in the immediate vicinity of the sprayed area.

Results and Discussion: *Sericea lespedeza* numbers were lower at the end of grazing in the subplots that were sprayed with molasses as compared to CON (P = 0.003); specifically, 12.5M and 25M had a more pronounced effect on *S. lespedeza* than CON. Spraying infested areas did not stop the growth of *S. lespedeza* as there were more plants in August as compared to May (P < 0.01). The steers spent more time grazing in the areas closest to 12.5M as compared to 50M and CON with 25M being intermediate (P = 0.01).

Implications and Applications: Overall, in this first year of data collection, it appeared that spraying with 12.5% molasses (v/v) will entice cattle to spend more time in an area with undesirable plant populations, ultimately resulting in a less pronounced growth of plants.

Keywords: tallgrass native range, molasses, invasive species

INTRODUCTION

Throughout Kansas, invasive species are taking over native prairie and grasslands, thus reducing the quantity of native grasses for sheep and cattle to graze. Ultimately, complete irradiation is unlikely for some invasive species, but working to manage population expansion is important in ecosystems.

Sericea lespedeza was first introduced in Kansas in the early 1930's and was used as a cover crop for strip-mining covering tactics. In the Southeastern United States, it is known as 'poor man's alfalfa.' Sericea lespedeza encompasses over 2600 square-km and is categorized as a category C noxious weed on rangelands across the state of Kansas (Fick, 2022). *Sericea lespedeza* is a perennial legume with trifoliate leaves that grow to ~3 feet tall and starts to bloom in August with cream-colored flowers with a purple throat. Although unlikely to find pure stands of *Sericea lespedeza* in pastures, when planted for crop purposes, one singular acre may produce 19.5 – 386 kg of seeds with each kg containing ~350,000 seeds (Cummings et al., 2017). Producers have tried a variety of options to decrease the rapid expansion and spread of *S. lespedeza*, including natural web worms, herbicides, intensive grazing, and controlled burns (Eddy et al., 2003; Voth, 2004; Doran, 2008; Eckerle et al., 2011; Eckerle et al., 2012; Pacheco et al., 2012). Each have had some success as well as challenges, and were not

Sheep have not been beneficial in the reduction of noxious weeds, thus Voth (2004) believes that cattle are more progressive and easier to train to graze weeds and ultimately increase profitability of producers by increasing consumption of noxious weeds. Nearly 1/3 of most pastures in Kansas and surrounding states consist of inedible species of forages, but by teaching cattle to eat inedible species, there can be an increase of quality forages by nearly 43% (Mantz et al., 2009). The objective of this study was to determine if molasses would entice steers to consume areas of heavy *Sericea lespedeza* infestation in tallgrass native range.

MATERIALS AND METHODS

Experimental Procedure

The current experiment was conducted at the Bressner Research Unit in Yates Center, KS. All animals were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Kansas State University Animal Care and Use Committee (protocol #5015).

A 92-day grazing study was conducted at the Bressner Research Unit at Yates, Center, KS. This experiment utilized native range pastures (n = 8), combined, totaling ~ 259 hectares of grazing land. Treatment was completely randomized design with four treatments of varying molasses concentration (v/v) sprayed in areas with heavy infestation of *S. lespedeza*: 12.5% molasses - 88.5% water mixture (12.5M), 25% molasses – 75% water mixture (25M), and 50% molasses – 50% water mixture (50M). The control (CON) locations were areas in pasture that were identified as having high levels of *S. lespedeza* infestation and were not sprayed or had any other management. Molasses nutritional values are as follows according to the Nutritional Requirements of Beef Cattle – Eighth Revised Edition (2016): 66.04 ± 15.09% DM, 12.20 ±

5.34% Ash, 72% TDN, 2.60 Mcal/kg ME, 1.70 Mcal/kg NEm, 1.08 Mcal/kg Neg, 11.98 ± 8.86 % DM sugar, 8.59 ± 3.54% CP, 1.86 ± 1.58 % fat. Each spray area was sprayed manually with Harvest King Lawn and Garden Sprayer 4 Gallon (Harvest King, Fort Worth, TX) weekly at an equal rate of 468 L/ha. Spray areas were 100 ft x 100 ft and identified with GPS locations at each corner for consistent spray area. Within every pasture there were four locations identified with heavy infestation of *S. lespedeza* plants, therefore there were 8 replicates of spray treatments.

Spray area concentration selection was determined at initial GPS marking of spray areas. The closest location to the water source was labeled as 12.5M, the next closest was labeled 25M, and finally the farthest from the water source was 50M. Although selection of spray areas in terms of proximity to a water source could have influenced grazing behaviors and trends, grazing stocker steers travel greater distances than a mature cow would.

Two hundred eighty-one predominantly black-hided steers (291 ± 5 kg) were weighed individually and randomly assigned to pasture based on order through the chute. Steers were weighed on April 30, 2024, and placed on pasture May 1, 2024. Steers grazed until removal from pasture on August 1, 2024. Steers originated in Montana from a single ranch. At initial processing the steers were restrained using a Silencer hydraulic squeeze chute (Moly Manufacturing, Lorraine, KS, 67459) and injected with Dectomax injectable (doramectin) (Zoetis, Parsippany, NJ, 07054), implanted with a Revalor-G implant (trenbolone acetate and estadiol) (Merck Animal Health, Madison, NJ, 07940), and Pyramid 5 + Presponse SQ (Boehringer Ingelheim, Ridgefield, CT, 06877). Steers were individually identified with visual ear tags. They were also tagged with GPS tracking ear tags (701X, Fargo, ND). Steers within pasture were randomly selected based on determined randomizer to be tagged with GPS tracking ear tags. Within each pasture 10% of the steers were tagged with GPS ear tags (4-5 steers per pasture). Number of steers within each pasture was different and was based on stocking rate calculations to provide similar forage grazing acreage.

Cattle behavioral data was documented using 701X Autonomous Rancher (Fargo, ND, 58103) PRO tags. 701X PRO GPS ear tags are solar-powered and communicate via satellite. Locations are recorded and transmitted every 5 s for each ear tag. Data was stored in the 701X Autonous Ranching software, then downloaded to Excel for data processing.

Analyzing the data recorded on the 701X software produced the ability to detect the percentage of time cattle spent in each transect that was sprayed and within close proximity of each transect, with a margin of error at ~5 feet. Close to proximity determined if GPS location was signaled within 100 m of spray area. In terms of cattle behavior, it should be reported that once the steers acknowledged the taste of molasses and the connection between the act of a human spraying and the application of molasses, steers followed the sprayer around to each transect weekly. Pasture management

Pastures were prescribed burned April 1, 2024, to reduce standing inedible forage and to increase new growth during the growing and grazing season. The previous 5 years, half of the pastures were burned in March and half were burned in April. Based on the results of the previous study, there were no differences in end of grazing biomass, thus these pastures started with similar initial biomass. Pastures had been sprayed for S. lespedeza in the fall of 2022. During the fall of 2023, locations within pasture were identified that had heavy infestation of *S. lespedeza* and GPS marked using Garmin GPSMAP 65 handheld multiband GPS (Garmin, Olathe, KS). Heavy infestation was determined when there was an obvious stand of *S. lespedeza* (± 15 stems per sq. m).

Sericea lespedeza Count

Sericea lespedeza plant counts took place on d 0, 30, 60, and 90 d of grazing. To accomplish plant count, a diagonal transect within spray area was marked using GPS location. A soft tape measure was stretched across the diagonal of the sprayed square. Every 1.2 m mark on the tape measure, a 0.3 by 0.3 m plastic PVC pipe outline was laid next to the tape measure. *S. lespedeza* plant stems (both growing and mature) were counted inside the square to determine the number of plants per square meter. Due to the fact *S. lespedeza* plants canopy, to conduct plant counts, stems were counted, not branches. CON counts were counted twice in each pasture for baseline and again at the end of grazing (d 90).

Statistical Analysis

Sericea lespedeza count data was analyzed using PROC GLIMMIX in SAS 9.4 (SAS Institute INC., Cary, NC) with pasture as experimental unit. Several comparisons were conducted and included specific measurements for actual count and then the subsequent changes in plant numbers based on differences in month or for the entire grazing season.

For plant counts within each month, data was analyzed using PROC GLIMMIX in SAS 9.4. Two sets of analysis were conducted: 1) counts in spray areas only (12M, 25M, and 50M) and 2) counts for all treatments (CON, 12.5M, 25M, and 50M) on d 0 and 90. During the intermediate sampling times, the CON was not measured at 30 and 60 d, thus the need to evaluate both ways. Fixed effects included treatment, sample time, and interaction. Random effect was pasture.

Change in plant counts was determined by subtracting measurements d (i.e. d 60 minus d 30 showed count change in the second month of grazing). Additionally total plant change was determined by subtracting d 0 measurements from d 90 measurements for CON, 12.5M, 25M, and 50M spray treatments. Data was analyzed using PROC GLIMMIX in SAS 9.4 with fixed effect of treatment. Random effect was pasture.

To evaluate total time in all areas of the pasture, the total time points for each steer in each d were determined through the grazing period and this was denominator for daily count. This number was then averaged for a wk recording of number of points collected. The GPS points where steers were identified as being in each of the treatment areas, close to the spray treatment areas, or in the remainder of pasture were identified and used as the numerator for the proportion calculation. This was first determined for d and then averaged within wk intervals. There were three steers whose ear tags did not record data and were removed from analysis. Some of the ear tags became non-functional through the grazing period thus, at the end of the grazing season only 41% of the ear tags were still transmitting. To have replications within pasture, prior to wk 8 of grazing, all pastures had at least two replicates of ear tags transmitting data. Therefore, only GPS tracking data was analyzed for wk 1 through 7 of the study were used in analysis (this equated to 88% of all ear tags inserted). The animal grazing behavioral data, also known as time, spent in or near sprayed transects, was analyzed using PROC GLIMMIX in SAS 9.4 with animal within pasture as experimental unit. Fixed effects included spray treatment, and treatment x wk interaction. Random effects were pasture, steer, and steer within pasture.

For all analyzed results, statistical significance was determined at ($P \leq 0.05$), with tendencies being declared ($0.05 < P < 0.10$).

RESULTS AND DISCUSSION

Sericea lespedeza Count

CON areas had the greatest increase ($P = 0.01$) in plant counts over the 90 d grazing period (Table 2.1). The 12.5M and 25M had a lower rate of plant count growth compared to CON with 50M being intermediate ($P = 0.02$).

When comparing plant counts for the sprayed treatments of 12.5M, 25M, and 50M there was no treatment by day of sampling interaction ($P = 0.81$), nor sampling day effect ($P = 0.17$; data not shown). Additionally, there was no change in plant counts based on spray treatments between d 0 and 30 ($P = 0.46$); between d 30 and 60 ($P = 0.23$); or between d 60 and 90 ($P = 0.23$) nor the grazing period when only comparing the spray treatments ($P = 0.42$; data not shown).

Sowers et al. (2018) found that during later months of the grazing season steers grazing the Kansas Flint Hills decreased the consumption of *S. lespedeza* due to creating an aversion, possible due to increased levels of tannins. Sowers et al. (2018) coincidentally held their experiment in the same location and pastures as this experiment. Eckerle et al. (2012) found that supplementing low levels of corn steeped liquor (0.60 kg/d) increased the consumption and tolerance of *S. lespedeza*. In their experiment, 16 mature beef cows were fed individually and offered both hay uncontaminated with *S. lespedeza* and hay contaminated *S. lespedeza* and supplemented with corn steeped liquor. In fact, supplementation increased voluntary consumption by nearly 25% as compared to non-supplemented cattle (Eckerle et al., 2011). Similar to our experiment, Doran (2008) utilized molasses as an attractant for a noxious (Medusahead) while grazing sheep. Though, contrary to our findings, while using the same treatments, it was found that molasses did not attract sheep to consume the noxious weed.

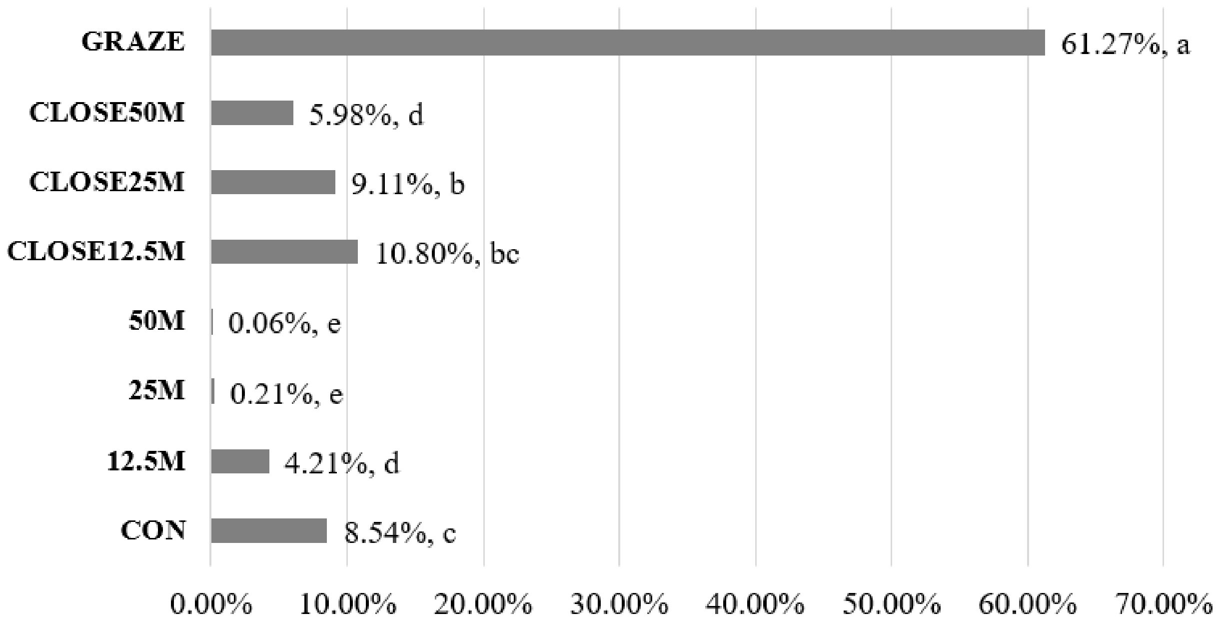
Animal Grazing Behavior

The greatest amount of time grazing was in the areas that were not designated as the spray areas or close to the spray areas which accounted for 60.21% of the time. The spray areas of 25M and 50M had less percentage of time being inhabited (1.74 and 1.58%, respectively) as compared to the areas close to 12.5M and close to 25M (9.87 and 9.13%, respectively) with CON, 12M, and close to 50M being intermediate (7.55, 4.37, and 5.5%, respectively; SEM = 5.78%; Figure 2.1). This makes sense when calculating the designated areas that were sprayed and the areas that were determined to the close to the spray area. This area equaled the amount of grazeable acreage, thus spraying the molasses did not really seem to increase time spent in the area, above what might have been without spraying. Cows and stocker steers and heifers graze differently and spend different amounts of time grazing. For example, Walker et al. (1989) reported that cattle typically graze 11.3 hrs per day in the months of May and June and graze 9.5 hrs per day in August and September due to a decrease in available sunlight. In contrast, Hepworth et al. (1991) stated that yearling steers often graze for only 8.5 hrs per day during the daylight hours. Villalba et al. (2015) recognized that through selective foraging, associated conditioning occurs, ultimately changing future grazing techniques forever. Grazing decisions, especially with naïve yearling steers, are often due to two aspects; wanting a certain plant with motivation to consume or liking a plant consciously or unconsciously (Pacheco et al., 2012). Although research regarding supplementation on S. lespedeza plants, physically, is not thoroughly studied, it is known that external stimuli can increase consumption of anticipated plants. Additional research is warranted.

APPLICATION

Overall, in this first year of data collection, it appeared that of the molasses treatments used, 12.5% molasses (v/v) enticed cattle to spend more time in and close to that area with undesirable plant populations, ultimately resulting in a less pronounced growth of plants during a summer grazing season. Use of this method, though came with challenges such as a high cost of molasses and cost for application, and the molasses was damaging to several pieces of spray equipment. Although there was some promise that steers could reduce stand growth, the feasibility of this practice is questionable.

Figure 2.1 Average percentage of point locations based when steers had access to entire pasture.



[abcde] Letters that are different indicate treatment differences at $P < 0.05$.
CON: area of heavy *S. lespedeza* infestation that was not sprayed or managed differently.
12.5M: 12.5% molasses - 88.5% water mixture spray (v/v).
25M: 25% molasses – 75% water mixture spray (v/v).
50M: 50% molasses – 50% water mixture spray (v/v).
CLOSE12.5M: 1000 sq m surrounding the 12.5M spray location.
CLOSE25M: 1000 sq m surrounding the 25M spray location.
CLOSE50M: 1000 sq m surrounding the 50M spray location.
GRAZE: all other remaining areas in pasture, not identified by previous treatments.

Table 2.11 *S. lespedeza* counts and change based on d 0 and d 90 pf grazing tallgrass native range with stocker steers.

	CON	12.5M	25M	50M	SEM	*P*-value
Day 0	1.99[ab]	2.86[a]	2.29[ab]	0.84[b]	0.9	0.06
Day 90	6.73[a]	4.58[ab]	4.36[b]	3.63[b]	0.9	0.04
Change day 0 to 90	4.74[a]	1.72[b]	2.07[b]	2.79[ab]	0.9	0.02

[ab] Letters that are different indicate treatment differences within day (row) at $P < 0.05$.
There was no sampling date difference or treatment by sampling date ($P > 0.31$).
CON: area of heavy *S. lespedeza* infestation that was not sprayed or managed differently.
12.5M: 12.5% molasses - 88.5% water mixture spray (v/v).
25M: 25% molasses – 75% water mixture spray (v/v).
50M: 50% molasses – 50% water mixture spray (v/v).

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Chapter 3 - Effects of Stocker Steer Performance While Consuming Essential Oil or Ionophore Minerals

ABSTRACT

Objectives: The objectives of these studies were 1) to evaluate an alternative to ionophores approved for growth performance in grazing stocker steers; and 2) evaluate ruminal fermentation differences in ionophores and essential oils for forage diets.

Materials and Methods: Study 1: Cattle effects. Steers (n = 281; 291 ± 5 kg) were assigned to one of two mineral treatments and grazed tallgrass native range. Treatments consisted of the positive control ionophore (**ION**; lasalocid at 1,633 g/ton) and essential oil (**EO**; garlic oil at 1.4 kg/ton and essential oil blend at 2.7 kg/ton) in free-choice mineral. Steers were weighed individually at the beginning (May) and end (August) of the grazing period (92 d). Steers were randomly allocated to pasture (n = 4 pastures) based on predetermined sort order through chute. At initial processing, steers (n = 29 total steers; 4-5 steers per pasture, equal to 12.8% of total steers per pasture) were fitted with commercial GPS and activity tracking ear tags to monitor biological and behavioral data. Pasture biomass production and mineral intake were recorded weekly. Study 2: Gas production, VFA, and ruminal digestibility's were determined using *in situ* procedures. Treatments evaluated were forage (GRASS), control mineral (CON), mineral with lasalocid at 1,633/ton (ION), essential oil blend (same as one from Study 1; EO), and the combination of lasalocid and essential oils (COMBO).

Results and Discussion: There was no difference in total gains (P = 0.92; 93 kg for ION vs. 92 kg for EO; SEM = 3.9) nor average daily gain (P = 0.92; 0.98 kg/d for ION vs. 0.97 kg/d for EO; SEM = 0.04) between the two minerals fed to the steers. Steer mineral intake was not different for both treatments ($P = 0.54$) and was slightly higher than formulated intake (148 g/d as compared to 113 g/d). Available forage was not different between treatment pastures ($P = 0.67$). There was no difference in average daily steps taken ($P = 0.24$), time spent walking ($P = 0.41$), ruminating ($P = 0.85$), resting ($P = 0.25$), or grazing ($P = 0.94$). Heart rate (beats per mi**n**) tended ($P = 0.07$) to be lower in ION supplemented steers than EO steers. Acetate, propionate, and acetate:propionate ratio favored COMBO mineral over both ION and EO ($P < 0.10$). There was no difference in any VFA or gas production measures between EO and ION ($P > 0.15$). Including mineral, especially with additives like EO and ION reduced acetate:propionate ratio ($P < 0.05$) over GRASS.

Implications and Applications: Overall, there was no difference between feeding ionophore or essential oils in mineral in regard to cattle gain during summer double stock grazing on tallgrass native range. This result was supported by ruminal fermentation characteristics where the treatment minerals (EO and ION) were not different, but improved energetics above simply supplementing with a mineral. This study could provide operations that implement natural marketing systems with an option to reduce cost of gain for a more profitable feeding system.

Keywords: lasalocid, tallgrass native range, garlic, cinnamon, average daily gain

INTRODUCTION

Alternative methods to reduce use of synthetic products in cattle production as well as reduction in feeding antibiotics to cattle have been a growing preference in consumer opinions. Essential oils/spices have been found to alter rumen microbial population (Elcoso et al., 2019) and replace feed antibiotics in feedlot diets (Araujo et al., 2019), all of which may increase cattle gains. There have been varying responses to cattle gains based on types of essential oil within feedlot diets, with a greater majority reporting similar gains as control diets. Limited other studies have reported cattle gains while grazing pastures, thus the importance of evaluating essential oils on stocker cattle gains is to be investigated. In studies where growing cattle grazed either tallgrass native range or bromegrass pastures, these calves gained on average, 0.05 kg/d more with an essential oil mineral than control minerals (range 0.04-0.11 kg/d depending on year and animal type; (Farney et al., 2017; Farney, 2020; Farney et al., 2023; Farney et al., 2024).

Ionophores are antibiotics that alter rumen microbial populations to increase efficiency in cattle production systems. This alters the ratio of volatile fatty acids (VFA) to more propionate, which is more energy dense than acetate. In general, the gains are greater when grazing a higher energy diet than grass alone. Spears et al. (1990), studies have shown monensin and lasalocid to improve stocker cattle gains but including them in a mineral package has been less consistent. Outside of one grazing study (Beck et al., 2017), directly comparing essential oils to ionophore, there is limited information about the differences in performance between the two in pasture systems.

Therefore, we propose to compare cattle performance and mineral intakes between essential oils and ionophores while grazing tallgrass native range. A secondary objective was to determine fermentation characteristics between essential oils and ionophores in a grass-based diet.

MATERIALS AND METHODS

The current experiment was conducted at the Bressner Research Unit in Yates Center, KS. All animals were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Kansas State University Animal Care and Use Committee (protocol #5015).

Study 1: Cattle and Pasture responses to Essential Oils and Ionophores

Treatment Structure

A 92-day grazing study was conducted at the Bressner Research unit in Yates Center, KS. The unit consists of 8 pastures on 253 hectares of tallgrass native range. Treatments consisted of two minerals offered ad libitum to the steers and applied in completely randomized design. The positive-control mineral was a stocker mineral that contained 1,633 g/ton of lasalocid (Ionophore; Table 1; Bovatec 91; Zoetis, Kalamazoo, MI). The treatment mineral was the same base mineral with 1.4 kg per ton of garlic oil and 2.7 kg per ton of Solace (Essential oil; Table 3.1; Wildcat Feeds LLC, Topeka, KS). There were four pastures of each mineral offered to the steers in AmeriAg mineral feeders (Burlington, NC). Mineral was offered weekly at 125% of the formulated intake (142 g/steer daily was provided; 113 g/steer daily formulated intake). The amount placed in feeders was weighed prior to placement in the feeders and the remainder was weighed weekly prior to adding new mineral. This was used to calculate average daily mineral intake for each week while on grass.

Two hundred eighty-one predominantly black-hided steers (291 ± 5 kg), originating from one ranch in Montana, were weighed individually and randomly assigned to pasture based on predetermined sort order through the chute. Steers were weighed on April 30, 2024, and placed on pasture May 1, 2024. Steers grazed until removal from pasture on August 1, 2024. Steers were weighed individually on April 30, 2024 at a grower yard in Allen, KS. The steers were restrained using a Silencer hydraulic squeeze chute (Moly Manufacturing, Lorraine, KS). At initial processing steers were injected with Dectomax injectable (doramectin; Zoetis, Parsippany, NJ), implanted with a Revalor-G implant (trenbolone acetate and estadiol; Merck Animal Health, Madison, NJ,), and Pyramid 5 + Presponse SQ (Boehringer Ingelheim, Ridgefield, CT). Steers were individually identified with visual eartags. They were also eartagged with GPS tracking eartags (701X Autonomous Rancher, Fargo, ND). Steers were randomly assigned to one of 8 pastures via chute order and allowed to stand for 12 hrs with ad libitum access to prairie hay before being transported to Yates Center, KS to begin the grazing study. Steers were not weighed again until they were removed from their respective pastures and transported to Hy-Plains Feedyard, LLC (Montezuma, KS) and weighed again to determine final weights. Initial weight was subtracted by final weight to determine weight gain per calf during the 92-d grazing period. Steers were allowed to rest and consume starter at feedyard for 3 days prior to weighing. This allowed all cattle to consume the same rations to minimize potential gut fill issues with weighing at both the start of the study and the final weight.

Steers within pasture were randomly selected based on a pre-determined randomizer to be tagged with GPS tracking eartags (701X Autonomous Rancher). Within each pasture 12.8% of the steers were tagged with GPS eartags (4-5 head per pasture). The number of steers within each pasture was different because stocking rates were based on calculations to provide similar forage grazing acreage within every pasture.

Steer behavioral data was documented using 701X Autonomous Rancher PRO eartags which are solar-powered and communicate via satellite. Locations are recorded and transmitted every 5 s for each eartag. Data was stored in the 701X Autonomous Ranching software, then downloaded to Excel for data processing. Behavioral data [steps per day (number/d), time spent resting (s/d), time spent lying (s/d), time spent eating (s/d), time spent walking (s/d), and heart rate (beats/min)] were recorded by day for each animal within the software.

Pasture Management and Forage Analysis

Pastures were burned in entirety April 1, 2024 to reduce standing inedible forage and to increase new growth during the growing and grazing season. Pasture biomass was determined weekly in the areas that steers grazed to determine the amount of available forage. To determine pasture biomass, three sections within each pasture were randomly selected each week and were clipped to 2.54 cm in height in 0.3-meter x 0.3-meter squares. The samples were weighed and dried in a 55°C forced air oven until completely dry. Dry weighed amounts were then converted to dry matter per hectare. Weekly biomass clippings were averaged by month to determine the total average available biomass per month. To determine forage accumulation, there were exclusion cages in each pasture. At the end of grazing (August 2, 2024) the exclusion cages were clipped, weighed, dried, and calculated to determine dry matter per hectare. The difference between the amount of forage in the exclusion cage and the pre-grazing biomass measurement was forage accumulation for the 92-day window of May 1, 2024, to August 2, 2024.

Weekly samples were sent to SDK Laboratories (Hutchinson, KS) for nutrient composition. Analysis was done using wet chemistry tests for DM, CP, NDF, ADF, calculated TDN and net energy values, Ca, Mg, P, and K.

Study 2: Ruminal Fermentation and Forage Digestibility

All *in situ* studies were completed using the same grass that the steers in Study 1 consumed through the summer. Specifically, forage was collected weekly from the Bressner

Research Unit to determine forage accumulation and biomass details and was dried in a 55°C oven for 48 hs. All forage samples that were collected during the grazing season were then ground to pass through a 1-mm screen in a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA) and combined to give an accurate representation of the entire summer of grazing and forage production. Equal amounts of grass samples from each pasture for each week were composited into one sample that was used as forage substrate for incubation procedures.

Two Holstein cows (~13 yr of age) with ruminal cannulas were utilized as donors for *in situ* projects. The donor cows had ad libitum access to fescue hay and were supplemented with 0.11 kg soybean hull with melagesterone acetate (MGA; NUTRA BLEND, LLC, Neosho, MO) to provide 0.5 mg MGA daily.

Treatment Structure

Gas production was used to evaluate five treatments in a completely randomized design. Treatments included forage (GRASS) and the addition of four different minerals. Minerals evaluated included control mineral (CON), essential oil mineral (EO), ionophore mineral (ION), and combination of ionophore and essential oil (COMBO; Table 3.1). The EO and ION minerals were the same minerals fed to steers in Study 1.

Gas Production

Preparation of flasks and medium: Forage samples were weighed into 0.5 g increments and added to 250 mL reagent bottle for the Generation 3 ANKOM RF gas pressure system (ANKOM Technology, Macedon, NY). Bottles containing minerals had an addition of 0.0278 g of each respected mineral. Incubation was performed in duplicates, including two blank ANKOM reagent bottles. Blank bottles, used as controls, contain medium and inoculant without substrate. Medium was then prepared by combining, in order, dH_20, KOH, trypicase, micromineral, IV buffer, micromineral, and finally resazarin (which acts as an indication for the reduction state of the buffer).

Collection of rumen fluid. Two liters of rumen fluid was collected from two donor Holstein cows 45 minutes before the start of the procedure. Rumen fluid was blended under constant gassing of CO_2 to ensure rumen fluid stayed anaerobic and kept rumen microbes alive. Rumen fluid was filtered through 4 layers of cheesecloth into a warm flask with constant gassing of CO_2.

Inoculation and fermentation. Following Pell and Schofield (1993) methods for inoculation conditions, 10 mL of rumen fluid was added to each of the premade 250 mL reagent bottles using a repeating syringe fitted with a 3-way valve. Following a final inoculation of CO2, module heads to measure gas production were fitted and placed on a Solaris 4000 I Large Incubated Benchtop Orbital Shaker (Thermo Scientific, Waltham, MA) for constant movement and proper temperature of 38-42 °C. Each module head placed on reagent bottles was connected to the computer program to record temperatures, cumulative pressure, absolute pressure and battery volage and recorded every 2 minutes. Blank modules were used to adjust for atmospheric pressure. An initial gas production run was conducted to 72 hr and found that after 48 hr there was no additional gas production, thus for purposes of concurrent running of samples for gas production, VFAs, and digestibility, a second run was conducted that lasted 48 hr before termination. To determine total gas produced by time, the Ideal gas law was used; [Ideal Gas Law $PV = nRT$, where pressure (P) times volume (V) equals moles (n) times the ideal gas constant (R) times temperature (T)]. Due to the fact the jar modules detected the cumulative pressure (kPA) and temperature every 2 minutes, there were 2,882 recordings per jar. Once the Ideal Gas Law was used to determine the actual gas produced in mol/mL, the pressure was then subtracted by the pressure from our constant jars (also known as rumen fluid only). Averages of each treatment were calculated and depicted every two hours.

Fiber Digestibility

To determine fiber digestibility, 50 mL centrifuge tubes were filled with 10 mL rumen fluid collected from the same donor cows used for gas production. The 0.25 g of the same forage used in gas production and 0.0139 g of respective mineral for each treatment, along with 28 mL of McDougall's solution (McDougall, 1948) were added to the rumen fluid. Each treatment was measured in triplicate, and had time collection points of 0, 3, 6, 9, 12, 18, 24, and 48 h. At each termination time point, triplicates of each treatment were removed from the incubator and placed in the freezer (-4°C) to terminate digestion. Following all terminations, each 50 mL centrifuge tube was thawed and strained to remove particles using Whatman Quantitiative Filter paper, Grade 54 (Cytiva Life Sciences, Chicago, IL). The filter papers were dried in a forced-air 105°C oven for 24 h and weighed to determine mass of product. Dried particles were then transferred into ANKOM F57 fiber filter bags (ANKOM Technology, Macedon, NY) to analyze NDF and sequential ADF following the ANKOM standard operating procedure (Methods 4 and 5). Briefly, in NDF protocol, 2 L of solution was added to machine with tray filled with samples in fiber bags along with 20 g sodium sulfite and 4.0 mL of alpha-amylase to the solution in the vessel. During the ADF run, 2 L of ADF solution was placed in the machine. Samples incubated in NDF solution for 75 min with heat and agitation and ADF solution for 60 min with heat and agitation. Samples were rinsed three times with hot water and in two rinses included alpha-amylase (4 mL) for NDF method and only water for ADF method. After removal from machine, the sample bags were rinsed in acetone then dried in a forced air oven a minimum of 2 hr at 100°C, then weighed.

Volatile Fatty Acid Analysis

The liquid extract drained from thawed centrifuged tubes from the digestibility incubation were used for VFA analysis. The liquid extract was centrifuged at 14,000 x g for 15 minutes and 0.4 mL of supernate was transferred to chromatography vials along with 1.2 mL of pivalic acid which was used as the internal standard. Concentrations of VFA were determined using Agilent 7890 gas chromatography with hydrogen gas as the carrier (Agilent Technologies, Santa Clara, CA) equipped with a flame ionization detector and capillary column (DB-WAX 10 m x 100 µm x 0.1 µm film thickness; Agilent Technologies, Santa Clara, CA).

Statistical Analysis

Steer gains and average daily gains were analyzed using PROC GLIMMIX in SAS 9.4 (SAS Institute, Cary, NC). Fixed effect was treatment and random effects were pasture and steer within pasture. The experimental unit was pasture with steer as subsample.

Forage biomass, forage quality, and mineral intake were analyzed using PROC GLIMMIX procedure with fixed effects of treatment, week, and the interaction of treatment by week. The random effect was pasture. Pasture was experimental unit.

Gas production, fiber digestibility, and VFAs were analyzed using PROC GLIMMIX in SAS 9.4 with the fixed effects of treatment, time, and the interaction of treatment by time. Random effects were replicates. Gas production also included preplanned contrasts that included GRASS vs. all supplements (CON, EO, ION, COMBO); EO vs ION; additives vs. combination (EO and ION vs. COMBO), and control versus feed additives (CON vs. EO, ION, COMBO).

For all analyzed results, statistical significance was determined at ($P \leq 0.05$), with tendencies being declared ($0.05 < P < 0.10$). For any interactions, SLICE statements were used to determine treatment differences.

RESULTS AND DISCUSSION

Study 1: Live animal study and pasture characteristics

Steer Gains and Mineral Intake

There was no difference based on treatment (essential oil mineral vs. ionophore mineral) in steer BW gains, ADG, initial BW, nor final BW ($P > 0.12$; Table 3.2). Pflughoeft et al. (2023) reported similar findings; when supplementing stocker steers in the Flint Hills of Kansas with mineral with the addition of lasalocid, they saw no difference when compared to the control in total BW gain, ADG, nor mineral consumption. Kunkle et al. (2000) found that grazing steers and heifers that were supplemented with 115 mg of monensin per day had an increase in average daily gain of 0.08 kg (or 13.5%) as compared to their non-supplemented counterparts. Over a 5 yr period on the same pastures as the current study, Farney et al. (2020, 2021, 2022, 2023, 2024) found that essential oils increased ADG by an average of 0.05 kg/d over a control mineral. In contrast to Farney's findings, Beck et al. (2017) found that steers grazing either wheat pasture or native range in Arkansas and Oklahoma did not show different gains while feeding a control mineral, essential oil mineral, or monensin mineral in either hand-fed supplement or free-choice. Beck et al. (2017) study matches the results observed in the current study. Torres et al. (2021) observed that replacing monensin with a blend of essential oils had no impact on the performance of finishing beef cattle. Bretschneider et al (2008) also found that cattle consuming monensin had an increased average daily gain of 12.1% and cattle consuming lasalocid had an increased average daily gain of 10.3% while consuming a forage-based diets.

Mineral intake was also not different based on minerals ($P = 0.54$; Table 3.2) nor the interaction of week by treatment ($P = 0.51$). Even though no difference in intake based on mineral type was observed, overall actual intake was higher than formulated intake by ~31%

(averaged 148 g/steer daily as compared to formulated amount of 113 g/steer daily). Based on experimental design, steers were to be offered 125% of weekly amount per pasture, but feeding amounts were greater than that to facilitate ease of feeding within pasture and utilize mineral bags more efficiently, thus each pasture was fed mineral amounts in 11.33 kg increments. This then equated to an average weekly offered amount of mineral being 132% of formulated intake. Based on historical mineral intake on these pastures, steer consumption is generally very high in the first several weeks on pasture (Farney et al., 2020, 2021, 2022, 2023, 2024), thus during the first 3 wk in order to try and reach a satiety effect, double the recommended feeding amount was offered to steers. Subsequently, it was found that mineral consumption was impacted by week ($P < 0.0001$; Figure 3.1) where during the initial portion of grazing season, steers consumed nearly twice the amount of mineral during the second week of grazing. This impacted their consumption for the following 2 weeks, before it eventually averaged back out. Mineral that was left in the feeders remained in the feeder, and each week new mineral was provided at 131% of formulated intake for the pasture, thus allowing steers to potentially have access to greater than the weekly 131% offered and overall, intakes were greater than formulated amount of 113 g/d. . Contrary to our findings of daily mineral intake, Weiss et al. (2018) reported grazing steers supplemented with free choice monensin mineral consumed 70-100 grams per steer per day, which was much less than what we observed grazing steers to consume. Pflughoeft et al. (2023) reported that stockers steers consuming mineral with the addition of lasalocid had no difference in mineral consumption compared to a control mineral.

Pasture Biomass, Forage Accumulation, and Forage Quality

Pasture biomass was not different based on the type of mineral that was fed on the pasture ($P = 0.67$; Table 3.2), nor the interaction of month by treatment ($P = 0.22$). There was a difference observed based on month ($P = 0.0001$) where pasture biomass was greatest during August (1738.61 kg), lowest during May and June (950.14 and 845.03 kg), with the intermediate being July (1285.05 kg; SEM = 111.78 kg). This observation was expected as grass is less palatable during the end of the grazing season, increasing the amount of pasture biomass not consumed by grazing steers. There were no differences based on forage accumulation ($P = 0.89$; 1735 kg vs. 1798 kg SEM = 294 kg; Table 3.2).

Forage quality was not different based on mineral supplements ($P > 0.29$; Table 3.2). There was no treatment by week interactions detected for any nutrient ($P > 0.37$, data not shown). Nutrients were different from the beginning of the grazing season to the end ($P < 0.001$; Table 3.2). The first 5 weeks, regardless of nutrient analyzed, were the highest values, while later in the season there was lower nutritional quality. With no differences observed in nutritional quality of the pastures, it supports the observation of similar mineral intake. Nutrient levels of pastures can influence free-choice mineral intake (McDowell, 1996), which luckily in this study, there were no nutrient differences in pasture.

Behavioral Data

There were no differences in essential oil or ionophore mineral for steps taken per day (54771 vs. 63207 steps; SEM = 4,341.78), time spent ruminating (13435 vs.13782 s/steer; SEM = 1,595.22), time spent walking (3687 vs. 3530 s/steer; SEM = 3,609.64), time spent resting (17435 vs. 16486 s/steer; SEM = 568.53), nor time spent eating (23462 vs. 23385 s/steer; SEM = 756.72; Table 3.3). There was a tendency ($P = 0.07$) for steers consuming essential oil mineral to have a higher average heart rate (81.2 beats/min) compared to ionophore mineral consuming steers (79.7 beat/min; SEM = 0.56). In horses, essential oils in the form of aromatherapy reduced heart rate and other measures of "calming" effects (Kosiara and Harrison, 2021). The essential oil from Siberian fir was included in milk replacer for calves and found that in instances of respiratory distress that calves consuming the essential oil returned to normal heart rate faster than those on other treatments and were able to return to health conditions nearly 2.5 d earlier (Popov et al., 2018).

Functional oils, which are like essential oils but a different feed classification due to the fact they are not completely derived from the essence or spice of plants, were tested against the ionophore (monensin) in dairy cows undergoing heat stress (Ghizzi et al., 2018). In that comparison there were no statistical differences in heart rate even though numerically cows that were on functional oils had 5 less beats per min than those consuming monensin while under heat stress.

During heat stress dairy cows consuming monensin have a greater increase in respiration rates and rectal temperatures as compared to those consuming control diets (Baumgard et al., 2011), which these symptoms often occur with increased heart rates. Spraying steers with essential oils for fly control worked to reduce populations of flies on the steers and reduced respiration and heart rates compared to the steers that were subjected to populations of 500 horn flies (Schwinhammer et al., 1986). Essential oils have had success for fly control while being used as a spray (Wooley et al., 2018); feed-through products have had less success at controlling fly populations (Farney et al., 2020, 2021, 2022, 2023, 2024). Based on success of essential oils as a fly repellent, it was hypothesized that the feed-through essential oil may be beneficial to controlling flies. If it was successful, then behavior responses would have mirrored that seen by Wooley et al. (2018) where cows that were treated with an essential oil fly repellent spent more time grazing, tended to spend less time ruminating, and travelled shorter distances on pasture.

Time spent ruminating, number of rumination events, or mean rumination length was not different when essential oils were added to a 42:58 forage:concentrate ration TMR for lactating Holstein dairy cows (Tager and Krause, 2011). In a feedlot lamb study comparing monensin, a control diet (53:47 forage:concentrate TMR), and the essential oil of copaiba oil the time spent eating was increased with the essential oil over control or monensin diets, but did not impact the time spent standing, laying, ruminating or drinking (Moura et al., 2017).

Study 2: In situ Evaluations and Ruminal Fermentation for Different Minerals

Maximum Gas Production and Gas Production Over Time

There were no differences in maximum gas production based on treatment, nor the preplanned contrasts: GRASS vs. mineral addition *(P* = 0.15); EO vs. ION *(P* = 0.82)*,* EO and ION vs. COMBO *(P* = 0.59); and CON vs. additives (EO, ION, COMBO; *P* = 0.77). In terms of gas production over time, there was no treatment x time interaction (*P* = 0.87). There was a difference based on time (*P* < 0.001) where a plateau occurred at 48 hr, resulting in a logical termination time point (Figure 3.2).

VFA Analysis

There were no treatment x time interactions (*P* > 0.16) for any VFAs analyzed (Table 3.4). There were time effects for all VFAs (Table 3.5) where like gas production, the concentration of VFAs increased with time.

Acetate concentrations were not different based on the mineral treatments used in incubation (*P* = 0.16, Table 3.4). The COMBO mineral resulted in 4.68 mol/mL greater acetate than either EO or ION (*P* = 0.01). Essential oils minerals resulted in the same acetate as ION (*P*

= 0.91). Addition of minerals with or without the additives (EO or ION) did not alter acetate concentration as compared to forage only (*P* = 0.44; Table 3.4).

Propionate tended (*P* = 0.08) to be greater in COMBO compared to EO and ION with GRASS and CON being intermediate (Table 3.4). Similarly, the contrast confirmed that COMBO had 1.44 mol/mL more propionate than EO and ION (*P* = 0.01). Propionate was not different between the additives of EO and ION (*P* = 0.70). Addition of minerals with or without the additives (EO or ION) did not alter propionate concentration as compared to forage only (*P* = 0.65) and the additives (EO or ION) did not result in different propionate concentration than CON mineral (*P* = 0.85; Table 3.4).

Total concentration of acetate and propionate provides some insight into digestibility differences, and in order to truly detect a shift in potential energy supplied to ruminant animals, the ratio of acetate to propionate becomes important. The lower the ratio number the more energetically dense the feedstuff evaluated. The COMBO mineral had a lower ratio than GRASS and CON with ION and EO being intermediate (*P* = 0.05; Table 3.4). Adding a mineral to forage reduced the acetate:propionate ratio (*P* = 0.05) and additionally, adding the additives of EO and ION reduced the acetate:propionate ratio over mineral (CON) alone (*P* = 0.04; Table 3.4).

Butyrate tended (*P* = 0.08) to be greater with COMBO compared to EO and ION with GRASS and CON being intermediate (Table 3.4). The COMBO mineral resulted in 29.3% more butryate than EO or ION (*P* = 0.01). Addition of minerals with or without the additives did not result in different concentrations of butyrate (*P* > 0.89), and there was no difference in EO and ION (*P* = 0.57). Isobutyrate was greater (*P* = 0.03) in COMBO than CON, EO, and ION, with GRASS being intermediate (Table 3.4). As with butyrate, the COMBO had twice as much isobutyrate than either EO and ION (*P* = 0.002). Addition of minerals with or without the additives did not result in different concentrations of isobutyrate ($P > 0.80$), and there was no difference in EO and ION ($P = 0.73$).

Valerate tended ($P = 0.10$) to be greater in COMBO mineral than CON, EO, and ION with GRASS intermediate (Table 3.4). The COMBO mineral had 45.5% more valerate than EO and ION minerals ($P = 0.01$). Addition of minerals with or without the additives did not result in different concentrations of valerate ($P > 0.39$), and there was no difference in EO and ION ($P = 0.98$). When comparing all five treatments, there was no difference in isovalerate ($P = 0.26$) concentration, but there was 35.9% more isovalerate in COMBO mineral compared to EO and ION ($P = 0.02$). Addition of minerals with or without the additives did not result in different concentrations of isovalerate ($P > 0.75$), and there was no difference in EO and ION ($P = 0.91$; Table 3.4).

Martinez et al. (2006) studied in vitro ruminal degradation and the production of volatile fatty acids using a negative control, a positive control of monensin (7.5 µg/mL), and two treatments with essential oils at 1.35 µg/mL; Thymus hyemalis which is rich in carvacrol and Thymus zygis which is rich in thymol. It was found that the negative and positive control had higher values of potential degradability, compared to the essential oil treatments. Similarly, the negative and positive controls had higher values of VFA production than the essential oil treatments. It was concluded that the essential oils, at these doses and with the essential oils used, would not be nutritionally beneficial to create a more energetic metabolism in the rumen (Martinez et al., 2006). Linde et al. (2023) researched the elimination of monensin from feedlot diets by the inclusion of either essential oils or a probiotic (*Bacillus*) and how they impacted the microbiome composition. During the first stage of the feeding trial, the monensin supplemented cattle had significantly lower acetate to propionate ratios compared to the probiotic and essential oil supplemented steers. It was concluded that there was limited variability between rumen microbial compositions between the treatment groups.

Castillejos et al. (2008) completed a thorough trial evaluating the effects of ten essential oils at three doses on ruminal fermentation on high concentrate feedlot diets; clove leaf, hyssop, lavandin, lavender, thyme, oregano, rosemary, sage, savory, and tea tree essential oils. The feedlot diet was 10:90 forage: concentrate (161 h/kg CP, 320 g/kg NDF, 380 g/kg starch DM) and consisted of a negative control, a positive control of 10 mg/L of monensin, and three doses of each essential oil at 5, 50, and 500 mg/L. Compared to the negative control and the three doses of essential oils, Monensin was found to have increased VFA concentrations and propionate:valerate proportion, but decrease acetate:propionate concentrations and the ammonia N concentration. Lower doses (5 and 50 mg/L) were found to increase VFA concentrations by 39-56%. 500 mg/L of rosemary, hyssop, sage, tea tree and close leaf oils acted in a similar fashion as monensin, compared to negative and low doses of essential oils. Castillejos et al. (2008) suggested that most of the ten essential oils studied modified rumen microbial fermentation and potentially have the ability to change rumen fermentation to improve animal production. In the current study, even though we did not know the concentration or types of essential oils used in the blend, at the feeding rates supplied we still saw improvements in ruminal energetics. The garlic oil product used in the current fermentation process supplied 120.12 g/L of the garlic oil product. However, the oil was mixed with a dry powder carrier and we do not know the concentration of garlic essential oil in that product to make an equal comparison to Castillejos results. The Solace product that was used supplied 446.80 g/L of that product, yet once again we do not know the concentration of essential oil as it is contains a carrier and we do not know the specific essential oils included due to proprietary information.

Fiber Digestibility

There were no differences observed based on treatment for both NDF or ADF (*P* > 0.27; Table 3.4). Both NDF and ADF were impacted by time (*P* = 0.0001; Table 3.5); as time increased, numerical numbers decreased. There was an ADF x time interaction (*P* = 0.03; Figure 4). The primary differences occurred at 9 and 24 hr of digestion. ADF was greater (*P* = 0.03) in EO than ION, CON, and GRASS with COMBO being intermediate at 9 hr. Then at 24 hr CON had lower ADF than GRASS, ION, EO, and COMBO (*P* = 0.01; Figure 3.4).

Neutral detergent fiber was not different comparing GRASS to any mineral with or without additives (*P* = 0.51; Table 3.4). Essential oil mineral and ION mineral were also not different in NDF after digestion (*P* = 0.26). Acid detergent fiber tended (*P* = 0.07) to be 1.2% higher in EO, ION, and COMBO than CON mineral with no difference in EO, ION, or COMBO (*P* > 0.47). Oba and Allen (1999) reported that each 1-unit increase of NDF in vitro is connected with increases of 0.17 kg/d of dry matter intake and an increase in milk yield of 0.23 kg per day.

APPLICATION

Essential oils showed no difference in gains as ionophores. This might provide a marketing option for operations that utilize branded programs such as natural and potentially organic systems. Essential oils responded similarly to ionophores in regard to rumen metabolism, suggesting that both may have similar energetic enhancing properties and can be interchangeable on pasture based grazing systems with growing calves. Even though no live animal data was collected, the *in situ* work suggests that the combination of ionophore and essential oil may be additive and might increase gains further. With similar gains and improving acetate to propionate ratios the use of essential oils offers an alternative to feeding antibiotics and offers a natural marketing option for producers.

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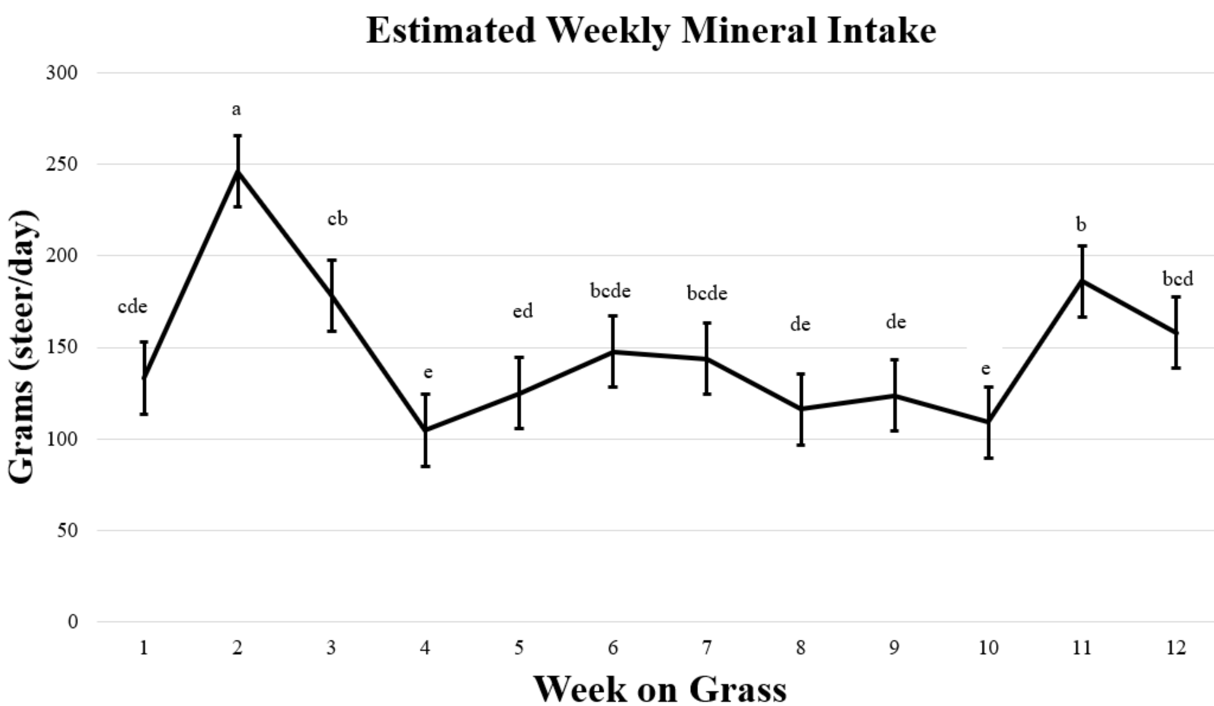
Table 3.1 Mineral composition used in both Study 1 and Study 2

Item (DM basis)	Control	Ionophore [1]	Essential Oil [2]	Combination[3]
Crude Protein (%)	5.69	5.48	5.50	5.46
Calcium (%)	16.67	16.11	16.17	16.05
Phosphorus (%)	3.33	3.44	3.44	3.47
Salt (%)	22.54	22.53	22.53	22.54
Magnesium (%) [4]	2.51	2.48	2.48	2.49
Potassium (%)	0.89	0.88	0.88	0.88
Iron (mg/kg)	5546	5529	5529	5521
Copper (mg/kg) [5]	1153	1153	1153	1153
Zinc (mg/kg) [5]	3471	3471	3471	3471
Manganese (mg/kg) [5]	1817	1818	1818	1718
Selenium (mg/kg)	22	22	22	22
Iodine (mg/kg)	333	333	333	333
Cobalt (mg/kg)	13	13	13	13
Vitamin A (IU/kg)	64,259	64,259	64,259	141,667
Vitamin D (IU/kg)	6,426	6,426	6,426	14,167
Vitamin E (IU)	172	172	172	172

[1]Ionophore: ionophore mineral (Bovatec 91 included at 8.2 kg per ton to provide 1,633 g/ton lasalocid; Zoetis, Kalamazoo, MI) which is same as control mineral with ionophore replacing part of the dried distillers grains and limestone.
[2]Essential oil: essential oil mineral (1.4 kg per ton garlic oil and 2.7 kg per ton of Solace; Wildcat Feeds LLC, Topeka, KS) which is same as control mineral with essential oil replacing part of the dried distillers grains and limestone..
[3]Combination mineral: essential oil mineral (1.4 kg per ton garlic oil and 2.7 kg per ton of Solace; Wildcat Feeds LLC and Bovatec 91 included at 8.2 kg per ton to provide 1,633 g/ton lasalocid; Zoetis). Same base mineral as control mineral just replaced portion of the dried distillers grains with the ionophore and essential oil blends.
[4]Nuplex Mg/K (Nutech Biosciences Inc., Oneida, NY) contributed 25% of the magnesium in the minerals.
[5]Nuplex 3-chelate blend (Nutech Biosciences Inc., Oneida, NY) contributed 25% of the copper, zinc, and manganese of the total trace mineral supplied in the minerals.

Figure 3.1 Mineral intake by week (g/steer daily)



TRT P-value = 0.54
WEEK P-value = 0.0001
TRT*WEEK P-value = 0.51
[abc] Letters indicate difference between weeks and are different at $P < 0.05$.

Table 3.2 Effects of mineral types on growth performance, average daily gain, average daily mineral intake, and pasture biomass.

Item	Ionophore[1]	Essential Oil[2]	SEM[3]	*P*-value
Initial BW, kg	285	296	4.5	0.16
Final BW, kg	378	388	4.1	0.12
Total BW gain, kg	92	91	4	0.92
ADG, kg/d	0.97	0.96	0.09	0.92
Pasture biomass, kg DM/hectare	535	557	36	0.67
Forage Accumulation, kg DM/hectare	1735	1798	294	0.89
CP, % DM	10.85	10.22	0.41	0.33
NDF, % DM	56.19	58.36	1.71	0.40
ADF, % DM	38.05	28.65	0.54	0.46
TDN, % DM	51.19	50.38	0.72	0.46
NEm, Mcal/kg	0.21	0.20	0.005	0.46
NEg, Mcal/kg	0.10	0.07	0.005	0.46
Ca, % DM	0.73	0.67	0.05	0.46
P, % DM	0.18	0.18	0.005	0.56
K, % DM	1.77	1.70	0.04	0.27
Mg, % DM	0.29	0.27	0.02	0.65
Average mineral intake, g/steer/day	146.85	159.61	1.13	0.58

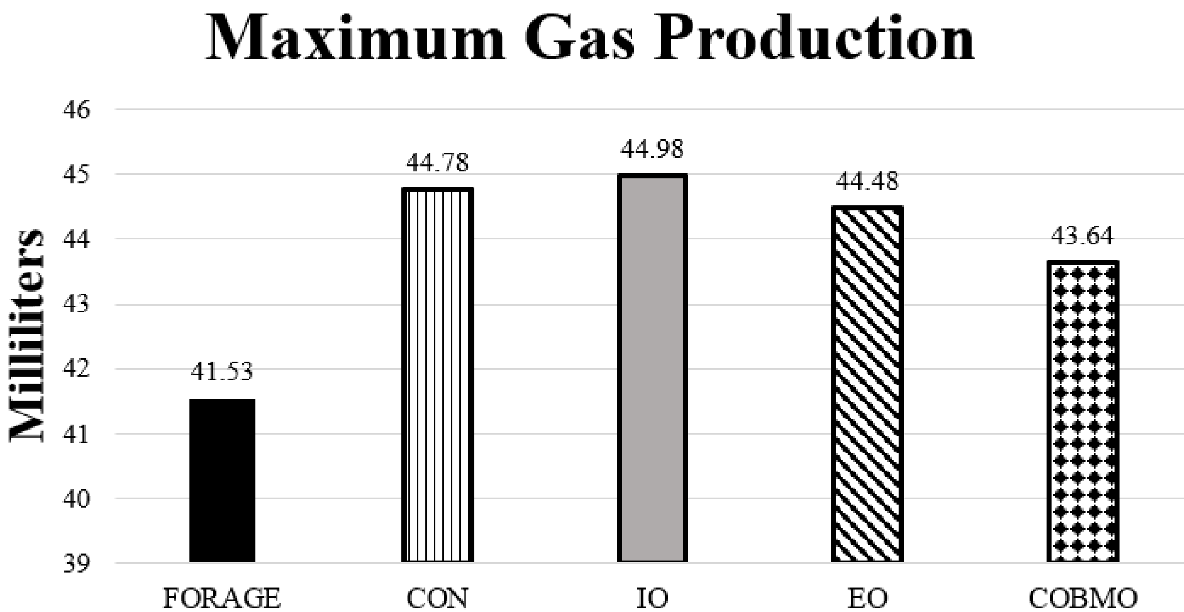
[1]Ionophore: ionophore mineral (Bovatec 91 included at 8.2 kg per ton to provide 1,633 g/ton lasalocid; Zoetis, Kalamazoo, MI).
[2]Essential oil: essential oil mineral (1.4 kg per ton garlic oil and 2.7 kg per ton of Solace; Wildcat Feeds LLC, Topeka, KS).
[3]SEM: standard error of means.

Table 3.3 Steer behavioral data collected by 701X GPS tags

Item	Ionophore[1]	Essential Oil[2]	SEM[3]	*P*-value
Daily Steps (steer/day)	63207	54771	4341	0.24
Time Spent Ruminating (hr/steer daily)	3.85	3.73	0.44	0.85
Time Spent Walking (hr/steer daily)	0.98	1.02	0.04	0.41
Time Spent Resting (hr/steer daily)	4.58	4.84	0.16	0.25
Time Spent Eating (hr/steer daily)	6.50	6.52	0.21	0.94
Average Heart Rate (beats per min/steer daily)	79.7	81.2	0.56	0.07

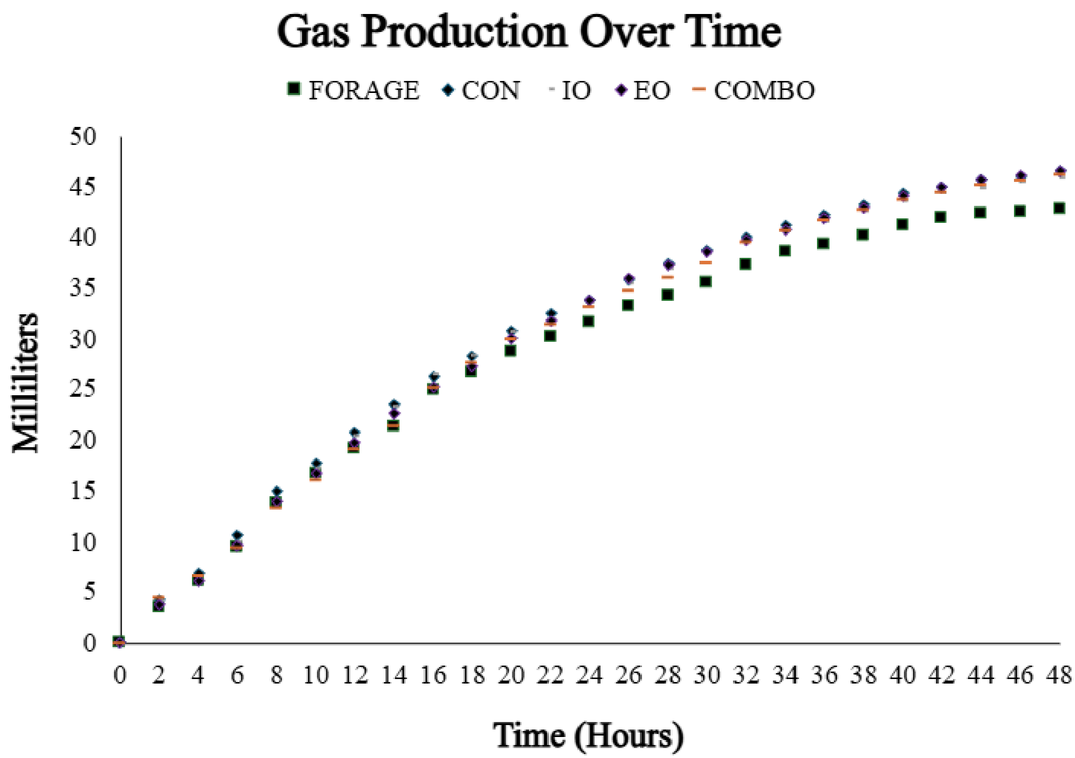
[1]Ionophore: ionophore mineral (Bovatec 91 included at 8.2 kg per ton to provide 1,633 g/ton lasalocid; Zoetis, Kalamazoo, MI).
[2]Essential oil: essential oil mineral (1.4 kg per ton garlic oil and 2.7 kg per ton of Solace; Wildcat Feeds LLC, Topeka, KS).
[3]SEM: standard error of means.

Figure 3.2 Maximum Gas Production.



Treatments represented by each bar include:
GRASS: forage only consists of a composite sample of tallgrass native range collected over summer.
CON: control mineral with forage treatment
EO: essential oil mineral (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds LLC, Topeka, KS) with forage
ION: ionophore mineral (Bovatec 91 included at 8.2 kg/ton to provide 1,633 g/ton lasalocid, Zoetis, Kalamazoo, MI) with forage
COMBO: mineral that contains both essential oil and ionophore (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds

Figure 3.3 Gas production over time (0 - 48h).



TRT P-value = 0.87
TIME P-value = 0.0001
TRT*TIME P-value = 0.98
Treatments represented by each dot within plot include:
GRASS: forage only consists of a composite sample of tallgrass native range collected over summer.
CON: control mineral with forage treatment
EO: essential oil mineral (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds LLC, Topeka, KS) with forage
ION: ionophore mineral (Bovatec 91 included at 8.2 kg/ton to provide 1,633 g/ton lasalocid, Zoetis, Kalamazoo, MI) with forage
COMBO: mineral that contains both essential oil and ionophore (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds

Table 3.4 VFA and fiber digestibility analysis results.

	Treatments						*P* - values						
Item	**GRASS[1]**	**CON[2]**	**EO[3]**	**ION[4]**	**COMBO[5]**	**SEM**	**Trt[6]**	**Time[7]**	**Trt x Time[8]**	**G vs M[9]**	**C vs A[10]**	**M vs A[11]**	**E vs I[12]**
Acetate	21.61	20.78	18.40	18.66	23.21	1.57	0.16	**<0.0001**	0.88	0.43	**0.02**	0.71	0.91
Propionate	5.79^{ab}	5.51^{ab}	5.01^{b}	5.23^{b}	6.55^{a}	0.41	**0.08**	**<0.0001**	0.73	0.65	**0.01**	0.85	0.70
Acetate: Propionate	3.71^{a}	3.69^{ab}	3.62^{abc}	3.55^{bc}	3.54^{c}	0.005	0.005	**<0.0001**	0.14	0.05	**0.51**	0.04	0.33
Butyrate	2.55^{ab}	2.43^{ab}	2.16^{b}	2.32^{b}	2.90^{a}	0.19	**0.01**	**0.0001**	0.62	0.63	**0.0039**	0.88	0.56
Isobutyrate	0.37^{ab}	0.34^{b}	0.25^{b}	0.28^{b}	0.56^{a}	0.07	**0.006**	**0.0001**	0.16	0.88	**0.009**	0.82	0.78
Valerate	0.52^{ab}	0.45^{b}	0.45^{b}	0.45^{b}	0.64^{a}	0.06	0.10	**<0.0001**	0.77	0.74	**0.001**	0.39	0.98
Isovalerate	0.57	0.53	0.49	0.48	0.67	0.06	0.26	**<0.0001**	0.81	0.75	**0.02**	0.83	0.91
NDF, %	62.35	59.57	60.77	62.40	61.08	1.13	0.27	**<0.001**	0.36	0.22	0.69	0.12	0.26
ADF, %	35.32	34.00	34.89	35.47	35.24	0.62	0.38	**<0.001**	**0.03**	0.51	0.92	**0.07**	0.47

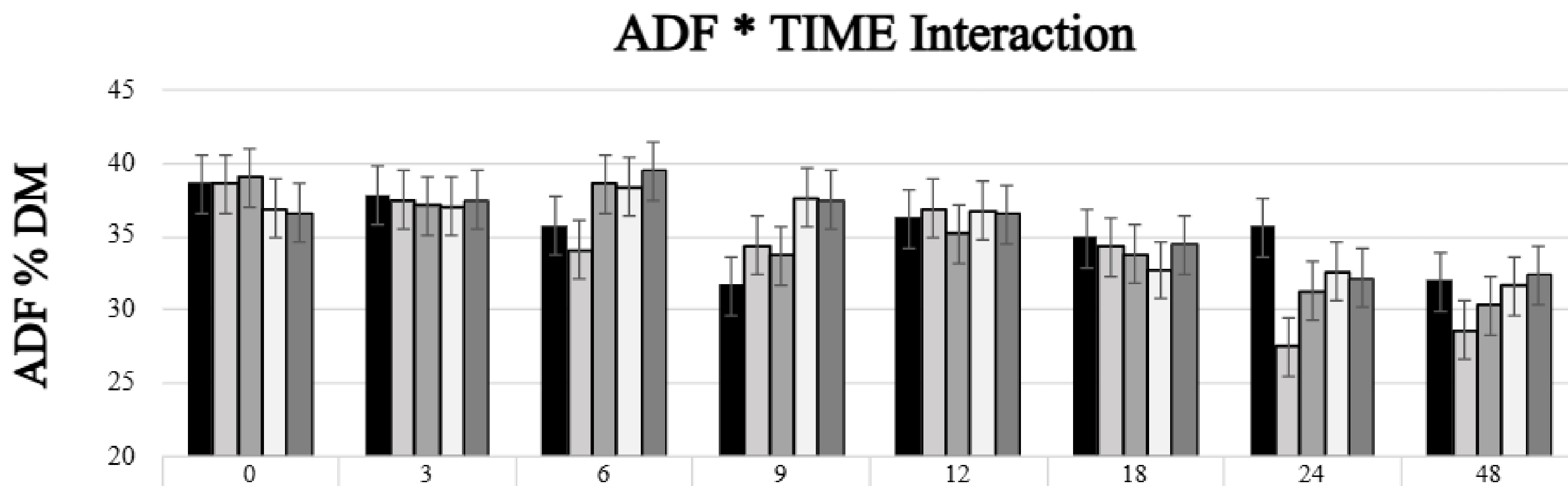
[ab] Letters that are different within row are different $P < 0.05$.
[1]GRASS: forage only which consisted of composited sample of tallgrass native range collected over summer.
[2]CON: control mineral with forage treatment
[3]EO: essential oil mineral (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds LLC, Topeka, KS) with forage
[4]ION: ionophore mineral (Bovatec 91 included at 8.2 kg/ton to provide 1,633 g/ton lasalocid, Zoetis, Kalamazoo, MI) with forage
[5]COMBO: mineral that contains both essential oil and ionophore (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds LLC, and Bovatec 91 included at 8.2 kg/ton to provide 1,633 g/ton lasalocid, Zoetis)
[6] Treatment*:*comparing all 5 treatments.
[7] Time*:* comparing differences in time.
[8] Trt x Time*:* comparing differences in treatments within time measurements.
[9] G vs M: pre-planned contrast of GRASS vs. minerals (CON, ION, EO, and COMBO).
[10]C vs A: pre-planned contrast of COMBO vs. additives (EO and ION).
[11]M vs A: pre-planned contrast of CON mineral vs. additives (EO, ION, and COMBO).
[12]E vs I: pre-planned contrast of EO vs. ION.

Table 3.5 VFA and fiber digestibility time results.

Item	0 h	3 h	6 h	9 h	12 h	18 h	24 h	48 h	SEM
Acetate	9.05^{e}	15.01^{d}	17.02^{cd}	21.00^{bc}	27.22^{a}	28.00^{a}	21.32^{bc}	25.59^{ab}	1.98
Propionate	2.70^{e}	4.11^{de}	4.56^{cd}	5.5^{cd}	7.14^{ab}	7.72^{a}	5.94^{bc}	7.25^{ab}	0.41
Acetate: Propionate	3.29^{c}	3.61^{b}	3.72^{ab}	3.81^{a}	3.82^{a}	3.62^{b}	3.54^{b}	3.55^{b}	0.006
Butyrate	1.11^{e}	1.65^{de}	2.03^{cd}	2.47^{bc}	3.36^{a}	3.46^{b}	2.67^{b}	3.01^{ab}	0.24
Isobutyrate	0.0001^{c}	0.13^{c}	0.0003^{d}	0.08^{c}	0.48^{b}	0.77^{a}	0.66^{ab}	0.77^{a}	0.09
Valerate	0.00069^{d}	0.09^{d}	0.14^{d}	0.40^{c}	0.81^{b}	1.02^{a}	0.72^{b}	0.83^{ab}	0.07
Isovalerate	0.0009^{d}	0.12^{d}	0.18d^{c}	0.35^{c}	1.00^{a}	1.05^{a}	0.76^{b}	0.92^{ab}	0.08
ADF	0.37^{a}	0.37^{a}	0.37^{a}	0.35^{bc}	0.36^{ab}	0.34^{c}	0.32^{d}	0.31^{d}	0.006
NDF	64.21^{b}	67.85^{a}	64.58^{b}	62.76^{b}	63.57^{b}	58.56^{c}	56.88^{c}	52.43^{c}	1.25

^{abcde} Letters that are different indicate treatment differences within row at $P < 0.05$.

Figure 3.4 ADF x TIME Interaction.



	0	3	6	9	12	18	24	48
■GRASS	38.6	37.8	35.71	31.63	36.27	34.92	35.68	31.91
◻CON	38.63	37.5	34.07	34.42	36.93	34.34	27.49	28.6
◻ION	39.08	37.13	38.63	33.69	35.2	33.82	31.26	30.28
◻EO	36.9	37.09	38.42	37.66	36.78	32.72	32.58	31.63
◻COMBO	36.6	37.51	39.52	37.48	36.55	34.43	32.14	32.37

■GRASS ◻CON ◻ION ◻EO ◻COMBO

GRASS: forage only consists of a composite sample of tallgrass native range collected over summer.
CON: control mineral with forage treatment
EO: essential oil mineral (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds LLC, Topeka, KS) with forage
ION: ionophore mineral (Bovatec 91 included at 8.2 kg/ton to provide 1,633 g/ton lasalocid, Zoetis, Kalamazoo, MI) with forage
COMBO: mineral that contains both essential oil and ionophore (1.4 kg/ton garlic oil and 2.7 kg/ton Solace, Wildcat Feeds

Chapter 4 - Effects of Corn Silage Supplementation Feeding of Fall-Calving Cows Grazing Varieties of Fescue

ABSTRACT

Objectives: The objective of this study was to determine if supplementing corn silage on different varieties of fescue being grazed by gestating and lactating beef cows would affect performance, physiological biomarkers, and forage production.

Materials and Methods: Multiparous and primiparous Angus cross-bred cows (Year 1: n = 45; 151 ± 7 d gestation; Year 2: n = 48; 140 ± 0.5 d gestation) were stratified by age within pasture (n = 3/pasture). The treatment structure was 2 x 2 factorial with two types of fescues (**TOX:** n = 8; and **NONTOX:** n=7 Year 1; n = 8 Year 2) and two levels of supplementation (**SUPP:** corn silage at 1% BW daily; and no-supplement: **NONSUPP**). BW, BCS, hair score (HS), hair length (HL), ultrasound rump fat (RF), and serum were collected ~ middle of 2nd trimester (initiation of study), beginning of 3rd trimester, and ~two weeks prior to parturition with BW and BCS collected at peak lactation. Calves were weighed at birth, weaning, and peak lactation (weigh-suckle-weigh to estimate milk output). Forage accumulation (FA) and mass (FM) were estimated every 28 d using the paired-cage method.

Results and Discussion: Supplemented cows tended to have greater weight gain through the entire supplementation period (P = 0.10), and had greater increase in BCS from 3rd trimester through lactation (P < 0.06). Supplementation had no effect on calf birth weight or milk production (P > 0.33). Supplementation tended (P = 0.06) to increase FM by 7.48% over

NONSUPP pastures, while not impacting FA or quality ($P > 0.10$). Weaning weight tended ($P = 0.08$) to be greater for NONTOX-SUPP as compared to TOX-SUPP and TOX-NONSUPP. Cows grazing TOX fescue tended to have lower weight gains, more HL, greater HS, and lighter calf birth weights than NONTOX ($P < 0.10$)**.** TOX pastures had 12.27% greater FM with no differences in FA *(*$P = 0.54$). Serum cortisol and prolactin concentrations were not impacted by treatment ($P > 0.12$).

Implications and Applications: Replacing toxic fescue with non-toxic varieties is an option to improve productivity in cow herds than offsetting issues with supplementation. Supplementation may only have benefits during low forage years.

Keywords: Cow-calf performance, fescue toxicosis, forage management, endophyte-free

INTRODUCTION

Tall fescue (*Festuca arundinacea*), a perennial bunchgrass, is a predominant cool-season grass that covers more than 14 million hectares in the United States (Jackson et al., 1984; Thompson et al., 2001). Being one the most abundant forage crops in the United States, Hoveland (1993) reported the grass grown in 21 states in the contiguous U.S., and used for hay production and grazing. Tall fescue provides forage for 8.5 million cattle and 688,000 horses (Hoveland). Due to its ability to withstand drought and, produce forage in the winter and withstand defoliation, tall fescue is attractive to producers (Thompson et al., 2001; Gunter and Beck, 2004).

Although attractive as a forage production plant, animal performance is often hindered due to being infested with an endemic endophyte that lives in the intercellular spaces of the plant (Gunter and Beck, 2004). The most common toxic fescue is known as Kentucky-31 (KY-31).

Consumption of endophyte infected fescue, known as toxic fescue, is often characterized by the appearance of fescue foot, fat necrosis, agalactia and fescue toxicosis (Paterson et al., 1995). Researchers have developed an endophyte-free variety of fescue, known as non-toxic fescue, which can help to provide excellent animal performance. According to Gunter and Beck (2004), non-toxic fescue is not as resilient to drought and defoliation like toxic fescue, and often results in nearly a complete loss of a stand in three to four years.

To help offset fescue toxicosis, research has been conducted to identify if supplementation has the ability to mitigate toxicosis with varying responses (Marston et al., 1998; Lalman and Holder, 2024). The objective of this study was to determine if supplementing corn silage on different varieties of fescue being grazed by gestating and lactating beef cows would affect performance, physiological biomarkers, and forage production.

MATERIALS AND METHODS

Experimental Procedures

The experiment was conducted at the Mound Valley Branch of the Southeast Research and Extension Center in Mound Valley, KS. All animals were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Kansas State University Animal Care and Use Committee (protocol #4883).

Treatment Structure

Two years of data (2023: Year 1 and 2024: Year 2) were collected with similar protocols. During both years the study was conducted from May to early December and consisted of the cow production periods of mid-second trimester through early lactation. The experiment utilized fescue pastures (n = 15 in Year 1 and n = 16 in Year 2; 2.02 hectares each) of either a toxin producing variety of tall fescue (K-31, n = 8 in both years) or non-toxic varieties (n = 7 in Year 1 and n = 8 in Year 2) consisting of the novel tall fescue (MaxQ) and endophyte-free fescue variety (HM4). The original long-term pasture design consisted of 16 pastures with an equal number of toxin-producing and non-toxin varieties, however, due to drought conditions the prior year (2022) causing a lack of regrowth, one endophyte-free pasture was unable to be utilized during the 2023 grazing year (Year 1 of study), therefore seven pasture replicates of non-toxic fescue were grazed and eight toxic fescue pastures. The experiment was a randomized complete design with a 2 x 2 factorial arrangement of treatments. Treatment factors were: 1) fescue cultivar type (toxic = TOX or non-toxic = NONTOX) and 2) supplementation (non-supplemented = NONSUPP or supplemented = SUPP). Supplementation consisted of feeding corn silage (32-42% DM and 10.65% CP, DM basis) at 1% of BW on DM-basis daily (Table 4.1) for Year 1. Year 2 corn silage was calculated to have 9.3 ± 0.50% CP with a TDN of 66.07 ± 1.96 (Table 4.1). Corn silage was fed in fence-line bunks and refusal amounts were measured every Monday, Wednesday, and Friday. Supplemented cows were fed silage from mid-second trimester through early lactation, and all cows grazed their respective treatment pastures during this same time in Year 1. Due to concerns about forage availability in Year 2, all cows were removed from pasture on November 15, but the cows that received silage continued to receive silage until December 7, 2024. The cows continued to graze fescue pastures for that 3 wk supplementation period. The DM content of the silage was determined weekly, and a three-week running average was used to determine the feeding rate for the subsequent three weeks. Cattle in all pasture replicates were offered free choice access to a dry, granular mineral supplement (Table 4.2).

Endophyte and Ergot Alkaloid Measurements

To determine ergot alkaloid concentration, 10 samples were collected throughout each pasture in early June for both years. Samples were collected by clipping ~2.54 cm from ground the whole plant, and samples were composited within pasture for analysis. Samples were placed on ice before being sent overnight to the University of Missouri Diagnostic Lab (University of Missouri, Columbia, MO). Upon arriving at the lab, HPLC analysis for the ergot alkaloid panel was conducted (Rottinghaus et al., 1991; Bailey et al., 2022).

For endophyte presence 20 random tillers were collected from each pasture and samples were placed on ice, and endophyte measurements were performed using the Agrinostics Phytoscreen© field tiller endophyte detection kit (Agrinostics Ltd. Co., Watkinsville, GA). The lower portion of the stem was placed on a nitrocellulose membrane and incubated overnight. This allowed for the migration of the endophyte organisms to the nitrocellulose membrane which were then bound with color indicators determining the presence of the endophyte organism. The number of positives were identified and multiplied by five to determine total percent infection for each pasture.

Pasture Management

In mid-June of each year, pastures were mowed upon inflorescence to remove the seedhead, thus ensuring pasture integrity and preventing toxic fescue infestation of non-toxic fescue pastures. Pastures were fertilized with 149 units of N per hectare in March of both years and were also fertilized with P and K based on soil tests collected October of 2022 for each specific pasture. Pastures were fertilized with approximately 99 units of N per hectare in September of both years for fall growth.

Cow Management

Crossbred primiparous and multiparous Angus-based cows (n = 45, Year 1; n = 48, Year 2) originating from the Southeast Research and Extension Center production herd were utilized. Cows used in Year 1 where estrus was synchronized using the seven-day CIDR protocol and cows were artificially inseminated on December 14, 2022, and exposed for natural service breeding 2 weeks later. Pregnancy was diagnosed via trans-rectal ultrasound on February 12, 2023, and bulls were removed on this date. Females utilized for the experiment were confirmed as pregnant to either AI or natural service mating in the first two weeks of the breeding season. One cow from the NONTOX-NONSUPP treatment was determined to be non-pregnant prior to commencement of the study according to BioPRYN Pregnancy-Specific Protein B blood serum test (Ag Health Laboratories Inc., Sunnyside WA) conducted by SEK Genetics (Galesburg, KS). This blood pregnancy test occurred using serum samples collected from collection time point during gestation and analyzed after calving to retrospectively determine time of fetal loss. The one female from the NONTOX-NONSUPP treatment was excluded from the percentage of live calves born analysis. Cows used in Year 2 were estrus synchronized using the seven-day CIDR protocol and cows were artificially inseminated on December 13, 2023, and exposed for natural service breeding one week later. Pregnancy was diagnosed via trans-rectal ultrasound on February 14, 2024, and bulls were removed on this date. Females used in Year 2 were all identified via the ultrasound pregnancy to be bred to AI sires. Cows were diagnosed via rectal palpation prior to initiation of study to confirm pregnancy prior to start of grazing. After grazing respective treatment pastures all the cows were managed similarly until weaning (April 20, 2024 and April 26, 2025). The cow-calf pairs grazed fescue-based pastures with free-choice access to fescue hay and 1.81 kg of a 50:50 blend of cracked corn and dried distillers grains fed on Mondays, Wednesdays, and Fridays.

Cows were stratified by age and randomly assigned to pasture replicates with each pasture designed to include an animal from three age groups: a young (first-calf heifer), middle-aged (3-5 yrs.), and old (≥ 6 yrs.) cow. The average age of all cows used during the experiment was 4.75 ± 0.30 yrs old in Year 1 and 3.8 ± 0.3 yrs old in Year 2.

Cow and Calf Performance

Cattle were restrained in an Arrowquip Q-Power 107 Series hydraulic squeeze chute (Arrowquip, Woodlands, MB), with weights being recorded by a Gallagher TWR chute scale head (Gallagher Group Limited, Riverside, MO). In both years, cows were weighed for two consecutive days after being commingled in a dry-lot pen with ad libitum access to prairie hay for 3 days prior to first weigh date to manage for gut fill.

Year 1 specifics: Cows were placed on pasture May 8, 2023, corresponding to 151 ± 7 d of gestation, which was midway through the second trimester. Cows were also weighed at the beginning of 3rd trimester (June 21, 2023); and ~2 weeks prior to calving on August 29-30, 2023. Cow measurements post-partum were recorded at time of CIDR insertion (December 3, 2023) and corresponded to peak lactation (~60 days post-calving). Calves were weighed at birth using a hanging scale, and calving occurred from September 5, 2023 through October 10, 2023.

Year 2 specifics: Cows were weighed for two consecutive days after being dry lotted with ad libitum access to prairie hay for 3 days prior to the first weigh date. Cows were placed in pasture on May 22, 2024, averaging 140 ± 0.5 d of gestation. Cows were also weighed at the beginning of their third trimester (June 18, 2024), 2 weeks prior to calving (August 28, 2024), and during peak lactation (December 2, 2024). Calves were weighed at birth using a hanging scale, with calving starting on September 4, 2024, and ending on October 16, 2024.

Calves were weighed at birth with a hanging scale. At weaning calves were weighed using the same chute and scale as the cows. Actual calf weight, adjusted to 205 d of age, and adjusted 205 d weaning weights (American Angus Association) were determined. Not all cows calved once starting on the study, thus a percentage of calves born was calculated. One cow was removed from the analysis as retrospective analysis of blood samples found that she was not pregnant prior to the start of the study.

Body Condition Scoring and Rump Fat Measurement

For both years, three independent evaluators, blinded to treatments, evaluated BCS at each measurement period using the standard 1-9 scale (Selk et al., 1988). Rump fat was measured by a trained technician using an ALOKA 500 ultrasound machine (Hitachi, LTD., Wallingford, CT) with a 3.5-megahertz short probe to capture the image. The image was then analyzed using the Cattle Performance Enhancement Company software package (CPEC, Oakley, KS).

Hair Score and Hair Length

In both years, one trained technician evaluated hair scores at each measurement period using the standard 1-5 scale (American Angus Association, St. Joseph Missouri). In brief, a hair score of 1 means the animal has shed 100% of hair coat; 2 indicates 75% shedding; 3 is 50% shedding; 4 is 25% shedding; and a 5 means the animal still has a full winter hair coat. Hair length was measured by a different technician than the one completing the hair score. Measurement was done using a slide ruler over the forerib, on the left side of the animal and recorded in millimeters (mm).

Calf Weigh-Suckle-Weigh

In Year 1, cows and calves were sorted ~60 days after calving (December 3, 2023) to perform a weigh-suckle-weigh measurement, with this time of the experiment coinciding with peak lactation. Weigh-suckle-weigh methods were modelled after Grings et al., (2008). Pairs were gathered and sorted on December 2, 2023, with calves being separated from dams overnight. On December 3, 2023, calves were weighed empty. After empty weight was recorded, calves were turned back in with their dams and allowed to nurse until full and weighed. This process was replicated twice in a 24-hour period with a 6-hour removal of the calf from the dam in the middle of the day. The empty weight was then subtracted from the full weight to determine the change in calf body weight due to milk in kg at each period. The weights were added then multiplied by two for an estimated 24-hr milk output value. In Year 2, on December 1, 2024 calves were separated from their respective dams overnight. On December 2, 2024, cows and calves were weighed individually. After 'empty' weights were recorded, cows and calves were reunited with each other and allowed to nurse until all calves had stopped nursing for ~30 minutes. After which all cows and calves were individually weighed again, resulting in a 'full' weight. The empty weight of the calf was then subtracted from the full weight of the calf and multiplied by two for an estimated 24-hr milk output value.

Hormonal Analyses

Blood was collected via jugular vein puncture (Year 1) and middle caudal vein (Year 2) using Greiner bio-one VACUETTE 4 mL Serum Clot Activator blood collection tubes (Model: 2016-06, Greiner bio-one, Monroe, NC) and samples were allowed to clot a minimum of two hour at room temperature before centrifugation. Following the clotting period, samples were centrifuged using a Beckman Coulter Allegra® X-22R Centrifuge (Beckman Coulter Inc., Brea, CA) for 20 mins at 4°C at 1000 x g. Post centrifuging, samples were hand pipetted to obtain serum, which was then transferred to a 1.5 ml centrifuge tube. Serum samples were placed in a freezer at -20°C until analysis for prolactin and cortisol. Serum cortisol was analyzed by the Kansas State University College of Veterinary Medicine Department of Anatomy and Physiology Lab (Kansas State University, Manhattan, KS) using a radioimmune assay (MP Biomedicals ImmuChem™ Cortisol Coated Tube RIA kit catalog #: 207221; MP Biomedicals, LLC, Solon, Ohio) as described by Reppert et al. (2020). Briefly, 25 µL of sample and standards were placed into pre-coated tubes, with the addition of cortisol-125, and allowed to incubate. Then tubes were measured with a gamma counter for I125. The coefficient of variance for the inter-assay variability was 7.02% in Year 1 and 7.05% in Year 2. Prolactin was analyzed using the Cattle Prolactin (PRL) ELISA Kit (MyBioSource, Inc. San Diego, CA) according to manufacturer protocol. Briefly, 50 µL of sample and standards were placed in a 98-well plate using the competitive enzyme immunoassay technique utilizing a polyclonal anti-prolactin antibody and a prolactin-HRP conjugate. The plate was read spectrophotometrically at 450 nm in a microplate reader (BioTek ELx800, Agilent, Santa Clara, CA). Results were calculated noting the inverse relationship between prolactin concentration in the sample and the assay signal intensity, with a standard curve created by placing the log of the prolactin concentration along the y-axis and absorbance along the x-axis and determining a best fit line via regression analysis. The detection range of the assay was 2.47-200 ng/mL, with intraassay variability and inter-assay variability being 7.6% and 14.8% respectively in Year 1 and 7.5% and 12.2% in Year 2.

Pasture Measurements

Forage mass is defined as the total dry weight of forage per unit area of land, usually above ground level and at a defined reference level (Forage, and Grassland Terminology

Committee, 1991). Forage mass measurements were collected at the beginning of the study and then every 28 d using a 0.33 m^2 area was clipped at approximately 2.54 cm of height remaining outside of the exclusion cage. There were four exclusion cages per pasture, thus four forage mass samples were collected each time and used to determine the average forage mass production per pasture. This measurement was used to determine the amount of available forage for the cows. Forage accumulation is defined as the increase in forage mass per unit area over a specified period of time (Forage, and Grassland Terminology Committee, 1991). Forage accumulation was determined via destructive methods and were collected according to the paired cage method (Paraiso et al., 2019). Briefly, four exclusion cages (0.66 m^2) were placed in each pasture and were moved every 28 d. At each sampling period a 0.33 m^2 area was clipped to 2.54 cm height within the exclusion cage. To calculate forage accumulation, the amount of forage measured within the exclusion cage was used and then the amount of forage measured from outside the cage (forage mass) during the previous 28 days was subtracted. The below equation illustrates the equation used to calculate forage accumulations.

$$Forage\ accumulation = Biomass\ in\ exclusion\ cage - Biomass\ outside\ cage\ 28\ d\ prior$$

Clippings from outside the cage were analyzed by SDK laboratories (Hutchinson, KS) using NIR equations to determine nutrient composition in May (at turnout), in July (when mostly dormant), and November (end of grazing). Analysis included CP, TDN, ADF, NDF, and macrominerals.

Statistical Analysis

Changes in BW, RF, HL, and HS measured during the gestation period were analyzed using the GLIMMIX procedure in SAS 4.3 (SAS Institute, Cary, NC). There were three change periods evaluated for RF, HL, and HS (period 1: beginning of third trimester minus mid second trimester; period 2: ~2 weeks prior to calving minus beginning of third trimester; total gestation period: ~2 weeks prior to calving minus mid-second trimester). Body weight changes were calculated for those same periods as well as post-calving, where gain in lactation was calculated by weight at peak lactation minus weight ~2 weeks prior to calving. Total weight gain was calculated from weight difference at the start of supplementation (mid-second trimester) through early lactation. To minimize biased effects of continuing supplementation without the cows lactating, all cows that did not have a calf were removed from the weight measurements post-calving and BCS measurements. Main effects in the model included fescue variety, supplementation, and interaction. Random variables were year, pasture, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year. Sample periods were analyzed independently, as well as the entire grazing period. Pasture was the experimental unit with cow as subsamples.

Body condition score was analyzed as a proportion, using the GLIMMIX procedure, with main effects of fescue type, supplement, and interaction. The random effects included scorer, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year. Pasture within year was the experimental unit with cow as subsamples.

Calf birth weight, calving date, and milk production were analyzed using the GLIMMIX procedure of SAS 4.3 with main effects of fescue variety, supplementation, cow age, calf sex, and interactions of all main effects. Random effects were calf, pasture, year, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year

Prolactin and cortisol were measured using the GLIMMIX procedure of SAS 4.3. Main effects included fescue variety, supplementation, cow age, and the interactions. Each time point of sampling was analyzed independently. Random effects included year, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year.

Forage mass and accumulation were analyzed using the MIXED procedure of SAS 4.3 with main effects of fescue type, supplementation method, time of sample, year, and interactions. Random effect was pasture within year. In terms of forage measurements, there were no interactions by year of study ($P > 0.10$) and were subsequently removed from all reported responses.

If an interaction effect was greater than $P > 0.10$ then it was removed from model. For all analyzed results, statistical significance was determined at ($P \leq 0.05$), with tendencies being declared ($0.05 < P < 0.10$). If an interaction effect was detected, SLICE effects were conducted to determine within treatment differences

RESULTS AND DISCUSSION

Fescue Pasture and Weather

Non-toxic fescue pastures in Year 1 had 38.6 ± 7.38% of endophyte and 5 ± 2.5 ppb of total ergots. In year 2 these same pastures had 43.13 ± 0.1% of endophyte and 228.38 ± 3.26 ppb of total ergots. For the TOXIC pastures in Year 1 there was 92.5 ± 11.2% endophyte and 507 ± 0.82 ppb of total ergot alkaloids and in Year 2 there was 89.1% ± 16% of endophyte and 1709.5 ± 0.36 ppb of total ergot alkaloids. The TOXIC pastures were highly toxic based on reported levels that impede cattle production (Inc., 2021). In the Merck Veterinary Manual (2021), the ergovaline concentration often ranges from 100-500 ppb, with anything over 200 ppb considered a toxic concentration. With both years having well over the respected ergovaline concentration, it was expected to witness extreme levels of toxicosis.

Rainfall during the summer of 2023 was 52.45 cm with an average temperature of 24.1 C (minimum = 17.8 C; maximum = 30.33 C). During 2024, rainfall during the summer was 43.87 cm with an average temperature of 24.64 C (minimum = 18.9 C; maximum = 30.33 C), according to Kansas State University Weather Data Library

Cow Weight Changes

There were no interaction effects for cow BW or BW changes ($P > 0.13$), thus only main effects will be discussed. At the initiation of the study (~ middle of second trimester) there were no differences in initial cow BW ($P > 0.12$; Table 4.3). By the beginning of the third trimester cows that were on NONTOX weighed more ($P = 0.04$) than those on TOX (646 vs 604 kilograms, respectively: SEM = 14) and this advantage continued prior to calving ($P = 0.01$; 679 vs. 628 kg: SEM = 13) and through peak lactation ($P = 0.05$; 634 vs 594 kg: SEM = 14). This follows the observation that there was greater weight gain ($P = 0.03$) in cows on NONTOX as compared to TOX through the entirety of gestation (105 vs 84 kg: SEM = 9.5). Multiple studies from around the country have found that cows grazing endophyte infected fescues (toxic-producing varieties) will have decreased daily gains and/or more BW loss than those grazing endophyte free fescues (non-toxin producing) (Schmidt et al., 1982; Hoveland et al., 1983; Paterson et al., 1995)

Schmidt et al. (1982) reported that reduction in gains due to consuming toxic fescue can occur at any time throughout the year. But, similar to this study's findings, it has been suggested that with each increase of 10% of toxic fescue in grazing pasture, there is a decrease in average daily gain of 0.045 kg/day (Crawford et al., 1989; Paterson et al., 1995). Research has found the greatest concentrations of ergopeptines during May (Paterson et al., 1995), but signs of toxicosis are most common during the end of the grazing season (Jackson et al., 1984). Thus, toxicosis from consumption of toxic fescue interacts with temperatures and daily feed intake of grazing beef cows (Peters et al., 1992).

Interestingly, cows that were SUPP tended to only be heavier from period of calving through early lactation (*P* = 0.10) as observed by seeing a reduced rate of weight loss in early lactation as compared to NONSUPP (-36 kg vs. –52 kg: SEM = 17). There was no difference in BW gains during gestation based on supplementation method (*P* = 0.27). The magnitude of increased weight gain during lactation for SUPP as compared to NONSUPP resulted in an overall greater BW change through the entire feeding period evaluated which included mid-second trimester through early lactation (*P* = 0.05; 65 vs 43 kg; SEM = 11.7).

Tanner et al. (2020) found that body weight, body condition score and dry matter intake was affected by corn supplementation of 0.2% of BW of dry-rolled corn when supplemented from parturition to 21 days post parturition where gains were greater and intake decreased with corn supplementation. Corn supplementation with varying levels of UIP were fed to spring-calving cows grazing endophyte infected fescue from May to late July in Forcherio et al. (1995) study. In this study, the low level of UIP and feeding corn at rowing beef cattle were successfully supplemented with corn silage when there were high level% of BW resulted in cows having positive rate of gain, whereas those supplemented with higher UIP level lost weight.

Growing beef cattle were successfully supplemented with corn silage when there were higher levels of protein in the pasture and this allowed stocking densities to be doubled without inhibiting rate of gain (Vogel et al., 1989). Grazing temperate grasses in Argentina while being supplemented corn silage had impacts on animal performance, but based on study design did have a stocking rate increase (Abdelhadi et al., 2005). Corn gluten feed, although much lower in starch than corn silage, did increase rate of gain in yearling heifers that were fed fescue hay

(Cordes et al., 1988). In that same study, higher levels of corn with urea did depress hay intake and subsequently heifers had lower gains than those supplemented with corn gluten feed.

Body Condition Score Changes and Rump Fat Changes

There were no interaction effects for any timepoint for BCS ($P > 0.23$; Table 4.4). Body condition score at the beginning of the third trimester was affected by fescue type ($P = 0.06$) where NONTOX cows had greater BCS than their TOX counterparts (5.96 vs. 5.7; SEM = 0.38). This trend ($P = 0.003$) continued at calving (6.84 vs. 6.39 SEM = 0.38) but was not different through lactation ($P = 0.16$). Even though there were differences in BCS scores, the change in BCS was not different through second trimester ($P = 0.59$), BCS was approaching a tendency ($P = 0.14$) during the third trimester for cows on NONTOX to have a greater increase in BCS and this same trend was observed through lactation ($P = 0.13$; Table 4.4). Looper et al. (2010) grazed cows on endophyte-infected fescue or bermudagrass for 60 d during breeding season. The cows in the study started at moderate BCS (average 4.7 BCS) or good BCS (average 6.6 BCS). Through the 60 d grazing season (while lactating), cows in both BCS categories and grazing endophyte-infected fescue lost BCS, as well as the cows starting at good BCS and grazing bermudagrass. Those cows that were of moderate BCS and grazing bermudagrass were the only ones that gained weight during that time frame. Cows grazed or fed hay from novel fescue varieties post-calving had greater BW and BCS by time of weaning than those consuming endophyte-infected fescue (Coffey et al., 2015). Contrary to the current study, Langford (2020) found that BW, BCS, and fat thickness over the 12^{th} and 13^{th} rib was not different in gestating fall-calving cows that grazed summer stockpile novel or toxic fescue varieties. These authors attributed the lack of response to the fact that cows had been pre-exposed to endophyte infected pastures prior to initiation of study, thus were potentially adapted.

Body condition score at calving was impacted by supplementation type (*P* = 0.04) where SUPP cows had greater BCS than NONSUPP cows (6.79 vs. 6.46 SEM = 0.26; Table 4.4). This continued at lactation measurement (*P* < 0.001; 6.93 vs. 5.92, SEM = 0.32). This then led to cows that were SUPP to have a greater increase (*P* = 0.001) in BCS through the entire supplementation period of second trimester through lactation (1.67 vs. 0.48 BCS change, SEM 0.18). The greatest BCS change occurred during early lactation where cows that were SUPP had a positive increase in BCS (*P* = 0.003) where those that were NONSUPP lost 0.3 BCS in a 60 d period (0.59 vs. -0.3 BCS change, SEM = 0.18; Table 4.4).

Matching the BCS scored, RF was greater for cows grazing NONTOX pastures at the beginning of the third trimester (11.41 vs 10.14 mm, SEM = 1.46). However, the changes across time based on fescue type were not different when measured via ultrasound (*P* > 0.16; Table 4.5). Supplementation did increase RF (*P* = 0.06) through the 3rd trimester (2.77 vs. 1.75 mm, SEM = 0.98).

Similarly, to supplementing with corn silage, corn supplementation during gestation increased BW and BCS in cows consuming a forage diet of grass hay, wheat straw, and sugar beet byproduct (Tanner et al., 2020). It generally is difficult to increase BCS after calving (Spitzer et al., 1995), yet corn silage on fall-calving cows in this study did have an increase in BCS after calving. When supplementing either an energy or protein source for spring-calving cows on native range during gestation or in early lactation, Marston et al., (1995) found that cows fed an energy source during gestation had greater BW gains than those supplemented with a protein source. After calving both protein and energy supplements had similar body weight gains (Marston et al., 1995). For cows grazing endophyte-infected tall fescue with red clover, those that were supplemented with a 70% dried distillers grain:30% soyhull feed at 8.61

kg/cow/d in the last trimester had greater BW and BCS than those supplemented at a lower level or not at all (Shoup et al., 2015).

Hair Score and Hair Length Changes

Supplementation did not affect hair coat as measured by HL or HS (*P* > 0.21; Tables 4.6 and 4.7). Similarly, Harrelson et al. (2019, 2020) found that supplementing a yeast product to cows grazing toxic fescue had no effect on hair coat. On the contrary, Harrelson et al. (2020) found that cattle supplemented with a hydrolyzed yeast product included in a free-choice mineral did in fact help to increase hair shedding due to cows spending a greater percentage of time being active, and less time being inactive. Soyhull pellets were effective to induce hair shedding for steers grazing toxic fescue (Carter et al., 2010). However, Aiken et al., (2008) did not observe alleviation of fescue toxicity with supplementation of soyhulls.

Hair score was affected by fescue type (*P* = 0.05) where there were lower HS for NONTOX compared to TOX when measured during the beginning of the 3rd trimester (1.71 vs. 2.6; SEM = 0.27) and prior to calving (*P* = 0.05; 1.19 vs. 1.94; SEM = 0.27). Cows grazing NONTOX fescue had greater shedding ability (*P* = 0.05) as evidenced by greater reduction in HS through 2nd trimester (-1.59 vs. -0.60 SEM = 1.24), and through the gestation period (*P* = 0.05; -2.12 vs. -1.28 SEM = 1.06). Hair score prior to calving and the change in hair score through gestation tended to be affected by fescue type x supplementation method (*P* = 0.06; Table 4.6), where TOX-NONSUPP had a greater HS than both supplementation methods on NONTOX pastures with TOX-SUPP being intermediate (Table 4.6).

Hair length was not affected by fescue type x supplementation (*P* > 0.15; Table 4.7). Fescue type impacted HL prior to calving (*P* = 0.10) where similar to HS, cows on TOX had greater HL than NONTOX (5 mm vs. 2.84 mm; SEM = 3). Hair length tended to change for the entire gestation period (*P* = 0.07). NONTOX cattle tended (*P* = 0.07) had a greater amount of hair length change than their TOX counterparts during gestation (-4.74 mm vs. -1.99 mm; SEM = 2.85) indicating a greater shedding ability with NONTOX fescues. Supplementing steers grazing endophyte infested pasture with either a condensed tannin *Sericea lespedeza* pellet or with polyethylene glycol (control) found that supplementation decreased hair retention (*P* = 0.05) and increased ADG (*P* = 0.10; Poudel et al., 2025). It was suggested that supplementing with condensed tannins has the possibility to improve blood flow (decrease hair retention) and reduce stress that is found when consuming toxic fescue. Condensed tannins bind to different steroidal and protein-like alkaloids, including toxic alkaloids found in toxic fescue (Okuda et al., 1982).

Calf Crop

TOX fescue reduced number of calves born (either dead or alive) compared to NONTOX (*P* = 0.03; Table 4.8). This reduction in calves born can be directly associated with late term pregnancy loss as the cows were pregnancy diagnosed prior to initiation of the study. Supplementation did not impact pregnancy retention (*P* = 0.77; Table 4.8). There was no effect of fescue, supplementation, or interaction on percentage of calves that were born alive to weaning (*P* = 0.33; Table 4.8). Overall, percentage of calves weaned from cows diagnosed as pregnant tended (*P* = 0.08) to be lower with TOX fescue compared to NONTOX (Table 4.8). Supplementation had no effect on percentage of calves weaned (*P* = 0.95; Table 4.8). Toxic fescue has been determined to reduce pregnancy rates (Brown et al., 1992; Brown et al., 2000; Gay et al., 1988), but not as many studies have evaluated pregnancy retention. Heat intolerance has been suggested as issue with fescue toxicity that can result in early embryonic mortality (Zavy, 1994). Pregnancy losses from grazing endophyte-infected fescue has been mainly identified to occur before 30 d of pregnancy (Waller et al., 2001). Induction of fescue toxicity symptoms via use of ergotamine tartrate found that embryo recovery and percentage of transferable embryos were reduced with endophyte toxicity, yet those embryos that were collected and transferred did not have different between toxic animals and controls (Schuenemann et al., 2005).

Calf Birth Weight, Weaning Weight, and Weigh-Suckle-Weigh

Calf birth weight was affected by fescue type ($P = 0.05$), sex of the calf ($P = 0.0001$), and age of the dam ($P = 0.002$; Table 4.8). Pregnant cows grazing NONTOX fescue had larger birth weight calves than TOX (34 vs. 31 kg SEM = 1.5 kg). As expected, bull calves weighed more than heifer calves (35 vs. 30 kg SEM = 3.4 kg). Cow age also impacted calf birth weight, where old cows (6 years of age or older) had the heaviest calves, first-calf heifers had the lightest, with middle aged cows (3-6 years of age) being intermediate (34, 30, and 34 kg, respectively; SEM = 1.2 kg). Brown et al. (1992) reported similar results to our findings; cows grazing endophyte infested fescue (TOX) reduced calf birth weight and decreased weaning weights of the calves. Lanford (2020) did not find any differences in calf birth weight when fall calving cows were grazing toxic or nontoxic varieties of fescue.

Weigh-suckle-weigh data was not affected by fescue type, supplement type, the interaction of fescue by supplementation, sex of the calf, nor age of the cow ($P = 0.17$; Table 4.8). Contrary to what was found in this study, cattle grazing toxic fescue reportedly produce 25% less milk than their counterparts grazing non-toxic fescue, thus decreasing the calf weaning weight of calves nursing toxic fescue consuming cows (Crawford et al., 1989; Peters et al., 1992). Novel varieties of fescue for fall-calving cows resulted in greater milk production as measured via weigh-suckle-weigh method in Langford (2020). Ball et al. (2015) reported that there is a possibility of the toxins decreasing blood flow, and energy flow, to the mammary glands, thus reducing milk production.

Weaning weight tended to be different based on fescue x supplement (*P* < 0.09; Table 4.8). For actual weaning weight and calculated 205 d weaning weight calves whose dams were on the NONTOX-SUP treatment had greater weaning weights than TOX-SUP with NONTOX-NONSUPP and TOX-NONSUPP being intermediate. When calculating 205 d adjusted weaning weight that considers dam age and calf sex, then no differences were detected (*P* > 0.21; Table 8). Even though there were no differences in milk-output estimates, calves that were born to cows that grazed NONTOX fescue while pregnant and in early lactation had heavier weaning weights (*P* = 0.04) than those on TOX, when calculated based on actual weaning weight or adjusted for age. Based on adjusted 205 d calculations, this advantage at weaning was 10.06 kg more weight for calves from cows that were pregnant and grazing NONTOX pastures (207.10 kg for NONTOX vs. 197.04 kg for TOX; SEM = 5.98). Supplementation had no impact on calf weaning weight (*P* > 0.25; Table 8). Paterson et al. (1995) summarized that decreased milk production caused by cattle consuming toxic fescue results in decreased calf weaning weight, compared to those consuming nontoxic fescue.

Weaning weights were heavier (*P* < 0.001) for steer calves as compared to heifer calves (211.89 vs. 192.25 kg; SEM = 3.95). Age of dam also impacted (*P* = 0.001) calf weaning weights. Calves born to mid-aged cows (2-4 yrs of age) had heavier weaning weights than those born to 1st calf heifers and older cows (> 6 yrs of age).

Prolactin and Cortisol

Serum cortisol was not affected by fescue type, supplementation type, any interaction (*P* > 0.12; Table 4.9). Cortisol tended (*P* = 0.09) to be the higher for YOUNG cows (1st calf heifers) than OLD cows (>6 yr of age) with MID aged cows (3-5 yrs of age) being intermediate (11.52, 7.49, 10.65 ng/mL, respectively; SEM = 2.4). Even though it has been identified as a stress marker of fescue toxicity, cortisol is often not affected by endophyte presence for grazing lambs or heifers (Hurley et al., 1980; Fiorito et al., 1991; Aldrich et al., 1993). Some other studies have indicated cortisol as a hormone that increases blood pressure which can indicate ability of the animal to tolerate heat stress (Sales et al., 2010) and a lower cortisol level is sometimes correlated to fescue toxicity. Older steers have greater hair cortisol concentrations than younger feedlot steers (Baier et al., 2019), which is opposite of results in the current study. Baier et al., (2019) found a weak positive correlation between cortisol and hair length. Due to the fact that there was no difference in serum cortisol in this study, this correlation was not detected with TOX fescue in current study.

Serum prolactin tended ($P = 0.079$) to have varying concentrations at the beginning of the second trimester. Prolactin was greater in TOX-NONSUPP than NONTOX-NONSUPP (Table 9). This became more pronounced when evaluating the change in prolactin concentration during the third trimester ($P = 0.08$) where cows on TOX fescue had a lower increase in prolactin concentration than those on NONTOX (5.01 vs 26.17 ng/mL; SEM = 13.3). A classic symptom of fescue toxicosis is decrease serum prolactin (Elsasser and Bolt, 1987; Schillo et al., 1988). This mirrors what was observed in the current study where there was a lower change in prolactin in cows grazing TOX fescue, which could be indicative of a decrease on serum prolactin.

Forage Accumulation and Forage Mass

There was no difference in forage accumulation in terms of the main effects of fescue type (NONTOX vs. TOX), supplementation (NONSUPP vs. SUPP), nor the interaction of fescue type by supplementation ($P > 0.17$; Table 4.10). Although, there was a difference in month ($P <$

0.0001; Figure 4.1) but not year (*P* = 0.22). Forage accumulation was greater in June and July than August through November (Figure 4.1). Maximum forage accumulation was seen during the beginning of the grazing season, before dormancy began shortly after. Abdelhadi et al. (2005) found that supplementing cattle grazing fresh pasture with either 400 kg per head per day of corn silage or 310 kg per head per day of high moisture corn had the ability to increase stocking rates, due to increased forage accumulation, 15%. Forage accumulation generally is not different in wild-type fescues and endophyte-free or novel fescue (Gunter and Beck, 2004; Burns et al., 2006; Poudel et al., 2023).

In terms of forage mass, there was no difference in the interaction of fescue type by supplement (*P* = 0.66; Table 4.10). Pastures where cows were SUPP tended to have 7.48% more FM (*P* = 0.06) than NONSUPP pastures (5,532 vs. 5,147 kg/ha; SEM = 145). Warner et al. (2017) supplemented cow-calf pairs with 1.13% of BW on a DM basis with modified distillers grains plus solubles while also feeding corn stocks. It was found that supplemented pairs consumed 7.1 kg of DM per pair each day, replacing 35% of their daily forage intake; thus, increasing available forage. On the other hand, Paterson et al. (1995) reported that the supplementation of steers with either soybean hulls or cracked corn shows no difference in intake of either toxic (endophyte infested) fescue or non-toxic fescue, thus not impacting the forage mass over the grazing season.

Toxic fescue pastures had 12.27% more FM (*P* = 0.01) than NONTOX pastures (5,030 vs. 5,648 kg/ha; SEM = 141). Crawford et al. (1989) found an increase in forage mass due to cattle actively avoiding toxic fescue. In their study, 11 out of 12 heifers grazing in Missouri avoided diets with toxic fescue included. In mixed grass pastures cattle select fescue to a much lower degree than other plant species (Nelson et al., 2019). Within fescue cultivars, cattle preferentially select endophyte free varieties above those that contain the endophyte fungus (van Santen, 1992).

There was no fescue x month, fescue x year, supplementation x month, supplementation x year, or any other interactions for FM, FA, or nutrient quality ($P > 0.16$; data not shown). However, there were differences in month ($P < 0.0001$; Figure 4.2) and year ($P = 0.0001$) for forage mass. There was more FM in May through August than September through November (Figure 4.2). Forage mass was greater during the 2023 grazing season compared to the 2024 grazing season (6,613 vs. 4065 kg/ha; SEM = 144). This was driven by greater moisture in 2023 as compared to 2024.

Energy and protein content was not different for fescue varieties and supplementation ($P > 0.16$; Table 4.9). Crude protein was greater ($P = 0.02$) in TOX-NONSUPP pastures NONTOX-NONSUPP, with NONTOX-SUPP and TOX-SUPP being intermediate (Table 4.9). The macrominerals of Mg ($P = 0.01$) and K ($P = 0.08$) were higher in TOX fescue than NONTOX. Calcium, P, and Mg were also different based on supplementation and fescue type ($P < 0.05$; Table 4.9). For all those macrominerals, the main difference detected was SUPP pastures that were NONTOX had greater levels of these minerals than NONSUPP.

Energy and protein decreased ($P < 0.001$; Table 4.9) from May through November in all pastures (Figure 4.3) regardless of fescue type or supplementation method ($P > 0.21$; data not shown). Macrominerals of Ca, P, and K measured different at each timepoint ($P < 0.0001$). For Ca, P, and K the May clipping had greater levels of mineral than the November clipping (Figure 4.4). During the summer "dormant" season of fescue P and K were greater or the same as May sampling (Figure 4). Calcium was the only micromineral tested that was lowest in the summer "dormant" timeframe (Figure 4.4). Calcium levels followed trends seen by Hagsten et al. (1976)

and Powell et al., (1978) where winter and summer grown fescues have lower calcium levels. An early examination of fungus-infected and fungus-free tall fescue found that fungus-free tall fescue had higher Ca than fungus-infected pastures (Hoveland et al., 1984). Magnesium showed the opposite effect where fungus-free was lower than fungus-infected. Phosphorus and potassium were the same, regardless of fungus presence.

APPLICATIONS

Nontoxic fescue, compared to toxic fescue, will increase cow body weight, body condition scores and weight of suckling calves. Additionally, due to pregnancy loss observed, even in a fall-calving operation, leads to serious economic consideration for replacing toxic fescue with non-toxic varieties. Supplementation of corn silage did not mitigate toxicity caused from consuming toxic fescue. Although, supplementation is a strategy used by producers to increase forage mass and availability during times of drought. Supplementation after calving was also beneficial to improve post-calving body condition score, which may have longer term impacts on reproduction. The largest driver for producers is cost, so determining the supplementation method and product, along with the production stage of the animal will determine the amount of return and cost effectiveness.

Table 4.1 Average silage nutrient composition for both years.

ITEM	2023 SIILAGE	2024 SILAGE
Moisture, % As Fed	73.68 ± 5.99	61.14 ± 0.78
Dry Matter, % As Fed	26.32 ± 5.99	38.86 ± 0.78
Crude Protein, % DM	9.305 ± 0.51	7.615 ± 0.22
ADF, % DM	27.12 ± 2.42	22.825 ± 0.235
aNDF, % DM	45.645 ± 4.76	37.63 ± 0.85
NE_L, Mcal/lb DM	0.72 ± 0.02	0.76 ± 0
NE_G, Mcal/lb DM	0.465 ± 0.03	0.505 ± 0.005
NE_M, Mcal/lb DM	0.79 ± 0.02	0.83 ± 0
TDN, % DM	69.97 ± 1.74	73.06 ± 0.17
Calcium, % DM	0.26 ± 0.06	0.23 ± 0.01
Phosphorus, % DM	0.22 ± 0	0.195 ± 0.005
Potassium, % DM	0.71 ± 0.07	0.775 ± 0.005
Magnesium, % DM	0.22 ± 0.005	0.19 ± 0

Table 4.2 Free-choice mineral provided to grazing cattle both years

ITEM	MINIMUM	MAXIMUM
Calcium, %	15.00	17.5
Phosphorus, %	6.50	---
Salt, %	18.00	23.00
Magnesium, %	2.00	---
Potassium, %	0.50	---
Copper, ppm	1550	---
Selenium, ppm	26	---
Zinc, ppm	4800	---
Iodine, ppm	90	---
Vitamin A, IU/kg	158,000	---
Vitamin D, IU/kg	11,450	---
Vitamin E, IU/kg	880	---

[1]Free-choice mineral: Cattle King Nutrition Mineral 6.5% Cow IGR #3058; A mineral supplement for beef cattle on pasture or range with active ingredient of S-methoprene (0.009%) per lb. Wildcat Feeds LLC, Topeka, KS

Table 4.3 Cow BW through feeding and grazing periods.

Item	NONTOX[1]		TOX[2]		SEM[5]	*P*-value		
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP		FES[6]	SUPP[7]	FES x SUPP[8]
Mid second trimester, kg	568	580	540	548	19.0	0.13	0.60	0.94
Start of 3rd trimester, kg	640	651	594	614	20.0	**0.04**	0.45	0.82
Prior to calving, kg	676	683	611	645	18.6	**0.04**	0.29	0.48
Peak lactation, kg	618	651	574	613	19.5	**0.04**	**0.06**	0.90
Change through 2nd trimester, kg	72.6	71.2	54.4	65.8	12.7	0.13	0.51	0.40
Change through 3rd trimester, kg	35.4	31.7	17.2	31.3	6.8	0.18	0.45	0.20
Change through gestation, kg	107.5	103.9	71.7	96.6	11.8	**0.03**	0.27	0.11
Change in early lactation, kg	-56.2	-41.7	-47.6	-31.3	18.6	0.31	**0.10**	0.93
Change second trimester through early lactation, kg	50.8	62.6	34.5	67.6	14.1	0.61	**0.05**	0.34

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method

Table 4.4 Cow BCS through feeding and grazing periods.

Item	NONTOX[1]		TOX[2]		SEM[5]	*P*-value		
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP		FES[6]	SUPP[7]	FES x SUPP[8]
Mid second trimester	5.44	5.46	5.27	5.31	0.20	0.31	0.88	0.90
Start of 3rd trimester	5.88	6.05	5.58	5.82	0.15	**0.06**	0.12	0.79
Prior to calving	6.78	6.94	6.13	6.64	0.28	**0.003**	**0.04**	0.23
Peak lactation	6.09	6.96	5.85	6.72	0.17	0.16	**<0.001**	0.99
Change through 2nd trimester	0.43	0.59	0.31	0.51	0.16	0.59	0.28	0.90
Change through 3rd trimester	0.90	0.89	0.55	0.82	0.18	0.14	0.39	0.23
Change through gestation	1.34	1.45	0.86	1.33	0.26	0.13	0.13	0.33
Change in early lactation	-0.26	0.33	0.19	0.59	0.26	0.57	**0.003**	0.71
Change second trimester through early lactation	0.77	1.54	0.44	1.46	0.24	0.33	**0.001**	0.54

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method

Table 4.5 Cow rump fat thickness (mm) through feeding and grazing periods.

Item	NONTOX[1]		TOX[2]			P-value		
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP	SEM[5]	FES[6]	SUPP[7]	FES x SUPP[8]
Mid second trimester, mm	8.83	9.27	7.50	7.80	1.20	0.16	0.69	0.71
Start of 3rd trimester, mm	11.65	11.22	10.21	10.07	0.81	**0.10**	0.74	0.88
Prior to calving, mm	12.99	13.88	12.31	12.96	0.88	0.36	0.40	0.91
Change through 2nd trimester, mm	3.11	1.93	1.81	2.07	1.29	0.80	0.98	0.43
Change through 3rd trimester, mm	1.34	2.65	2.10	2.89	0.54	0.38	**0.06**	0.67
Change through gestation, mm	4.48	4.06	3.87	5.35	1.60	0.63	0.44	0.37

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method

Table 4.6 Cow hair score through feeding and grazing periods.

Item	NONTOX[1]		TOX[2]		SEM[5]	*P*-value		
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP		FES[6]	SUPP[7]	FES x SUPP[8]
Mid second trimester	3.56	3.13	3.25	3.17	0.18	0.56	0.21	0.42
Start of 3rd trimester	1.7	1.74	3.04	2.17	0.39	**0.05**	0.30	0.24
Prior to calving	1.13[b]	1.26[b]	2.42[a]	1.46[ab]	0.32	**0.05**	0.15	**0.07**
Change through 2nd trimester	-1.82	1.41	-0.21	-1.0	0.42	**0.05**	0.61	0.20
Change through 3rd trimester	-0.59	-0.46	-0.63	-0.71	0.24	0.55	0.91	0.66
Change through gestation	-2.37[b]	-1.93[b]	-0.83[a]	-1.71[ab]	0.35	**0.05**	0.50	**0.06**

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method

Table 4.7 Cow hair length (mm) through feeding and grazing periods.

	NONTOX[1]		TOX[2]			*P*-value		
Item	**NOSUPP[3]**	**SUPP[4]**	**NOSUPP**	**SUPP**	**SEM[5]**	**FES[6]**	**SUPP[7]**	**FES x SUPP[8]**
Mid second trimester, mm	8.62	6.83	7.52	6.45	1.04	0.52	0.19	0.78
Start of 3rd trimester, mm	9.55	9.92	11.03	10.43	1.08	0.36	0.90	0.66
Prior to calving, mm	2.75	2.91	6.8	3.2	1.26	**0.10**	0.19	0.15
Change through 2nd trimester, mm	0.93	3.09	3.51	3.97	1.08	0.13	0.26	0.29
Change through 3rd trimester, mm	-6.83	-7.09	-4.23	-7.23	1.08	0.27	0.15	0.20
Change through gestation, mm	-5.87	-3.85	-0.72	-3.26	1.48	**0.07**	0.83	0.15

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).

[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types

[2]TOX: Pasture treatment consisting of K-31 toxic fescue

[3]NONSUPP: Pasture treatments that were not supplemented with corn silage

[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks

[5]SEM: standard error of means

[6]FES: main effect of fescue type (NONTOX vs TOX)

[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)

[8]FESxSUPP: interaction effect of fescue type and supplementation method

Table 4.8 Calf weights (kg), estimate of milk production, weaning weight and percent calf crop.

Item	NONTOX[1]		TOX[2]			*P*-value				
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP	SEM[5]	FES[6]	SUPP[7]	FES x SUPP[8]	SEX[9]	AGE[10]
Calves born, dead or alive, %	99.47	91.67	79.17	83.33	7.57	**0.03**	0.77	0.33	--	--
Calves weaned from birth, %	95.24	100	100	100	2.16	0.27	0.27	0.27	--	--
Calves weaned from pregnancy diagnosis, %	94.94	91.67	79.17	83.33	7.35	**0.08**	0.95	0.57	--	--
Calf birthday within year[11]	230	230	229	230	26	0.78	0.76	0.78	0.68	0.17
Calf birth weight, kg	34	34	31	31	1.5	**0.05**	0.59	0.95	**0.001**	**0.01**
Calf WSW weight gain, kg	4.95	9.52	5.38	5.61	4.78	0.44	0.29	0.33	0.47	0.11
Actual Calf weaning weight, kg[11]	239^{ab}	254^{a}	239^{ab}	231^{b}	5.2	**0.04**	0.56	**0.04**	**<0.001**	**0.01**
205 d Weaning wt, kg[12]	198^{ab}	216^{a}	199^{ab}	195^{b}	5.98	**0.10**	0.25	**0.09**	**0.0001**	**0.01**
Adjusted 205 d weaning wt. kg[13]	215	232	214	211	15.5	0.49	0.67	0.52	0.21	0.39

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method
[9]SEX: main effect of calf sex (female vs. male)
[10]AGE: main effect of cow age (young, mid, old)
[11] Day 1 = January 1 with Day 365 = December 31
[12]Average weight at weaning which occurred on April 20, 2024 and April 29, 2025.
[13] Weaning weight adjusted for average gain at 205 d of age.
[14]Weaning weight adjustment based on American Angus Association adjustments for dam age and calf sex (https://www.angus.org/ahir/reports/adjusted-weights).

Table 4.9 Fescue Prolactin and Cortisol Results.

Item	NONTOX[1]		TOX[2]			P - value			
	NOSUPP[3]	SUPP[4]	NOSUPP	SUPP	SEM[5]	FES[6]	SUPP[7]	FES x SUPP[8]	Age [9]
Serum Prolactin									
Mid second trimester, ng/mL	44.42[b]	53.44[ab]	72.84[a]	45.47[ab]	27	0.30	0.35	**0.07**	0.54
Start of 3rd trimester, ng/mL	33.08	34.46	35.79	35.59	26	0.70	0.90	0.87	0.16
Prior to calving, ng/mL	45.63	57.44	43.33	38.24	33	0.27	0.71	0.37	0.78
Change through 2nd trimester, ng/mL	-13.71	-18.22	-32.63	-9.04	10.56	0.65	0.38	0.20	0.67
Change through 3rd trimester, ng/mL	22.22	22.63	10.33	-0.77	10.80	0.12	0.62	0.60	0.14
Change through gestation, ng/mL	0.77	-4.39	-30.77	-10.04	12.75	0.18	0.57	0.34	0.90
Serum Cortisol									
Mid second trimester, ng/mL	20.81	18.25	19.73	18.32	2.5	0.96	0.89	0.96	0.80
Start of 3rd trimester, ng/mL	12.62	6.48	9.67	10.80	2.34	0.77	0.29	0.13	**0.09**
Prior to calving, ng/mL	9.59	6.92	9.73	8.05	2.27	0.79	0.32	0.87	0.42
Change through 2nd trimester, ng/mL	-8.16	-12.52	-10.07	-7.56	8.64	0.59	0.74	0.24	0.33
Change through 3rd trimester, ng/mL	-3.56	1.26	0.07	-2.73	2.36	0.93	0.67	0.12	0.60
Change through gestation, ng/mL	-11.82	-10.10	-9.94	-10.33	8.13	0.69	0.75	0.62	**0.09**

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).

[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types

[2]TOX: Pasture treatment consisting of K-31 toxic fescue

[3]NONSUPP: Pasture treatments that were not supplemented with corn silage

[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fence line bunks

[5]SEM: standard error of means

[6]FES: main effect of fescue type (NONTOX vs TOX)

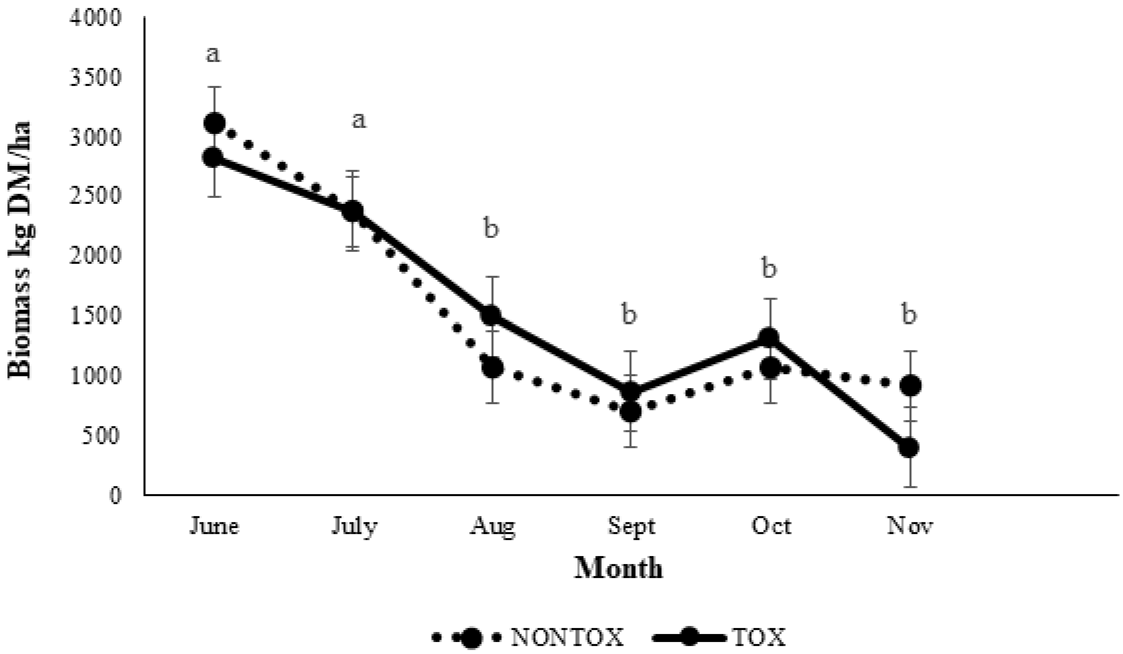
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method
[9]AGE: main effect of cow age (young, mid, old)

Table 4.10 Forage Quality and Forage Production.

Item	NONTOX[1] NOSUPP[3]	NONTOX[1] SUPP[4]	TOX[2] NOSUPP	TOX[2] SUPP	SEM[5]	*P*-value FES[6]	*P*-value SUPP[7]	*P*-value FES x SUPP[8]	*P*-value Month [9]	*P*-value Year[10]
Forage Accumulation, kg DM/ha	1406.25	1670.02	1758.68	1327.11	251	0.98	0.74	0.17	**<0.0001**	0.22
Forage Mass, kg DM/hectare	4875.57	5185.11	5417.58	5878.81	201	**0.01**	**0.06**	0.71	**0.0001**	**<0.0001**
Crude Protein, % DM	12.64	13.67	14.25	13.25	0.41	0.16	0.98	0.02	**<0.0001**	**<0.0001**
NDF, % DM	56.37	55.32	55.81	55.86	0.70	0.99	0.48	0.44	**<0.0001**	**<0.0001**
ADF, % DM	35.74	34.83	35.66	35.26	0.52	0.75	0.22	0.63	**0.001**	**<0.0001**
TDN, % DM	54.29	55.52	54.41	54.95	0.71	0.75	0.22	0.63	**0.001**	**<0.0001**
NEm, Mcal/kg DM	0.23	0.24	0.23	0.23	0.005	0.74	0.22	0.67	**0.001**	**<0.0001**
NEg, Mcal/kg DM	0.11	0.12	0.11	0.12	0.005	0.73	0.21	0.70	**0.001**	**<0.0001**
Ca, % DM	0.47[b]	0.51[a]	0.51[a]	0.48[ab]	0.01	0.55	0.53	**0.05**	**<0.0001**	**0.02**
P, % DM	0.24[b]	0.26[a]	0.26[a]	0.25[ab]	0.01	0.26	0.76	**0.09**	**<0.0001**	0.14
K, % DM	1.72	1.71	1.84	1.78	0.05	**0.08**	0.52	0.74	**<0.0001**	0.62
Mg, % DM	0.25[b]	0.29[a]	0.30[a]	0.29[a]	0.01	**0.01**	0.19	**0.02**	0.15	**0.001**

P-value[a,b]: Values within row with different superscripts either statistically significant ($P < 0.05$) or display a tendency ($0.05 < P < 0.10$).
[1]NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types
[2]TOX: Pasture treatment consisting of K-31 toxic fescue
[3]NONSUPP: Pasture treatments that were not supplemented with corn silage
[4]SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks
[5]SEM: standard error of means
[6]FES: main effect of fescue type (NONTOX vs TOX)
[7]SUPP: main effect of feeding type (NONSUPP vs SUPP)
[8]FESxSUPP: interaction effect of fescue type and supplementation method
[9]Month: main effect of month
[10]Year: main effect of year (2023 vs. 2024)

Figure 4.1 Forage accumulation by month x fescue type.



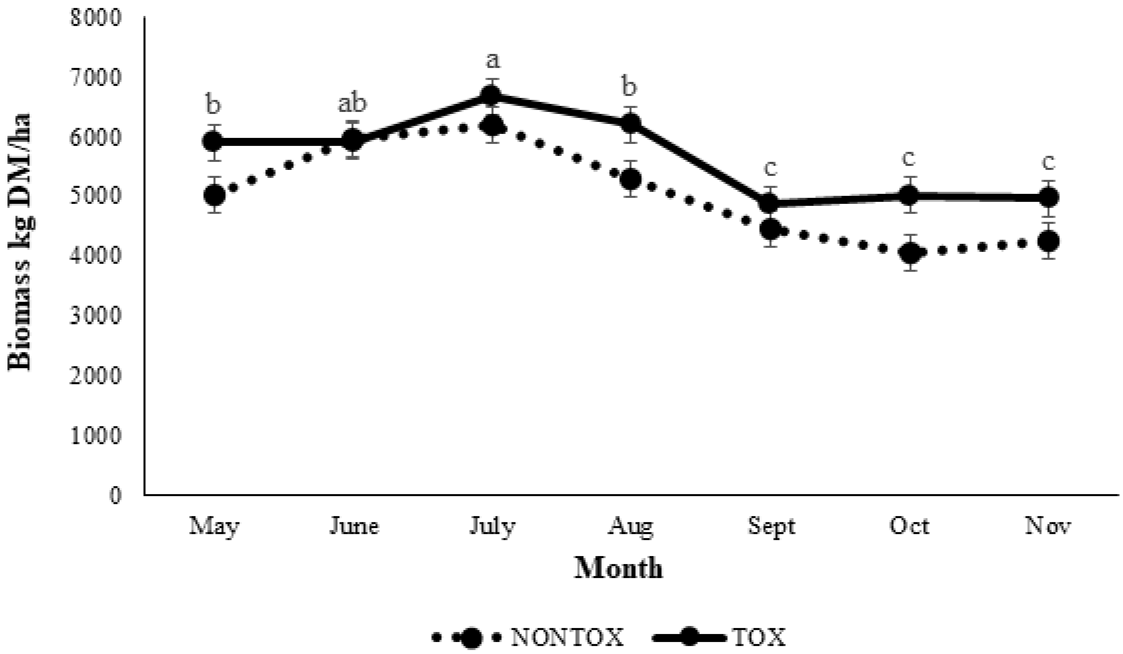
No difference in fescue type x month ($P = 0.83$). Month was different for forage mass ($P < 0.0001$).

[ab] Letters for each month that are different indicate difference at $P < 0.05$.

NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types

TOX: Pasture treatment consisting of K-31 toxic fescue

Figure 4.2 Forage mass by month x fescue type.



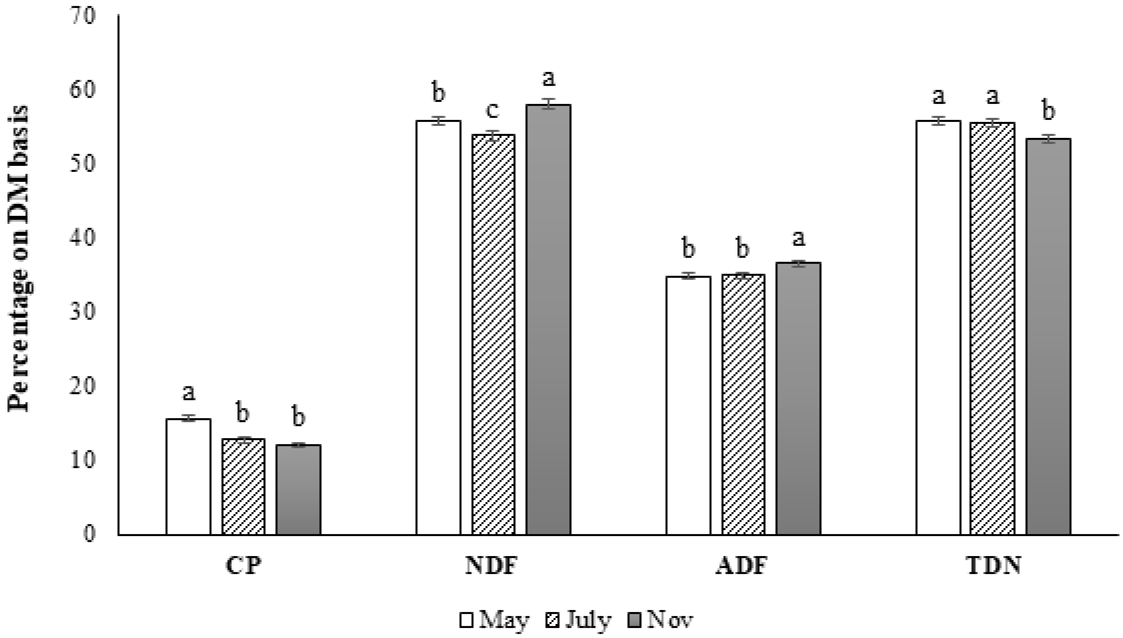
No difference in fescue type x month (P = 0.58). Month was different for forage mass (P < 0.0001).

abc Letters for each month that are different indicate difference at P < 0.05.

NONTOX: Pasture treatment consisting of endophyte-free and novel fescue types

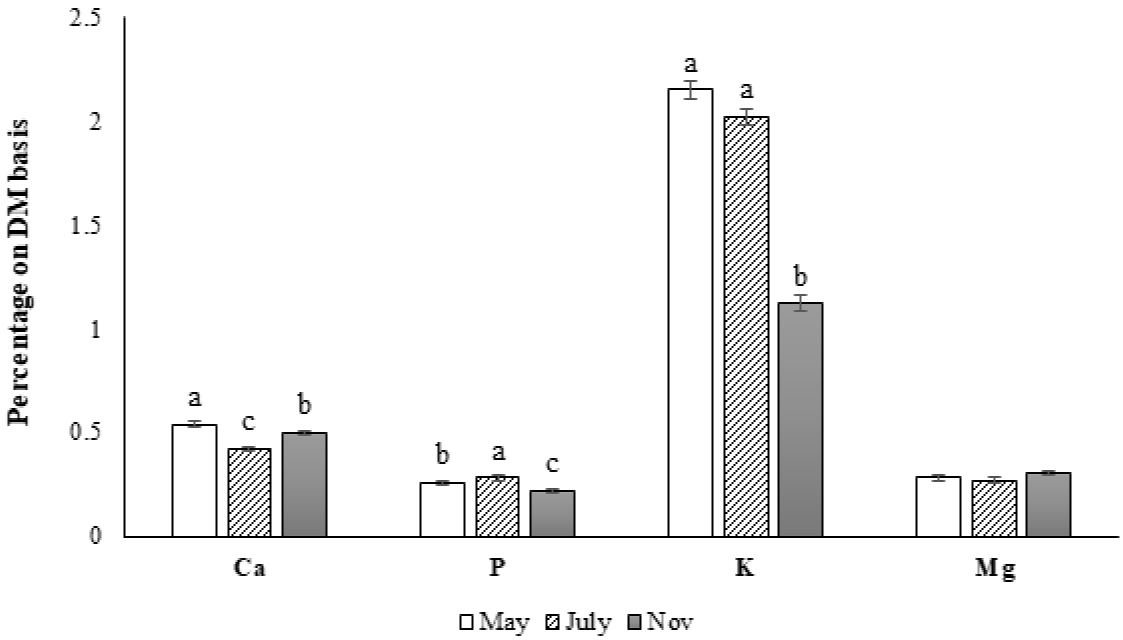
TOX: Pasture treatment consisting of K-31 toxic fescue

Figure 4.3 Forage protein and energy levels by month.



[abc] Letters within category that are different indicate difference at $P < 0.05$.

Figure 4.4 Forage macrominerals by month.



[abc] Letters within category that are different indicate difference at $P < 0.05$.

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Chapter 5 - Effects of Corn Silage Supplemental Feeding of Fall-Calving Cows Grazing Bermudagrass

ABSTRACT

Objective: The objective was to evaluate if corn silage supplementation during gestation while grazing bermudagrass impacts cow and calf performance and forage utilization.

Materials and Methods: Multiparous and primiparous Angus cross-bred cows (Year 1: n = 24; 4.8 ± 0.48 yrs; Year 2: n = 24; 4.2 ± 0.5 yr) were stratified by age within pasture (n = 3/pasture). Treatment consisted of non-supplementation (**NONSUPP**) or supplementation (**SUPP**) of corn silage fed daily at 1% of BW on DM basis (n = 4 pastures/treatment/year). Cows grazed and were supplemented from late-May through mid-September then managed as one herd calving through weaning. BW, BCS, hair score, hair length, ultrasound rump fat, and serum blood metabolites were measured ~ middle of 2nd trimester, beginning of 3rd trimester, and ~two weeks prior to parturition. Cow BW and BCS were collected at peak lactation. Calves were weighed at birth and weaning and used in weigh-suckle-weigh to estimate milk output. Forage accumulation (FA) and mass (FM) were estimated every 28 d using the paired-cage method.

Results and Discussion: Supplementing had no effect on BW (P > 0.35), BCS (P > 0.15), hair length (P > 0.45), nor hair score (P > 0.27). Rump fat was increased (P = 0.05) with SUPP during the second trimester. Supplementation had no effect on calf birth weight (P = 0.97) and estimated milk output (P = 0.76), but dams that were NONSUPP during gestation had greater dam adjusted 205 d weaning weight (P = 0.03). First calf heifers had the lightest

birthweight calves ($P = 0.06$), lowest milk output ($P = 0.01$), and lightest actual weaning weight ($P = 0.04$) while the OLD (>6 yr old) dams had the highest values and MID (3-5 yr old) aged cows intermediate. Forage accumulation, FM, and forage nutrient quality was not impacted by supplementation methods ($P > 0.27$).

Implications and Applications: Offering corn silage to pregnant non-lactating cows grazing high quality bermudagrass could slightly improve cow condition, in terms of rump fat thickness, but had no other economic benefits. Feeding 1% of corn silage daily was not enough to result in more available forage.

Keywords: Cow-calf performance, forage management, warm season perennial

INTRODUCTION

Bermudagrass (*Cynodon dactylon*) is a warm-season perennial, commonly used for pasture and hay production in the southern U.S. (Thompson et al., 2001). King (2016) recognized bermudagrass as being extremely drought tolerant, but due to forage quality degradation with maturity, rotational grazing should be utilized to ameliorate grass efficiency.

In years of drought, when there is an inability to remove cattle from grasses, and other natural disasters, supplementation of grazing cattle is a strategic tool for producers. More times than not, the requirement of energy in form of supplementation is often not met as requirements is a moving target depending on stage of production, supplementation method, breed of cattle, and energetic outputs (Caton and Dhuyvetter, 1997). Commonly, supplementation of energy or harvested forages are used to decrease forage intake and increase forage utilization (McCollum and Horn, 1990; Pordomingo et al., 1991; Hibbard and Thrift, 1992).

During times of drought, producers often face financial hardships, decreasing the option to supplement grazing cattle with expensive feedstuffs. But, if producers are financially stable enough to provide an energy supplement, ruminants have the ability to improve feed efficiency, production levels, and forage management by reducing total forages required to reach sufficient nutritional requirements (Hibbard and Thrift, 1992; Warner et al., 2017).

The objective of this study was to evaluate if supplemental feeding of corn silage impacts cow and calf performance during gestation while grazing bermudagrass in Southeast Kansas. A secondary objective is to determine how supplementation of corn silage will impact forage availability.

MATERIALS AND METHODS

Experimental Procedures

The experiment was conducted at the Mound Valley Branch of the Southeast Research and Extension Center in Mound Valley, KS. All animals were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Kansas State University Animal Care and Use Committee (protocol #4883).

Treatment structure

Two years of data (2023: Year 1 and 2024: Year 2) were collected with similar protocols. During both years the study was conducted from May to early December and consisted of the cow production periods of mid-second trimester through early lactation. Utilizing a total of the same eight bermudagrass pastures, the experiment was a completely randomized design with two treatments. Treatments included supplementation (SUPP) and non-supplemented (NONSUPP). Pastures were split equally between treatments with 4 replicates for each treatment. Supplementation consisted of daily feeding corn silage (average 32-42% DM and 7.6-9.3% CP;

Table 5.1) at 1% of cow BW on a DM-basis. Corn silage was delivered daily in fence-line bunks and silage refusal amounts were measured every Monday, Wednesday, and Friday. Corn silage was fed based on DM content that was measured weekly and a 3-week average DM was used in feeding amounts. Cattle in all pasture replicates were offered access to free choice mineral (Table 5.2).

Pasture Management

Pastures were fertilized with 56 units of N per hectare in late April of each year and again in mid-July. Pastures were also fertilized with P and K based on soil tests collected October of 2022 for each specific pasture.

Cow Management

During year 1 of the study (2023), primiparous and multiparous Angus-based crossbred cows (n = 24; 548 ± 22 kg SEM; 5.2 ± 0.16 BCS SEM) from the Southeast Research and Extension Center production herd were utilized. Estrus was synchronized using the 7-day CIDR protocol, and cows were artificially inseminated on December 13, 2023. Herd bulls were turned in two weeks following AI date. Cows were first checked for pregnancy on February 13, 2023, and were found to not be bred via AI or by herd bull exposure within the first two weeks of the breeding season. Then cows were re-checked for pregnancy via trans-rectal ultrasound on April 15, 2023, at which time pregnant cows would have been 60- 90 d into gestation. Cows that were pregnant at the April ultrasound were collected and randomly assigned to pasture based on age. Cow age was used to balance within pasture, designing each pasture to include a bred heifer (YOUNG), a cow between 3- 5 years old (MID), and a cow that was over 6 years old (OLD), with the average age of all cows being 4.8 ± 0.48 yrs.

Cows were placed on pasture on June 1, 2023, which corresponded to being mid-way through the second trimester of gestation (155 ± 14 d of gestation based on fetal aging from ultrasound). Mid-point measurements were collected on July 27, 2023, which corresponded to the beginning of the third trimester. Final gestation measurements were taken ~2 weeks prior to the herd estimated calving date, October 2-3, 2023. After the gestation end weigh date, all cows were commingled into one herd and managed the same on a mixed grass pasture, and the SUPP cows no longer received corn silage. Cows were supplemented with 1.81 kg of 50:50 blend on cracked corn and dried distillers grains fed on Mondays, Wednesdays, and Fridays. While on the pasture, post-calving cows also had free-choice access to a fescue-bermudagrass hay.

During year 2 of the study (2024), primiparous and multiparous Angus crossbred cows (n=24; 547 ± 5.3 kg SEM; 5 ± 0.07 SEM BCS) from the Southeast Research and Extension Center production herd were utilized to conduct this experiment. Following the 7-day CIDR synchronization protocol, the cows were artificially inseminated on December 11, 2024. Two weeks following the AI date, herd bulls were placed with cows. Cows were checked for pregnancy on February 14, 2024 and were found to not be bred via AI, nor by bull exposure within the first two weeks of the breeding season. Pregnancy diagnosis was conducted again via trans-rectal ultrasound of March 26, 2024. At this point, the cows were between 60 and 90 d into gestation and were selected for the study. Identically to year 1, cow age was used to balance each pasture. Therefore, each pasture included a YOUNG, MID, and OLD cow with the average age of the cows in year 2 of 4.2 ± 0.5 yrs.

Cows were placed into their respective pastures on May 22, 2024, which corresponded to being mid-way through the second trimester of gestation (146 ± 3 d based on fetal aging from ultrasound). July 10, 2024, cows were sampled, which corresponded to the beginning of the third trimester. Final gestation measurements were collected ~2 weeks prior to parturition on September 18, 2024. Cows grazed for a total of 119 days. After the gestation end weigh date, all cows were commingled into one herd and managed the same on a mixed grass pasture, and the SUPP cows no longer received corn silage. Cows were supplemented with 1.81 kg of 50:50 blend on cracked corn and dried distillers grains fed on Mondays, Wednesdays, and Fridays. While on the pasture, post-calving cows also had free-choice access to a fescue-bermudagrass hay.

Cow and Calf Performance Measurements

Cattle were restrained in an Arrowquip Q-Power 107 Series hydraulic squeeze chute (Arrowquip, Woodlands, MB), with weights being recorded by a Gallagher TWR chute scale head (Gallagher Group Limited, Riverside, MO). Prior to initial and end of gestation weight measurements, all cows were commingled in a dirt lot pen and fed prairie hay for three days prior to weighing to minimize variation in intestinal tract fill.

Three independent evaluators, blinded to treatments, evaluated BCS at each measurement period using the standard 1-9 scale (Selk et al., 1988). Rump fat was measured using an ALOKA 500 ultrasound machine (Hitachi, LTD., Wallingford, CT) with a 3.5-megahertz short probe to capture the image. The image was then analyzed using the Cattle Performance Enhancement Company software package (CPEC, Oakley, KS). Measurements were taken over the rump by a trained technician and recorded in millimeters (mm).

Calves were weighed at birth with a hanging scale. Calving dates ranged from October 10, 2023 to November 11, 2023 in Year 1 and from September 9, 2024 to October 10, 2024 in Year 2. At weaning calves were weighed using the same chute and scale as the cows. Actual calf weight, adjusted to 205 d of age, and adjusted 205 d weaning weights (American Angus

Association, St. Joseph, MO) were determined. Not all cows calved once starting on the study, thus a percentage of calves born was calculated.

Hair Score and Hair Length

One trained technician evaluated hair scores at each measurement period during both years using the standard 1-5 scale (American Angus Association, St. Joseph Missouri). In brief, a hair score of 1 means the animal has shed 100% of hair coat; 2 indicates 75% shedding; 3 is 50% shedding; 4 is 25% shedding; and a 5 means the animal still has full winter hair coat. Hair length was measured by a different technician than the one completing the hair score and was conducted using a slide ruler over the forerib, on the left side of the animal and recorded in millimeters (mm).

Calf Weigh-Suckle-Weigh

Weigh-suckle-weigh methods were modelled after Grings et al., (2008). During year 1, pairs were gathered and sorted on December 2, 2023, with calves being separated from dams overnight. On December 3, 2023, calves were weighed empty. After empty weight was recorded, calves were turned back in with their dams and allowed to nurse until full. Then calves were sorted once more and weighed to measure a post-nursing weight. The empty weight was then subtracted from the full weight to determine the change in calf body weight due to milk in kg. This process was replicated twice in a 24-hour period with a 6-hour removal of the calf from the dam in the middle of the day. Weight differences were added together and multiplied by two for an estimate of 24-hour milk production. Cows were removed from bermudagrass pastures and were no longer offered supplement on September 30, 2023, and then grazed in two large pastures of each treatment (n = 4 total pastures) through calving, up to ~60 days lactation. Pastures were composed of a mixture of bermudagrass and fescue. This was to determine if there were any long-term effects due to supplementing in late gestation.

For year 2, the process was somewhat different than the first year. In attempt to decrease maternal stress and calf stress due to being separated for long periods of time, calves were separated from their dams on December 1, 2024 and weighed individually. The following morning at 7 AM, calves were returned to their damns and allowed to nurse until all calves had ended nursing (~30 minutes minimum). The calves were them separated once again and weighed. Although the process only involved one set of weights, when multiplied by 2, we receive a 24-hour milk production estimate for the 2024 cows during peak lactation. Cows were them removed from bermudagrass pastures and were no longer offered a supplement on September18, 2024. Cows then grazed two large pastures of each treatment (n = 4) through calving and ~ 60 days of lactation. To determine long-term effects due to supplementing in late gestation, the pastures were composed of both bermudagrass and fescue.

Hormonal Analysis

During year 1, blood was collected from the jugular vein into a Greiner bio-one VACUETTE 4 mL Serum Clot Activator blood collection tube (Model: 2016-06, Greiner bio-one, Monroe, NC) and allowed to clot a minimum of two hours at room temperature before centrifugation. Year 2, blood was collected from the tail head into a Greiner bio-one VACUETTE 4 mL Serum Clot Activator blood collection tube (Model: 2016-06, Greiner bio-one, Monroe, NC) and allowed to clot a minimum of two hours at room temperature before centrifugation. Following clotting, blood was centrifuged using a Beckman Coulter Allegra® X-22R Centrifuge (Beckman Coulter Inc., Brea, CA) for 20 mins at 4°C at 1000 G. Post-centrifuging, samples were hand pipetted to obtain serum, which was then transferred to a 15 ml centrifuge tube. Serum samples were placed in a freezer at -20℃ until analysis for cortisol and prolactin.

Serum cortisol was analyzed by the Kansas State University College of Veterinary Medicine Department of Anatomy and Physiology Lab (Kansas State University, Manhattan, KS) using a radioimmune assay (MP Biomedicals ImmuChem™ Cortisol Coated Tube RIA kit catalog #: 207221; MP Biomedicals, LLC, Solon, Ohio) as described by Reppert et al. (2020). Briefly, 25 μL of sample and standards are placed into pre-coated tubes, followed by the addition of cortisol-125 and allowed to incubate. Tubes were subsequently measured with a gamma counter for I125. The coefficient of variance for the inter-assay and intra-assay variabilities were 7.02% and 8.92%, respectively.

Prolactin was analyzed using the radioimmune Cattle Prolactin (PRL) ELISA Kit (MyBioSource, Inc. San Diego, CA) according to manufacturer protocol. Briefly, 50 μL of sample and standards were placed in a 98-well plate using the competitive enzyme immunoassay technique utilizing a polyclonal anti-prolactin antibody and a prolactin-HRP conjugate. The plate was read spectrophotometrically at 450 nm in a BioTek ELX 800 microplate reader (BioTek Instruments, Winooski, VT). Results were calculated noting the inverse relationship between prolactin concentration in the sample and the assay signal intensity, with a standard curve created by placing the log of the prolactin concentration along the y-axis and absorbance along the x-axis and determining a best fit line via regression analysis. The detection range of the assay was 2.47-200 ng/mL, with intra-assay variability and inter-assay variability being 5.8% and 16.4% for Year 1 and 7.5% and 12.2% in Year 2, respectively.

Pasture Measurements

Forage mass is defined as the total dry weight of forage per unit area of land, usually above ground level and at a defined reference (Forage, 1991). Forage mass measurements were collected at the beginning of the study and then every 28 days by clipping a 0.33 m^2 area to about 2.54 cm of height. These clippings occurred at 4 locations in the pastures and corresponded to close proximity to the 4 exclusion cages that were in the pasture. This measurement was used to determine the amount of available forage for the cows. Forage accumulation is defined as the increase in forage mass per unit area over a specified period of time (Forage, 1991) Forage accumulation was determined via destructive methods and were collected according to the paired cage method (Paraiso et al., 2019). Briefly, four exclusion cages (0.66 m^2) were placed in each pasture and were moved every 28 days. At each sampling period a 0.33 m^2 area was clipped to 2.54 cm height within the exclusion cage. To calculate forage accumulation the amount of forage measured within the exclusion cage was used and then the amount of forage measured from outside the cage (forage mass) during the previous 28 days was subtracted.

$$Forage\ accumulation = Biomass\ in\ exclusion\ cage - Biomass\ outside\ cage\ 28\ d\ prior$$

Clippings were taken outside of the cage at the beginning of grazing (May), middle of grazing (July), and end of grazing (December). The clippings within month were composited into one sample to determine the consumed nutritional quality of the pastures the cows were grazing

Statistical Analysis

Changes in BW, RF, HL, and HS measured during the gestation period were analyzed using the GLIMMIX procedure in SAS 4.3 (SAS Institute, Cary, NC). There were three change periods evaluated for RF, HL, and HS (period 1: beginning of third trimester minus mid second trimester; period 2: ~2 weeks prior to calving minus beginning of third trimester; total gestation period: ~2 weeks prior to calving minus mid-second trimester). Body weight changes were calculated for those same periods as well as post-calving, where gain in lactation was calculated by weight at peak lactation minus weight ~2 weeks prior to calving. Total weight gain was calculated from weight difference at the start of supplementation (mid-second trimester) through early lactation. To minimize biased effects of non-lactation, all cows that did not have a calf were removed from the weight measurements post-calving and BCS measurements. Main effects in the model included supplementation. Random variables were year, pasture, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year. Sample periods were analyzed independently. Pasture was the experimental unit with cow as subsamples.

Body condition score was analyzed using the GLIMMIX procedure, with main effect of supplementation. The random effects included scorer, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year. Pasture within year was the experimental unit with cow as subsamples.

Calf birth weight, calving date, milk production, actual weaning weight, weight at 205 d of age, and adjusted 205 weaning weights were analyzed using the GLIMMIX procedure of SAS 4.3 with main effects of supplementation, cow age, calf sex, and interactions of all main effects. Random effects were calf, pasture, year, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year.

Percentage of calves born dead or alive was calculated by averaging calves born within pasture using the GLIMMIX procedure of SAS 4.3 with main effects of supplementation. Random effects were year, pasture, and pasture within year. Percentage of calves weaned from birth was calculated based on proportion of calves at weaning within respective pasture divided by the number of calves born alive. Analysis was GLIMMIX procedure of SAS 4.3 with main effects of supplementation. Random effects were year, pasture, and pasture within year. Percentage of calves weaned from pregnancy diagnosis was calculated within each pasture by taking the proportion of calves alive at weaning and dividing by the total number of cows within pasture that were pregnant at beginning of grazing. Analysis was GLIMMIX procedure of SAS 4.3 with main effects of supplementation. Random effects were year, pasture, and pasture within year.

Prolactin and cortisol were measured using the GLIMMIX procedure of SAS 4.3. Main effects included supplementation, cow age, and the interactions. Each time point of sampling was analyzed independently. Random effects included year, cow, cow within pasture, cow within year, pasture within year, and cow within pasture within year.

Forage mass and accumulation were analyzed using the MIXED procedure of SAS 4.3 with main effects of fescue type, supplementation method, time of sample, year, and interactions. Random effect was pasture within year. Forage quality was evaluated using the MIXED procedure of SAS 4.3 with main effects of fescue, supplementation, year, time of sample, and interactions. Random effect was pasture within year.

If an interaction effect was greater than $P > 0.10$ then it was removed from model. For all analyzed results, statistical significance was determined at ($P \leq 0.05$), with tendencies being declared ($0.05 < P < 0.10$). If an interaction effect was detected, SLICE effects were conducted to determine within treatment differences.

RESULTS AND DISCUSSION

Cow Weight Changes

There were no differences in weights or changes in weight of cows grazing Bermudagrass between the two years due to treatment (Table 5.3). Like our findings, Tanner et al. (2020) found that supplementation of corn at 0.2% of BW did not impact body weight, cow body condition score, nor dry matter intake in supplemented cows from birth to 21 d post-partum. Although this is similar to our findings, their supplementation was 5x smaller than this study. Abdelhadi et al. (2005) reported that the supplementation of corn silage at 400 g/kg DM of total diet and high moisture corn at 310 g/kg DM of total diet (~900 g/kg DM of fresh pasture daily) did not impact cow performance. In growing steers, supplementing ground corn increases ADG and final body weights while grazing bermudagrass (Aiken, 2002). In Wheeler et al., (2002) study cows that were supplemented in one year gained more weight than non-supplemented cows, but the other year, the supplemented cows lost more weight and body condition.

Body Condition Score Changes and Rump Fat Changes

There were no differences in BCS or changes in BCS for cows grazing bermudagrass through feeding and grazing periods ($P > 0.15$; Table 5.3). Measuring body condition in an objective fashion, via rump ultrasound there was an increase in RF for SUPP as compared to NONSUPP ($P = 0.05$) during the second trimester. However, this did not continue through the supplementation period and overall, during gestation there was a greater numerical increase in RF for SUPP ($P = 0.14$; Table 5.3). Warner et al. (2011) supplemented cows ~ 20 days after the beginning of the grazing season with 1 kg/d per cow of dried distillers grains cattle cubes and found that BCS was improved during the last trimester, compared to not supplementing, but did not affect reproduction, calf performance, nor reproductive performance of heifer calves. Looper et al., (2010) found during the breeding season where cows were grazing either bermudagrass or endophyte-infected fescue that cows that started the grazing period in a moderate BCS (BCS averaged 4.7) had the greatest increases in BCS, especially compared to those that started in a good (BCS averaged 6.6). The cows in the current study were all in moderate BCS at start of the grazing period and ended in good BCS. In Looper et al. (2010) study they also found that without supplementation cows gained BCS on bermudagrass when starting at mid-four BCS, but those that started with a mid-6 BCS they lost weight.

Hair Score and Hair Length Changes

There were no differences in hair score, nor the change in hair score for cattle either SUPP or NONSUPP ($P > 0.27$; Table 5.4). Hair length was measured at three timepoints; initiation of the study (mid-second trimester), third trimester, and prior to calving. No differences were observed during all three timepoints in terms of SUPP and NONSUPP ($P > 0.45$; Table 5.4).

Calf Crop, Calf Birth Weight, Birthdate within year, Weigh-Suckle-Weigh, and Weaning Weight

Percentage of calves born (dead or alive) was not different based on supplementation method ($P = 0.20$; Table 5). There was a tendency ($P = 0.06$) for NONSUPP cows to have less calves survive to weaning (Table 5). Overall, from confirmed pregnant until weaning there was no difference in calf crop weaning percentage ($P = 0.62$; Table 5).

Day within the yr that calves were born tended ($P = 0.10$) to be 8 d later in SUPP cow than NONSUPP (Table 5). Cow age also resulted in different average d within yr that calves were born where YOUNG cows calved nearly 13 d on average before OLD cows and 11 d before MID (247, 260, 258 respectively, SEM 28.1). This was probably not due to sire, as the cows and the heifers were bred to embryo transfer full brothers, to minimize potential confounding effects of sire. Also, based on EPDs all sires utilized were in the top 30% of the breed for calving ease direct. There were no effects of calf sex or interactions on d within yr calves were born ($P > 0.13$).

Calf birth weight was not different based on supplementation ($P = 0.97$; Table 5.5). YOUNG cows had calves that were lighter than OLD cows with MID calf birth weight intermediate (67, 80, and 75 kg, respectively; SEM 3.8). Calf birth weight was not impacted by any other effect.

Estimation of milk output as measured via weigh-suckle weigh method was not different based on supplementation that occurred during gestation ($P = 0.76$; Table 5.5). YOUNG cows had lower milk output ($P = 0.01$) than MID and OLD cows (10.13, 15.37, and 16.45 kg, respectively; SEM 5.74). Additionally, the sex of the calf influenced estimate milk output by the cow where heifer calves had a greater weigh-suckle-weigh number than steer calves (15.67 vs. 12.30 kg; SEM 5.7). No other interactions were found to affect milk output estimate ($P > 0.19$; Table 5.5).

Actual weaning weight was not different based on cow supplementation methods during gestation ($P = 0.83$; Table 5.5). As expected, cow age and calf sex did impact actual weaning weight. The YOUNG cows had lighter weaning weights ($P = 0.04$) than OLD cows with MID cows being intermediate (222, 246, and 237 kg, respectively; SEM 7.86). Steer calves were also heavier ($P = 0.01$) than heifer calves at weaning (244 vs. 226 kg; SEM 6.76). When calculating weaning weight to 205 d of age, supplementation still did not impact weaning weights ($P = 0.61$); but dam age still resulted in the same trend ($P = 0.01$) as actual weaning weight where

YOUNG had lighter weaning weights than OLD with MID intermediate (207, 237, and 228 kg, respectively; SEM 7.67). Many breed associations have identified that cow age and calf sex can influence actual weaning weights, and in their calculations for contemporary group differences to be utilized in EPDs have included adjustments to account for those factors. When implementing the adjustments based on the American Angus Association (St. Joseph, MO), calves whose dams were NONSUPP during gestation had a greater 205 d adjusted weaning weight that SUPP calves ($P = 0.03$; Table 5.5). Part of this difference in treatment could be associated with the fact that there was a greater percentage of male calves born in the NON treatment group. Based on the American Angus Association adjustments those male calves get an additional weight advantage.

Hormonal Analysis

There were no differences between supplementation methods for any time points measured for prolactin or cortisol ($P > 0.34$; Table 5.6). Cow age tended ($P = 0.07$) to affect cortisol concentrations where through the second trimester MID age cows had a greater reduction in serum cortisol than YOUNG cows with OLD cows being intermediate (Figure 5.1). There was no difference ($P = 0.72$) in cortisol concentration changes during the third trimester, but through the entire gestation period evaluated, it tended ($P = 0.07$) for the MID aged cows to have a greater reduction in cortisol than YOUNG cows with OLD cows being intermediate (Figure 5.1). Hair cortisol concentrations have been found to increase throughout pregnancy (Braun et al., 2017), which is opposite of what was observed in present study measuring serum cortisol, which decreased.

The cortisol concentration when measured at beginning of third trimester did have a supplementation method x age interaction ($P = 0.03$). The only difference was located in the OLD cows where SUPP-OLD cows tended ($P = 0.06$) to have a greater cortisol concentration than NONSUPP-OLD cows with no differences in the other age groups (Figure 5.2). Investigations into glucose and insulin on cortisol levels have shown varying responses. A dextrose bolus in Angus-cross calves has increased cortisol (Burdick Sanchez et al., 2016). In a glucose tolerance test with Holstein cows, the addition of the glucose had no effect on cortisol levels (Chalmeh et al., 2015). In humans increasing levels of insulin result in increased concentration of cortisol (Greenwood et al., 1966). Potentially, in the older cows used in this study, there were greater levels of insulin and glucose which may explain the increase in cortisol.

There were no interactions ($P > 0.22$; Table 5.6) for prolactin concentration. There were also no age differences ($P > 0.12$; Table 5.6) for any timepoint except the change in prolactin concentration during the third trimester. During the third trimester prolactin concentration tended ($P = 0.06$) decrease in MID aged cows, while increasing in YOUNG and OLD cows (Figure 5.3). Cows grazing bermudagrass during the breeding period irregardless of BCS had similar prolactin concentrations (Looper et al., 2010).

Forage Accumulation, Forage Mass, and Nutrient Composition

There was no difference between supplementation methods for FM ($P = 0.27$; Table 5.7) nor FA ($P = 0.66$; Table 5.7). Forage mass was greater ($P < 0.0001$) in 2024 than in 2023 (4,831.01 vs. 2,893.95 kg/ha; SEM 223.7) but forage accumulation was not different ($P = 0.30$). There were no interaction effects for FM or FA ($P > 0.14$). Forage mass was greatest in June, followed by September and May with the lowest FM in July ($P = 0.01$; Figure 5.4). Many studies have been able to prove that supplementation of corn has both increased and decreased forage intake, thus increasing or decreasing forage mass. For example, supplementing corn increased forage intake when fed at 7.8% of DM intake (Henning et al., 1980). But, Pordomingo et al.

(1991) reported that cattle grazing summer pastures in New Mexico exhibited a reduction in forage intake when supplemented with corn.

Supplementation method had no impacts ($P > 0.31$) on forage measures of nutrient composition nor yr x supplementation interaction ($P > 0.53$; Table 5.7). There were differences in yr where CP and TDN were lower in 2024 than 2023 ($P < 0.001$) and NDF and ADF were higher in 2024 than 2023 ($P < 0.0001$; Figure 5.5). Additionally, Ca was lower in 2024 than 2023; P and K were higher in 2024 than 2023 ($P < 0.0001$; Figure 5.6). The protein and energy reduction in nutrient composition makes sense in 2024 as compared to 2023 as there was greater forage mass in 2024. Greater biomass production generally results in lowered nutritional quality.

APPLICATION

Although supplementation of energy and harvested forages has been known to mitigate drought conditions for grazing cattle, it was discovered that corn silage supplementation had no positive impact on forage availability during this study. Similarly, supplementation of corn silage at 1% of cows body weight did not positively, or negatively, impact cow performance.

Table 5.1 Average silage nutrient composition for both years and free-choice mineral supplement.

Item	2023 Silage	2024 Silage
Moisture, % as fed	73.68 ± 5.99	61.14 ± 0.78
Dry matter, % as fed	26.32 ± 5.99	38.86 ± 0.78
Crude protein, % DM	9.305 ± 0.51	7.615 ± 0.22
ADF, % DM	27.12 ± 2.42	22.825 ± 0.235
NDF, % DM	45.645 ± 4.76	37.63 ± 0.85
NE_L, mcal/kg DM	0.33 ± 0.01	0.34 ± 0.01
NE_G, mcal/kg DM	0.21 ± 0.01	0.23 ± 0.002
NE_M, mcal/kg DM	0.36 ± 0.01	0.38 ± 0.01
TDN, % DM	69.97 ± 1.74	73.06 ± 0.17
Calcium, % DM	0.26 ± 0.06	0.23 ± 0.01
Phosphorus, % DM	0.22 ± 0	0.195 ± 0.005
Potassium, % DM	0.71 ± 0.07	0.775 ± 0.005
Magnesium, % DM	0.22 ± 0.005	0.19 ± 0.005

Table 5.2 Free-choice mineral provided to grazing cattle both years.

Item	Minimum	Maximum
Calcium, %	15.00	17.5
Phosphorus, %	6.50	---
Salt, %	18.00	23.00
Magnesium, %	2.00	---
Potassium, %	0.50	---
Copper, ppm	1550	---
Selenium, ppm	26	---
Zinc, ppm	4800	---
Iodine, ppm	90	---
Vitamin A, iu/kg	71,668	---
Vitamin D, iu/kg	5,194	---
Vitamin E, iu/kg	399	---

[1]Free-choice mineral: Cattle King Nutrition Mineral 6.5% Cow IGR #3058; A mineral supplement for beef cattle on pasture or range with active ingredient of S-methoprene (0.009%) per lb.
Wildcat Feeds LLC, Topeka, KS

Table 5.3 Cow BW, BCS, and RF through feeding and grazing periods.

Item	NONSUPP[1]	SUPP[2]	SEM[3]	TRT[4]
Body weight				
Mid second trimester, kg	549	550	19	0.97
Start of 3rd trimester, kg	629	617	21.4	0.70
Prior to calving, kg	674	661	22.4	0.67
Peak lactation, kg	629	601	20.2	0.33
Change through 2nd trimester, kg	75	67	5.50	0.34
Change through 3rd trimester, kg	46	44	8.70	0.90
Change through gestation, kg	120	112	9.70	0.55
Change in early lactation, kg	-48	-54	7.70	0.55
Change in second trimester through early lactation, kg	74	58	9.40	0.27
Body condition score				
Mid second trimester	4.67	4.66	0.27	0.97
Start of 3rd trimester	6.06	6.31	0.61	0.17
Prior to calving	6.33	6.38	0.49	0.80
Peak lactation	5.79	5.95	0.17	0.50
Change through 2nd trimester	1.27	1.54	0.45	0.22
Change through 3rd trimester	0.37	0.17	0.30	0.36
Change through gestation	1.64	1.72	0.35	0.76
Change in early lactation	-1.08	-0.62	0.47	0.15
Change in second trimester through early lactation	1.07	1.02	0.47	0.87
Rump fat				
Mid second trimester, mm	7.53	7.42	0.85	0.93
Start of 3rd trimester, mm	11.55	13.53	2.14	0.23
Prior to calving	10.70	12.63	1.03	0.19
Change through 2nd trimester, mm	4.01	6.11	1.81	**0.05**
Change through 3rd trimester, mm	-0.89	-0.90	2.55	0.99
Change through gestation, mm	3.16	5.21	0.96	0.14

[1] NONSUPP: Pasture treatments that were not supplemented with corn silage.
[2] SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks.
[3] SEM: standard error of means.
[4] TRT: main effect of feeding type (SUPP vs. NONSUPP).

Table 5.4 Cow hair score and hair length through feeding and grazing periods.

Item	NONSUPP[1]	SUPP[2]	SEM[3]	TRT[4]
Hair Score[5]				
Mid second trimester	2.67	2.54	0.47	0.71
Start of 3rd trimester	1.95	1.96	0.24	0.97
Prior to calving,	1.22	1.29	0.12	0.66
Change through 2nd trimester, kg	-0.73	-0.58	0.27	0.64
Change through 3rd trimester, kg	-0.77	-0.67	0.22	0.64
Change through gestation, kg	-1.54	-1.25	0.45	0.27
Hair length				
Mid second trimester	18.17	19.92	1.62	0.45
Start of 3rd trimester	16.08	16.25	2.04	0.93
Prior to calving	12.69	13.21	2.94	0.55
Change through 2nd trimester	-2.08	-3.67	2.04	0.59
Change through 3rd trimester	-3.55	-3.04	1.36	0.77
Change through gestation	-5.50	-6.71	2.47	0.62

[1] NONSUPP: Pasture treatments that were not supplemented with corn silage.
[2] SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks.
[3] SEM: standard error of means.
[4] TRT: main effect of feeding type (SUPP vs. NONSUPP).
[5] Hair score based on scale of 1-5 with 1 being slick haired and 5 no hair shedding.

Table 5.5 Calf crop, calf birthdate, and calf weights.

Item	NONSUPP[1]	SUPP[2]	SEM[3]	TRT[4]	AGE[5]	SEX[6]
Calves born (dead or alive), %	95.8	87.5	8.9	0.20	--	--
Calves weaned from birth, %	87.5	100.0	4.3	**0.06**	--	--
Calves weaned from pregnancy diagnosis, %	83.3	87.5	11.5	0.62	--	--
Calf birthdate within year	251	259	28	0.10	**0.07**	0.22
Calf birth weight, kg	34	34	1.1	0.97	**0.06**	0.98
Calf WSW weight gain, kg	6.45	6.23	2.58	0.76	**0.01**	**0.05**
Actual weaning weight, kg	234	236	7.4	0.83	**0.04**	**0.03**
Weaning weight at 205 d of age, kg	222	227	9.2	0.61	**0.01**	0.15
Adjusted 205 d weaning wt, kg	233	225	6.7	**0.03**	0.28	0.99

[1] SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks

[2] NONSUPP: Pasture treatments that were not supplemented with corn silage

[3] SEM: standard error or means

[4] TRT: main effect of feeding type (SUPP vs. NONSUPP)

[5] AGE: main effect of cow age (YOUNG vs. MID vs. OLD)

[6] SEX: main effect of sex of calf (female vs. male)

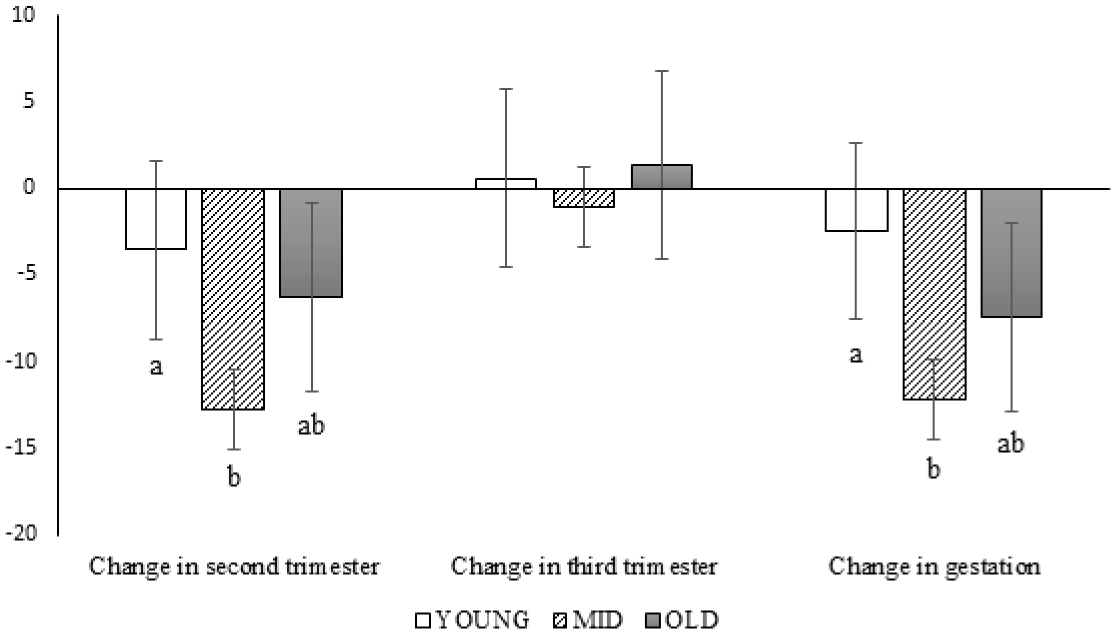
[7] Adjustments for age of dam and sex of calf included in adjusted 205 d weight (American Angus Association, St. Joseph, MO).

Table 5.6 Prolactin and cortisol concentration results.

Item	NONSUPP[1]	SUPP[2]	SEM[3]	TRT[4]	AGE[5]	TRT x AGE[6]
		Prolactin				
Mid second trimester	102.32	122.92	74.32	0.55	0.67	0.31
Start of 3rd trimester	79.18	91.25	49.49	0.53	0.35	0.22
Prior to calving,	166.31	148.53	126.35	0.73	0.12	0.89
Change through 2nd trimester, kg	-24.91	-3.35	22.52	0.51	0.86	0.69
Change through 3rd trimester, kg	89.26	40.03	76.66	0.34	**0.06**	0.69
Change through gestation, kg	63.71	23.36	64.35	0.47	0.17	0.39
		Cortisol				
Mid second trimester	18.13	20.60	3.12	0.52	0.21	0.12
Start of 3rd trimester	11.52	12.68	2.11	0.65	0.18	0.03
Prior to calving	12.44	12.24	2.35	0.95	0.50	0.19
Change through 2nd trimester	-6.55	-8.52	4.99	0.68	**0.08**	0.77
Change through 3rd trimester	0.59	0.01	2.32	0.86	0.72	0.99
Change through gestation	-6.40	-8.35	5.12	0.59	**0.07**	0.62

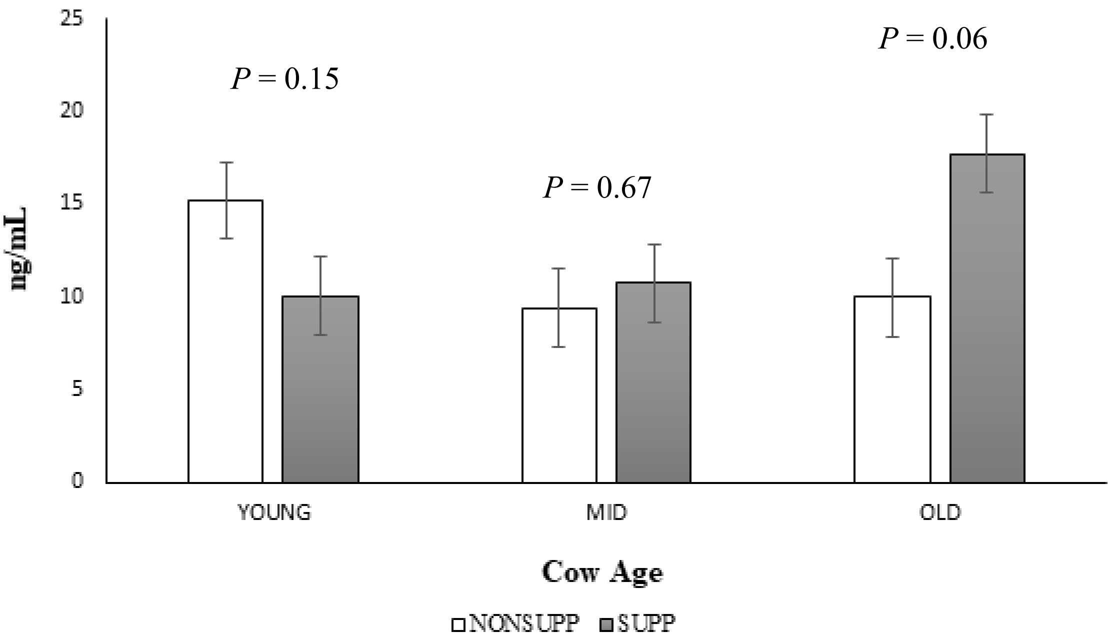
[1] NONSUPP: Pasture treatments that were not supplemented with corn silage.
[2] SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks.
[3] SEM: standard error of means.
[4] TRT: main effect of feeding type (SUPP vs. NONSUPP).
[5] AGE: main effect of cow age (YOUNG vs. MID vs. OLD).
[6] TRT x AGE: interaction effect of treatment (SUPP vs NONSUPP) by age of dam (YOUNG, MID, or OLD).

Figure 5.1 Cortisol concentration changes through gestation based on age of cows.



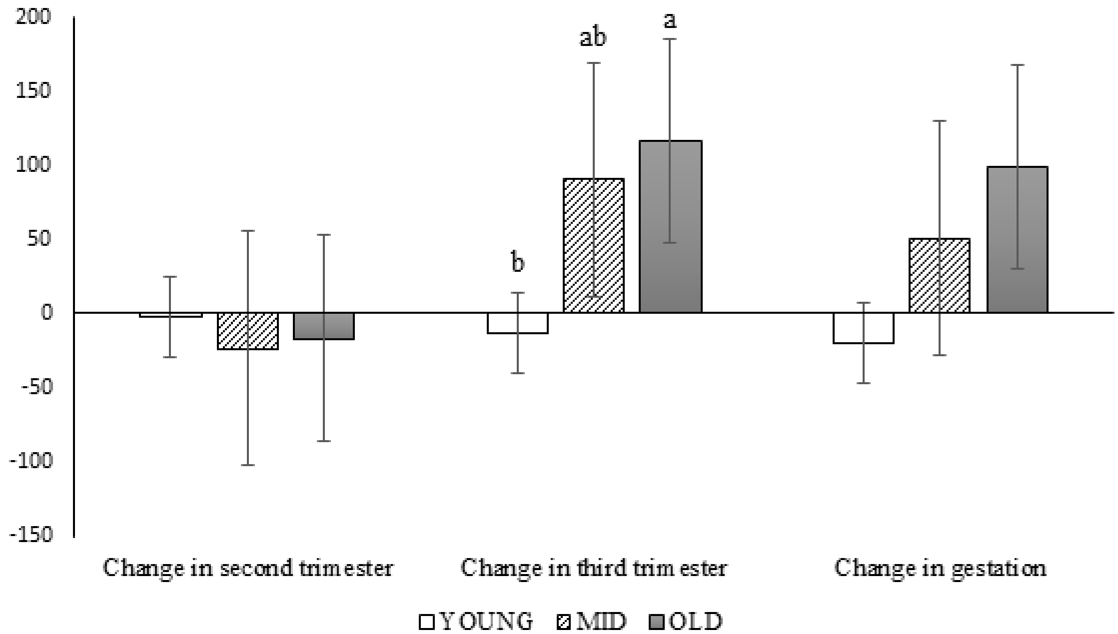
[a,b] Values within sample period with different superscripts are different at $P < 0.05$.
YOUNG: primiparous cows under age of 2 yr.
MID: multiparous cows between age of 3-5 yr.
OLD: multiparous cows over 6 yr.

Figure 5.2 Cortisol concentration at beginning of third trimester based on supplementation method x cow age.



P – values above age groups indicate treatment differences within age.
NONSUPP: Pasture treatments that were not supplemented with corn silage.
SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks.
YOUNG: primiparous cows under age of 2 yr.
MID: multiparous cows between age of 3-5 yr.
OLD: multiparous cows over 6 yr.

Figure 5.3 Prolactin concentration changes through gestation based on age of cows.



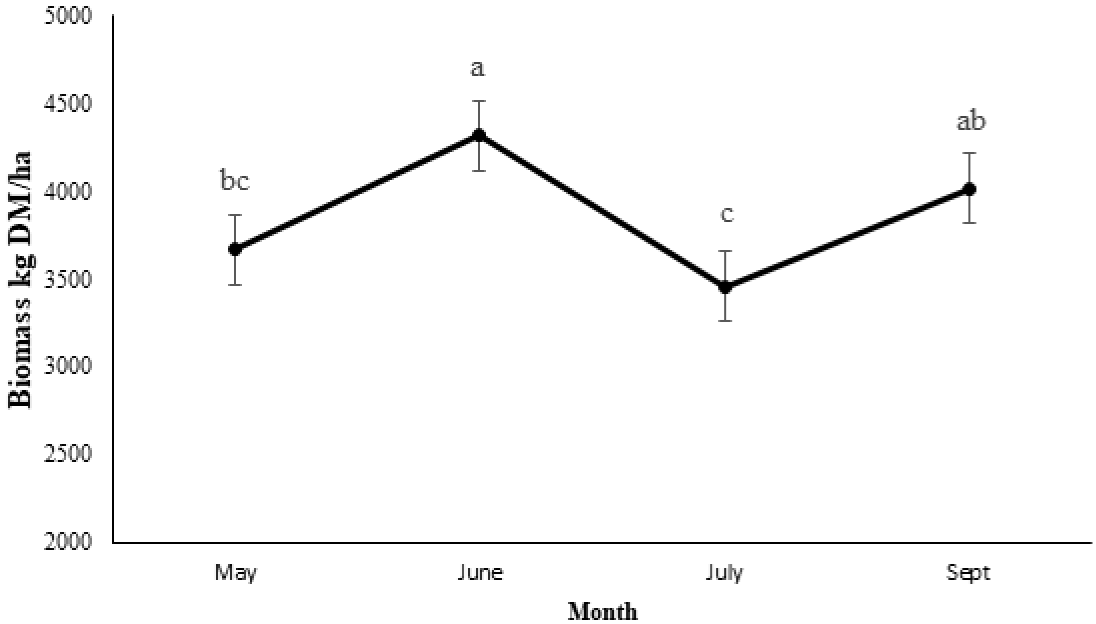
[a,b] Values within sample period with different superscripts are different at $P < 0.05$.
YOUNG: primiparous cows under age of 2 yr.
MID: multiparous cows between age of 3-5 yr.
OLD: multiparous cows over 6 yr.

Table 5.7 Bermudagrass Forage Results.

Item	NONSUPP[1]	SUPP[2]	SEM[3]	TRT[4]	Month[5]	YEAR[6]	TRT x YEAR[7]
Forage mass, kg DM/ha	3681.44	4043.51	223.71	0.27	**0.01**	**<0.0001**	0.14
Forage accumulation, kg DM/ha	1804.00	1965.96	252.28	0.66	**<0.0001**	0.30	0.79
CP, %	8.47	8.06	0.48	0.45	0.35	**0.001**	0.53
TDN, %	51.51	51.84	0.77	0.75	0.24	**<0.0001**	0.62
NEm, Mcal/kg	0.46	0.47	0.02	0.72	0.25	**<0.0001**	0.59
NEg, Mcal/kg	0.21	0.22	0.94	0.84	0.25	**<0.0001**	0.69
NDF, %	63.08	63.04	0.65	0.97	0.43	**0.01**	0.86
ADF, %	37.81	37.56	0.53	0.75	0.24	**<0.0001**	0.62
Ca, %	0.41	0.41	0.02	0.99	**0.06**	**0.01**	0.72
P, %	0.23	0.23	0.02	0.83	**0.02**	**0.01**	0.72
K, %	1.82	1.84	0.13	0.93	0.76	**0.07**	0.96
Mg, %	0.24	0.22	0.01	0.75	0.24	0.97	0.62

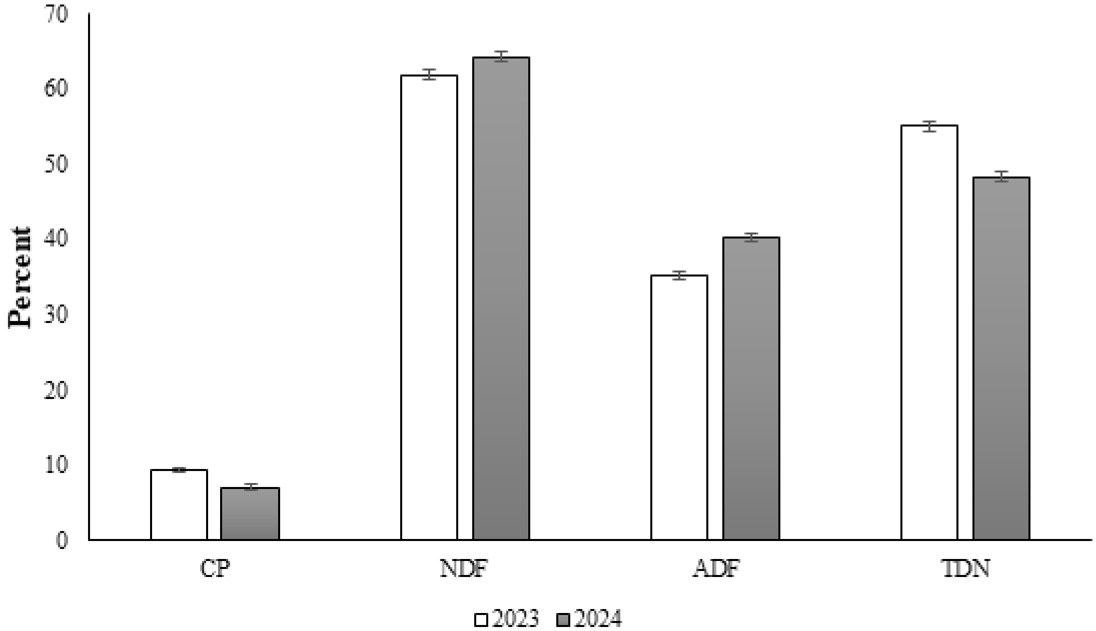
[1] NONSUPP: Pasture treatments that were not supplemented with corn silage.
[2] SUPP: Pasture treatments where cows were supplemented with corn silage at 1% of BW on DM basis in fenceline bunks.
[3] SEM: standard error of means.
[4] TRT: main effect of feeding type (SUPP vs. NONSUPP).
[5] Month: main effect of month (measured May, June, July, September)
[6] YEAR: main effect of year (2023 vs. 2024).
[7] TRT x YEAR: interaction effect of feeding type and year.

Figure 5.4 Forage mass by month.



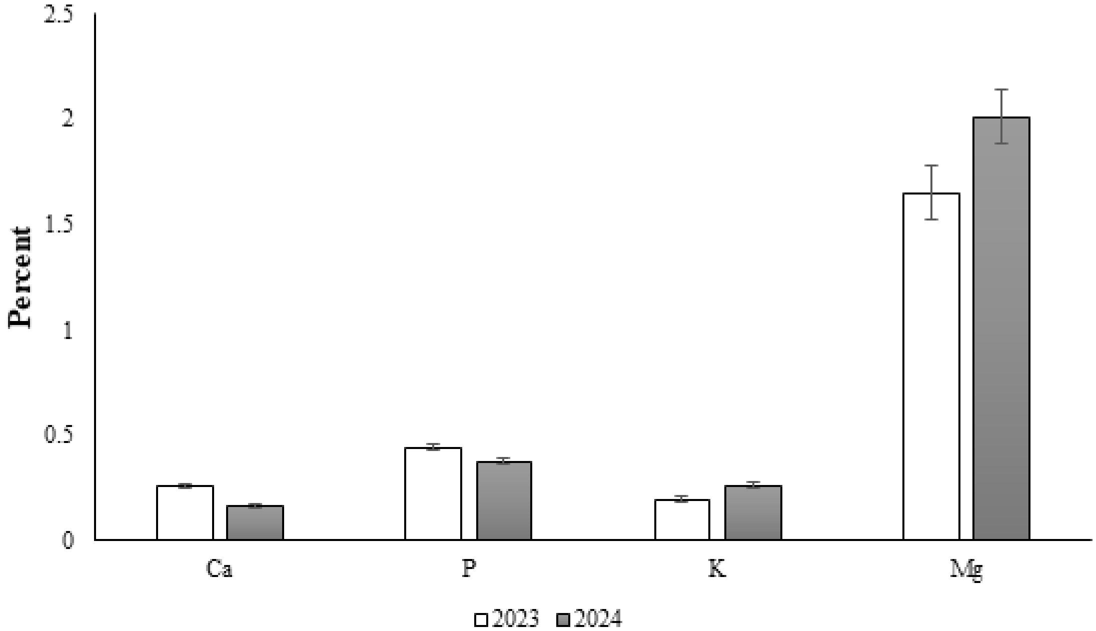
[a,b,c] Values with different superscripts are different at $P < 0.05$.

Figure 5.5 Nutrient composition based on year for CP, ADF, NDF, and TDN.



All nutrients represented in figure are different within category for each year ($P < 0.001$).

Figure 5.6 Macromineral differences based on year.



Calcium, P, and K are different within year ($P < 0.0001$). Magnesium is not different between years ($P = 0.97$).

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