SHEEP AND GOAT PREFERENCE OF FIVE COMMON COVER CROPS

A Thesis

Presented to

The Faculty of the Department of Agricultural Sciences

Sam Houston State University

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

---

by

Jaclyn L. J. Robinson

August, 2020

SHEEP AND GOAT PREFERENCE OF FIVE COMMON COVER CROPS

by

Jaclyn L. J. Robinson

APPROVED:

Shyam S. Nair, PhD
Committee Director

Robert A. Lane, PhD
Committee Member

Marcy M. Beverly, PhD
Committee Member

John B. Pascarella, PhD
Dean, College of Science and Engineering Technology

ABSTRACT

Robinson, Jaclyn L. J., *Sheep and goat preference of five common cover crops*. Master of Science (Agriculture), August, 2020, Sam Houston State University, Huntsville, Texas.

While the use of cover crops continues to gain widespread acceptance, producers frequently seek other means of deriving economic value from such crops. The alternative use of cover crops as livestock forage is of interest to many producers. In this study, we evaluated sheep and goat intake and apparent preference when provided free access to freshly harvested cereal rye (*Secale cereal* cv. "Elbon"), annual ryegrass (*Lolium multiflorum*), berseem clover (*Trifolium alexandrinum* cv. "Frosty"), daikon radish (*Raphanus sativus* subsp. *longipinnatus*), and Austrian winter pea (*Pisum sativum*) with advancing plant maturation (from March 5, 2020 to March 27, 2020). While there was significant interaction between sheep and goats in terms of dry matter consumption over time (trial date), in analyzing total dry matter consumption both animal species preferred ryegrass over daikon radish. However, total dry matter consumption of ryegrass was not significantly greater than that of the other three crops. Goats spent significantly more time at ryegrass, rye, and berseem clover treatments (troughs filled with fresh forage) while sheep spent more time on berseem clover and ryegrass. Austrian winter pea and daikon radish were the least preferred forages. Interestingly, animals spent significantly more time on ryegrass at the early feeding trial and significantly more on berseem clover at the last feeding trial, 22 days later. The two legumes used in this study were significantly higher in crude protein and lower in acid detergent fiber values than the non-legume species throughout the study, however, there was no significant correlation between measured forage quality parameters and animal preference. While there may be other factors that limit the use of these species as cover crops, our results indicate that ryegrass, berseem clover, and rye have good potential to serve alternatively as forage for small ruminants while daikon radish and Austrian winter pea would be less suitable for such use.

KEY WORDS: Preference, Cover crops, Sheep, Goat, Rye, Ryegrass, Daikon radish, Austrian winter pea, Berseem clover

ACKNOWLEDGEMENTS

First, I would like to extend thanks to my committee, Dr. Shyam Nair, Dr. Robert Lane, and Dr. Marcy Beverly. Without the guidance and support given by them, my thesis would not have been possible. I would also like to thank the rest of the faculty and staff within the Department of Agricultural Sciences, as they have made significant impacts on my professional life. Thank you to Mr. Sam Harris with Harris County Farms for allowing the use of the animals for research. A special thank you to Emaline Robinson, Lindsey Wilder, and all the other graduate and undergraduate students who assisted me in the successful completion of this thesis. The staff at Gibbs Ranch were also very helpful throughout the project. For that, they deserve my gratitude as well. Finally, I would like to thank my family for their commitment to my education. I am the person I am today because of the support, guidance, and opportunities provided to me by my family.

PREFACE

Cover crops have been used for various benefits to crop production for thousands of years. Cover crops are planted for erosion control, improving soil structure, moisture, and nutrient content, increasing beneficial soil biota, suppressing weeds, providing habitat for beneficial predatory insects, facilitating crop pollinators, and providing wildlife habitat. Other uses for planting cover crops include nitrogen fixation, reduction of nitrate leaching, and possible increase in yield of subsequent crops. An additional possible benefit of cover crops is their use as a livestock feed/forage. Cover crops can be grazed or harvested and fed as a fresh feed, ensiled, or dried for hay production.

Utilization of cover crops as a livestock feed has the potential to create an immediately measurable value and benefit to those growing cover crops. Limited research has been conducted to evaluate the preference and palatability of cover crops to small ruminants. Information gained on the subject of cover crop forage preference could be valuable to those who desire to gain the additional value and benefits from feeding such crops. Recognizing the preference/palatability of various cover crops potentially allows for those growing such crops to make planting decisions in order to gain benefits in subsequent crop production and additional value by providing a feed source to livestock.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

CHAPTER I

Introduction

Cover crops have been in use for over two thousand years and provide farmers and gardeners alike with various benefits. These include improvements to the soil, such as nutrient cycling, nitrogen fixation, and increases in soil organic matter (Sainju et al., 2002; Weinert, et al., 2002; Wyland et al., 1996) Cover crops also reduce soil erosion from wind and water by creating a vegetative ground cover, usually during a time of year when the primary crop is not being grown. This reduces the incidence of weeds and may aid in control of other pest populations (Natural Resources Conservation Service, n.d.). An additional possible benefit of cover crops is their use as a livestock feed/forage. Cover crops can be grazed or harvested and fed as a fresh feed, ensiled, or dried for hay production.

Utilizing cover crops as a livestock feed source creates an immediate benefit and value for those growing cover crops. Producers in a crop-livestock production system (producing both crops and livestock) can reduce feed costs or allow those producing livestock to graze or harvest and feed the crops at cost to generate revenue. Ruminant species are well-suited to derive nutritional benefits from cover crops due to their ability to digest fibrous materials. Several studies have observed the intake and grazing of various cover crops by sheep, goats, and cattle (Andueza et al., 2012; Lesoing et at., 1997; Savian et al., 2019; Westbrook, 2016). While it is known that ruminant species are best suited to consume the fibrous diet provided by cover crops, limited research has been conducted evaluating the preference or palatability of various cover crops, especially with regard to small ruminants. This information could be valuable to those utilizing cover crops and wanting to take advantage of the additional benefit from feeding such crops.

Selection of cover crops depends on the needs of the producer, with each crop species providing specific benefits. Leguminous cover crops that have been inoculated with the proper species and strain of N-fixing bacteria are best known for their ability to fix nitrogen in the soil, while both legume and non-legume species contribute to added soil organic matter. Both also allow for other benefits, including erosion and weed control, nutrient cycling, and potentially increased yields of subsequent crops. Realizing the preference/palatability of various cover crops might allow producers to make better decisions regarding the cover crops most suitable for meeting their needs while providing additional value as a feedstuff.

Objectives

The objectives of this research were to:

I. determine the forage preferences of sheep and goats when provided free access to five different cover crops: cereal rye (*Secale cereal* cv. "Elbon"), annual ryegrass (*Lolium multiflorum*), berseem clover (*Trifolium alexandrinum* cv. "Frosty"), daikon radish (*Raphanus sativus* subsp. *longipinnatus*), and Austrian winter pea (*Pisum sativum*);

II. determine any relationships that may exist between forage preference, nutritional quality and stage of maturity; and

III. determine the variations of selected forage preference between sheep and goats.

CHAPTER II

Literature Review

Cover Crops

A "cover crop," in its original use, described a crop planted as a winter (or "off-season") cover of the ground and was most commonly used for green-manuring. Green manuring is the process of tilling green plant material into the soil, where it decomposes and improves the soil quality. Due to the crossover between green-manure crops and cover crops, the terms were used interchangeably (Pieters, 1927). Use of cover crops is currently gaining popularity and producers are exploring avenues to derive value from such crops other than as a green-manure crop or a mulch into which the cash crop is planted. The uses, definition, and benefits of cover crops have changed and expanded since its original application. Today, a cover crop is defined by the USDA Natural Resource Conservation Service (USDA-NRCS) (n.d.) as a grass, legume, or other forb planted for erosion control, improving soil structure, moisture, and nutrient content, increasing beneficial soil biota, suppressing weeds, providing habitat for beneficial predatory insects, facilitating crop pollinators, providing wildlife habitat, and as forage for farm animals. Other uses for planting cover crops include nitrogen fixation, reduction of nitrate leaching, and possible increase in yield of subsequent crops.

Many plant species have been utilized as cover crops. According to the Sustainable Agriculture Research & Education (n.d.-a), cover crops can be legumes, cereals, grasses, and broadleaf species. Cover crops can be split into varying categories based on growth habit, seasonality, and longevity (annual, biennial, or perennial growth cycles) (Sustainable Agriculture Research & Education, n.d.-b). Annual plants complete their growth cycle in a single growing season, after which all the plant material dies and dormant seeds sprout or need to be re-planted for growth again the following year. Biennial plants complete their growth cycle within two years or growing seasons, while perennial plants grow for more than two years or growing seasons through the proliferation of perenniating structures such as rhizomes, stolons, crowns, tubers, or other below ground structures.

Producer needs determine which type or types of cover crops to plant, based on their individual beneficial characteristics. Legumes are beneficial in controlling erosion, increasing organic matter in the soil, supporting beneficial pollinators and insects, but are most notably used for nitrogen fixation. Common leguminous cover crops include clovers, vetch, peas, and beans. Cereal crops, other annual grasses, and broadleaf species planted as cover crops are used to suppress weeds, provide erosion control, and are capable of producing significant amounts of biomass, both within the soil profile and on the soil surface, contributing to increased soil organic matter. Rye, wheat, barley, oats, ryegrass, sudangrass, buckwheat, mustard, rapeseed, and radish are all common non-leguminous cover crops. Producers may use a stand of only legumes, only non-legumes, or a mix of both types, reaping the benefits of both legumes and non-legumes to meet their needs (Sustainable Agriculture Research & Education, n.d.-a, n.d.-b).

Cover Crop Benefits

Cover crop benefits were realized as early as two thousand years ago in China, with renewed interest during the 19^{th} century (Pieters, 1927). The many potential benefits of cover crops are outlined in the definition of a cover crop by the USDA-NRCS mentioned previously.

Loss of nutrient rich topsoil through erosion can significantly impact soil fertility and negatively affect crop yields. The impact of erosion caused by rain, water, and wind is decreased when the ground is covered in a canopy formed from a planted cover crop. Creamer, et al. (1997) found 13 blends of cover crops achieved 100 percent ground cover within three months after planting. Rye has been found to aid in erosion control without adversely affecting other crop yields (Kessavalou & Walters, 1990). The ground cover provided by cover crops aids weed control. In a trial using cowpea cover crop mulch, weed suppression was experienced. The emergence of weeds in cowpea mulch plots was reduced by 80 percent in year one and 90 percent in year two of the study (Hutchinson & McGiffen, 2000).

An additional benefit from the use of cover crops is improvements in soil nutritional status. This is achieved by a reduction in nitrate leaching, nitrogen fixation from leguminous crops, and nutrient cycling. Nitrates are an inorganic form of nitrogen used by plants for growth and the production of proteins. Various winter cover crops were all shown to reduce nitrate leaching and increase the use of nitrates by subsequent crops. (Weinert, et al., 2002; Wyland et al., 1996). One form of biological nitrogen fixation is through the symbiotic relationship between rhizobium or bradyrhizobium bacteria and leguminous plants. When placed near or on the legume seed, with good seedling germination and emergence the symbiotic bacteria invades the growing root hairs of legumes, eventually forming root swellings referred to as nodules. The bacterial colonies within the nodules convert gaseous nitrogen from the soil air into ammonium, a form of nitrogen able to be utilized by plants, while the plant provides a carbohydrate energy source to the bacteria (Mylona et al., 1995). Under good growing conditions leguminous crop species used for cover crop purposes may provide a residual nitrogen source in the soil for future crop intake (Karpenstein-Machan & Stuelpnagel, 2000; Ramos et al., 2001; Senaratne & Ratnasinghe, 1995). All cover crops, legume and non-legume alike, are important in nutrient cycling, or making nutrients available for subsequent crops. Tanaka et al. (2019) found the use of cover crops in the *Urochloa* family aided in the nutrient cycling of nitrogen, phosphorus, potassium, calcium, and magnesium. Roots of the cover crop were able to reach deeper depths of the soils, take up the leached nutrients, and return them to the topsoil via decomposition. Increasing soil organic matter is another potential benefit of cover crops. Sainju (2002) found using hairy vetch as a cover crop increased both soil nitrogen and soil organic carbon.

While the cover crop itself requires added expense by way of planting and other production-related expenses, higher yields of the subsequent cash crop, coupled with other improvements to the land, and conservation of the soil generally offset these costs. Cover crops in the brassica family, such as mustard, rapeseed, and canola, as well as barley and clover, have been shown to inhibit the growth of soil borne pathogens that are detrimental to crop productivity and yields. Canola and barley not only inhibited pathogens, but increased yield in a following potato crop (Larkin & Griffin, 2007, Larkin et al., 2010). The incorporation of a wheat cover crop into a no-till cropping system proved to increase cotton lint yields (DeLaune et al., 2020), and soybean yield increased due to a cover crop mixture of cereal rye, oats, daikon radish, purpletop turnips, crimson clover, and hairy vetch (Chu et al., 2017).

Cover Crops in Texas

The cover crops chosen by a producer should be suitable for the environment in which they are planted. In Texas, a variety of plant species have been found to serve successfully as cover crops. In a study completed on the Southern High Plains of Texas, “Elbon” rye, Austrian winter pea, hairy vetch, and winter wheat were found to be best at providing adequate ground coverage for reduced soil erosion (Keeling et al., 1996). The scientists in that study also suggested with favorable rains for growth, several cultivars of subterranean clover and Overton rose clover have the possibility of providing a protective vegetative cover as well. Soil microbial biomass and microbial functioning in plant material decomposition was increased using a sorghum-sudangrass hybrid, grain sorghum, and rye rotation in Lubbock, Texas (Acosta-Martinez & Cotton, 2017). This study also found soil organic carbon increased from crop rotation implementation. Treatments of rye and a mix of rye, radish, winter pea, and hairy vetch increased soil carbon and nitrogen in the Texas High Plains (Lewis et al., 2018). Soil erosion was reduced at the Blacklands Experimental Watershed near Riesel, Texas, by planting cover crops, particularly wheat or oats, during the fall and spring, which are times of high potential for water runoff and erosion (Harmel et al., 2006). Berseem clover, initially used as a cover crop, then as a green manure crop, increased final grain yield in the subsequent sorghum crop and nitrogen availability in the soil at the Texas Agricultural Experiment Station Research Farm in Burleson County, Texas (Lemon et al., 1990). Using rye and a mixture of rye, hairy vetch, radish, and Austrian winter pea as cover crop rotations in a study near Lamesa, Texas, Burke et al. (2019) found soil organic carbon was increased. These results indicate that cereal rye, ryegrass, hairy vetch, wheat, sorghum, sudangrass, winter pea, and various clovers, along with many other crops, are beneficial and suitable for use as cover crops in Texas.

Small Ruminant Digestive Tract

To determine what and how much to feed small ruminants, it is important to understand the digestive system of said species of animals. Ruminant animals have a unique four-chambered stomach, which consists of the reticulum, rumen, omasum, and abomasum. The digestive process of ruminant animals begins with rumination, after initial consumption. Rumination is the process of regurgitating feedstuff from the reticulum back to the mouth for re-chewing. Rumination allows for further breakdown of the feedstuffs, particularly fibrous materials, through mechanical and chemical processes. Rumination reduces feedstuff particle size, while increasing surface area. This process is important to efficient and enhanced fermentation and digestive processes (Faichney, 1986; National Research Council, 2007). After rumination, the feedstuffs pass to the rumen. The rumen houses microbes and is the site of fermentation in the ruminant stomach. Fermentation converts carbohydrates into readily available sources of energy. The microbes in the rumen also convert non-protein nitrogen into a protein source for the animal (Van Soest, 1994, National Research Council, 2007). The remainder of the digestive process and absorption of nutrients, in the form of amino acids, fatty acids, and sugars, is completed in the small intestines. Finally, the large intestines allow for the absorption of water and inorganic substances. A ruminant animal’s ability to house microbes and ferment feedstuffs in its specialized stomach allows for digestion and utilization of the nutrients in fibrous feedstuffs. Breakdown of fibrous feedstuffs is not able to be completed solely by digestive enzymes (National Research Council, 2007).

Cover Crops as a Feed Source

Using a cover crop as a feedstuff is not only a potential benefit of growing cover crops, but it may be crucial to some producers by creating an immediate economic value. According to Gardner & Faulkner (1991), planting and caring for a crop that apparently serves no immediate economic and harvestable purpose is both a foreign and unknown practice. Immediate value could come from incorporating ruminant livestock into the crop production system. Various ruminant species, including cattle, sheep, goats, and cervids, are able to utilize cover crops as a feed source. Feeding cover crops is suitable for ruminant species due to the ability to ruminate and the specialization of the ruminant digestive tract. The rumen, which houses microbes, allows ruminants to efficiently ferment, break down, and subsequently, utilize fibrous feedstuffs. According to Lesoing et al. (1997), a beef cattle herd can graze for approximately one month on winter cover crops during the spring months. The dairy industry also utilizes cover crops as a feed source, stockpiling and allowing grazing of annual ryegrass (Kallenbach et al., 2003).

Ryegrass, cereal rye, berseem clover, and Austrian winter pea have all been used as a feed source, through grazing or hay, for sheep and goats (Andueza et al., 2012; Lema, et al., 2007; Molle et al., 2017; Osoro et al., 2007; Savian et al., 2019; Shetaewi et al., 2001; Westbrook, 2016). Grazing cover crops by ruminant livestock species, or utilization as a harvested feedstuff, has the possibility to reduce feed costs in the livestock enterprise. Another value from grazing of cover crops comes from livestock manure. While grazing, it is inevitable for livestock to produce excrement. Livestock manure aids with nutrient cycling by returning readily available plant nutrients to the soil. Manure additions to crops has the potential to improve not only soil structure, but water holding capacity and microbiological activity, thereby increasing plant nutrient absorption (Liu et al., 2010). While improvements to soil quality from grazing may increase the yield of subsequent crops, grazing of cover crops may have negative impacts if not correctly managed. Overgrazing or improper management of grazing has potential to lead to soil compaction and a reduction in subsequent crop yield (Franzluebbers & Stuedemann, 2008). With proper management of grazing, the possibility of soil compaction persists, but has either no effect on yield or may cause an increase in future crop yield (Bell et al., 2011; Tracy & Zhang, 2008). In some cases, the benefits from the integration of livestock into the production system more than compensates for any losses in future crop yield (Franzluebbers & Stuedemann, 2014).

Diet Selection and Intake

When provided the opportunity to be selective in their forage diet, animals typically prefer a diet high in digestibility and protein content (National Research Council, 2007). While animals tend to select a diet of higher quality, nutritional quality is not the sole factor affecting diet selection. Other factors influencing diet selection include the nature of the individual animal or the animal species, physical and chemical features of the plant material, and the degree to which an animal is allowed to exhibit a preference. Animals reared in captivity do not always have a choice in diet. It is well known that sheep are grazers, preferring a diet of grasses and forbs. Goats, on the other hand, are considered mixed foragers, making selections based on season and availability. Goats tend to be classified as browsers, usually selecting the leaves of woody plants and shrubs, but also consume and digest herbaceous forages, making them mixed foragers (Hart, 2001, National Research Council, 2007).

Feed intake is affected by a number of factors. A major internal factor affecting feed intake is the design of the digestive tract. In ruminants, the capacity of the rumen is a limiting factor in feed intake. The animal will stop feeding once the rumen is full. Sensory cues and nutrient content of the diet are external factors affecting intake. Olfactory cues, like taste and smell, determine if an animal will initiate consumption and the length of consumption. As the nutritional content and quality of the diet increases, consumption decreases. This is because the animal will reach its nutritional needs sooner, therefore reducing consumption (National Research Council, 1987).

Palatability of Cover Crops

Palatability, stemming from the word palatable, describes something agreeable to the palate or taste (Merriam-Webster, n.d.). Heady (1964) defines palatability as plant characteristics or conditions which stimulate a selective response by animals. Olfactory cues determine the acceptability of a plant for consumption, as well as the length of consumption. When attempting to utilize cover crops as a feedstuff, it is important to take palatability into consideration. There is no added value when the forages will not be consumed, or consumed to the fullest extent possible. Several sources have noted the palatability of ryegrass and recommend its use as a livestock feed (Anderson, n.d.; Ogle et al., n.d.; Sustainable Agriculture Research & Education, 2007). Rye, while very productive, is not always suitable or the most palatable cover crop for forage use (Anderson, 2019; Beck et al., n.d.; Oelke et al., 1990). Alternatively, barley and oats were found to be more preferable when compared to hard wheat, soft wheat, rye, and annual ryegrass (Staten, 1949). Berseem clover is a unique legume crop which is known to be low risk in causing bloat (Sustainable Agriculture Research & Extension, 2007, Wingert, 2013). It has also been noted to be a palatable and accepted forage (Chapman et al., 2009; Chauchan et al., 1992; Das & Singh, 1999; McCann & Hoveland, 1991). Austrian winter pea has also been found to be a preferred forage. Chapman (2009) found winter pea to be the preferred forage, behind berseem clover, over turnips and canola. In contrast, winter pea was not preferred when compared to arrowleaf clover, crimson clover, and hairy vetch (Freeman et al, 2016). In the same study, it was concluded that when the preferred forage became unavailable, the other forages were consumed, indicating winter pea is suited for use as a forage. There is limited information concerning the palatability of daikon radish. Palatability and intake of various crop species decreases significantly when plants mature and produce seedheads (Brummer et al., 2018).

Current Study

Several crop species in this trial have been proven to be palatable. This study tested the preferences between those palatable crops: cereal rye (*Secale cereal* cv. “Elbon”), annual ryegrass (*Lolium multiflorum*), berseem clover (*Trifolium alexandrinum* cv. “Frosty”), daikon radish (*Raphanus sativus* subsp. *longipinnatus*), and Austrian winter pea (*Pisum sativum*) in sheep and goats when given free choice in consumption. Other goals of this research included determining the possible relationships between the preferred forages, nutritional quality, and stage of maturity of each forage. Finally, variations between the selected forages for sheep and goats was analyzed, due to the differences in diet selection behavior.

CHAPTER III

Methodology

Prior to beginning this study, the Sam Houston State University Institutional Animal Care and Use Committee approved all care, handling, and use of the sheep and goats tested within the study (Protocol Number: 20-02-10-1008-3-01). With routine animal husbandry practices along with no inflicted pain or distress, this study fell into the USDA Pain/Distress Category C. All persons involved in the handing of the animals had completed required animal handling and "Working with the IACUC" training.

Sixteen total animals, including eight ram Dorper sheep, six Boer/Boer-cross doe goats, and two Boer/Boer-cross wether goats were used in the trial. The animals were on loan from a private owner. All animals selected for study of each specie were of about the same size. Ram average weight was 29.9 kilograms, while average weight of the goats was 20.0 kilograms. At the time of initial weighing, each animal was randomly assigned a different color collar for identification purposes. Upon arrival to the study facility, the animals were inspected for health status, with checks made throughout the study. Treatments to improve or maintain good health were provided as needed. The animals were housed in a roughly one-half hectare pasture comprised of cool season legumes and grasses, with access to an enclosed barn for weather protection. A 15 percent crude protein, balanced ration (Sheep and Goat Pellet) was fed daily. High quality Coastal bermudagrass hay was offered daily along with free access to excellent quality pasture.

Study forage/feed samples were collected from cover crop research plots using a pair of handheld, battery-powered clippers and placed into large plastic bags to prevent moisture loss for the duration of each feeding trial. Forage species used in the study consisted of annual ryegrass (*Lolium multiflorum*), rye (*Secale cereale* cv. “Elbon”), berseem clover (*Trifolium alexandrinum* cv. “Frosty”), daikon radish (*Raphanus sativus* subsp. *longipinnatus*), and Austrian winter pea (*Pisum sativum*). Approximately three kg of each forage was harvested for each feeding trial. Once all the forage had been collected for a given feeding trial, a subsample of each forage was collected, placed in a paper bag, weighed, and placed into a drying oven at 330°K. After drying, the subsample was weighed again to determine moisture content and to compute forage dry matter content at the varying stages of maturity. All subsamples were sent to the Texas A&M AgriLife Extension Service Soil, Water, and Forage Testing Laboratory for nutritional analysis, including crude protein (N content) and acid detergent fiber levels according to accepted laboratory protocols.

Fifty-one cm diameter corrugated plastic pipe was used to construct five plastic feed troughs for the feeding trials. Each trough was 1.8 m long, 25.4 cm deep, with a total height of 35.6 cm. Each trough was color coded with spray paint for identification of the forages placed in the troughs during the trials. For the feeding trials, the troughs were set up in a pentagon shape, enclosed in a circular pen attached to the barn in which the animals were temporarily housed. Forage species were randomly assigned a trough color for the duration of each feeding trial. All test animals were housed in the barn overnight, with access to good quality Coastal bermudagrass hay and water, before each feeding trial to ensure limited gut fill prior to the trials to induce hunger and reduce handling stress on the day of the trial. Once forage treatments were loaded into their respective troughs and weighed, animals were released from the barn into the feeding trial area in random pairs by species. Troughs were moved after each run to randomize the location of each forage treatment.

Figure 1

Feeding trial area

Upon acquisition of the test animals, it was apparent they were not accustomed to regular human handling or feeding from a trough, so they were allowed a 14 day acclimation period. During the acclimation period, animals were allowed to graze on white clover and ryegrass pasture and fed each day from the five feed troughs to be used during the feeding trials. Animals were gradually introduced to feeding from the troughs, providing less than 0.45 kg of feed per head per day initially, while slowly transitioning to approximately 0.45 to 0.68 kg of feed per head per day, plus Coastal bermudagrass hay. Fresh forage from each of the forage treatments was also introduced during this period by hand harvesting and placing the material in the feed troughs, allowing free choice access to the harvested forage. Upon conclusion of the acclimation period, a pre-trial feeding trial was conducted. The pre-trial event provided confirmation animals should be run in pairs during the trials and that persons standing close to or approaching the trial area might affect the location of the animals in the pen, therefore affecting forage selected for consumption. The pre-trial also allowed for determination of the approximate amount of fresh forage needed to be collected for the actual feeding trials. To adjust for possible human interference with animal feeding and forage selection, a camera set upon a tripod was placed near the trial area to record video footage of each feeding trial. Video footage was later used to collect data from each animal at each trial date. Trial one was conducted on day 0, with trials two and three following at 10 day intervals on day 11, and day 22, respectively.

Video footage was used to calculate time spent in consumption of each forage for each animal. Time was recorded in total seconds. Each pair of animals was allowed 10 minutes in the feeding area. Fresh weights of all forages were recorded before allowing animals into the trial area. After each pair was removed, fresh weights of all remaining forage material were recorded. Additional fresh material was added to replace what had been consumed and the fresh weight was again calculated. Dry matter consumption was later determined for each pair of animals based on the moisture content of the subsamples collected for analysis.

One of the wether goats developed urinary calculi between trials one and two. He died due to complications of this disorder. As a result, the goats in trials two and three were placed randomly into the feeding trial area in two groups of two and one group of three. A warmer than expected winter and early spring accelerated plant growth and development of the test forages, resulting in diakon radish maturing, losing leaf tissue and producing seed prior to feeding trial three. Therefore, daikon radish was not included in the final trial. To maintain continuity, all five troughs were used in the trial area, in a pentagon shape, but one was empty during trial three.

Analysis of Variance (ANOVA) was performed in STATA® (StataCorp, 2013) to identify the effects of type of forage (annual ryegrass, rye, berseem clover, daikon radish, and Austrian winter pea), type of animal (goat and sheep), time (3 repeated measures at 10 day intervals) and all of their two-way (forage x animal, forage x time, and animal x time) and the three-way (forage x animal x time) interactions on dry matter intake (DMI) and time spent in consumption of each forage. ANOVA was also used to analyze the influence of type of forage and time on forage quality parameters [Crude Protein (CP) and Acid Detergent Fiber (ADF)]. Fisher's Least Significant Difference (LSD) method (Williams & Abdi, 2010) was used to perform mean separation for effects found to be statistically significant ($p<0.05$). A correlation analysis was also conducted to identify the association between DMI and time spent in consumption, and between the quality parameters (CP and ADF), DMI, and time spent in consumption by the sheep and goats.

CHAPTER IV

Results and Discussion

Dry Matter Intake

Results of the ANOVA on dry matter intake is presented in Table 1. These results show that forage type significantly influenced dry matter intake ($p<0.05$) and that forage type did not have significant interaction with type of animal or time at 5% alpha level. Although type of animal significantly influenced the dry matter intake ($p<0.0001$), there was significant interaction between type of animal and time ($p<0.05$). The impact of time on dry matter intake and the three-way interaction among forage type, type of animal, and time were also statistically insignificant at 5% alpha level.

Table 1

Results of the ANOVA on dry matter intake

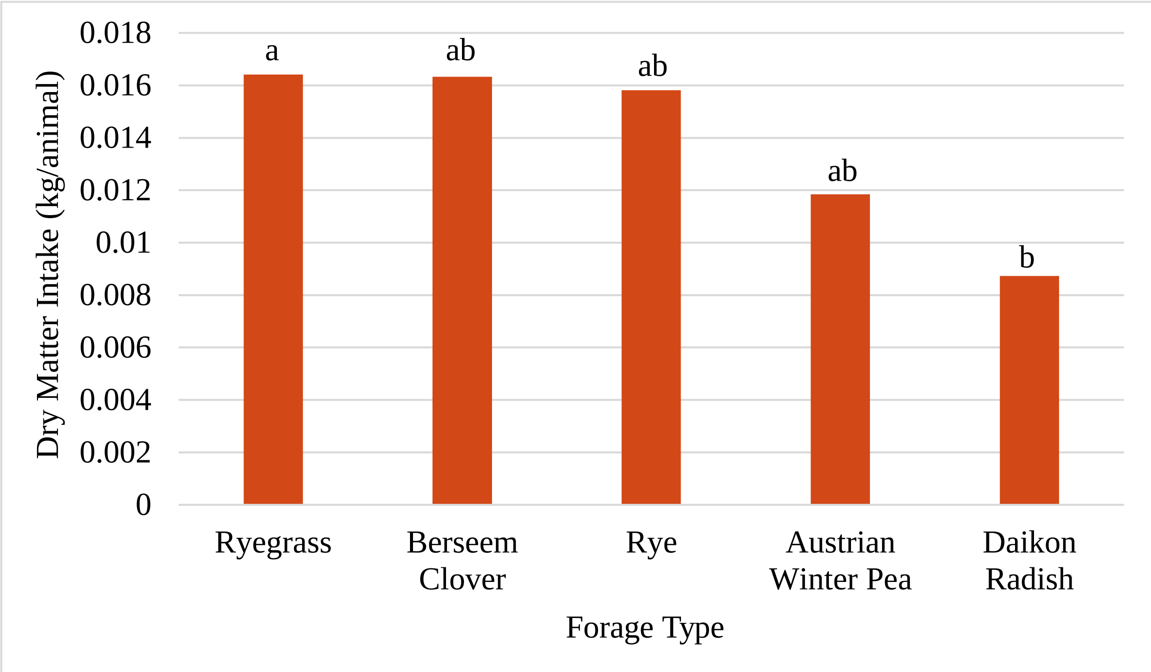
Source	Sum of squares	Degrees of freedom	F statistic	P-value
Model	0.0193	36	1.84	0.0046
Forage	0.0038	4	3.29	0.0124*
Animal	0.0058	1	20.14	<0.0001*
Block	0.0031	7	1.53	0.1590
Time	0.0008	2	1.37	0.2558
Forage x Animal	0.0007	4	0.63	0.6396
Forage x Time	0.0019	8	0.81	0.5909
Animal x Time	0.0019	2	3.35	0.0371*
Forage x Animal x Time	0.0018	8	0.77	0.6334

*$p<0.05$.

The results of the means separation test on the impact of forage type on dry matter intake is presented in Figure 2. The mean dry matter intake for ryegrass was significantly higher than that of daikon radish. However, the dry matter intake of berseem clover, cereal rye, and Austrian winter pea were on par with that of ryegrass. The dry matter intake of daikon radish was statistically not different from that of berseem clover, cereal rye, or Austrian winter pea.

Figure 2

Influence of the type of forage on mean dry matter intake

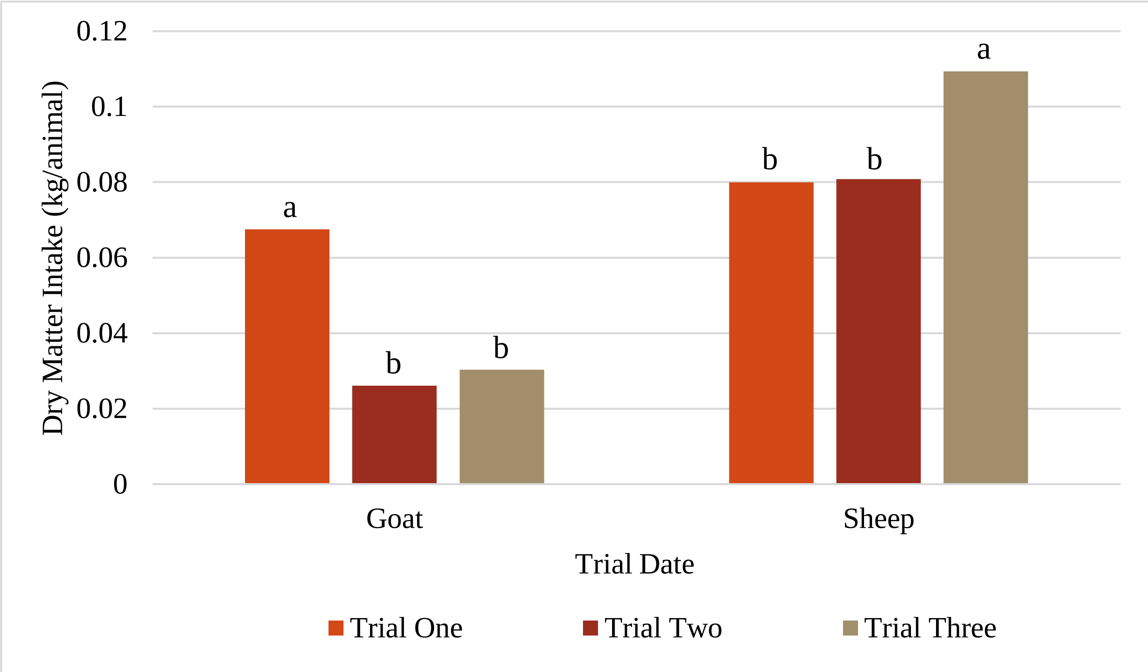


Note. Treatment means that share the same letter are not significantly different by the Least Significant Difference (LSD) test at α = .05.

There was significant interaction between animal type and time (Table 1) indicating significant variation between sheep and goats in terms of dry matter consumption over time (trial date). The mean dry matter intake of sheep and goats over time are shown in Figure 3. The mean dry matter intake for goats was highest on the first trial date (0.067 kg/animal), which was significantly higher than the mean dry matter intake in the second and third trial dates. The mean dry matter intake for goats during the second and third trial dates were on par with each other at 5% alpha level. The dry matter intake by sheep showed a different trend over time with the last trial resulting in significantly greater dry matter intake (0.109 kg/animal). The average dry matter intake for sheep during the first two trial dates did not differ from one another.

Figure 3

The average dry matter intake of goat and sheep over time (trial date)



Note. Treatment means for each livestock species that share the same letter are not significantly different by the Least Significant Difference (LSD) test at $\alpha = .05$.

The results of the means separation test on forage type indicates there is a preference for ryegrass over daikon radish. Although there was no statistical difference between berseem clover, rye, and Austrian winter pea, and daikon radish, the average consumption of the first three was considerably higher than that of daikon radish indicating they are potentially preferred to daikon radish. When solely considering dry matter intake, the research suggests a preference for ryegrass first, then berseem clover, rye, followed by Austrian winter pea and daikon radish least preferred. The results of this analysis support Anderson's (n.d.; 2019) conclusions that, while both ryegrass and rye are palatable, rye is not always the most palatable or preferred forage for livestock feed.

The findings concerning dry matter intake are comparable with the results from Chapman (2009), who found berseem clover to be utilized as a forage more than winter pea. Grazing behavior of the two livestock species is an important consideration to determining preference. Sheep prefer a diet of grasses (National Research Council, 2007). While goats are browsers and prefer the plant material of woody plants, they will select a diet of grass over clover (Hart, 2001; Luginbuhl et al., 2000). This literature supports the results of this research showing a preference for ryegrass.

Goats consumed significantly more forage during the first trial date in comparison to the two other trial dates. This reduction in consumption may be due to the maturity of the plant material. Over the course of the 22 days of the study, the plant material matured significantly. The rye started to head and daikon radish matured to the point of producing seed and loss of leaf tissue. Brummer and colleagues (2018) found the palatability and, consequently, the intake of crop forage significantly decreases upon maturity of the plants. Interestingly, sheep intake was opposite that of goats. Sheep mean dry matter intake was significantly higher during trial three compared to trials one and two, contradicting Brummer’s (2018) findings.

Time Spent in Consumption

Table 2 presents the results of the ANOVA on time spent in consumption. Forage type significantly influenced time spent in consumption ($p<0.0001$). Forage type had significant interactions with type of animal and time (trial date) ($p<0.05$). The impact of animal type or time (trial date) on time spent in consumption was not significant. The interactions between animal type and time and forage type, animal type, and time were also statistically insignificant at a 5% alpha level.

Table 2

Results of the ANOVA on time spent in consumption

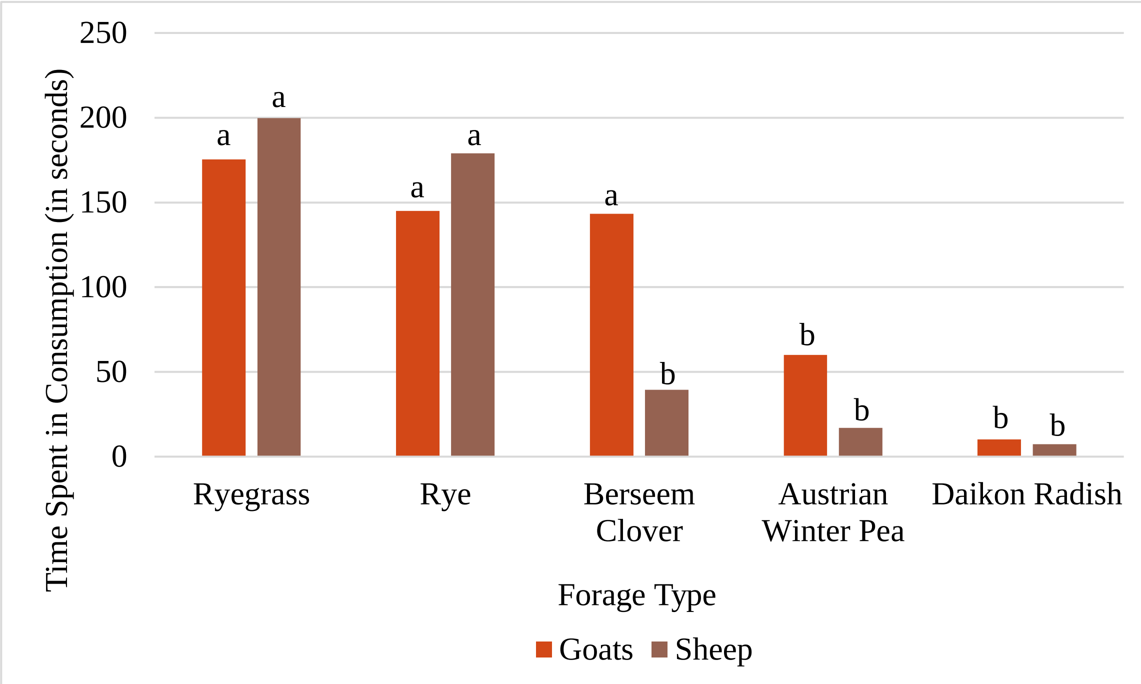
Source	Sum of squares	Degrees of freedom	F statistic	P-value
Model	1611591.10	36	3.52	<0.0001
Forage	1018670.86	4	20.02	<0.0001*
Animal	9779.88	1	0.77	0.3816
Block	48621.45	7	0.55	0.7986
Time	8365.64	2	0.33	0.7201
Forage x Animal	165368.18	4	3.25	0.0131*
Forage x Time	262652.21	8	2.58	0.0106*
Animal x Time	9340.35	2	0.37	0.6931
Forage x Animal x Time	66816.01	8	0.66	0.7291

*p<0.05.

The results of the means separation test on impact of the interaction between forage type and animal type on time spent in consumption is presented in Figure 4. The mean time spent in consumption for goats was highest with ryegrass (175.45 s/animal) but was on par with the time spent in consumption of rye (144.99 s/animal) and berseem clover (143.25 s/animal). The mean time spent in consumption was significantly different between ryegrass, rye, and berseem clover, and Austrian winter pea and daikon radish for goats, while mean time spent in consumption of Austrian winter pea (60.12 s/animal) and daikon radish (10.19 s/animal) were on par with each other. The mean time spent in consumption for sheep was highest for berseem clover (199.83 s/animal), while on par for mean time spent in consumption in ryegrass (178.91 s/animal). Sheep time spent in consumption of rye (39.42 s/animal), Austrian winter pea (16.94 s/animal), and daikon radish (7.30 s/animal) were on par with each other, but significantly different from berseem clover and ryegrass.

Figure 4

The average time spent in consumption by sheep and goats for each forage

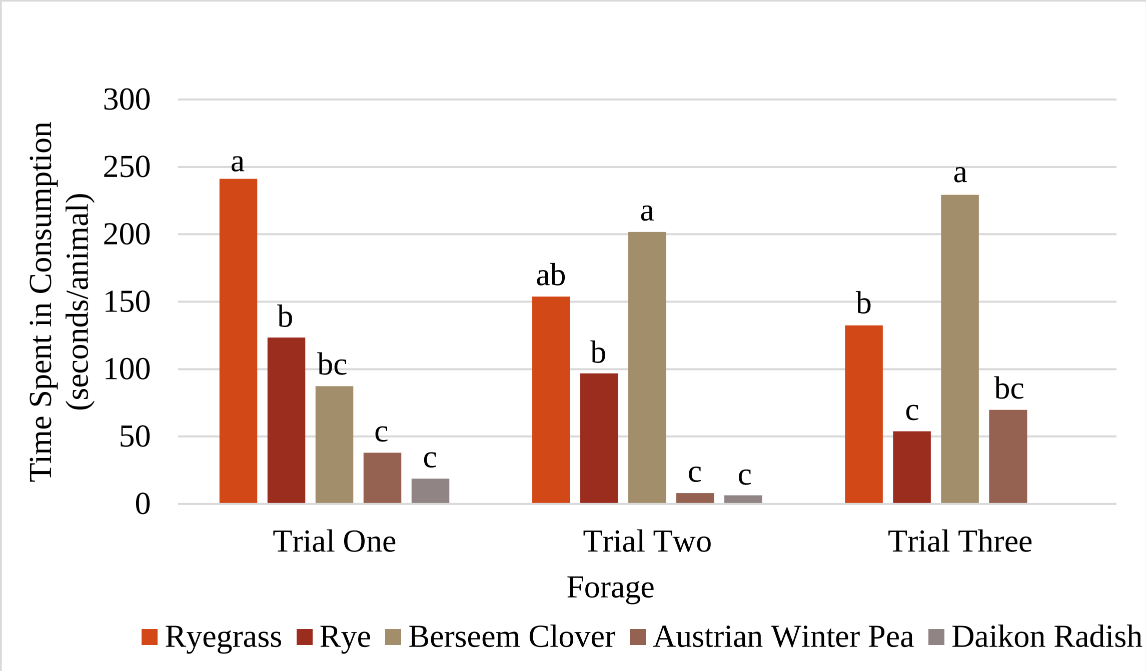


Note. Treatment means for each livestock species that share the same letter are not significantly different by the Least Significant Difference (LSD) test at $\alpha = .05$.

Figure 5 presents the results of the means separation test on the significant interaction between forage type and time (trial date). During trial 1, mean time spent in consumption of ryegrass (241.25 s/animal) was highest, and significantly different from rye (123.34 s/animal), berseem clover (87.41 s/animal), Austrian winter pea (38.01 s/animal), and daikon radish (18.65 s/animal). Time spent in consumption of rye in trial one was significantly different from Austrian winter pea and daikon radish. Time spent in consumption of berseem clover in trial one was on par with rye, and not significantly different from Austrian winter pea and daikon radish. Mean time spent in consumption during trial two was highest for berseem clover (201.67 s/animal) and was significantly different from time spent in consumption of rye (96.75 s/animal), Austrian winter pea (7.99 s/animal), and daikon radish (6.32 s/animal). Time spent in consumption of ryegrass (153.86 s/animal) was on par with the time spent in consumption of berseem clover, and not significantly different from rye during trial two. The time spent in consumption of Austrian winter pea and daikon radish did not significantly differ during trial two. During trial three, berseem clover (229.38 s/animal) had the highest mean time in consumption. The time spent in consumption of berseem clover was significantly different from time spent in consumption of ryegrass (132.56 s/animal), Austrian winter pea (69.71 s/animal), and rye (53.91 s/animal). In trial three ryegrass and rye were significantly different in mean time spent in consumption. The mean time spent in consumption of Austrian winter pea was not different from rye but was also on par with ryegrass.

Figure 5

The average time spent in consumption by forage type and trial date



Note. Treatment means that share the same letter are not significantly different by the Least Significant Difference (LSD) test at α = .05.

With respect to time spent in consumption, goats spent significantly more time consuming ryegrass, rye, and berseem clover in comparison to Austrian winter pea and daikon radish. These results suggest Austrian winter pea and daikon radish are the least preferred forages for goats. Sheep spent the highest mean time in seconds of consumption on berseem clover, followed closely by ryegrass. The time spent in consumption of berseem clover and ryegrass is significantly greater than the other three forages for sheep. These data shows a preference of berseem clover and ryegrass for sheep when only considering time spent in consumption. These findings concur with the results of other studies indicating preference and palatability of rye, ryegrass, and berseem clover (Beck et al., n.d.; Das & Singh, 1999; Sustainable Agriculture Research & Education, 2007).

The maturity of the plant significantly impacted the preference for each forage. Over the course of the study, Austrian winter pea and daikon radish have a significantly shorter time spent in consumption, indicating a low preference. The results of the means separation analysis of time spent in consumption of each forage showed a preference for ryegrass in trial one. As ryegrass matured, even though still potentially the second preferred forage, it became less preferred than berseem clover. The results concur with Brummer (2018), who states maturity decreases palatability. In trial two and three, the data show a preference for berseem clover, which is supported by Chapman (2009), who found berseem clover was grazed more during the end of the grazing period in his study.

Forage Crude Protein Content

Results of the ANOVA on the CP content of each forage is presented in Table 3. The ANOVA indicates forage type significantly influenced the CP content ($p<0.05$). Time (trial date), although not significant at the 5% alpha level, is significant at the 10% alpha level.

Table 3

Results of the ANOVA on forage crude protein content

Source	Sum of squares	Degrees of freedom	F statistic	P-value
Model	550.2830	6	13.42	0.0016
Forage	527.1494	4	19.28	0.0007*
Time	61.2194	2	4.48	0.0559

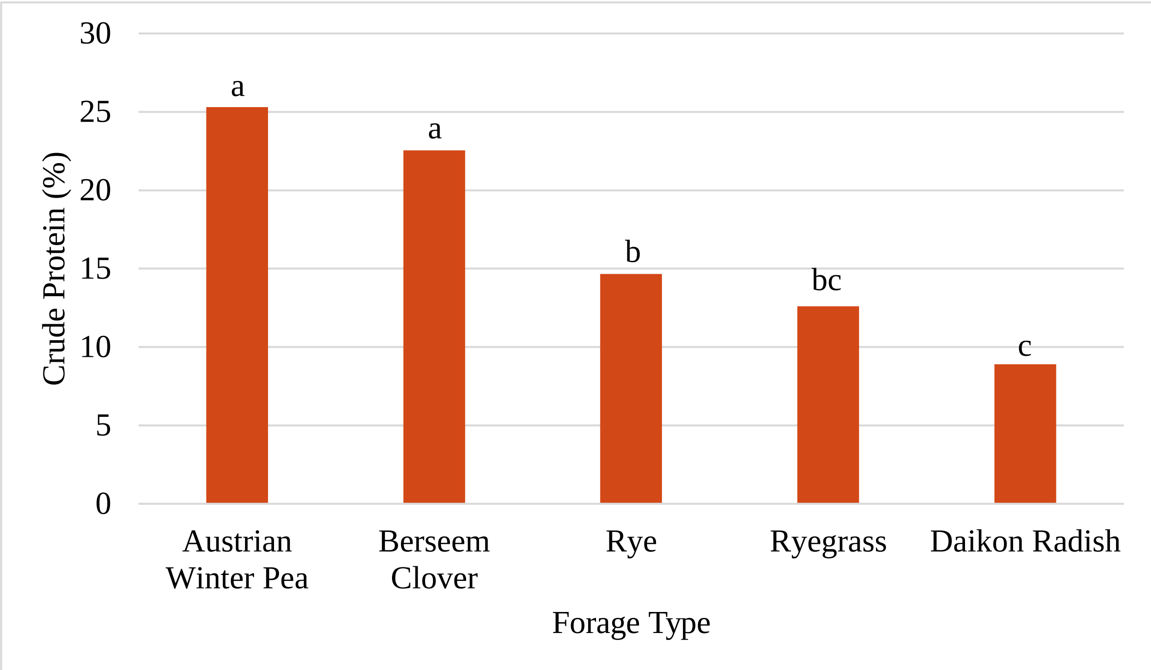
*$p<0.05$.

The results of the means separation test on the impact of forage type on average CP content is displayed in Figure 6. The average CP content of Austrian winter pea (25.30%) and berseem clover (22.55%) were statistically on par with each other and different from rye (14.65%), ryegrass (12.6%), and daikon radish (8.90%). The average

CP content of rye was significantly different from daikon radish at the 5% alpha level. Ryegrass average CP content was on par with the protein content of rye, but not significantly different from daikon radish.

Figure 6

Average crude protein content for each forage



Note. Treatment means that share the same letter are not significantly different by the Least Significant Difference (LSD) test at α = .05.

The National Resource Council (2007) claims an animal will select a diet high in protein content. In this study, the two legume species showed to have the highest average CP content. While the NRC statement was likely meant to be a generalization, the results of this study are in disagreement with the view that an animal will select a diet higher in protein content. Based on this assumption, the animals in the study should have shown an overall preference for Austrian winter pea, due to it having the highest average protein content. However, based on dry matter intake and time spent in consumption, Austrian winter pea was one of the least preferred forages. There was no significant difference in the CP content of berseem clover compared to Austrian winter pea. Based on the literature from the National Resource Council (2007), berseem clover should be a preferred forage in comparison to rye, ryegrass, and daikon radish. The results of the CP content analysis, shows a preference for berseem clover based on CP content, supports the results of the analyses on dry matter intake and time spent in consumption, which show a preference for berseem clover (Figures 2, 4, and 5).

Forage Acid Detergent Fiber Content (ADF)

Table 4 presents the results of the ANOVA on forage ADF. Both forage type ($p<0.05$) and time (trial date) ($p<0.0001$) significantly influence the ADF content of the various forages.

Table 4

Results of the ANOVA on forage acid detergent fiber content

Source	Sum of squares	Degrees of freedom	F statistic	P-value
Model	951.9682	6	37.06	0.0001
Forage	561.3490	4	32.78	0.0001*
Time	489.6510	2	57.19	<0.0001*

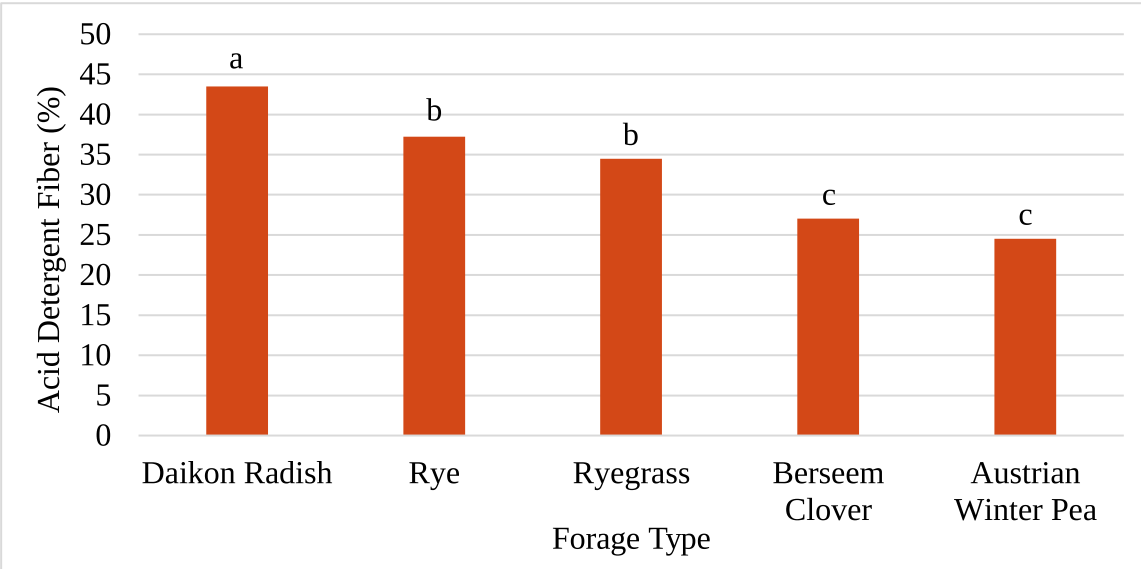
*p<0.05.

Figure 7 presents the results of the means separation test on forage ADF content. Acid detergent fiber represents the least digestible plant components, including cellulose, lignin, and other insoluble minerals. The acid detergent fiber value is inversely related to digestibility, indicating forages with lower acid detergent fiber values are more digestible (Rasby & Martin, n.d.). The average ADF content of daikon radish (43.50%), was significantly higher than rye (37.23%) and ryegrass (34.50%), which were both significantly higher than berseem clover (27.03%) and Austrian winter pea (24.50%).

Rye and ryegrass average ADF content did not differ significantly from each other, but from berseem clover and Austrian winter pea. There was not a significant difference in the average ADF content between berseem clover and Austrian winter pea.

Figure 7

Average acid detergent fiber content of each forage

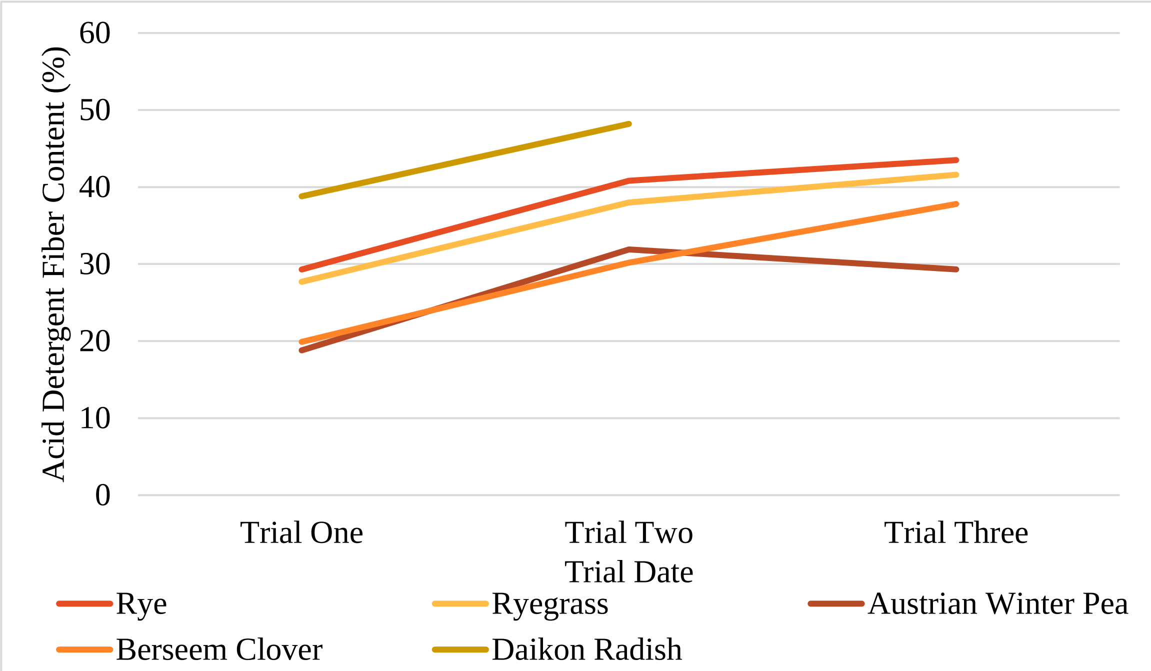


Note. Treatment means that share the same letter are not significantly different by the Least Significant Difference (LSD) test at $\alpha = .05$.

Time (trial date) was shown to significantly influence the ADF of each forage ($p<0.05$). The results of the mean separation analysis ADF content over time for each forage is displayed in Figure 8. The ADF content of rye, ryegrass, and berseem clover increased over time. During trial one, the rye ADF level was 29.3%, and 40.8% and 43.5% in trials two and three. Ryegrass ADF percent increased from 27.7% in trial one to 38.0% in trial two, and up to 41.6% in trial three. The ADF content of berseem clover was 19.9%, 30.2%, and 37.8% in trials one, two, and three, respectively. Although daikon radish was omitted from trial three, it also showed an increase in ADF content from trial one (38.8%) to trial two (48.2%). Interestingly, Austrian winter pea ADF content differed from the other forages by increasing in percentage, then decreasing slightly in trial three. The ADF content of Austrian winter pea in trial one was 18.8%, increased in trial two to 31.9%, then decreased to 29.3% in trial three. This minimal difference between trials two and three is likely due to sampling error.

Figure 8

Acid detergent fiber content over time



As would be expected, as cell wall thickness increases under advancing plant maturity, the general trend for the forages studied here was that ADF levels increased over time. The two legume species in this study were significantly lower in average ADF percentage, signifying higher digestibility in comparison to the other forage species. If animal selectivity was based primarily on forage quality, measured here by CP and ADF levels, Austrian winter pea and berseem clover should have been the preferred forages. The results of the means separation analysis based on dry matter intake and time spent in consumption show that Austrian winter pea was one of the least preferred forages in this study. Obviously, there are other factors, olfactory or otherwise, that contribute to the low preference for Austrian winter pea. Berseem clover, however, does follow the premise that a preferred forage will be high in digestibility (National Resource Council, 2007).

Berseem clover was found to be the preferred forage in trials two and three based on time spent in consumption. In trial two, berseem clover was found to have the lowest ADF percentage in comparison to the other forages. In trial three, it had the second lowest ADF content. As expected, due to the high digestibility based on low ADF percentage, berseem clover would be a preferred forage. The results of the ADF content analysis supports the findings that berseem clover was the preferred forage from the time spent in consumption over time (trial date) analysis.

Correlation Analysis

A correlation analysis between dry matter intake and time spent in consumption was performed. Although the correlation coefficient was positive as expected, the correlation was not really strong ($r=0.2276$). The relationship between dry matter intake was not statistically significant ($p=0.4439$). The value is positive, as expected, although not as high as expected. This variance from expectation could be due to the possibility of animals not "actively" eating, but instead nibbling or trying the forage before deciding to consume a large amount of the forage.

Table 5 establishes correlation coefficients between animal type, dry matter intake, forage quality (CP and ADF), and time spent in consumption. There is a strong positive relationship between CP content and ADF ($r = 0.7228$). Sheep dry matter intake has a positive relationship with forage quality. The correlation value between sheep dry matter intake and CP content is 0.3498, and ADF content is 0.3677. This differs from goat dry matter intake. There is relatively no correlation between goat dry matter intake and CP content ($r = 0.1022$), while there is a strong negative correlation between dry matter intake and ADF content ($r = -0.7121$). There are no strong correlation values for sheep or goat time in consumption. There is one significant correlation ($p<0.05$), between goat dry matter intake and ADF content.

Table 5

Results of correlation analysis between animal type, forage quality, dry matter intake, and time spent in consumption

	Crude protein	Acid detergent fiber	Sheep dry matter intake	Sheep time in consumption	Goat dry matter intake	Goat time in consumption
Crude protein						
Acid detergent fiber	0.7228 (0.0035)					
Sheep dry matter intake	0.3498 (0.2201)	0.3677 (0.1958)				
Sheep time in consumption	0.0760 (0.7963)	-0.2113 (0.4684)	0.3564 (0.2110)			
Goat dry matter intake	0.1022 (0.7282)	-0.7121 (0.0043*)	0.0352 (0.9050)	0.4259 (0.1289)		
Goat time in consumption	0.0110 (0.9703)	-0.0658 (0.8232)	0.2363 (0.4160)	0.6958 (0.0057)	0.2048 (0.4824)	

Note. P-values associated with each correlation coefficient are displayed in parenthesis below the correlation coefficient.

*p<0.05.

The correlation coefficient between goat intake and ADF content is a strong negative relationship (-0.7121). This would indicate it can be expected goats will consume more forage as digestibility increases or as ADF levels decrease (NRC reference). While not a strong relationship, CP and sheep dry matter intake is positively related. It can be expected as CP content of the forage increases, the dry matter intake of sheep will also increase. CP content has relatively no relationship with sheep time spent in consumption or goat dry matter intake or time spent in consumption.

CHAPTER V

Conclusions

While there are several benefits potentially achieved from the utilization of cover crops to the soil, as well as potential future yield increases, other benefits and value can be derived from them as a livestock feedstuff. Although cover crops have been utilized in crop production for hundreds of years, the potential use as a livestock feed was realized only relatively recently. This study was designed to examine the preference of five common cover crops in sheep and goats.

This information is valuable to those growing cover crops who desire an additional benefit from feeding them to livestock. Producer decisions regarding which plant species to select is dependent upon producer needs and benefits experienced from the various species. For those producers which desire to create the additional value from feeding cover crops to livestock, realizing preference/palatability allows for better decision making in species selection.

The results of this study show a preference for annual ryegrass (*Lolium multiflorum*), cereal rye (*Secale cereale* cv. “Elbon”), and berseem clover (*Trifolium alexandrinum* cv. “Frosty”). While still consumed, the results indicated daikon radish (*Raphanus sativus* subsp. *longipinnatus*) and Austrian winter pea (*Pisum sativum*) were least preferred. Producer needs ultimately determine which species to plant, however, this study concludes annual ryegrass, rye, and berseem clover are most suitable to serve as a potential alternative feed source to small ruminants. Small ruminants are able to consume and utilize both Austrian winter pea and daikon radish, but prefer other forage species.

Future Research

Due to the limited information concerning the preference of cover crops being utilized as a livestock feed, it is important to continue research in this field. Future research should replicate this study in various climatic zones and growing regions. Other important research would include determining consumption of least preferred forages when the preferred option is unavailable. Also, producers will want to know which cover crops are most likely to experience the least damage to the cover crop while being grazed by livestock or harvested for feeding livestock while still providing a high quality feedstuff. Finally, an economic analysis determining a cost-benefit analysis of the cover crops being utilized as forage should be conducted. This potential future research will further assist producers in making better decisions when selecting a plant species to achieve their cover crop needs while enjoying the additional benefit derived from its utilization as a feedstuff.

REFERENCES

Acosta-Martinez, V., & Cotton, J. (2017). Lasting effects of soil health improvements with management changes in cotton-based cropping systems in a sandy soil. *Biology and Fertility of Soils*, 53(30), 533-546.

Anderson, B. (n.d.). Rye and ryegrass: What's the difference?. *University Communications, University of Nebraska Lincoln*. https://newsroom.unl.edu/announce/beef/3039/17303

Anderson, B. (2019, August 1). Which one do I want? Rye or ryegrass?. *University of Nebraska Lincoln Cropwatch*. https://cropwatch.unl.edu/2019/which-one-do-i-want-rye-or-ryegrass

Andueza, D., Delgado, I. & Munoz, F. (2012). Relationships of digestibility and intake by sheep of whole-crop cereal hays with different chemical, biological, and physical methods. Small Ruminant Research, 108, 73-76.

Beck, P., Gadberry, S., & Jennings, J. (n.d.). *Using cool-season annual grasses for grazing livestock*. University of Arkansas Division of Agriculture Research & Extension. https://www.uaex.edu/publications/PDF/FSA-3064.pdf

Bell, L. W., Kirkegaard, J. A., Swan, A., Hunt, J. R., Huth, N. I., & Fettell, N. A. (2011, May). Impacts of soil damage by grazing livestock on crop productivity. *Soil & Tillage Research*, 113(1), 19-29.

Brummer, J., Johnson, S., Obour, A, Caswell, K., Moore, A., Holman, J., Schipanski, M., & Harmoney, K. (2018, December). Managing spring planted cover crops for livestock grazing under dryland conditions in the high plains region. Colorado State University Extension. https://extension.colostate.edu/topic-areas/agriculture/managing-spring-planted-cover-crops-for-livestock-grazing-under-dryland-conditions-in-the-high-plains-region-0-309/

Burke, J. A., Lewis, K. L., Ritchie, G. L., Moore-Kucera, J., DeLaune, P. B., & Keeling J. W. (2019, June 27). Temporal variability of soil carbon and nitrogen in cotton production on the Texas high plains. *Agronomy Journal*, 111(5), 2218-2225.

Chauhan, T. R., Gupta, R., & Chopra, A. K. (1992). Comparative nutritive values of legume hays for buffalo. *Journal of Buffalo Science*, 3, 243-246.

Chapman, G., Bork, E., Donkor, N., & Hudson, R. (2009). Yields, quality, and suitability of four annual forages for deer pasture in north central Alberta. *The Open Agriculture Journal*, 3, 26-31.

Chu, M., Jagadamma, S., Walker, F. R., Eash, N. S., Buschermohle, M. J., & Duncan, L. A. (2017, December 7). Effect of multispecies cover crop mixture on soil properties and crop yield. *Agricultural & Environmental Letters*.

Creamer, N. G., Bennett, M. A., & Stinner, B. R. (1997). Evaluation of cover crop mixtures for use in vegetable production systems. *HortScience,* 32(5), 866-870.

Das, A. & Singh, G. P. (1999). Effect of different levels of berseem (Trifolium alexdrinum) supplementation of wheat straw on some physical factors regulating intake and digestions. *Animal Feed Science and Technology*, 81, 133-149.

DuLaune, P. B., Mubvumba, P., Ale, S., & Kimura, E. (2020). Impact of no-till, cover crop, and irrigation on cotton yield. *Agricultural Water Management*, 232. https://doi.org/10.1016/j.agwat.2020.106038

Faichney, G. J. (1986). The kinetics of particulate matter in the rumen. In I. W. McDonald and A. C. I. Warner (Eds.), Digestion and metabolism in the ruminant (pp. 173-195). The University of New England Publishing Unit, Armidale, Australia.

Franzluebbers, A. J. & Stuedemann, J. A. (2008). Soil physical response to cattle grazing cover crops under conventional and no tillage in the southern Piedmont USA. *Soil & Tillage Research*, 100, 141-153.

Franzluebbers, A. J. & Stuedemann, J. A. (2014). Crop and cattle production responses to tillage and cover crop management in an integrated crop-livestock system in the southeastern USA. *European Journal of Agronomy*, 57, 62-70.

Freeman, S. R., Poore, M. H., Glennon, H. M., & Shaeffer, A. D. (2016). Winter annual legumes seeded into bermudagrass: Production, nutritive value, and animal preference. *Crop, Forage & Turfgrass Management*, 2(1), 1-9.

Gardner, J. C., & Faulkner, D. B. (1991). Use of cover crops with integrated crop-livestock production systems. In W.L. Hargrove (Ed.), *Cover Crops for Clean Water* (pp. 185-191). Soil and Water Conservation Service. Ankeny, IA, United States.

Harmel, R. D., Richardson, C. W., King, K. W., & Allen, P. M. (2006). Runoff and soil loss relationships for the Texas blackland prairies ecoregion. *Journal of Hydrology*, 331(3-4), 471-483.

Hart, S. P. (2001). Recent perspectives in using goats for vegetation management in the USA. *Journal of Dairy Science*, 84(E. Suppl.), E170-E176.

Heady, H. F. (1964). Palatability of herbage and animal preference. *Journal of Range Management*, 17(2), 76-82.

Hutchinson, C. M., & McGiffen, M. E., Jr. (2000). Cowpea cover crop mulch for weed control in desert pepper production. *HortScience*, 35(2), 196-198.

Kallenbach, R. L., Bishop-Hurley, G. J., Massie, M. D., Kerley, M. S., & Roberts, C. A. (2003, July). Stockpiled annual ryegrass for winter forage in the lower midwestern USA. Crop Science, 43(4), 1414-1419.

Karpenstein-Machan, M., & Stuelpnagel, R. (2000). Biomass yield and nitrogen fixation of legumes monocropped and intercropped with rye and rotation effects on a subsequent maize crop. *Plant and Soil*, 218(1-2), 215-232.

Keeling, J. W., Matches, A. G., Brown, C. P., & Karnezos, T. P. (1996, March). Comparison of interseeded legumes and small grains for cover crop establishment in cotton. *Agronomy Journal*, 88(2), 21-222.

Kessavalou, A., & Walters, D. T. (1990, July). Winter rye cover crop following soybean under conservation tillage: Residual soil nitrate. *Agronomy Journal*, 91(4), 643-649.

Larkin, R. P., & Griffin, T. S. (2007). Control of soilborne potato diseases using brassica green manures. *Crop Protection*, 26(7), 1067-1077.

Larkin, R. P., Griffin, T. S., & Honeycutt, C. W. (2010, November 4). Rotation and cover crop effects on soilborne potato diseases, tuber yield, and soil microbial communities. *Plant Disease*, 94(12), 1491-1502.

Lema, M., Fenderson, C., Adefope, N., Kebe, S., & Opio, R. (2007). Evaluation of TRICAL-336 Triticale, Maton Rye and Kentucky-31 Fescue as winter pasture for meat goats. *Journal of Sustainable Agriculture*, 30(2), 89–104.

Lemon, R. G., Hons, F. M., & Saladino, V. A. (1990). Tillage and clover crop effects on grain sorghum yield and nitrogen uptake. *Journal of Soil and Water Conservation*, 45(1), 125-127.

Lesoing, G., Klopfenstein, T. J., Williams, M., Mortensen, D., & Jordon, D. J. (1997, January). *Cover crops in crop/livestock production systems*. University of Nebraska-Lincoln. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1443&context=animalscinbcr

Lewis, K. L., Burke, J. A., Keeling, W. S., McCallister, D. M., DeLaune, P. B., & Keeling, J. W. (2018, June 21). Soil benefits and yield limitations of cover crop use in Texas high plains cotton. *Agronomy Journal*, 110(4), 1616-1623.

Liu, E., Yan, C., Mei, X., He, W., Bing, S. H., Ding, L., Liu, Q., Liu, S., & Fan, T. (2010). Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*, 158(3-4), 173-180.

Luginbuhl, J. M., Poore, M., Mueller, P., & Green, J. (2000, January 1). *Forage needs and grazing management for meat goats in the humid southeast* (Animal Science Facts Series). North Carolina State Extension. https://content.ces.ncsu.edu/forage-needs-and-grazing-management-for-meat-goats-in-the-humid-southeast

McCann, J. S. & Hoveland, C. S. (1991). Equine grazing preferences among winter annual grasses and clovers adapted to the southeastern United States. *Journal of Equine Veterinary Science*, 11(5), 275-277.

Merriam-Webster. (n.d.). Palatable. In *Merriam-Webster.com dictionary.* Retrieved Febrary 24, 2020, from https://www.merriam-webster.com/dictionary/palatable

Molle, G., Decandia, M., Giovanetti, V., Manca, C., Acciaro, M., Epifani, G., Salis, L., Cabiddu, A., Sitzia, M., & Canna, A. (2017). Grazing behaviour, intake and performance of dairy ewes with restricted access time to berseem clover (Trifolium alexandrium L.) pasture. Grass & Forage Science, 72(2), 194-210. https://dio-org.ezproxy.shsu.edu/10.1111/gfs.12228

Mylona, P., Pawlowski, K. & Bisseling, T. (1995, July). Symbiotic Nitrogen Fixation. *The Plant Cell*, 7(7), 869-885.

National Research Council (1987). Predicting feed intake of food-producing animals. National Academies Press. Washington, DC, United States.

National Research Council (2007). Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids. National Academies Press. Washington, DC, United States.

Natural Resources Conservation Service (n.d.). *Cover crops.* United States Department of Agriculture. Retrieved January 13, 2020, from https://plants.usda.gov/about_cover_crops.html

Oelke, E. A., Oplinger, E. S., Bahri, H., Durgan, B. R., Putnam, D. H., Doll, J. D., & Kelling, K. A. (1990). *Alternative field crops manual: Rye*. University of Wisconsin-Extension & University of Minnesota: Center for Alternative Plant & Animal Products. https://hort.purdue.edu/newcrop/afcm/rye.html

Ogle, D., Engle, S., & Shewmaker, G. (n.d.). *Plant guide: Perennial ryegrass*. United States Department of Agriculture Natural Resources Conservation Service. https://plants.usda.gov/plantguide/pdf/pg_lopep.pdf

Osoro, K., Mateos-Sanz, A., Frutos, P., Garcia, U., Ortega-Mora, L. M., Ferreira, L. M. M., Celaya, R., & Ferre. I. (2007). Anthelmintic and nutritional effects of heather supplementation on Cashmere goats grazing perennial ryegrass-white clover pastures. *Journal of Animal Science*, 85(3), 861-870.

Pieters, A. J. (1927). *Green manuring: Principles and practice*. John Wiley & Sons. New York, NY, United States.

Ramos, M. G., Villatoro, M. A. A., Urquiaga, S., Alves, B. J. R., & Boddey, R. M. (2001, February). Quantification of the contribution of biological nitrogen fixation to tropical green manure crops and the residual benefit to a subsequent maize crop using ^{15}N-isotope techniques. *Journal of Biotechnology*, 91(2-3), 105-115.

Rasby, R., & Martin, J. (n.d.). Understanding Feed Analysis. University of Nebraska-Lincoln Extension. https://beef.unl.edu/learning/feedanalysis.shtml

Sainju, U. M., Singh, B. P., & Yaffa, S. (2002, May). Soil organic matter and tomato yield following tillage, cover cropping, and nitrogen fertilization. *Agronomy Journal*, 94(3), 594-602.

Savian, J. V., Priano, M. E., Nadin, L. B., Tieri, M. P., Tres Schons, R. M., Basso, C., Prates, A. P., Bayer, C., & de Faccio Carvalho, P. C. (2019). Effect of sward management on the emissions of CH4 and N2O from faeces of sheep grazing Italian ryegrass pastures. *Small Ruminant Research*, 178, 123–128. https://doi-org.ezproxy.shsu.edu/10.1016/j.smallrumres.2019.08.011

Senaratne, R., & Ratnasinghe, D. S. (1995). Nitrogen fixation and beneficial effects of some grain legumes and green-manure crops on rice. *Biology and Fertility of Soils*, 19(1), 49-54.

Shetaewi, M. M., Abdel-Samee, A. M. & Bakr, E. A. (2001). Reproductive performance and milk production of Damascus goats fed acacia shrubs or berseem clover hay in North Sinai, Egypt. *Tropical Animal Health and Production*, 33(1), 67-79.

StataCorp. (2013). Stata Statistical Software: Release 13. College Station, TX. StataCorp LP.

Staten, H. W. (1949, March). Palatability trials of winter pasture crops, and effect of phosphate fertilizers on palatability. Oklahoma Agricultural Experiment Station, Department of Agronomy.

Sustainable Agriculture Research & Education. (n.d.-a). *Cover Crops*. Retrieved January 13, 2020, from https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops?gclid=Cj0KCQiAnL7yBRD3ARIsAJp_oLaTO71CQFP1836AIW92r-87n0IJl3cIplKk-Htsg3jSaq0OrakOCK4aAsniEALw_wcB

Sustainable Agriculture Research & Education. (n.d.-b). *Types of Cover Crops*. Retrieved January 13, 2020, from https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition/Text-Version/Cover-Crops/Types-of-Cover-Crops

Sustainable Agriculture Research & Education. (2007). *Managing cover crops profitably* (3rd ed.). United States Department of Agriculture.

Tanaka, K. S., Crusicol, C. A. C., Soratto, R. P., Momesso, L., Costa, C. H. M., Franzluebbers, A. J., Oliveira, A., Jr., & Calonego, J. C. (2019, February). Nutrients released by urochloa cover crops prior to soybean. Nutrient Cycling in Agroecosystems, 113(3), 267-281.

Tracy, B. F. & Zhang, Y. (2008, May 1). Soil compaction, corn yield response, and soil nutrient pool dynamics within an integrated crop-livestock system in Illinois. Crop Science, 48(3), 1211-1218.

Van Soest, P. J. (1994). Nutritional ecology of the ruminant (2nd ed.). Comstock, Ithica, New York, United States.

Weinert, T. L., Pan, W. L., Moneymaker, M. R., Santo, G. S., & Stevens, R. G. (2002, March). Nitrogen recycling by nonleguminous winter cover crops to reduce leaching in potato rotations. *Agronomy Journal*, 94(2), 365-372.

Westbrook, J. K. (2016). *The effects of sheep grazing for Pisum sativum or Melilotus officinalis cover crop termination* [Master’s thesis, Montana State University]. ScholarWorks, Theses and Dissertations at Montana State University. https://scholarworks.montana.edu/xmlui/handle/1/9868

Williams, L. J., & Abdi, H. (2010). Fisher's least significant difference (LSD) test. Encyclopedia of research design, 218, 840-853.

Wingert, J. (2013, February 14) *Tips for preventing pasture bloat*. PennState Extension. https://extension.psu.edu/tips-for-preventing-pasture-bloat

Wyland, L. J., Jackson, L. E., Chaney, W. E., Klonsky, K., Kioke, S. T., & Kimple, B. (1996, August). Winter cover crops in a vegetable cropping system: Impacts on nitrate leaching, soil water, crop yield, pests and management costs. *Agriculture, Ecosystems & Environment*, 59(1-2), 1-17.

APPENDIX

Sam Houston State University

A Member of the Texas State University

Institutional Animal Care and Use Committee

Committee Members

Regular Members	Alternate Members
Marcy Beverly, Ph.D.	Jeremy Bechelli, Ph.D.
James Harper, Ph.D.	Jessica Bedore, Ph.D.
Kyle Stutts, Ph.D.	Ilona Petrikovics, Ph.D.
Bill Lutterschmidt, Ph. D.	Stephen White, Ph.D.
Douglas Constance, Ph.D.	Michael Moore, D.V.M.
Diego Alvarez, M.D., Ph.D.	Vernette Porter, Community Member
Gerald Etheredge, D.V.M.	
Frank Adams, Ph.D., Community Member	

Date: February 17, 2020

To: Jaclyn Robinson [Faculty Supervisor: Dr. Marcy Beverly]
Department of Agricultural Sciences
Box 2088
On-Campus

From: Dr. Jim Harper, IACUC Member

Re: **Form C**: Research
ID #20-02-10-1008-3-01
Project Title: *Palatability of Cover Crops in Small Ruminant Animals [Student Thesis]*

Species: *Goats and Sheep*

Start: February 10, 2020 **End:** February 10, 2023

Your **IACUC Research** submission was reviewed under **Designated Member Review** (DMR) procedures on **February 10, 2020** with the following result:

Approved

Annual Review Form Deadline: September 30, 2020

VITA

Jaclyn L. J. Robinson

EDUCATION

Sam Houston State University, Huntsville, Texas August 2020
Master of Science in Agriculture Sciences, GPA 4.0
Emphasis in Agricultural Business
Thesis Concentration

Relevant Coursework:

- Capital Management in Agricultural Business
- Economics of Agricultural Production
- Contemporary Agricultural Business Issues
- Contemporary Animal Agriculture Issues
- International Agriculture

Sam Houston State University, Huntsville, Texas May 2018
Bachelor of Science in Agricultural Business, GPA 4.0
Minor in Animal Science & Secondary Education

Agriculture, Food, and Natural Resources Texas Teacher Certification

Relevant Coursework:

- Agricultural Finance
- Agricultural Sales & Consulting
- Agribusiness Marketing
- Animal Reproduction
- Animal Breeding & Genetics
- Animal Nutrition

SCHOLARLY WORKS

Sheep and Goat Preference of Five Common Cover Crops
Master of Science Thesis, August 2018 – August 2020

The Effects of Team Instruction on Scores in a Team-Based Learning Course
Poster Presentation, Undergraduate Research Symposium at Sam Houston State University, January – April 2016

PROFESSIONAL EXPERIENCE

Sam Houston State University, Huntsville, Texas
Agricultural Business Graduate Teaching Assistant, August 2018 – May 2020

Assist Agricultural Business professors in teaching various agribusiness courses. Provided student support, guidance, and feedback on course material and content. Updated the Department of Agricultural Sciences website using WebCMS. Prepared and facilitated various Texas FFA State Leadership Development and Career Development Events.

Courses Facilitated:

- AGBU 2317: Principles of Agricultural Economics
- AGBU 3367: Agricultural Finance
- AGBU 3385: Quantitative Methods for Agribusiness
- AGBU 4363: Agricultural Sales & Consulting
- AGBU 4378: Farm & Ranch Management

Texas FFA & Sam Houston State University, Huntsville, Texas
Creed Speaking Leadership Development Event Coordinator, December 2019
Coordinated agriculture students, teachers, volunteers, and judges on the day of the contest. Insured correct scoring. Addressed questions, concerns, and needs during the contest.

Coldspring-Oakhurst High School, Coldspring, Texas
Student Teacher, 9th – 12th Grades, January 2018 – May 2018
Organized lessons, activities, and assessments for courses taught. Trained Milk Quality Products Career Development Event Team and Woodland Clinic Career Development Event Team. Participated in weekly professional development and STAAR training

Courses Facilitated:

- Principles of Agriculture, Food, and Natural Resources
- Livestock Production
- Horticulture
- Principles and Elements of Floral Design

Sam Houston State University, Huntsville, Texas
Research Assistant, January – April 2016
Assisted in research projects pertaining to Team Based Learning. Conducted a literature review of other studies. Presented findings at Undergraduate Research Symposium

Robinson Ranch & Carraway Farms, Dayton, Texas
Owner & Farm Hand, Continuous
Provide animal care and humane handling, general farm maintenance and repair, and business functioning such as finance, purchasing, and marketing

HONORS, AWARDS, & ORGANIZATIONS

SHSU Face to Face Scholarship Luncheon Student Speaker 2019

Jeff Rhode Memorial Scholarship	2019
Raven Scholar	2018
Elliot T. Bowers Honors College Graduate	2018
SHSU Summa Cum Laude Graduation Honor	2018
Outstanding Delta Tau Alpha Member	2018
Ann Christian Memorial Service Award	2017
Who's Who Among College Students Award	2016, 2017
Houston Livestock Show & Rodeo Calf Scramble Intern	2016
SHSU Agricultural Ambassador	2015-2017
SHSU Delta Tau Alpha Member	2015-2018
Secretary	2016-2017
SHSU Agribusiness Association Member	2015-2018
Heath Schielack Memorial Cook-Off Chair	2016
SHSU Block & Bridle Association	2015-2018
Historian	2016-2017
Mud Run Chair	2016
National Society of Collegiate Scholars	2015-2018
Society for Collegiate Leadership and Advancement	2015-2018
SHSU Alpha Chi	2015-2018
American FFA Degree Recipient	2015
SHSU Collegiate FFA	2014-2018
Treasurer	2016-2017
Sentinel	2015-2016
SHSU Alpha Lambda Delta Member	2014-2018
SHSU Elliot T. Bowers Honors College Member	2014-2018
SHSU President's List	2014-2018
SHSU Dean's List	2014-2018
Mid-Coast Santa Gertrudis Association Member	Continuous
Santa Gertrudis Breeder International Member	Continuous
Texas Farm Bureau Member	Continuous
Texas Cattlewomen's Association Member	Continuous
Southeast Texas Independent Cattlemen's Association Member	Continuous

COMMITTEES SERVED

SHSU Academic Review Panel	2018-2019