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Utilizing Legumes to Improve Production and Nutritive Value of Intermountain West Pastures

Jacob T. Briscoe
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UTILIZING LEGUMES TO IMPROVE PRODUCTION AND NUTRITIVE VALUE OF INTERMOUNTAIN WEST PASTURES

by

Jacob T. Briscoe

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Plant Science

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UTAH STATE UNIVERSITY
Logan, Utah

2018
ABSTRACT

Utilizing Legumes to Improve Production and Nutritive Value of Intermountain West Pastures by Jacob T. Briscoe, Master of Science Utah State University, 2018

Major Professor: Dr. Earl Creech
Department: Plants, Soils and Climate

Forage legumes increase pasture productivity and nutritive value when incorporated into cool-season grass pastures of the Intermountain Western USA. Studies were conducted to determine the best method to successfully inter-seed legumes into grass pastures, animal grazing preference in mixed birdsfoot trefoil-grass pastures and the seasonal change in nutritive value of six forage species. The effect of light tillage, close mowing, and a low rate (232.2 g ha⁻¹ ae) of glyphosate [N-phosphonomethyl) glycine] on the frequency of alfalfa, birdsfoot trefoil and cicer milkvetch presence when inter-seeded into grass monocultures was tested. Early spring and fall inter-seeding was unsuccessful, while late spring was moderately successful with an overall alfalfa frequency of 30% after a year. Summer plantings were most successful with birdsfoot trefoil, alfalfa, and cicer milkvetch frequency of 42, 32, and
22%, respectively. The grazing preference of heifers in mixed pastures of birdsfoot trefoil with tall fescue, perennial ryegrass, orchardgrass and meadow bromegrass was tested. When compared to tall fescue, birdsfoot trefoil was always utilized more, with an average of 23 percentage points difference. In most observations, birdsfoot trefoil utilization was higher than orchardgrass utilization, with an average difference of 14 percentage points. In contrast, there was no difference in utilization in all comparisons with meadow bromegrass. During early growth, perennial ryegrass utilization was higher than birdsfoot trefoil utilization, but no difference in utilization was detected in later observations, though, perennial ryegrass averaged 9 percentage points higher utilization than birdsfoot trefoil. In the third study, the interaction of growth stage and time of season on the nutritive value of alfalfa, birdsfoot trefoil, cicer milkvetch, orchardgrass, perennial ryegrass and tall fescue was determined. In spring to early summer, legume nutritive value decreased rapidly with maturity. In midsummer, nutritive value decreased slowly with maturity, while in late summer the nutritive value remained stable. In the spring, grass nutritive value decreased rapidly, while in mid to late summer all grass regrowth was vegetative and nutritive value remained stable. By inter-seeding in the summer, effectively managing mixed pastures, and utilizing forage at its highest nutritive value, legumes can benefit the pastures of the Intermountain West.
PUBLIC ABSTRACT

Utilizing Legumes to Improve Production and Nutritive Value of Intermountain West Pastures

Jacob T. Briscoe

Pastures in the Intermountain Western United States mainly consist of cool-season grasses which lack production without supplemental nitrogen. Legumes provide nitrogen at reduced cost compared to nitrogen fertilizer. There is a need for proven methods of inter-seeding legumes into existing cool-season grass pastures as well as knowledge of how animals prefer legumes to grasses and how the nutritive value of forages change throughout the growing season. This research provides a resource for effective integration of legumes into pastures of the Intermountain West. Alfalfa, birdsfoot trefoil, and cicer milkvetch were inter-seeded into existing cool-season grass pastures following pretreatments of light tillage, mowing and glyphosate. Early spring and fall inter-seeding was unsuccessful, while late spring was moderately successful with overall alfalfa frequency of 30% after a year. Summer inter-seeding was the most successful with birdsfoot trefoil, alfalfa, and cicer milkvetch frequency of 42, 32, and 22%, respectively. In the animal preference study, when compared to tall fescue, birdsfoot trefoil was always utilized more. In most observations birdsfoot trefoil utilization was higher than orchardgrass. While in all comparisons with meadow bromegrass there was no difference in utilization. During early growth, perennial ryegrass utilization was higher than birdsfoot trefoil utilization, but no difference in
utilization was detected in later observations. Overall, birdsfoot trefoil was utilized 73% overall while grass utilization was 74, 67, 64, and 53 % for perennial ryegrass, meadow bromegrass, orchardgrass and tall fescue, respectively. The interaction of growth stage and time of season on the nutritive value of alfalfa, birdsfoot trefoil, cicer milkvetch, orchardgrass, perennial ryegrass and tall fescue was determined. In the spring to early summer, legume nutritive value decreased rapidly with maturity, in midsummer the nutritive value decreased slowly with maturity, while in late summer the nutritive value remained stable. In the spring, grass nutritive value decreased rapidly, while in mid to late summer all grass regrowth was vegetative and the nutritive value remained stable. By inter-seeding in the summer, effectively managing mixed pastures, and utilizing forage at its highest nutritive value, legumes can benefit the pastures of the Intermountain West.
Dedicated to my best friend and wife, Courtney, who constantly encouraged and supported me through the process of this degree
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Jacob T. Briscoe
## CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT .......................................................................................................................... ii</td>
</tr>
<tr>
<td>PUBLIC ABSTRACT ................................................................................................................ iv</td>
</tr>
<tr>
<td>DEDICATION ........................................................................................................................... vi</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS ............................................................................................................. vii</td>
</tr>
<tr>
<td>LIST OF TABLES .................................................................................................................... x</td>
</tr>
<tr>
<td>LIST OF FIGURES ................................................................................................................... xi</td>
</tr>
</tbody>
</table>

### CHAPTER

1. LITERATURE REVIEW

   - Introduction ....................................................................................................................... 1
   - Grass-Legume Mixtures .................................................................................................... 2
   - Forage Nutritive Value ..................................................................................................... 3
   - Forage Species .................................................................................................................. 5
   - Inter-seeding Legumes into Existing Grass Pastures ....................................................... 9
   - Research Objectives ........................................................................................................ 11
   - References ...................................................................................................................... 11

2. INTER-SEEDING FORAGE LEGUMES INTO EXISTING COOL-SEASON GRASS PASTURES

   - Abstract ............................................................................................................................ 19
   - Introduction ..................................................................................................................... 20
   - Materials and Methods ................................................................................................... 23
   - Results and Discussion
     - Millville ....................................................................................................................... 27
     - Lewiston ....................................................................................................................... 29
     - Panguitch ...................................................................................................................... 32
   - Conclusions ..................................................................................................................... 34
   - References ...................................................................................................................... 36
3. CATTLE GRAZING PREFERENCE IN BINARY MIXTURES OF BIRDSFOOT TREFOIL WITH MEADOW BROMEGRASS, ORCHARDGRASS, PERENNIAL RYEGRASS, AND TALL FESCUE

Abstract .................................................................................................................. 48
Introduction ............................................................................................................. 49
Materials and Methods............................................................................................ 51
Results
  Alternating Rows .................................................................................................... 56
  Mixed Rows ............................................................................................................ 58
  Preferred Grazing Location ...................................................................................... 59
Discussion .................................................................................................................. 61
Conclusion .................................................................................................................. 64
References .................................................................................................................. 64

4. MEASURING FORAGE ENERGY IN ALFALFA, BIRDSFOOT TREFOIL, CICER MILKVETCH, ORCHARDGRASS, PERENNIAL RYEGRASS AND TALL FESCUE AT DIFFERING STAGES OF MATURITY

Abstract .................................................................................................................. 76
Introduction ................................................................................................................ 77
Materials and Methods.............................................................................................. 80
Results
  Legume TDN .......................................................................................................... 85
  Legume CP .............................................................................................................. 86
  Legume NDF ........................................................................................................... 86
  Grass TDN .............................................................................................................. 89
  Grass CP .................................................................................................................. 89
  Grass NDF .............................................................................................................. 90
Conclusions ............................................................................................................... 92
References ................................................................................................................. 93

5. SUMMARY AND CONCLUSIONS

References ................................................................................................................. 109
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>Date of planting, season of planting, pasture species and soil type for each location and location-year</td>
</tr>
<tr>
<td>2-2</td>
<td>Average temperature (°C) and monthly precipitation (mm) in Panguitch, UT, Lewiston, UT, and Millville, UT from April to September and the 30-year average (1981-2010)</td>
</tr>
<tr>
<td>3-1</td>
<td>Grazing dates for three stocking cycle in 2016 and 2017</td>
</tr>
<tr>
<td>4-1</td>
<td>Sampling schedule at Evans farm, with growth series, the number of samples per growth series and sample date. Defoliation dates of each block and number of days after defoliation provided as a comparison between growth series.</td>
</tr>
<tr>
<td>4-2</td>
<td>Probabilities for differences between harvests within growth series 1-4 and among growth series.</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>2-1</td>
<td>Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 11 (B) months after planting. Planted 27 June 2016 at Millville, UT into tall fescue and Kentucky bluegrass mixed pasture on a silty clay loam soil. ......................................................................................................................... 43</td>
</tr>
<tr>
<td>2-2</td>
<td>Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 11 (B) months after planting. Planted 26 July 2013 at Lewiston, UT into tall fescue on a fine sandy loam soil................................................................................................................................. 44</td>
</tr>
<tr>
<td>2-3</td>
<td>Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at 36 months after planting. Planted 26 July 2013 at Lewiston, UT into tall fescue on a fine sandy loam soil. ................................................................. 45</td>
</tr>
<tr>
<td>2-4</td>
<td>Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 14 (B) months after planting. Planted 6 June 2016 at Panguitch, UT into tall fescue on a loam soil. ............................................................................................................................... 46</td>
</tr>
</tbody>
</table>
Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 14 (B) months after planting. Planted 6 June 2016 at Panguitch, UT into meadow bromegrass on a loam soil...

Planting layout of grass-birdsfoot trefoil mixtures, stripes depict alternating rows, solid depicts mixed rows, dotted lines indicate paddock layout, animals had access to both mixed and alternating rows. Animals started grazing in the east paddock, before moving to the next paddock, as indicated by the arrow. Individual paddocks were grazed for seven days, which was called a stocking period; following grazing, paddocks were rested for 28 days, resulting in a 35 day stocking cycle...
Percent utilization in alternating rows of perennial ryegrass (PRG), meadow bromegrass (MB), orchardgrass (OG) and tall fescue (TF) with birdsfoot trefoil (BFT) in three stocking cycles. Overall mixed row utilization is shown for comparison. Shorter, darker bars show day 3 utilization, while taller, opaque bars show day 7 utilization. Graph D compares cycle 1 day 7 utilization (dark bars) with cycle 3 day 7 utilization (opaque bars). Bars within a grass-trefoil group followed by different letters are significantly different ($P=0.05$). Uppercase letters indicate differences on day 3 (Graphs A, B, and C) and cycle 1 (Graph D) and lowercase letters indicate differences on day 7 (A, B & C) and cycle 3 (D)...

Percent utilization in mixed rows of perennial ryegrass (PRG), meadow bromegrass (MB), orchardgrass (OG) and tall fescue (TF) with birdsfoot trefoil (BFT) in three stocking cycles. Shorter, darker bars show day 3 utilization, while taller, opaque bars show day 7 utilization. Graph D compares cycle 1 day 7 utilization (dark bars) with cycle 3 day 7 utilization (opaque bars). Bars within a grass-trefoil group followed by different letters are significantly different ($P=0.05$). Uppercase letters indicate differences on day 3 (Graphs A, B, and C) and cycle 1 (Graph D) and lowercase letters indicate differences on day 7 (A, B & C) and cycle 3 (D)...
3-4 Visual representation of Rep 1 pasture and Rep 2 pasture, showing water access and alleyways that could influence animal behavior within the pasture. Numbers indicate percent of observations with animals in either mixed or alternating row in each grass- birdsfoot trefoil mixture

3-5 Percent of time heifers observed in mixed versus alternating rows at the time of observation on day 1 and day 3 of grazing. Day 1 observation was made within an hour of heifers being turned into a new paddock and between 0800 and 1000 on day 3. Averaged over both 2016 and 2017 with both repetitions shown

4-1 Percent total digestible nutrients (TDN), crude protein (CP), and neutral detergent fiber (NDF) of alfalfa, birdsfoot trefoil, cicer milkvetch at multiple sample dates (maturities) in four growth series across the growing season

4-2 Percent total digestible nutrients (TDN), crude protein (CP), and neutral detergent fiber (NDF) of orchardgrass, perennial ryegrass and tall fescue at multiple sample dates (maturities) in four growth series across the growing season
CHAPTER 1
LITERATURE REVIEW

INTRODUCTION

Pastures are used all over the world to provide feed for livestock and reduce effort and costs associated with feeding animals. In 2007, there were about 614 million acres in the United States dedicated to pasture, with 303 million acres in the Intermountain region (USDA-ERS 2016). In the Intermountain region of the Western United States of America most pastures consist of cool-season grasses. Cool-season, or C3 grasses, are “best adapted to cool climates with adequate moisture conditions” (Moser and Hoveland, 1996). In some cases, precipitation provides adequate moisture, such as in the Pacific Northwest, but in other areas irrigation is provided. Depending on the species, cool-season grasses can generally tolerate many different soil types and conditions (Moser and Hoveland, 1996). Soils with a high pH and high salt content or soils with a high water table can all be productive cool-season grass pastures if the right species is planted.

Pasture production improves with fertilization, particularly nitrogen, which is generally viewed as the most limiting nutrient to plant growth (Solomon et al., 2011; Chinea and Arevalo, 2013). According to Wedin (1974), when fertilized with nitrogen, the forage yield of cool-season grasses can increase by three- to six-fold. Applying
nitrogen fertilizer is costly. Livestock operations in the United States of America spent an average of $3,787 in 2015 and $3,332 in 2016 per farm on fertilizer and other soil conditioners (USDA-NASS, 2017). However, nitrogen for grasses does not have to be applied in the form of fertilizer. Rather, nitrogen can be provided by legumes, which fix atmospheric nitrogen. The legumes, when inoculated with the proper Rhizobia bacteria, convert atmospheric nitrogen into a usable form for the plants. In order to improve an animal’s diet, pastures are often supplemented with limiting nutrients. This can also be provided by introducing legumes into the pasture, which improves the forage nutritive value (Sleugh et al., 2000; Solomon et al., 2011; Brink et al., 2015).

Pastures in the Intermountain region of the United States consist of a variety of cool-season grass monocultures as well as some grass-forage legume mixtures. Cool-season perennial or annual grasses can provide the major nutrients for most domesticated ruminants and horses (Burns and Bagley, 1996). However, over the course of the growing season the nutritional value of grasses decline, so adding legumes to a pasture can maintain the nutritive value of the pasture throughout the season.

**GRASS-LEGUME MIXTURES**

Including legumes in cool-season grass pastures provide a boost in pasture productivity as well as increased nutritive value for the animals (Burns and Bagley, 1996). A mixture will provide higher daily animal responses than grass monocultures (Burns and Bagley, 1996). Using a grass-legume mixture provides higher production
because under temperate conditions, grass forage production is often bimodal (Moser and Hoveland, 1996). This means, in general, cool-season grasses exhibit prolific spring growth, followed by reduced growth and temporary dormancy in midsummer, and a second, but reduced growth phase occurring in the fall (Burns and Bagley, 1996). This bimodal production or ‘summer slump’ results in less production during summer months. However, many legumes produce well in the heat of the summer. A study of grass and legume monocultures and binary mixtures shows better forage distribution throughout the season as well as an increase in overall forage yield when legumes were included (Sleugh et al., 2000; Cox et al., 2017). Sleugh at al. (2000) showed the most productive legume in mixture with orchardgrass, smooth bromegrass and intermediate wheatgrass was alfalfa when compared to birdsfoot trefoil and kura clover.

FORAGE NUTRITIVE VALUE

There are numerous factors that determine the nutritive value of forage, including forage species, growth stage, environment, and fertilization (Moore, 1994; Allen et al., 2013). One species may have high nutritive value in a certain environment, but considerably less in another environment. Orchardgrass, for example, may have high nutritive value in a well-watered pasture in the spring but will have reduced nutritive value in a dry pasture in the middle of the summer. As plants mature they typically lose nutritive value. This drop can partially be attributed to a decrease in the leaf to stem ratio (Nelson and Moser, 1994). This drop is found in both grasses and
legumes, though the leaf to stem ratio is different for the two. Leaf tissue is typically more digestible, less fibrous, and consists of higher protein content. At an early stage of growth, it has been observed that there is a greater yield of leaf tissue than stem tissue, but at later growth stages there are lower yields of leaf tissue (Griffin and Jung, 1983; Nordkvist and Aman, 1986; Albrecht et al., 1987).

The nutritive value of cool-season grasses in pasture is generally adequate for animal production in the first part of the growing season, when the leaf to stem ratio is favorable. But during the ‘summer slump’ when grass production is depressed the nutritive value of the pasture may not be adequate for animal production. By integrating legumes into the pasture, not only does forage production improve, but so does nutritive value. Studies have shown that adding legumes to a mixture the in vitro dry matter digestibility and crude protein are increased compared to the grasses in monoculture. The neutral detergent fiber in grass-legume mixtures is less (better) than in grass monocultures (Sleugh et al., 2000; Cox, 2013).

Forage nutritive value can be measured by animal productivity, as in daily gains, milk production or by concentration of nutrients, digestibility of nutrients, and the composition of digestion end products (Moore, 1994). Nutrient values typically used to convey parts of nutritive quality are digestibility, crude protein (CP) and fiber, though there are other methods to measure nutritive value including energy, digestible neutral detergent fiber (dNDF) and fat. Digestibility is measured in a few ways, but many studies measure and express digestibility by in vitro dry matter digestibility. Crude protein is a
calculated value from the nitrogen content of a sample, 6.25 multiplied by the nitrogen. Fiber is expressed as neutral detergent fiber (NDF) or acid detergent fiber (ADF). NDF is an approximate measure of the cell wall elements, such as hemicellulose and is an inverse predictor of intake for animals (Belyea and Ricketts, 1993; Ball et al., 2001). ADF approximates the cellulose and lignin of the forage, and is used to predict digestibility (Ball et al., 2001). Energy of forage is often expressed as digestible energy, which is calculated from other quality measures. An equation developed by Fonnesbeck (1981) uses the crude protein, acid detergent fiber, hemicellulose percentage, fat, digestible nonstructural carbohydrate, and ash to determine the digestible energy of a forage (Pagan, 1998). Another, updated method of determining energy, or total digestible nutrients (TDN), is calculated using neutral detergent fiber, in vitro true digestibility, crude protein, ether extract and ash (Saha et al., 2013; National Research Council, 2001).

**FORAGE SPECIES**

Each forage species has its own unique attributes and qualities that provide a benefit or a detriment to a pasture. Some grow better in certain environments than others and some are better suited to the Intermountain Region of the Western United States.

Tall fescue (*Festuca arundinacea* Schreb.) is a very common grass species in the United States, though according to Sleper and West (1996) tall fescue is better adapted
to the transition zone than the mountain region of the United States. Tall fescue is a perennial bunchgrass that produces well in cool and humid climates with soil pH of 5.5 to 7 (Henson, 2001). Like other cool-season grasses tall fescue produces best in the spring and fall and especially in soil temperatures as low as 40 degrees F. The hot summer months result in very little growth of the grass. (Sleper and West, 1996; Jensen et al., 2001a; Roberts et al., 2009) In the spring when the grass is young, it is palatable for cattle, but as it ages it becomes coarse and less palatable. This decreased palatability results in animals preferentially grazing other species and eventually causes those species to be grazed out of the pasture (Jensen et al., 2001a). In pastures, tall fescue is often more productive than orchardgrass and perennial ryegrass, but has similar or slightly lower nutritive value in comparison to orchardgrass (Hannaway et al., 1999a; Hannaway et al. 1999b; Cox et al., 2017).

Often, tall fescue is infected with an endophytic fungus. This fungus is associated with increased persistence, growth and higher resistance to certain stresses (Belesky and West, 2009). Drought-stress or stresses associated with high pH or soil nutrients are mitigated when tall fescue is infected with the endophyte. The endophyte infected plants are more resistant to certain stresses, but the endophyte sometimes causes “fescue toxicosis” in cattle. Fescue toxicosis along with fescue foot and bovine fat necrosis are caused when animals feed on the infected plants (Sleper and West, 1996). The benefits of tall fescue endophyte are not realized in pastures of the Intermountain region of the western United States; therefore, endophyte free tall fescue is used.
Orchardgrass (*Dactylis glomerata* L.) is a perennial, cool-season, bunchgrass. Orchardgrass is well adapted to grow in shade and is palatable to livestock throughout the growing season (Jensen et al., 2001a). Orchardgrass matures earlier than most other cool-season grasses including tall fescue and perennial ryegrass (Henning and Risner, 1993; Hall, 2008). While it is more palatable than tall fescue, it is less drought resistant and more susceptible to disease and insects. Orchardgrass is highly responsive to nitrogen fertilizer, when coupled with sufficient water. Orchardgrass is among the highest producing cool-season grasses in the Intermountain region behind tall fescue (Jensen et al., 2001a; Hall, 2008). The nutritive value of orchardgrass is similar to tall fescue when comparing crude protein and neutral detergent fiber (Allen et al., 2013; Cox et al., 2017).

Perennial ryegrass (*Lolium perenne* L.), or English ryegrass, is closely related to annual ryegrass, with only a few morphological differences (Jensen et al., 2001a). However, perennial ryegrass is more suited to pastures due to its longevity, though perennial ryegrass is relatively short lived compared to other cool-season grasses. Forage production of perennial ryegrass declines rapidly in the summer months when the temperatures are greater than 80 degrees F (Jensen et al., 2001a), and perennial ryegrass is less productive than orchardgrass or tall fescue throughout the growing season (Jensen et al., 2001b). However, perennial ryegrass shows better nutritive value characteristics than either tall fescue or orchardgrass (Jensen et al., 2001b; Allen et al., 2013). In conjunction, perennial ryegrass is more palatable than most other species,
which results in preferential grazing, especially when planted with other grasses (Jung et al., 1996; Jensen et al., 2001a).

Alfalfa *Medicago sativa* L. is one of the most widely grown forage species in the world and has been adapted to multiple environments and uses (Bolton et al., 1972). Alfalfa is grown for pasture as well as hay production in the Intermountain region of the United States. Alfalfa is most productive when it receives adequate rainfall or irrigation as well as high temperature (Lowe et al., 1972) but is also somewhat drought tolerant. The wide use of alfalfa is mainly due to its wide adaptation, but also to its high palatability and nutritive value, namely, high crude protein (Sleugh et al., 2000; Cox et al., 2017). As a legume, it is very efficient at fixing atmospheric nitrogen for plant use. One limitation with alfalfa is that it causes bloat in ruminants when they eat young, lush plants during certain times; such as heavy dew or a frost, which can cause increased bloating (Hall 1994).

Birdsfoot trefoil *Lotus corniculatus* L., like alfalfa, is a perennial forage legume. It produces well in less than ideal soil conditions, like low pH, poorly drained or low fertility soils (Hall and Cherney, 1993). Birdsfoot trefoil may produce well in less than ideal soils, but it produces best in well-drained, fertile soils. Birdsfoot trefoil’s best production is less than alfalfa, perhaps only 50 to 80 percent the yield of alfalfa on similar soils (Hall and Cherney, 1993; Sleugh et al. 2000; Sheaffer et al., 2003); however, studies have shown that birdsfoot trefoil can have higher production than alfalfa in the heat of the summer (Cox et al., 2017). An advantage of birdsfoot trefoil is that it does
not cause bloat in grazing animals (Hall and Cherney, 1993; Jensen et al., 2001a; Bush, 2002). Though somewhat less productive than alfalfa, birdsfoot trefoil is similar in nutritional characteristics, with slightly lower crude protein and lower neutral detergent fiber values as well (Sleugh et al., 2000; Cox et al., 2017).

Cicer Milkvetch (*Astragalus cicer* L.) is a less well known forage legume. Cicer milkvetch is difficult to establish, but once established it produces well, similar in yield or better than alfalfa (Townsend et al., 1990; Jensen et al., 2001a; Tilley et al., 2008). Cicer milkvetch is a perennial that spreads with rhizomatous growth, so it persists well in pastures and can be grazed for long periods (Tilley et al., 2008). Cicer milkvetch is most productive in soils with adequate moisture, but will survive drought (Sheaffer et al., 2003; Acharya et al., 2006). Cicer milkvetch has high nutritive content, mainly due to a high leaf to stem ratio and retention of leaves even when dried (Tilley et al., 2008). Cicer milkvetch has a similar nutrient content to both birdsfoot trefoil and alfalfa (Acharya et al., 2006; Cox et al., 2017).

**INTER-SEEDING LEGUMES INTO EXISTING GRASS PASTURE**

Many existing pastures used for grazing livestock in the Intermountain region are predominately cool-season grasses. A pasture may have originally been planted to grass-legume mixes but over time the grass dominates. This situation could be due to a variety of reasons, such as improper soil nutrients, poor legume nodulation or improper grazing management (Barnhart, 2004). A grass pasture that isn’t very vigorous could be
due to a lack of soil nitrogen, which could be alleviated by adding nitrogen fixing legumes. By including grasses with bloating legumes, the bloating qualities of the legume could be mediated (Kilgore, 1998; Jensen et al., 2001a), though the bloating could be made worse in some circumstances. Inter-seeding legumes into grass pastures may also improve the nutritive value of the total forage (Cuomo et al., 2001).

Adding legumes into an existing pasture can be difficult since established plants usually out-compete new seedlings (Brummer et al., 2011). Broadcasted seed have problems reaching the soil and establishing seed-soil contact. (Brummer et al., 2011). Finding a way to reduce competition from existing grasses, while ensuring soil contact is essential to establishing an adequate stand. A few methods of establishing legumes into grass pasture have been tested. Prior to planting the legume seed the grass competition can be reduced in multiple ways, such as: by close mowing or grazing, light tillage of the soil, or applying a reduced rate of herbicide to suppress grasses (Wheaton and Roberts, 1993; Brummer et al., 2011). Following treatment, the seed should be drilled into the existing sod with a no-till drill. This type of drill should be heavy enough to drill in the sod and, in some cases, will have coulters to break up the soil and provide a competition-free furrow for new seedlings (Brummer et al., 2011).

Following planting, the legumes must be given time to establish before they are grazed. With some legumes, like cicer milkvetch, this could take some time, up to a year or more. Others, such as alfalfa, can be grazed rotationally, without overgrazing, after the first establishment year (Wheaton and Roberts, 1993).
RESEARCH OBJECTIVES

The research objectives of this project are as follows:

Objective 1)

Compare the efficacy of three methods of stand suppression: close mowing, a low rate of glyphosate, and light tillage on the frequency of alfalfa, birdsfoot trefoil and cicer milkvetch presence when inter-seeded into existing grass pastures.

Objective 2)

Determine the grazing preference of dairy cattle in binary mixtures of birdsfoot trefoil with orchardgrass, meadow bromegrass, tall fescue, and perennial ryegrass.

Objective 3)

Elucidate how forage nutritive value of alfalfa, birdsfoot trefoil, cicer milkvetch, orchardgrass, perennial ryegrass and tall fescue change with the interaction of progressing growth stage and time of season.

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CHAPTER 2

INTER-SEEDING FORAGE LEGUMES INTO EXISTING COOL-SEASON GRASS PASTURES

ABSTRACT

Successfully inter-seeding forage legumes into cool-season grass pasture will improve productivity and forage nutritive value. Our objective was to compare close mowing, light tillage and a low rate of glyphosate [N-phosphonomethyl) glycine] on the frequency of alfalfa (Medicago sativa L.), birdsfoot trefoil (Lotus corniculatus L.) and cicer milkvetch (Astragalus cicer L.) presence when inter-seeded into cool-season grass monocultures. Plots were established at three Utah locations in 2013, 2014 and 2016. Stand-suppression pretreatments were applied in a longitudinal direction and legumes inter-seeded perpendicular to the pretreatments. Frequency of presence (%) was measured at 1 and 12 months after planting. Early spring and fall plantings were not successful. Late spring plantings were moderately successful with overall alfalfa frequency of 30% after a year, with pretreatments ranging from 50% to 14%. Birdsfoot trefoil and cicer milkvetch frequency was not different than zero in late spring plantings. Summer plantings were most successful with birdsfoot trefoil, alfalfa, and cicer milkvetch frequency of 42, 32, and 22%, respectively, after a year. For alfalfa, pretreatments ranged from 91% in the mowing to 14% in the untreated, birdsfoot trefoil pretreatments ranged from 62% in the mowing to 24% in the glyphosate and cicer
milkvetch pretreatments ranged from 28% in the mowing to 9% in the untreated. An earlier planting showed cicer milkvetch increasing over a three year period. After a year, no pretreatment was significantly different than another, while frequency of alfalfa was greater than birdsfoot trefoil, and cicer milkvetch was not significantly different than zero.

INTRODUCTION

Many existing pastures used for grazing livestock in the Intermountain region of the Western USA are dominated by decadent stands of cool-season grasses. These are often characterized as grass monocultures with high productivity in the spring, followed by low summer productivity and moderate productivity in the fall. The pastures may have originally been planted to a desirable mixture containing both grasses and legumes but over time the grass has dominated. This situation could be due to poor soil fertility, the wrong legume, poor nodulation, or improper grazing management (Barnhart, 2004). A grass pasture with low productivity is likely lacking adequate soil nitrogen, which is easily alleviated with the addition of nitrogen fertilizer. Nitrogen fertilizer however, is expensive, and productivity can otherwise be improved with the proper use of the right forage legume as demonstrated by Cox et al. (2017) and at the same time increase forage nutritive value beyond that possible with grass monocultures (Cuomo et al. 2001). The most common forage legume is alfalfa (Medicago sativa L.) but it causes bloat in ruminant livestock. Others, such as birdsfoot trefoil (Lotus corniculatus L.) and
cicer milkvetch (*Astragalus cicer* L.), are lesser known don’t cause bloat and are viable choices.

The best way to ensure a productive pasture that includes a good mixture of grasses and legumes is a complete renovation that includes tillage and replanting. The downside is that it is costly procedure and takes a pasture out of production until establishment is complete (Kunelius et al., 1982). As an alternative, producers frequently express the desire to inter-seed legumes into an existing grass pasture. However, successfully establishing legumes into an existing grass pasture can be difficult since established plants usually out-compete new seedlings (Brummer et al., 2011).

Successful inter-seeding requires that the established grasses be suppressed to allow the legumes a chance for establishment and survival. Numerous methods of suppressing grasses have been tested. Herbicide suppression options include glyphosate [N-phosphonomethyl]glycine] (Cuomo et al., 2001), dalapon (2,2-dichloropropanoic acid) (Anderson and Safley, 1996), clethodim ([(E,E)-(6)-2-[1-[[3-chloro-2-propenyl]oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] (Misar et al., 2016), or paraquat (1,1′-dimethyl-4,4′bipyridinium ion) (Kunelius et al., 1982) at various rates and timings. In addition to herbicide, mowing (Brummer et al., 2011) or clipping (Guretzky et al., 2004) the grass can be used to simulate grazing. Other studies use grazing by sheep (*Ovis aries*) (Seguin et al., 2001) or cattle (*Bos taurus*) (Min and Moyer, 2015) to suppress the grass to 5, 10, or 13 cm sward heights. Light tillage for grass suppression such as using a disk or harrow (Anderson and Safley, 1996) could also
be used. The method of grass suppression could be determined by the legume being planted. For example, Min and Moyer (2015) assert birdsfoot trefoil benefits from the quick impact of chemicals, while white clover needs a longer establishment period which could be achieved with grazing.

Following grass suppression the legume must establish seed-soil contact. Proper seed-soil contact can be achieved using no-till, or sod seeding drills, or broadcast seeding (Olsen et al., 1981; Cuomo et al., 2001; Jennings et al., 2012). A no-till, or sod seeding drill, should be heavy enough to penetrate the sod, or use coulters to break up the soil and provide a competition-free furrow for new seedlings (Brummer et al., 2011). Though broadcast seeding has worked for some, Brummer et al. (2011) argues that broadcasted seed has problems reaching the soil and establishing seed-soil contact. Jennings et al. (2012) recommends pulling a harrow, tire drag or similar implement following a broadcast spreader to rough up the soil surface. Cuomo et al. (2001) recorded greater than 20% legume establishment using a harrow or light disking after broadcasting seed. By roughing up the soil surface, the seeds have a greater chance of achieving seed-soil contact.

Once planted, the legumes must be allowed time to establish before they are grazed. With some legumes, like cicer milkvetch or kura clover, this could take up to a year or more (Laberge et al., 2005; Brummer et al., 2011). Others, such as alfalfa, may be grazed rotationally, without overgrazing, a month or two after establishment (Wheaton and Roberts, 1993, Martin et al., 1983). Gettle et al. (1996) recommends only
planting part of a pasture each year since the pasture will be out of production following inter-seeding. Once plants are established the pasture needs to be managed carefully to ensure the legumes remain in the pasture (Barnhart, 2004; Jennings et al., 2012).

There is existing research regarding inter-seeding legumes into cool-season and warm-season pastures; however, research is lacking on inter-seeding into irrigated pastures in the Intermountain region of the Western United States. While inter-seeding alfalfa and birdsfoot trefoil have been studied, there is no research on incorporating cicer milkvetch into existing cool-season pastures. The objectives of this research were to 1) compare the efficacy of three methods of stand suppression: close mowing, light tillage and glyphosate and 2) examine the frequency of presence of three inter-seeded legume species: alfalfa, birdsfoot trefoil and cicer milkvetch into cool-season grass pastures of the Intermountain Western USA.

**MATERIALS AND METHODS**

Inter-seeding studies were conducted at three Utah locations. The first location was the Utah State University Intermountain Irrigated Pasture Facility near Lewiston, Utah (41° 57' 1.4312" N, 111° 52' 30.0086" W), the second was on the private farm of Joe Fuhriman (a local cattle producer) in Millville, Utah (41° 41' 30.2359" N, 111° 50' 5.3238" W), and the third location was at Utah Agricultural Experiment Station’s Panguitch Research Farm in Panguitch, Utah (37° 52' 4.965"N, 112° 26' 8.2378" W). The soil at Lewiston is a Kidman fine sandy loam, Millville a Nibley silty clay loam
and Panguitch a Jodero loam (Soil survey staff, 2012). Planting at the Pasture facility in Lewiston was on 26 July 2013 and again on 22 May 2014 (Table 2-1), into healthy stands of tall fescue. Millville was planted on 22 Aug. 2014 and again on 27 June 2016, into pastures containing approximately 30% tall fescue, 60% Kentucky bluegrass and 10% assortment of other grass species. At Panguitch both plantings were made on 6 June 2016, one into a tall fescue pasture, which had substantial old, decadent growth and the second into meadow bromegrass, which had limited growth and dry soil. Prior to the inter-seeding, pastures had either been hayed with sufficient time for grass regrowth or grazed in the case of Millville.

At all locations, stand-suppression pretreatments were applied in a longitudinal direction and legumes inter-seeded perpendicular to the pretreatments, in a strip split plot design. The pretreatments included a 10 cm deep vertical tillage with 30% soil disturbance using straight shanks on a Triple K tillage tool (McKee Industries Limited, Lincoln, NE), mowing to 4 cm stubble length with riding lawn mower and 0.43 L ha⁻¹ (232.2 g ha⁻¹ ae) of glyphosate [N-phosphonomethyl)glycine], and untreated. The mowing was intended to simulate close grazing. The inter-seeded legumes were ‘Rugged’ alfalfa, ‘Monarch’ cicer milkvetch, with two cultivars of birdsfoot trefoil, ‘Norcen’ was planted in Lewiston for both plantings, while ‘Pardee’ was used for plantings in Panguitch and Millville. Planting rates for the legumes were 15 kg ha⁻¹ of cicer milkvetch, 9 kg ha⁻¹ of birdsfoot trefoil, and 12 kg ha⁻¹ of alfalfa. The high seeding rates were used to increase likelihood of good stand establishment. Prior to planting the
cicer milkvetch was scarified to ensure at least 70% germination. The plots in Lewiston, and the first planting in Millville were planted using a Tye drill (The Tye Co., Lockney, TX), while the second planting at Millville and both at Panguitch were planted with a Truax Flex II drill (New Hope, MN). Both drills were 1.8 m wide, no-till, range drills with 15 cm row spacings.

Locations differed with regard to type and availability of irrigation. At Lewiston there was on-demand irrigation provided by hand-moved sprinklers immediately after planting and seven days later to ensure establishment, and regular irrigation was provided throughout the season. In Millville, irrigation was turn-based flood irrigation. The August planting in Millville was only watered once after planting, whereas the June planting was watered immediately following planting and multiple times throughout the growing season. The August planting in Millville was only watered once because the producer’s irrigation water was cut off due to drought. Both Lewiston and Millville had grazing animals present at some time following inter-seeding so the plots were fenced to keep the livestock out. Irrigation at Panguitch was provided by on-demand wheel line irrigation for the first year, then a pivot irrigation system was installed the second year. Pivot installation did not interrupt the study. Irrigation was provided immediately after planting and 3 weeks after planting to ensure establishment, regular irrigation occurred throughout the summers of 2016 and 2017.

To determine the frequency of presence of the inter-seeded legume stands, plants were counted one, three and 12 months after planting. A grid was used for
counting each pretreatment × species combination as described by Vogel and Masters (2001). In Lewiston a 6 by 12 grid with 72 cells each measuring 6.35 cm per side was used. The total number of cells containing a legume was recorded. In the Millville and Panguitch locations a different grid was used, this grid was 5 by 14 with 70, 7.6 cm cells. All data was converted to percent for analysis and presentation.

Data was analyzed using SAS PROC GLM as a strip-split-plot design. The experimental unit for analysis was percent of cells in the grid containing a legume plant. Stand-suppression pretreatments and inter-seeded legumes were analyzed as fixed effects. The season of planting and the grass the legumes were planted into were considered random effects, as well as repetition. The separate planting at each location were treated independent as location/years. Mean separation was determined by LSD at $P=0.05$.

**RESULTS AND DISCUSSION**

Overall differences in frequency were detected among the legume species chosen for inter-seeding ($P<0.001$) and among pretreatments ($P=0.0081$). The frequency of the inter-seeded legumes was significant for years and locations ($P<0.001$). Further analysis revealed that season of planting within location (Spring, Summer, Fall) was also significant ($P<0.001$), and differences were detected in the frequency among the grasses seeded into ($P=0.0011$). Due to these differences the data are presented independently by location, time of planting, and grass species seeded into.
Millville

The 2014 planting in Millville was deemed a failure with no detectable legume presence, consequently no data is presented. While the 2016 planting was made in late June and had the whole summer to establish, the 2014 planting was made in late August with little time for growth and development. In addition, the limited irrigation may have been inadequate. Furthermore, three weeks following planting temperatures cooled down and the grass growth would have increased, resulting in more grass competition further slowing legume growth.

In the 2016 planting at Millville, one month after planting, the overall legume frequency was similar for both alfalfa, at 45%, and birdsfoot trefoil at 51%, both much higher than cicer milkvetch at 3% (Fig. 2-1A). The overall frequency of alfalfa and birdsfoot trefoil following pretreatment was greatest for mowing at 71%, while glyphosate, untreated and tillage were not different at 46, 38 and 37%, respectively. Mowing resulted in the highest frequency of alfalfa at 67% which was 21 percentage points higher than glyphosate but not significantly different and 27 and 43 percentage points greater than the untreated and tillage, respectively. Similarly, for birdsfoot trefoil, mowing resulted in the highest frequency at 74%, which was 24 percentage points higher than tillage but not significantly different and 29 and 39 percentage points higher than glyphosate and the untreated, respectively. Overall, the frequency of cicer milkvetch was low, with no differences in pretreatments detected.
Eleven months after planting, overall alfalfa frequency was 58% followed by birdsfoot trefoil at 43%, and cicer milkvetch at 17% (Fig. 2-1B). The frequency of alfalfa and birdsfoot trefoil was greatest for the mowing pretreatment at 76%, followed by tillage and glyphosate at 46 and 45%, respectively, and the untreated was lowest at 34%. Alfalfa frequency was 91% in the mowing pretreatment which was 24 percentage points higher than glyphosate, 50 percentage points greater than the untreated and 58 percentage points greater than tillage. Similarly, for birdsfoot trefoil, mowing resulted in frequency of 61%, which was not different than tillage, but 33 and 37 percentage points higher than the untreated and glyphosate, respectively. Again, no differences in frequency were detected among pretreatments for cicer milkvetch; however, mowing was 28% and tillage was 25%, each large increases from the one month count and significantly greater than zero.

In Millville, alfalfa and birdsfoot trefoil both had high frequency of presence, with alfalfa measurably better than birdsfoot trefoil, furthermore cicer milkvetch showed a dramatic increase from one month to one year. These observations of alfalfa and birdsfoot trefoil agree with previous studies comparing the two when inter-seeded into grass pastures (Cuomo et al. 2001; Brummer et al., 2011). The slow growth of cicer milkvetch verifies previous observations (Townsend and McGinnies, 1972; Cox et al., 2017). It was not determined if the increase was due to new plant recruitment or growth of previously germinated plants. While either is possible since cicer milkvetch has a high percentage of hard seed which may germinate over time (Acharya et al.,
2006), it is more likely plants were present, but not visible since the seed was heavily scarified prior to planting. Furthermore, Cox et al. (2017) has shown that cicer milkvetch seedlings are difficult to observe during the first months of growth. Overall, the best pretreatment at Millville was mowing, which when used in other studies has produced mixed results (Kunelius et al., 1982; Barnhart, 2004; Brummer et al., 2011; Jennings et al., 2012). Brummer et al. (2011) reported close mowing did not improve establishment, but glyphosate sprayed 1 week prior to planting did. In contrast, Kunelius et al. (1982) reported glyphosate and paraquat did not improve legume establishment, while mowing resulted in better establishment of alfalfa and birdsfoot trefoil at one of two sites. Comparing both mowing and grazing for suppression, Seguin et al. (2001) reported successful inter-seeding into a pasture was positively correlated with the severity of the suppression, regardless of mowing or grazing. Likewise, at Millville, alfalfa seed remaining in the drill after the 2016 planting was cleaned out by running the drill into the heavily grazed pasture surrounding the study, and was subsequently grazed heavily by cattle in both the fall of 2016 and spring of 2017. While no data was collected this seed appeared to have excellent establishment, and seemed to respond favorably to the close grazing, as was reported by Seguin et al. (2001).

**Lewiston**

Legume presence at the 2014 planting in Lewiston was insignificant and thus deemed a failure, consequently no data is presented. While the 2013 planting was in late July when the grasses were relatively dormant, the 2014 planting was in mid-May,
during peak growth for cool-season grasses. Pretreatment suppression of the grasses was insufficient to allow the inter-seeded legumes to establish.

One month after the 2013 Lewiston planting, the frequency of alfalfa was 71% and birdsfoot trefoil 65%, while cicer milkvetch was 7% (Fig. 2-2A). The frequency of alfalfa and birdsfoot trefoil was greatest following tillage and mowing at 89 and 82%, respectively, glyphosate was intermediate at 65% and the untreated frequency was 35%. Tillage resulted in the highest alfalfa frequency at 88%, but not significantly different than mowing and glyphosate, 4 and 13 percentage points lower, respectively. All of the pretreatments were significantly higher than the untreated. Results for birdsfoot trefoil were similar, where tillage resulted in frequency of 91%, with mowing 10 percentage points lower. While frequency was intermediate at 56% in the glyphosate, it was significantly better than the untreated at 31%. Cicer milkvetch had low frequency of presence and even though three-fold higher in the mowing and tillage pretreatments than the untreated, no differences were significant.

Eleven months after planting birdsfoot trefoil frequency was greatest at 71%, followed by cicer milkvetch at 16% and alfalfa at 10% (Fig. 2-2B). The frequency of birdsfoot trefoil and cicer milkvetch was greatest following mowing, tillage and glyphosate, ranging from 51 to 49%, compared with the untreated, at 24%. Alfalfa frequency ranged from 15% for tillage to 9% for the other pretreatments, none different from untreated at 6%. Birdsfoot trefoil frequency was highest for mowing, at 89%; tillage and glyphosate were no different, at 6 and 11 percentage points lower,
respectively, while the untreated was 55 percentage points lower. Cicer milkvetch frequency ranged from 20% following the glyphosate pretreatment to 13% for tillage, with no differences among pretreatments.

Overall, the frequency of both alfalfa and birdsfoot trefoil was good one month after planting but after eleven months, the birdsfoot trefoil stand count was still high, but the alfalfa stand had declined 60 percentage points from the initial count. This decrease was unexpected and unlikely due to winter-kill, since birdsfoot trefoil is more prone to winter injury and did not appear affected. However, from early December 2013 through mid-February 2014, there was continuous snow cover (US Climate Data, 2017), providing cover for an active population of voles which feed on alfalfa crowns and are a common problem with extended snow cover. Though only the alfalfa was affected, there is evidence that rodents prefer seeds with less tannin and that high tannin diets have negative physiological effects on rodents (Chung-MacCoubray et al., 1997; Wang and Yang, 2015). Perhaps birdsfoot trefoil was avoided for similar reasons due to its condensed tannin content.

Since the 2013 Lewiston planting was seeded years prior to the other plantings it allowed a final observation three years after planting. At this time birdsfoot trefoil frequency was good at 41%, followed by cicer milkvetch at 26% and alfalfa at 6% (Fig. 2-3). Among birdsfoot trefoil and cicer milkvetch, frequency was greatest for the glyphosate at 41%, the untreated and tillage were intermediate at 35 and 34%, respectively, and lowest for mowing at 24%. No differences were detected among
pretreatments for alfalfa frequency. The frequency of birdsfoot trefoil was best for the glyphosate pretreatment at 63%, which was significantly better than all other pretreatments. This is noteworthy since at 1 and 11 months after planting the glyphosate pretreatment was intermediate. This change could be due to a residual effect of the glyphosate treatment. For example, a study in Australia utilized glyphosate to reduce competition from bent grass (*Agrostis castellana*) by preventing the formation of seed heads and extending the vegetative growth (Hill et al., 1996). Perhaps there was a similar effect on the grasses in this pasture. However, it is notable that after two years of rotational grazing the alfalfa and birdsfoot trefoil stands had decreased, while cicer milkvetch had increased by about 20 percentage points. This increase in cicer milkvetch highlights its ability to improve over time as noted by Townsend et al. (1990), Tilley et al. (2008) and Cox et al. (2017), who found that cicer milkvetch is difficult to establish, but will increase with time.

**Panguitch**

Relative to Millville and Lewiston plantings, frequency of presence was low at Panguitch. One month after planting into the tall fescue at Panguitch alfalfa frequency was the highest at 20%, compared to birdsfoot trefoil at 5% and cicer milkvetch 1% (Fig. 2-4A). Overall frequency following pretreatment was highest for mowing and glyphosate, while tillage and the untreated were similar to each other. All pretreatments in alfalfa resulted in frequency significantly better than zero but only mowing was better than the untreated. Birdsfoot trefoil frequency was low, ranging
from 7 to 3% for mowing and tillage, respectively, none differed from zero. For cicer milkvetch there was little to no presence detected among the pretreatments.

Fourteen months after planting, overall alfalfa frequency was 23%, which was significantly higher than birdsfoot trefoil at 4% and cicer milkvetch at 1% (Fig. 2-4B). The frequency of alfalfa following all pretreatments was significant with mowing the highest at 34%, but no different than glyphosate and tillage which were 11 to 12 percentage points lower. No differences in birdsfoot trefoil and cicer milkvetch frequency were observed among pretreatments and none significantly different from zero.

Overall, the frequency of presence in meadow bromegrass at Panguitch was similar to that for tall fescue. One month after planting, alfalfa frequency was 12%, followed by birdsfoot trefoil at 8% and cicer milkvetch was 1% (Fig. 2-5A). No differences in frequency were observed for pretreatments ranging from 15% for tillage to 7% for glyphosate and the untreated. All pretreatments in alfalfa resulted in frequency of presence significantly better than zero but only tillage was better than the untreated. Tillage and mowing resulted in significant presence of birdsfoot trefoil, while glyphosate and the untreated did not. There was no significant presence of the cicer milkvetch. Overall, frequency was best for alfalfa, while no differences were detected among the pretreatments.

Fourteen months after planting into the meadow bromegrass, the overall frequency of alfalfa showed promise at 36%, whereas birdsfoot trefoil and cicer milkvetch did not (Fig. 2-5B). Alfalfa frequency following all pretreatments was
significant with glyphosate the highest at 50%, but no different than tillage which was 8 percentage points lower. Both were greater than the untreated and mowing at 29 and 24%, respectively. No differences in birdsfoot trefoil and cicer milkvetch frequency were observed among pretreatments and none was significantly different from zero.

Overall, frequency of presence at Panguitch was much worse than the other locations. A major difference was these pastures were not cut or grazed the fall or spring prior to planting, resulting in a heavy thatch layer which was seeded into and likely negatively affected legume growth. In addition, the grasses were not controlled the fall after planting; Barnhart (2004) and Jennings et al. (2012) recommend light grazing, clipping or mowing the pasture following establishment of the legumes so there is reduced competition for light. Furthermore, this location was planted in the spring, which is compounded by a high elevation at Panguitch with a cooler environment than the other locations (Table 2-2), all of which favor cool-season grasses.

CONCLUSIONS

Summer plantings yielded the best results in this study, which is attributed to higher temperatures, favoring legumes. Martin et al. (1983) found a similar result when they examined 4 different spring planting dates and found the earliest dates didn’t have the best establishment. Brummer (2009) contends that spring plantings benefit from good water and having an entire growing season to get established, but suffer from cool-season grass competition. Brummer (2009) also argues that late summer plantings
need irrigation in order to survive. Additionally, different soil types have resulted in successful inter-seeding, from clay loam and sandy loam (Misar et al., 2016) to silt loam (Taylor et al., 1969), and the three soil types in this study (loam, fine sandy loam and silty clay loam). So no particular soil type seems to benefit inter-seeding more than another.

Across all locations, frequency of legume presence following mowing was higher than all other treatments, though there was not always a significant difference in frequency. Mowing was used to simulate close grazing, and other studies have found either grazing or mowing to be effective at reducing grass competition (Kunelius et al., 1982; Seguin et al., 2001).

The diversity of results across the three locations highlights the difficulty of successfully inter-seeding legumes into an established pasture. The two locations with the best results, Lewiston and Millville, were also the locations with complete failures. It is difficult to make direct comparisons across the three locations, especially since they differed with respect to soil type, date of planting and seasonal temperatures. What is obvious is that when inter-seeding occurs early in the spring, when cool-season grass are the most competitive, success is limited as was noted at Panguitch, or is a complete failure as observed at Lewiston with an early spring planting. By the same token, when planting is late in the fall, too close to a killing frost, such as the 2014 Millville planting, the legumes are not able to establish sufficiently to survive the winter. This compared to
Lewiston 2013 and Millville 2016 when the plantings were completed when hot weather prevailed and the material had time to establish.

Successful inter-seeding is dependent upon a few things. The first is to plant the legumes in the summer when warm temperatures promote legume growth. Next, the existing grasses must be adequately suppressed; planting in the summer is a good start but close grazing, mowing or other method is also needed to ensure the legumes have a chance to establish. No matter what method is used initially, it is important to continue controlling the grasses into the fall, either by grazing or mowing, so there is no thatch layer the following spring. Finally, irrigation is essential for legume establishment in the summer; if irrigation isn’t available then a spring planting may be a better option.

REFERENCES


10.2134/agronj1981.00021962007300060029x.


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†TF = Tall Fescue, KBG = Kentucky Bluegrass, MB = Meadow Bromegrass
Table 2-2. Average temperature (°C) and monthly precipitation (mm) in Panguitch, UT, Lewiston, UT, and Millville, UT from April to September and the 30 year average (1981-2010)

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Fig. 2-1. Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 11 (B) months after planting. Planted 27 June 2016 at Millville, UT into tall fescue and Kentucky bluegrass mixed pasture on a silty clay loam soil.
Fig. 2-2. Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 11 (B) months after planting. Planted 26 July 2013 at Lewiston, UT into tall fescue on a fine sandy loam soil.
Fig. 2-3. Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at 36 months after planting. Planted 26 July 2013 at Lewiston, UT into tall fescue on a fine sandy loam soil.
Fig. 2-4. Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 14 (B) months after planting. Planted 6 June 2016 at Panguitch, UT into tall fescue on a loam soil.
Fig. 2-5. Frequency of presence (%) of alfalfa, birdsfoot trefoil and cicer milkvetch following close mowing, glyphosate, and light tillage pretreatments at one (A) and 14 (B) months after planting. Planted 6 June 2016 at Panguitch, UT into meadow bromegrass on a loam soil.
CHAPTER 3

CATTLE GRAZING PREFERENCE IN BINARY MIXTURES OF BIRDSFOOT TREFOIL WITH MEADOW BROMEGRASS, ORCHARDGRASS, PERENNIAL RYEGRASS, AND TALL FESCUE

ABSTRACT

Cattle often preferentially graze one forage species in mixed pastures typical of the Intermountain Western USA. Our objective was to determine cattle grazing preference in mixed birdsfoot trefoil-grass pastures. Birdsfoot trefoil (*Lotus corniculatus* L., BFT) was established in binary mixtures with tall fescue (*Festuca arundinacea* Schreb., TF), perennial ryegrass (*Lolium perenne* L., PRG), orchardgrass (*Dactylis glomerata* L., OG) and meadow bromegrass (*Bromus biebersteinii* Roem. & Schult., MB). Each grass was established in mixed rows and alternating rows with BFT. Jersey heifers were rotationally grazed in each mixture for 7 day stocking periods for a 35 day stocking cycle starting 21 June 2016 and 17 May 2017. Percent utilization of each species was visually determined on the 3rd and 7th day of each grazing period. When compared to TF, BFT was always utilized more, with an average of 23 percentage points difference on day 7. In most observations BFT utilization was higher than OG, with an average difference of 14 percentage points. In the MB-BFT mixture no difference in utilization was detected. During early growth PRG utilization averaged 11 percentage points higher than BFT utilization, with no difference in utilization detected in later observations. Over the
season, PRG averaged 9 percentage points higher utilization than BFT. The difference in utilization in the TF, OG and PRG mixtures could lead to mortality of the preferred species. Consequently a management strategy such as rotational grazing will minimize the impacts of preferential grazing.

**INTRODUCTION**

In the Intermountain region of the Western US, there is increased interest in pasture production, driven by grazing-based livestock production, including organic dairies. Organic milk production requires the animals be on pasture for the grazing season, receiving no less than 30% of their intake from pasture (USDA-National Organic Program, 2016). These pasture-based systems require high producing pastures with forage throughout the grazing season. Typical pastures in the region consist of cool-season grasses, which tend to have low production and poor forage distribution.

In grass pastures production is most often limited by available soil nitrogen (Solomon et al., 2011; Chinea and Arevalo, 2013). Supplemental nitrogen fertilizer is an added expense and for organic production fertilizer must be from approved sources, meaning no artificial fertilizer treatments (USDA-National Organic Program, 2016). Both of these can be mitigated through the inclusion of legumes in pastures. Legumes form a symbiotic relationship with Rhizobia bacteria, fixing atmospheric nitrogen which then can be used by surrounding grasses (Heichel and Henjum, 1991). Including legumes in pasture provides other benefits over grass monocultures including increased yield,
higher in-vitro dry matter digestibility and crude protein, lower neutral detergent fiber, and more uniform seasonal forage production (Sleugh et al., 2000; Cox et al., 2017).

Cool-season grasses such as those used in the Intermountain West produce best in the spring and fall, following a bimodal production curve (Burns and Bagley, 1996; Moser and Hoveland, 1996). This ‘summer slump’ results in decreased pasture production during hot summer months, which hinders the pasture’s ability to provide adequate forage for the dairy or the livestock. The ability of legumes to alleviate the summer slump and improve forage distribution throughout the growing season has been well documented (Davis and Klosterman, 1959; Sleugh et al., 2000; Cox et al., 2017). Specifically, when alfalfa (Medicago sativa L.), birdsfoot trefoil (Lotus corniculatus L.), and cicer milkvetch (Astragalus cicer L.) are included in cool-season grass based pasture, the summer slump is mitigated, since these legumes produce well in the heat of the summer (Sleugh et al., 2000; Cox et al., 2017). Birdsfoot trefoil is perhaps the most ideal legume to include in high mountain pasture with frequent cool nights since it is non-bloating and produces well in the summer with hot days.

However, when legumes, such as birdsfoot trefoil, are included in pastures they frequently do not persist, with studies indicating stand losses from 68 to 90% (Henson, 1962; Taylor et al., 1973; Beuselinck et al., 1984; Brummer and Moore, 2000; Wen et al., 2004). These losses could be due to disease (Beuselinck et al., 1984), lack of reseeding (Taylor et al., 1973) or grazing-susceptible cultivars (Brummer and Moore, 2000). Additionally, lack of persistence could be due to poor grazing management, such as
continuous grazing. Brummer and Moore (2000) show that losses in birdsfoot trefoil stands appear after one year of continuous grazing by beef cattle. However, stands have been shown to persist under rotational grazing by sheep (Davis and Bell, 1957; Davis and Bell; 1958; Van Keuren and Davis, 1968) and cattle (Van Keuren and Davis, 1968).

The high palatability of birdsfoot trefoil and potential to be selectively grazed in pastures is likely to result in poor persistence. This has been shown in studies where ruminants choose legumes over grasses (Forwood et al., 1989; Torres-Rodriguez et al., 1997; Wen et al., 2004; Boland et al., 2011a; Boland et al., 2011b). Selective grazing of birdsfoot trefoil in a mixed pasture by ruminants is certain to be detrimental to the birdsfoot trefoil stand over time if the pasture isn’t managed properly. There are studies examining animal grazing preference but there are none specific to persistence in irrigated pastures in the Intermountain West. The objective of this study was to determine if jersey dairy cattle (Bos taurus) in the Intermountain West preferentially graze one species in binary grass-birdsfoot trefoil mixtures. This was tested in pastures that were planted in close mixtures and spatially separated rows of grass and birdsfoot trefoil.

**MATERIALS AND METHODS**

This study was conducted at Utah State University’s Intermountain Irrigated Pasture Facility near Lewiston, Utah (41° 57' 01.6" N 111° 52' 30.5" W, Lewiston Fine Sandy Loam (Soil Survey Staff, 2012)), materials included ‘Pardee’ birdsfoot trefoil

These mixtures were planted in two, nine-acre pastures, each divided into eight treatments, four grass monocultures, and four BFTF-grass mixtures. The monocultures were not utilized in this study, but they were part of a larger study. Preference data was collected from the binary mixtures only. The four mixed planting treatments were subdivided into two parts: 1) containing the BFTF and grass planted in alternating rows and 2) BFTF and grass planted in the same row, or mixed.

Mixtures were planted in June of 2015 using a Great Plains model 1200 12-foot 3-point mounted drill (Great Plains Ag, Salina, KS), which has openers on 15 cm spacings. Planting rates in the mixtures were 10 kg ha\(^{-1}\) for tall fescue, meadow bromegrass and perennial ryegrass, and 9 kg ha\(^{-1}\) for orchardgrass. Birdsfoot trefoil was planted at 7 kg ha\(^{-1}\). All planting rates were made on a pure live seed basis. The drill had a main seed box as well as a small seed box mounted in front of the main seed box for small seeded legumes, both boxes were used in planting this study. Birdsfoot trefoil was put in the small seed box and grasses in the main box. To plant the mixed rows, the drill was calibrated for each species and then both birdsfoot trefoil and the grass were planted through all openers. To plant the alternating rows, every other opener on the main box was covered with duct tape and the same procedure was used on the small seed box, though offset by one opener so that only the grass or BFTF was planted in a row. The
resulting spacing between each grass or BFTF row was 30 cm, but individual rows remained at 15 cm. The seed was planted on a per unit area basis, with the same rate planted for mixed and alternating rows.

Each binary mixture was separated with electric fence, and sub-divided into five equal-sized paddocks, allowing access to both mixed and alternating rows (Fig. 3-1). These five paddocks were rotationally grazed (Allen et. al., 2011) by the same group of jersey heifers for the whole season. Each paddock was grazed for seven days (stocking period) and the grazed paddock was allowed to rest for 28 days, resulting in a stocking cycle of 35 days. Each treatment was stocked with two heifers in 2016 and three heifers in 2017, each of which weighed approximately 200 kg and was 12 months old. Differences in heifer numbers between years were due to funding constraints in 2016.

The first stocking cycle was initiated on 23 June 2016, followed by successive stocking cycles starting on 27 July 2016, and 31 Aug. 2016 (Table 3-1). The final stocking cycle in 2016 only consisted of three stocking periods, ending on 16 Sept. 2016. This was due to cold weather, resulting in pastures that could not maintain the animals. Grazing was initiated on 17 May 2017 with subsequent stocking cycles starting on 21 June 2017 and 26 July 2017. All stocking cycles consisted of five stocking periods in 2017, with the last day of grazing on 29 Aug. 2017. A stocking period started when the heifers were turned into each paddock, between 0900 and 1000 each Wednesday throughout the season.
Data collection consisted of visual ratings of utilization, forage mass samples and aerial pictures of cattle grazing location. On the third day of each stocking period a visual rating of the cattle forage utilization was made. A second visual rating was made on day 7 of grazing after the animals were moved to the next paddock. The evaluation was made by visually assessing utilization based on the height and density of the grazed section compared to an adjacent un-grazed section. Separate evaluations were made for mixed rows and alternating rows in each paddock. Additionally, the grass rows and birdsfoot trefoil rows in the alternating rows were evaluated separately. When differences could be seen between the grass and birdsfoot trefoil utilization in the mixed rows those differences were recorded as well. Utilization was rated on a scale of 0-10, with 0 = no utilization and 10 = 100% of the forage had been grazed to minimum recommended height of 8 cm.

To validate visual evaluations forage samples were taken on day 0, before the heifers were moved into a paddock and on day 7, after the heifers were moved to the next paddock. The samples were taken using a 0.25 square meter hoop to a height of eight cm. In 2016 six samples were taken from each paddock on day 0 and six samples on day 7. In 2017 there were four samples taken on day 0 and four on day 7. Half of the samples on each sampling date were taken from the alternating rows and half from the mixed rows. The samples were used to determine forage mass before and after grazing and used to calculate utilization. However, results from these samples were inconsistent and showed little correlation to the visual assessment data. This could be attributed to
lack of consistency in the sampling techniques and other confounding factors. Due to these issues, these data won’t be presented.

On day 1 when cattle were rotated to a new paddock their grazing location was recorded with an Unmanned Aerial Vehicle (Phantom 2 Vision, DJI Co. Shenzhen, Guangdong), either in the mixed rows or the alternating rows. This was done in an effort to document any immediate grazing preference. On day 3, the location of the animals was again documented relative to mixed or alternating rows. Each was recorded in the morning between 0900 and 1000 when the majority of the animals were actively grazing to get a good representation of the grazing behavior.

Utilization data was analyzed using SAS PROC GLM as a randomized complete block design. The experimental unit for analysis was utilization of the mixed rows as a whole, as well as grass utilization and birdsfoot trefoil utilization of the alternating rows. Birdsfoot trefoil-grass binary mixtures were analyzed as fixed effects. Stocking periods were combined within stocking cycles and considered random effects, along with the repetitions. Stocking cycle data was combined into means for each treatment and mean separation was determined by LSD at $P=0.05$.

**RESULTS**

Pasture forage utilization differed by binary mixture ($P<0.001$), day of observation ($P<0.001$) and utilization of mixed versus alternating rows differed ($P=0.0293$). Since the utilization of the mixed and alternating rows differed they are
presented separately. Utilization did not differ by year ($P=0.2137$); consequently years were combined for the final analysis. Stocking cycles differed ($P<0.001$), however stocking periods were not different within a cycle and were combined within stocking cycles. Overall, across all binary mixtures, grass and birdsfoot trefoil utilization differed ($P<0.001$), consequently utilization of grass and birdsfoot trefoil within each binary mixture is compared.

**Alternating Rows**

In all observations birdsfoot trefoil was utilized more than tall fescue (Fig. 3-2). In cycle 1 birdsfoot trefoil averaged 11 percentage points greater utilization than tall fescue on day 3 and 19 percentage points greater utilization on day 7 (Fig. 3-2A). In cycle 2, birdsfoot trefoil averaged 16 percentage points greater utilization than tall fescue on day 3 and 24 percentage points greater on day 7 (Fig. 3-2B). In cycle 3 birdsfoot trefoil averaged 23 percentage points greater utilization than tall fescue on day 3 and by day 7 birdsfoot trefoil averaged 28 percentage points greater utilization than tall fescue (Fig. 3-2C). Averaged over all stocking cycles and years birdsfoot trefoil had higher utilization than tall fescue, averaging 79% compared to tall fescue at 66%.

Overall, birdsfoot trefoil was utilized more than orchardgrass (Fig. 3-2). In cycle 1 birdsfoot trefoil averaged 8 percentage points greater utilization than orchardgrass on day 3 and 13 percentage points greater utilization on day 7. In cycle 2, birdsfoot trefoil utilization was no different than orchardgrass utilization on day 3, but by day 7 birdsfoot trefoil averaged 17 percentage points greater utilization than orchardgrass. In cycle 3
birdsfoot trefoil averaged 10 percentage points greater utilization than orchardgrass on
day 3 and 11 percentage points on day 7. Across all stocking cycles and years birdsfoot
trefoil was utilized more than orchardgrass with utilization of 77% versus 54%,
respectively.

Birdsfoot trefoil and meadow bromegrass showed no difference in utilization in
most observations (Fig. 3-2). In cycle 1 and 2 on both days 3 and 7 no difference in
utilization was detected between birdsfoot trefoil and meadow bromegrass. However,
in cycle 3, birdsfoot trefoil averaged 9 percentage points greater utilization than
meadow bromegrass on day 3, and 8 percentage points greater utilization on day 7.
Averaged over all stocking cycles and years, no significance was detected between
birdsfoot trefoil utilization, at 73%, and meadow bromegrass utilization, at 68%.

The perennial ryegrass versus birdsfoot trefoil utilization was quite unique in
that in half of the observations the perennial ryegrass utilization was greater than
birdsfoot trefoil utilization with no difference detected in the other observations (Fig. 3-2). In cycle 1 birdsfoot trefoil averaged 9 percentage points less utilization than
perennial ryegrass on day 3 and 13 percentage points less on day 7. In cycle 2, birdsfoot
trefoil averaged 10 percentage points less utilization than perennial ryegrass on day 3;
however, on day 7 no difference between birdsfoot trefoil and perennial ryegrass
utilization was detected. In cycle 3, no differences in utilization were detected on either
day. Overall, perennial ryegrass was preferred over birdsfoot trefoil, with utilization of
75% versus 66%.
Utilization was different across cycles with higher utilization in subsequent cycles (Fig. 3-2D). Average utilization in cycle 2 was 20 percentage points higher than utilization in cycle 1 and utilization in cycle 3 averaged 4 percentage points higher than utilization in cycle 2. In the tall fescue mixture from cycle 1 to cycle 3, utilization of birdsfoot trefoil increased by 22 percentage points and utilization of tall fescue increased by 15 percentage points. In the orchardgrass mixture from cycle 1 to cycle 3, birdsfoot trefoil utilization increased by 27 percentage points and orchardgrass utilization increased by 29 percentage points. In the meadow bromegrass mixture, utilization of birdsfoot trefoil increased by 30 percentage points and utilization of meadow bromegrass increased by 25 percentage points. In the perennial ryegrass mixture, birdsfoot trefoil utilization increased by 25 percentage points and perennial ryegrass utilization increased by 18 percentage points.

**Mixed Rows**

In the mixed rows the independent utilization of birdsfoot trefoil and the grasses were visually rated as well as total utilization, integrating both birdsfoot trefoil and the grass. It was easy to detect utilization differences between birdsfoot trefoil and the grasses in the alternating rows, but in the mixed rows for the majority of the ratings it was not possible to detect a utilization difference between birdsfoot trefoil and the grasses (Fig. 3-3).

In cycle 1, birdsfoot trefoil was utilized more than tall fescue by 8 percentage points on day 3 (Fig. 3-3A). No other differences were detected in cycle 1. In cycle 2
differences were detected in the tall fescue, perennial ryegrass and orchardgrass mixtures; where on day 7, birdsfoot trefoil was utilized more than tall fescue by 15 percentage points and more than orchardgrass by 7 percentage points, while perennial ryegrass was utilized more than birdsfoot trefoil by 6 percentage points (Fig. 3-3B). In cycle 3, differences were detected in the tall fescue, orchardgrass and meadow bromegrass mixtures (Fig. 3-3C). Birdsfoot trefoil utilization was greater than tall fescue utilization by 15 percentage points on day 3 and 19 percentage points on day 7. Also on day 7, birdsfoot trefoil was utilized more than orchardgrass by 4 percentage points and more than meadow bromegrass by 3 percentage points.

Similar to the alternating rows, mixed rows had greater utilization in successive stocking cycles (Fig. 3-3D). Average utilization in cycle 2 was 18 percentage points higher than utilization in cycle 1 and utilization in cycle 3 averaged 6 percentage points higher than utilization in cycle 2. Overall utilization of the tall fescue mixed rows increased 17 percentage points from cycle 1 to cycle 3. Overall utilization of the orchardgrass mixed rows increased 32 percentage points from cycle 1 to cycle 3. In the meadow bromegrass, the overall utilization increased 23 percentage points from cycle 1 to cycle 3. Overall utilization of the perennial ryegrass mixed rows increased 24 percentage points from cycle 1 to cycle 3.

Preferred Grazing Location

The data analysis indicated significant differences in time spent in the alternating or mixed rows. However, the analysis also indicated differences between the
repetitions. A separate analysis of each mixture revealed these rep differences in meadow bromegrass, perennial ryegrass and tall fescue, all at \( P<0.01 \). Orchardgrass was the only mixture with reps not different at the \( P=0.1738 \) level. Looking at the individual rep data presented in Figure 3-4 this is easily seen by comparing the meadow bromegrass mixes. The meadow brome paddock in the first rep pasture was bordered by a neighbor’s field, isolating the animals from the other animals. The animals in these pastures congregated to those in the adjoining orchardgrass pastures for nearly 80% of the time. The same was observed for perennial ryegrass in the second rep pasture, though this paddock was bordered by an empty alley across which was an independent grazing study that occasionally had cows. It is obvious from the rep differences that isolation played a greater role in the results than pasture forage composition. Additionally, as seen in Figure 3-4 water troughs were located between paddocks, which could have had a possible effect on the results. Overall, these results showed more about animal behavior, revealing a social nature of these heifers since they tended to congregate near other animals and people. Even so, based on the aerial photos showing heifer grazing location, overall the heifers spent more time in the mixed rows compared to the alternating rows (Fig. 3-4, 3-5), the exception was in the perennial ryegrass mixture of the second rep pasture.
DISCUSSION

Preference in this study was defined as the species utilized more heavily by the animal when given a choice. Preference was observed in all of the mixtures; birdsfoot trefoil was preferred over tall fescue, orchardgrass and meadow bromegrass, whereas perennial ryegrass was preferred over birdsfoot trefoil. Previous research has shown that domestic ruminants tend to consume a mixed diet, even when given choice between two monocultures, but they show partial preference (about 70%) for legumes, birdsfoot trefoil specifically (Torres-Rodriguez et al., 1997; Wen et al., 2004; Rutter, 2006). Birdsfoot trefoil is generally more palatable than many grasses, and that was evident in three of the four mixtures in this study. Tall fescue mixtures showed the most evidence of preferential grazing, due in part to the higher palatability of birdsfoot trefoil compared to tall fescue (Leep et al., 2002). Despite its low palatability tall fescue is a popular species in Intermountain West pastures, mainly because it is productive and competitive (MacAdam and Griggs, 2006). This demonstrates potential persistence issues if mixed pastures of tall fescue and birdsfoot trefoil are continuously grazed. Studies involving continuous grazing of tall fescue- birdsfoot trefoil mixtures indicate stands of birdsfoot trefoil decline to as little as 24% of its original stand within two years (Van Keuren and Davis, 1968; Brummer and Moore, 2000; Wen et al., 2004).

Orchardgrass is generally palatable, more so than tall fescue, though it does tend to lose palatability as it matures in the spring (Archibald et al., 1943; Jensen et al., 2001).
Even so, birdsfoot trefoil was preferred over orchardgrass the majority of the time in this study. Studies by Forwood et al. (1989) and MacAdam and Griggs (2006) indicate birdsfoot trefoil preference over orchardgrass and even state that orchardgrass is the least compatible with legumes when compared to meadow bromegrass, tall fescue, and perennial ryegrass.

Meadow bromegrass had the fewest incidences where birdsfoot trefoil was utilized preferentially, indicating similar preference between the two species, and potentially a stable mixture over time. Meadow bromegrass is a high to moderately productive cool-season grass depending on conditions but research has shown legume stands are maintained in mixtures with meadow bromegrass, demonstrating mixture compatibility (Jensen et al., 2001; Smeal et al., 2005; MacAdam and Griggs, 2006).

The other grass in this study, perennial ryegrass, is a low producing, less competitive grass, but very palatable (Sheaffer et al., 1984; Jensen et al., 2001). In this study it was preferred over birdsfoot trefoil in early cycles and probably would have been preferentially utilized throughout the study if its production was sustained through the growing season. Similarly, MacAdam and Griggs (2006) report potential for legume dominance when in mixture with perennial ryegrass.

The birdsfoot trefoil in this study was generally preferred more than the grasses. Due to that preference if grazed continuously it would not persist. These results agree with others and highlight the need for management such as rotational grazing to maintain the stand of birdsfoot trefoil in the pasture (Van Keuren and Davis, 1968; Davis
and Bell, 1957). In addition, Beuselinck et al. (1984) relate the persistence of birdsfoot trefoil stands to the natural reseeding of the plants every couple years, rather than the longevity of individual plants. As a result, the best practices for longevity of the birdsfoot trefoil stand are rotational grazing and allowing the plants to reseed.

The considerably higher utilization in cycle 3 than in cycle 1 is likely due to greater production early in the season (Fig. 3-2D, 3-3D). Since these cool-season grasses produce higher early in the season the animals would have eaten a lower percentage of the total to meet their nutritional needs. Conversely, as grass production grasses declined in the heat of the summer, the animals had to eat a higher percent of pasture forage production to meet their nutritional needs.

The results of this study agree with previous research indicating domestic ruminants prefer a mixed diet of grasses and legumes, but exhibit partial preference for legumes. Preference for legumes was demonstrated in tall fescue-, meadow brome-, and orchardgrass- birdsfoot trefoil mixtures. Early in the grazing season and in the first part of stocking periods the animals tended to prefer perennial ryegrass over birdsfoot trefoil, later in the year that preference wasn’t apparent. Though birdsfoot trefoil was shown to be preferred over meadow bromegrass in alternating rows, the utilization of these species tended to be similar, suggesting these species may be compatible in mixture. There was evidence of changes in preference as the summer progressed. By comparing alternating rows of grass-birdsfoot trefoil to intimately mixed rows, we
affirmed that grazing selection is more difficult in mixed rows, with the mixed row utilization closest to that of the least preferred alternating row component.

CONCLUSION

For producers using mixed pastures this study highlights the importance of rotational grazing. The heifers showed a preference for birdsfoot trefoil in orchardgrass and tall fescue mixtures and a preference for perennial ryegrass in that mixture. The issue that accompanies this grazing preference is that one of the species in mixture is being grazed heavier than the other, which could result in the eventual mortality of that species. This is especially true in alternating row plantings; the animals have easier access to the more preferred species and are able to graze it more readily. However, mixed row plantings that achieve ideal establishment are more difficult due to interspecies competition. To minimize a negative impact from preferential grazing, management such as rotational grazing is key to maintaining desirable pasture mixtures.

REFERENCES


Table 3-1. Grazing dates for three stocking cycle in 2016 and 2017

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Fig. 3-1. Planting layout of grass-birdsfoot trefoil mixtures, stripes depict alternating rows, solid depicts mixed rows, dotted lines indicate paddock layout, animals had access to both mixed and alternating rows. Animals started grazing in the east paddock, before moving to the next paddock, as indicated by the arrow. Individual paddocks were grazed for seven days, which was called a stocking period; following grazing, paddocks were rested for 28 days, resulting in a 35 day stocking cycle.
Fig. 3-2. Percent utilization in alternating rows of perennial ryegrass (PRG), meadow bromegrass (MB), orchardgrass (OG) and tall fescue (TF) with birdsfoot trefoil (BFT) in three stocking cycles. Overall mixed row utilization is shown for comparison. Shorter, darker bars show day 3 utilization, while taller, opaque bars show day 7 utilization. Graph D compares cycle 1 day 7 utilization (dark bars) with cycle 3 day 7 utilization (opaque bars). Bars within a grass-trefoil group followed by different letters are significantly different ($P=0.05$). Uppercase letters indicate differences on day 3 (Graphs A, B, and C) and cycle 1 (Graph D) and lowercase letters indicate differences on day 7 (A, B & C) and cycle 3 (D).
Fig. 3-3. Percent utilization in mixed rows of perennial ryegrass (PRG), meadow bromegrass (MB), orchardgrass (OG) and tall fescue (TF) with birdsfoot trefoil (BFT) in three stocking cycles. Shorter, darker bars show day 3 utilization, while taller, opaque bars show day 7 utilization. Graph D compares cycle 1 day 7 utilization (dark bars) with cycle 3 day 7 utilization (opaque bars). Bars within a grass-trefoil group followed by different letters are significantly different (P=0.05). Uppercase letters indicate differences on day 3 (Graphs A, B, and C) and cycle 1 (Graph D) and lowercase letters indicate differences on day 7(A, B & C) and cycle 3 (D).
Fig. 3-4. Visual representation of Rep 1 pasture and Rep 2 pasture, showing water access and alleyways that could influence animal behavior within the pasture. Numbers indicate percent of observations with animals in either mixed or alternating row in each grass- birdsfoot trefoil mixture.
Fig. 3-5. Percent of time heifers observed in mixed versus alternating rows at the time of observation on day 1 and day 3 of grazing. Day 1 observation was made within an hour of heifers being turned into a new paddock and between 0800 and 1000 on day 3. Averaged over both 2016 and 2017 with both repetitions shown.
CHAPTER 4

MEASURING FORAGE ENERGY IN ALFALFA, BIRDSFOOT TREFOIL, CICER MILKVETCH, ORCHARDGRASS, PERENNIAL RYEGRASS, AND TALL FESCUE AT DIFFERING STAGES OF MATURITY

ABSTRACT

Nutritive value of grasses and legumes change through the growing season. This study compared the interaction of growth stage and time of season on nutritive value of alfalfa (*Medicago sativa* L.(ALF)), birdsfoot trefoil (*Lotus corniculatus* L.(BFT)), cicer milkvetch (*Astragalus cicer* L.(CMV)), orchardgrass (*Dactylis glomerata* L.(OG)), perennial ryegrass (*Lolium perenne* L.(PRG)), and tall fescue (*Festuca arundinacea* Schreb (TF)). Multiple growth stages were present at any given sample date, forage samples were taken weekly and the target growth stages were jointing, early boot, late boot, heading and seed production for the grasses and prebud, bud, 10% bloom, 100% bloom and pod production for the legumes. In spring and early summer, as maturity progressed, TDN of legumes decreased by an average of 2.7 percentage points from 76, 78 and 77% for ALF, BFT and CMV, respectively, mid-summer TDN of legumes decreased little with maturity and in late summer TDN didn’t change, averaging 76%. Crude protein decreased with progressing maturity from 26 to 15% in ALF and BFT in spring, mid, and late summer, CMV decreased similarly but averaged 5 percentage points lower in the spring. Legume NDF increased (became less desirable) in spring and mid-summer by an average of 10
percentage points but was stable in late summer. In spring and early summer TDN of the grasses decreased as they matured by an average of 6 percentage points from 71, 74, and 67% for OG, PRG and TF, respectively, in mid to late summer all grass regrowth was vegetative and TDN remained stable around 67% for all grasses. Crude protein of the grasses decreased from 14 to 7% in the spring for all grasses, was stable around 14% mid-summer then increased from 11 to 17% in late summer for OG and PRG but remained stable for TF. In the spring NDF increased by an average of 10 percentage points, but then was stable throughout the summer. These results suggest that utilization at an early growth stage to obtain high nutritive value is more critical in spring and early summer, whereas in late summer nutritive value stays more constant with increasing maturity, even legumes.

INTRODUCTION

The value of forage in a ruminant animal’s diet is largely dependent upon the nutritive value of the forage which is dependent upon the maturity, as well as the season in which the forage was harvested, either by the animal or by mechanical means. Forage nutritive value can be measured by animal productivity, as in daily gains, milk production or by concentration of nutrients, digestibility of nutrients, and the composition of digestion end products (Moore, 1994). Nutrient factors typically used to convey parts of nutritive value are digestibility, crude protein (CP) and fiber, though there are other factors to measure nutritive value including energy, digestible neutral
detergent fiber (dNDF) and fat. Digestibility is measured multiple ways, but many studies measure and express digestibility by in-vitro dry matter digestibility. Crude protein is a calculated value from the nitrogen content of a sample, 6.25 multiplied by nitrogen (Belyea and Ricketts, 1993). Fiber is expressed as neutral detergent fiber (NDF) or acid detergent fiber (ADF). NDF is an approximate measure of the cell wall elements, such as hemicellulose and is an inverse predictor of animal intake (Belyea and Ricketts, 1993; Ball et al., 2001). ADF approximates the cellulose and lignin of the forage, and is used to predict digestibility (Belyea and Ricketts, 1993; Ball et al, 2001). Energy of forage, often expressed as digestible energy, is calculated from other quality measures. An equation developed by Fonnesbeck (1981) uses the crude protein, acid detergent fiber, hemicellulose, fat, digestible nonstructural carbohydrate, and ash to determine the digestible energy of a forage (Pagan, 1998). Another updated method of determining energy, or total digestible nutrients (TDN), is calculated using neutral detergent fiber, in vitro true digestibility, crude protein, ether extract and ash (Saha et al., 2013; National Research Council, 2001).

Factors that determine the nutritive value of forage are species, growth stage, growing environment and soil fertility (Moore, 1994; Allen et al., 2013). As plants mature nutritive value declines. This drop can partially be attributed to a decrease in the leaf to stem ratio (Nelson and Moser, 1994). The decreased ratio is observed in both grasses and legumes, though the leaf to stem ratio is different for the two. Leaf tissue is typically more digestible, less fibrous and consists of higher protein content. At early
stages of growth for legumes and grasses, it has been observed that there is a greater ratio of leaf tissue than stem tissue, but at later growth stages there is a lower ratio of leaf tissue (Griffin and Jung, 1983; Nordkvist and Aman, 1986; Albrecht et al., 1987).

The nutritive value of cool-season grasses in pasture is variable in the first part of the growing season, as NDF increases and CP decreases when the grasses undergo reproductive growth (Ferdinandez and Coulman, 2001). Though, the forage production is highest during reproductive growth. Not all grazing or harvesting of grasses is relegated to reproductive growth, however, so it is important to see how the nutritive value changes as the cool-season grasses progress in vegetative regrowth throughout the season. During the ‘summer slump’ when cool-season grass production is depressed, the grass regrowth consists mainly of leaves, resulting in a higher leaf to stem ratio. Even so, integrating legumes into the pasture improves forage production (Sleugh et al., 2000, Cox et al., 2017), and nutritive value (Brink et al., 2015). Studies have shown that adding legumes to a mixture increases in-vitro dry matter digestibility and crude protein compared to the same grasses in monoculture. The neutral detergent fiber in grass-legume mixtures is less (more desirable) than in grass monocultures (Sleugh et al. 2000; Cox, 2013).

There is an abundance of research on the effect of maturity on alfalfa and cool-season grass nutritive value; however, the interaction of growth stage with time of season is not widely documented for cool-season grasses and forage legumes when grown in the Intermountain region of the Western USA. This study was conducted to
elucidate the changes in nutritive value, specifically total digestible nutrients, of orchardgrass (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), alfalfa (*Medicago sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and cicer milkvetch (*Astragalus cicer* L.), at multiple maturities throughout the growing season.

**MATERIALS AND METHODS**

Forage samples from harvests in 2016 and 2017 were collected for measurements of forage nutritive value. Locations were Utah State University’s Intermountain Irrigated Pasture Facility near Lewiston, Utah (41° 57' 1.4312" N, 111° 52' 30.0086" W), and Utah Agricultural Experiment Station’s Evans Research farm, in Millville, Utah (41° 41' 37.6942" N, 111° 49' 55.1271" W). Soil at Lewiston is a Lewiston fine sandy loam and at Evans farm, a Nibley silty clay loam (Soil survey staff, 2012). Lewiston was planted June 2015 and Evans was planted September 2015.

Grasses were ‘Quickdraw’ orchardgrass, ‘Fawn’ tall fescue and ‘Amazon’ perennial ryegrass, and legumes; ‘Rugged’ alfalfa, ‘Pardee’ birdsfoot trefoil and ‘Monarch’ cicer milkvetch. Planting was done with a Hege (Hege Company, Waldenburg, Germany) five row cone seeder. Planting rates were 19, 13, 26, 20, 17, and 19 kg ha-1 for alfalfa, birdsfoot trefoil, cicer milkvetch, tall fescue, orchardgrass, and perennial ryegrass, respectively. Species entries were planted in a split-plot arrangement with two blocks containing four reps of each entry and managed such that there would be two
growth stages present at each sampling date. The first block was sampled as “Growth series 1” (Table 4-1), which corresponded to spring reproductive growth of cool-season grasses and legumes. “Growth Series 1” sampling started on 17 May 2017 and continued weekly until plants reached the seed pod production stage then sampling was terminated on 5 July 2017. The second block was defoliated on 30 May 2017 and sampling of “Growth Series 2” started on 21 June 2017, which corresponded to early summer growth; sampling continued until 16 Aug. 2017. Block 1 was defoliated on 7 July 2017 and regrowth subsequently sampled as “Growth Series 3” starting on 2 Aug. 2017, corresponding to mid to late summer growth, sampling continued until 12 Sept. 2017. Block 2 was completely defoliated for a second time on 17 Aug. 2017 and sampling of “Growth Series 4” started on 5 Sept. 2017, which corresponded to early fall growth. Only two harvests were made from Growth series 4 before plant growth ceased and plants started entering dormancy following sampling on 12 Sept. 2017.

Forage samples were taken weekly throughout the growing season. A rice knife was used to take five random sub-samples from each entry, strictly avoiding areas previously sampled. All sub-samples were cut at 8 cm above the ground, and then combined to ensure a representative sample for each plot. The growth stage was recorded for each species for each sample date. Desired growth stages for the grasses were jointing, early boot, late boot, heading and seed formation for first growth. With the weekly harvest schedule utilized, differences among the species at some stages were sampled disproportionally. All regrowth harvests of the grasses were vegetative.
Desired legume growth stages were pre-bud, bud, 10% bloom, 100% bloom and pod production. After the plants reached seed pod formation they were defoliated to a height of 8 cm. This complete defoliation allowed regrowth for subsequent growth series. All of the samples were dried in a forced air drier at 60° C for 72 hours.

Plots were irrigated on 6 June, 3 July, 10 July, 31 July and 21 August. The 3 July irrigation only applied 12.5 mm to water-in nitrogen fertilizer, while the other irrigations applied 50 mm. Grass plots were fertilized on 3 July and 21 August using 30-0-0 urea fertilizer at 48 kg N ha⁻¹.

For quality analysis, combined samples were ground using a Thomas Wiley Laboratory Model 4 mill (Arthur H Thomas Co, Swedesboro, NJ) until they passed through a one mm screen and were mixed thoroughly. Ground samples were scanned using a Foss XDS near infrared reflectance spectroscopy instrument (Foss, Eden Prairie, MN). In house NIR equations were used to determine neutral-detergent fiber (NDF), acid-detergent fiber (ADF), crude protein (CP), ash, and in vitro true digestibility (IVTD), all of which are needed to calculate total digestible nutrients (TDN). Samples were sent to Dairy One in Ithaca, NY to determine ether extract (EE) percentage.

To validate the results found by the NIR analysis, 63% of the samples in 2016 and 20% of the samples in 2017 were analyzed using wet chemistry for NDF, ADF, CP, ash and IVTD. For NDF analysis samples were weighed to 490 to 510 mg and deposited in F57 filter bags (ANKOM Technology Corporation, Macedon, NY), samples were then digested in accordance with ANKOM Technology “Method 6” using an ANKOM200 Fiber
Analyzer (ANKOM Technology Corporation, Fairport, NY). ADF samples were weighed in
the same manner and placed in F57 filter bags and subsequently digested following
ANKOM Technology “Method 5” and an ANKOM200 Fiber Analyzer (ANKOM Technology
Corporation, Fairport, NY). IVTD samples were weighed to between 250 and 252.5 mg
and placed in acetone-rinsed F57 filter bags, then following ANKOM Technology
“Method 3” and using a DAISYII Incubator and an ANKOM200 Fiber Analyzer, IVTD was
determined. Samples weighing 120 to 150 mg were placed in foil cups for combustion
and nitrogen content analysis using a LECO FP628 Nitrogen/Protein analyzer (Saint
Joseph, MI). Nitrogen content was multiplied by 6.25 to estimate crude protein. Ash
content was determined using a Milestone Srl Pyro 640 Microwave Ashing System
(Sorisole, Italy); samples were weighed in porcelain crucibles at 1.5-2.0 g and then dried
for 12 hours in a 100 degree C oven. After drying in the oven, the crucibles were
deposited in the ashing oven for 2 hours at 550 degrees C.

After NDF, CP, IVTD, ether extract (EE) and ash were determined, these
measures were used to calculate total digestible nutrients (TDN). The equation
developed by the National Research Council and presented in Saha et al. (2001) was
used for TDN determination. The equation differed slightly for legumes and grasses. For
legumes the equation used was as follows:

\[
TDN_{\text{Legume}} = (CP \times 0.93) + (FA \times 0.97 \times 2.25) + [NDFn \times (NDFD \div 100)] + (NFC \times 0.98) - 7
\]

Where:

\[
FA = EE - 1
\]

\[
NDFn = \text{nitrogen free NDF, estimated as NDF} \times 0.93
\]
NDFD = 48-hour in vitro NDF digestibility or IVTD

NFC = non fibrous carbohydrate = 100 – (NDFn + CP + EE + ash)

For grasses the TDN equation used was:

\[ \text{TDN}_{\text{Grass}} = (\text{CP} \times 0.87) + (\text{FA} \times 0.97 \times 2.25) + [\text{NDFn} \times \left(\frac{\text{NDFDp}}{100}\right)] + (\text{NFC} \times 0.98) - 10 \]

Where:

\[ \text{NDFDp} = 22.7 + 0.664 \times \text{NDF} \]

All other terms defined previously and remain the same.

Once the TDN was calculated the data was analyzed using SAS PROC GLM as a randomized complete block design. Percent TDN, percent CP and percent NDF were separate experimental units for analysis. Species were analyzed independently within growth series to determine significant changes among sample dates and growth stages. Subsequently growth series were compared to determine differences among them. The species of grass or legume and stage of maturity were considered fixed effects and repetition was considered a random effect. Differences in means were separated at \( P=0.05 \). Growth stage and date of sampling are used interchangeably in the presentation of results for presentation simplification. Results are only presented for 2017 data, inconsistencies in the 2016 data made it suspect.
Legume TDN

The legumes behaved similarly in regard to seasonal changes in TDN. For all legumes, TDN decreased significantly as the plants matured in growth series 1 (Fig. 4-1A, 4-1B, 4-1C; Table 4-2). This decrease ranged from 2.1 percentage points for cicer milkvetch to 3.7 percentage points for birdsfoot trefoil. While birdsfoot trefoil had the highest TDN of the legumes at the first harvest at 78%, it also had the greatest change, decreasing to 75% at the end of growth series 1. In growth series 1 cicer milkvetch TDN was 77% and alfalfa was 76%, decreasing to 75% and 73% for cicer milkvetch and alfalfa, respectively. Overall, TDN progressively decreased for all the legumes during growth series 2, with cicer milkvetch showing the least change in TDN, at only 1.5 percentage points from the first sample date to the last. In growth series 3, overall TDN changed little with increasing maturity and between sample dates. In particular, alfalfa showed no change during this growth series. Growth series 4 TDN may have been lower, but with only two harvests, there was not sufficient data to make conclusive observations. Overall, there were differences in TDN between growth stages for the legumes in growth series 1 and growth series 2 while in growth series 3 TDN for the legumes showed little, if any, change and remained constant across sample dates.
Legume CP

Differences were significant among harvests for CP for growth series 1-3, with all decreasing (Table 4-2). Growth series 1 CP decreases were similar for alfalfa and birdsfoot trefoil, starting around 26% at prebud and decreasing to 18% at pod production (Fig. 4-1D, 4-1E). In contrast, cicer milkvetch started at 19% and decreased to 15%, a decrease less than half that of alfalfa and birdsfoot trefoil, and lower overall (Fig. 4-1F). Crude protein decreases with harvest in growth series 2 were similar for all species, ranging from 9.6 percentage points for cicer milkvetch to 12.8 percentage points for birdsfoot trefoil. Overall while CP was similar for birdsfoot trefoil and alfalfa between growth series 1 and 2, it was higher for cicer milkvetch in growth series 2 and similar to alfalfa and birdsfoot trefoil, starting at 26% and dropping to 17% at pod production. In growth series 3, the change in CP was similar among the legumes decreasing on average 4.6 percentage points from prebud to pod production. Overall, in growth series 3, CP was lower and changed less than that observed in growth series 1 and 2, growth series 1 cicer milkvetch excepted. In growth series 4, CP of cicer milkvetch and birdsfoot trefoil reflected that of growth series 3, while in alfalfa it was much higher. Again, with only two harvests in the fourth growth series, changes with growth stages are not possible.

Legume NDF

The change in NDF across sample date within growth series was significant for all legumes in growth series 1 and 2 and birdsfoot trefoil and cicer milkvetch in growth
series 3 (Table 4-2). As expected, NDF increased as plants matured. In growth series 1, alfalfa NDF was 26.2%, while birdsfoot trefoil 22.4% and cicer milkvetch 23.7% (Fig. 4-1G, 4-1H, 4-1I). Over the course of growth series 1 NDF increased (became less desirable) by 9.4, 10.8 and 13.6 percentage points for cicer milkvetch, alfalfa and birdsfoot trefoil, respectively. In growth series 2, the change in NDF was less than in growth series 1 for alfalfa and cicer milkvetch. In contrast, at first sampling in growth series 1 and 2 birdsfoot trefoil NDF was 22%, but in growth series 2 the increase was greater than that observed in growth series 1. In growth series 3 changes across the series were minimal, with no change in alfalfa NDF detected, while birdsfoot trefoil and cicer milkvetch only increased 2.2 percentage points across harvests. Overall in growth series 3, NDF stayed low, (desirable), at 31% for alfalfa 30% for birdsfoot trefoil and 29% for cicer milkvetch. In growth series 4, NDF was similar to that observed in growth series 3. Across the growing season NDF of the legumes in growth series 1 and 2 increased with maturity, whereas in growth series 3 and 4 NDF did not change, or very little.

In this study, in the first two growth series, late spring to mid-summer, nutritive value decreased significantly with progressive growth stages. While in the third growth series nutritive value remained constant and fairly high throughout the growth stages. The general understanding is that nutritive value decreases with progressing growth stage, as the plants grow they produce more stems and the leaf to stem ratio decreases (Blaser et al., 1986; Albrecht et al., 1987; Ball et al., 2001). The legumes in this study followed this trend for the first two growth stages, the nutritive value decreased as they
matured, but during the last growth series, there was no change, which could have been due to environmental factors such as temperature changes and changing day length, the general consensus among area producers is that third growth is “leafier” and higher in quality.

Crude protein and TDN decreased in progressive alfalfa growth stages in a study by Darlington and Hershberger (1968), and Sanderson and Wedin (1989) concluded that the growth stage accounts for 97% of NDF variation in alfalfa. These studies do not account for changing seasons, however, in New York, Kalu and Fick (1981) reported that the relationship of nutritive value to morphological stage was consistent across seasons. Which is in contrast to this study, in which changes in CP, TDN and NDF were not constant relative to maturity throughout the season; differences in nutritive value with changing growth stage were more noticeable in the spring and tended to change less as the growing season progressed. Brink et al. (2010) reported a similar effect of the season, at locations in Wisconsin and Pennsylvania, they found NDF increased more rapidly in the spring than in early summer and fall harvests; however, at a site in Idaho, they reported the rate of change in nutritive value wasn’t as fast in the spring as later harvests. The results of our study and Brink et al.’s (2010) suggest that grazing or harvesting legumes at an early growth stage to obtain highest nutritive value is the most critical in the spring and early summer. In late summer nutritive value stays more constant throughout growth stages, meaning more forage mass could be obtained by
allowing the plants to grow longer prior to utilization without the same loss in nutritive value.

**Grass TDN**

The first sample dates of growth series 1 had the highest TDN of any growth series, and the largest change in TDN occurred in growth series 1 (Fig. 4-2A, 4-2B, 4-2C). Orchardgrass TDN at the first sampling date was 70.7% and dropped to 66.3% at seed production, while perennial ryegrass started higher at 74.2% and decreased to 67.22%, tall fescue declined from 67% to 61.3%. During growth series 2, differences among sample dates were significant for all the grasses (Table 4-2), but overall, TDN changed very little. Orchardgrass TDN ranged from 69% to 66% in growth series 2, perennial ryegrass from 71% to 68% and tall fescue from 65% to 62%. Growth series 3 was similar to growth series 2, samples dates among growth series differed, with the exception of perennial ryegrass (Table 4-2). In growth series 3 the grasses only changed by 2 percentage points throughout the series, 69 to 67% for orchardgrass, 70 to 68% for perennial ryegrass and 66 to 65% for tall fescue. Overall, in growth series 1, the early growth was highest in TDN, but decreased with successive growth stages, while the vegetative regrowth remained constant throughout subsequent growth series.

**Grass CP**

While TDN was highest in growth series 1, CP tended to be higher in the later growth series. In the first growth series the CP decreased significantly for all the grasses
(Fig. 4-2D, 4-2E, 4-2F; Table 4-2). Overall this decrease averaged 3.8 percentage points from jointing to seed production with the least change in tall fescue, which had the lowest CP overall. In growth series 1, orchardgrass started at 11%, perennial ryegrass at 14% and tall fescue at 10%. Subsequent growth series had higher CP overall than growth series 1, but there was greater variation among sample dates. Growth series 2, consisting primarily of vegetative growth, ranged from 11% to 7% in orchardgrass, perennial ryegrass ranged from 14% to 9% and tall fescue from 17 to 12%. Crude protein in growth series 3 increased from the first sampling date to the last for orchardgrass and perennial ryegrass, while it remained constant for tall fescue. Orchardgrass increased from 13.2% to 18.5%, and perennial ryegrass from 14.3% to 22.2%. Overall CP was lower in growth series 1 than that of regrowth.

**Grass NDF**

Neutral detergent fiber is expected to increase (become less desirable) as plants mature; and in the first growth series NDF showed significant increases. The change was greatest for perennial ryegrass, from 35% to 51%; however, orchardgrass and tall fescue had higher overall NDF, at 47% to 55% and 48% to 56%, respectively (Fig. 4-2G, 4-2H, 4-2I; Table 4-2). While differences among sample dates were significant within growth series 2 and 3 the change only averaged 4.6 and 3.1 percentage points compared to 10.3 percentage points in growth series 1. In growth series 4, orchardgrass and tall fescue NDF was similar to growth series 3, at 50% to 52% for orchardgrass and 51% to 52% for tall fescue, while perennial ryegrass NDF was higher than growth series 3, at
48% to 49%. Overall, NDF started low for all the grasses at the first sample date in growth series 1, then increased, in growth series 2, 3, and 4 NDF stayed pretty constant at the level it reached at the end of growth series 1, which was unexpected.

Since these are cool-season grasses and only have reproductive growth in the spring, it would be expected that changes in their nutritive value would be different from their reproductive growth to their vegetative regrowth. In this study, the reproductive growth showed the largest decline in nutritive value, while nutritive value of the regrowth was more constant across sampling dates. It is noteworthy that while CP was better in the vegetative regrowth of growth series 2-4, TDN and NDF of regrowth in growth series 2-4 was similar to that of mature grass in growth series 1. There has been considerable research regarding the change of NDF and CP as the grass completes it reproductive growth. Blaser et al. (1986) reported the CP of orchardgrass decreased from 33.9% to 6.1% from leafy spring growth to seeding and Fernandez and Coulman (2001) describe NDF increasing and CP decreasing as cool-season grasses matured from vegetative to anthesis. However, not all grazing or harvesting of grasses is relegated to reproductive growth, so it is important to see how the nutritive value changes as the cool-season grasses progress in vegetative regrowth throughout the season. Buxton and Marten (1989) related the decline in CP to calendar day, growing degree day and morphological stage, but found that morphological stage was not as closely related to CP decline as the other factors. Once the grass completes its reproductive growth, most of the variability is attributed to the growth of the plant and changes in the leaf to stem
ratio. The vegetative regrowth of the grasses is generally higher in nutritive value than the reproductive growth and is less variable over time, since the leaf to stem ratio is higher in the vegetative regrowth (Ball et al., 2001). The results of this study corroborate previous conclusions, there is a large change in nutritive value during reproductive growth, as in growth series 1, and then the vegetative regrowth remained constant, as in growth series 2, 3 and 4. There were spikes in CP for all the grasses around July 12 (Fig. 4-2D, 4-2E, 4-2F) which were likely related to fertilizer application on July 3, as nitrogen fertilizer is known to affect CP (Colville et al., 1963).

CONCLUSIONS

The results of this study demonstrate that changes in nutritive value do not follow the same trends from spring to fall, though factors that affect nutritive value, such as temperature, precipitation and others, are not constant throughout the growing season, so it stands to reason that nutritive value would not be constant either. In the spring nutritive value followed the conventional relationship with growth stage, decreasing in TDN and CP and increasing in NDF as the plants mature for both legumes and grasses. In mid-summer, the legumes again decreased in TDN and CP while NDF increased. At this time the reproductive growth of the grasses was complete, so all of their growth was vegetative regrowth, resulting in less favorable, but stable, TDN, CP and NDF. In late summer the TDN, CP and NDF of both grasses and legumes remained largely unchanged as they matured. The relationship between yield and nutritive value
is not constant throughout the season, so rather than utilizing the legumes at an early growth stage, harvest could be delayed to accumulate greater yield, and not give up nutritive value.

REFERENCES


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Cox, S.R. 2013. Forage Yield and Quality of Binary Grass-Legume Mixtures of Tall Fescue, Orchardgrass, Meadow Brome, Alfalfa, Birdsfoot Trefoil, and Cicer Milkvetch. All


Table 4-1. Sampling schedule at Evans farm, with growth series, the number of samples per growth series and sample date. Defoliation dates of each block and number of days after defoliation provided as a comparison between growth series.

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
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<td><strong>Growth Series</strong></td>
<td><strong>Sample # in Growth Series</strong></td>
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†The first growth series was not defoliated, all growth was spring growth, but 1 May is provided as a reference to compare with other growth series.
Table 4-2. Probabilities for differences between harvests within growth series 1-4 and among growth series.

<table>
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<tr>
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<th>Alfalfa</th>
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<th>Cicer</th>
<th>Milkvetch</th>
<th>Orchardgrass</th>
<th>Perennial</th>
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Fig. 4-1. Percent total digestible nutrients (TDN), crude protein (CP), and neutral detergent fiber (NDF) of alfalfa, birdsfoot trefoil, cicer milkvetch at multiple sample dates (maturities) in four growth series across the growing season.
Fig. 4-2. Percent total digestible nutrients (TDN), crude protein (CP), and neutral detergent fiber (NDF) of orchardgrass, perennial ryegrass and tall fescue at multiple sample dates (maturities) in four growth series across the growing season.
CHAPTER 5

SUMMARY AND CONCLUSIONS

Legumes benefit cool-season grass pastures by improving forage production and nutritive value. Multiple studies have demonstrated increased forage yield in mixtures of legumes and grasses when compared to grass monocultures (Sleugh et al., 2000; Cox et al., 2017). The increase in yield can be attributed to nitrogen provided by the legumes and by actual forage production of the legumes (Ta et al., 1986, Cox et al., 2017).

Nutritive value of a pasture is often difficult to ascertain, but typically decreases as grass and legume species mature (Griffin and Jung, 1983; Nordkvist and Aman, 1986; Albrecht et al, 1987). In general, legumes have greater crude protein and lower neutral detergent fiber than grasses (Van Soest, 1994; Sleugh et al., 2000; Cox et al., 2017). Increased forage yield and nutritive value benefit animals in the pasture, but often legumes do not persist well in pastures (Beuselinck et al., 1984; Brummer and Moore, 2000; Wen et al., 2004). Poor grazing management is often the cause of poor legume persistence, since stands are known to persist when the pasture is rotationally grazed (Davis and Bell, 1957; Davis and Bell; 1958; Van Keuren and Davis, 1968). The purpose of this research was to 1) determine the best method for inter-seeding legumes into existing cool-season grass pastures, 2) determine cattle grazing preference in mixed cool-season grass and birdsfoot trefoil pastures and 3) evaluate how legumes and cool-season grass changes in nutritive value at different maturities throughout the growing season.
Establishing legumes in an existing pasture is difficult due to competition from the established grasses; the first chapter of this study evaluates three methods of reducing competition to increase the success of inter-seeding three legume species. Pastures in Millville, Utah, Lewiston, Utah and Panguitch, Utah were used for inter-seeding. Inter-seeding occurred in the spring, summer and fall. The three treatments included close mowing to simulate heavy grazing, a light tillage and a reduced rate of glyphosate herbicide (232 g ha⁻¹ ae). The inter-seeded legumes were alfalfa (*Medicago sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and cicer milkvetch (*Astragalus cicer* L.).

In Millville there were two plantings, one in the fall of 2014 and one in early summer 2016. The fall planting was not successful, mostly due to inadequate irrigation and insufficient time to establish before onset of cool fall temperatures and increased grass competition. In the early summer planting, alfalfa and birdsfoot had high frequency of presence, at 58 and 43%, respectively, eleven months after planting, with the highest frequency in the mowing pretreatment at 76%. Cicer milkvetch was slow to establish, but continued to increase throughout the period of study. At Lewiston, there was a planting in the summer of 2013 and in the spring of 2014. The spring planting was not successful, which was largely due to grass competition, since May is during the peak growth period for cool-season grasses. In the summer planting, alfalfa and birdsfoot trefoil emerged well, but alfalfa suffered mortality through the winter and birdsfoot trefoil showed the highest frequency eleven months after planting at 71% and cicer
milkvetch was 16%. Mowing, tillage and glyphosate all resulted in similar frequency of presence, ranging from 51 to 49%.

The summer planting in Lewiston was planted 3 years prior to the other successful plantings in 2016, allowing an observation three years after planting. It was also grazed following the initial observations providing data on the survival of the legumes. Since alfalfa had suffered severe mortality it was virtually undetectable in the pasture, but birdsfoot trefoil frequency was good at 41% and cicer milkvetch had continued to increase to 26%. Among birdsfoot trefoil and cicer milkvetch the greatest frequency was 41% following the glyphosate pretreatment.

In Panguitch there were two planting as well, both in late spring 2016, one into tall fescue and the other meadow bromegrass. Similar frequency of presence was observed in the two pastures after eleven months, alfalfa had the highest frequency at 23 and 36% for the tall fescue and meadow brome pastures, respectively. No differences were detected among the pretreatments.

Overall, the best inter-seeding results were observed in summer plantings while late spring plantings were not failures they did not establish as well as summer plantings. Other studies have yielded similar results, with the caveat that summer plantings need irrigation or they won’t survive (Martin et al., 1983; Brummer, 2009). Alfalfa and birdsfoot trefoil generally were highest in initial establishment with cicer milkvetch increasing over time, which agrees with previous observations of these species (Townsend and McGinnies, 1972; Cuomo et al. 2001; Brummer et al., 2011; Cox
et al., 2017). Among the pretreatments, mowing generally resulted in the highest establishment, in this case mowing was used to simulate grazing, both of which have been shown to successfully control grass competition (Kunelius et al., 1982; Seguin et al., 2001).

The second chapter of this study concentrates on determining the degree that cattle preferentially graze binary mixed pastures of birdsfoot trefoil with tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.), orchardgrass (*Dactylis glomerata* L.) and meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.). Each grass was established in mixed and alternating rows with birdsfoot trefoil. Alternating rows generally lead to better establishment of both species. Jersey heifers were used to rotationally graze the pastures and utilization of the different species within each mixture measured. Grazing was measured across three grazing cycles from late spring to late summer.

Utilization of grass and birdsfoot trefoil was different for each mixture. Overall birdsfoot trefoil utilization averaged 73%, while grass utilization was 74, 67, 64 and 53% for perennial ryegrass, meadow bromegrass, orchardgrass and tall fescue, respectively. However, utilization differed by grass treatment and by the grazing cycle. In the first cycle, early-summer, birdsfoot trefoil utilization was 11 percentage points less than perennial ryegrass but averaged 9 percentage points greater than all other grasses. In the second cycle, mid-summer, birdsfoot trefoil utilization was 7 percentage points less than perennial ryegrass but averaged 11 percentage points greater than all other
grasses. In the third cycle, late-summer, birdsfoot trefoil utilization was no different than perennial ryegrass, averaged 7 percentage points greater than meadow bromegrass and orchardgrass and averaged 22 percentage points greater utilization than tall fescue. Utilization also differed by row type, either mixed or alternating. The alternating rows showed greater differences in utilization between the grass and birdsfoot trefoil than the mixed rows. In the mixed rows it is more difficult for the animals to select what they would prefer to graze, potentially accounting for lack of difference.

Birdsfoot trefoil was always preferred over tall fescue, which with unmanaged grazing could result in the loss of the birdsfoot trefoil stand in that pasture over time. Conversely, perennial ryegrass was preferred over birdsfoot trefoil in the early part of the grazing season. Orchardgrass was generally preferred less than birdsfoot trefoil and meadow brome grass had similar utilization to birdsfoot trefoil. The preference of one species over another highlights the importance for grazing management, especially if alternating rows are used. Allowing animals to graze continuously across a pasture could result in significant damage to the preferred forage species. Managing the pasture to allow sufficient regrowth is essential to ensure a stable stand of legumes and grasses.

The last chapter of this study focused on comparing the interaction of growth stage and time of season on the nutritive value of alfalfa, birdsfoot trefoil, cicer milkvetch, orchardgrass, perennial ryegrass and tall fescue. Samples were taken weekly and growth stage was determined for each sample. Target growth stages for the grasses
were: jointing, early boot, late boot, heading and seed production; and for the legumes: prebud, bud, 10% bloom, 100% bloom and pod production.

In spring and early summer, as maturity progressed, total digestible nutrients (TDN) of legumes decreased by an average of 2.7 percentage points from 76, 78 and 77% for alfalfa, birdsfoot trefoil and cicer milkvetch, respectively. Mid-summer TDN of legumes decreased little with maturity and in late summer TDN didn’t change, averaging 76% for the entire summer. Crude protein (CP) decreased with progressing maturity from 26 to 15% in alfalfa and birdsfoot trefoil in spring, mid, and late summer. Cicer milkvetch decreased similarly but averaged 5 percentage points lower in the spring. Legume NDF increased (became less desirable) in spring and mid-summer by an average of 10 percentage points but was stable in late summer. In spring and early summer TDN of the grasses decreased as they matured by an average of 6 percentage points from 71, 74, and 67% for orchardgrass, perennial ryegrass and tall fescue, respectively. In mid to late summer all grass regrowth was vegetative and TDN remained stable around 67% for all grasses. Crude protein of the grasses decreased from 14 to 7% in the spring for all grasses, was stable around 14% mid-summer then increased from 11 to 17% in late summer for orchardgrass and perennial ryegrass but remained unchanged at 14% for tall fescue. In the spring NDF increased by an average of 10 percentage points with increasing maturity, but then was stable throughout the summer at 52, 46 and 52% for orchardgrass, perennial ryegrass and tall fescue, respectively.
Overall, the legumes and cool-season grasses responded differently to the changing season. Legumes initiate reproductive growth throughout the growing season, with a corresponding decrease in nutritive value in spring, early and mid-summer, while remaining relatively stable in the late summer and early fall. Utilizing these species at an early growth stage in the spring, and early summer is critical for best nutritive value. However, in late summer, the pasture could be allowed to accumulate more forage at a later growth stage before grazing and the nutritive value would be less affected. Cool-season grasses complete reproductive growth in the spring, and decrease in nutritive value during this time. However, the regrowth of these grasses is vegetative during mid and late summer and nutritive value is relatively constant. Similar to the legumes, utilizing grasses at an early growth stage is most critical in the spring, but unlike the legumes, mid and late summer regrowth could be grazed whenever the forage mass is sufficient for animals, since the nutritive value is generally unchanged through the summer. For both legumes and grasses spring grazing can result in rapidly changing nutritive value, so careful management is crucial during this time.

As a whole, these studies provide information for producers who utilize mixed pastures or who want legumes in their cool-season grass pasture. Inter-seeding is a topic of interest, since renovating a whole pasture and starting over is expensive and reduces the total pasture available. By inter-seeding in the summer, a producer can incorporate legumes into his pasture without complete renovation. Once legumes are incorporated into the pasture, it will need to be managed with the goal of maintaining
the legume stand. Rotational grazing is a good management practice regardless of the pasture composition, but it becomes essential in mixed pastures with species of mixed palatability’s. Times with peak nutritive value have been demonstrated, which vary with time of season and growth stage. This provides the producers with information needed to utilize pastures at peak nutritive value.

REFERENCES


Kunelius, H.T., A.J. Campbell, K.B. McRae, J.A. Ivany. 1982. Effects of Vegetation Suppression and Drilling Techniques on the Establishment and Growth of Sod-


