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# TABLE OF CONTENTS

Sugarbeet performance under strip-till and no-till management  
R.K. Afshar, C. Chen, W.B. Stevens, and W. Iversen .................................................................3

Preference and forage quality of 13 cultivars of forage barley and 2 cultivars of oats when grazed by sheep  
D.M. Staudenmeyer, D. Fuga, and E.C. Glunk .................................................................................7

Seeding date impact on production of three cool-season forage species under flood irrigation  
E. Glunk ...........................................................................................................................................10

Modifying seeding date for successful establishment of bluebunch wheatgrass (*Pseudoroegneria spicata*)  
A. Harvey, S. Davis, and J. Mangold ...............................................................................................14

Nutrient management for increasing wheat grain protein  
C. Jones and K. Olson-Rutz .............................................................................................................17

The effects of shredded sugar beets on sheep nutrient metabolism  
I. McGregor, C.M. Page, C. Ryan, A.R. Hubbard, M. Manoukian, W.C. Stewart, and M.L. Van Emon ........20

Can targeted sheep grazing suppress sulfur cinquefoil?  
J.C. Mosley, R.A. Frost, B.L. Roeder, and R.W. Kott .................................................................24

Effects of zinc source and dietary concentration on zinc status, growth performance, and wool characteristics in developing rams  

Distribution and clearance of chopped net wrap in the digestive tract of beef cattle  

Recovery of surface applied urea is maximized through spring application and Agrotain® use  
C.M. Romero, R.E. Engel, C. Chen, and C.A. Jones ........................................................................36

Evaluating hay feeding methods on heifer performance, hay waste, and economics  
M. Van Emon, M. Hoffman, R. Endecott, and E. Glunk ..................................................................39
# ABBREVIATIONS/ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>acid detergent fiber</td>
</tr>
<tr>
<td>ADG</td>
<td>average daily gain</td>
</tr>
<tr>
<td>AFD</td>
<td>fiber diameter</td>
</tr>
<tr>
<td>BF</td>
<td>back fat</td>
</tr>
<tr>
<td>BW</td>
<td>body weight</td>
</tr>
<tr>
<td>CF</td>
<td>crude fat</td>
</tr>
<tr>
<td>CP</td>
<td>crude protein</td>
</tr>
<tr>
<td>CT</td>
<td>conventional tillage</td>
</tr>
<tr>
<td>DM</td>
<td>dry matter</td>
</tr>
<tr>
<td>DMI</td>
<td>dry matter intake</td>
</tr>
<tr>
<td>FNR</td>
<td>fertilizer nitrogen recovery</td>
</tr>
<tr>
<td>G:F</td>
<td>feed efficiency</td>
</tr>
<tr>
<td>LMD</td>
<td>loin muscle depth</td>
</tr>
<tr>
<td>N</td>
<td>nitrogen</td>
</tr>
<tr>
<td>NDF</td>
<td>neutral detergent fiber</td>
</tr>
<tr>
<td>NEI</td>
<td>net energy of lactation</td>
</tr>
<tr>
<td>NEm</td>
<td>net energy of maintenance</td>
</tr>
<tr>
<td>NEFA</td>
<td>non-esterified fatty acids</td>
</tr>
<tr>
<td>NT</td>
<td>no-till</td>
</tr>
<tr>
<td>RFV</td>
<td>relative feed value</td>
</tr>
<tr>
<td>SL</td>
<td>staple length</td>
</tr>
<tr>
<td>SLM</td>
<td>sucrose losses to molasses</td>
</tr>
<tr>
<td>ST</td>
<td>strip-till</td>
</tr>
<tr>
<td>TDN</td>
<td>total digestible nutrients</td>
</tr>
<tr>
<td>TMR</td>
<td>total mixed ration</td>
</tr>
<tr>
<td>Zn</td>
<td>zinc</td>
</tr>
</tbody>
</table>
Sugarbeet Performance Under Strip-Till and No-Till Management

R.K. Afshar\textsuperscript{1}, C. Chen\textsuperscript{1*}, W.B. Stevens\textsuperscript{2}, and W. Iversen\textsuperscript{2}

\textsuperscript{1} Eastern Agricultural Research Center, Montana State University, Sidney, MT 59270 and \textsuperscript{2} USDA-ARS Northern Plains Agricultural Research Laboratory, Sidney, MT 59270

\section*{IMPACT STATEMENT}

Conventional tillage is still widely used by sugarbeet growers in Montana. This tillage system has many unintended consequences for soils and the environment as well as a high cost of fuel, machinery, and equipment, labor. Our face to face interviews with growers in eastern Montana confirmed that conservation tillage such as no-till can offer up to $200 savings per ac (depending on the management practices) with no or minimum yield penalties. The results of present study showed sugarbeet yield and quality did not differ when strip-till and no-till were adopted.

\section*{SUMMARY}

Conventional tillage (CT) is still widely used by sugar beet growers, with many unintended consequences for soils and the environment. Conventional tillage is also expensive, requiring large labor and fossil energy inputs. Therefore, shifting from CT to reduced tillage practices such as strip-till (ST) and no-till (NT) has drawn attention. Nutrient management, especially nitrogen (N), needs to be optimized when tillage system is changed. A field experiment was conducted in 2016 in Sidney Montana to evaluate the performance of sugar beet under CT vs. ST and NT under various rates of N (50, 100, 150, 200 lb ac\textsuperscript{-1}). No significant difference was observed between tillage systems in terms of root yield, sucrose percent, and sucrose yield. This is highly important since NT provided economic benefits (lower cost, less labor, less fuel consumption) as well as ecosystem services (less soil erosion, soil compaction, etc.) while producing similar yield as CT. No significant difference was observed regarding sugarbeet response to N rate in respect to the tillage system.

\section*{INTRODUCTION}

Montana ranks 6th in the nation in sugarbeet production. Conventional tillage (CT) is still widely used by growers, which consists of five or more passes across a field for plowing or ripping, leveling, and hilling. CT has many unintended consequences for soils and the environment such as loss of organic matter and beneficial soil organisms, increased soil erosion and pesticide runoff, reduced soil fertility, loss of soil structure and porosity, compaction, surface crusting, the formation of plow pans, reduced root growth, and poor drainage. CT is also expensive, requiring large labor and fossil energy inputs. Shifting from CT to conservation tillage practices such as strip tillage (ST) and no-till (NT) would offer numerous agronomic, environmental, and economic benefits. However, more research is needed proving the benefits of conservation tillage.

The main objective of this study was to evaluate yield and quality of sugarbeet under NT and ST management compared to CT. We also evaluated if sugarbeet response to nitrogen rate varied by type of tillage in this environment.

\section*{PROCEDURES}

A field experiment was conducted in 2016 at EARC irrigated farm located in Sidney MT to evaluate the response of sugarbeet to nitrogen rate (50, 100, 150, 200 lb N/ac supplied with 46-0-0) under CT, ST, and NT. Soil at this location is containing 2.3\% organic matter and pH of 8.3. Soil residual N to 4 ft depth was 23 lb NO\textsubscript{3}-N/ac.

The experiment was conducted in a split plot arrangement based on a randomized complete block design with four replications. Main plots were tillage systems and subplots were nitrogen
rate. Weather data during the sugarbeet growth period are shown in Table 1.

CT was performed in early spring consisted of three passes to deep disking and two passes of much packing. ST was performed at the same time as CT using a specialized equipment described in detail by Evans et al. (2009).

The previous crop was spring wheat and its chaff and straw were uniformly spread after combine harvest. The six-row strip tiller was set to a depth of 8 inches with a straight coulter in front of a semi-parabolic shank followed by two wavy coulters and a crowfoot packer wheel (Schlagel TP 6524, Schlagel Mfg., and Torrington, WY) that tills 12-inch wide strips and leaves 12-inch of standing stubble between tilled rows. In NT plots, seeds were sown directly without any seed bed preparation.

Sugarbeet (cv. American Crystal S360) was planted on May 6, 2016, at a rate of 1.09 seed/ft² (5.5 inches between plant and 24 inches between rows). Due to sprinkler irrigation, all tillage treatments were flat-planted (no furrow created).

Nitrogen fertilizer was banded 3 inches away from the seeding row after seeding using a plot drill. All plots received an equal amount of P (20 lb/ac 11-52-0) and K (40 lb/ac potash) fertilizers which were broadcasted on soil surface three days before seeding. Roundup was applied at a total rate of 48 ounces/ac for weed control. One application of Minerva-Duo fungicide was also used to control fungal disease.

Plots were harvested on Sep 19, 2016. Prior to harvest, aboveground biomass samples were taken. At the time of harvest, plots were mechanically defoliated then a scale-mounted harvester was used to dig and weigh the roots from 30 ft long of the central row. Pre-wash root yield was recorded then a sample of 12 roots was randomly taken from each plot. The samples were transported to Sidney Sugar Inc. Tare soil and sucrose percentage were determined. Extracted juice sent to Agterra Technologies Inc. (Sheridan, WY) for impurity analysis. To measure Impurity Value and the percentage of sucrose losses to molasses (SLM). Laboratory results for Na, K, amino N, impurity index, and SLM was obtained from this laboratory as well. Based on SLM, extractable sucrose yield was determined (Eckhoff et al., 2005).

Data were analyzed using Proc GLM of SAS and menas were separated by LSD test at $P<0.05$.

### RESULTS AND DISCUSSION

The effect of tillage and nitrogen rate on sugarbeet yield and other variables are shown in Table 2. Tillage had a significant effect only on aboveground biomass and plant stand. Interestingly, aboveground biomass and plant stand were higher in no-till compared to CT and ST (Table 3). Due to a problem with irrigation system at the time of seed germination and establishment, it seems that better moisture availability in NT soil at this time led to the better establishment in this treatment. No significant difference was found between tillage systems in terms of root yield, sucrose percent, sucrose yield, and SLM. This is highly important since NT can provide economic benefits (lower cost, less labor, less fuel consumption) as well as ecosystem services (less soil erosion, soil compaction, etc.) while producing similar yield as CT. No significant response was observed with increasing nitrogen rate in either of tillage systems. Nitrogen Use efficiency (lb sucrose/lb N used) followed a decreasing trend in response to increasing rate of N regardless of tillage system (Fig. 1).

<table>
<thead>
<tr>
<th>Month</th>
<th>Max Temp (°F)</th>
<th>Min Temp (°F)</th>
<th>Avg Temp (°F)</th>
<th>Total Rainfall (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr.</td>
<td>60</td>
<td>33</td>
<td>46</td>
<td>3.5</td>
</tr>
<tr>
<td>May</td>
<td>71</td>
<td>43</td>
<td>57</td>
<td>2.1</td>
</tr>
<tr>
<td>June</td>
<td>81</td>
<td>54</td>
<td>67</td>
<td>1.4</td>
</tr>
<tr>
<td>July</td>
<td>85</td>
<td>57</td>
<td>71</td>
<td>2.7</td>
</tr>
<tr>
<td>Aug.</td>
<td>84</td>
<td>53</td>
<td>68</td>
<td>0.7</td>
</tr>
<tr>
<td>Sept.</td>
<td>70</td>
<td>47</td>
<td>59</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Data from [https://ndawn.ndsu.nodak.edu](https://ndawn.ndsu.nodak.edu)
Based on the results obtained in this experiment, no significant variation was found in sugarbeet response to nitrogen rate based on tillage practices. More efforts are needed to optimize nitrogen fertilization for sugarbeet under various tillage practices in this region.

REFERENCES


**ACKNOWLEDGMENTS**

This project was financially supported by Western SARE grant # SW16-051 and a grant from Montana Fertilizer Advisory Committee.

*Corresponding author: cchechn@montana.edu*

Table 3. Main effect of tillage and nitrogen on sugarbeet measured variables.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Aboveground biomass (lb/ac)</th>
<th>Plant/ac</th>
<th>Sugar (%)</th>
<th>Root YLD (ton/ac)</th>
<th>Sucrose YLD (lb/ac)</th>
<th>Impurity Value</th>
<th>SLM</th>
<th>Extractable Sucrose (lb/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>3418b</td>
<td>24756a</td>
<td>17.4</td>
<td>26.9</td>
<td>9510</td>
<td>0.65</td>
<td>0.97</td>
<td>8743</td>
</tr>
<tr>
<td>ST</td>
<td>3503b</td>
<td>22148b</td>
<td>17.1</td>
<td>28.3</td>
<td>9620</td>
<td>0.68</td>
<td>1.01</td>
<td>8837</td>
</tr>
<tr>
<td>NT</td>
<td>4469a</td>
<td>26358a</td>
<td>17.5</td>
<td>27.4</td>
<td>9577</td>
<td>0.65</td>
<td>0.97</td>
<td>8351</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 50</td>
<td>4036</td>
<td>24799</td>
<td>17.5</td>
<td>28.6</td>
<td>10009</td>
<td>0.65</td>
<td>0.98</td>
<td>9147</td>
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<tr>
<td>N 100</td>
<td>3974</td>
<td>25851</td>
<td>17.5</td>
<td>26.8</td>
<td>9312</td>
<td>0.64</td>
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<tr>
<td>N 150</td>
<td>3778</td>
<td>23650</td>
<td>17.1</td>
<td>26.3</td>
<td>8994</td>
<td>0.66</td>
<td>1.00</td>
<td>8125</td>
</tr>
<tr>
<td>N 200</td>
<td>3485</td>
<td>23705</td>
<td>17.3</td>
<td>28.7</td>
<td>10000</td>
<td>0.66</td>
<td>0.99</td>
<td>8737</td>
</tr>
</tbody>
</table>
Figure 1. NUE of sugarbeet in response to nitrogen rate under conventional tillage (CT), strip tillage (ST), and no-till (NT).
Preference and Forage Quality of 13 Cultivars of Forage Barley and 2 Cultivars of Oats when Grazed by Sheep

D.M. Staudenmeyer¹, D. Fuga², and E.C. Glunk¹*

¹Department of Animal and Range Sciences, Montana State University, Bozeman 59717, USA and
²Federal University of Sao Carlos, Sao Carlos-SP, Brazil

IMPACT STATEMENT

Annual forages are an important feed source for Montana producers. With new cultivars entering the market, it is important to know their nutrient quality in order to determine how they can fit into your livestock management. We also wanted to evaluate differences in animal preference, an important tenant of forage quality.

SUMMARY

Annual forages are an important part of the Montana agricultural community, and provide a valuable and high-quality forage source for livestock. Varieties are continuously being developed for improved forage quality and digestibility. This study aimed to evaluate the forage quality of several new cultivars of forage barley, as well as commonly-used varieties that are already available. Two cultivars of oats were also included in the trial which are commonly used throughout MT. Sheep were allowed to graze all varieties at the same time in order to evaluate preference. All plots were sampled for forage quality and herbage mass production. Sampling and grazing was initiated at approximately 5-10 days post heading. All forages sampled were considered to be fairly high-quality livestock feed, with crude protein ranging from 16.2-21.5%, and total digestible nutrients ranging from 60.3-65%. However, nitrates were elevated in all plots, with oat plots having the highest. Oats also were the most preferred by sheep, with visual estimates of forage mass removed ranging from 55-87%, while the forage barley estimates ranged from 21.7-56.7% removal, depending on cultivar. This research demonstrates that annual forages can be a high-quality, highly-accepted grazing source, however care must be taken to avoid nitrate toxicity.

INTRODUCTION

Small grains are highly-ranked commodities contributing to the Montana economy. Barley for grain is one of the top crop items (in acres) produced in Montana (USDA, 2016) and forage barley acres are increasing as grain prices decrease. Barley and oat production has risen in Montana since the last census conducted in 2012. The Montana State Agriculture Overview (2015) reported a total of 860,000 acres of barley and 22,000 acres of oats harvested in 2015. Although there has been a rise in small grain production, overall cereal grain prices in 2016 have caused concern among producers. A combination of a declining livestock market, lower international/domestic corn prices, and an adequate supply of eastern and western feed grains has reduced small grain prices. Concerned producers have begun looking for an alternative market for their small grains, sparking an interest in the use of annual cereal crops as forage.

The economic value of feeding cereals as forage to livestock depends on both yield and quality. Factors that influence year-to-year variability in forage quality are species composition, plant maturity, and environment (Buxton, 1996). Grazing animals avoid certain components of vegetation based on chemical characteristics and “anti-quality” factors. Grazing preference is usually influenced by nutritive characteristics and the proportion of
indigestible components present in forage (Thomas et al., 2010). Thomas et al. (2010) reported that the grazing strategy for sheep allowed them to respond to changing vegetation characteristics. The sheep in this study preferred to consume forage that did not limit nutrient availability and allowed for increased intake of digestible dry matter. The authors of this study suggest that grazing strategy and preference by sheep allows them to maintain nutrients essential for optimal rumen function.

Variation in yield and quality of cereal forages depends on cultivar, stage of growth, year, and planting location (Berkenkamp, et al, 1987a). Oats used as forage are generally higher yielding than other cereal crops such as barley, wheat, triticale, and rye (Berkenkamp, et al., 1987a; Berkenkamp, et al., 1987b). However, yields comparable to oat have been reported in the literature in both barley and triticale (Cherney and Marten, 1982). Utilizing cereal crops as forage is a potential alternative market option for producers during times when cereal grain prices are low. Cereal forages have high yield potential; however, producers need to be mindful of the trade-off between yield and forage quality. Grazing preference varies due to differences in quality between cultivars. Research regarding grazing selection and preference between different cereal forages may be useful for producers during cultivar selection. Selection will vary based on environmental conditions, the goals of the producer, and the type of animal being used.

PROCEDURES

Fifteen cultivars were established on May 18, 2016 at the Bozeman Agricultural Research and Teaching farm. Species were established into a prepared seedbed using a no-till drill at a rate of approximately 65 pounds pure live seed per acre. Fertilizer amounts were based off of soil samples taken prior to establishment. All species were grown in a dryland environment, with no supplemental irrigation.

The study was planted as a randomized complete block design, with a total of three reps per cultivar. Each block contained all fifteen cultivar entries. Individual plots measured 6 ft x 15 ft. Initial plant heights were taken in three locations within each plot across the diagonal using a meter stick. Initial herbage mass samples for all plots were taken on July 13, 2016, after a majority of the cultivars had begun heading. All cultivars were within 5-10 days of heading at harvest. As all plots were uniform in growth, a 1 ft x 1 ft quadrat was randomly thrown into the middle of each plot, and samples were cut to a 3-inch height. Samples were immediately weighed and placed in a 60°C oven to determine dry weight. Density was determined using dry herbage mass weights.

Each replication was fenced off individually using mesh nylon fencing. On July 18, 2016 at 0800, eight Rambouillet rams (47.0 ± 8.3 kg) were placed into block 1 for a 24-h grazing period. Sheep were removed after 24-h and placed into block 2 for the second day of data collection. On day 3, sheep were moved into block 3 for the final 24-h grazing period. Sheep had ad libitum access to water.

Residual herbage mass samples were taken each day immediately after sheep removal in a similar manner to determine initial herbage mass. Herbage mass removal was calculated by subtracting residual plot herbage mass from initial plot herbage.

Forage samples were submitted to Midwest Laboratories (Omaha, NE) for nutrient analysis. Acid detergent fiber (ADF), total digestible nutrients (TDN), crude protein (CP), crude fat (CF), net energy for maintenance (NEm), and nitrate levels were evaluated.

RESULTS AND DISCUSSION

No differences were observed between cultivars in herbage mass production, residual herbage mass production, or initial or residual plant heights (Table 1). It is not surprising that there were no differences between the initial heights and herbage mass production of cultivars, as all entries appeared to have fairly similar growth. The two oat entries did mature a little quicker, with seed heads appearing about 3 days ahead of the forage barley entries.

A trend for significance was observed for herbage mass removal, and there was a significant difference in visual estimation of
herbage mass removal. It is likely that the sampling method decreased the differences in herbage mass removal, as there was significant variation throughout the plots due to grazing, which was difficult to capture using only two quadrat clippings. Researchers observed that every day sheep were placed into a new block, they immediately grazed on the oat plots before grazing on the barley plots.

No significant differences were observed between cultivars for CP or CF, but there were differences for ADF, TDN, NEm, and nitrates (Table 2). The cultivar MT103101-5 is part of a program breeding for improved digestibility, so it is not surprising that it had the highest TDN. These findings are similar to previous research where ‘Horsford’ and ‘Haybet’ were found to have higher TDN and CP than ‘Otana’ and ‘Stampede’ (Cash et al., 1997).

The forage quality of all entries is acceptable for livestock at most production classes, with the biggest concern being the nitrate levels. Particularly with oats, grazing livestock on forages with levels above 1% NO3 is not recommended, as issues with reproduction and performance are often observed. It is not surprising that the oats had the highest nitrate levels, as oats are known to be nitrate-accumulators, and our values are in agreement with several other published reports (Bolan and Kemp, 2003; Crawford, et al., 1961; Gul and Kolp, 1960). We did not observe issues in our rams, likely because they were able to access other lower-quality forages, plus they were not reproductively active, decreasing likelihood of symptoms.

**REFERENCES**


*Corresponding author: emily.glunk@montana.edu
Seeding Date Impact on Production of Three Cool-Season Forage Species Under Flood Irrigation

E. Glunk

Department of Animal and Range Sciences, Montana State University, Bozeman, MT

IMPACT STATEMENT

Two seeding dates, late spring and early summer, were used to establish three cool-season perennial forage species. Plant and weed densities, as well as forage production were evaluated the year following seeding. This information may help Montana producers in deciding if an alternative seeding date may work on their operation.

SUMMARY

Spring is a busy time for many producers across Montana. Having the ability to spread out seeding dates may help to alleviate some of the stress of the spring workload. Additionally, weed pressure from winter annuals and cool season species is generally lower later in the growing season. However, inadequate moisture and high temperatures and evapotranspiration may limit seed germination and growth. To evaluate the impact of seeding date, two cultivars of three species of perennial cool-season forages were seeded: alfalfa, intermediate or pubescent wheatgrass, and meadow bromegrass. No differences were observed in herbage mass production the year following seeding between the two seeding dates in any of the entries. Plant density was higher on average in the summer-planted versus spring-planted plots. Additionally, no impact of seeding date was observed on weed count. A later seeding date may be a viable option for producers, provided there is adequate moisture, and seeds are not planted too late in the season to avoid frost damage.

INTRODUCTION

In the Northern Great Plains, spring seeding is the most commonly used time for perennial forage establishment. With historically plentiful spring moisture, most producers find it the best time to guarantee adequate stand establishment. However, in recent years, with increases in the number of irrigated acres (MT DNRC, 2008), altering timing of establishment may be a more feasible option.

Planting later in the season offers several advantages: it spreads out the workload, as many producers are very busy in the spring; it often has decreased weed pressure, with summer annuals being more prominent versus cool season annuals and perennials; allows for potential double cropping after an annual crop has been harvested; provides for an extra herbicide application prior to planting; and it can also allow for a “normal” harvest season the following year. There are also some disadvantages to summer seeding, including moisture shortage, which can lead to decreased germination and growth, as well as frost damage that may occur if stands are planted too late.

Previous studies performed many years ago have evaluated the impact of sowing date on stand performance. Blaser et al. (1956) measured the seedling growth rate and stand density of several species of grasses and legumes planted in March or August in Virginia. They found that species had significant effects on plant growth, as well as sowing date, but that species such as alfalfa produced adequate stands when compared to their spring seeded counterparts. Legumes most commonly had higher rates of growth with the later seeding date compared to the cool season grass species entered, likely due to their higher optimum temperature requirements.
Conversely, a study by Buxton and Wedin (1970) conducted in Iowa found that for all species evaluated, summer seeding of perennial forages often resulted in increased presence of weeds, and lower forage production the year following seeding compared to plots that were established in spring, or even established with a companion crop. It should be noted that in this study, the spring plots were hand-weeded during the growing season of the seeding year, likely resulting in lower weed counts and higher plant productivity the following year.

While there have been studies conducted in the past evaluating seeding date and impact on stand performance, many of them are several decades old, and have not been conducted in Montana. Therefore, the objectives of this experiment were to evaluate the impacts of seeding date on flood irrigated fields in southeastern MT, a semi-arid environment. We hypothesized that a later seeding date, coupled with adequate water availability, would not negatively impact stand establishment and production.

PROCEDURES

Plots were established at the NRCS Plant Materials Center in Bridger, MT. The experiment had four replications of each of the plots for both planting dates: a total of twenty-four plots for spring seeded and twenty-four plots for summer seeded. Spring seeded plots were established on June 12, 2015, and the summer seeded were established on July 27, 2015. An application of glyphosate at a rate of 20 oz/acre was applied to all plots immediately prior to spring seeding, and an additional glyphosate application was placed on the summer seeded plots only immediately prior to planting.

The plot area was irrigated using flood irrigation. Each plot measured 1.8 m x 6 m. The cultivars used included two cultivars of alfalfa (Medicago sativa L.), ‘Shaw’ and ‘Cooper’, two cultivars of meadow bromegrass (Bromus biebersteinii) ‘Cache’ and ‘Macbeth’, and two cultivars of wheatgrass (Thinopyrum intermedium) ‘Manska’ and ‘Oahe’. Two cultivars of sainfoin (Onobrychis viciifolia) ‘Shoshone’ and ‘Delaney’ were also planted, but yield data is not included due to heavy wildlife predation concentrated in these plots only. Plots were seeded at a rate of approximately 10 pounds pure live seed per acre for ‘Manska’, ‘Oahe’, and ‘Cache’, 8 pounds pure live seed per acre for ‘Shaw’ and ‘Cooper’, and 30 pounds pure live seed per acre for ‘Delaney’ and ‘Shoshone’.

Plant and weed counts were taken on April 26, 2016 and June 9, 2016. Herbage mass production was evaluated on June 20, 2016 and August 15, 2016. Herbage mass was estimated by harvesting a 3’ wide strip down the middle of each plot. Herbage mass was weighed to obtain fresh weight, then subsamples were taken to determine dry matter percentage. Herbage mass production per plot was then estimated by multiplying the wet weight of herbage mass collected by the percent dry matter.

RESULTS AND DISCUSSION

There was a significant impact of planting date on plant densities (P = 0.039; Table 1), with summer planting on average having higher plant counts compared to spring planting. There was no impact of variety, replication, or their interaction on plant count (P > 0.05). There was a trend for an effect of variety (P = 0.052) and replication (P = 0.076) on weed count, but there was no effect of planting date (P = 0.231) on weed count.

There was a significant impact of variety, harvest, and the interaction of variety*harvest (P < 0.001) on yield. There was no effect of replication (P = 0.194) or seeding date (P = 0.522) on yield. Harvest 1 had significantly higher yields for all varieties compared to yields in harvest 2.

This data shows that planting later in the season may be a viable alternative, provided there is adequate moisture for seed germination and growth. Similar to Blaser et al. (1956), alfalfa produced the most herbage mass compared to the other cultivars. It was interesting to note that the alfalfa plots also had higher weed counts compared to the other grass entries. This may be due to the fact that even though there was adequate growth, in many of the plots the alfalfa appeared to grow slower initially than the grasses, allowing more room for weed growth.
The data is not presented, but plant heights were significantly higher in the wheatgrass plots compared to alfalfa, which may have created a shading effect, decreasing weed pressure as well.

It was interesting to observe that there were no yield differences amongst cultivars for either of the plantings. There was an impact of species and harvest, which is expected based on previous research (Blaser et al., 1956; Rumbaugh et al., 1982; Wichman and Glunk, 2016; Berdahl et al., 2001). It is known that alfalfa typically produces a majority of its seasonal production in the first harvest, from 30-75% (Caddel et al., 1981). It is typical for cool-season forages to produce a majority of their herbage mass by early summer and again in the fall, compared to summer harvests due to water availability and the “summer slump”. This was evidenced by the difference in harvest yield, from harvest 1 to harvest 2 for all species. An additional fall harvest was not taken in order to avoid any negative impacts on species persistence the following year due to decrease fall root carbohydrate reserves.

More research is needed before recommending a late summer seeding on dryland fields. However, this research demonstrates that under adequate irrigation, or with appropriate moisture timing, late summer planting can be a viable option for MT producers.

REFERENCES

*Corresponding author: emily.glunk@montana.edu
Figure 1. Effect of harvest and cultivar on forage yield production.
Modifying Seeding Date for Successful Establishment of Bluebunch Wheatgrass 
(*Pseudoroegneria spicata*)

Audrey Harvey¹, Stacy Davis¹, and Jane Mangold¹*

¹ Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT

**IMPACT STATEMENT**

Land managers can modify seeding date of native perennial plant species during the revegetation of disturbed sites to increase establishment success. Modifying seeding date may be used to influence competitive interactions between native perennial grasses and invasive annual grasses. After one growing season, seeding bluebunch wheatgrass (*Pseudoroegneria spicata*) in fall (early November) or early spring (early April) produced larger individuals and more dense stands than seeding later in the spring.

**SUMMARY**

The objective of this project was to determine how modifying seeding date affected the size and abundance of bluebunch wheatgrass (*Pseudoroegneria spicata*). Seeding occurred in fall 2015 to late spring 2016 in a controlled field setting at two locations near Bozeman, MT. After one growing season, fall-seeded cohorts were larger in size and less dense than spring-seeded cohorts, which were smaller in size but more dense.

**INTRODUCTION**

Re-establishing native perennial grasses on degraded range and wildlands is important to achieving various land management objectives. However, revegetation efforts are often unsuccessful (Schantz et al., 2016). In habitats dominated by invasive plants, seedlings of weedy species can outcompete seedlings of native perennial grasses due to faster emergence and higher relative growth rates of weedy species (Mangla et al., 2011). In addition, abiotic environmental stressors, like seasonal drought, can limit native grass seedling recruitment (Mangla et al., 2011).

Revegetation of weed-infested rangeland typically involves applying herbicide to control weeds in the summer or fall; herbicide application is followed by seeding of native species, most often grasses, in fall of the same year. Seeded native perennial grasses remain dormant throughout winter and emerge the following spring. Even though fall dormant seedings are common practice, some research investigating the role of timing of seeding on perennial grass establishment in degraded rangeland has shown that spring seeding results in higher density and biomass of seeded species than seeding in the fall (Schantz, 2015; Schantz et al., 2016). Furthermore, seeding date may be used to manipulate competitive interactions between native perennial grasses and invasive annual grasses. In a greenhouse study, the order of emergence of seedlings of bluebunch wheatgrass and cheatgrass (*Bromus tectorum*) were manipulated by altering seeding date (Orloff et al., 2013). The native grass species was able to suppress cheatgrass when seeded four weeks prior due to its larger size and increased competitive abilities (Orloff et al., 2013).

Modifying seeding date as an ecologically-based management tool could facilitate desired species attaining a size-advantage over invasive plants, thus avoiding suppression by invasive plants. In addition, stressful abiotic environmental conditions may be overcome due to earlier seeded species having better access to limited resources (Schantz et al., 2016). The objective of this project was to examine whether fall or spring seeding results in the best establishment of the native perennial grass
bluebunch wheatgrass. Furthermore, our project examined how late seeding could occur in the spring and still result in acceptable bluebunch wheatgrass establishment.

PROCEDURES

Our study was conducted at two sites near Bozeman, MT. Both sites were fallow crop fields at Montana State University’s Arthur H. Post and Fort Ellis Research Farms. Fields were tilled and any existing vegetation removed prior to fall 2015. Eight seeding dates of bluebunch wheatgrass treatments included: Fall = 8 November 2015; S1 = 1 April 2016; S2 = 7 April 2016; S3 = 13 April 2016; S4 = 21 April 2016; S5 = 29 April 2016; S6 = 5 May 2016; and S7 = 12 May 2016. Seeds for bluebunch wheatgrass were sourced from the Goldar variety provided by Bruce Seed Farm (Townsend, MT) and originated from Washington. Seeds were hand-broadcasted at 667 seeds per m², following the high seeding rate used by Orloff et al. (2013). Each treatment was replicated eight times at Post Farm and 12 times at Fort Ellis in a completely randomized design consisting of 1 x 1 m plots. Hand-weeding was used to control weeds within plots; broadleaf herbicide and tilling were used to control weeds along buffer strips between plots.

In September 2016, we sampled bluebunch wheatgrass tillers per individual plant, density, seed heads produced per m², and plant height averaged across each plot. Average height was estimated to the nearest 5 cm across each plot. We determined survival by comparing density measurements between June and September. Each site was analyzed separately using log-linear regression models and Tukey’s HSD, where appropriate, to determine differences among seeding groups (α = 0.05).

RESULTS AND DISCUSSION

Over 15,000 individual seedlings were counted over a 12-week tracking period. Across all seeding groups, percent emergence ranged from 2 – 30%, with an average of 12%. Across both sites, percent survival was relatively high; ranging from 50 – 75% (Figure 1). There were no differences in survival among seeding dates at Post Farm and minimal differences at Fort Ellis (Figure 1).

In September 2016, we found that fall-seeded cohorts were larger in size but had fewer individuals than spring-seeded cohorts. Across both sites, a size comparison between seeding dates showed that fall-seeded cohorts averaged 32 – 43 tillers per plant compared to spring-seeded cohorts with an average 15 – 25 tillers per plant (Figure 2). At Fort Ellis, S1 seeding date resulted in the second highest average number of bluebunch wheatgrass tillers per plant. Across sites we found the cohorts seeded earlier in spring

![Figure 1](image1.png)

**Figure 1.** Survival (%) of bluebunch wheatgrass individuals from emergence to September 2016. Differences between seeding groups are indicated by letters and p-values. Seeding dates: Fall = 8 November 2015; S1 = 1 April 2016; S2 = 7 April 2016; S3 = 13 April 2016; S4 = 21 April 2016; S5 = 29 April 2016; S6 = 5 May 2016; and S7 = 12 May 2016.

![Figure 2](image2.png)

**Figure 2.** Size of bluebunch wheatgrass (tillers per plant) in September 2016, one growing season after seeding. Differences between seeding groups are indicated by letters and p-values. Seeding dates: Fall = 8 November 2015; S1 = 1 April 2016; S2 = 7 April 2016; S3 = 13 April 2016; S4 = 21 April 2016; S5 = 29 April 2016; S6 = 5 May 2016; and S7 = 12 May 2016.
had higher September density than fall-seeded or late spring-seeded cohorts. S2 at Fort Ellis had the highest average density at 80 individuals per m² (Figure 3). At Post Farm, S1, S2 and S5 had the highest average density of 95, 77, and 80 individuals per m², respectively (Figure 3). Plants seeded in the fall were taller and had more reproductive stems than late spring-seeded plants at both sites (data not shown).

Overall, our study indicates that fall or early spring seeding results in acceptable establishment of bluebunch wheatgrass. It should be noted, however, that our results are limited to bluebunch wheatgrass, and other native grasses may differ in optimal timing of seeding. Furthermore, our study took place in fallow fields, and establishment of seeded native perennial grasses may be more challenging in more natural settings, including degraded rangeland, where seeded grasses may have to compete with weedy species. In spite of these limitations, our study shows that land managers can continue to implement fall seeding or delay seeding to early spring for effective grass establishment during revegetation.

REFERENCES

ACKNOWLEDGEMENTS
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*Corresponding author: jane.mangold@montana.edu
Nutrient Management for Increasing Wheat Grain Protein

C. Jones* and K. Olson-Rutz

Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT

IMPACT STATEMENT

A pound of nitrogen (N) put into protein may be better for the bottom line than a pound of N put into yield when protein discounts are high. Mid- to late-season N may provide a necessary protein boost to prevent revenue lost to protein discounts.

SUMMARY

We provide guidelines for optimum N management for grain protein based on local and regional research, as presented in Practices to Increase Wheat Grain Protein. Management considerations include: basing N rates on realistic yield potential, knowing the soil residual N, using appropriate fertilizer N rates, timing, placement, and sources, and using tissue N concentrations to determine the likelihood of a protein increase. Combining a conservative early season N rate followed by fertilization near heading to enhance protein, is generally an economically and environmentally efficient N fertilization strategy.

INTRODUCTION

Low wheat grain protein can have a financial impact on Montana producers resulting in reduced economic returns equivalent to $25 to $60/acre. Statewide this is tens of millions of lost revenue dollars. Nitrogen is essential for protein production; thus its management is critical for maximizing returns. In addition to N, protein production requires sufficient amounts of several nutrients such as sulfur and potassium, however, here we focus on N management. This report provides suggestions to guide management for improved wheat grain protein (additional resources listed at the end).

PRACTICES TO INCREASE PROTEIN

1. Variety Growing wheat with high grain protein begins with selecting the varieties with known high grain protein potential. High grain protein varieties sometimes produce slightly less than low protein varieties, but the economic return from high protein varieties can be greater. The MSU small grain variety selection tool is available to identify the best variety for a given goal and location.

2. Nitrogen management

2.a. Realistic Yield Goal to Determine N rate
Past yields and protein are a good indication of future performance. Advances in equipment and technology for mid- to late-season N application allow a conservative yield goal to be used to determine pre-plant N rates.

2.b. Residual Soil N
November to early spring soil samples better reflect available soil nitrate-N than late summer samples, which can result in under- or over fertilization depending on whether soils lose or gain N overwinter. In general, MT soils gain about 20 lb N/ac from late summer to early spring, though amounts depend on previous crop and soil depth. However, some soils can easily lose that amount (Fertilizer Facts No. 55). Tracking field specific patterns of overwinter loss or gain can guide adjustments to spring N rates based on fall samples or the decision to spring sample.

2.c. Rate
Winter wheat requires about 2.6 lb N/bu, and spring wheat requires roughly 3.3 lb N/bu (with 14% protein; Fertilizer Facts No. 17). Further adjustments are made for soil organic matter, residual stubble, N ’credit’ from legume rotations, and soil sampling timing and depth. These are described in Fertilizer Rate Calculations.
MSU's small grains economic N rate calculation tool incorporates yield goal, residual soil N, soil organic matter, fertilizer costs, grain protein discounts, and grain prices to determine N rate for optimal net revenue.

If available N is known to be high, yet protein is low, there may be a sulfur (S) deficiency. This shows up first as yellowing upper (younger) leaves, whereas N deficiency shows up as yellowing lower (older) leaves. A foliar application of 3-5 lb S/acre in a sulfate form should correct the problem if there is sufficient rain or irrigation water after application to wash the sulfate into the root zone.

2.d. Source Urea (46-0-0) is the preferred N source by MT producers because of cost, yet it is susceptible to volatilization (loss to air). Treating urea or UAN (28-0-0 or 32-0-0) with N-butyl-thiophosphoric triamide (NBPT, the active ingredient in Agrotain® and Arborite® AG) can buy time for incorporation by precipitation, which may increase grain protein. Slow or controlled release N fertilizers can be too slow to benefit yield, but may increase protein.

2.e. Timing Nitrogen available to wheat plants after stem elongation has completed contributes directly to grain protein and has less chance of causing lodging. Urea or UAN to boost protein are ideally applied at flowering and must be followed by irrigation or rain to move the fertilizer into the root zone. If there is high risk of scab, avoid watering, and therefore applying N, within 5 days of flower. In dryland production, apply N between boot and the onset of flowering to increase the chance rainfall will move N into the soil. Control or slow release N fertilizers are best seed-placed to benefit grain protein. Under irrigation they can be spring broadcast to benefit spring wheat protein. To increase wheat protein by 1 point (percent) requires roughly an additional 0.75 lb N/bu of expected yield, applied before or during flowering in dryland production, and roughly an additional 0.45 lb N/bu yield, applied around flowering in irrigated production.

Irrigated spring wheat grain protein is likely to increase with late-season N if the flag-leaf N concentration is less than 4.2% (Fertilizer Facts No. 12). The critical flag-leaf N (CFLN) is the flag-leaf N below which a late-season top-dress should increase protein enough to maximize profit. It goes down as N cost goes up and protein discount goes down (CFLN = 4.2 – 0.18(N cost/protein discount), using N cost as $/lb N and protein discount as cents/bu per 1% protein). Chlorophyll readings are another tool for irrigated spring wheat. Readings at heading that are less than 93% of a well-fertilized reference plot indicate grain protein will likely respond to late-season N. Neither flag-leaf N concentration, nor chlorophyll readings are a reliable tool to predict protein response in dryland wheat in our region.

2.f. Placement Foliar applications should be limited to less than 30 lb N/acre of UAN and 45 lb N/acre of liquid urea to minimize leaf burn and yield loss, and far less should be applied if tank-mixed with surfactant, NBPT, herbicide or fungicide. Liquid, as well as broadcast N, needs about ½-inch of rain or irrigation to be washed into the soil to be very effective due to risk of volatilization and minimal uptake by leaf.

2.g. Crop rotation Legumes in rotation can help increase protein, especially at low N rates. Legumes grown as a green manure (nitrogen-rich cover crop) rather than for grain should be terminated by flowering to retain more soil moisture and allow time for the N to become available (Miller et al., 2006).

REFERENCES

No. 12. Flag Leaf Diagnosis of Grain Protein Response to Late-Season N Application in Irrigated Spring Wheat.

No. 17. Predicting Spring Wheat Yield and Protein Response to Nitrogen
No. 55. Changes in Soil Nitrate-N Levels from Late Summer to Early Spring in Montana

MSU Small Grain Variety Selection Tool http://www.sarc.montana.edu/php/varieties/

MSU Small Grains Economic Nitrogen Calculator http://landresources.montana.edu/soilfertility/small-grains-economic-calculator.html


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*Corresponding author: clainj@montana.edu
The Effects of Shredded Sugar Beets on Sheep Nutrient Metabolism

I. McGregor¹, C.M. Page¹, C. Ryan¹, A.R. Hubbard¹, M. Manoukian¹, W.C. Stewart², and M.L. Van Emon¹*

¹Department of Animal and Range Sciences, Montana State University, Bozeman, MT and ²Department of Animal Science, University of Wyoming, Laramie, WY

IMPACT STATEMENT

The current research suggests that whole shredded sugar beets can replace barley up to 45% without having any deleterious effects on fiber or nitrogen digestion. Utilizing sugar beets may potentially provide greater economic returns for sugar beet producers, as well as decreasing feed costs for livestock producers.

SUMMARY

Non-harvested sugar beets represent an underutilized yet cost effective feedstuff for livestock producers in Montana. The objective of this study is to evaluate the effects of shredded sugar beets fed at increasing levels on sheep nutrient metabolism. Eight wethers were used in a 4 × 4 replicated Latin Square and allocated to one of four dietary treatments where sugar beets replaced 0% (0SB), 15% (15SB), 30% (30SB), or 45% (45SB) of barley on a DM basis. The digestibility of DM, NDF, ADF, and nitrogen were not affected (P ≥ 0.10) by treatment. There was quadratic tendency observed for ADF digestibility (P = 0.10), with 0SB and 45SB wethers being greater than 15SB and 30SB wethers. Nitrogen concentration in fecal matter and serum were not affected by treatment (P ≥ 0.22).

INTRODUCTION

Montana is a major producer of sugar beets in the Northern Great Plains (5th in the U.S.; USDA, 2015a), and excess or non-harvested sugar beets could provide a readily available alternative feedstuff for cattle and sheep producers. In Montana, during the 2014-2015 sugar beet harvest, approximately 45.2 million pounds of sugar beets were not harvested (USDA, 2015b).

Sugar beets are an excellent energy source (81% TDN; Lardy and Schafer, 2008), which can be complimentary to, or even replace traditional feedstuffs, such as barley or corn. Sugar beets differ due to the much higher moisture content (70-80% moisture; Lardy and Schafer, 2008) and how they store energy in the form of sugar rather than starch (12-20% sugar; Agribusiness Handbook, 2009). Numerous studies have observed the effects of sucrose on nutrient metabolism and the rumen environment (Broderick & Smith, 2001; Vallimont et al., 2004). Some studies have observed an increase in NDF digestibility when sugar beets replaced a high starch feed source (Huhtanen, 1988; Arrizon et al., 2012). Because rumen anaerobic fungi are capable of fermenting sugars such as sucrose and glucose, the sugar from sugar beets may be able to create a favorable rumen environment resulting in enhanced NDF digestibility (Emanuele, 2004).

Therefore, the objective of this study is to evaluate the effects of shredded sugar beets fed at increasing levels on sheep nutrient metabolism. We previously conducted a study that suggests sugar beets can replace barley up to 45% in the diet on a DM basis when fed to backgrounding steers (McGregor et al., 2016) without deleterious effects on performance. Based on the previous data, we hypothesize that when sheep are fed increasing levels of sugar beets (0, 15, 30, and 45% of DM), there will be no deleterious effects on fiber or nitrogen digestibility.
PROCEDURES

All procedures were approved by the animal care and use committee of Montana State University (#2016-AA09).

A 4 × 4 replicated Latin Square design was used to evaluate the effects of four diets varying in sugar beet concentration on the nutrient metabolism of wethers. Dietary treatments (Table 1) were; 1) 0% sugar beets (0SB), 2) 15% sugar beets (15SB), 3) 30% sugar beets (30SB), and 4) 45% sugar beets (45SB). Sugar beets directly replaced barley on a DM basis. All dietary treatments were formulated to meet or exceed the nutrient requirements of growing wethers (NRC, 2007). Each experimental period was 20 d in length with 4 d between periods (d 1 to 5; to remove wethers from metabolism crates). All wethers were kept in a single pen with ad libitum access to hay and water d 1 to 5. On d 5 wethers were assigned to a dietary treatment and placed in metabolism crates in a temperature controlled enclosed room for a 10-d adaptation period to metabolism crates and diets. These wethers were on a 12 h light, 12 h dark schedule. Each treatment was fed as a TMR at 3% of each wethers initial BW (as fed).

Total mixed ration (TMR) samples were collected d 15 through d 19 and ort samples were collected d 16 through d 20. Ort and TMR samples were dried in a 60°C forced air drying oven for 48-h for DM analysis. Total fecal output was collected and weighed on d 16 through d 20 with 7.5% of the total fecal sample collected, weighed, and placed in a 60°C forced air drying oven for 96-h for DM analysis. On d 16 through d 20, total urine output was collected. Sufficient 6 N HCl (100 mL) was added daily to urinals to maintain urine pH < 3. A 25% subsample of the total urine weight was collected and composited by individual lamb.

Blood samples were collected on d 15 through d 19, 4 hours post-prandially via jugular venipuncture into 16 × 100 mm blood collection tubes (no. 367988; BD Vacutainer, Franklin Lakes, NJ) and refrigerated (4°C) for 2.5 h.

Data were analyzed as a replicated Latin Square, with lamb serving as the experimental unit. Nutrient metabolism data were analyzed using the MIXED procedure of SAS (SAS 9.4; SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

The nutrient metabolism results are presented in Table 2. Initial body weights, by design, did not differ ($P = 1.00$) between treatments. Daily DMI was not affected by treatment ($P \geq 0.30$). The intake of NDF was affected quadratically by treatment ($P = 0.04$), with the greatest being 0SB and the least being 15SB wethers. The intake of ADF demonstrated a quadratic tendency ($P = 0.09$), with the greatest being for 45SB and the least being 15SB. These results contrast with Huhtanen (1988), where both NDF intake and ADF intake were greater when sugar beet pulp replaced barley in a silage based diet for cattle.

Dry matter digestibility was not affected by treatment ($P \geq 0.25$). Results from the current study agree with Vallimont et al. (2004) that reported no effects on DM digestibility when corn starch was replaced with sucrose in vitro. In contrast, Huhtanen (1988) demonstrated a decrease in DM digestibility when sugar beet pulp replaced barley in a silage based diet.

### Table 1. Ingredient and nutritional composition of diets fed to growing wethers (DM basis).

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<tr>
<th>Item</th>
<th>0SB</th>
<th>15SB</th>
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<tr>
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\(^1\)Diets (DM basis) were formulated for growing wethers according to NRC (2016). Treatments: 0SB) 0% sugar beets, 15SB) 15% sugar beets, 30SB) 30% sugar beets, & 45SB) 45% sugar beets.

\(^2\)Sugar beets were coarse ground with a flail chopper designed for woody biomass, to reduce choking hazard.
There was no treatment effect on NDF digestibility ($P \geq 0.33$), however there was a quadratic tendency for ADF digestibility ($P = 0.10$) with the lowest value for 15SB (40.41%) and the highest value for 0SB (51.64%). Our results differ from those observed by Arrizon et al. (2012) that reported increased NDF digestibility when dried shredded sugar beets replaced steam flaked corn. The results of the current study also differ from results observed by Huhtanen (1988) who observed an increase in NDF and ADF digestibility when sugar beet pulp replaced barley in a silage based diet.

Nitrogen digestibility, fecal nitrogen excretion, and SUN were not affected by treatment ($P \geq 0.19$). There was no treatment × day interaction ($P = 0.95$; Figure 1) for SUN concentrations. These results agree with the results from Vallimont et al., (2004) where replacing corn starch with sucrose in vitro also had no effect on nitrogen digestibility.

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*Corresponding author: megan.vanemon@montana.edu
Can Targeted Sheep Grazing Suppress Sulfur Cinquefoil?

J.C. Mosley¹, R.A. Frost¹, B.L. Roeder², and R.W. Kott¹

¹Department of Animal and Range Sciences, Montana State University, Bozeman, MT and ²Teton County Extension, Montana State University Extension, Choteau, MT

IMPACT STATEMENT

Targeted sheep grazing during late June or mid-July can effectively suppress sulfur cinquefoil, a major noxious weed on rangelands of northwestern USA and southwestern Canada. Sheep nutrition is optimized by targeted sheep grazing applied in mid-July.

SUMMARY

We investigated whether targeted sheep grazing could suppress sulfur cinquefoil in a rangeland field experiment in northwestern Montana. We evaluated targeted sheep grazing with and without protein-energy supplementation during late-June and mid-July. Sheep readily consumed sulfur cinquefoil stems, leaves, flowers, and developing seed heads, with or without supplementation. Sulfur cinquefoil comprised the largest proportion of sheep diets during both late June and mid-July, averaging 46% of sheep diets. Supplementation did not improve dry matter intake of sulfur cinquefoil, nor did supplementation improve the nutritive quality of sheep diets. We also documented that 1) targeted sheep grazing achieved heavy use of sulfur cinquefoil (67%) while keeping use of desirable perennial grasses light to moderate (18-41%); 2) targeted sheep grazing reduced viable seed production of sulfur cinquefoil by 97% in June-grazed pastures and 95% in July-grazed pastures; and 3) targeted sheep grazing reduced sulfur cinquefoil yield the next summer by 41% in June-grazed pastures and 47% in July-grazed pastures, without decreasing yield of desirable perennial grasses. We conclude that supplemented or nonsupplemented targeted sheep grazing applied in either late June or mid-July can effectively suppress sulfur cinquefoil. Sheep nutrition was optimized by targeted sheep grazing applied in mid-July.

INTRODUCTION

Sulfur cinquefoil (Potentilla recta) is a non-native, perennial noxious weed that currently infests large amounts of rangeland in the northwestern United States and southwestern Canada. The plant also has likely avoided detection in many North American rangelands because it is similar in appearance to native plants that grow in similar places, particularly slender cinquefoil (a.k.a., Northwest cinquefoil; Potentilla gracilis). Sulfur cinquefoil can invade forests, grasslands, shrublands, and riparian areas throughout the western United States and western Canada. Sulfur cinquefoil displaces native plants, decreases biological diversity, and reduces desirable forage for livestock and wildlife. Sulfur cinquefoil is especially worrisome because it can invade relatively undisturbed areas. In some places, sulfur cinquefoil outcompetes other noxious weeds such as spotted knapweed (Centaurea stoebe), yellow star-thistle (Centaurea solstitialis), and leafy spurge (Euphorbia esula) (Rice 1999).

Few options currently exist for suppressing sulfur cinquefoil on rangelands. Sulfur cinquefoil is closely related to domestic strawberries and native plants, making it a poor candidate for biological control with insects (Duncan et al. 2004). Prescribed fire is ineffective (Lesica and Martin 2003), and herbicides have provided only mixed results. Picloram herbicide is usually, but not always effective, and retreatment is necessary every 3 to 5 years (Duncan et al. 2004). Fortunately, our previous research demonstrated that hand-clipping sulfur cinquefoil when it is
flowering or in its early seedset stage can significantly suppress the yield and viable seed production of sulfur cinquefoil (Frost and Mosley 2012).

Targeted sheep grazing is a potential tool for defoliating sulfur cinquefoil on rangelands. However, sulfur cinquefoil is generally considered unpalatable to livestock. Another potential limitation is that sulfur cinquefoil contains tannins, plant toxins that in high concentrations can impair livestock nutrition. Protein and energy supplementation may be a practical, cost-effective way to enable livestock to consume tannins without suffering adverse effects. Supplementation can help supply the protein and energy needed by livestock to detoxify tannins and limit their absorption (Villalba et al. 2002).

PROCEDURES
Our field experiment was located on a rangeland terrace adjacent to the Flathead River near Polson, MT. The study occurred within a heavy infestation of sulfur cinquefoil in which sulfur cinquefoil comprised 49% of the plant community. We constructed 30 small pastures and applied targeted sheep grazing during 2 years. Each year, 12 pastures were grazed by yearling ewes, with 6 of the pastures grazed when sulfur cinquefoil was in the early flowering stage (late-June treatment) and 6 pastures grazed when sulfur cinquefoil was in the late flowering-early seedset stage (mid-July treatment). Consequently, we applied targeted sheep grazing each year before most sulfur cinquefoil plants had produced viable seeds. Three other small pastures per year were not grazed by sheep (control treatment).

Each year, sheep in 3 of the 6 late-June treatment pastures and sheep in 3 of the mid-July treatment pastures were fed supplemental protein and energy. A barley-based commercial sheep pellet (18% crude protein, 77% total digestible nutrients) was hand-fed daily during late morning at a rate of 0.5 lbs. per ewe.

We measured forage intake, botanical composition and nutritive quality of sheep diets, and forage utilization in the sheep-grazed pastures. In all sheep-grazed pastures and ungrazed control pastures, we collected seedheads from sulfur cinquefoil plants immediately before seed dispersal in late July. In the laboratory, we counted sulfur cinquefoil seeds and tested them for viability. In all pastures we also measured plant yield during mid-July of the year after grazing treatments were applied.

RESULTS AND DISCUSSION
Sheep readily consumed sulfur cinquefoil stems, leaves, flowers, and developing seed heads, with or without supplementation. Sulfur cinquefoil comprised the largest proportion of sheep diets during both late June and mid-July, averaging 46% of sheep diets. Supplementation did not improve dry matter intake of sulfur cinquefoil, nor did supplementation improve the nutritive quality of sheep diets. Nutritional requirements for maintenance of yearling range ewes were exceeded during June and July, but nutritional requirements for maintenance plus growth of yearling range ewes were satisfied during July only.

Targeted sheep grazing achieved heavy use of sulfur cinquefoil (67%) while keeping use of desirable perennial grasses light to moderate (18-41%), and targeted sheep grazing reduced viable seed production of sulfur cinquefoil by 97% in June-grazed pastures and 95% in July-grazed pastures. Targeted sheep grazing also reduced sulfur cinquefoil yield the next summer by 41% in June-grazed pastures and 47% in July-grazed pastures, without decreasing yield of desirable perennial grasses.

Sheep do not need to be confined to a corral before moving to a new area if targeted grazing occurs during the early flowering stage (late June) when sulfur cinquefoil plants have not yet produced viable seeds. However, some viable seeds may be present in the seed heads of sulfur cinquefoil when an infestation is judged on whole to be in the late flowering-early seedset stage. Sheep that graze sulfur cinquefoil infestations during the late flowering-early seedset stage should be kept in a corral for at least 3 days to prevent transporting viable sulfur cinquefoil seeds to other areas (Frost et al. 2013).

We conclude that supplemented or nonsupplemented targeted sheep grazing applied
in either late June or mid-July can effectively suppress the yield and viable seed production of sulfur cinquefoil. Sheep nutrition and sulfur cinquefoil dry matter intake will be optimized by targeted sheep grazing applied in mid-July. Given that most sulfur cinquefoil plants (> 85%) in untreated infestations do not live longer than 5 years (Perkins et al. 2006), and given that only 18% of sulfur cinquefoil seeds in the soil seedbank survive from one year to the next (Kiemnec and McInnis 2009), targeted sheep grazing that dramatically reduces sulfur cinquefoil viable seed production for 5 or more consecutive years should significantly suppress sulfur cinquefoil infestations. Complete details of our study are published in Mosley et al. (2017).

REFERENCES

ACKNOWLEDGMENTS
We thank the Polson Indian Stockmen’s Association and the Confederated Salish and Kootenai Tribes, especially Doug Dupuis, for use of the land for this project. We also thank Lucy Cooke, Kelsy Payne, Ryan Allen, Charles Glenn, Ben Roeder, Jason Frost, and Cindy Selensky for help with data collection and laboratory analyses. This work was supported by the USDA National Institute of Food and Agriculture Rangeland Research Grants Program, the Montana Agricultural Experiment Station, and Montana State University Extension.

*Corresponding author: jmosley@montana.edu
Effects of Zinc Source and Dietary Concentration on Zinc Status, Growth Performance, and Wool Characteristics in Developing Rams

C. M. Page¹, I. McGregor¹, M. L. Van Emon¹, T. W. Murphy¹, C. K. Larson², J. G. Berardinelli¹, W. C. Stewart³*

¹Department of Animal and Range Sciences, Montana State University, Bozeman MT, ²Zinpro Corporation, Eden Prairie, MN, and Department of Animal Science, and ³University of Wyoming, Laramie, WY

IMPACT STATEMENT

Overall, Zn source and concentration affected ADG, serum Zn concentrations, staple length, and tended to increase feed efficiency. Results indicate the beneficial effects of supranutritional Zn concentrations beyond basal dietary concentrations. Although Zn retention and metabolic pathways of Zn metabolism were not investigated, results indicate that greater dietary Zn concentrations can enhance nutritional strategies in ram development. These findings might be especially applicable to producers developing white-face type rams for fall ram sales in the mountain west and northern plains regions.

SUMMARY

The objectives of this study were to evaluate the effects of dietary zinc source and concentration on Zn status, growth performance, and wool characteristics in developing rams. There were no differences in DMI (P = 0.18), BW (P = 0.45), LMD (P = 0.48), BF (P = 0.47), and AFD (P = 0.9) among treatment groups. ZnSO₄ had greater (P ≤ 0.03) serum Zn concentrations compared to ZnAA and CON treatments. Rams consuming ZnAA had greater (P ≤ 0.03) ADG than ZnSO₄ and CON. There tended to be differences among groups for G:F (P = 0.06), with ZnAA being greater than ZnSO₄ and CON. SL was greater (P < 0.001) in the ZnSO₄ treatment group and tended to be longer (P = 0.06) in ZnAA treatment group compared to CON. These results indicate that the source and concentration of a Zn supplement appears to improve ram development, specifically ADG, serum Zn concentrations, SL, with a tendency to improve G:F. Although zinc retention and metabolic pathways of zinc metabolism were not investigated, results indicate that greater dietary zinc concentrations could be beneficial to ram development. This evidence can be utilized to make sound management decisions when accounting for minerals with developing rams in Montana and other northern range lands.

INTRODUCTION

Western sheep production systems rely largely on rangeland plant communities as the primary feed source. This reliance on the rangeland plant community could lead to mineral deficiencies, which may limit the productivity of livestock operations. Mineral concentrations in forages are highly variable across rangelands (Mathis et al., 2004) with influential factors such as soil geochemistry (Smith et al., 2013) and forage stage of maturity (Jones and Tracy, 2015). Numerous studies have suggested that the chemical form of a mineral source plays an important role in bioavailability; generally with organic sources being more bioavailable than inorganic sources (Rojas et al., 1995; Spears, 2003). A survey conducted to quantify serum Zn concentrations in Montana ram lamb populations indicated that approximately 14% of ranches sampled were categorized as being deficient and 52% marginally deficient in Zn (Page et al., 2016).

Zinc is the second most abundant trace mineral in the body with important functions
involved in reproduction (Kumar et al., 2006), gene expression (Berg, 1990), immune function (Spears and Weiss, 2008), and wool growth in sheep (White et al., 1994). Cholecystokinin, an appetite regulating hormone is thought to be affected by the gene expression properties of zinc which in turn could affect growth rate (Blanchard and Cousins, 1996). Subclinical deficiencies in Zn could be more frequent than other trace minerals because the body does not sequester large amounts of available Zn in any one organ. (NRC, 2007; Herdt and Hoff, 2011). Optimal concentrations of dietary Zn are not well understood, and with such high tolerance to dietary Zn in most mammals, there is potential for higher supplementation levels than the recommended concentrations for sheep (NRC, 2007). The objective of the present study was to quantify the effects that dietary zinc source and concentration have on developing ram zinc status, growth performance, and wool characteristics.

PROCEDURES

Experimental procedures described herein were approved by the Agriculture Animal Care and Use Committees of Montana State University (#2016-AA09). All animals used in this study were provided by the Montana Agricultural Experiment Station, and the study was conducted at the Fort Ellis Research Station at Montana State University in Bozeman, MT.

Forty-four purebred Targhee rams (14 mo of age; 150 ± 40 lb BW) were utilized in an 84 d completely randomized design. Rams were stratified by BW, serum Zn concentrations and allocated to one of three pelleted dietary treatments: 1) control diet without fortified Zn (CON; n = 15; Table 1); 2) a diet fortified with a Zn amino acid complex (ZnAA, Zinpro Corp; n = 14); and 3) a diet fortified with ZnSO4 (ZnSO4; n = 15). The basal diet was formulated to meet 100% of nutrient and Zn requirements of developing rams (24 mg of Zn/kg; NRC, 2007). Zinc dietary treatments were formulated to provide 300% of Zn (72 ppm Zn) and 100% of nutrient requirements. Rams were fitted with an electronic identification tag and each pen was equipped with two GrowSafe bunks (GrowSafe Systems Ltd., Airdrie, AB, Canada) to monitor individual intake. Rams were denied access to a complete free choice granulized mineral premix d -50 to d 0 of the study to normalize trace mineral status.

Feed intake was monitored daily and additional feed was added to the bunk as needed. Rams were weighed on consecutive days on d -1 and 0, 27 and 28, 55 and 56, and 83 and 84. For the consecutive days at the beginning and end of the study rams were fasted 12 h before weights were recorded. On d 27, 28, 55, and 56 rams were given free access to feed prior to BW being recorded.

Ultrasonic measurements of loin muscle depth (LMD) and back fat (BF) were taken on d 0, 28, 56, and 84 of the study. Wool side samples were collected from rams on d 0 and d 84, and wool staple length (SL) growth over the 84-d

<table>
<thead>
<tr>
<th>Item</th>
<th>CON</th>
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<th>ZnSO4</th>
</tr>
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<tbody>
<tr>
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</tr>
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<tr>
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<tr>
<td>Soybean hulls</td>
<td>15</td>
<td>15</td>
<td>15</td>
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<tr>
<td>Malt sprouts</td>
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<tr>
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<td>4</td>
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<tr>
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<td>Mn, ppm</td>
<td>89.14</td>
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<td>89.14</td>
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<td>Cu, ppm</td>
<td>7.87</td>
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<td>7.87</td>
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<tr>
<td>Zn, ppm³</td>
<td>47.5</td>
<td>95.5</td>
<td>91.5</td>
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<td>I, ppm</td>
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</table>

1Dietary treatments: 1) control diet without fortified zinc (CON); 2) a diet fortified with a Zn amino acid complex (ZnAA); and 3) a diet fortified with ZnSO4.

²Calculated concentration in diets.

³Analyzed concentration in diets.
study was measured at 5 locations and averaged for each ram. Wool side samples were prepared and analyzed for fiber diameter (AFD) and other wool traits by the Montana State Wool Lab utilizing the OFDA 2000 optical scanning device.

Blood samples were collected via jugular venipuncture into trace mineral royal blue top vacutainer tubes (Covidien, Mansfield, MA) without additives for blood serum analysis. The first blood sample was obtained on d -16 of the study for the purpose of stratifying groups by serum Zn status. Blood samples were then collected on d 28, 56, and 84 of the study. Serum Zn concentrations were determined by a commercial laboratory (Michigan State University Diagnostic Center for Population and Animal Health, East Lansing).

Data were analyzed as a completely randomized design with individual ram as experimental unit. Growth performance and intake data were analyzed as repeated measures using the MIXED procedure of SAS (version 9.4; SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

Effects of Zn source and dietary concentration on ADG, DMI, G:F, and BW are presented in Tables 2 and 3. There was no difference (P = 0.18) among treatments for DMI. Overall, there was no difference (P = 0.45) among treatments in BW. Rams consuming ZnAA had greater (P ≤ 0.03) ADG than ZnSO4 and CON rams. Similar results were found in lambs supplemented with Zn-methionine and ZnO, with a tendency of Zn-methionine to increase growth performance (Spears, 1989). There tended to be differences among groups for G:F (P = 0.06) with ZnAA being greater than ZnSO4 and CON. Although Zn deficiency is less of a clinical problem in ruminant animals (Herdt and Hoff, 2011), some of the initial signs of deficiency include poor feed intake and reduced growth rates (Herdt and Hoff, 2011). Zinc’s effects on growth and intake performance may be in part modulated by its relationship with cholecystokinin. Cholecystokinin secretion is increased in Zn-deficient intestinal tissues and serves roles in endocrine and neurocrine functions regulating gall bladder contraction, pancreatic secretion, gastric emptying, and satiety mechanisms (Blanchard and Cousins, 1996).

Effects of Zn on ultrasound measurements of LMD and BF are presented in Table 3. There were no differences in LMD (P = 0.48) and BF (P = 0.47) among treatments.

Wool traits for rams measured in the study are presented in Table 3. Average wool fiber diameter (AFD) did not differ (P = 0.96) among treatments regardless of Zn source or concentration. Staple length (SL) was greatest (P < 0.001) in rams consuming fortified ZnSO4 diets compared to CON; whereas ZnAA tended (P = 0.06) to have longer staple length over the 84-d study than CON. Zinc is a major constituent in wool (NRC, 2007), and Zn plays a critical role in the keratinization process through structural and regulatory factors (Tomlinson et al., 2004), which could provide a reasonable explanation for rams consuming greater concentrations of Zn, despite different sources, tended to have longer SL. Zinc deficiencies reduce wool growth and impair keratinization in wool through a specific mechanism, perhaps involving protein synthesis (White et al., 1994).

Serum Zn concentrations were greatest (P ≤ 0.03) in ZnSO4 (Table 3; Figure 1); whereas, serum Zn concentration did not differ (P = 0.12) between ZnAA and CON. Zinc homeostasis is tightly regulated in the body (Herdt and Hoff, 2011).
and resultant Zn tissue concentrations remain relatively constant over a wide range of Zn intakes. There is no clear site of accumulation of Zn throughout the body and Zn absorption is reduced under conditions of ample Zn intake (NRC, 2007; Herdt and Hoff, 2011), which could offer a reasonable explanation for not having observed an increase in serum Zn levels in ZnAA, with this study. In a similar study, Zn absorption did not differ between Zn sources, but retention was greater in lambs treated with Zn Methionine than with a ZnO source, indicating difference in metabolism post-absorption or tissue retention (Spears, 1989).

REFERENCES


ACKNOWLEDGEMENTS

Authors wish to thank the Montana Agricultural Station, Zinpro Corporation, Kim Hager and David Miller from CHS, and the
National Sheep Industry Improvement Center for partial funding of this research.

*Corresponding author: whit.stewart@uwyo.edu
### Table 2. Effects of dietary Zn source and period on the performance of rams, carcass traits, serum Zn concentrations, and wool traits

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>SEM²</th>
<th>Period</th>
<th>P – value</th>
<th>SEM²</th>
<th>P – value</th>
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<tbody>
<tr>
<td></td>
<td>CON</td>
<td>ZnAA</td>
<td>ZnSO₄</td>
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<tr>
<td>ADG, lb/d</td>
<td>0.73ᵇ</td>
<td>0.88ᵃ</td>
<td>0.75ᵇ</td>
<td>0.40</td>
<td>0.03</td>
<td>0.97ᵃ</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>0.88ᵃ</td>
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<td>0.51ᵇ</td>
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<td>DMI, lb/d</td>
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<td>7.32</td>
<td>7.01</td>
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<td>G:F</td>
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<td>0.124ᵃ</td>
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¹Dietary treatments: 1) control diet without fortified zinc (CON; Table 1); 2) a diet fortified with a Zn amino acid complex (ZnAA, Zinpro Corp); and 3) a diet fortified with ZnSO₄.

²Greatest SEM presented (n = 15).

ᵃ⁻ᶜ LS means, within a row, lacking common superscripts differ (P < 0.05).

### Table 3. Effects of dietary Zn source and day on the performance of rams, carcass traits, serum Zn concentrations, and wool traits

<table>
<thead>
<tr>
<th>Item</th>
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<td></td>
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<td></td>
<td></td>
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<td>84</td>
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<tr>
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<td>BF, mm</td>
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<td>Serum Zn, µg/mL</td>
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<td>25.91ᵇ</td>
<td>26.67ᵃ</td>
<td>1.02</td>
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<tr>
<td>AFD, micron</td>
<td>22.1</td>
<td>22.1</td>
<td>22.0</td>
<td>0.34</td>
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<td></td>
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</table>

¹Dietary treatments: 1) control diet without fortified zinc (CON; Table 1); 2) a diet fortified with a Zn amino acid complex (ZnAA, Zinpro Corp); and 3) a diet fortified with ZnSO₄.

²Greatest SEM presented (n = 15).

³LMD: loin muscle depth; BF: back fat; SL: wool staple length; AFD: average fiber diameter.

⁴d 0 measurements were collected d -16.

ᵃ⁻ᵈ LS means, within a row, lacking common superscripts differ (P < 0.05).
Distribution and Clearance of Chopped Net Wrap in the Digestive Tract of Beef Cattle

J. V. Pizol, R. R. Dennis, J. F. Thorson, L. D. Prezotto*

Nutritional & Reproductive Physiology Laboratory, Northern Agricultural Research Center, Department of Research Centers, Montana State University-Bozeman, Havre, MT

IMPACT STATEMENT

Beef cattle producers have adopted the practice of chopping forage without removing the plastic net wrap from the bale. However, results from the current study indicate that forage chopped with the plastic net wrap should not be offered for extended periods of time or over multiple seasons due to the large proportion of net wrap retained within the digestive tract and the risk of developing software disease.

SUMMARY

Commercial beef cattle producers have increased the frequency with which they feed chopped forage to winter cattle. As a result of economic and time constraints, a growing number of producers have chosen to chop forage without removing the indigestible plastic net wrap that can accumulate in the digestive tract over time. Therefore, the objective of this research was to determine 1) where the net wrap accumulates within the digestive tract and 2) the amount of net wrap the animal is able to clear from the digestive tract. To address these objectives, non-pregnant commercial beef cows were individually fed a ration that contained 0.07% plastic net wrap for 7 months. The treatment did not result in digestive disturbances or loss of body weight. However, 47% of the net wrap offered to the animals were collected from the digestive tracts and therefore this material was not digested, regurgitated, or passed by the digestive tract. The greatest proportion of net wrap was observed in the rostral (reticulum and rumen) region of the digestive tract that comprised 99.9% of the total net wrap within the digestive tract. Long-term feeding of forage that contains net wrap has the potential to create large, impassable masses within the digestive tract that accumulate over the seasons and result in wasting, digestive tract blockage, and death.

INTRODUCTION

Chopped forage is widely utilized within the region to winter cattle. Due to the economic and time constraints of chopping forage, many producers chop forage without removing the plastic net wrap from the bale. As a result, a large proportion of the diet is littered with plastic debris that can lead to a syndrome known as software disease (Thomas, 2016). This syndrome is a result of indigestible plastic accumulating in the digestive tract that make the animal feel full and thus have reduced feed intake and body weight. Furthermore, net wrap can reduce the rate of passage of digesta while promoting the rate of water passage resulting in diarrhea and excessive thirst (Thomas, 2016). If the accumulation of plastic is excessive, it can result in wasting, digestive tract blockage, and death. It is currently unknown how this debris is distributed along the digestive tract and what proportion of the debris the animal is able to clear. Therefore, we sought to determine 1) where the net wrap accumulates within the digestive tract and 2) the amount of net wrap the animals are able to clear from the digestive tract.

PROCEDURES

Animal protocols were approved by the Montana State University Agricultural Animal Care and Use Committee.
Non-pregnant, commercial cows (n = 4; 3 years old; initial body weight 1273.8 ± 94.3 lbs; final body weight 1383.7 ± 82.5 lbs) were individually fed a total mixed ration (TMR) to meet or exceed dietary requirements (NRC, 2000) and formulated for 0.50 pounds of gain per day. The ration was composed of hay, straw, and a vitamin and mineral supplement. The hay and straw were chopped and processed without removing the plastic net wrap using a commercial large-scale bale processing unit with a 5 inch screen. The TMR was offered in a Calan gate feeding system to control the individual daily intake. Animals were fed the TMR for 7 months in order to mimic the interval chopped forage would be offered on a commercial operation over the winter. Samples of the TMR were collected at three time points during the experiment to assess the proportion of net wrap offered to the animals. Fasted body weights were recorded at the beginning and end of the feeding period and average daily gain (ADG) calculated. Animals were observed daily for signs of digestive disturbances. At the end of the 7 month feeding period, cows were euthanized at a commercial abattoir and digestive tracts harvested. The digestive tracts were divided into three regions: rostral (reticulum and rumen), medial (omasum and abomasum), and caudal (small and large intestines). Each region was weighed with digesta and then digesta was manually evacuated. Following evacuation, net wrap was manually sorted and total weight of tissue, digesta, and net wrap were recorded within each region.

RESULTS AND DISCUSSION

Animals did not exhibit any signs of digestive disturbances during the experimental period. Furthermore, animals gained an average of 0.53 pounds per day as estimated with the formulated TMR. Samples of the TMR were composed of 0.07 % net wrap (as fed basis) that over the course of 7 months were calculated to total 3.86 pounds of net wrap offered to each animal. As cattle are less selective foragers and have a greater prevalence to consume foreign bodies when compared to other ruminants (Sheferaw et al., 2014), it can be interpreted that a majority of this net wrap was consumed. Furthermore, net wrap was rarely seen in the feed bunk or unconsumed portion of the daily ration.

Upon evaluation of the digestive contents, it was clearly evident by gross visualization that a large amount of the net wrap consumed in the diet was not cleared from the digestive tract by digestion, regurgitation, or passage (Figure 1). Previous reports have demonstrated that plastic net wrap is not digested within the rumen (Klein and Dahlen, 2014). Therefore, passage and regurgitation are the only means to clear net wrap from the digestive tract. The greatest proportion of net wrap was observed in the rostral (reticulum and rumen) region of the digestive tract that comprised 99.9223 % of the total net wrap within the digestive tract (Table 1). This observation is supported by previous data that observed the greatest occurrence of foreign bodies (plastic bags, cloth, ropes, etc.) ingested by cattle are located within the rumen (Mushonga et al., 2015). The digesta from the medial (omasum and abomasum) and caudal (small and large intestines) regions of the digestive tract had very little net wrap (medial 0.0746 %; caudal 0.0031 %; Table 1). Of the net wrap observed within the medial and caudal regions of the digestive tract, only small particles (less than 3 inches in length) were observed. This is in stark contrast to the large, ball-like masses of net wrap observed.

Figure 1. Image of net wrap collected within the caudal (A), medial (B), and rostral (C) regions of the digestive tract of a single commercial beef cow offered a ration containing 0.07 % net wrap for 7 months.
within the rostral region of the digestive tract. These observations indicate that only small particles are able to pass from the rostral region to medial and caudal regions of the digestive tract. The remaining net wrap is retained within the rostral region where it is compressed into a tightly wound mass that either stays within the rostral region or is regurgitated during rumination (visual observation). Regurgitation appears to be a modestly effective means for the animal to clear the net wrap from the rostral digestive tract as only 47.2% of the total offered net wrap was recovered from the rostral digesta. However, this also means that approximately half of the net wrap was retained within the digestive tract of the animal and may result in detrimental effects when plastic wrap is offered in the diet for extended periods of time.

In conclusion, it is not advised to feed chopped forage that contains net wrap for extended periods of time or over multiple seasons due to the large proportion of net wrap retained within the digestive tract and the risk of developing software disease.

REFERENCES

ACKNOWLEDGEMENTS
The authors would like to acknowledge support from the Northern Agricultural Research Center staff for their contributions to this body of work.

*Corresponding author: ligia.prezotto@montana.edu

Table 1. Average weight of net wrap within the rostral, medial, and caudal regions of the digestive tract of commercial beef cattle offered a ration containing 0.07 % net wrap for 7 months.

<table>
<thead>
<tr>
<th>Digestive Tract Region</th>
<th>Rostral</th>
<th>Medial</th>
<th>Caudal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Wrap, lbs</td>
<td>1.81780</td>
<td>0.00132</td>
<td>0.00006</td>
</tr>
</tbody>
</table>
Recovery of Surface Applied Urea is Maximized Through Spring Application and Agrotain® Use

C.M. Romero¹, R.E. Engel¹, C. Chen², and C.A. Jones¹*

¹Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT and ²Eastern Agricultural Research Center, Montana State University, Sidney, MT

IMPACT STATEMENT

Ammonia (NH₃) volatilization is a critical factor affecting fertilizer-N recovery (FNR) by winter wheat. Urease inhibitor Agrotain® is effective in reducing volatile losses from surface applied urea during cold weather months. However, maximum benefits to FNR and grain protein are achieved when fertilizer-N is applied during spring rather than late-fall or winter timings.

SUMMARY

Surface applications of urea are susceptible to volatilization as NH₃, and management strategies are needed to enhance FNR. The objective of this study was to determine the effect of application timing (late-fall, winter, and spring) and urease inhibitor Agrotain® on FNR and winter wheat grain protein. FNR was greater for spring (46.1%) than late-fall (31.7%) and winter (34.1%) applications. Addition of Agrotain® to urea improved FNR of all timings, but the response was greater for late-fall and winter compared to spring applications. The greater FNR of spring timings resulted in higher protein concentrations (0.6-0.8% points) relative to late-fall and winter applications. Management strategies to enhance FNR in Montana should consider delaying surface application of urea until the spring or addition of Agrotain® for late-fall and winter timings that are more susceptible to NH₃ volatilization.

INTRODUCTION

Urea is currently the most common fertilizer-N source used by Montana growers, comprising approximately 86% of total N consumption. In winter wheat systems, urea is often surface broadcast in a separate operation following seeding. The timing of these applications varies, but can occur from late-fall to early spring. Although urea is a low-cost fertilizer-N source, it is susceptible to volatility as NH₃ gas, affecting FNR and crop productivity. Previous MSU trials have shown that NH₃ volatilization will vary greatly with application timing; losses can be quite large (>20% of applied N rate) following urea applications in the late-fall and winter (i.e., Nov to March). Volatility can be decreased by 60-65% with the addition of Agrotain® (active ingredient N-(n-butyl) thiophosphoric triamide, NBPT). Similarly, NH₃ loss can be mitigated by applying urea to dry soil surfaces in advance of large (>0.5 inch) precipitation events that are more likely to occur in early spring than late-fall or winter. The goal of fertilizer-N management should be to minimize N loss and produce the highest FNR by the crop. Given the importance of application timing and Agrotain® on NH₃ loss from urea, this study was conducted to determine the impact of these two parameters on FNR and grain protein.

PROCEDURES

Field trials were conducted near Denton, MT during the 2011/12, 2012/13, and 2013/14 seasons. The experiments were located in large fields (> 150 acre) that were under no-till, crop-fallow management with winter wheat being the dominant crop. We applied fertilizer-N at three different times (late-fall, winter, and spring) and used two N sources (urea and urea+Agrotain®). The late-fall application was made in late-November to early-December at approximately soil freeze up. The winter application occurred in
February onto frozen soil. The spring application was in April following ground thaw and crop green-up. Urea and urea+Agrotain® were applied at rates of 45 and 90 lb N/ac. The urea was coated with Agrotain® (0.1% rate) as a liquid formulation (26.7% active ingredient). FNR in grain plus straw was determined using 15N-enriched fertilizer (at 45 and 90 lb N/ac rates) (Romero et al., 2017) and NH3 volatility by a micrometeorological approach (only at 90 lb N/ac rate) (http://landresources.montana.edu/ureavolatilization/methodology.html).

RESULTS AND DISCUSSION
Application timing and Agrotain® both affected FNR (Figure 1). On average, spring application resulted in greater FNR (46.1%) than late-fall (31.7%) and winter (34.1%) timings. We attribute this response to the better synchrony of spring-applied N with crop-N demand and the lower volatility loss of spring-applied urea (Figure 1). We found NH3 loss was lower for spring applied-N because large precipitation events (≥0.5 inch) followed fertilizer-N application and presumably allowed urea to infiltrate to a depth where it couldn’t volatilize to the atmosphere. In contrast, precipitation events that followed late-fall and winter applications were typically light (≤0.2 inch) and scattered, and as a result urea likely remained near the surface where it was susceptible to volatility (Engel et al., 2017).

Addition of Agrotain® to urea reduced cumulative NH3 loss by 66%. The average FNR response was greater for late-fall (by 11.3%) and winter (by 6.9%) than spring (by 4.0%) applications. Grain protein was sensitive to fertilizer-N management (Figure 1) and increased 0.6-0.8% points from spring applications or Agrotain® addition. The strong relationship between FNR and cumulative NH3 loss is further evidence that NH3 volatilization represents an important pathway of N loss in Montana’s dryland cropping systems (Figure 2). Broadcast urea should be applied in the spring to provide the highest FNR compared with overwinter timings. Alternatively, addition of Agrotain® can improve urea FNR for broadcast applications made during cold weather months.

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ACKNOWLEDGEMENTS
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*Corresponding author: clainj@montana.edu

Figure 2. Fertilizer-N recovery in grain plus straw of winter wheat was directly related to cumulative NH₃ loss for the nine trials (three years x three application timings at 90 N/ac application rate).
Evaluating Hay Feeding Methods on Heifer Performance, Hay Waste, and Economics

M. Van Emon*, M. Hoffman, R. Endecott, and E. Glunk

Department of Animal and Range Sciences, Montana State University, Bozeman, MT

IMPACT STATEMENT

Feed costs during the winter make up the largest portion of production costs. Reductions in amount of hay waste produced can lead to direct increases in producer profits. The most common method of feeding hay on pasture is to roll the bales out on the ground. The use of a bale feeder, which contains more of the hay and increases availability to the animal, can help to decrease the overall amount of hay waste.

SUMMARY

The objective of this study was to determine the impacts of two different bale feeder designs (ring bale vs. LS) on heifer performance, hay waste, and economics. Initial bale weight and total bale disappearance were not different between the hay feeders. However, hay waste was significantly greater for the ring-bale feeder compared with the LS feeder. This reduction in waste will save costs associated with labor, fuel, and hay when using the LS feeder. Although the LS feeder has a greater up-front cost, the return on investment may occur within the first feeding season.

INTRODUCTION

Bell and Martz (1973) determined that 45% of hay is wasted when rolled out on the ground due to trampling. The use of a bale feeder, which contains more of the hay and increases availability to the animal, can help to decrease the overall amount of hay waste. Several bale feeder designs are available, such as: ring, cone, cradle, or trailers. Landblom et al. (2007) found that using a cone feeder can decrease hay waste by 4.3 to 5 times when compared to rolling out or bale processing. Martinson et al (2012) found that when horses were fed round bales without a feeder 57% of the hay fed was wasted, compared to a 24-52% reduction in hay waste depending on type of feeder. Similarly, Buskirk et al. (2003) observed a reduction in hay waste when feeding bales via cone or ring bale feeders (3.5 and 6.1%, respectively) compared with the trailer or cradle (11.4 and 14.6%, respectively). Therefore, to reduce hay waste, utilizing bale feeders may be more economical, and some feeders may be more economical than others.

A new bale feeder design has recently become commercially available from Cattle Systems by LS. This new Cattle Systems by LS bale feeder is collapsible, easily transportable, and could potentially help to significantly reduce hay waste and associated hay costs. Therefore, the objective of this research trial is to compare the Cattle Systems by LS bale feeder with two other common bale feeders to evaluate impacts of feeder type on beef cattle performance, hay waste, and economic impact.

PROCEDURES

Fourteen heifers were used in a 2 × 2 Replicated Latin Square design. Heifers were housed at the Bozeman Agriculture Research and Teaching (BART) Farm. Heifers were stratified by body weight to one of two bale feeding methods (n = 7 heifers per pen). Bale feeding methods included: 1) traditional ring feeder and 2) Cattle Systems by LS feeder. Each pen contained one feeder treatment, and both pens had a cement floor for ease of data collection.

Each period was 5 days in length for a total of 10 days for each replication, with two replications during the experiment, for a total 20
days for the trial. Heifers were weighed on two consecutive days at the beginning and end of the trial. Heifers were weighed on day 1 of each period in the interim.

Three composited forage samples of the hay were collected prior to feeding to ensure all bales are of uniform quality to minimize the effects of quality on intake. Several cores were taken from each bale and three subsamples collected. Subsamples were sent to a commercial laboratory for proximate analysis. All bales were weighed immediately before feeding and wrapping was removed. Heifers had continuous access to the feeders during each period. Hay that fell onto the concrete surrounding the feeder was considered waste and collected from each pen every other day and weighed. Care was taken to avoid manure contamination in waste samples. After collection and weighing of the waste, a sub-sample was collected, weighed, and dried for proximate analysis (n = 24; 3/pen/period). Sufficient hay was placed in each feeder to last each 5-day period to avoid any potential intake effects. Any remaining hay at the end of the 5-day period was collected and reweighed in order to determine animal intake. Waste was calculated as pounds wasted each 5-day period, as well as a percent of total hay consumed each period.

Data were analyzed using the GLM procedure of SAS. Significance was set at $P \leq 0.05$.

**RESULTS AND DISCUSSION**

Forage quality analysis for initial hay quality and waste quality is presented in Table 1. There were period effects observed during the trial, as indicated in Table 1, but this is mainly due to weather changes; therefore, only main feeder effects will be discussed. Initial quality of the hay bales was not different between the feeders. Overall quality of the hay waste was significantly lower compared to the initial bale quality. The reduction in quality of the waste suggests that all heifers were sorting the hay to consume the higher-quality plant parts, which was expected.

<table>
<thead>
<tr>
<th>Nutrient&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Initial</th>
<th>SEM&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Feeder</th>
<th>SEM</th>
<th>Feeder</th>
<th>Period</th>
<th>Feeder*Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>90.75</td>
<td>0.05</td>
<td>Ring</td>
<td>89.26</td>
<td>89.40</td>
<td>0.11</td>
<td>0.39</td>
</tr>
<tr>
<td>CP</td>
<td>15.75</td>
<td>0.75</td>
<td>LS</td>
<td>9.30</td>
<td>10.70</td>
<td>0.22</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TDN</td>
<td>61.00</td>
<td>2.00</td>
<td>LS</td>
<td>43.10</td>
<td>41.50</td>
<td>0.48</td>
<td>0.03</td>
</tr>
<tr>
<td>ADF</td>
<td>36.50</td>
<td>1.75</td>
<td>LS</td>
<td>52.10</td>
<td>53.60</td>
<td>0.42</td>
<td>0.03</td>
</tr>
<tr>
<td>NE&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.63</td>
<td>0.03</td>
<td></td>
<td>0.43</td>
<td>0.41</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>RFV</td>
<td>127.00</td>
<td>12.00</td>
<td></td>
<td>70.30</td>
<td>68.15</td>
<td>0.95</td>
<td>0.13</td>
</tr>
</tbody>
</table>

<sup>1</sup>P-values represent the statistical significance of the feeder, period, and the interaction for the hay waste.

<sup>2</sup>Nutrient abbreviations: DM – dry matter; CP – crude protein; TDN – total digestible nutrients; ADF – acid detergent fiber; NE<sub>1</sub> – net energy of lactation; and RFV – relative feed value.

<sup>3</sup>Standard error of the means.
the ring-bale feeder compared with the LS feeder. As a percentage of total bale disappearance, waste tended to be greater ($P = 0.08$) in the ring-bale feeder. This also means that cattle were likely consuming less from the ring feeder, even though total bale disappearance was not different, because more of that disappearance resulted in waste. The use of an LS feeder was able to decrease the amount of the bale wasted by 25%, resulting in significant cost savings.

When evaluating return on investment (ROI) for the ring versus LS feeder, it is evident that it would not take long in order to recoup the cost of the pricier feeder. With the LS feeder costing $3900, compared to $319.99 for the ring feeder, it may cause many producers to baulk. However, when looking at how much more money is spent in waste, it can make up the change in capital investment fairly quickly.

When evaluating on a per ton basis, and using the average cost of alfalfa and alfalfa/ grass mix hay for 2016 in Montana ($133/ton; USDA, 2016), we see that per ton, we lose approximately 608 pounds/ton ($40) using the ring feeder, and 106 pounds/ton ($7.05) with the LS feeder. The difference in cost between the two feeders is $3580, and when that is divided by the amount saved per ton, we find that it only takes 109 tons of hay fed before the LS feeder recoups its investment compared to a ring feeder. Compared to using no feeder at all, it would likely take significantly less time to recoup its investment costs.

For example, if you have a group of 100 cows weighing 1,200 pounds and consuming 3% of their body weight each day in hay, it would take approximately 60 days to recoup the cost of the LS feeder.

Additionally, the LS feeder can hold two large round bales compared with the single bale the ring feeder holds. This will allow the producer to spend less resources filling bale feeders. Based on the initial bale weights in Table 2, and the average consumption of the 7 heifers including waste (ring feeder: 88.2 pounds/day and LS feeder: 77.7 pounds/day), the ring-bale feeder would need to be filled every 14 days and the LS feeder would need to be filled every 32 days. This would result in less time, labor, and mechanical resources being devoted to the LS feeder compared to a ring feeder, saving the producer money as well as time.

Overall, the LS feeder had significantly less waste than the ring-bale feeder. This reduction in waste will save costs associated with labor, fuel, and hay when using the LS feeder. Although the LS feeder has a greater up-front cost, the return on investment may occur within the first feeding season.

**REFERENCES**


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**Table 2. Differences in amount of hay wasted by feeder.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Feeder</th>
<th>Ring</th>
<th>LS</th>
<th>SEM¹</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Weight, lb</td>
<td></td>
<td>1236</td>
<td>1262</td>
<td>10.6</td>
<td>0.19</td>
</tr>
<tr>
<td>Total Consumed, lb</td>
<td></td>
<td>617.3</td>
<td>543.9</td>
<td>46.3</td>
<td>0.34</td>
</tr>
<tr>
<td>Waste, lb</td>
<td></td>
<td>175.7a</td>
<td>25.8b</td>
<td>30.2</td>
<td>0.04</td>
</tr>
<tr>
<td>Percent of Total Consumed as Waste, %</td>
<td></td>
<td>30.4a</td>
<td>5.3b</td>
<td>6.8</td>
<td>0.08</td>
</tr>
</tbody>
</table>

¹Standard error of the means.
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*Corresponding author:
megan.vanemon@montana.edu