Botanical composition of yearling-steer and mature-ewe diets in the Kansas Flint Hills

by

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Abstract

Eight native tallgrass pastures infested with sericea lespedeza (initial basal frequency = 2.9 ± 2.74%) were grazed by yearling beef steers (n = 279 / yr; 1.1 ha / steer) from 15 April to 15 July for 2 grazing seasons. Subsequent to steer grazing, mature ewes (n = 813 / yr) were allowed to graze 4 of the 8 pastures (0.15 ha / ewe) from 31 July to 1 October. Remaining pastures were rested until the subsequent April. Animals were allocated randomly to pastures annually; grazing treatments remained fixed for the 2-yr experiment. Four permanent 100-m transects were laid out in a north-south gradient in each pasture. Beginning 1 May, steer diet composition was monitored by collecting 5 fresh fecal pats along each transect at 2-wk intervals until steers were removed on 15 July. Fecal pats were dried and ground individually and then composited by weight within transect. Twenty-five mature ewes from each pasture were randomly selected to monitor diet composition. On 15 August and 15 September, ewes were gathered and restrained; fecal grab samples were then collected from the individuals selected for diet composition analysis. Microhistological analysis was conducted on steer fecal composites and fecal samples from individual ewes, using pure samples of 17 predominant grass, forb, and browse species from the experimental site as reference standards. Fecal and standard samples were prepared for microhistological analysis and viewed using a compound microscope at 100× magnification. Botanical composition of pastures was measured in October and compared with botanical composition of yearling beef steer and mature ewe diets. Diet selection exercised by yearling steer and mature ewes was evaluated using Kulcyznski’s Similarity Index. Proportions of bare soil, litter cover, and total basal vegetation cover did not differ ($P \geq 0.38$) between pastures for either steer or sheep diet evaluations. Similarly, basal cover of the 17 plants selected as microhistological standards did not differ ($P \geq 0.07$) between pastures for either steer or sheep

diet evaluations. The proportions of total graminoids and total forbs and forb-like plants in the diets of grazing steers were not different ($P = 0.37$) between sampling periods and were interpreted to indicate steer diets were strongly dominated by graminoids (≥ 88.4% of diets). Yearling beef steers consistently exhibited strong preference (i.e., ≤ 6% similarity with pasture composition) for *Bouteloua gracilis*, *Bouteloua dactyloides*, *Dalea purpurea*, and *Liatris punctata*, whereas they strongly avoided *Lespedeza cuneata* and *Symphyotrichum ericoides*. The proportions of total graminoids and total forbs and forb-like plants in the diets of grazing ewes were not different ($P = 0.67$) between sampling periods and were interpreted to indicate that mature ewes selected consistent proportions of grasses and forbs over time (average = 58 and 42% of diets for grasses and forbs, respectively). Mature ewes consistently exhibited strong preference (i.e., ≤ 10% similarity with pasture composition) for *Bouteloua gracilis*, *Bouteloua dactyloides*, *Dalea purpurea*, *Liatris punctata*, *Vernonia baldwinii*, and *Ambrosia artemisiifolia*. None of the 17 microhistological reference standards were consistently avoided by ewes.

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Chapter 1 - Review of Literature

Interspecies Competition for Resources

The Hofmann Classification Scheme identifies 3 types of ruminants: bulk and roughage eaters, intermediate feeders, and concentrate selectors (Van Soest, 1982). Bulk and roughage eaters include species such as cattle and buffalo; they select greater amounts of grasses than forbs and shrubs. The grass:forb:shrub ratio changes with intermediate feeders, such as sheep. Grasses make up approximately half of sheep diets, the other half consists of forbs and shrubs. Pronghorn antelope are an example of a concentrate selector. Shrubs account for at least 75% of a concentrate selector's diet, whereas shrubs contribute less than 25% of the diet of a roughage eater (Hofmann and Stewart, 1972).

Diet selection is linked to mouth structure (Van Soest, 1982). Deer and pronghorn antelope, have narrow snouts and tongues and are more capable of finely selecting nutritious parts of shrubs (i.e., individual leaves, fruits, or nuts) than cattle. Domestic cattle have broad snouts and plump, piston-like tongues. As such, they tend to be less capable of fine manipulation of feedstuffs and less selective in dietary choices.

According to Van Soest (1982), diet selection is also related to the amount of structural carbohydrate in plants. Structural carbohydrate content is related to extent of digestion, rate of digestion, and rate of passage. As rate of digestion and rate of passage increase, extent of digestion decreases. Roughage eaters can tolerate greater amounts of fibrous material and typically have longer ruminal retention times compared with concentrate selectors. A longer retention time allows ruminal microorganisms greater opportunity to break down plant cell walls. Rate of passage is generally slower in a roughage eater than in a concentrate selector. As grasses are less nutrient-dense and contain greater amounts of fibrous cell wall than forb and shrub leaves, more time is required to achieve an adequate extent of digestion. Since rate of passage is generally more rapid in concentrate selectors than in roughage eaters, less time is available for the breakdown of fibrous cellular components. Intermediate feeders are able to shift diet selection patterns depending on feedstuff availability (Van Soest, 1982). Retention times and rates of passage tend to fall between those typical of roughage eaters and concentrate selectors.

To properly manage rangelands, diet compositions of grazing animals in relation to plant species composition must be known (Olsen and Hansen, 1977). Domesticated animals share forage resources with non-domesticated animals. Optimal forage allocation can be determined only when dietary preferences of all herbivore species that occupy a common range are taken into account; this requires an estimate of dietary overlap between species (Holechek et al., 1982). Dietary overlap refers to similarities in diets of two or more species. When dietary overlap is relatively high, animals compete for the same forage resources. Competition between herbivore species can lead to over-utilization and an associated decline in preferred forage plants. If no action is taken to reduce grazing pressure on over-utilized forage plants, plant community regression results. Over-utilization of preferred forage plants also provides an opportunity for undesirable species to encroach into the destabilized plant community.

Determining Dietary Overlap

Developed by Oosting (1956), Kulcyznski's Similarity Index is a widely-used method of determining interspecies dietary overlap and relative selectivity of a single herbivore species compared with botanical composition of pasture (Ferreira et al., 2009). This index reflects similarity in diet-selection habits between two species of herbivores and uses a threshold of 50% similarity to determine the existence of competition for forage resources. When used to evaluate diet selection of a single species, values ≥ 83.5% for a plant or group of plants indicate little or no discriminatory selection by a given species of herbivore (Ferreira et al., 2009). The formula for this index, as adapted by Alipayo et al. (1992), is:

$$KSI = \left[\frac{2c_i}{a_i + b_i}\right] * 100$$

c_i = lesser % of component i

a_i = % of component i for species a

b_i = % of component i for species b

Proportional Similarity Index (PSI) is also used to measure similarity (Feinsinger et al., 1981). The formula for this index is:

$$PSI = 1 - 0.5 \sum (|P_i - Q_i|)$$

P_i = proportion of species i in diet of animal P

Q_i = proportion of species i in diet of animal Q

Another example of a similarity index is Spearman's rank correlation, which is an analytical technique that measures the relationship between two variables (Beck and Peek, 2005). Other statistical analyses, such as Chi-square, can be used to test for similarity between two variables rather than differences. It appears that Kulcyznski's Similarity Index is the most frequently used method to estimate dietary overlap between potentially-competing herbivores.

Resource Competition with Cattle

Most research on diet comparison has focused on overlap between wildlife and domestic cattle. In areas with significant populations of wild herbivores, forage availability for cattle must be discounted to allow for consumption by wildlife in order to maintain carrying capacity (Holechek et al., 1982). Species such as pronghorn antelope and whitetail deer do not compete with cattle for forage resources (Olsen and Hansen, 1977; Kingery et al., 1996; Torstenson et al., 2006). In contrast, diets of elk and feral horses overlap with those of cattle during various seasons of the year (Olsen and Hansen, 1977). Resource competition between elk and cattle is dependent on season, environment, and available plant species (Olsen and Hansen, 1977; Kingery et al., 1996; Beck and Peek, 2005; Torstenson et al., 2006). Feral horse diets reflect competition with cattle during summer and fall (Olsen and Hansen, 1977). Furthermore, prairie dog and cottontail rabbit diets are similar to those of cattle, regardless of season (Hansen and Gold, 1977; Mellado et al., 2005). Beck and Peek (2005) estimated botanical composition of sheep, cattle, elk, and pronghorn diets on a common range. They reported that sheep diets were not similar to cattle diets across seasons, suggesting that sheep and cattle may graze a common range without negatively affecting plant species composition or carrying capacity.

Sericea Lespedeza

Noxious weeds are described as having one or more of the following characteristics: extensive, perennial root systems; reproductively prolific; canopy dominant; allelopathic; or resistant to herbivory (Launchbaugh and Walker, 2006). Sericea lespedeza (**SL**; *Lespedeza cuneata*) possesses each of these characteristics. In addition, SL is capable also of thriving in many environments due to its resiliency in drought-stricken, acidic, or shallow soils (Vermeire et al., 2007).

Sericea lespedeza was introduced to the United States from Japan by the North Carolina Agricultural Experiment Station in 1896 (Ohlenbusch et al., 2007; Eddy and Moore, 1998). Sericea lespedeza was first planted in the 1930s, to combat soil erosion, to provide habitat for wildlife, and as a forage crop (Ohlenbusch et al., 2007). The spread of SL increased geographically during the 1980s, due to the unintentional inclusion of SL seed in diverse seed mixtures intended for croplands enrolled in the Conservation Reserve Program (Davidson et al., 1997; Eddy et al., 2003; Silliman and Maccarone, 2005).

Sericea lespedeza was planted in Kansas on strip-mined land in the 1930s to promote soil stabilization and around reservoirs from the 1940s to 1970s to provide cover for wildlife (Ohlenbusch et al., 2007). In 1988, the Kansas state legislature declared SL a county-option noxious weed, giving counties the authority to penalize land owners who did not control infestations (Eddy and Moore, 1998; Ohlenbusch et al., 2007). State-wide declaration of SL as a noxious weed followed in 2000. In 2006, SL reportedly infested 242,002 ha in Kansas. By 2012, infestation of SL in Kansas increased to 288,395 ha (KDA, 2014). Sericea lespedeza also affects other states such as Colorado, Missouri, Nebraska, and Oklahoma, where it is also considered to be noxious. Geographical spread of SL occurs primarily through inadvertent transport of seed by humans on vehicles and agricultural equipment and in contaminated hay; minor routes of spread via seed occur via flowing surface water and ingestion by wild and domestic herbivores (Eddy et al., 2003).

Once established, SL frequently grows taller than competing native plants and it tends to have a dense, branching aerial structure that can prevent sunlight from reaching understory plants (Ohlenbusch et al., 2007; Vermeire et al., 2007). Canopy dominance of SL thus decreases photosynthetic potential of competing plants, rendering them less capable of synthesizing carbohydrates.

Prolific seed production makes elimination of SL difficult once establishment has taken place. Vermeire et al. (2007) reported seed production of SL grown in pure stands to be approximately 950 kg /ha. Following traditional early-spring prescribed burning, SL can produce ~710 seeds per stem in the Kansas Flint Hills (Alexander et al., 2017).

Allelopathic compounds are toxins produced by the root system of a plant that depress germination or growth of competing plants or sequester resources from competing plants (Rice, 1984). Sericea lespedeza has a fibrous and extensive root system that requires significant carbohydrate resources during plant establishment (Ohlenbusch et al., 2007); it has allelopathic properties as well (Dudley and Fick, 2003). Kalburtji and Mosjidis (1992) reported that the addition of SL residues to soil reduced bermudagrass biomass by 28%. Dudley and Fick (2003) reported that SL residue applied to seeds of big bluestem, indiangrass, and Kentucky bluegrass reduced germination rates by 15 to 27%, 25 to 39%, and 47 to 60%, respectively. Conversely, SL allelopathy did not affect growth and germination of SL seeds added to soil with established SL plants (Cope, 1982).

Nutritionally, SL appears to be a nutritious forage. It contains approximately 11 to 14% crude protein when vegetative (Brink and Fairbrother, 1988). Unfortunately, it also contains high levels of condensed tannins (**CT**). Condensed tannins are phenolic compounds found in certain legume and browse species that reduce herbivory, disease, and stress in the plants that produce them (Min et al., 2003; Hoehn et al., 2017). Tannin phenolic compounds are classified into two types: CT or hydrolysable tannins (Haslam, 1989); however, hydrolysable tannins are rarely found in forages (Min et al., 2003). Condensed tannins are the main form found in SL. Condensed tannin concentration of SL in pelleted form has been reported as high as 13.2% (Kommuru et al., 2014). In the Kansas Flint Hills, tannin content of SL is greatest during the months of August and September; CT concentration ranged from 16 to 23% DM in fresh SL samples (Eckerle et al., 2010; Preedy et al., 2013b).

Condensed tannins bind protein in the rumen of herbivores through hydrogen and hydrophobic bonding (Min et al., 2003), rendering protein indigestible and reducing DMI and

DMD (Eckerle et al., 2011a). Condensed tannin affinity for proteins depends on molecular weight and chemical structure of the protein; CT have greatest affinity for proteins with large concentrations of hydrophobic amino acids (Min et al., 2003). Protein-binding properties of CT are also pH dependent, binding to proteins at near-neutral pH and releasing proteins at pH less than 3.5 (Jones and Mangan, 1977; Min et al., 2003). Condensed tannins in the rumen prevent ruminally-degradable proteins from being accessed by microbial enzyme systems, thereby decreasing ruminal ammonia availability and microbial-cell protein production.

Grazing of SL by cattle is generally infrequent due to the high levels of CT in the plant. While beef cattle are highly sensitive to CT (Eckerle et al., 2011a, 2011b, and 2011c), small ruminants such as sheep and goats tend to be more tolerant. Hart (2000) utilized stocker goats as a means of controlling SL and reported a high tolerance to CT, as evidenced by consumption of high-CT oak saplings in addition to SL. Similarly, Pacheco et al. (2012) noted greater consumption of SL in pastures where goats were co-grazed with cattle compared with pastures grazed by cattle alone. In a recent study, Lemmon et al. (2017) grazed mature ewes on native tallgrass pastures following early-intensive stocking of steers. They reported that sheep grazed more SL plants compared to steers, which reduced SL presence and did not compromise steer performance.

Avoidance of SL by beef cattle is thought to be a result of a negative post-ingestive feedback response (Mantz et al., 2009). A negative post-ingestive feedback response occurs as a result of consumption of a feedstuff that causes internal malaise (Provenza, 1995) and intake of the responsible feedstuff by the affected animal is thereafter limited. Triggers for such a response are generally plant-defense mechanisms to resist herbivory; CT are such a mechanism. Following CT ingestion, beef cattle become deficient in ruminally-available N. Fermentation rate would progressively decline as CT accumulated in the rumen and a sensation of general malaise would result (Eckerle et al., 2011c).

Research exploring additives that can be fed in conjunction with SL to improve acceptance has shown promise. Jones and Mangan (1977) reported that polyethylene glycol reduced the protein-binding properties of CT. Mantz et al. (2009) found that cattle ingested more SL when their diets were supplemented with polyethylene glycol, compared to cattle fed no supplement. Unfortunately, this approach would not be feasible in a commercial setting because the amount of polyethylene glycol needed to improve consumption of SL would be cost prohibitive and disallowed from a regulatory standpoint (Eckerle et al., 2011b).

Eckerle et al. (2011b) found that cattle ingestion of SL-contaminated tallgrass prairie hay was stimulated by corn steep liquor (**CSL**) supplementation. They speculated that the increase in contaminated forage consumption was due to rapid binding between CSL and CT within the rumen. Subsequent research by Eckerle et al., (2011c) reported that beef cows supplemented with CSL did not distinguish between SL-contaminated hay and non-contaminated hay, whereas beef cows that were not fed CSL selected non-contaminated hay preferentially. Preedy et al. (2013a, 2013b) indicated that CSL supplementation increased SL herbivory by beef cows grazing native tallgrass prairie pastures in a large-scale commercial setting. They also reported that SL ingestion did not have adverse effects on cow performance (Preedy et al., 2013a), suggesting that CSL improved CT tolerance of beef cows maintained under field conditions (Preedy et al., 2013b).

Control

Currently, control of SL involves application of herbicides, grazing by small ruminants, and prescribed burning. Herbicides commonly used to control broadleaf weeds, such as 2,4-

dichlorophenoxyacetic acid (2,4-D), picloram + 2,4-D (Grazon®), and dicambia + 2,4-D (Weedmaster®) were ineffective at controlling SL (Eddy et al., 2003; Ohlenbusch et al., 2007; Vermeire et al., 2007). Recommended herbicides for SL control include tryclopyr (Remedy Ultra®) applied in June and July and metasulfuron (Escort XP®) applied in September (Eddy et al., 2003; Ohlenbusch et al., 2007; Vermeire et al., 2007).

Dense plant canopies, such as those characteristic of the tallgrass prairie region, prevent aerially-applied herbicides from penetrating to or near the level of the soil; this results in adequate control of mature SL plants and inadequate control of juvenile SL plants (Eddy et al., 2003). Additionally, SL plants need to be actively growing for herbicide application to be effective (Vermeire et al., 2007) and follow-up applications are required. Herbicide application tends to be expensive, labor-intensive, and has undesirable effects on non-target plant species (Eddy et al., 2003).

Lemmon et al. (2017) evaluated the effects of traditional intensive-early stocking of steers followed by late-season sheep grazing on SL in native tallgrass prairie. They reported that steer grazing followed by sheep grazing reduced SL seed production 7-fold, compared to steer grazing alone. Pastures grazed by sheep also reflected reductions in forb-canopy dominance; moreover, sheep grazing did not affect steer growth performance. Hart (2000) applied stocker goats onto pastures infested with SL and found that goats had a preference for SL stems with seeds, reducing seed production from 960 seeds / stem to 2 to 3 seeds / stem. Goats also reduced the biomass of SL plants when co-grazed with cow-calf pairs without compromising performance of beef cows or calves (Pacheco et al., 2012).

Recent research examined the effects of prescribed-burn timing on SL and non-target plant species. Traditional spring prescribed burning of native tallgrass prairie, followed by intensive-early stocking with yearling beef cattle allows SL a full growing season to mature and reproduce, generally in the absence of grazing pressure because yearling beef cattle have been removed from pastures by the time SL begins to flower and produce seed. Alternatively, mid- and late-summer prescribed burning - at a time when locally-conventional yearling cattle grazing has normally ceased - may be effective in reducing SL biomass, aerial frequency, and seed production (Gurule et al., 2015). Alexander et al. (2017) reported decreases in aerial frequency of SL of 37.1% and 59.3% with mid- and late-summer prescribed burning, respectively, compared to locally-conventional spring prescribed burning. They also reported decreases in seed production per plant of 95.4% for mid-summer and 99.9% for late-summer burning, compared to traditional spring-season prescribed burning practices. Although mid- and late-summer prescribed burning reduced SL presence, total forage biomass production was not different between treatments.

Estimating Botanical Composition of Herbivore Diets

Botanical composition of grazing herbivore diets can be assessed using direct observation of grazing activities, manual utilization techniques, and microhistological evaluation of esophageally-collected masticate, ruminally-collected masticate, masticate collected from the gastric stomach, or fecal material (Holechek et al., 1982; McInnis et al., 1983). Direct observation methods require little equipment but are difficult to conduct because plants must be identified at a distance, observers must be in close proximity to animals, and many lengthy observations must be conducted for adequate characterization of dietary botanical composition (Holechek et al., 1982).

Utilization techniques involve the use of exclusion cages within a pasture that is grazed by one or more species of herbivore; forage biomass and plant species composition inside the exclusion cage are compared to biomass and plant species composition accessed by herbivores. Utilization techniques allow researchers to determine where grazing is occurring and to what extent; however, these techniques are subject to underestimation of herbivory during periods of rapid plant growth or senescence and they do not distinguish between grazing activities of herbivore species (Holechek et al., 1982). Additionally, utilization techniques fail to provide accurate estimates of herbivory habits when grazing pressure is light (Smith and Shandruk, 1979).

Microhistological evaluation of digesta or feces involves microscope-aided identification of individual plants and proportions of individual plants selected by individual herbivores during foraging activities. Microhistological evaluation of gastric-stomach contents is generally coupled with animal sacrifice, allowing only one sample collection and loss of the animal (Smith and Shandruk, 1979). Avoiding animal sacrifice allows for endangered or rare animals to be studied (Anthony and Smith, 1974; Wydeven and Dahlgren, 1982), as it does not decrease population (Dusi, 1949). Analysis of digesta from either ruminal or esophageal fistulation does not require animal sacrifice but does require animals undergo surgery, which increases research costs, animal stress, and the potential for altered grazing behaviors (McInnis et al., 1983).

Microhistological analyses of animal feces does not require animal sacrifice or surgical alteration; moreover, the number of samples collected is limited only by analytical cost and time. This technique allows for little interaction between researcher and animal and does not interfere with normal animal grazing habits and movements (Vavra and Holechek, 1980; Holechek et al., 1982; McInnis et al., 1983). Microhistological examination of feces is thought to reflect a broader spectrum of eating behavior compared with alternative sampling sites because it represents 4 to 8 grazing bouts; analysis of ruminal and esophageal masticate reflects only 1 to 2 grazing bouts (Anthony and Smith, 1974; Smith and Shandruk, 1979).

Microhistological Analysis of Feces

One of the first attempts to characterize animal diets via microhistology was made by Baumgartner and Martin (1939) who evaluated squirrel diets via examination of gastric-stomach contents. They were the first to document detailed descriptions of sample preparation and instructions on microhistologically differentiating plant species. Their methods served as the basis from which all recent microhistological procedures were developed. Microhistological analysis utilizes a compound microscope to evaluate distinctive structural characteristics of plant fragments for identification. Species identification is accomplished based on the epidermis and cuticle structures of plants (Norris, 1943). Sparks and Malechek (1968) determined dry weight percentages of various plant mixtures had a 1:1 ratio with relative frequency of plant fragments on microscope slides made from homogenized, ground subsamples of the plant mixtures. Conversely, Holechek and Valdez (1985a and 1985b) reported the ratio was not consistent across all forages.

Some limitations of microhistological analysis of feces include the time needed to complete analysis, observer errors in plant identification, unidentifiable plant species, differential total-tract digestibility between plant species, extensive sample preparation, complex mathematical manipulation of data, and the need for a large numbers of reference standards (Holechek et al., 1982; Alipayo et al., 1992; Carrière, 2002). Collection of fecal material is a relatively rapid process; however, significant time is required for sample preparation and plant fragment identification.

Norris (1943) was perhaps the first to characterize diets of sheep fed a diet of known botanical composition by analyzing stomach contents via microhistology. Norris (1943) found that digestibility of individual diet components was critical to accurate diet characterization, as highly digestible plant species were present in stomach contents in lesser proportions than in the diet. In a later experiment, Wydeven and Dahlgren (1982) compared the botanical composition of prairie dog stomach contents and feces. They reported that success of microhistological analysis depended on the amount of each plant ingested. Plants ingested in small amounts resulted in greater detection difficulty using fecal analysis than stomach-content analysis, due to the greater extent of digestion of fecal material (Slater and Jones, 1971; Smith and Shandruk, 1979; Wydeven and Dahlgren, 1982).

Vavra et al. (1978) microhistologically compared botanical composition of grazing steer diets using esophageally-collected masticate and fecal material during a 2-yr experiment. They also ranked individual species present in the diet from most common to least common. They identified fewer graminoids and more forbs in esophageal samples than in fecal samples; however, they found both methods were similar when ranking the relative dietary abundance of individual plant species. There were fewer changes in relative abundance among grass species than among forb species; moreover, blue grama was the most frequently-encountered plant species in both esophageal and fecal samples.

McInnis et al. (1983) compared four methods to estimate the botanical composition of standardized diets fed to sheep (i.e., utilization, microhistological evaluation of esophageal masticate, microhistological evaluation of ruminal masticate, and microhistological evaluation of feces) and outlined the benefits and liabilities of each. They reported that microhistological analysis of esophageal masticate was a more accurate reflection of known dietary botanical composition than utilization, ruminal masticate, or feces. Ruminal masticate analysis underestimated forbs compared to esophageal masticate analysis and underestimated both graminoids and forbs compared to fecal analysis. Utilization estimates resulted in lesser graminoid and greater forb content compared with other methods and failed to detect some plant species. Analysis of fecal material resulted in greater estimates of graminoid and lesser estimates of forb content compared with other methods; however, they indicated that fecal material was likely representative of a greater number of grazing bouts than esophageal masticate.

Alipayo et al. (1992) conducted a similar study in which sheep, Angora goat, and cattle diets were compared. Animals were fed a diet of known botanical composition. Consumption was recorded via ocular observation and fecal samples were collected. They concluded that fecal estimates of dietary botanical composition were not influenced by differential digestibility coefficients among plant species. A later study by Smith et al. (1994) microhistologically evaluated the diets of beef cattle grazing Chihuahuan desert range that had been assigned either ‘excellent’ or ‘good’ range condition scores. They reported cattle diets were comprised of 89% graminoids, 8% forbs, and 2% shrubs under excellent range conditions and 80% graminoids, 12% forbs, and 8% shrubs under good range conditions. The variation in diet composition between the two range condition scores was attributed to greater plant diversity on rangeland classified as good compared to that classified as excellent.

Beck and Peek (2005) microhistologically compared botanical composition of sheep, cattle, elk, and mule deer diets on aspen-sagebrush range. Elk diets were evaluated during spring and summer, while diets of sheep, cattle, and mule deer were evaluated during summer only. In spring, elk diets were 30 to 55% forbs, 18 to 60% graminoids, and 10 to 35% browse. In contrast, elk diets were 59 to 78% forb in the summer. Sheep diets contained little browse (1 to

5%) and were dominated by graminoids (70%), and forbs (23%). Cattle diets were overwhelming graminoid-based (92%), whereas mule deer diets consisted of only 2 to 5% graminoids and were dominated by forbs (64 to 72%) and browse (30%).

Summary

Dietary competition between sheep and beef cattle should be minimal based on forage preferences predicted by the Hofmann Classification Scheme (Hofmann and Stewart, 1972; Van Soest, 1982); however, direct comparisons of the dietary preferences of these herbivores are lacking in scientific literature. Assuming dietary overlap between small ruminants and beef cattle is modest, sheep could be maintained on the same pastures as beef cattle without compromising cattle performance or stocking rates. As sheep tend to be more tolerant of CT than beef cattle, they can be used to increase grazing pressure on SL that is normally avoided by beef cattle. In the Kansas Flint Hills, targeted grazing of this type could provide land managers with an opportunity to control SL without the costs of herbicide application, while adding an income stream in the form of wool, mutton, or lamb sales. Microhistological analysis of fecal material can be used to evaluate the degree of dietary competition between sheep and beef cattle during particular seasons of the year.

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Chapter 2 - Botanical Composition of Yearling Steer Diets in the Kansas Flint Hills

Abstract

Eight native tallgrass pastures (31 ± 3.3 ha) were grazed by yearling beef steers (n = 279 / yr) at a relatively high stocking density (1.1 ha / steer) from 15 April to 15 July for 2 yr. Four permanent 100-m transects were laid out on a north-south gradient in each pasture. Beginning 1 May, 5 fresh fecal pats were collected along each transect at 2-wk intervals until 15 July. Microhistological analyses were conducted on fecal samples composited by transect within pasture, using pure samples of 17 predominant grass, forb, and browse species from the experimental site as reference standards. Fecal-composite samples and reference standards were prepared for microhistological analyses and viewed using a compound microscope at 100× magnification. Botanical composition of yearling beef steer diets was compared with botanical composition of pastures, which was measured on 15 October ± 10.4 d during 2014, 2015, and 2016. Proportions of bare soil, litter cover, and total vegetation cover did not differ ($P \geq 0.38$) between pastures. Similarly, basal cover of the 17 microhistological standards did not differ ($P \geq 0.11$) between pastures. Pasture and period × pasture effects on selection patterns for plant-species reference standards were not detected ($P \geq 0.09$); therefore, period sums of squares were partitioned using orthogonal polynomial contrasts. The proportions of total graminoids and total forbs and forb-like plants in the diets of grazing steers were not different ($P = 0.37$) between sampling periods and were interpreted to indicate steer diets were strongly dominated by graminoids (≥ 88.4% of diets). Steer selection of *Andropogon gerardii*, *Ambrosia artemisiifolia*, *Ambrosia psilostachya*, *Amphiachyris dracunculoides*, *Lespedeza cuneata*, *Liatris punctata*, and *Symphyotrichum ericoides* were also not influenced ($P \geq 0.07$) by sampling period. Conversely, steer selection of *Schizachyrium scoparium* decreased ($P < 0.01$) linearly with advancing season, whereas selection of *Panicum virgatum*, *Sorghastrum nutans*, and *Vernonia baldwinii* increased ($P \leq 0.04$) linearly with advancing season. Proportions of *Bouteloua gracilis* and *Dalea purpurea* in yearling-steer diets responded quadratically ($P \leq 0.05$), proportions of *Bouteloua dactyloides* and *Carex* spp.in yearling-steer diets responded cubically ($P \leq 0.03$), and proportions of *Amorpha canescens*, unidentified grasses, and unidentified forbs in yearling-steer diets responded quartically ($P \leq 0.02$) to advancing season. Based on Kulcyznski's Similarity Index, yearling beef steers consistently exhibited strong preference (i.e., ≤ 6% similarity with pasture composition) for *Bouteloua gracilis*, *Bouteloua dactyloides*, *Dalea purpurea*, and *Liatris punctata*, whereas they strongly avoided *Lespedeza cuneata* and *Symphyotrichum ericoides*.

Introduction

The Kansas Flint Hills have traditionally been grazed by yearling beef cattle in the summer months, when forage quality is at its peak. Early-season, intensive grazing of yearling steers or heifers on native pastures – known locally as intensive early stocking - allows producers to maximize ADG and beef production per ha with little input cost (Owensby et al., 2008). Cattle are classified as roughage eaters; a majority of their diet is comprised of graminoids with relatively few forbs or browse species (Hofmann and Stewart, 1972; Van Soest, 1982). Concomitantly, sericea lespedeza - a state-recognized noxious weed - infests the Flint Hills region and competes with native plant species (Eddy and Moore, 1998).

Microhistological analysis of feces has been used to estimate the botanical composition of domestic and non-domestic animal diets since 1939, when Baumgartner and Martin first described the technique. It allows for microscopically-aided differentiation of plant species based on epidermal and cuticular structures and provides species-specific descriptions of herbivore diets (VanDyne and Heady, 1965; Holechek et al., 1982). In addition, it can be used to study diets of animals in a grazing setting without disturbing natural feeding habits. In our study, 17 predominant graminoids, forbs, and forb-like plants in the Kansas Flint Hills were examined in the diets of yearling beef steers. Our objective was to determine the botanical composition of yearling beef steer diets grazing sericea lespedeza-infested native tallgrass prairie.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee reviewed and approved all animal handling and animal care practices used in our experiment. All animal procedures were conducted in accordance with the Guide for the Care and Use of Animals in Agricultural Research and Teaching (FASS, 2010).

Our experiment was conducted at the Kansas State University Bressner Range Research Unit located in Woodson County, Kansas during the growing seasons of 2015 and 2016. Eight native tallgrass pastures (31 ± 3.3 ha) infested with sericea lespedeza (initial basal frequency = 2.9 ± 2.74%) were burned annually in April.

Pastures were grazed by beef steers (n = 279 / yr; initial BW = 264 ± 34 kg) at a relatively high stocking density (1.1 ha / steer) from 15 April to 15 July annually. Yearling beef steers were obtained from various commercial cattle growers in southeastern Kansas. Steers were weighed individually before grazing began each April and were assigned randomly to pastures. Steers were weighed individually again in late July.

Four permanent 100-m transects were laid out on a north-south gradient in each pasture; ends were marked using steel posts. Steers were allowed a 14-d adaptation period before sampling began each yr. Beginning 1 May, five fresh fecal pats (≥ 30 g wet weight) were collected along each transect (n = 20 samples / pasture) at 2-wk intervals until 15 July (i.e., 5 sampling periods annually: early May, late May, early June, late June, and early July). Care was taken to avoid contamination of fecal samples with soil or vegetation. Wet fecal samples were placed in a plastic container upon retrieval and frozen (-20 °C) pending processing and analysis.

Individual fecal samples were dried in a forced-air oven (55ºC; 96 h). Dried samples were ground (#4 Wiley Mill, Thomas Scientific, Swedesboro, NJ, USA) to a 1-mm particle size and composited by weight across transect and within pasture (n = 32 composite samples / collection period). A Daisy II in vitro incubator (Ankom Technologies, Macedon, NY) was used to mix composite samples for 120 min without heat (Sullivan and Bradford, 2011).

Plant species composition and soil cover were assessed along 2 permanent transects in each pasture on 15 October ± 10.4 d in 2014 (i.e., pre-treatment), 2015, and 2016 (i.e., post-treatment) using a modified step-point technique (Owensby, 1973; Farney et al., 2017). Transect points (n = 100 / transect) were evaluated for bare soil, litter, or basal plant cover (% of total area). Plants were identified by species; basal cover of individual species was expressed as a percentage of total basal plant area. Common names, scientific names, and taxonomic authority for plants referred to in this manuscript were taken from Haddock (2005). Comprehensive lists of graminoids, forbs, and shrubs encountered during plant-composition analyses are listed in tables 2.1, 2.2, and 2.3, respectively.

Approximately 65% of total basal vegetation cover on pastures used in our experiment was composed of the following forage species: big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), switchgrass (*Panicum virgatum* L.), Indian grass (*Sorghastrum nutans* [L.] Nash), blue grama (*Bouteloua gracilis* [Willd. Ex Kunth] Lag. Ex Greenm.), side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.), buffalo grass (*Bouteloua dactyloides* [Nutt.] Engelm.), sedges (*Carex* spp.), purple prairie-clover [*Dalea* *purpurea* Vent.], leadplant (*Amorpha canescens* Pursh), dotted gayfeather [*Liatris punctata* Hook.], heath aster [*Symphyotrichum ericoides* (L.) G.L. Nesom], sericea lespedeza (*Lespedeza cuneata* [Dumont] G. Don), Baldwin's ironweed (*Vernonia baldwinii* Torr.), Western ragweed (*Ambrosia psilostachya* DC.), annual broomweed (*Amphiachyris dracunculoides* [DC.] Nutt.), and common ragweed (*Ambrosia artemisiifolia* L.).

Reference standards for each above-named plant species were prepared using methods described by Holechek et al. (1982). Each standard sample was derived by hand-clipping 10 to 20 individual plants from a homogeneous stand of each plant type. Fruiting culms were discarded, whereas leaves, flowers, and vegetative stems were dried in a forced-air oven (55 ºC; 96 h). Dried samples were ground to a 1-mm particle size using a cyclone-style sample mill (model no. 80335R, Hamilton Beach, Glen Allen, VA).

Composite fecal samples and reference standards were prepared for microhistological analyses using methods described by Holechek et al. (1982), as adapted by Bennett et al. (1999) and Preedy et al. (2013b). A small amount (approximately 0.5 to 1 g) of sample material was placed into a beaker. Samples were soaked individually overnight in 50% EtOH (v/v). Ethanol was decanted after soaking and samples were homogenized and washed with deionized H_2O over a No. 200 US-standard sieve. Samples were then soaked in a 0.05M NaOH solution for 20 min and again washed with deionized H_2O for an additional 5 min through a No. 200 US-standard sieve.

Composite fecal samples and reference standards were placed on slides (5 slides per composite fecal sample and 3 slides per reference standard) using a dissecting needle. Two to 3 drops of Hertwig's solution were applied and slides were held 2 to 5 sec over a propane flame to dry. Slides were not permanently mounted, as the addition of glass covers slips and Hoyer's solution (Baumgartner and Martin, 1939) decreased visibility of plant fragments.

Sample slides and reference-standard slides were viewed with a compound microscope (DC5-163, Thermo Fisher Scientific, Asheville, NC) at 100× magnification. The microscope was equipped with a digital camera; 20 randomly-selected slide fields from each fecal-composite sample slide and each reference-standard slide were photographed digitally and stored (Preedy et al., 2013b).

Observers of microscopically-photographed images were trained using methods similar to those described by Holechek and Gross (1982). Observers viewed photographs of reference-standard slides until establishing familiarity with the epidermal and cuticular characteristics of each plant species. Observers were able to view reference-standard slide photos simultaneously with fecal-sample slide photographs for reference.

Individual plant fragments on each sample-slide field of view were counted and identified by plant species. The total number of fragments of each plant species on a given slide were converted to frequency of occurrence (i.e., [total of individual species ÷ total of all species] * 100; Holechek and Vavra, 1981).

Plant fragment prevalence in fecal-sample slide fields was assumed to be equivalent to prevalence in fecal samples and equivalent, on a percentage basis, to botanical composition of the diets grazed by beef steers (Sparks and Malechek, 1968). Plant fragments that were not among the 17 range-plant species for which reference standards were prepared were classified as either unidentified graminoids or unidentified forbs.

Steer growth performance data were analyzed as a completely randomized design using a mixed model (SAS Inst. Inc., Cary, NC). Class variables included animal, pasture, and year. The model contained a term for pasture only and animal within pasture and year was used as a random term. Least squares means were considered different when protected by a significant *F*-test ($P \leq 0.05$).

Mean basal cover percentages, standard deviations, minimum basal covers, and maximum basal covers for bare soil, litter, total basal vegetation, graminoids, forbs, shrubs, and individual plant species were calculated using the PROC MEANS procedure (SAS Inst. Inc., Cary, NC). Values were summarized across pastures and yr of the experiment.

The percentages of bare soil, litter cover, total basal vegetation cover, grass basal cover, forb basal cover, shrub basal cover, and basal cover of individual plant species were analyzed as a completely randomized design using a mixed model (SAS Inst. Inc., Cary, NC). Class variables were pasture, transect, and year. The model contained a term for pasture only and transect within pasture was used as a random term. Least squares means were considered different when protected by a significant *F*-test ($P \leq 0.05$).

Diet composition data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Class variables included pasture, transect, period, and yr. The model contained terms for pasture, period, and the 2-way interaction. Transect within pasture and year and period within pasture and year were considered random effects. Pasture effects on selection patterns for each of the 17 plant-species standards, unknown grass plants, and unknown forb plants were not detected ($P \geq 0.09$); moreover, period × pasture effects on diet selection patterns were also not detected ($P \geq 0.11$). Therefore, period sums of squares were partitioned using preplanned orthogonal polynomial contrasts ($n = 4$). Period effects for the highest-order, significant contrast ($P \leq 0.05$) are discussed.

Kulcyznski's Similarity Index (**KSI**; $((2c_i) / (a_i + b_i)) * 100$, where a_i is the % basal cover of component *i*, and b_i is the % of component *i* selected by an herbivore, and c_i is the lesser of a_i *and* b_i) was used to evaluate yearling-steer diet selection patterns in relation to botanical composition of pastures. For the purposes of our analysis, we assumed that KSI values ≥ 80% indicated little or no discrimination (i.e., selection patterns were very similar to plant availability), that KSI values between 21 and 79% indicated moderate discrimination, and that KSI values ≤ 20% indicated either strong preference for or avoidance of individual plant species. When KSI values were ≤ 20%, preference and avoidance were distinguished from one another by comparing the proportion of the specific plant in yearling-steer diets with basal cover of the specific plant on pastures.

Results and Discussion

Initial BW, final BW, and ADG of steers were not influenced ($P \geq 0.22$) by pasture (Table 2.4). In general, steer growth performance was excellent during the term of our experiment (mean ADG = 1.4 ± 0.32 kg); therefore, we concluded that any potential differences in forage composition between native tallgrass pastures used in our experiment were insufficient to influence steer BW gain.

Proportions of bare soil, litter cover, and total basal vegetation cover were not different ($P \geq 0.38$) between pastures (Table 2.5). Similarly, collective contributions of grasses, forbs, and shrubs to total basal vegetation cover were not different ($P \geq 0.07$) between pastures and varied by 8.7, 8.7, and 0.7% from minimum value to maximum values for grasses, forbs, and shrubs, respectively.

Collective basal cover of the 17 reference standards selected for microhistological analyses of steer feces comprised approximately 65% of total basal vegetation cover (Table 2.6);

therefore, we concluded that the selected standards were likely sufficient to characterize the majority of plants selected by grazing beef steers. Proportions of total graminoids, big bluestem, little bluestem, switchgrass, Indian grass, blue grama, buffalo grass, sedges, total forb and forb-like plants, purple prairie-clover, leadplant, dotted gayfeather, heath aster, Baldwin's ironweed, annual broomweed, and common ragweed were not different ($P \geq 0.06$) between pastures. Conversely, there were differences ($P < 0.01$) in proportions of unidentified graminoids, sericea lespedeza, and western ragweed between pastures, whereas dotted gayfeather was not detectable in our analysis of pasture forage composition.

No pasture or period × pasture effects were detected ($P \geq 0.09$) in selection of total graminoids, total forb or forb-like plants, or any of the 17 reference standards selected for microhistological analyses (Table 2.7); however, period effects ($P \leq 0.03$) in selection were detected for little bluestem, switchgrass, Indian grass, buffalo grass, sedges, unidentified graminoids, leadplant, and unidentified forbs. Therefore, period effects on selection of individual plant species or groups of plant species were characterized using orthogonal polynomial contrasts (Table 2.8). The proportions of total graminoids and total forbs and forb-like plants in the diets of grazing steers were not influenced ($P = 0.25$) by sampling period and were interpreted to indicate steer diets were strongly dominated by graminoids (≥ 88.4% of diets).

Selection of big bluestem, dotted gayfeather, heath aster, sericea lespedeza, western ragweed, annual broomweed, and common ragweed were also not influenced ($P \geq 0.07$) by sampling period (Table 2.8). Conversely, steer selection of little bluestem decreased ($P < 0.01$) linearly with advancing season, whereas selection of switchgrass, Indian grass, and Baldwin's ironweed increased ($P \leq 0.04$) linearly with advancing season. Unidentified graminoids and forbs were detected in only small amounts (i.e., 0.3 to 0.9% of graminoid fragments and 1.1 to 2.4% of forb or forb-like plant fragments) in yearling beef-steer diets; therefore, the 17 standards that we chose for microhistological characterization of diets were sufficient to allow other researchers evaluating beef cattle diets in the tallgrass prairie region to describe a large majority of diet components. Similar microhistological standards were useful for identifying > 90% of plant fragments in beef cattle diets in related experiments (Eckerle et al., 2009; Sproul et al., 2010; Aubel et al., 2011, Preedy et al., 2013b).

The significance of period effects on the appearance of remaining microhistological reference standards in the diets of yearling steers was less clear (Table 2.8). Proportions of blue grama in steer diets appeared to be greater (quadratic effect – $P = 0.02$) in May, late June, and early July when compared with early June. Conversely, purple prairie-clover appeared with greatest (quadratic effect - $P = 0.05$) frequency in yearling-steer diets in early June compared with other sampling periods. Proportions of buffalo grass and sedges in yearling-steer diets responded cubically ($P \leq 0.03$) to advancing season, with the greatest selection of both forage types occurring in late June. Proportions of side-oats grama, unidentified graminoids, leadplant, and unidentified forbs in yearling-steer diets responded quartically ($P \leq 0.02$) to advancing season, with peak selection occurring in early May, late June, late May, and early June, respectively.

Sericea lespedeza and heath aster appeared to be the least-preferred plant species by yearling beef steers among the 17 reference standards that were evaluated microhistologically, resulting in only one period (i.e., late June) in which more than trace amounts of either plant were detected in steer fecal material (Table 2.8). Significant heath aster consumption by beef cows grazing tallgrass prairie has been documented recently (Aubel et al., 2011; Preedy et al., 2013b), leading us to speculate that steers avoided heath aster from lack of grazing experience.

Avoidance of sericea lespedeza by confined beef cattle consuming tallgrass prairie hay (Eckerle et al., 2011a and 2011b) or by grazing beef cows (Preedy et al., 2013a and 2013b) is well-documented. Yearling steers likely learned to avoid sericea lespedeza early during the grazing period during each year of our experiment. We speculated that consumption of sericea lespedeza and the condensed tannins therein were unlikely to have caused a negative post-ingestive feedback response (Provenza, 1995) related to a dearth of ruminally-available N, because consumed amounts were miniscule. Provenza and Balph (1988) noted that young livestock were more likely than experienced livestock to consume small amounts of potentially harmful plant species; furthermore, Eckerle et al. (2011b) reported that beef cows likely developed a flavor-related aversion to sericea lespedeza before a general ruminal malaise occurred. Condensed tannins are astringent in nature and may be perceived by some herbivores as having a bitter flavor (Provenza et al., 1990; Hagerman et al., 1992). We concluded that steers avoided sericea lespedeza because of the astringent flavor associated with condensed tannins rather than because of any detrimental effects of condensed tannins on ruminal N metabolism.

Microhistological detection of plant fragments in feces may depend on rate and extent of digestibility of plant species under observation (Anthony and Smith, 1974; Smith and Shandruk, 1979). Prior research indicated that the technique may overestimate graminoid consumption and underestimate forb consumption (Lewis, 1994). Conversely, relatively large proportions of forbs were detected in the diets of yearling beef steers in our experiment. This was also true in reports dealing with beef-cow diets by Sproul et al. (2010), Aubel et al. (2011), and Preedy et al. (2013b).

Vavra et al. (1978) microhistologically compared botanical composition of grazing steer diets using esophageally-collected masticate and fecal material. They noted fewer grasses and more forbs in esophageal samples than in fecal samples; however, they found both methods were similar when ranking the relative dietary abundance of individual plant species. McInnis et al. (1983) also compared methods to estimate the botanical composition of standardized diets fed to sheep. They reported that microhistological analysis of esophageal masticate was a more accurate reflection of known dietary botanical composition than feces; however, they indicated that fecal material was likely representative of a greater number of grazing bouts than esophageal masticate. Alipayo et al. (1992) estimated the dietary botanical composition via fecal microhistology and ocular observation when cattle were offered a diet of known botanical composition. They concluded that fecal estimates of dietary botanical composition were not influenced by differential digestibility coefficients among plant species.

In spite of limits to detection of highly-digestible plant parts, fecal microhistology has several distinct advantages over alternative techniques for characterizing the botanical composition of herbivore diets: analyses of animal feces does not require animal sacrifice or surgical alteration; the number of samples collected is limited only by analytical cost and time; the technique allows for little interaction between researcher and animal and does not interfere with normal grazing habits and movements; and it is thought to reflect a broader spectrum of eating behavior compared with alternative sampling sites because it represents a greater number of grazing bouts (Anthony and Smith, 1974; Smith and Shandruk, 1979; Vavra and Holechek, 1980; Holechek et al., 1982; McInnis et al., 1983).

Sproul et al. (2010), Aubel et al. (2011), and Preedy et al. (2013b) indicated that forage preferences by beef cows grazing tallgrass prairie shifted with season of the year or experience level of cows. At the outset of our experiment, we hypothesized that diets selected by yearling beef steers would vary little over time because of a relative lack of grazing experience. The relative abundance (1 to 17; 1 = most abundant, 17 = least abundant) in yearling beef steer diets of each of the plant standards used in microhistological analyses is depicted in Table 2.9. The relative ranking of 6 graminoid-plant reference standards varied by only 1 placement during the May to July interval; moreover, the remaining 2 graminoid-plant reference standards varied by 4 placements or less. In general, the relative ranking of all graminoid-plant reference standards (range = 1 to 11) was relatively high compared to forb or forb-like plants (range = 7 to 17).

The relative ranking of forb and forb-like plants appeared to be less variable than that of graminoids (Table 2.9). Of the 9 forb reference standards, the relative ranking of 3 did not change from early May to late July, 3 varied by only one placement, 2 varied by 2 placements, and one varied by 4 placements. We affirmed that yearling beef steers strongly preferred graminoid-based diets and further concluded that only modest variation in diet selection occurred from early May to early July.

Walker (1994) indicated that beef cattle diets could be expected to consist of > 70% graminoids during the growing season. This was confirmed by Kingery et al. (1996) who reported that the graminoid contribution to cattle diets was greater than 90% from early summer to early fall in northern Idaho forests. Conversely, graminoid dominance in the diets of grazing beef cattle is not universally observed; beef cattle appear to adapt their diets to compensate for the lack of graminoid species in arid climates. Rosiere et al. (1975) evaluated beef-steer diets in southern New Mexico over the course of 2 growing seasons and reported graminoid dominance in the first yr of the study (70% of the diet) but not the second yr (42% dietary graminoids). Subsequently, Mohammad et al. (1995) investigated botanical composition of beef steer diets in the same region as Rosiere et al. (1975) and found that the average contributions of graminoids, forbs, and shrubs to steer diets were 58%, 33%, and 9%, respectively. These researchers concluded that the temporal differences in graminoid selection by beef cattle were driven by availability, which in turn was driven by differences in rainfall and pasture conditions over time.

Kulcyznski's Similarity Index (**KSI**) was used to evaluate yearling-steer diet selection patterns in relation to botanical composition of pastures (Table 2.10). The purpose of this comparison was an attempt to judge how much discrimination these relatively-inexperienced cattle exercised in dietary choices. Forage plants that were consistently selected in proportion to their availability in native tallgrass prairie pastures were total graminoids, big bluestem, total forb and forb-like plants, and western ragweed. Forage plants that were consistently selected in greater proportions than their availability in native tallgrass prairie pastures were blue grama, buffalo grass, purple prairie-clover, and dotted gayfeather, whereas those that were avoided were sericea lespedeza and heath aster. All other forage plants were ranked as receiving moderate selection discrimination from yearling beef cattle. It is difficult to characterize one class of beef cattle as being discriminant or indiscriminate grazers without an additional class of beef cattle or another herbivore species for comparison; however, it is clear from our experiment that even young beef cattle exercised some degree of selection discrimination.

Implications

Yearling beef cattle grazing native tallgrass pastures selected diets of fairly consistent composition during the early May to early July time frame. Yearling steer diets were strongly dominated by grasses (i.e., $\geq$ 88.4%); however, a significant proportion of forb or forb-like plants were also detected in steer diets (i.e., 8.9 to 11.6%). Cattle are reportedly willing to incorporate greater proportions of forbs into their diets as they mature and gain additional grazing experience (Soder et al., 2009). In cases where temporal trends were noted in selection of individual plant species, we speculated that those changes were driven by small, coincident changes in availability of alternative diet choices or by learned forage preferences or aversions. Contrary to our original hypothesis, we developed evidence to support the idea that even relatively inexperienced grazers can exhibit strong positive or negative discrimination in diet-component selection. In particular, yearling beef steers avoided sericea lespedeza and health aster and exhibited strong preferences for purple prairie-clover and dotted gayfeather. Small differences in selection patterns from month to month and small differences in botanical composition of pastures did not negatively influence growth performance of yearling beef steers grazing native tallgrass pastures.

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Table 2.1 Graminoid species encountered on native tallgrass pastures grazed by yearling beef steers from April to July in 2015 and 2016

Common name	Scientific name	Classification	Status	Metabolism	Growth form
Barnyard grass	*Echinochloa crus-galli*	Annual	Introduced	C4	n.a.
Big bluestem	*Andropogon gerardii*	Perennial	Native	C4	Tall
Blue grama	*Bouteloua gracilis*	Perennial	Native	C4	Short
Broomsedge	*Andropogon virginicus*	Perennial	Native	C4	Mid
Buffalo grass	*Buchloe dactyloides*	Perennial	Native	C4	Short
Canada bluegrass	*Poa compressa*	Perennial	Introduced	C3	n.a.
Canada wild rye	*Elymus canadensis*	Perennial	Native	C3	n.a.
Common witchgrass	*Panicum capillare*	Annual	Native	C4	n.a.
Eastern gamagrass	*Tripsacum dactyloides*	Perennial	Native	C4	Tall
Fall panicgrass	*Panicum dichotomiflorum*	Annual	Introduced	C4	n.a.
Fall witchgrass	*Digitaria cognata*	Perennial	Native	C4	Mid
Florida paspalum	*Paspalum floridanum*	Perennial	Native	C4	Mid
Green foxtail	*Setaria viridis*	Annual	Introduced	C4	n.a.
Hairy crabgrass	*Digitaria sanguinalis*	Annual	Introduced	C4	n.a.
Hairy grama	*Bouteloua hirsuta*	Perennial	Native	C4	Short
Indian grass	*Sorghastrum nutans*	Perennial	Native	C4	Tall
Japanese brome	*Bromuis japonicus*	Annual	Introduced	C3	n.a.
Kentucky bluegrass	*Poa pratensis*	Perennial	Introduced	C3	n.a.
Knotroot foxtail	*Setaria parviflora*	Perennial	Native	C4	Mid
Little bluestem	*Schizachyrium scoparium*	Perennial	Native	C4	Mid
Plains lovegrass	*Eragrostis intermedia*	Perennial	Native	C4	Mid
Poverty dropseed	*Sporobolus vaginiflorus*	Annual	Native	C4	n.a.
Prairie cordgrass	*Spartina pectinata*	Perennial	Native	C4	Tall
Prairie threeawn	*Aristida oligantha*	Annual	Native	C4	n.a.
Puffsheath dropseed	*Sporobolus neglectus*	Annual	Native	C4	n.a.
Purple lovegrass	*Eragrostis spectabilis*	Perennial	Native	C4	Mid
Purpletop	*Tridens flavus*	Perennial	Native	C4	Tall
Rush	*Juncus* spp.	Perennial	Native	C3	n.a.
Scribner dichanthelium	*Dichanthelium oligosanthes*	Perennial	Native	C3	n.a.
Sedge	*Carex* spp.	Perennial	Native	C3	n.a.
Side-oats grama	*Bouteloua curtipendula*	Perennial	Native	C4	Mid
Switchgrass	*Panicum virgatum*	Perennial	Native	C4	Tall
Tall dropseed	*Sporobolus asper*	Perennial	Native	C4	Mid
Tall fescue	*Schedonorus arundinaceus*	Perennial	Introduced	C3	n.a.
Tumble windmill grass	*Chloris verticillata*	Perennial	Native	C4	Short
Tumblegrass	*Schedonnardus paniculatus*	Perennial	Native	C4	Mid
Winter bentgrass	*Agrostis hyemalis*	Perennial	Native	C3	n.a.
Wooly cupgrass	*Eriochloa villosa*	Annual	Introduced	C3	n.a.
Yellow foxtail	*Setaria pumila*	Annual	Introduced	C4	n.a.

Table 2.2 Forb species encountered on native tallgrass pastures grazed by yearling beef steers from April to July in 2015 and 2016[*]

Common name	Scientific name	Growth	Status
Annual broomweed	*Amphiachyris dracunculoides*	Annual	Native
Annual marshelder	*Iva annua*	Annual	Native
Aromatic aster	*Symphyotrichum oblongifolium*	Perennial	Native
Ashy sunflower	*Helianthus mollis*	Perennial	Native
Baldwin's ironweed	*Vernonia baldwinii*	Perennial	Native
Bigbract verbena	*Verbena bracteata*	Perennial	Native
Black-eyed susan	*Rudbeckia hirta*	Perennial	Native
Blue wild indigo	*Baptisia australis*	Perennial	Native
Brittlebract plantain	*Plantago spinulosa*	Annual	Native
Buffalo bur	*Solanum rostratum*	Annual	Native
Bushy knotweed	*Polygonum ramosissimum*	Annual	Native
Carolina horse-nettle	*Solanum carolinense*	Perennial	Native
Carpetweed	*Mollugo verticillata*	Annual	Native
Catclaw sensitive briar	*Mimosa quadrivalvis var. nuttallii*	Perennial	Native
Clammy ground cherry	*Physalis heterophylla*	Perennial	Native
Clasping Venus’ looking-glass	*Specularia perfoliata*	Annual	Native
Cocklebur	*Xanthium strumarium*	Annual	Native
Common dandelion	*Taraxacum officinale*	Perennial	Introduced
Common evening primrose	*Oenothera biennis*	Biennial	Native
Common ragweed	*Ambrosia artemisiifolia*	Annual	Introduced
Common St. John’s-wort	*Hypericum perforatum*	Perennial	Introduced
Common yellow oxalis	*Oxalis stricta*	Perennial	Native
Curly dock	*Rumex crispus*	Perennial	Introduced
Daisy fleabane	*Erigeron strigosus*	Annual	Native
Dotted gayfeather	*Liatris punctata*	Perennial	Native
Eastern toothed spurge	*Euphorbia dentata*	Annual	Introduced
Eyebane	*Euphorbia maculata*	Annual	Native
False boneset	*Brickellia eupatorioides*	Perennial	Native
Field bindweed	*Convolvulus arvensis*	Perennial	Introduced
Field pussy-toes	*Antennaria neglecta*	Perennial	Native
Flat-top goldentop	*Euthamia graminifolia*	Perennial	Native
Fringe-leaf ruellia	*Ruellia humilis*	Perennial	Native
Giant ragweed	*Ambrosia trifida*	Annual	Native
Green antelopehorn	*Asclepias viridis*	Perennial	Native
Grooved flax	*Linum sulcatum*	Annual	Native
Heath aster	*Symphyotrichum ericoides*	Perennial	Native
Horseweed	*Conyza canadensis*	Perennial	Native
Illinois bundle-flower	*Desmanthus illinoensis*	Perennial	Native
Indian hemp dogbane	*Apocynum cannabinum*	Perennial	Native
Korean lespedeza	*Kummerowia stipulacea*	Annual	Introduced
Lance-leaf ragweed	*Ambrosia bidentata*	Annual	Native
Lemon beebalm	*Monarda citriodora*	Perennial	Native
Long-bearded hawkweed	*Hieracium longipilum*	Annual	Native
Missouri goldenrod	*Solidago missouriensis*	Perennial	Native
Missouri violet	*Viola missouriensis*	Perennial	Native
New England aster	*Symphyotrichum novae-angliae*	Perennial	Native
Nodding beggar-ticks	*Bidens cernua*	Annual	Native
Nodding ladies’-tresses	*Spiranthes cernua*	Perennial	Native

[*] This table is continued on the following page

Table 2.2 Forb species encountered on native tallgrass pastures grazed by yearling beef steers from April to July in 2015 and 2016 (continued)

Common name	**Scientific name**	**Growth**	**Status**
One-seed croton	*Croton monanthogynus*	Annual	Native
Pale comandra	*Comandra umbellata*	Perennial	Native
Pale poppy-mallow	*Callirhoe alcaeoides*	Perennial	Native
Pennsylvania smartweed	*Polygonum pensylvanicum*	Annual	Native
Pitcher sage	*Salvia azurea*	Perennial	Native
Plains wild indigo	*Baptisia bracteata*	Perennial	Native
Prairie coneflower	*Ratibida columnifera*	Perennial	Native
Prairie groundsel	*Senecio plattensis*	Perennial	Native
Purple poppy-mallow	*Callirhoe involucrata*	Perennial	Native
Purple prairie-clover	*Dalea purpurea*	Perennial	Native
Red clover	*Trifolium pratense*	Perennial	Introduced
Sericea lespedeza	*Lespedeza cuneata*	Perennial	Introduced
Showy partridge pea	*Chamaecrista fasciculata*	Annual	Native
Slender lespedeza	*Lespedeza virginica*	Perennial	Native
Slick-seed bean	*Strophostyles leiosperma*	Annual	Native
Small spotted sandmat	*Chamaesyce maculata*	Annual	Native
Stiff goldenrod	*Solidago rigida*	Perennial	Native
Tall goldenrod	*Solidago canadensis*	Perennial	Native
Velvetweed	*Oenothera curtiflora*	Annual	Native
Violet lespedeza	*Lespedeza violacea*	Perennial	Native
Virginia three-seeded mercury	*Acalypha virginica*	Annual	Native
Virginia groundcherry	*Physalis virginiana*	Perennial	Native
Virginia pepperweed	*Lepidium virginicum*	Perennial	Native
Wavy-leaf thistle	*Cirsium undulatum*	Perennial	Native
Western ragweed	*Ambrosia psilostachya*	Perennial	Native
Western spotted beebalm	*Monarda punctata*	Perennial	Native
Western yarrow	*Achillea millefolium*	Perennial	Native
White clover	*Trifolium repens*	Perennial	Introduced
White-eyed grass	*Sisyrinchium campestre*	Perennial	Native
White prairie-clover	*Dalea candida*	Perennial	Native
Whorled milkweed	*Asclepias verticillata*	Perennial	Native
Wild strawberry	*Fragaria virginiana*	Perennial	Native
Woolly verbena	*Verbena stricta*	Perennial	Native

Table 2.3 Shrub species encountered on native tallgrass pastures grazed by yearling beef steers from April to July in 2015 and 2016

Common name	Scientific name	Growth	Status
Blackberry	*Rubus spp.*	Perennial	Native
Buckbrush	*Symphoricarpos orbiculatus*	Perennial	Native
Eastern pricklypear	*Opuntia humifusa*	Perennial	Native
False indigo	*Amorpha fruticosa*	Perennial	Native
Lead plant	*Amorpha canescens*	Perennial	Native
Mulberry	*Morus* spp.	Perennial	Native
New Jersey tea	*Ceanothus americanus*	Perennial	Native
Prairie wild rose	*Rosa arkansana*	Perennial	Native
Slippery elm	*Ulmus rubra*	Perennial	Native
Smooth Sumac	*Rhus glabra*	Perennial	Native

Table 2.4 Growth performance of yearling beef steers grazing native tallgrass pastures from April to July in 2015 and 2016

Item	n[*]	Mean	Std. dev.	Minimum	Maximum	SEM[†]	*P*-Value[‡]
Initial BW, kg	558	264	33.7	145	397	6.1	0.22
Final BW, kg	527	839	50.5	209	503	9.7	0.26
ADG, kg	525	1.4	0.32	0.2	2.2	0.06	0.47

[*] n = 33 to 35 yearling steers / pasture × 8 pastures × 2 years; not all cattle were available for initial and final BW measurement.

[†] Mixed model SEM associated with comparison of pasture main effect means.

[‡] Mixed model *P*-value associated with pasture *F*-test.

Table 2.5 Bare soil, litter, basal vegetation cover, total graminoid cover, total forb cover, and total shrub cover on native tallgrass pastures grazed by yearling beef steers from April to July in 2015 and 2016

Item	n[*]	Mean	Std. dev.	Minimum	Maximum	SEM[†]	*P*-Value[‡]
Bare soil, % total area	48	20.8	13.64	10.8	29.2	7.87	0.49
Litter, % total area	48	68.1	14.42	60.3	78.2	8.17	0.38
Basal vegetation cover, % total area	48	11.1	4.21	8.0	12.8	2.79	0.48
Total graminoid cover, % total basal cover	48	86.8	4.70	81.6	90.3	2.54	0.07
Total forb cover, % total basal cover	48	12.9	4.66	9.6	18.3	2.52	0.08
Total shrub cover, % total basal cover	48	0.3	0.14	*tr*	0.7	0.11	0.71

[*] n = 8 pastures × 3 annual observations × 2 transects / observation annually

[†] Mixed model SEM associated with comparison of pasture main effect means.

[‡] Mixed model *P*-value associated with pasture *F*-test.

Table 2.6 Basal cover of forage plants detected in the diets of yearling beef steers grazing native tallgrass pastures from April to July in 2015 and 2016

Item	n[*]	Mean	Std. dev.	Minimum	Maximum	SEM[†]	*P*-Value[‡]
Total grass and grass-like	48	86.8	4.70	75.0	96.0	2.54	0.07
Andropogon gerardii	48	16.2	7.51	5.0	39.0	5.74	0.32
Schizachyrium scoparium	48	8.3	6.37	*tr*	28.0	3.41	0.13
Panicum virgatum	48	5.8	3.14	*tr*	12.0	1.68	0.16
Sorghastrum nutans	48	7.5	3.48	1.0	16.0	2.03	0.45
Bouteloua gracilis	48	0.2	0.52	*tr*	3.0	0.33	0.76
Bouteloua curtipendula	48	3.5	3.98	*tr*	19.0	2.23	0.06
Bouteloua dactyloides	48	0.1	0.24	*tr*	1.0	0.14	0.66
Carex spp.	48	13.7	5.29	3.0	26.0	2.76	0.11
Other graminoids	48	31.6	10.64	14.0	55.0	4.81	<0.01
Total forb and forb-like	48	12.9	4.64	4.0	24.0	2.50	0.07
Dalea purpurea	48	0.1	0.12	*tr*	0.5	0.09	0.37
Liatris punctata	48	-	-	-	-	-	-
Amorpha canescens	48	0.2	0.46	*tr*	2.6	0.44	0.63
Symphyotrichum ericoides	48	1.0	1.07	*tr*	4.1	0.61	0.47
Lespedeza cuneata	48	3.7	3.33	0.2	13.8	1.24	<0.01
Vernonia baldwinii	48	0.6	0.61	*tr*	2.0	0.58	0.57
Ambrosia psilostachya	48	2.4	1.46	*tr*	5.8	0.61	<0.01
Amphiachyris dracunculoides	48	0.7	1.68	*tr*	8.0	1.70	0.54
Ambrosia artemisiifolia	48	0.4	0.77	*tr*	4.8	0.64	0.54
Other forbs	48	3.7	1.99	0.4	9.4	1.09	0.22

[*] n = 8 pastures × 3 observations (i.e., fall of 2014, 2015, and 2016) × 2 transects / observation annually

[†] Mixed model SEM associated with comparison of pasture main effect means.

[‡] Mixed model *P*-value associated with pasture *F*-test.

[¶] Basal cover of *Liatris punctata* was below the detection limits of the plant-species composition survey technique used in this experiment; however, it was detected in steer fecal material.

Table 2.7 Botanical composition of yearling steer diets in the Kansas Flint Hills: period and pasture effects

	Botanical composition (% of diet DM)						*P*-Value		
Item	Early May	Late May	Early June	Late June	Early July	SEM	Period	Pasture	Period × Pasture
Total graminoids	91.1	90.2	88.4	90.1	90.3	1.77	0.66	0.61	0.99
Andropogon gerardii	21.4	23.9	23.3	18.4	20.5	2.51	0.21	0.99	1.00
Schizachyrium scoparium	27.0	23.6	19.7	16.0	16.9	1.76	<0.01	0.88	0.99
Panicum virgatum	11.5	13.4	15.7	17.0	18.0	1.53	<0.01	0.93	0.89
Sorghastrum nutans	9.8	11.1	14.0	15.1	14.1	1.87	0.03	0.99	1.00
Bouteloua gracilis	9.7	9.0	7.4	9.3	10.5	1.13	0.11	0.95	0.99
Bouteloua curtipendula	3.6	3.4	1.4	3.1	2.4	0.81	0.07	0.99	0.99
Bouteloua dactyloides	5.8	3.4	4.1	6.8	4.7	0.92	<0.01	0.99	0.98
Carex spp.	1.9	2.0	2.4	3.4	2.9	0.35	<0.01	0.09	0.41
Unidentified graminoids	0.3	0.4	0.3	0.9	0.3	0.19	<0.01	0.76	0.99
Forb and forb-like	8.9	9.8	11.6	9.9	9.7	1.77	0.66	0.61	0.99
Dalea purpurea	1.8	2.0	3.0	2.8	2.1	0.54	0.14	0.95	0.80
Liatris punctata	0.4	0.8	0.6	0.6	0.5	0.20	0.31	0.95	0.98
Amorpha canescens	0.1	0.2	*tr*	0.1	*tr*	0.07	<0.01	0.87	0.69
Symphyotrichum ericoides	*tr*	*tr*	*tr*	0.1	*tr*	0.03	0.19	0.57	0.68
Lespedeza cuneata	*tr*	*tr*	*tr*	0.1	*tr*	0.04	0.43	0.81	0.52
Vernonia baldwinii	1.0	1.6	2.2	2.0	2.2	0.59	0.21	0.69	0.99
Ambrosia psilostachya	2.4	2.0	2.3	2.1	2.3	0.54	0.94	0.46	0.99
Amphiachyris dracunculoides	0.2	0.1	0.2	0.2	0.2	0.08	0.64	0.72	0.57
Ambrosia artemisiifolia	1.2	0.9	1.0	0.9	1.0	0.30	0.84	0.86	0.99
Unidentified forb	1.8	2.0	2.4	1.1	1.3	0.21	<0.01	0.24	0.11

Table 2.8 Botanical composition of yearling steer diets in the Kansas Flint Hills: orthogonal polynomial contrasts by period

	Botanical composition (% of diet DM)						*P*-Value*			
Item	Early May	Late May	Early June	Late June	Early July	SEM	Lin.	Quad.	Cubic	Quartic
Total graminoids	91.1	90.2	88.4	90.1	90.3	1.77	0.68	0.25	0.89	0.37
Andropogon gerardii	21.4	23.9	23.3	18.4	20.5	2.51	0.21	0.45	0.08	0.40
Schizachyrium scoparium	27.0	23.6	19.7	16.0	16.9	1.76	<0.01	0.07	0.21	0.76
Panicum virgatum	11.5	13.4	15.7	17.0	18.0	1.53	<0.01	0.52	0.85	0.82
Sorghastrum nutans	9.8	11.1	14.0	15.1	14.1	1.87	<0.01	0.19	0.36	0.78
Bouteloua gracilis	9.7	9.0	7.4	9.3	10.5	1.13	0.46	0.02	0.93	0.21
Bouteloua curtipendula	3.6	3.4	1.4	3.1	2.4	0.81	0.16	0.24	0.72	0.02
Bouteloua dactyloides	5.8	3.4	4.1	6.8	4.7	0.92	0.62	0.29	<0.01	0.33
Carex spp.	1.9	2.0	2.4	3.4	2.9	0.35	<0.01	0.44	0.03	0.28
Unidentified graminoids	0.3	0.4	0.3	0.9	0.3	0.19	0.33	0.08	0.02	0.02
Total forb and forb-like	8.9	9.8	11.6	9.9	9.7	1.77	0.68	0.25	0.89	0.37
Dalea purpurea	1.8	2.0	3.0	2.8	2.1	0.54	0.26	0.05	0.27	0.43
Liatris punctata	0.4	0.8	0.6	0.6	0.5	0.20	0.75	0.16	0.21	0.29
Amorpha canescens	0.1	0.2	*tr*	0.1	*tr*	0.07	0.09	0.17	0.18	<0.01
Symphyotrichum ericoides	*tr*	*tr*	*tr*	0.1	*tr*	0.03	0.73	0.30	0.19	0.07
Lespedeza cuneata	*tr*	*tr*	*tr*	0.1	*tr*	0.04	0.58	0.69	0.44	0.10
Vernonia baldwinii	1.0	1.6	2.2	2.0	2.2	0.59	0.04	0.35	0.77	0.57
Ambrosia psilostachya	2.4	2.0	2.3	2.1	2.3	0.54	0.94	0.58	0.83	0.54
Amphiachyris dracunculoides	0.2	0.1	0.2	0.2	0.2	0.08	0.45	0.39	0.36	0.56
Ambrosia artemisiifolia	1.2	0.9	1.0	0.9	1.0	0.30	0.56	0.41	0.90	0.58
Unidentified forbs	1.8	2.0	2.4	1.1	1.3	0.21	<0.01	<0.01	<0.01	<0.01

* *P*-values associated with linear (lin.), quadratic (quad.), cubic, and quartic single-degree-of-freedom orthogonal polynomial contrasts.

Table 2.9 Relative abundance of individual plant species identified in feces of yearling steers grazing native range in the Kansas Flint Hills during August and September in 2015 and 2016

	Relative abundance*				
Item	Early May	Late May	Early June	Late June	Early July
Graminoids					
Andropogon gerardii	2	1	1	1	1
Schizachyrium scoparium	1	2	2	3	3
Panicum virgatum	3	3	3	2	2
Sorghastrum nutans	4	4	4	4	4
Bouteloua gracilis	5	5	5	5	5
Bouteloua curtipendula	7	7	11	8	8
Bouteloua dactyloides	6	6	6	6	6
Carex spp.	9	9	8	7	7
Forb and forb-like					
Dalea purpurea	10	8	7	9	11
Liatris punctata	13	13	13	13	13
Amorpha canescens	15	14	15	15	15
Symphyotrichum ericoides	16	16	16	16	16
Lespedeza cuneata	17	17	17	17	17
Vernonia baldwinii	12	11	10	11	10
Ambrosia psilostachya	8	10	9	10	9
Amphiachyris dracunculoides	14	15	14	14	14
Ambrosia artemisiifolia	11	12	12	12	12

* Relative abundance scale: 1 to 17 (1 = most abundant, 17 = least abundant).

Table 2.10 Kulcyznski's Similarity Index calculations comparing basal cover of major forage plants (Table 2.5) with presence of major forage plants in fecal material of yearling steers (Table 2.7)

	KSI*, % similarity				
Item	Early May	Late May	Early June	Late June	Early July
Total graminoids	98	98	99	98	98
Andropogon gerardii	86	81	82	94	88
Schizachyrium scoparium	47	52	59	68	66
Panicum virgatum	67	60	54	51	49
Sorghastrum nutans	87	81	70	66	69
Bouteloua gracilis	4	4	5	4	4
Bouteloua curtipendula	99	99	57	94	81
Bouteloua dactyloides	3	6	5	3	4
Carex spp.	24	25	30	40	35
Unidentified graminoids	2	3	2	6	2
Total forb and forb-like	82	86	95	87	86
Dalea purpurea	11	10	6	7	9
Liatris punctata	0	0	0	0	0
Amorpha canescens	67	100	0	67	0
Symphyotrichum ericoides	0	0	0	18	0
Lespedeza cuneata	0	0	0	5	0
Vernonia baldwinii	75	55	43	46	43
Ambrosia psilostachya	100	91	98	93	98
Amphiachyris dracunculoides	44	25	44	44	44
Ambrosia artemisiifolia	50	62	57	62	57
Unidentified forbs	24	27	31	16	18

* Kulcyznski's Similarity Index: KSI = $((2c_i) / (a_i + b_i)) * 100$, where a_i is the % basal cover of component *i*, and b_i is the % of component *i* selected by an herbivore, and c_i is the lesser of a_i *and* b_i; KSI values ≥ 80% were interpreted to indicate little or no discrimination (i.e., selection patterns were very similar to plant availability), values between 21 and 79% were interpreted to indicate moderate discrimination, and that KSI values ≤ 20% indicated either strong selection or avoidance of individual plant species.

Chapter 3 - Botanical Composition of Mature Ewe Diets in the Kansas Flint Hills

Abstract

Four native tallgrass pastures (30 ± 1.2 ha) infested with sericea lespedeza (*Lespedeza cuneata* [Dumont] G. Don; initial basal frequency = 1.9 ± 1.39%) were grazed by mature ewes at a relatively high stocking density (0.15 ha / ewe) from 30 July to 1 October during 2015 and 2016, immediately following grazing with yearling beef cattle. Ewes (n = 813; initial BW = 65 ± 3.1 kg) were assigned randomly to pastures annually; 25 individual ewes were selected randomly from each pasture to monitor diet composition. On 15 August and 15 September annually, ewes were gathered and restrained; fecal grab samples were collected from each individual selected for diet composition analysis. Microhistological analyses were conducted on fecal samples from individual ewes, using pure reference-standard samples of 17 predominant graminoid, forb, and shrub species from the experimental site. Fecal and reference-standard samples were prepared for microhistological analyses and viewed using a compound microscope at 100× magnification. Botanical composition of mature ewe diets was compared with botanical composition of pastures, which was measured on 15 October ± 10.4 d during 2014, 2015, and 2016. Proportions of bare soil, litter, and total basal vegetation cover did not differ ($P \geq 0.85$) between pastures. Total basal cover of graminoids, forbs, and shrubs also did not differ ($P \geq 0.55$) between pastures; moreover, basal cover of the 17 plants selected as microhistological standards did not differ ($P \geq 0.07$) between pastures. The proportions of total graminoids and total forbs and forb-like plants in the diets of grazing ewes were not different ($P = 0.67$) between sampling periods and were interpreted to indicate that mature ewes selected consistent proportions of graminoids and forbs during late summer (average = 58 and 42% of diets for graminoids and forbs,

respectively). Ewe selection of *Andropogon gerardii*, *Schizachyrium scoparium*, *Panicum virgatum*, *Sorghastrum nutans*, *Bouteloua gracilis*, *Bouteloua curtipendula*, *Carex* spp., unidentified grasses, *Dalea purpurea, Liatris punctata*, *Amorpha canescens*, *Symphyotrichum ericoides*, *Lespedeza cuneata*, *Vernonia baldwinii*, *Ambrosia psilostachya*, *Amphiachyris dracunculoides*, and *Ambrosia artemisiifolia* was not different ($P \geq 0.06$) between sampling periods. Conversely, ewe selection of *Bouteloua dactyloides* increased ($P < 0.01$) from mid-August to mid-September, whereas selection of unidentified forbs decreased ($P = 0.04$) during the same period. Kulcyznski's Similarity Index (**KSI**) was used to compare botanical composition of pastures with diet selection patterns by ewes. Mature ewes consistently exhibited strong preferences (i.e., ≤ 10% similarity with pasture composition) for *Bouteloua gracilis*, *Bouteloua dactyloides*, *Dalea purpurea*, *Liatris punctata*, *Vernonia baldwinii*, and *Ambrosia artemisiifolia*; moreover, they did not avoid *Lespedeza cuneata* (KSI = 70 and 73% in mid-August and mid-September, respectively).

Introduction

Microhistological analysis of feces was first utilized to characterize squirrel diets by Baumgartner and Martin (1939). The technique has since been widely used to characterize the botanical composition of herbivore diets. Other methods of characterizing diets include microhistological analysis of esophageal extrusa, or ruminal digesta, botanical composition surveys in adjacent grazed and ungrazed areas (i.e., utilization techniques), and direct observation of animal selection (Holechek et al., 1982). Microhistological analyses of animal feces has several advantages over alternative techniques when ascertaining the botanical composition of herbivore diets: it does not require animal sacrifice or surgical alteration; the number of samples collected is limited only by analytical cost and time; it requires little interaction between researcher and animal; and it does not interfere with normal animal grazing habits and movements (Vavra and Holechek, 1980; Holechek et al., 1982; McInnis et al., 1983). Microhistological examination of feces is thought to reflect a broader spectrum of eating behavior compared with microhistological examination of esophageal or ruminal extrusa because it represents 4 to 8 grazing bouts, whereas analysis of ruminal and esophageal extrusa reflects only 1 to 2 grazing bouts (Anthony and Smith, 1974; Smith and Shandruk, 1979)

Sericea lespedeza is recognized in Kansas as a noxious weed that threatens the biotic integrity of the tallgrass prairie in Kansas and Oklahoma (Eddy and Moore, 1998). Biological control using targeted grazing with sheep following traditional stocker steer grazing, effectively controlled vegetative propagation and seed production by sericea lespedeza (Lemmon et al., 2017). Compared with beef cattle, sheep appeared to be more accepting of sericea lespedeza and more tolerant of its condensed-tannin content (Terrill et al., 1989; Frutos et al., 2004; Lemmon et al., 2017); however, few direct comparisons of condensed-tannin tolerance exist (Frutos et al., 2004; Hoehn et al., 2018). In this experiment, we evaluated mature ewe selection of 17 common graminoid, forb, and shrub species previously identified as being significant components of ruminant diets in the tallgrass prairie region of the US (Eckerle et al., 2009; Sproul et al., 2010; Aubel et al., 2011; Preedy et al., 2013). The objectives for this experiment were to: 1) characterize mature ewe diets grazing sericea lespedeza-infested rangeland in the Kansas Flint Hills and 2) to identify patterns of discrimination by mature ewes in selection of dietary components on native tallgrass prairie.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee reviewed and approved all animal handling and animal care practices used in our experiment. All animal procedures were conducted in accordance with the Guide for the Care and Use of Animals in Agricultural Research and Teaching (FASS, 2010).

Our study was conducted in Woodson County, Kansas during the growing seasons of 2015 and 2016 on the Kansas State University Bressner Range Research Unit. Four native tallgrass pastures (30 ± 1.2 ha) infested with sericea lespedeza (initial basal frequency = 1.9 ± 1.39%) were grazed by mature ewes at a relatively high stocking density (0.15 ha / ewe) from 30 July to 1 October during 2015 and 2016, immediately following grazing with yearling beef cattle.

Ewes (n = 813; initial BW = 65 ± 3.1 kg) were leased from 2 commercial sheep operations located in western Kansas and transported via motor carrier to the research site each year (arrival date = 30 July). Ewes were weighed collectively by pasture groups before grazing began on 1 August and assigned randomly to graze 1 of 4 pastures. Twenty-five individual ewes were selected randomly from each pasture group at the outset of each grazing season to monitor diet composition. On 15 August and 15 September annually, all ewes in each pasture were gathered in a central corral. Individual ewes selected for diet composition analysis were sorted from the group and restrained for fecal grab sampling. Samples were placed in individual plastic containers and frozen (-20ºC) pending processing. Subsequently, individual fecal samples were dried in a forced-air oven (55ºC; 96 h) and ground (#4 Wiley Mill, Thomas Scientific, Swedesboro, NJ, USA) to a 1-mm particle size.

Ewes were weighed collectively by pasture groups at the end of the grazing season (i.e., 1 October annually). Final BW of ewes averaged 71 ± 3.6 kg. Ewes were monitored daily during the grazing period to assure they remained in assigned pastures and that fresh water was available continually. Death loss was 1.6 ± 0.22% annually and was assumed to occur through predation or disease.

Plant species composition and soil cover were assessed along 2 permanent transects in each pasture on 15 October ± 10.4 d in 2014 (i.e., pre-treatment), 2015, and 2016 (i.e., post-treatment) using a modified step-point technique (Owensby, 1973; Farney et al., 2017). Transect points (n = 100 / transect) were evaluated for bare soil, litter, or basal plant area (% of total area). Plants were identified by species; basal cover of individual species was expressed as a percentage of total basal plant area. Common names, scientific names, and taxonomic authority for plants referred to in this manuscript were taken from Haddock (2005). Comprehensive lists of the graminoids, forbs, and shrubs encountered during plant-composition analyses are listed in tables 3.1, 3.2, and 3.3, respectively.

Approximately 59% of total basal vegetation cover on pastures used in our experiment was composed of the following forage species: big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), switchgrass (*Panicum virgatum* L.), Indian grass (*Sorghastrum nutans* [L.] Nash), blue grama (*Bouteloua gracilis* [Willd. Ex Kunth] Lag. Ex Greenm.), side-oats grama (*Bouteloua curtipendula* [Michx.] Torr.), buffalo grass (*Bouteloua dactyloides* [Nutt.] Engelm.), sedges (*Carex* spp.), purple prairie-clover [*Dalea purpurea* Vent.], leadplant (*Amorpha canescens* Pursh), dotted gayfeather [*Liatris punctata* Hook.], heath aster [*Symphyotrichum ericoides* (L.) G.L. Nesom], sericea lespedeza (*Lespedeza cuneata* [Dumont] G. Don), Baldwin’s ironweed (*Vernonia baldwinii* Torr.), Western ragweed (*Ambrosia psilostachya* DC.), annual broomweed (*Amphiachyris dracunculoides* [DC.] Nutt.), and common ragweed (*Ambrosia artemisiifolia* L.).

Reference standards for each above-named plant species were prepared using methods described by Holechek et al. (1982). Individual reference standards were derived by hand-clipping 10 to 20 individual plants from a homogenous stand of each plant type. Samples included vegetative stems, leaves, and flowers; fruiting culms were discarded. Samples were dried in a forced-air oven (55ºC; 96 h) then ground to a 1-mm particle size in a cyclone-style sample mill (model no.80335R, Hamilton Beach, Glen Allen, VA).

Individual fecal samples and reference standards were prepared for microhistological analysis using methods as described by Holechek et al. (1982), as adapted by Bennett et al. (1999) and Preedy et al. (2013). Approximately 1g of individual fecal sample or reference standard was placed into a beaker and soaked overnight in 50% EtOH (v/v). After soaking, ethanol was decanted and residue was washed with deionized H_2O over a No. 200 US- standard sieve. Samples were then soaked in 0.05M NaOH for 20 min and washed again with deionized H_2O for 5 min over a No. 200 US-standard sieve.

Wet samples were placed onto microscope slides (5 slides per fecal sample and 3 slides per reference standard) using a dissecting needle. Two to 3 drops of Hertwig's solution were applied to mounted samples and slides were held over a propane flame until dry. Hoyer's solution was not used to permanently fix slide-mounted samples, as has been reported previously (Baumgartner and Martin, 1939). The addition of Hoyer's solution and glass cover slips diminished plant fragment visibility. Slides were observed using a compound microscope (DC5-163, Thermo Fisher Scientific, Asheville, NC) at 100× magnification. The microscope was equipped with a digital camera; 20 randomly-selected fields from each fecal-sample slide and each reference-standard slide were photographed and stored (Preedy et al., 2013).

Observers of microscopically-photographed images were trained using methods described by Holechek and Gross (1982). Observers viewed photos of reference standards until establishing familiarity with the structural characteristics of each plant. Observers were able to view reference-standard photographs simultaneously with fecal-sample slide photographs for reference. Plant fragments were individually identified and counted within each selected slide field. The total number of occurrences of each plant species on a given slide were converted to frequency of occurrence (i.e., [total of individual species ÷ total of all species] * 100; Holechek and Vavra, 1981).

Plant fragment prevalence in slide fields was assumed to be equivalent to prevalence in fecal samples and equivalent, on a percentage basis, to botanical composition of the diets selected by mature ewes (Sparks and Malechek, 1968). Fragments not identifiable as one of the 17 range-plant species collected for use as reference standards were classified collectively as either unidentified graminoids or unidentified forbs.

Mean basal frequencies, standard deviations, minimum basal frequencies, and maximum basal frequencies of bare soil, litter, total basal vegetation, graminoids, forbs, shrubs, and individual plant species were calculated using the PROC MEANS procedure (SAS Inst. Inc., Cary, NC). Values were summarized across pastures and yr of our experiment.

The percentages of bare soil, litter cover, total basal vegetation cover, graminoid basal cover, forb basal cover, shrub basal cover, and basal cover of individual plant species were analyzed as a completely randomized design using a mixed model (SAS Inst. Inc., Cary, NC). Class variables were year, pasture, and transect. The model contained a term for pasture only and transect within pasture was used as a random term. Least squares means were considered different when protected by a significant F-test ($P \leq 0.05$).

Diet composition data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Class variables included year, period, pasture, and sheep. The model contained terms for period, pasture, and the 2-way interaction. Sheep within year and pasture and period within year and pasture were considered random effects.

Pasture × period effects on diet selection patterns of mature ewes were not detected ($P \geq 0.27$; data not shown) for all 17 plant-species standards, total graminoids, unidentified graminoids, total forbs, and unidentified forbs. Pasture effects on selection patterns for 16 of the 17 plant-species reference standards, total graminoids, unidentified graminoids, total forbs, and unidentified forbs were not detected ($P \geq 0.08$; data not shown); however, pasture effects on selection of heath aster ($P = 0.01$) were detected. Pair-wise comparisons of pasture means for heath aster selection (1.8, 0.7, 1.2, and 0.8 ± 0.20% of mature ewe diets for pastures 1, 2, 3, and 4 respectively; data not shown) indicated atypically high ($P \leq 0.03$) selection in pasture 1 compared to pastures 2, 3, and 4. The influence of that effect on the outcome of our experiment was judged to be inconsequential. Therefore, period means for selection patterns of 17 range-plant reference standards, total graminoids, unidentified graminoids, total forbs, and unidentified forbs were reported. When protected by a significant *F*-test ($P \leq 0.05$), period means were separated using the method of Least Significant Difference.

Kulcyznski's Similarity Index (**KSI**; $((2c_i) / (a_i + b_i)) * 100$, where a_i is the % basal cover of component *i*, and b_i is the % of component *i* selected by an herbivore, and c_i is the lesser of a_i *and* b_i) was used to evaluate mature-ewe diet selection patterns in relation to botanical composition of pastures. For the purposes of our analysis, we assumed that KSI values ≥ 80% indicated little or no discrimination (i.e., selection patterns were very similar to plant availability), that KSI values between 21 and 79% indicated moderate discrimination, and that KSI values ≤ 20% indicated either strong preference for or avoidance of individual plant species. When KSI values were ≤ 20%, preference and avoidance were distinguished from one another by comparing the proportion of the specific plant in yearling-steer diets with basal cover of the specific plant on pastures.

Results and Discussion

Proportions of bare soil, litter, and total basal vegetation cover were not different ($P \geq 0.85$) between pastures (Table 3.4), and averaged 22.5 ± 12.05, 64.8 ± 11.50, and 12.7 ± 3.74% for bare soil, litter cover, and total basal vegetation cover, respectively. Total basal-vegetation cover attributable to graminoids, forbs, and shrubs were also not different ($P \geq 0.55$) between pastures.

Basal cover of the 17 reference standards selected for microhistological analyses of ewe feces comprised approximately 59% of total basal vegetation cover (Table 3.5); therefore, we concluded that the selected standards were likely sufficient to characterize the majority of plants selected by ewes grazing native tallgrass pastures. Proportions of total graminoids, big bluestem, little bluestem, side-oats grama switchgrass, indiangrass, blue grama, buffalograss, sedges, unidentified graminoids, total forb and forb-like plants, purple prairie clover, leadplant, heath aster, sericea lespedeza, Baldwin’s ironweed, western ragweed, annual broomweed, common ragweed, and unidentified forbs were not different ($P \geq 0.07$) between pastures (Table 3.5). Dotted gayfeather was not detected in our analysis of plant-species composition.

Period effects on selection of individual plant species by mature ewes are summarized in Table 3.6. The proportions of total graminoids and total forb and forb-like plants (i.e., all forbs plus leadplant) in the diets of grazing ewes were not different ($P = 0.67$) between sampling periods and were interpreted to indicate that mature-ewe diets during late summer were not strongly dominated by either graminoids (57.4 and 58.4% of diets for mid-August and mid-September, respectively) or forbs (42.6 and 41.6% of diets for mid-August and mid-September, respectively). Hofmann and Stewart (1972) and Van Soest (1982) indicated that intermediate feeders, such as sheep, should be expected to select diets that are approximately 50% grasses and 50% forbs. Our results generally support that assertion; however, graminoids made up slightly more than half of sheep diets in our experiment.

Most researchers that used fecal microhistology to describe botanical composition of sheep diets reported graminoid-to-forb proportions that were substantially different from the idealized ratios proposed by Hofmann and Stewart (1972) or Van Soest (1982). VanDyne and Heady (1965) characterized sheep diets on annual California grasslands at several times during the growing season. During late summer, sheep diets were 61% grasses and 33% forbs. In arid environments, sheep diets were dominated (> 60%) by forbs during the summer months (Hulet et al., 1992; De Oliveira et al., 2016). Conversely, Beck and Peek (2005) noted that sheep diets during summer were dominated by graminoids (70%), while forbs were selected at a lesser rate (23%). Even fewer forbs (< 10%) were detected in the diets of sheep grazing in a savanna environment during summer (Mphinyane et al., 2015). In Mediterranean-heath woodlands, grazing sheep consumed significant proportions of shrubs (52%) and graminoids (31%) in their diets; selection of forbs was relatively minor (17%; Bartolome et al., 1998). We concluded that environmental factors that influence the relative availabilities of graminoids, forbs, and shrubs likely play a more significant role in diet selection by sheep than specialized anatomical or digestive features. Intermediate feeders, such as sheep, are postulated to be adaptable to diet regimens of grass-and-roughage eaters and concentrate selectors (Van Soest, 1982). The weight of evidence seems to indicate this hypothesis has merit.

Selection of big bluestem, little bluestem, switchgrass, Indian grass, blue grama, side-oats grama, sedges, and unidentified graminoids were not influenced ($P \geq 0.06$) by sampling period (Table 3.6). Conversely, ewe selection of buffalo grass nearly doubled ($P < 0.01$) between mid-August and mid-September. Selection of forbs was similarly consistent between sampling periods. Proportions of purple prairie-clover, dotted gayfeather, lead plant, heath aster, sericea lespedeza, Baldwin's ironweed, Western ragweed, annual broomweed, and common ragweed in ewe diets did not change ($P \geq 0.19$) between mid-August and mid-September. Selection of unidentified forbs, however, decreased ($P = 0.04$) between mid-August and mid-September. Unidentified grasses and unidentified forbs were detected in only small amounts in mature-ewe diets (i.e., < 1% of both graminoid and forb or forb-like plant fragments). We concluded that the 17 standards that we chose for microhistological characterization of ewe diets was sufficient to allow other researchers evaluating sheep diets in the tallgrass prairie region to describe a large majority of diet components. Notably, mature ewes selected 1.5% sericea lespedeza in mid-August and 1.6% sericea lespedeza in mid-September. Lemmon et al. (2017) reported that this level of consumption was associated with significant depressions in seed production by sericea lespedeza and reductions in sericea lespedeza basal cover compared to pastures not grazed by sheep during August and September.

The relative abundance (1 to 17; 1 = most abundant, 17 = least abundant) in mature ewe diets of each of the plant standards used in microhistological analyses is depicted in Table 3.7. In general, the relative rankings of all graminoids and all forbs and forb-like plants used as microhistological standards was stable over the 2 collection periods and 2 yr under study.

Relative ranks of little bluestem, switchgrass, side-oats grama, sedges, purple prairie clover, dotted gayfeather, lead plant, heath aster, sericea lespedeza, and annual broomweed did not change between mid-August and mid-September. The relative ranks of big bluestem, Indian grass, blue grama, Baldwin's ironweed, and Western ragweed changed by only one placement, whereas the relative ranks of buffalo grass and common ragweed changed by 3 and 2 placements, respectively, between mid-August and mid-September. We concluded that mature ewe diets were characterized by little variation in botanical composition during late summer in the tallgrass prairie region.

Kulcyznski's Similarity Index (**KSI**) was used to compare botanical composition of pastures with botanical composition of mature ewe diets in order to evaluate the level of discrimination mature ewes exercised in selecting diet components (Table 3.8). Forage plants that were consistently selected in proportion to their availability (i.e., KSI values ≥ 80% during both mid-August and mid-September) in native tallgrass prairie pastures used in our experiment were big bluestem, Indian grass, lead plant, and heath aster. Switchgrass appeared also to be selected in proportion to its availability (KSI = 94 and 75% in mid-August and mid-September, respectively).

In contrast, forage plants that were consistently selected in greater proportions relative to their availabilities in native tallgrass prairie pastures were blue grama, buffalo grass, purple prairie-clover, dotted gayfeather, Baldwin's ironweed, and common ragweed (Table 3.8). The only plants or plant groups which mature ewes seemed to avoid were unidentified graminoids during both collection periods and annual broomweed during mid-September only. All other forage plants or groups of forage plants were ranked as receiving moderate selection discrimination from mature ewes. Most notable was sericea lespedeza (KSI = 70 and 73% in mid-August and mid-September, respectively). Alipayo et al. (1992) used KSI to compare diets of known composition fed to sheep and with estimates of diet composition derived using fecal microhistology. They indicated that actual diet composition and fecal estimates of diet composition overlapped by 92%. We concluded from our experiment that mature ewes exercised notable discrimination in diet-component selection.

Implications

Mature ewes grazing native tallgrass pastures selected diets of consistent composition during mid-August and mid-September. Mature ewe diets did not appear to be strongly dominated by either grasses or forbs; rather, they reflected a balance between the two. In keeping with our original hypothesis, we determined that sheep exhibited strong positive discriminations in diet-component selection, particularly with C4 short grasses, purple prairie-clover, dotted gayfeather, Baldwin's ironweed and common ragweed. Negative discrimination in diet-component selection (i.e., avoidance) was not as evident. Significantly, mature ewes did not avoid sericea lespedeza (KSI = 70 and 73% in mid-August and mid-September, respectively).

Small ruminant grazing may prove beneficial in reducing stands of noxious plant species, like sericea lespedeza, in tallgrass prairie pastures. Mature ewes selected 1.5% sericea lespedeza in mid-August and 1.6% sericea lespedeza in mid-September during this experiment. These levels of consumption were associated with significant depressions in seed production by sericea lespedeza and reductions in sericea lespedeza basal frequency compared to pastures not grazed by sheep during August and September (Lemmon et al., 2017). Biological control through targeted grazing has promise to not only assist land managers with control of noxious plant species but also to create additional revenue streams. Further research is warranted to determine the dietary overlap between yearling beef steers and small ruminants in co-grazing situations.

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Table 3.1 Graminoid species encountered on native tallgrass pastures grazed by mature ewes during August and September in 2015 and 2016

Common name	**Scientific name**	**Classification**	**Status**	**Metabolism**	**Growth form**
Barnyard grass	*Echinochloa crus-galli*	Annual	Introduced	C4	n.a.
Big bluestem	*Andropogon gerardii*	Perennial	Native	C4	Tall
Blue grama	*Bouteloua gracilis*	Perennial	Native	C4	Short
Broomsedge	*Andropogon virginicus*	Perennial	Native	C4	Mid
Buffalo grass	*Buchloe dactyloides*	Perennial	Native	C4	Short
Canada bluegrass	*Poa compressa*	Perennial	Introduced	C3	n.a.
Canada wild rye	*Elymus canadensis*	Perennial	Native	C3	n.a.
Common witchgrass	*Panicum capillare*	Annual	Native	C4	n.a.
Eastern gamagrass	*Tripsacum dactyloides*	Perennial	Native	C4	Tall
Fall panicgrass	*Panicum dichotomiflorum*	Annual	Introduced	C4	n.a.
Fall witchgrass	*Digitaria cognata*	Perennial	Native	C4	Mid
Florida paspalum	*Paspalum floridanum*	Perennial	Native	C4	Mid
Green foxtail	*Setaria viridis*	Annual	Introduced	C4	n.a.
Hairy crabgrass	*Digitaria sanguinalis*	Annual	Introduced	C4	n.a.
Hairy grama	*Bouteloua hirsuta*	Perennial	Native	C4	Short
Indian grass	*Sorghastrum nutans*	Perennial	Native	C4	Tall
Japanese brome	*Bromuis japonicus*	Annual	Introduced	C3	n.a.
Kentucky bluegrass	*Poa pratensis*	Perennial	Introduced	C3	n.a.
Knotroot foxtail	*Setaria parviflora*	Perennial	Native	C4	Mid
Little bluestem	*Schizachyrium scoparium*	Perennial	Native	C4	Mid
Plains lovegrass	*Eragrostis intermedia*	Perennial	Native	C4	Mid
Poverty dropseed	*Sporobolus vaginiflorus*	Annual	Native	C4	n.a.
Prairie cordgrass	*Spartina pectinata*	Perennial	Native	C4	Tall
Prairie threeawn	*Aristida oligantha*	Annual	Native	C4	n.a.
Puffsheath dropseed	*Sporobolus neglectus*	Annual	Native	C4	n.a.
Purple lovegrass	*Eragrostis spectabilis*	Perennial	Native	C4	Mid
Purpletop	*Tridens flavus*	Perennial	Native	C4	Tall
Rush	*Juncus* spp.	Perennial	Native	C3	n.a.
Scribner dichanthelium	*Dichanthelium oligosanthes*	Perennial	Native	C3	n.a.
Sedge	*Carex* spp.	Perennial	Native	C3	n.a.
Side-oats grama	*Bouteloua curtipendula*	Perennial	Native	C4	Mid
Switchgrass	*Panicum virgatum*	Perennial	Native	C4	Tall
Tall dropseed	*Sporobolus asper*	Perennial	Native	C4	Mid
Tall fescue	*Schedonorus arundinaceus*	Perennial	Introduced	C3	n.a.
Tumble windmill grass	*Chloris verticillata*	Perennial	Native	C4	Short
Tumblegrass	*Schedonnardus paniculatus*	Perennial	Native	C4	Mid
Winter bentgrass	*Agrostis hyemalis*	Perennial	Native	C3	n.a.
Wooly cupgrass	*Eriochloa villosa*	Annual	Introduced	C3	n.a.
Yellow foxtail	*Setaria pumila*	Annual	Introduced	C4	n.a.

Table 3.2 Forb species encountered on native tallgrass pastures grazed by mature ewes during August and September in 2015 and 2016[*]

Common name	**Scientific name**	**Growth**	**Status**
Annual broomweed	*Amphiachyris dracunculoides*	Annual	Native
Annual marshelder	*Iva annua*	Annual	Native
Aromatic aster	*Symphyotrichum oblongifolium*	Perennial	Native
Ashy sunflower	*Helianthus mollis*	Perennial	Native
Baldwin's ironweed	*Vernonia baldwinii*	Perennial	Native
Bigbract verbena	*Verbena bracteata*	Perennial	Native
Black-eyed susan	*Rudbeckia hirta*	Perennial	Native
Blue wild indigo	*Baptisia australis*	Perennial	Native
Brittlebract plantain	*Plantago spinulosa*	Annual	Native
Buffalo bur	*Solanum rostratum*	Annual	Native
Bushy knotweed	*Polygonum ramosissimum*	Annual	Native
Carolina horse-nettle	*Solanum carolinense*	Perennial	Native
Carpetweed	*Mollugo verticillata*	Annual	Native
Catclaw sensitive briar	*Mimosa quadrivalvis var. nuttallii*	Perennial	Native
Clammy ground cherry	*Physalis heterophylla*	Perennial	Native
Clasping Venus' looking-glass	*Specularia perfoliata*	Annual	Native
Cocklebur	*Xanthium strumarium*	Annual	Native
Common dandelion	*Taraxacum officinale*	Perennial	Introduced
Common evening primrose	*Oenothera biennis*	Biennial	Native
Common ragweed	*Ambrosia artemisiifolia*	Annual	Introduced
Common St. John's-wort	*Hypericum perforatum*	Perennial	Introduced
Common yellow oxalis	*Oxalis stricta*	Perennial	Native
Curly dock	*Rumex crispus*	Perennial	Introduced
Daisy fleabane	*Erigeron strigosus*	Annual	Native
Dotted gayfeather	*Liatris punctata*	Perennial	Native
Eastern toothed spurge	*Euphorbia dentata*	Annual	Introduced
Eyebane	*Euphorbia maculata*	Annual	Native
False boneset	*Brickellia eupatorioides*	Perennial	Native
Field bindweed	*Convolvulus arvensis*	Perennial	Introduced
Field pussy-toes	*Antennaria neglecta*	Perennial	Native
Flat-top goldentop	*Euthamia graminifolia*	Perennial	Native
Fringe-leaf ruellia	*Ruellia humilis*	Perennial	Native
Giant ragweed	*Ambrosia trifida*	Annual	Native
Green antelopehorn	*Asclepias viridis*	Perennial	Native
Grooved flax	*Linum sulcatum*	Annual	Native
Heath aster	*Symphyotrichum ericoides*	Perennial	Native
Horseweed	*Conyza canadensis*	Perennial	Native
Illinois bundle-flower	*Desmanthus illinoensis*	Perennial	Native
Indian hemp dogbane	*Apocynum cannabinum*	Perennial	Native
Korean lespedeza	*Kummerowia stipulacea*	Annual	Introduced
Lance-leaf ragweed	*Ambrosia bidentata*	Annual	Native
Lemon beebalm	*Monarda citriodora*	Perennial	Native
Long-bearded hawkweed	*Hieracium longipilum*	Annual	Native
Missouri goldenrod	*Solidago missouriensis*	Perennial	Native
Missouri violet	*Viola missouriensis*	Perennial	Native

[*] This table is continued on the following page

Table 3.2 Forb species encountered on native tallgrass pastures grazed by mature ewes during August and September in 2015 and 2016 (continued)

Common name	Scientific name	Growth	Status
One-seed croton	*Croton monanthogynus*	Annual	Native
Pale comandra	*Comandra umbellata*	Perennial	Native
Pale poppy-mallow	*Callirhoe alcaeoides*	Perennial	Native
Pennsylvania smartweed	*Polygonum pensylvanicum*	Annual	Native
Pitcher sage	*Salvia azurea*	Perennial	Native
Plains wild indigo	*Baptisia bracteata*	Perennial	Native
Prairie coneflower	*Ratibida columnifera*	Perennial	Native
Prairie groundsel	*Senecio plattensis*	Perennial	Native
Purple poppy-mallow	*Callirhoe involucrata*	Perennial	Native
Purple prairie-clover	*Dalea purpurea*	Perennial	Native
Red clover	*Trifolium pratense*	Perennial	Introduced
Sericea lespedeza	*Lespedeza cuneata*	Perennial	Introduced
Showy partridge pea	*Chamaecrista fasciculata*	Annual	Native
Slender lespedeza	*Lespedeza virginica*	Perennial	Native
Slick-seed bean	*Strophostyles leiosperma*	Annual	Native
Small spotted sandmat	*Chamaesyce maculata*	Annual	Native
Stiff goldenrod	*Solidago rigida*	Perennial	Native
Tall goldenrod	*Solidago canadensis*	Perennial	Native
Velvetweed	*Oenothera curtiflora*	Annual	Native
Violet lespedeza	*Lespedeza violacea*	Perennial	Native
Virginia three-seeded mercury	*Acalypha virginica*	Annual	Native
Virginia groundcherry	*Physalis virginiana*	Perennial	Native
Virginia pepperweed	*Lepidium virginicum*	Perennial	Native
Wavy-leaf thistle	*Cirsium undulatum*	Perennial	Native
Western ragweed	*Ambrosia psilostachya*	Perennial	Native
Western spotted beebalm	*Monarda punctata*	Perennial	Native
Western yarrow	*Achillea millefolium*	Perennial	Native
White clover	*Trifolium repens*	Perennial	Introduced
White-eyed grass	*Sisyrinchium campestre*	Perennial	Native
White prairie-clover	*Dalea candida*	Perennial	Native
Whorled milkweed	*Asclepias verticillata*	Perennial	Native

Table 3.3 Shrub species encountered on native tallgrass pastures grazed by mature ewes during August and September in 2015 and 2016

Common name	**Scientific name**	**Growth**	**Status**
Blackberry	*Rubus spp.*	Perennial	Native
Buckbrush	*Symphoricarpos orbiculatus*	Perennial	Native
Eastern pricklypear	*Opuntia humifusa*	Perennial	Native
False indigo	*Amorpha fruticosa*	Perennial	Native
Lead plant	*Amorpha canescens*	Perennial	Native
Mulberry	*Morus* spp.	Perennial	Native
New Jersey tea	*Ceanothus americanus*	Perennial	Native
Prairie wild rose	*Rosa arkansana*	Perennial	Native
Slippery elm	*Ulmus rubra*	Perennial	Native
Smooth Sumac	*Rhus glabra*	Perennial	Native

Table 3.4 Bare soil, litter cover, basal vegetation cover, total graminoid cover, total forb cover, and total shrub cover on native tallgrass pastures grazed by mature ewes during August and September in 2015 and 2016

Item	n[*]	Mean	Std. dev.	Minimum	Maximum	SEM[†]	*P*-Value[‡]
Bare soil, % total area	24	22.5	12.05	2.0	47.0	7.35	0.89
Litter cover, % total area	24	64.8	11.50	41.0	87.0	6.99	0.85
Basal vegetation cover, % total area	24	12.7	3.74	7.0	20.0	2.35	0.99
Total graminoid cover, % total basal cover	24	88.7	4.25	80.0	96.0	3.29	0.75
Total forb cover, % total basal cover	24	11.2	4.25	4.0	20.0	3.27	0.76
Total shrub cover, % total basal cover	24	0.1	0.15	*tr*	0.7	0.09	0.55

[*] n = 8 pastures × 3 annual observations × 2 transects / observation annually

[†] Mixed model SEM associated with comparison of pasture main effect means.

[‡] Mixed model *P*-value associated with pasture *F*-test.

Table 3.5 Basal cover of forage plants detected in the diets of mature ewes grazing native tallgrass pastures during August and September in 2015 and 2016

Item	n[*]	Mean	Std. dev.	Minimum	Maximum	SEM[†]	*P*-Value[‡]
Total graminoids	24	88.7	4.25	80.0	96.0	3.29	0.75
Andropogon gerardii	24	12.6	5.24	5.0	22.0	4.88	0.68
Schizachyrium scoparium	24	6.7	5.43	*tr*	25.0	3.94	0.61
Panicum virgatum	24	5.2	2.95	*tr*	11.0	1.56	0.21
Sorghastrum nutans	24	6.9	2.93	2.0	15.0	1.65	0.20
Bouteloua gracilis	24	0.3	0.68	*tr*	3.0	0.44	0.72
Bouteloua curtipendula	24	4.1	3.67	*tr*	16.0	2.38	0.15
Bouteloua dactyloides	24	0.1	0.20	*tr*	1.0	0.12	0.48
Carex spp.	24	14.8	4.93	6.0	26.0	2.51	0.15
Unidentified graminoids	24	38.0	9.22	24.0	55.0	4.57	0.10
Total forb and forb-like	24	11.3	4.23	4.0	20.0	3.27	0.76
Dalea purpurea	24	0.1	0.14	*tr*	0.5	0.11	0.44
Liatris punctata[¶]	24	-	-	-	-	-	-
Amorpha canescens	24	0.3	0.25	*tr*	1.0	0.20	0.53
Symphyotrichum ericoides	24	1.2	1.19	*tr*	3.9	0.69	0.54
Lespedeza cuneata	24	2.8	2.31	0.2	8.4	1.59	0.33
Vernonia baldwinii	24	0.5	0.58	*tr*	1.9	0.57	0.46
Ambrosia psilostachya	24	1.6	0.97	0.2	3.6	0.45	0.07
Amphiachyris dracunculoides	24	1.1	2.27	*tr*	8.0	2.38	0.53
Ambrosia artemisiifolia	24	0.3	0.34	*tr*	1.2	0.18	0.29
Unidentified forbs	24	3.4	2.01	0.6	3.4	0.99	0.11

[*] n = 8 pastures × 3 annual observations (i.e., fall of 2014, 2015, and 2016) × 2 transects / observation annually

[†] Mixed model SEM associated with comparison of pasture main effect means.

[‡] Mixed model *P*-value associated with pasture *F*-test.

[¶] Basal cover of *Liatris punctata* was below the detection limits of the plant-species composition survey technique used in this experiment; however, it was detected in steer fecal material.

Table 3.6 Botanical composition of mature-ewe diets in the Kansas Flint Hills: period effects

	Botanical composition (% of diet DM)			
Item	Mid-August	Mid-September	SEM[*]	*P*-Value[†]
Total graminoids	57.4	58.4	2.13	0.67
Andropogon gerardii	11.9	9.3	1.76	0.23
Schizachyrium scoparium	20.5	20.0	1.31	0.76
Panicum virgatum	4.6	3.1	0.55	0.06
Sorghastrum nutans	5.8	5.6	1.10	0.81
Bouteloua gracilis	6.5	8.6	1.05	0.12
Bouteloua curtipendula	1.0	0.9	0.19	0.53
Bouteloua dactyloides	4.8	7.9	0.60	<0.01
Carex spp.	1.8	2.0	0.40	0.55
Unidentified graminoids	0.7	1.0	0.18	0.17
Total forb and forb-like	42.6	41.6	2.13	0.67
Dalea purpurea	12.2	12.1	1.33	0.90
Liatris punctata	2.3	2.7	0.49	0.54
Amorpha canescens	0.4	0.3	0.10	0.70
Symphyotrichum ericoides	1.0	1.2	0.13	0.22
Lespedeza cuneata	1.5	1.6	0.20	0.45
Vernonia baldwinii	11.3	11.1	1.04	0.89
Ambrosia psilostachya	5.3	4.6	0.54	0.26
Amphiachyris dracunculoides	0.2	0.1	0.08	0.19
Ambrosia artemisiifolia	7.8	7.3	1.28	0.90
Unidentified forbs	0.9	0.6	0.09	0.04

[*] Mixed model SEM associated with comparison of pasture main effect means.

[†] Mixed model *P*-value associated with pasture *F*-test.

Table 3.7 Relative abundance of individual plant species identified in feces of mature ewes grazing native range in the Kansas Flint Hills during August and September in 2015 and 2016

	Relative abundance*	
Item	Mid-August	Mid-September
Graminoids		
Andropogon gerardii	3	4
Schizachyrium scoparium	1	1
Panicum virgatum	10	10
Sorghastrum nutans	7	8
Bouteloua gracilis	6	5
Bouteloua curtipendula	15	15
Bouteloua dactyloides	9	6
Carex spp.	12	12
Forb and forb-like		
Dalea purpurea	2	2
Liatris punctata	11	11
Amorpha canescens	16	16
Symphyotrichum ericoides	14	14
Lespedeza cuneata	13	13
Vernonia baldwinii	4	3
Ambrosia psilostachya	8	9
Amphiachyris dracunculoides	17	17
Ambrosia artemisiifolia	5	7

* Relative abundance scale: 1 to 17 (1 = most abundant, 17 = least abundant).

Table 3.8 Kulcyznski's Similarity Index calculations comparing basal cover of major forage plants (Table 3.5) with presence of major forage plants in fecal material of mature ewes (Table 3.6)

	KSI*, % similarity	
Item	Mid-August	Mid-September
Graminoids	79	79
Andropogon gerardii	97	85
Schizachyrium scoparium	49	50
Panicum virgatum	94	75
Sorghastrum nutans	91	90
Bouteloua gracilis	9	7
Bouteloua curtipendula	39	36
Bouteloua dactyloides	4	3
Carex spp.	22	24
Unidentified graminoids	4	5
Forb and forb-like	42	43
Dalea purpurea	2	2
Liatris punctata	0	0
Amorpha canescens	86	100
Symphyotrichum ericoides	91	100
Lespedeza cuneata	70	73
Vernonia baldwinii	8	9
Ambrosia psilostachya	46	52
Amphiachyris dracunculoides	31	17
Ambrosia artemisiifolia	7	8
Unidentified forbs	42	30

[*] Kulcyznski's Similarity Index: KSI = Kulcyznski's Similarity Index: KSI = $((2c_i) / (a_i + b_i)) * 100$, where a_i is the % basal cover of component i, and b_i is the % of component i selected by an herbivore, and c_i is the lesser of a_i and b_i; KSI values ≥ 80% were interpreted to indicate little or no discrimination (i.e., selection patterns were very similar to plant availability), values between 21 and 79% were interpreted to indicate moderate discrimination, and that KSI values ≤ 20% indicated either strong selection or avoidance of individual plant species.