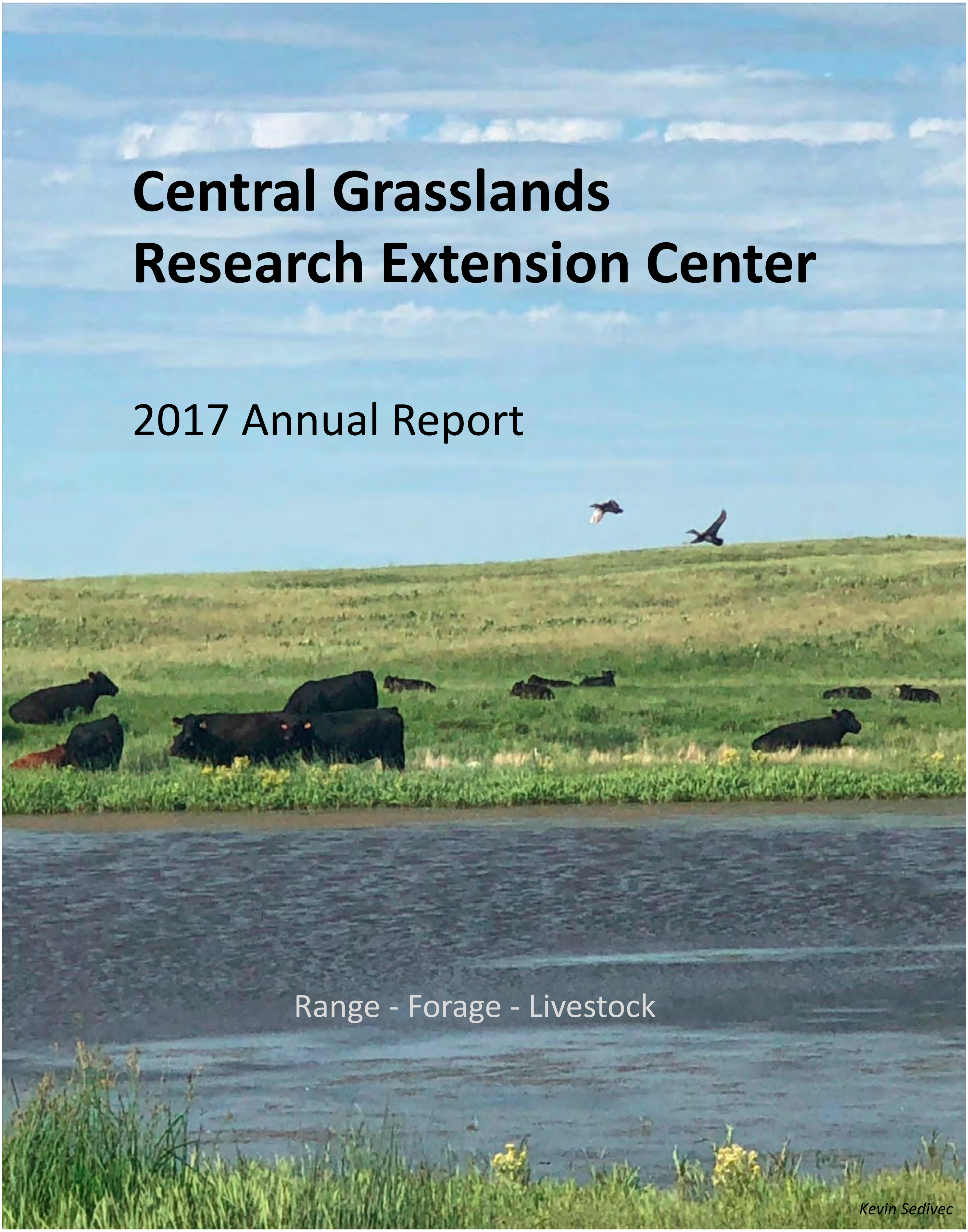
Central Grasslands Research Extension Center

2017 Annual Report



Range - Forage - Livestock

Kevin Sedivec

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

NDSU EXTENSION

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Summary of the Year

Welcome to the 2017 CGREC Annual Report

2017 brought my first field season at the center. It was once again busy with new experiments developed and the new range and forage laboratory in full use.

Much of North Dakota experienced severe drought in 2017; however, the center received above-average rainfall in June, creating good growing conditions for the pastures, perennial hay crops and cool-season annual hay crops. We experienced the drought starting in July, but rainfall was timely enough to secure fair to good silage.

The year started with the new patch-burn grazing projects put in place. We had to remove some old fence and add new fence to build infrastructure for the studies. We added fresh water to all experimental pastures to reduce any livestock drinking water effects, and built two new corrals for handling the cattle.

The new experiments included four replicates of 1) a spring burn with cattle grazing, 2) a spring and summer burn with cattle grazing and 3) seasonlong grazing with no fire. A fourth treatment will be implemented in 2018 to study a modified twice-over rotation/rest rotation grazing strategy.

We continued with our beef nutrition, cattle genetics and cattle reproduction studies, which started in 2016, and added a mineral trial on pasture to look at cattle reproduction. Michael Undi, our animal scientist, went into his second year of late-season grazing strategies using bale grazing and corn residue/cover crop options. Scott Alm, our forage specialist, started some alfalfa trials in 2017 and continued our long-term alfalfa variety trial.

The dry conditions in July and August created poor growing conditions for the new alfalfa seedings, reduced grain corn yields and brought failure to our cover crops interseeded into the corn. Weather is always part of any experiment in North Dakota and still allows us to study late-season grazing strategies under less-than-desirable conditions.

We said goodbye to Jessalyn Bachler in 2017. Jessalyn took a full-time teaching position at Williston State College and started her new career in January 2018. We thank her for her dedication to our livestock herd and making improvements to our herd genetics.

I realize this is our 2017 report, but I must mention the passing of Rodney Schmidt, the center's herdsman and employee since 1999. We lost Rodney in an accident May 12, 2018. Rodney was the face of our livestock unit and will be truly missed. He was the most humble, kind-hearted man I have ever met.

The CGREC became home to numerous graduate students and summer seasonals. Our graduate students included Megan Dornbusch, advised by Ryan Limb, range scientist in the School of Natural Resource Sciences at NDSU; Cameron Duquette and Brooke Karasch, advised by Torre Hovick, range scientist in the School of Natural Resource Sciences, NDSU; Nicolas Negrin Pereira, advised by Carl Dahlen and Pawel Borowicz, animal scientists in the Animal Sciences Department, NDSU; Felipe Alves Correa Carvalho Da Silva and Kacie McCarthy, advised by Dahlen; Micayla Lakey, advised by Devan McGranahan, range scientist in the School of Natural Resource Sciences at NDSU; Haley Johnson, advised by Limb and me; and Leslie Gerhard, advised by Caley Gasch, soil scientist in the School of Natural Resource Sciences at NDSU. Articles summarizing these students' projects can be found in this year's report.

The CGREC continues to address our original mission of conducting research and outreach on range and grassland science, forage management and applied beef cattle systems production. We have been developing new infrastructure, hiring new graduate students and working closely with the NDSU Main Station scientists (Range Sciences, Animal Sciences, Soil Science and Plant Sciences) to start new range, forage, wildlife and pollinator, soil health and beef cattle research in 2018.

We invite you to our 2018 annual field day on July 9 from 4 to 7 p.m., followed by a supper and good conversation.

We hope to continue serving you for many years to come. You always are welcome to stop by the center.

Kevin Sedivec, Interim Director

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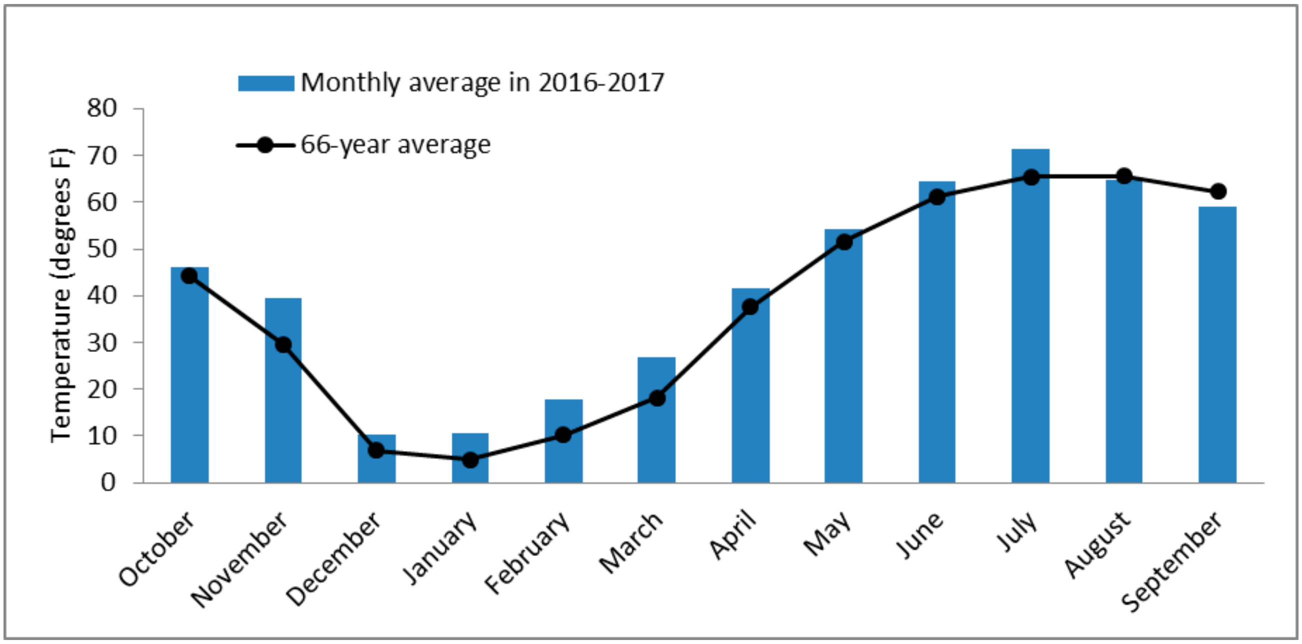
Monthly Temperatures for the 2016-2017 Crop Year



Month	Maximum temperature[1]	Minimum temperature	Average temperature	Long-term[2] average temperature	2016-2017 deviation from long-term[2] average
October	77	25	46.2	44.2	2.0
November	77	10	39.6	29.6	10.0
December	34	-28	10.2	6.9	3.3
January	36	-23	10.7	5.0	5.7
February	44	-17	17.8	10.2	7.6
March	61	-8	26.9	18.2	8.7
April	74	21	41.6	37.6	4.0
May	82	31	54.3	51.5	2.8
June	94	41	64.5	61.2	3.3
July	97	50	71.3	65.4	5.9
August	92	46	64.7	65.5	-0.8
September	94	36	59.1	62.3	-3.2

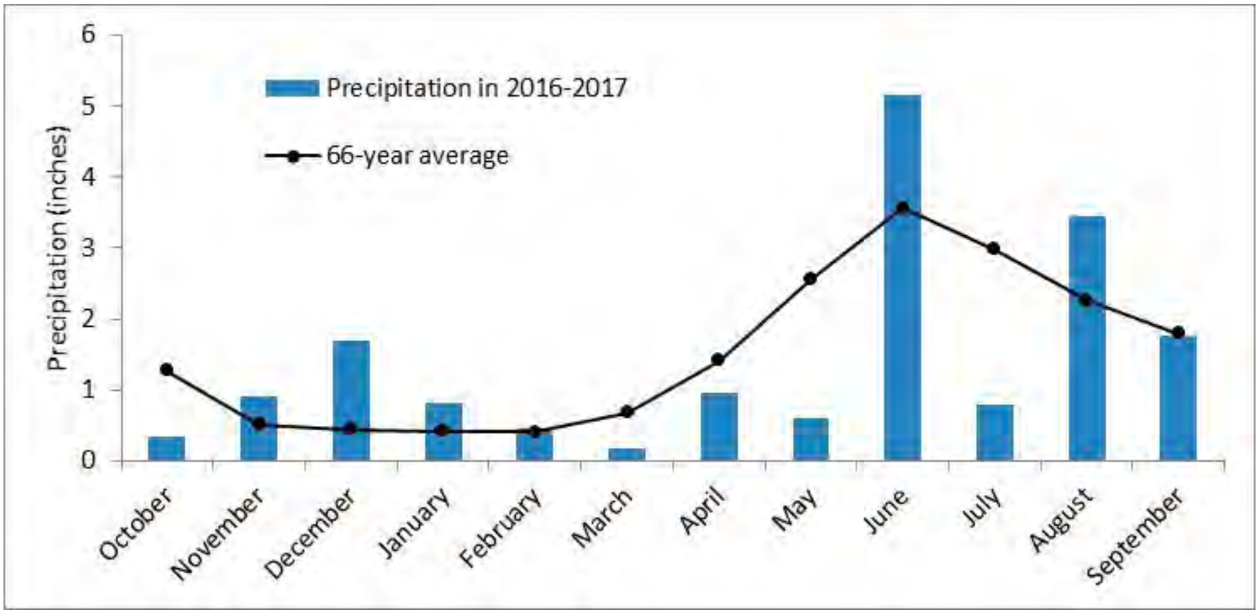
[1] Degrees F.

[2] 1951 to 2017; 66 years

Last spring frost: May 2, 2017 (31°F)
First fall frost: Oct. 9, 2017 (31°F)
160 frost-free days

Average[2] last spring frost: May 13
Average first fall frost: Sept. 22
Average: 132 frost-free days

Monthly Precipitation for the 2016-2017 Crop Year



Month	Precipitation[1]	Long-term average precipitation[1,2]	Deviation from long-term[2] average	Accumulated precipitation[1,2]	Accumulated long-term[2] average	2016-2017 accumulated percent of long-term[2] average	Snow[3]
October	0.34	1.28	-0.94	0.34	1.28	27	0
November	0.90	0.52	0.38	1.24	1.79	69	6.5
December	1.70	0.44	1.26	2.94	2.23	132	32
January	0.81	0.41	0.40	3.75	2.65	142	17
February	0.46	0.40	0.06	4.21	3.05	138	3
March	0.17	0.68	-0.51	4.38	3.72	118	3.5
April	0.96	1.41	-0.45	5.34	5.14	104	0
May	0.61	2.55	-1.94	5.95	7.69	77	0
June	5.16	3.56	1.60	11.11	11.25	99	0
July	0.79	2.98	-2.19	11.90	14.23	84	0
August	3.44	2.26	1.18	15.34	16.49	93	0
September	1.76	1.79	-0.03	17.10	18.28	94	0
Total	**17.10**	**18.28**	**-1.18**	**17.10**	**18.28**	**94**	**62**

[1] Rain and melted snow; in inches

[2] 1951-2017; 66 years

[3] Depth in inches

Strategies for Supplementing Cattle Grazing Corn Residue

Michael Undi and Stephanie Becker
Central Grasslands Research Extension Center, Streeter, N.D.

Methods of supplementing cattle grazing in winter should aim to reduce winter feed costs, which are the single highest annual cost in a cow-calf operation. Methods that eliminate pasture visits in winter can reduce labor and fuel costs. This study evaluated the use of a cover crop and a grazing lick tub as strategies for supplying extra nutrients to cattle grazing corn residue. In the first year, supplementation with a cover crop or grazing lick tub did not impact animal performance. This is the first year of a long-term study to evaluate these supplementing strategies for cows that are partially overwintered on corn residue.

Summary

Methods of supplementing beef cows grazing corn residue were investigated in a study conducted at the Central Grasslands Research Extension Center near Streeter, N.D. Nonlactating pregnant Angus cows (n = 90, body weight [BW] = 1,391 ± 67 pounds, body condition score [BCS] = 5.5 ± 0.20) were divided into nine groups of similar total body weight and allowed to graze corn residue treatments as follows: a) corn residue, b) corn residue intercropped with a cover crop and c) corn residue supplemented with a grazing lick tub (Crystalyx – HE-12%).

Two-day body weights were taken at the start and end of the grazing period. Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese) at the start and end of the period.

Below-normal rainfall severely limited cover crop establishment and growth in the first year of the study. Supplementation with a cover crop or a grazing lick tub did not impact ($P > 0.05$) animal performance. This is the first year of a long-term study to evaluate these strategies for supplementing cows that are partially overwintered on corn residue.

Introduction

The abundance of corn residue in North Dakota gives beef producers a readily available feed resource to graze cattle in the winter. Corn residue is a poor-quality feed, low in protein and minerals, with limited feed intake and digestion when fed as a sole feed. Nutrient supply to cows grazing corn residue can be improved by targeted supplementation.

Supplementation methods that reduce labor and fuel costs by eliminating pasture visits are of interest to beef producers. Providing grazing animals with feeds that possess complementary characteristics can eliminate pasture visits. Poor-quality/good-quality feed combinations such as corn residue and alfalfa hay (Klopfenstein and Owen, 1981) or corn residue and creeping forage legumes (Undi et al., 2001) have been shown to improve performance in beef cattle (Klopfenstein and Owen, 1981) and sheep (Undi et al., 2001). Cover crops intercropped into corn can be grazed in combination with corn residue after corn harvest.

The benefits of cover crops in improving cropping systems and agricultural sustainability are well-documented (Magdoff and van Es, 2009; Blanco-Canqui et al., 2012; Wortman et al., 2012). Cover crops increase soil organic matter, reduce soil erosion, improve soil physical and biological properties, increase nutrient cycling, suppress weeds, improve soil water availability, supply nutrients to the following crop and break pest cycles (Magdoff and van Es, 2009; Blanco-Canqui et al., 2012; Wortman et al., 2012). Some cover crops are able to break into compacted soil layers, allowing the following crop's roots to develop more fully (Magdoff and van Es, 2009).

An additional benefit of cover crops, which normally receive the least consideration, is the importance of cover crops as a source of livestock feed. For poor-quality feeds such as corn residue, cover crops improve animal performance by supplying the nutrients that are low in residue. Intercropping corn residue with forage legumes improves corn residue quantity and quality (Alford et al., 2003).

This study evaluated methods of supplementing cows grazing corn residue for part of the winter. Methods evaluated included grazing corn residue intercropped with a cover crop and the use of a grazing lick tub as sources of extra nutrients for cattle grazing corn residue.

Procedures

This study was conducted from Nov. 9, 2017, to Dec. 19, 2017, at the Central Grasslands Research Extension Center, Streeter, N.D. The study was conducted on a 90-acre field planted to corn. The field was divided into nine 10-acre paddocks using high-tensile wire electric fencing. One water tank was installed between two paddocks.

A cool-season cover crop (triticale, winter rye, oats, peas, yellow clover, crimson clover and brassicas) was intercropped at 38 pounds/acre into three standing corn paddocks at the V6 to V7 stage. Components of the corn residue and individual cover crops in the cover crop mixture were sampled for nutrient analysis before grazing.

Nonlactating pregnant Angus cows (n = 90, BW = 1,391 ± 67 pounds, BCS = 5.5 ± 0.20) were divided into nine groups of similar total body weight and allowed to graze one of three corn residue treatments: a) corn residue, b) corn residue intercropped with a cover crop or c) corn residue supplemented with a grazing lick tub (Crystalyx – HE-12%). Cows were allotted a portion of the corn field, and access to new sites was controlled using portable electric fencing.

Windbreaks were placed in each paddock. Cows had *ad libitum* access to fresh water, mineral supplement (6-12+ mineral supplement; CHS Inc. Sioux Falls, S.D.) and salt blocks.

Two-day body weights were taken at the start and end of the study. Two observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988; Rasby et al., 2014) at the start and end of the study. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Results

The nutrient composition of corn residue is shown in Table 1. Components with the highest nutrient content are the grain and the leaf. The husk is low in protein but has a good energy profile, while the cob is poor in protein and energy.

The nutrient composition of the cover crop is shown in Table 2. All cover crops have high crude protein (CP) content, but rapeseed and radish have extremely low dry-matter content.

Initial cow BW and BCS were similar ($P > 0.05$) among treatments (Table 3). Supplementation of a cover crop or grazing lick tub did not influence ($P > 0.05$) final BW or daily gains (Table 3). We found no difference ($P > 0.05$) in BCS change among cows on all treatments. Whether on corn residue alone or supplemented, cows maintained weight and BCS.

Table 1. Nutrient composition of whole corn and corn residue components.

	Whole Plant	Residue[1]	Component				
			Grain	Leaf	Husk	Cob	Stalk
Dry matter (DM), %	71.5	67.8	84.1	91.8	85.9	80.3	64.0
Nutrient composition, % DM							
CP[2]	9.0	3.0	9.8	8.2	4.1	3.0	3.2
TDN	74.6	56.5	89.1	55.9	60.9	15.9	52.8
NDF	35.1	75.1	8.3	69.4	77.8	85.4	76.3
ADF	18.9	44.8	2.0	45.7	38.6	43.5	50.1
Ca	0.17	0.14	0.04	0.76	0.16	0.06	0.16
P	0.23	0.05	0.24	0.11	0.10	0.05	0.07
K	0.51	0.58	0.26	0.63	0.73	0.37	1.58
Mg	0.16	0.24	0.11	0.87	0.16	0.07	0.14
S	0.09	0.04	0.11	0.11	0.03	0.03	0.04

[1]Whole plant minus grain.

[2]Crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg) and sulfur (S).

Table 2. Nutrient composition of individual crops in the cover crop mix.

	Rapeseed	Radish	Winter Peas	Oats	Winter Rye	Triticale
DM[1], %	17	9	63	79	67	66
Nutrient composition, %DM						
CP[1]	21.8	20.1	18.5	10.3	10.9	11.0
TDN	75	73	61	60	61	64
NDF	18.0	25.1	38.0	62.6	56.4	49.2
ADF	16.5	20.2	35.7	37.2	35.7	32.2
Ca	1.6	1.5	2.1	0.3	0.2	0.2
P	0.4	0.4	0.4	0.3	0.3	0.3
K	2.9	3.9	2.9	1.6	1.1	1.1
Mg	0.3	0.3	0.4	0.2	0.1	0.1
S	0.5	0.4	0.6	0.1	0.1	0.1

[1] Dry matter (DM), crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg) and sulfur (S).

Table 3. Performance of cows grazing corn residue.

	Corn Residue	Cover Crop[1]	Tub[2]	SE	P-value
Initial BW, lb.	1,398	1,388	1,388	17.5	0.817
Final BW, lb.	1,396	1,402	1,394	22.8	0.930
Daily gain, lb./d	0.03	0.32	0.12	0.32	0.634
Initial BCS	5.5	5.5	5.5	0.05	0.994
Final BCS	5.7	5.6	5.6	0.04	0.814
BCS change	0.20	0.17	0.18	0.04	0.732

[1]Corn residue/cover crop. [2]Corn residue + grazing lick tub.

Discussion

Producers are concerned that intercropping a cover crop into corn fields may reduce corn yields. The cover crop normally is planted when corn is well-established, thus minimizing competition for nutrients; hence, intercropping does not impact corn yield negatively (Scott et al., 1987; Baributsa et al., 2008). Intercropping corn with red clover and ryegrass (Scott et al., 1987) or red clover and vetch (Baributsa et al., 2008) did not impact corn yield negatively.

In cereal-legume mixes, agronomic features such as fertilizer application, sowing time and the proportion of crop mixture are basic determinants of competition among component crops (Belel et al., 2014). Where constituent crops are arranged in rows, the degree of competition is determined by the comparative growth rates, growth duration and proximity of roots of the diverse crops (Belel et al., 2014). The cereal component in a cereal-legume intercrop has a faster growth rate, a height advantage and a more widespread rooting system that gives it an upper hand in competition with associated legumes (Belel et al., 2014).

This study investigated nonvisit methods of supplementing cows grazing corn residue. Due to scheduling issues, corn planting commenced late. The cover crop was intercropped into corn at the corn V6 to V7 stage in early July (July 7-10). Below-normal rainfall (Figure 1) severely limited cover crop establishment and growth in the first year of the study. Temperatures during the study are shown in Figure 2.

Results in the first year show that the use of a cover crop or grazing lick tub as strategies for supplying extra nutrients to cattle grazing corn residue did not impact animal performance. This is the first year of a long-term study to evaluate these strategies for supplementing cows that are partially overwintered on corn residue.

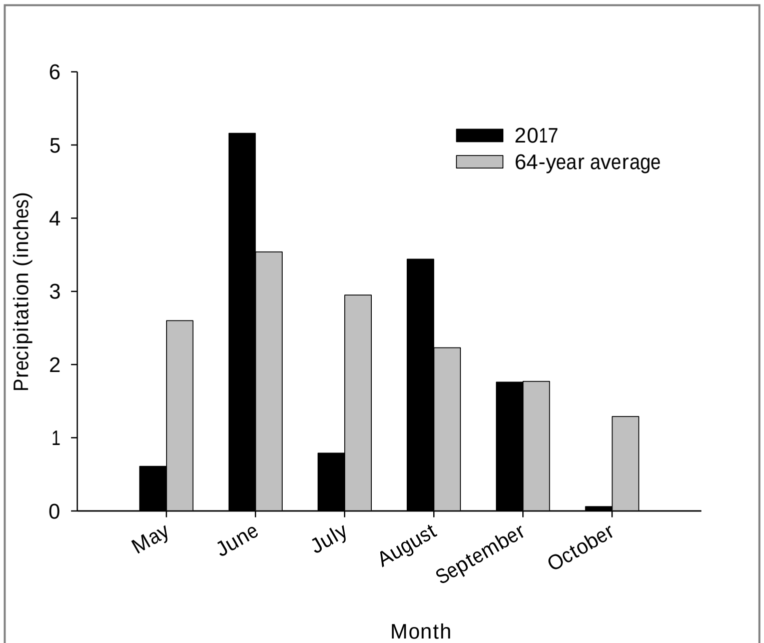


Figure 1. Monthly precipitation (inches) for the 2017 crop year.

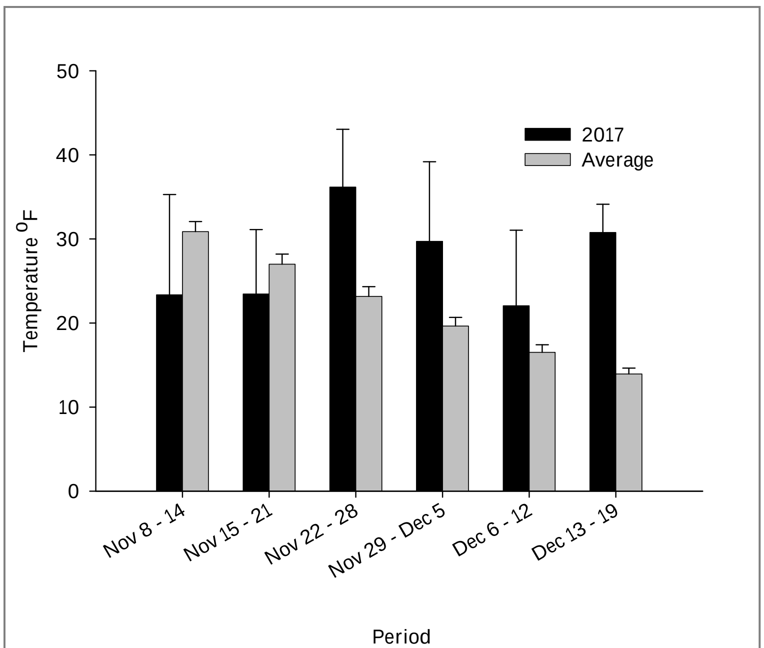


Figure 2. Weekly temperatures (mean ± SD) during the study. Study period: Nov. 9 to Dec. 19. Data from North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu

Acknowledgments

We thank Dwight Schmidt, Rodney Schmidt, Ryan Odenbach (Stutsman County Soil Conservation District, Jamestown, N.D.), and Hal Weiser (Natural Resources Conservation Service, Jamestown, N.D.) for technical assistance.

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Photos by Michael Undi, CGREC-NDSU

Supplementation of Beef Cows Bale Grazing Grass Hay in Winter

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Ensuring that animals have adequate nutrition is important when bale grazing late in the season. For cows receiving poor-quality feed, this can be achieved by using supplementation methods that minimize labor and energy costs. This study examines methods of supplementing cows while bale grazing poor-quality hay. Preliminary results suggest that grass hay fed in severely cold winters may not contain adequate energy, protein and phosphorus to meet the requirements of pregnant beef cows in early to midgestation. Under such conditions, supplementation with good-quality alfalfa hay or liquid supplement is not adequate and high-energy supplements such as corn dried distillers grains with solubles (DDGS) will be required to meet the nutrient shortfall. Supplementation with good-quality alfalfa hay or grass hay treated with a liquid supplement may be an option during mild winters.

Summary

Four methods of supplementing beef cows bale grazing grass hay were investigated in a study conducted during the winters of 2016 and 2017 at the Central Grasslands Research Extension Center, Streeter, N.D. Starting in the fall of each year, non-lactating pregnant Angus cows (2016: n = 64, body weight [BW] = 1,312 ± 142 pounds, body condition score [BCS] = 5.5 ± 0.29; 2017: n = 80, BW = 1,368 ± 131 pounds, BCS = 5.4 ± 0.24) were divided into eight groups of similar total body weight and allowed to bale graze one of four bale grazing treatments: a) poor-quality hay, b) poor-quality hay supplemented with good-quality alfalfa hay, c) poor-quality hay supplemented with corn DDGS and d) poor-quality hay treated with a liquid supplement.

Two-day body weights were taken at the start and end of each grazing period. Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese) at the start and end of each grazing period. Despite heavy snow accumulation from three blizzards in the first year, cows were able to graze for 70 days before termination of the grazing period.

Environmental conditions influenced animal performance, with the first year colder than the second year. In the first year, supplementation with good-quality alfalfa hay or grass hay treated with a liquid supplement did not improve animal performance relative to cows offered grass hay alone. In the second year, weight gain and BCS change were greater in supplemented cows relative to cows offered grass hay.

These preliminary results suggest that grass hay fed in severely cold winters may not contain adequate energy, protein and phosphorus to meet the requirements of pregnant beef cows in early to mid-gestation. Under such conditions, supplementation with good-quality alfalfa hay or liquid supplement is not adequate and high energy supplements such as corn DDGS will be required to meet the nutrient shortfall for such cows. Supplementation with good-quality alfalfa hay or grass hay treated with a liquid supplement may be an option during mild winters.

Introduction

Beef cattle in the northern Great Plains typically graze poor-quality forages in winter (Marshall et al., 2013). Poor-quality forages are generally low in energy, protein and minerals, impairing rumen microbial function, which leads to poor forage intake and digestion (Köster et al., 1996). Utilization of poor-quality forages can be improved through supplementation, which is especially important at critical times such as summer plant dormancy or fall and winter months (Caton and Dhuyvetter, 1997).

Effective supplementation requires regular supplement intake at levels that do not vary significantly on a daily basis (Garossino et al., 2003). Cost-effective supplement delivery methods help minimize feed costs by minimizing supplement delivery frequency (Schauer et al., 2005; Canesin et al., 2014; Gross et al., 2016) or eliminating pasture visits altogether (Klopfenstein and Owen, 1981).

Supplementation techniques that minimize or eliminate pasture visits in extended grazing systems will further the goal of minimizing winter feed costs. This study was conducted to investigate methods of supplementing cows bale grazing poor-quality hay in winter. The study examined beef cow performance and cost effectiveness of bale grazing supplementation strategies.

Procedures

This study was conducted during two winters: 2016 and 2017. Starting in the fall of each year, nonlactating pregnant Angus cows (2016: n = 64, BW = 1,312 ± 142 pounds, BCS = 5.5 ± 0.29; 2017: n = 80, BW = 1,368 ± 131 pounds, BCS = 5.4 ± 0.24) were divided into eight groups of similar total body weight and kept on a bale-grazing pasture in winter. The cows were pregnancy-checked prior to the start of the study to eliminate open cows. Cows were treated with IVOMEC (Ivermectin) pour-on during sorting.

The bale grazing site was a 26-acre field that was historically cropland, using a corn and small-grain rotation. In the two years prior to commencement of this study, the site was planted to cool-season cover crops, mainly annual rye grass and brassicas. The site was sprayed with 2, 4-D and glyphosate in late April 2016 and seeded to a meadow brome grass in early May 2016.

The field then was divided into eight three-acre paddocks using four-strand, high-tensile wire electric fencing. One water tank was installed between two paddocks. The site was mowed prior to bale placement to reduce the possibility of cows grazing standing forage.

Forty round hay bales were placed in each paddock in two rows in the fall. Net wrap was removed prior to feeding. Bales were placed on their sides to reduce waste and loss of liquid supplement.

Cows were allotted four bales at a time, and access to new bales was controlled using portable electric fencing. Cows were moved to a new set of bales when the depth of waste feed remaining across the diameter of each bale was less than four inches. Windbreaks were placed in each paddock for protection.

Cows were assigned to one of four bale grazing treatments as follows: a) poor-quality hay (control), b) poor-quality hay supplemented with alfalfa hay, c) poor-quality hay supplemented with corn DDGS and d) poor-quality hay treated with a liquid supplement (Table 1). Poor-quality hay was obtained from a Conservation Reserve Program (CRP) field of mixed cool-season grasses that had not been harvested for several years.

Cows supplemented with alfalfa hay received one bale of alfalfa hay for every three bales of poor-quality hay. Cows supplemented with DDGS were fed four pounds of DDGS/head/day twice weekly. For the liquid supplementation, approximately nine gallons of liquid supplement (Quality Liquid Feeds Inc.) was poured onto upright bales. This amount was calculated to increase hay protein content by approximately three percentage points. Bales were allowed to sit upright after pouring until the supplement had seeped into the bale, after which the bales were flipped on their sides.

Cows had *ad libitum* access to water. Cows on the control, alfalfa hay and liquid supplement hay treatments were fed a 6-12+ mineral supplement (CHS Inc., Sioux Falls, S.D.). All cows were offered a salt block. Two-day body weights were taken at the start and end of each grazing period. Two observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988; Rasby et al., 2014) at the start and end of the period. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Results

Initial cow BW and BCS were similar ($P > 0.05$) among treatments in both years. In the first year, supplementation with

Table 1. Composition of grass hay alone (control) and grass hay supplemented with alfalfa hay (ALF), a liquid supplement (QLF) or distillers dry grain with solubles (DDGS).

	Control[1]	ALF[2]	QLF[3]	DDGS[4]
Dry matter (DM), %	94.3	94.1	86.4	93.7
Nutrient composition, % DM				
Crude protein	7.5	9.9	8.8	11.1
Total digestible nutrients	51.7	54.1	51.0	55.2
Neutral detergent fiber	66.3	63.5	65.9	60.9
Acid detergent fiber	47.8	44.7	48.7	42.6
Calcium	0.56	0.91	0.51	0.48
Phosphorus	0.10	0.11	0.16	0.25
Potassium	0.77	1.03	0.93	0.84
Magnesium	0.18	0.23	0.15	0.21

[1]Grass hay, [2]grass hay + alfalfa hay, [3]liquid supplement-treated hay and [4]grass hay + DDGS.

good-quality alfalfa hay or grass hay treated with a liquid supplement had no impact on improving animal performance. With the exception of cows supplemented with DDGS, cows lost weight and body condition (Figures 1 and 2).

In the second year, weight gains and BCS change were greater in supplemented cows relative to cows offered grass hay only. Cow weight gains and BCS change were positive on all diets but greater on supplemented diets relative to the control (Figures 1 and 2).

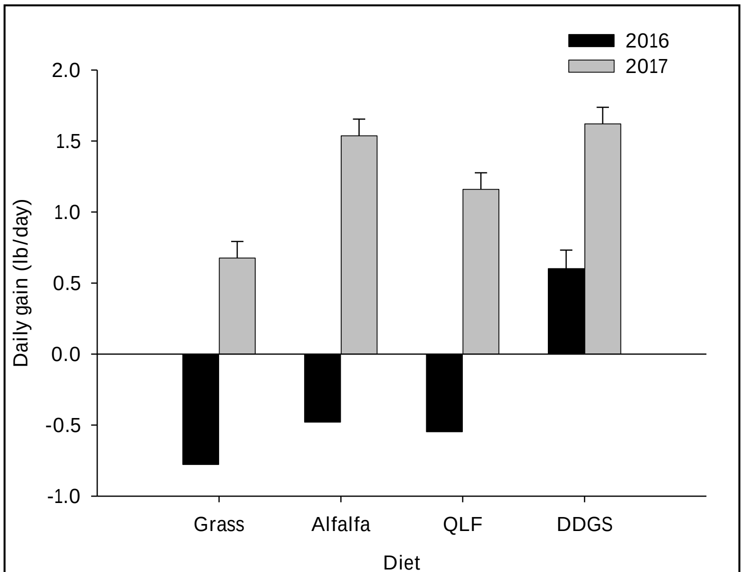

Figure. 1. Cow daily gains following bale grazing grass hay and grass hay supplemented with alfalfa hay (alfalfa), a liquid supplement (QLF) or dried distillers grains with solubles (DDGS).

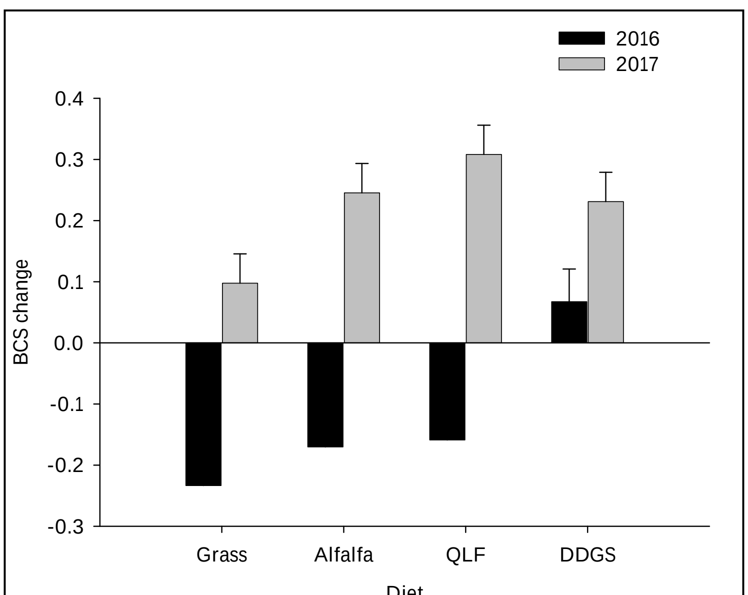

Figure. 2. Cow BCS changes following bale grazing grass hay and grass hay supplemented with alfalfa hay (alfalfa), a liquid supplement (QLF) or dried distillers grains with solubles (DDGS).

Discussion

Environmental conditions will play a part in determining the success of supplementing cows bale grazing grass hay in winter. During the first year of this study (2016), three blizzards occurred, which led to heavy snow accumulation in the paddocks. Despite snow depths greater than 20 inches in some places, cows were able to bale graze for 70 days. The grazing period was terminated when the cows no longer were able to reach water sources.

When winters are harsh, grass hay may not contain adequate energy, protein and phosphorus to meet nutritional requirement of cows in early to midgestation. In the first year, cows supplemented with DDGS maintained BW and BCS, while cows supplemented with alfalfa hay or hay treated with a liquid supplement lost BW and BCS, suggesting that cow nutrient requirements were met by DDGS supplementation but not alfalfa hay or liquid supplementation. With more favorable winter conditions, as in the second year, supplementation with alfalfa hay, a liquid supplement and DDGS all improved animal performance.

Acknowledgments

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Photos by Michael Undi , NDSU

Performance of Beef Cows Managed in two Overwintering Environments

Michael Undi, Jessalyn Bachler, Kevin Sedivec and Stephanie Becker
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Allowing beef cattle to harvest their own forage potentially can decrease production costs by reducing inputs of labor and machinery required for forage harvest. This study assesses performance of beef cattle kept on pasture to bale graze or fed in drylot pens during the winter in North Dakota. Preliminary results show that bale grazing may be a viable alternative to keeping cattle in drylots in winter. Further, environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure that animals have access to water, feed and shelter.

Summary

Performance of beef cows managed in two overwintering environments (pasture or drylot pens) was assessed in a study conducted during two winters, 2016 and 2017, at the Central Grasslands Research Extension Center, Streeter, N.D.

Starting in the fall of each year, non-lactating pregnant Angus cows (2016: n = 32, body weight [BW] = 1,322 ± 150 pounds, body condition score [BCS] = 5.7 ± 0.34; 2017: n = 40, BW = 1,367 ± 131 pounds, BCS = 5.4 ± 0.23) were divided into four groups of similar BW and kept on pasture to bale graze or in drylot pens. Pastured cows were kept in paddocks separated by four-strand, high-tensile wire electric fencing. Drylot pens, bedded with straw, contained hay feeding bunk and water bowl.

Cows in both housing scenarios were offered the same Conservation Reserve Program (CRP) hay free choice. Two-day body weights were taken at the start and end of each grazing period. Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese) at the start and end of each grazing period.

Keeping cows on pasture or in drylot pens in winter did not influence ($P > 0.05$) final BW, daily gain, BCS or BCS change. Environmental conditions, with the first year being colder than the second, influenced animal performance because daily gain and BCS change were greater ($P > 0.05$) in the second year relative to the first year.

Whether on pasture or in drylot pens, cows lost body weight and condition in the first year but maintained or gained weight and BCS in the second year. Preliminary results show that bale grazing may be a viable alternative to keeping cattle in drylots in winter. Further, environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure that animals have access to water, feed and shelter.

Introduction

Winters in North Dakota are characterized by cold temperatures, low wind chills, freezing rain and snow. A large portion of winter (40 to 70 days) averages 0° F, although extreme minimum temperatures of minus 60° F have been recorded (Enz, 2003).

The majority of beef cows in the northern Plains is housed in open drylot pens during the winter (Asem-Hiablie et al., 2016) and is exposed to these extreme winter conditions. In drylots, cattle are fed mechanically harvested feeds such as hay and silage.

Winter feed costs, resulting from labor, machinery and energy required to provide feed, water and bedding to cattle kept in drylots, make up more than 60 percent of total feed costs for most beef cow-calf operations. Because feed costs account for approximately 60 percent of cow-calf production costs (Taylor and Field, 1995), beef producers are interested in reducing winter feed costs by extending the grazing season.

Extending the grazing season by keeping cattle on pasture for a significant period of time during the winter allows animals to harvest their own food and decreases reliance on inputs such as machinery and energy required to harvest forage (D'Souza et al., 1990). By maximizing the use of grazed grass, the cheapest feed resource for ruminants (Hennessy and Kennedy, 2009), extending the grazing season can decrease production costs and enhance profitability of livestock production (D'Souza, et al. 1990; Hennessy and Kennedy, 2009).

Strategies for extending the grazing season such as swath grazing, bale grazing and stockpiling have been evaluated (D'Souza et al., 1990; Willms et al., 1993; Volesky et al., 2002; McCartney et al., 2004; Jungnitsch et al., 2011; Kelln et al., 2011; Baron et al., 2014). The economic benefits from these strategies accrue mainly from cost reductions of feeds and feeding, labor, fuel, machinery maintenance and repair, and manure removal.

Environmentally, keeping cattle on pasture returns nutrients directly onto the land and allows for optimal nutrient capture by growing plants (Jungnitsch et al., 2011; Kelln et al., 2011). Depositing manure directly on pastures avoids nutrient accumulation in one place, minimizing nutrient loss to the environment through runoff or leaching (Kelln et al., 2012; Bernier et al., 2014).

Extending the grazing season must show benefits to the animal as well as to the producer. Local information on animal performance in extended grazing systems, especially bale grazing, as well as data on the economics of extended grazing under North Dakota winter conditions, is limited. Therefore, this study was conducted to assess the performance of pregnant beef cows managed in two overwintering environments (pasture or drylot) under south-central North Dakota winter conditions.

Procedures

This study was conducted during two winters: 2016 and 2017. Starting in the fall of each year, nonlactating pregnant Angus cows (2016: n = 32, BW = 1,322 ± 150 pounds, BCS = 5.7 ± 0.34; 2017: n = 40, BW = 1,367 ± 131 pounds, BCS = 5.4 ± 0.23) were divided into four groups of similar BW and kept on pasture to bale graze or in drylot pens in the winter.

Pastured cows were kept in paddocks separated by four-strand, high-tensile wire electric fencing. Drylot pens, bedded with straw, contained hay feeding bunk and water bowl. Cows in both housing scenarios were offered the same Conservation Reserve Program (CRP) hay free choice.

Two-day body weights were taken at the start and end of each grazing period. Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988; Rasby et al., 2014) at the start and end of each grazing period. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Bale Grazing

Historically, the bale grazing site was cropland in a corn and small-grain rotation. In the two years prior to the start of this study, the site was planted with cool-season cover crops, mainly rye and brassicas. In 2016, the site was burned down with 2, 4-D and Roundup in late April, after which meadow brome was planted in early May.

Three-acre paddocks were separated using four-strand, high-tensile wire electric fencing. One water tank was placed between two paddocks. Windbreaks were placed in each paddock.

In early fall, round CRP hay bales (7.5 percent crude protein [CP]; 51.7 percent total digestible nutrients [TDN]; Table 1) were placed in each paddock in two rows approximately 50 feet apart. Cows were allotted four bales in one grazing session; access to new bales was controlled using portable electric fencing.

Cows were moved to a new set of four bales when the depth of waste feed remaining across the diameter of each bale was less than 4 inches. Cows had *ad libitum* access to fresh water, mineral supplement and salt blocks.

Table 1. Nutrient composition of grass hay offered to cows bale grazing on pasture or kept in a drylot.

Nutrient, % dry matter	
Dry matter	94.3
Crude protein	7.5
Total digestible nutrients	51.7
Neutral detergent fiber	66.3
Acid detergent fiber	47.8
Calcium	0.56
Phosphorus	0.10
Potassium	0.77
Magnesium	0.18

Drylot

Two groups of cows were kept in drylot pens. Each pen contained a two-bale hay feeder and a Richie water tank. Pens were bedded with straw as needed throughout the study. Drylot cows were fed the same CRP hay (7.5 percent CP; 51.7 percent TDN) as the bale-grazed cows. Like the bale-grazed cows, drylot cows had *ad libitum* access to fresh water, mineral supplement and salt blocks.

Results

Animal Performance

Initial cow BW and BCS were similar (*P* > 0.05) between housing treatments in both years. Housing did not influence (*P* > 0.05) final BW, daily gain, BCS or BCS change.

Environmental conditions, with the first year being colder than the second, influenced animal performance because daily gain and BCS change were greater (*P* > 0.05) in the second year relative to the first year. Whether on pasture or in drylot pens, cows lost body weight and condition in the first year but maintained or gained weight and BCS in the second year (Figures 1 and 2).

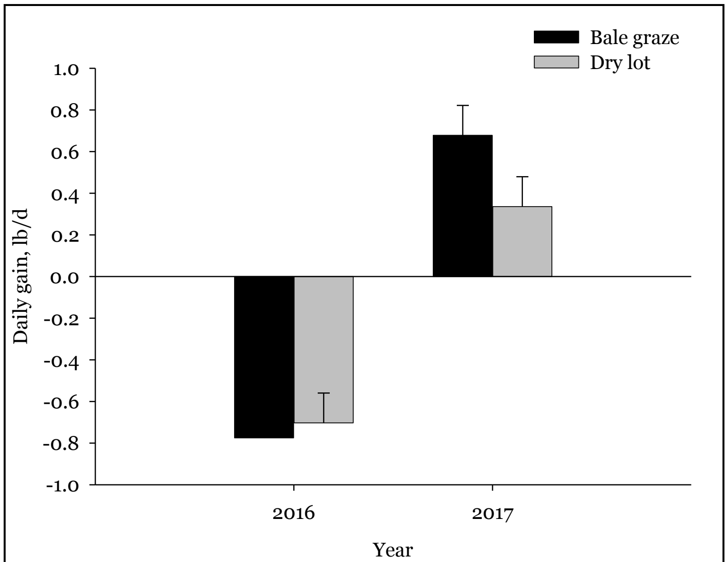

Figure 1. Average daily gain of cows (2016, n = 32; 2017, n = 40) kept on pasture or in a drylot in winter during two winters.

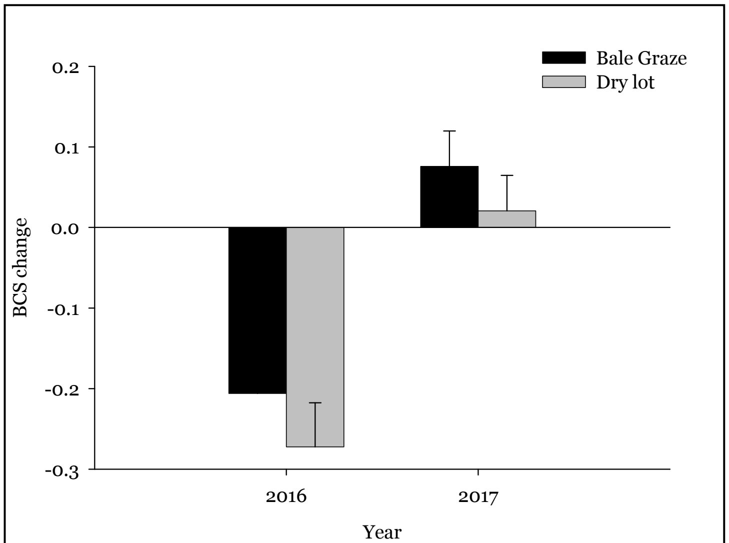

Figure 2. Changes in BCS in cows (2016, n = 32; 2017, n = 40) kept on pasture or in a drylot in winter during two winters.

Discussion

The first year of the study was marked by three blizzards, which led to huge snow accumulations. Despite snow depths being greater than 20 inches in some places, cows were able to bale graze for 70 days before termination of the grazing period. Grazing was terminated after accessing water points became impossible. This shows that strategies for extending the grazing season should be accompanied by a contingency plan for feed and water supplies in case grazing becomes impossible.

Some interesting observations from blizzard events in 2016:

First, despite windbreaks, not all cows sought shelter during the blizzards. Some would simply stand on the leeward side of the bales while other cows did not seek shelter at all and continued to graze.

Secondly, when water troughs were cleared of snow after each blizzard and re-filled, not all cows visited the water troughs immediately, as anticipated. However, a “catch up” period of several days seemed to follow blizzards when water intake increased, as noted by more frequent filling of water troughs.

Events such as blizzards can prevent or drastically reduce access to water, requiring pastured cows to utilize snow as a source of water. Animals can survive on snow, as shown in beef calves (Degen and Young, 1990a) and pregnant beef cows (Degen and Young, 1990b).

Cows in both housing scenarios lost body weight and condition in the first year, which was probably a function of the combination of quality of hay offered to cows and environmental conditions. The hay may have been low in energy, protein and phosphorus content and did not supply these nutrients to meet requirements of cows in midgestation (National Research Council, 1996), particularly during adverse weather conditions as encountered in 2016 (Figure. 1). The positive animal performance during the second year may be attributed to a very mild winter.

Keeping cows on pasture or in drylot pens did not influence animal performance in this study because both housing scenarios provided similar protection from the elements, particularly wind. The windbreaks used in this study seemed to be effective in ensuring that both groups of cows had adequate protection.

Many producers in the northern Plains use windbreaks to protect cattle from harsh winter weather (Asem-Hiablie et al., 2016). Using windbreaks minimizes convective heat loss, thereby reducing the use of endogenous reserves (Olson and Wallander, 2002). However, using windbreaks may not improve overall performance because time spent behind windbreaks is time spent not feeding or foraging (Olson and Wallander, 2002).

The smaller size drylot pens would be expected to give drylot cows a competitive energy expenditure advantage over cows on pasture. Animals on pasture spend more energy walking in search of food and water or shelter and more time eating and foraging for food than housed animals (Osuji, 1974). Extra muscular activities, in addition to those observed indoors, might increase maintenance energy requirements of animals on range by 25 to 50 percent (Osuji, 1974). However, this might not apply in bale grazing situations where animals do not travel long distances to feed.

Keeping cattle on pasture or in drylot pens in winter must be assessed against benefits to the animal, as well as financial benefits to the producer. Extending the grazing season reduces feed costs significantly because animals harvest their own food (D’Souza et al., 1990). Several studies (D’Souza et al., 1990; Willms et al., 1993; McCartney et al., 2004; Jungnitsch et al., 2011; Kelln et al., 2011; Baron et al., 2014) have shown economic advantages of extending the grazing season associated with reducing costs of feeds and feeding, labor, fuel, machinery maintenance and repair, and manure removal.

Conclusions

Results show that bale grazing may be a viable alternative to keeping cattle in drylots in the winter. Further, environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure that animals have access to water, feed and shelter.

Acknowledgments

Technical assistance provided by Dwight Schmidt, Rodney Schmidt, Thomas Mittleider and Rick Bohn is gratefully acknowledged.

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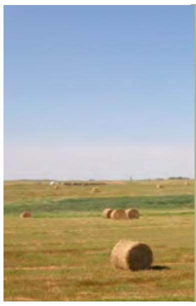
Photos by Michael Undi, NDSU



Impacts of Bale Grazing on Herbage Production, Forage Quality and Soil Health in South-central North Dakota

Fara Brummer, Kevin Sedivec, Mary Berg, Chris Augustin, Penny Nester, Sheldon Gerhardt, Jackie Buckley, Ashley Stegeman and Dennis Whitted

North Dakota State University Extension

This project examines the effect of winter hay bale-grazing on subsequent years' herbage production and nutritional quality six and 18 months after treatment. Parameters measured included herbage production, nutritional quality, soil nutrient content, cow body condition and system costs.

Summary

The effect of bale grazing on grass production six months and 18 months after treatment varied, based on ranch site location, from our demonstration trials conducted in 2015 through 2017. The overriding variables that appear to affect grass production are distance between bales and stocking rate intensity (density and duration of time).

Grass production was greater on the bale-grazed treatment, compared with the control treatment (no bales on site) 15 feet from the bale center; however, no difference was found within the zone 0 to 10 feet from the bale center six months after treatment. However, grass production was greater on the bale-grazed treatment, compare with control 0, 5 and 10 feet from bale center 18 months after treatment.

Bale grazing enhanced grass crude protein and phosphorus content six months after treatment from bale center out to 10 feet. Although bale grazing did not enhance total grass biomass production from within the 0- to 10-feet zone from the bale center, it increased grass crude protein content within this zone. Bale grazing increased grass phosphorus content within the 0- to 5-feet zone of the bale center.

Soil nitrates, phosphorus and potassium at the 0- to 6-inch soil profile increased on the bale-grazed treatment at all distances from the bale edge six to nine months after treatment with no increase on the control sites. The percentage of organic matter at the same soil depth increased up to 1.4-fold at the bale-grazed sites, compared with the control sites.

Our field trials demonstrated that the added urine, feces and hay waste within the 10-feet zone of the bale center did not impact grass production (no benefits or negative effects) six months after treatment; however, it did increase grass production 18 months after treatment.

Grass nutritional content was improved within the 10-feet zone of the bale center six months after treatment, enhancing forage quality. Herbage within the 5-feet zone of the bale center also had enhanced phosphorus content, a direct result from the added urine and feces. This additional phosphorus is beneficial in meeting the requirements of grazing livestock, as well as removing excess phosphorus from the soil. Soil nutrient parameters were enhanced significantly at the bale-grazed sites at the 0- to 6-inch soil profile from bale edge out to 12.5 feet, when compared with the control.

Introduction

Bale grazing is the practice of allowing livestock access to hay bales in a hayfield or improved pasture to reduce labor and feed delivery costs (Lardner et al., 2008). Livestock growers in the northern Great Plains practicing this technique also are interested in improving soil health and forage production through manure distribution while maintaining adequate livestock performance. Recently published data have shown a positive relationship between bale grazing and nitrogen capture, as well as forage growth (Jungnitsch et al., 2010; Kelln et al., 2012); however, local producer concerns in our region prompted the need for further applied research.

This project was conducted on four ranches in North Dakota to examine winter hay bale-grazing effects on subsequent years' herbage production and nutritional quality six and 18 months after treatment. Parameters measured included herbage production, nutritional quality, soil nutrient content, cow body condition and system costs.

Because bale grazing introduces higher nitrogen and phosphorus into a system, bale grazing on native pastures is not recommended. Therefore, this project was conducted on improved pastures planted to domesticated cool-season grasses. Herbage production, nutritional quality and soil nutrient content are presented in this report.

Methods and Design

Four ranches were selected on different ecological sites - claypan, thin loamy, loamy and shallow gravel - from south-central North Dakota. Sites consisted of improved, cool-season grass pastures/ hay. Three of the sites had not been bale grazed.

Four bales of similar hay type were selected randomly per ranch to represent bale grazing (BG) treatment in September 2015. Bale grazing on all sites occurred from January through March 2016. Four control sites without bales (C) were selected systematically on the same soil series, slope and plant community directly outside the bale-grazed area and sampled using the same protocol as the bale-graze sites (See Figures 1 and 2).

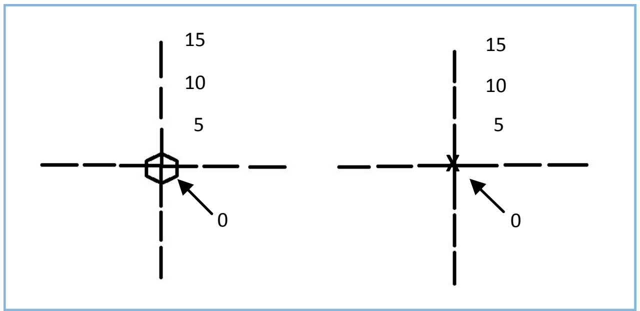


Figure 1. Example of collection locations from bale center and control center, 5, 10 and 15 feet from center for herbage production and soil nutrient content.

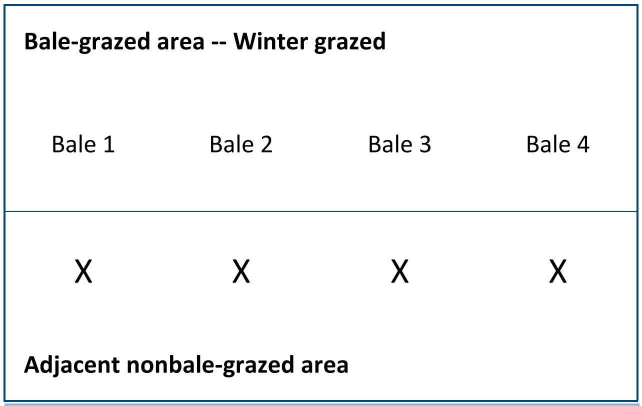


Figure 2. Example of bale-grazed study area showing a smooth brome grass pasture split into bale grazing treatment and the parallel nonbale grazing treatment (control), with "X" representing a corresponding sample location.

Herbage production was collected during peak production for cool -season grasses in North Dakota and before summer grazing occurred. Vegetation was clipped for biomass in late June or early July at four distance points (0, 5, 10, 15 feet) along each cardinal direction (16 total plots) from the bale center after cattle had grazed the bales in 2016 (Figure 1).

Grasses and forbs were separated and composited by plant form from all cardinal directions per bale distance point (four composited samples per bale distance). Hay residue was sampled at the same points and similarly composited to determine waste post-grazing, and to test for a possible relationship with herbage regrowth and quality.

Herbage samples were weighed, oven-dried at 65° C for 72 hours and reweighed for moisture content. Wet chemistry nutritional analysis on the grass component was conducted at the North Dakota State University Animal Science Nutrition Laboratory. Analysis included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash, calcium (Ca), magnesium (Mg) and phosphorus (P).

Soil samples were collected pre-treatment in September 2015, and 12 and 24 months later in 2016 and 2017. Soil cores were collected at 0 to 6-inch depths from the same four bale treatment sites and four bale control sites that were used for herbage production. Soil parameters collected included penetrometer (compaction), electrical conductivity, Haney soil health calculation, nitrate, phosphorus, potassium, pH and organic matter.

Results and Discussion

Herbage Production

We found no difference ($P > 0.1$) in total grass biomass production among samples from the bale center, and 5 and 10 feet from the bale center on hay/pastureland that was bale grazed or on similar control hay/pastureland sites six months after treatment. However, bale grazing enhanced ($P \leq 0.1$) grass production 15 feet from the bale center (Table 1). In contrast to six months after treatment, grass production was greater at the bale center, and 5 and 10 feet from the bale center, compared with 15 feet from the bale center and the control hay/pasture sites 18 months after treatment (Table 1).

Table 1. Grass production at the bale's center, and 5, 10 and 15 feet from bale center on winter-grazed bales versus no winter grazing six months after treatment (collected late June/ early July at peak production) in south-central and central North Dakota in 2016 and 2017.

Treatment	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
	lb/acre grass in 2016[1]			
Bale grazed	5,274[a]	5,320[a]	4,613[a]	8,604[b]
Control	5,358[a]	5,823[a]	5,888[a]	6,160[a]
	lb/acre grass in 2017[1]			
Bale grazed	3,114[a]	2,611[a]	2,413[ab]	1,848[b]
Control	1,553[b]	1,405[b]	1,383[b]	1,154[b]

[1] Grass production by treatment and distances from bale within years with the same letter (a, b) are not significantly different ($P > 0.1$).

When bales were placed close together (less than 15 feet), as seen at the Napoleon study site, the bale-grazed site produced from 21 to 172 percent less grass production, depending on distance from the bale, than the control site six months after treatment. However, 18 months after treatment, the bale-grazed site produced 37 to 73 percent greater grass production, with the percentage increase greatest at the furthest distance from bale (Table 2).

Because of the close bale spacing, manure and waste are naturally more prominent, as seen in the high residue levels, negatively impacting grass production the first year following treatment but

Table 2. Grass production and hay residue remaining six months after treatment at different distances from the bale when bales were grazed in early winter (January-March) in south-central North Dakota in 2016.

Location	Bale distance average (ft.)	Parameter	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
			lb/acre in 2016			
Tuttle	25 to 30	Residue from bale	28.5	16.0	7.1	NC[1]
		Bale-grazed production	2,860	3,620	5,083	NC
		Control production	3,103	3,740	6,779	NC
			lb/acre in 2017			
		Bale-grazed production	1,766	2,485	1,992	1,558
		Control production	958	1,575	1,456	1,467
			lb/acre in 2016			
Wing	10 to 50[2]	Residue from bale	18.7	36.5	44.6	14.2
		Bale-grazed production	9,196	10,749	3,202	9,604
		Control production	5,695	8,423	5,789	6,125
			lb/acre in 2016			
Napoleon	15	Residue from bale	87.2	140.6	79.2	71.2
		Bale-grazed production	5,587	3,366	2,727	7,199
		Control production	8,775	7,865	7,432	8,679
			lb/acre in 2017			
		Bale-grazed production	3,379	2,569	3,029	2,422
		Control production	2,466	1,736	1,918	1,400
			lb/acre in 2016			
Fort Rice	50	Residue from bale	69.0	71.2	9.8	11.6
		Bale-grazed production	3,454	3,544	7,440	9,009
		Control production	3,859	3,264	3,551	3,677
			lb/acre in 2017			
		Bale-grazed production	4,196	2,779	2,269	1,563
		Control production	1,232	880	752	538

[1] NC = Not collected

[2] Spread unevenly throughout the field

positively impacting production the second year following treatment (Table 2). Plus, stock density may have been lower than recommended, leaving a high level of residue on the ground the first year following treatment, especially within 5 feet of the bale.

When bales were placed 50 feet apart at the Fort Rice study site, bale grazing had no effect on grass production up to 5 feet away from the bale center within six months of treatment (Table 2). However, bale grazing increased grass production by 109 to 145 percent at 10 and 15 feet from the bale center, respectively. At 18 months after treatment, the bale-grazed sites produced 190 to 241 percent more grass production, with the greatest increase closest to the bale.

This open spacing pattern reduces selection; more evenly distributes cattle and leaves fewer residues if cattle are forced to clean up the hay. This spacing causes higher levels of residue close to the bales but distributes manure more evenly away from the bales, helping explain the bale grazing's positive effect on grass production.

When the bales were placed 25 to 30 feet apart at the Tuttle study site, we found no difference between the bale-grazed sites and control sites six months after treatment (Table 2). Herbage production 10 feet away from the bale showed trends toward higher herbage production on the bale-grazed site, but without data from the 15-foot location, we were unable to determine if this production trend would continue to increase. At 18 months after treatment, bale grazing increased grass production by 6 to 84 percent, with the greatest increase closest to the bale (similar to the Fort Rice study site).

The Wing study site was the only location to show increased herbage production from bale grazing within the first 5 feet around the bale, with an increase of 28 to 61 percent. This site also showed a reduction in herbage production at 10 feet from the bale, that area with the greatest level of residue on the ground (Table 2). However, where residue was low, as seen at 15 feet away from the bale, the bale-grazing site had an increased herbage production of 56 percent.

This study site had bales spread irregularly, ranging from 10 to 50 feet. This uneven distribution of bales may have created uneven feeding patterns and increased the pecking order, creating these positive and negative impacts due to bale grazing within the same unit. No data were collected 18 months after treatment due to cattle grazing the site in May and June.

Forage Quality

Our demonstration trials exhibited that bale grazing increases ($P \leq 0.1$) crude protein content of the grass portion of the vegetation six months after treatment (late June/early July) at the bale center out to 10 feet (Table 3). Grass crude protein content was greater ($P \leq 0.1$) than the control at the bale center, and 5 and 10 feet from the bale but not ($P > 0.1$) at 15 feet from the bale center.

These findings indicate that benefits from bale grazing occur throughout the zone within 10 feet of the bales. This benefit is a result of added nitrogen from urine and fecal material, concentrated within this 10-feet zone.

Table 3. Grass quality parameters at the bale center, and 5, 10 and 15 feet from the bale center on winter-grazed bales versus no winter grazing in south-central and central North Dakota in 2016 six months after treatment (collected late June/early July at peak production).

Treatment	Bale center	5 ft. from center	10 ft. from center	15 ft. from center
	Crude protein (%) content[1]			
Bale grazed	17.2[ax]	17.3[ax]	15.9[ax]	13.0[bx]
Control	9.8[ay]	9.8[ay]	10.2[ay]	10.9[ax]
	Phosphorus (%) content[1]			
Bale grazed	0.30[ax]	0.30[ax]	0.27[ax]	0.27[ax]
Control	0.23[ay]	0.23[ay]	0.22[ax]	0.24[ax]
	Calcium (%) content[2]			
Bale grazed	0.48	0.44	0.41	0.38
Control	0.41	0.42	0.39	0.39
	Neutral detergent fiber (%) content[2]			
Bale grazed	61.7	60.9	62.4	64.4
Control	64.2	64.4	63.7	64.1
	Acid detergent fiber (%) content[2]			
Bale grazed	34.2	33.4	33.7	35.2
Control	33.9	34.7	33.7	34.1

[1] Nutritional parameters by treatment and distances from bale with the same letter (a, b) within row (treatment) are not significantly different ($P > 0.1$), and with same letter (x, y) within columns (between treatments) are not significantly different ($P > 0.1$).

[2] No differences ($P > 0.1$) were found among treatments or distances.

Grass phosphorus content was not ($P > 0.1$) different among bale treatment distances or control distances (Table 3). However, the bale-grazing treatment increased ($P \leq 0.1$) grass phosphorus content when compared with the control at the bale center and 5 feet from the bale center six months after treatment (Table 3).

No differences ($P > 0.1$) in neutral detergent fiber (NDF), acid detergent fiber (ADF) or calcium content of the grass component were found between the bale-grazed and control sites six months after treatment (Table 3). Within our demonstration trials, bale grazing had no effect on NDF, ADF or calcium content within the 15-feet zone six months after treatment.

Soil Nutrient Content

Nitrates (NO_3-N) increased 4.4- to 7.6-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment at the 0- to 6-inch soil profile; however, they declined to similar pre-treatment levels 18 to 21 months after treatment (Table 4). In contrast, NO_3N declined each year, with a total reduction of 70 percent 18 to 21 months after treatment on the control at the same soil depth.

Phosphorus (P) increased 2- to 2.4-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment, maintaining a similar reduction 18 to 21 months after treatment at the 0- to 6-inch soil profile (Table 4). In contrast, P was similar between the post-treatment six to nine months after treatment and increased 26 percent 18 to 21 months after treatment on the control at the same soil depth.

Potassium (K) increased 2.4- to 3.1-fold, depending on distance from bale edge, on the bale-grazed treatment six to nine months after treatment, maintaining a similar reduction 18 to 21 months after treatment at the 0- to 6-inch soil profile (Table 4). Potassium increased six to nine months after treatment and 18 to 21 months after treatment.

The percentage of organic matter increased 1.3- and 1.4-fold six to nine months after treatment at the bale edge (2.5 feet from center), and 5 and 10 feet from the bale edge; respectively (Table 5). However, organic matter returned to the pre-treatment levels 18 to 21 months after treatment. Organic matter on the control site was similar across all three years of the study.

The pH level declined from 7.6 and 7.5 pre-treatment for all distances from the bale edge and control, respectively, to 7.2 and 6.8 at 18 to 21 months after treatment for all distances from the bale edge and control; respectively (Table 5). Although electrical conductivity (EC) increased at all distances from the bale edge when comparing pre-treatment to six to nine months post-

Table 4. Soil nutrient parameters at the bale edge, and 7.5 and 12.5 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale edge	NO_3-N (lbs/ac)			Phosphorus (ppm)			Potassium (ppm)		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Bale edge (2.5 ft. from center)	11.4	74.0	21.0	11.3	30.0	23.9	366.7	888.9	875.9
7.5 feet from center	12.2	92.2	26.1	8.9	22.8	26.8	336.6	1,047.5	912.3
12.5 feet from center	14.8	65.6	21.9	10.1	20.7	24.8	334.5	1,007.3	881.3
Control (no bale grazing)	29.6	18.4	8.9	9.7	9.9	12.2	292.4	408.7	252.4

Table 5. Soil nutrient parameters at the bale edge, and 7.5 and 12.5 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale edge	Organic matter (%)			pH			EC (mmhos/cm)		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Bale edge (2.5 ft. from center)	3.9	5.2	3.8	7.6	7.0	7.2	0.31	0.44	0.29
7.5 feet from center	3.9	4.9	4.2	7.6	7.0	7.2	0.35	0.48	0.31
12.5 feet from center	4.1	5.6	4.1	7.6	7.1	7.2	0.32	0.41	0.29
Control (no bale grazing)	4.2	4.6	3.8	7.5	6.9	6.8	0.29	0.19	0.19

treatment, the levels returned to pre-treatment levels 18 to 21 months after treatment (Table 5). The increased EC observed in 2016 likely would have little adverse effect on forage production.

The Haney soil health calculation increased at all distances from the bale edge and on the control from 2015 to 2016 (Table 6). The Haney soil health declined to pre-treatment levels for all distances from the bale edge and control 18 to 21 months after treatment. Because the control had a similar positive, and negative, trend, compared with the bale-grazing treatment, the increase and decrease occurred due to environment or climatic effects and not due to the bale-grazing treatment during our sampling period.

Table 6. Haney soil health calculation, pH and electrical conductivity (EC) at the bale edge, and 5 and 10 feet from bale center, and the control in the 0- to 6-inch profile on winter-grazed bales pre- and post-treatment in south-central and central North Dakota in 2015 (pre-treatment), 2016 (six to nine months post-treatment) and 2017 (18 to 21 months post-treatment).

Distance from bale center	Haney soil health calculation (range: 1 to 50+)		
	2015	2016	2017
Center	19.7	38.8	18.6
5 feet from center	19.4	37.0	18.2
10 feet from center	19.2	35.7	18.0
Control (no bale grazing)	20.5	34.6	15.5

Conclusion

The effects of bale grazing on herbage production varied by ranch location; however, the distance between bales was the variable with the most impact on production. Residue and manure appeared to be a limiting factor affecting forage production where bales were spaced at 15 feet or less.

The open spacing pattern of bales at 40 to 50 feet apart appeared to better distribute cattle and minimize hay residue. Bale grazing positively affected crude protein and phosphorus content of grass growth during the growing season following the bale-grazing treatment; however, bale-grazing treatment had no effect on acid detergent fiber, neutral detergent fiber or calcium content.

Bale grazing increased soil nitrate, phosphorus and potassium levels, irrelevant of distance from bale edge the first growing season after treatment. However, soil nitrate reduced to pre-treatment levels during the second growing season. Interestingly, the phosphorus and potassium increase was sustained during the second growing season after treatment.

Bale grazing did not change pH or improve the Haney soil health calculation during the first or second growing season following treatment. Although EC increased in the first growing season after the bale grazing treatment, the EC levels declined to pre-treatment levels in the second growing after treatment.

This project has provided insight on the impacts of bale grazing on herbage production, forage quality and soil nutrient composition when studying different scales of bale distribution and stocking densities. Bale grazing appears to be a late-season grazing strategy that creates opportunity to increase forage production and quality, enhance some soil nutrients, and eliminate the labor and fuel associated with hauling manure and feeding cattle in a feed lot.

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Impacts of Kentucky Bluegrass Invasion on Soil Hydrological Properties in the Northern Great Plains

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Kentucky bluegrass (Poa pratensis L.) is a non-native, cool-season (C_3), perennial grass that has become naturalized throughout the entire U.S. This species is an aggressive reproducer and produces abundant litter when not properly managed, which, in turn, creates a thick thatch layer of living and dead plant material between the soil surface and the plant canopy. This thatch layer has the potential to influence ecosystem services, including soil hydrological function, significantly by altering physical conditions at the soil surface.

Introduction

The grasslands of the northern Great Plains provide a wide array of services significant for many environmental, economic and ecological reasons. These ecosystems provide grazing rangeland for cattle by supplying a diverse mixture of nutritious native grasses and forbs throughout the growing season (Toledo et al., 2014).

They also provide habitat for threatened and endangered plant species (Cully et al., 2003), native birds, insects and small-mammal populations. All of these ecosystem services are possible as a result of the soils that support their function.

These important grassland ecosystems, and the functionality of their soils, have been threatened recently as environmental and anthropogenic shifts have caused fragmented and degraded fractions of land in their wake (Cully et al., 2003). One of the primary contributing factors in the deterioration of native prairie grassland is the rapid expansion of Kentucky bluegrass (*Poa pratensis* L.).

This invasive cool-season perennial species is an aggressive colonizer and an extremely successful reproducer. Its success is due, in part, to being able to take advantage of shifts in land management such as fire suppression, longer growing seasons and deferment (Printz and Hendrickson, 2015).

Kentucky bluegrass now dominates many grasslands in the Northern Great Plains and, consequently, reduces populations of native plant species (DeKeyser et al., 2009). This species also produces abundant litter, which paired with its characteristic shallow, dense rooting structure, creates a thick thatch layer between the soil surface and the plant canopy (Toledo et al., 2014).

This thatch layer can accumulate to the point that it affects the physical, mechanical and chemical conditions at the soil surface (Bosy and Reader, 1995). Through this process, Kentucky bluegrass has the potential to alter the ecological community structure and reduce vegetative biodiversity significantly, and potentially intercept rainfall from reaching the soil surface.

While the fact that Kentucky bluegrass affects certain ecosystem services is well-established, a principal knowledge gap still exists in understanding exactly how this litter layer affects the hydrological function of the soil (Toledo et al., 2014). Soil hydrological function is of key importance in these semiarid grassland ecosystems because rainfall and soil moisture often are the most limiting factors for vegetation growth (NRCS, 2017, Ecological Site Description), which, in turn, provides nutrition for grazing cattle and habitat for native fauna.

Cross section of Kentucky bluegrass thatch.

With the need identified to better understand the influence of Kentucky bluegrass on soil water, we conducted field experiments to assess the impact of Kentucky bluegrass dominance on soil water infiltration, runoff and the distribution of water in the soil profile.

Procedures

This study was conducted at the Central Grasslands Research Extension Center (CGREC) in south-central North Dakota during the fall of 2017. Eight sites distributed across the research center, all within the thin loamy Zahl-Williams-Zahill soil series complex, were selected. This soil type typically occurs on moderately sloped uplands and is moderately slow or slowly permeable, with low runoff, depending on the slope and the vegetative cover (Natural Resources Conservation Service Web Soil Survey, 2017). This is a common soil type in the area and was selected to be representative of the region as a whole.

Treatments (left to right)

1) Kentucky bluegrass + thatch

2) Kentucky bluegrass – thatch

3) burned

Half of the sites (n=4) were selected to represent Kentucky bluegrass-dominated vegetative communities. These sites historically had been excluded from grazing and burning, which resulted in the accumulation of a thick thatch layer. The other half of the sites (n=4) were in areas that had been burned in patches of 10 to 40 acres between April and May of 2017. These sites had a similar vegetative composition to the Kentucky bluegrass sites prior to burning, after which the fire disturbance resulted in a regeneration of predominantly native prairie grass and forb species. Each of these sites also was open to seasonlong, moderate grazing, which helped control litter.

At each site, we conducted field testing to measure the infiltrability of the soil. Two separate conditions were tested at each Kentucky bluegrass-dominated site: 1) undisturbed Kentucky bluegrass thatch conditions (KBG + Thatch), and 2) Kentucky bluegrass with above-ground vegetation and thatch manually removed to the mineral soil surface (KBG – Thatch).

Across four replicates of each of the three treatments, we used the Cornell Sprinkler Infiltrometer method to measure infiltration through ponded ring infiltration paired with simulated rainfall (Ogden et al., 1997). Following the experiment, we collected soil samples from depths of 0 to 5 centimeters (cm), 5 to 10 cm and 10 to 15 cm directly under the infiltrometer, and from an adjacent control site. These samples were measured for moisture content to determine the resulting distribution of water from the simulated rainfall event.

Results

Infiltration and Runoff

The difference between the simulated rainfall rate (r) and runoff rates (ro_t) was used to calculate the infiltration rate (i_t). Additional properties including sorptivity and field-saturated infiltrability were calculated to better characterize rainfall patterns in each treatment.

The estimation of sorptivity (S) is a hydraulic property describing early infiltration independent of rainfall rate, and the estimation of field-saturated infiltrability (i_{fs}) describes the steady-state infiltration capacity of the soil after an initial wetting period (Ogden et al., 1997). The adjustment factor used in the i_{fs} calculation is based on Reynolds and Elrick (1990) modeling.

KBG – Thatch treatments had the lowest overall rates of water runoff and highest infiltration, followed by KBG + Thatch (Figure 1). The burned treatment had the highest runoff and lowest infiltration.

Average sorptivity and field-saturated infiltrability followed a similar trend. Both parameters were highest in KBG – Thatch, followed by KBG + Thatch, and then burned treatments, with sorptivity values of 2.82, 1.74 and 1.40 cm/minute (min), and field-saturated infiltrability rates of 0.29, 0.17 and 0.10 cm/min, respectively (Table 1). No statistically significant differences for these parameters were detected across treatments using a paired t-test.

Soil Water Distribution

Burned sites retained the highest relative percentage of rainfall in the top 0 to 5 cm of soil out of all treatments (Figure 2). This treatment also had the greatest difference in percentage of rainfall retained between the 0 to 5 cm and 5 to 15 cm soil range. Both KBG + Thatch and KBG - Thatch treatments retained the majority of the rainfall water in the top 0 to 5 cm of soil as well. However, water distribution was more uniform with depth in these two treatments when compared with the burned treatment. KBG + Thatch retained more relative water than KBG – Thatch in the top 0 to 5 cm of soil. However, this pattern reverses in the 5 to 15 cm depths, with KBG – Thatch retaining more water than KBG + Thatch in these lower depths (Figure 2). We did not observe statistically significant differences for the distribution of water into the soil profile across treatment means.

Discussion

Soils that are dominated primarily by Kentucky bluegrass vegetation did not show any statistically significant changes in infiltration parameters after removing thatch (by hand or with fire) due to high variability within treatments. However, observed trends in infiltration parameters are supported by field observations of Kentucky bluegrass thatch and rooting characteristics.

An increase in infiltration with the manual removal of surface thatch may indicate that the thatch material can intercept water and impede infiltration. This idea additionally is supported by the observation that the KBG + Thatch retained more relative water in the top 5 cm of soil than the KBG – Thatch, which is opposite of the trend seen between these two treatments in the lower soil depths. These observations may indicate that the thatch layer is

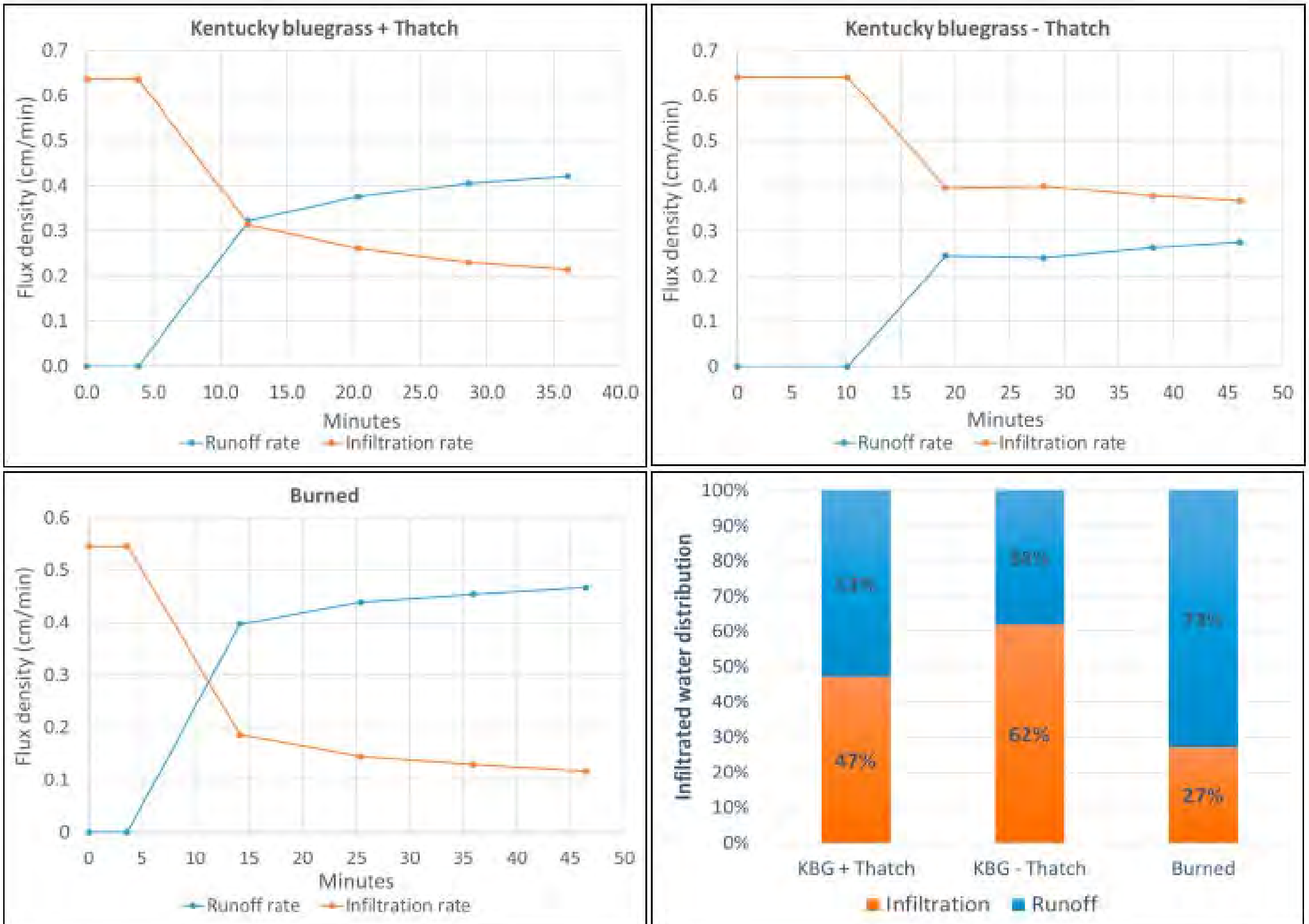

Figure 1. Average runoff and infiltration rates between treatments, and relative water budget (bottom right).

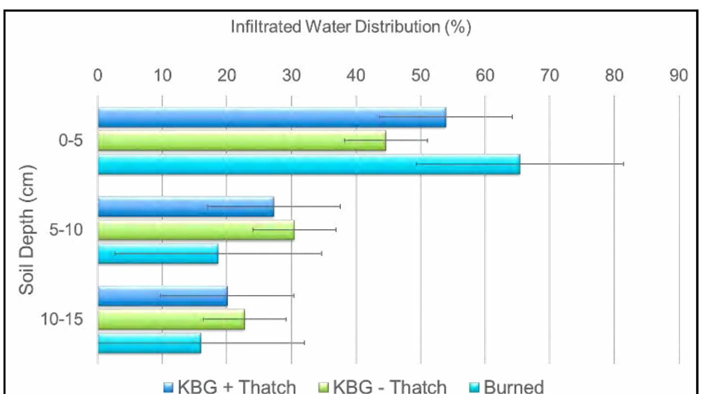

Figure 2. Percent of infiltrated water (by mass) within the top 15 cm of the soil profile.

Treatment	Sorptivity (cm/min)	Field-Sat Infiltrability (cm/min)
KBG + Thatch	1.74	0.17
KBG - Thatch	2.82	0.29
Burned	1.40	0.10

Table 1. Average sorptivity and field-saturated infiltrability rates.

retaining rainfall water and preventing it from reaching lower soil depths.

The decrease in infiltration in the burned treatment may be explained by the shift in vegetation from Kentucky bluegrass to native grass and forb species following a fire disturbance. Kentucky bluegrass produces a thick layer of dense, shallow roots, which are presumed to promote water flow and conductivity at the surface and deeper into the soil profile.

Immediately following a burning event, the above-ground vegetation and rooting structures die, and pores may collapse as sparse native species re-establish. The change in soil surface condition and porosity may result in reduced infiltration after fire.

With time, this pattern may become less pronounced as native species colonize and generate more roots deeper into the soil profile.

Directions for research in 2018 include:

- Examination of soil structure (pore distribution) under Kentucky bluegrass before and after fire
- Continued infiltration testing to observe differences in burned treatments as sites recover from the disturbance
- Characterizing the differences between treatments in soil moisture and temperature in the top 15 cm of soil through in-situ stations and sensors

Conclusion

The preliminary results from this study indicate that Kentucky bluegrass dominance and land management practices may play a role in soil water infiltration. Soil water infiltration, in turn, affects plant growth and, thus, nutritional value for grazing livestock. Future research will help provide important characterization of soil properties, water dynamics and the rebounding nature of these grassland ecosystems following a fire disturbance.

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Mixed-grass Vegetation Response to Grazing Management Strategies in Kentucky Bluegrass-invaded Pastures

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The response of vegetation to seasonlong (SL), patch-burn (PB) and early intensive (EI) grazing and idle management strategies is being analyzed on Kentucky bluegrass (Poa pratensis L.)-invaded pastures in the mixed-grass prairie of the northern Great Plains. Research has shown that burning alone can reduce Kentucky bluegrass for a year, but a return to preburn levels the following year suggests that additional disturbance is necessary.

Burning followed by grazing may control Kentucky bluegrass proliferation by removing senescent material and promoting fire-tolerant grasses and forbs. Early grazing also may control Kentucky bluegrass by disturbing it during active growth, and promote native grasses and forbs by removing livestock before the grasses and forbs have received significant grazing pressure.

Results from 2017 suggest that plant communities under PB and EI grazing management have less Kentucky bluegrass, increased diversity and higher annual forage production than SL and idle plant communities. Analysis between study years is necessary to reveal if these trends are consistent and to confirm the mechanisms behind differences in the plant communities. Before these management strategies can be recommended for control of Kentucky bluegrass in invaded communities, additional research is required to evaluate their effects on livestock production.

Introduction

The influence of grazing and fire on the evolution of the Great Plains grassland ecosystem is widely recognized (Fuhlendorf et al., 2009; Samson et al., 2004). These disturbances had complex spatial and temporal interactions that, when coupled with climatic variability, resulted in structurally and compositionally diverse plant communities across the landscape consisting of patches with varying degrees of disturbance (Fuhlendorf and Engle, 2004).

As European colonization replaced bison with domestic cattle, suppressed natural wildfires and introduced new species, the composition of the landscape changed dramatically (Samson and Knopf, 1994). Intensive agricultural production in North America has further impaired grassland communities by fragmenting the landscape and reducing their land area to small fractions of their native range.

Prairie fragments that remain today are increasingly threatened by overgrazing, lack of fire and exotic invasive species (Bahm et al., 2011). Outdated land management strategies further threaten prairie integrity by promoting homogeneity and invasive species spread (Fuhlendorf and Engle, 2004; Toledo et al., 2014).

Kentucky bluegrass (*Poa pratensis* L.) invasion in the mixed-grass prairie of the northern Great Plains has accelerated rapidly during the past 30 years but only recently has received attention (Toledo et al., 2014). Kentucky bluegrass is a cool-season, perennial grass native to northern Europe that is displacing mixed-grass prairie species and altering ecosystem properties by filling a previously unoccupied phenological niche and developing a dense root and thatch layer (Toledo et al., 2014).

Kentucky bluegrass monoculture in an idle pasture.

Thatch, a layer of live and dead plant material between the soil surface and canopy not only restricts the growth and establishment of native species by limiting their access to light but also alters surface hydrology (Taylor and Blake, 1982), soil structure (Herrick et al., 2001) and nutrient cycling (Badra et al., 2005). The forage quality of Kentucky bluegrass is high in the spring during active growth but decreases as dormancy occurs with heat and water stress experienced during summer, unlike native warm-season species (Hockensmith et al., 1997).

Grassland ecosystems managed for livestock production typically utilize grazing systems that promote uniform distribution and forage utilization (Fuhlendorf and Engle, 2001, 2004) such as seasonlong or rotational grazing (Bailey et al., 1998). Uniform disturbances promote homogeneity because they do not allow the development of areas with varying levels of disturbance intensity or frequency (Bailey et al., 1998; Fuhlendorf and Engle, 2004).

Kentucky bluegrass has the ability to regenerate quickly by rhizomes, and often develops a monoculture with a dense root and thatch layer that prevents the establishment of other species (Toledo et al., 2014). Traditional seasonlong grazing results in an increase in Kentucky bluegrass, implying that its invasion expands under uniform disturbance regimes (Smith and Owensby, 1978). Alternative grazing regimes are necessary to control

Kentucky bluegrass invasion but have yet to be developed and tested empirically (Toledo et al., 2014).

High-intensity grazing in early spring during active Kentucky bluegrass growth may have the potential to reduce its competitive pressure on later-emerging native species when grazing is absent. Research on early intensive grazing indicates that it can decrease or stabilize populations of Kentucky bluegrass, along with other nondesirable cool-season species in a warm-season prairie (Smith and Owensby, 1978).

Preliminary research on the effect of prescribed burns on Kentucky bluegrass invasion suggests fire may be an effective management tool. Studies in the Kansas Flint Hills (Anderson et al., 1970; Owensby and Smith, 1979) and South Dakota (Bahm et al., 2011; Engle and Bultsma, 1984) indicate that burning has the potential to decrease Kentucky bluegrass and other cool-season species cover.

Bahm et al. (2011) found that fire substantially reduced Kentucky bluegrass cover in the first year post-fire but its cover returned to pretreatment levels in the second year. Additional disturbance, therefore, is necessary to maintain the long-term benefits of burning for Kentucky bluegrass management (Bahm et al., 2011).

Furthermore, a study in the tallgrass prairie of Oklahoma found patch-burn grazing management to be effective for the suppression of sericea lespedeza (*Lespedeza cuneate*), an exotic invasive legume, because focused post-fire grazing maintained the plant at a young maturity level (Cummings et al., 2007). Patch-burn grazing not only should remove Kentucky bluegrass thatch and allow other species to move in, but it also should increase the carbon-to-nitrogen ratio and favor native grassland species, which have a competitive advantage in coping with low nitrogen (Wedin and Tilman, 1990).

To our knowledge, research comparing the effects of traditional seasonlong grazing management with alternative grazing management approaches on Kentucky bluegrass-invaded plant communities is lacking. By making these comparisons, our goal is to elucidate management strategies that not only promote diversity but also promote the functionality of invaded ecosystems for livestock production in the face of extensive Kentucky bluegrass invasion.

The objectives of this study were to:

- Determine the effects of idle, seasonlong, patch-burn and early intensive grazing management strategies on plant community composition
- Evaluate the effects of each management strategy on forage production

Grazing Treatment	Year	Average Head/Pasture	Date On	Date Off	Days Grazed	Stocking Rate (AUM/acre)
Early intensive (EI)	2011	41.7	May 2	June 6	35	0.98
	2012	46.0	April 13	May 24	41	1.26
	2013	50.0	May 6	June 7	32	1.10
	2014	43.6	April 30	June 6	37	1.19
	2015	44.7	April 23	June 2	40	1.27
	2016	41.3	May 12	June 7	26	0.72
	2017	33.0	May 2	June 10	39	0.86
Seasonlong (SL)	2011	15.0	May 13	Sept. 15	125	1.30
	2012	18.3	May 9	Sept. 21	135	1.85
	2013	15.7	May 23	Aug. 28	97	0.96
	2014	13.3	April 30	Sept. 2	125	1.23
	2015	13.0	April 23	Aug. 27	126	1.20
	2016	12.3	May 12	Sept. 1	112	0.92
	2017	9.7	May 2	Sept. 5	126	0.81
Patch-burn (PB)	2015	13.7	April 23	Aug. 27	126	1.22
	2016	13.0	May 12	Sept. 1	112	0.94
	2017	9.7	May 2	Sept. 5	126	0.79

Table 1. Stocking history of the early intensive (EI) and seasonlong (SL) grazing treatments for 2011 to 2017 and patch-burn (PB) treatments for 2015 to 2017 at the Central Grasslands Research Extension Center, Streeter, N.D.

Methods

This study is being conducted in the mixed-grass prairie of the northern Great Plains at the Central Grasslands Research Extension Center in Stutsman County northwest of Streeter, N.D. Various grazing experiments have occurred on the study site in previous years, but the site received only light summer grazing in 2009 and 2010 prior to the initiation of management strategies associated with this study.

In 2011, six of 12 pastures of roughly 30 to 40 acres each were assigned seasonlong (SL) grazing, while the other six were assigned early intensive (EI) grazing. In 2014, patch-burn (PB)

Treatment	Litter	Bare Ground	Kentucky Bluegrass	Smooth Brome	Western Snowberry	Western Wheatgrass	Green Needlegrass
Idle	92.9 ± 0.6	0.2 ± 0.1	46.8 ± 3.2	1.8 ± 0.6	5.3 ± 1.0	0.2 ± 0.1	0.5 ± 0.1
Seasonlong	96.7 ± 0.6	0.1 ± 0.1	47.8 ± 3.9	0.8 ± 0.3	3.2 ± 0.1	0.1 ± 0.1	0.8 ± 0.1
Patch-burn	90.2 ± 3.9	1.8 ± 1.7	27.0 ± 2.3	2.8 ± 0.3	3.7 ± 0.6	0.4 ± 0.2	1.3 ± 0.8
Early intensive	96.6 ± 0.6	0.2 ± 0.1	29.8 ± 0.7	2.8 ± 1.0	7.4 ± 1.8	0.1 ± 0.1	0.5 ± 0.4

Table 2. Relative canopy cover of litter, bare ground, Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), western snowberry (*Symphoricarpos occidentalis*), western wheatgrass (*Pascopyrum smithii*) and green needlegrass (*Nassella viridula*) in 2017. Values reflect percent relative canopy cover plus or minus the standard error of mean.

grazing was assigned to three of the 12 pastures, with three others assigned as idle pastures not to be grazed. The six pastures remaining were assigned to continue their original seasonlong or early intensive grazing treatments. Livestock are not rotated among pastures, and each pasture receives the same treatment each year.

SL-grazed pastures receive moderate stocking rates and are grazed mid-May through August. EI pastures receive similar stocking rates but are grazed at triple stock density for the first 1.2 months of the grazing season and then the cattle are removed. PB-grazed pastures receive the same stocking rate and grazing duration as SL pastures, but a patch-burn treatment is incorporated.

Beginning in 2014, a different fourth of each pasture has been burned annually when vegetation is dormant. Table 1 details the grazing start and end dates, average head per pasture, number of days grazed and stocking rate for each grazing treatment since 2011.

Prescribed burn on a patch-burn grazed pasture.

Vegetation response data have been collected July through early August each year since 2014. Due to differences in sampling procedures, we are able to report findings only from 2017 at this time.

We obtained information on plant community composition by sampling the relative canopy cover of all plant species, litter, bare ground, rock and fecal pat in 20 0.5- by 0.5-meter frames along 40-meter transects at four locations within each pasture. Canopy cover was estimated utilizing a modified Daubenmire cover class (1 = trace to 1 percent, 2 = 1 to 2 percent, 3 = 2 to 5 percent, 4 = 5 to 10 percent, 5 = 10 to 20 percent, etc.) and midpoint values were used for analysis (Daubenmire, 1959).

Species richness, evenness, and Simpson’s and Shannon’s diversity indices were determined for each pasture using ANOVA (analysis of variance) procedures. Mean species composition was analyzed with nonmetric multidimensional scaling (NMS) in PC-ORD 6.22 after compiling data from the 20 quadrats in each transect and averaging across the four transects for each pasture.

Annual forage production is determined for each pasture by clipping standing forage at peak production (mid to late July) from the interior of three caged grazing enclosures at four locations within each pasture. Harvested samples were oven-dried to constant weight and averaged across the three cages, four locations and three pastures for each treatment for analysis with ANOVA.

2017 Results

Relative Canopy Cover

We recorded a total of 89 plant species across the study’s 12 pastures in 2017. Average relative cover of Kentucky bluegrass was higher in idle (46.8 ± 3.2 percent) and SL-grazed pastures (47.8 ± 3.9 percent) than EI (29.8 ± 0.7 percent) and PB (27.0 ± 2.3 percent). Table 2 details additional relative canopy cover information for litter (standing and basal litter combined) and bare ground, along with native and invasive species of interest.

Richness, evenness and diversity analyses for 2017 are detailed in Figure 1. Plant species richness averages the highest for patch-burn (S = 58, SE = 1) and early intensive (S = 56.67, SE = 2.73) grazed pastures, while richness was similar for seasonlong (S = 48.67, SE = 6.67) grazed and idle (S = 49, SE = 3) pastures. Average evenness and diversity indices were the highest for patch-burn grazed pastures followed by early intensive, seasonlong and idle treatments, respectively (see Figure 1).

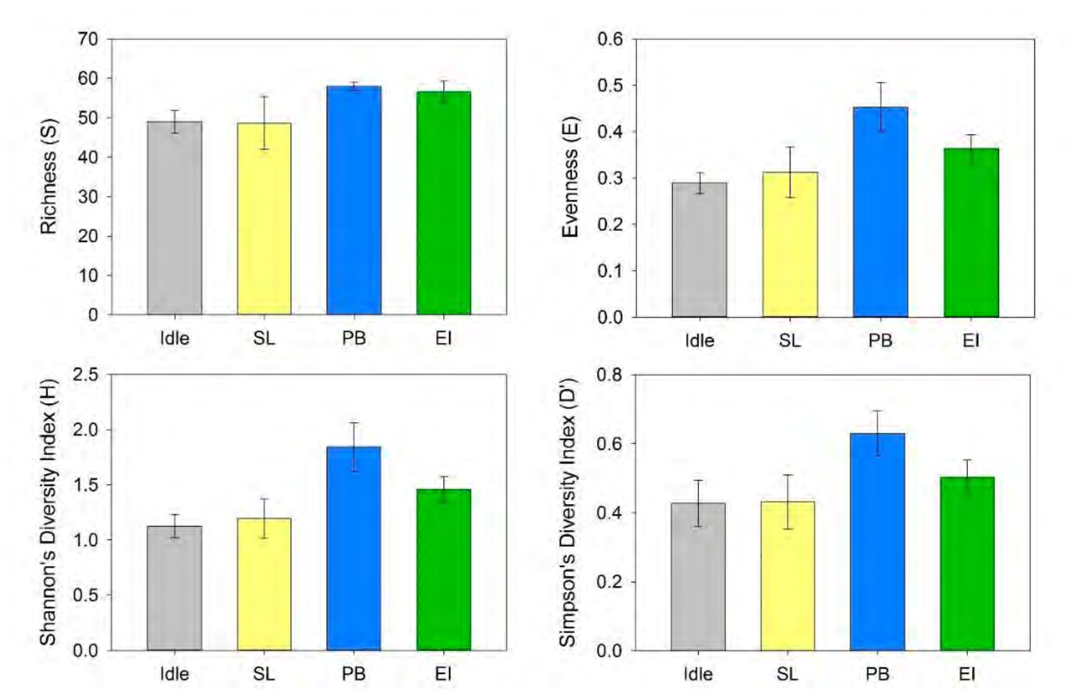


Figure 1. Richness, evenness, Shannon's Diversity and Simpson's Diversity indices on idle, seasonlong (SL), patch-burn (PB) and early intensive (EI) pastures from 2017. Error bars represent standard error of mean.

annual forage production because it provides all plants with more access to light and space resources. We expect that early grazing may control Kentucky bluegrass proliferation by disturbing it during its early active growth. Further analysis of past years' data will reveal if these treatments have reduced or controlled Kentucky bluegrass dominance throughout the study.

This year also was marked by higher average biomass production in EI-grazed pastures than in PB, SL and ID, respectively. Although increased forage production is attractive for livestock, this measure does not account for differences in early and late-season production.

Furthermore, the EI treatment was marked by high western snowberry and litter cover, which are nondesirables that typically don't contribute to forage available for livestock. PB-grazed pastures, on the other hand, had slightly lower average annual forage production but also had the lowest average relative cover of litter and lower western snowberry cover, compared with EI-grazed and ID pastures.

While patch-burn and early intensive grazing management may be effective strategies to control Kentucky bluegrass dominance, livestock performance should be considered. Kentucky bluegrass production can vary widely, and experiences reduced nutritive value and annual production during dry or drought years (Hockensmith et al., 1997; Toledo et al., 2014).

The NMS analysis on 2017 data indicate that the species composition of SL and idle treatments were similar to one another and different from EI and PB, which also were similar to one another (see Figure 2, next page). While Kentucky bluegrass was present at all sites in 2017, it was the most highly correlated with idle and SL treatments with values of 0.98 and 0.99, respectively. Native western wheatgrass and green needlegrass were the species most highly correlated with PB and EI treatments.

Annual Forage Production
Figure 3 details the results of annual forage production sampling for SL, PB, EI and idle pastures in 2017 ($p \leq 0.05$). The idle treatment (control) produced the lowest average standing biomass among all grazing treatments, while the early intensive treatment produced the highest and most variable average standing biomass among pastures. Biomass production was similar for seasonlong and patch-burn treatments.

Discussion

At this stage of the project, Kentucky bluegrass remains dominant in each pasture. However, PB and EI grazing management appear to control its dominance in the plant community and promote the diversity of other grasses and forbs.

As cattle select for recently burned areas of high nutritive value (Fuhlendorf and Engle, 2004), we expect that increased grazing pressure, coupled with the removal of senescent vegetation, mostly Kentucky bluegrass thatch, is controlling the proliferation of Kentucky bluegrass in PB pastures.
Removal of senescent vegetation also may permit increased

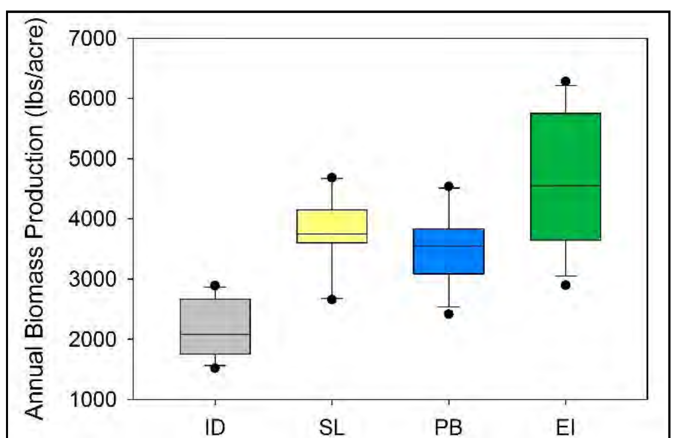
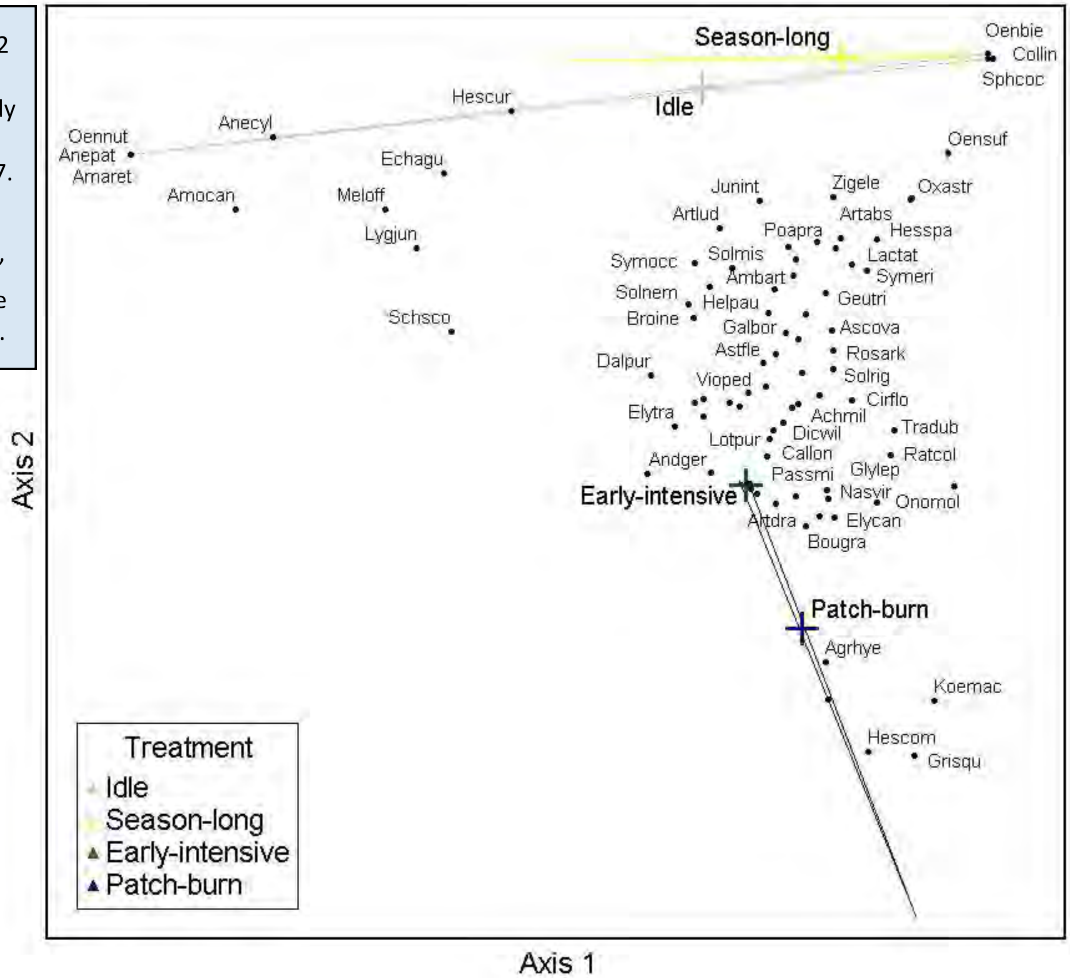


Figure 3. Annual biomass production (pounds/acre) for idle (ID), seasonlong (SL), patch-burn (PB) and early intensive (EI) pastures in 2017.

Figure 2. NMS ordination of axes 1 and 2 with regard to treatment, pastures and mean vegetation composition from study sites at the Central Grasslands Research Extension Center, Streeter, N.D., in 2017. Colored polygons represent treatments while individual points represent plant species; refer to table below for species' code names. Crosshairs indicate average species composition for each treatment.



Code	Scientific Name	Common Name
Achmil	*Achillea millefolium*	western yarrow
Amaret	*Amaranthus retroflexus*	rough pigweed
Ambart	*Ambrosia artemisiifolia*	common ragweed
Amocan	*Amorpha canescens*	leadplant
Andger	*Andropogon gerardii*	big bluestem
Anecyl	*Anemone cylindrica*	candle anemone
Anepat	*Anemone patens*	pasque flower
Arghye	*Agrostis hyemalis*	tickle grass
Artabs	*Artemisia absinthium*	wormwood
Artdra	*Artemisia dracunculus*	green sagewort
Artlud	*Artemisia ludoviciana*	cudweed sagewort
Ascova	*Asclepias ovalifolia*	ovalleaf milkweed
Astfle	*Astragalus flexuosus*	slender milk-vetch
Bougra	*Bouteloua gracilis*	blue grama
Broine	*Bromus inermis*	smooth brome
Callon	*Calamovilfa longifolia*	prairie sandreed
Cirflo	*Cirsium flodmanii*	Flodman's thistle
Collin	*Collomia linearis*	collomia
Dalpur	*Dalea purpurea*	purple prairie-clover
Dicwil	*Dichanthelium wilcoxianum*	Wilcox's panic grass
Elycan	*Elymus caninus*	bearded wheatgrass
Elytra	*Elymus trachycaulus*	slender wheatgrass
Galbor	*Galium boreale*	northern bedstraw
Geutri	*Geum triflorum*	prairie smoke
Glylep	*Glycyrrhiza lepidota*	wild licorice
Grisqu	*Grindelia squarrosa*	curly-cup gumweed
Helpau	*Helianthus pauciflorus*	stiff sunflower
Hescom	*Hesperostipa comata*	needle-and-thread

Code	Scientific Name	Common Name
Hescur	*Hesperostipa curtiseta*	western porcupine grass
Hesspa	*Hesperostipa spartea*	porcupine-grass
Junint	*Juncus interior*	inland rush
Koemac	*Koeleria macrantha*	prairie Junegrass
Lactat	*Lactuca tatarica*	blue lettuce
Lotpur	*Lotus purshianus*	deer vetch
Lygjun	*Lygodesmia juncea*	skeletonweed
Meloff	*Melilotus officinalis*	yellow sweetclover
Nasvir	*Nassella viridula*	green needlegrass
Oenbie	*Oenothera biennis*	common evening primrose
Oennut	*Oenothera nuttallii*	Nuttall's evening primrose
Oensuf	*Oenothera suffrutescens*	scarlet gaura
Onomol	*Onosmodium molle*	false gromwell
Oxastr	*Oxalis stricta*	yellow wood sorrel
Passmi	*Pascopyrum smithii*	western wheatgrass
Poapra	*Poa pratensis*	Kentucky bluegrass
Ratcol	*Ratibida columnifera*	prairie coneflower
Rosark	*Rosa arkansana*	prairie rose
Schsco	*Schizachyrium scoparium*	little bluestem
Solmis	*Solidago mollis*	soft goldenrod
Solnem	*Solidago nemoralis*	gray goldenrod
Solrig	*Solidago rigida*	stiff goldenrod
Sphcoc	*Sphaeralcea coccinea*	scarlet globe mallow
Symeri	*Symphyotrichum ericoides*	white aster, heath aster
Symocc	*Symphoricarpos occidentalis*	western snowberry, buckbrush
Tradub	*Tragopogon dubius*	goat's beard
Vioped	*Viola pedatifida*	larkspur violet
Zigele	*Zigadenus elegans*	death camas, white camas

Although burning initially removes all standing forage, post-fire conditions typically provide increased forage quality because most native species are fire-tolerant and have nutritious regrowth. For example, research has shown that little bluestem (*Schizachyrium scoparium*), a native warm-season forage species, does not experience adverse effects from burning (Limb et al., 2011a).

Furthermore, research indicates that cattle performance responds the same under PB grazing management as traditional SL stocking (Limb et al. 2011b). Consequently, further research is required to evaluate cattle performance differences among SL, PB and EI grazing management in Kentucky bluegrass-invaded rangelands.

Further analysis of all study years combined will reveal overall responses of vegetation composition and annual production to each grazing treatment. Although we expect Kentucky bluegrass to persist as the dominant plant species, PB and EI grazing management may control its proliferation enough to promote the abundance and diversity of other grasses and forbs. Without active land management, the invasion of Kentucky bluegrass in the mixed-grass prairie likely will result in homogeneous plant communities with impaired forage quality and production across the landscape.

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Cattle on a recently burned patch.

Spatial Heterogeneity in Forage Quality, Quantity and Vegetation Structure Determines Where Cattle Graze in Patch-burned Rangeland

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Heterogeneity in forage and vegetation structure can enhance rangeland quality for livestock and wildlife. We seek to increase heterogeneity by applying a rotational patch burn-grazing treatment to pastures with seasonlong grazing. Low vegetation structure and high forage quality in recently burned patches should attract livestock and maintain structural contrast during the season. We present preliminary data from our first year of treatment comparing forage and vegetation structure across recently burned and unburned patches.

Introduction

Disturbance-driven heterogeneity is important to maintain rangelands that evolved with disturbances such as fire and grazing (Bowman et al., 2009; Kay, 1998). Historically, rangeland management in the Great Plains has minimized disturbance or made it spatially even.

By combining seasonlong grazing with a yearly rotation of spatially discrete fires, patch-burn grazing creates contrast in forage quality, forage quantity and vegetation structure between recently burned and unburned patches within a pasture (Fuhlendorf et al., 2017).

Grazers are often more attracted to recently burned patches than to unburned patches (Archibald et al., 2005; Fuhlendorf and Engle, 2004). This "magnet effect" comes from greater protein content and lower fiber in recently burned patches, creating higher forage quality despite lower plant biomass, compared with unburned patches (Fuhlendorf et al., 2017; Sensenig et al., 2010).

Preference for the burned patch allows other patches to accumulate biomass and increase vegetation height and density, creating contrasting patches throughout the pasture (Powell et al., 2018). The contrasting vegetation structure created by patch burning enhances habitat diversity for grassland-dependent wildlife (Hovick et al., 2012).

Objectives

Our objectives are to determine the effectiveness of patch burn-grazing in northern mixed grass prairie and to monitor forage quality, forage biomass, grazer occupancy and vegetation structure during a four-year patch burn rotation, which began in spring 2017. We predict that grazer occupancy will be higher in the recently burned patches, even though they might have lower available forage; forage in recently burned patches will have higher protein and lower fiber content; recently burned patches will have lower vegetation structure than unburned patches; but contrast in vegetation structure and forage quality will decrease with time.

Procedures

We sampled eight burned pastures at the CGREC (see Figure 1). Four pastures received an entire 40-acre patch burn in the spring, while in the other four pastures, the 40 acres were split in half, with one half burned in the spring and the other half in the summer.

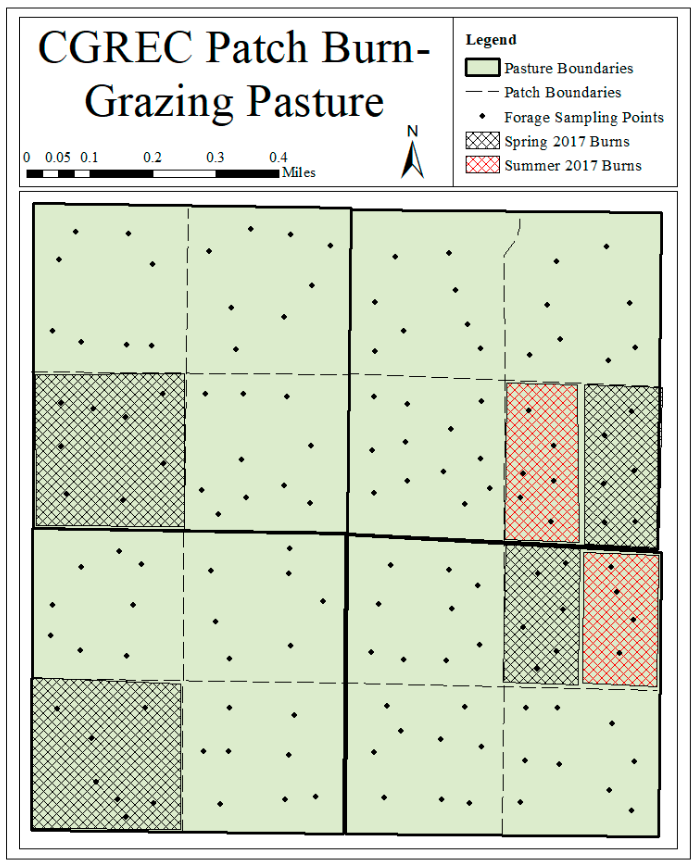


Figure 1. Map depicting one pasture in the patch-burn grazing study at CGREC in 2017.

Cow-calf pairs grazed at a stocking rate to achieve an average 50 percent degree of disappearance from mid-May to mid-October and a carrying capacity of 0.85 to 0.94 animal unit months (AUMs)/acre (variability was due to difference in ecological site composition).

Forage Quantity and Quality
We measured forage production as total above-ground plant biomass clipped from 25-centimeter (cm) by 25-cm quadrats at predetermined points along transects in each patch per pasture once per month into the grazing season. At each forage sampling point, we counted fecal pats within 5 meters (m) of the point to determine grazer usage of each patch.

All forage samples were dried for 48 hours in a 150° C drying oven, weighed and ground in a Wiley mill through a 1-millimeter (mm) screen. We used near infrared spectroscopy (NIR) to determine crude protein and fiber content based on calibrations for hay-alfalfa because we still are developing rangeland-specific calibrations for NIR. Here we use crude protein as our measure of forage quality.

Vegetation Structure
Laid out to quantify grassland bird habitat, transects for vegetation structure were placed 15 m off either side of existing bird transects in each pasture. Measurements were taken every 15 m, for 20 observations per transect.

At each point, percentages of plant functional and structural groups were estimated visually with a canopy cover index. Groups included Kentucky bluegrass, smooth brome, native and introduced cool-season grasses, native and introduced warm-season grasses, native and introduced legumes, native and introduced forbs, native and introduced woody plants, bare ground and standing dead. We also measured visual obstruction using a graduated Robel pole (Robel, 1970) at each measurement point to estimate vegetation density.

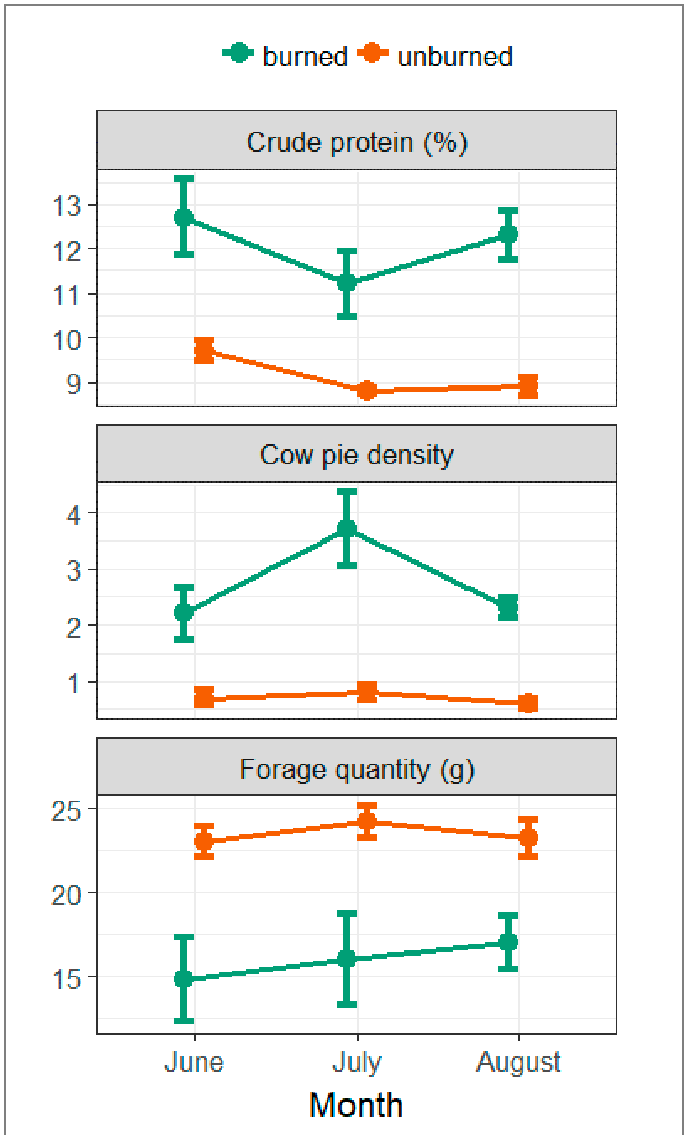


Figure 2. Graphs comparing average quality (% crude protein per sample), grazer preference (fecal pats per 100 m^2 circle around each sample point) and quantity (grams per sample) for burned vs. unburned patches.

Results
Forage biomass was predictably lower in recently burned patches than in unburned patches. As the growing season progressed, biomass in the burned patches steadily increased, while biomass in the unburned patches was relatively stable (Figure 2). Crude protein percentages were much higher in recently burned patches and also were higher in low-biomass samples (Figure 3).

Average counts of fecal pats were comparatively high in burned patches and very low in unburned patches, indicating higher livestock usage of recent burns (Figure 2). This attraction was less pronounced in August, toward the end of the growing season, likely because forage quantity was decreasing.

We also found a difference in vegetation structure, with burned patches having lower structure (shorter plants) and unburned patches having slightly higher structure (taller plants).

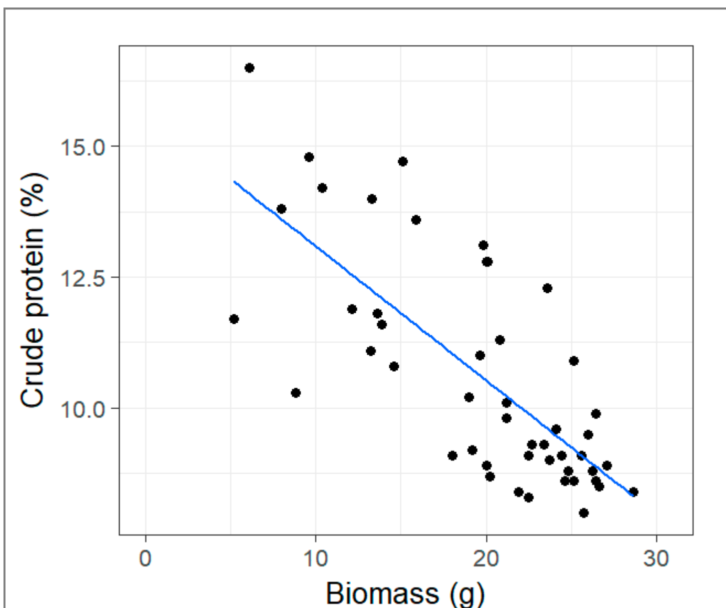


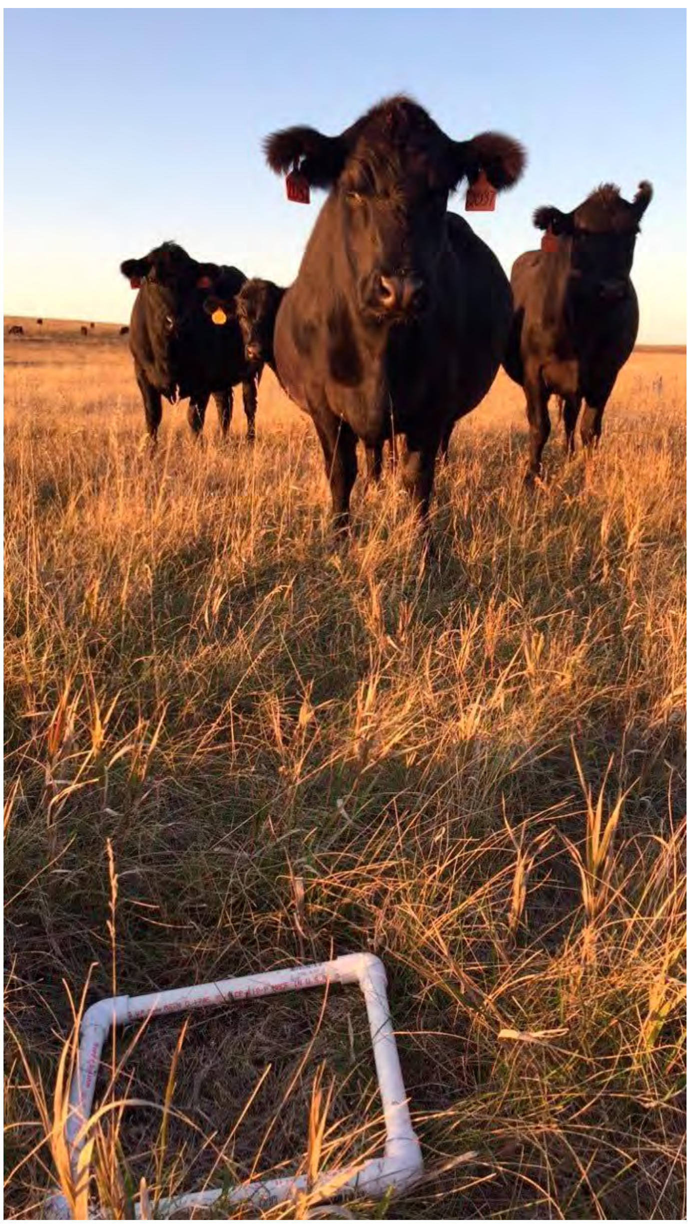
Figure 3. Graph depicting the inverse relationship between biomass and crude protein content over the grazing season.

Discussion

In preliminary analysis of livestock usage data, livestock show a preference for recently burned patches vs. unburned patches, despite those patches having lower available forage. This is likely due to the increased forage quality in the burned patches.

We expect to continue seeing this preference exhibited as we analyze other forage quality parameters such as fiber and lignin content because this attraction has been documented in similar studies (Powell et al., 2018; Sensenig et al., 2010). While producers might be concerned that this attraction will diminish as the time since fire increases, our data indicate that is not the case. Cattle remain attracted to recently burned patches and continue to avoid unburned patches (Figure 2).

As our study progresses and we rotate burns through the remaining patches, we expect to see continued grazer attraction to the most recently burned patch in each pasture, and greater landscape-level contrast in forage quality, forage quantity and structure driven by this gradient in time-since-fire.



We expect this gradient will create a patchy mosaic of available forage and habitat that will change as the burn patches shift. Although patches are intensively grazed for a season, the subsequent seasons of rest ensure the long-term sustainability of the forage base.

Photos by Micayla Lakey, NDSU

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Manipulating Western Snowberry With Prescribed Burning to Promote Livestock Grazing

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Introduction

Woody encroachment threatens the structure, function, stability and productivity of rangelands by altering light quality (Peltzer and Konchy, 2001) and available nutrients and water to other herbaceous plant species. This causes variations in vegetation composition, and decreased plant species diversity, richness and overall forage productivity (Briggs et al., 2005; Limb et al., 2014; Van Auken, 2009).

Expansion of woody species is caused by changes in climate, increased atmospheric CO_2 (Archer, 1995), poor grazing management and lack of fire (Briggs et al., 2005). Absence of fire in the system has been the major cause of western snowberry or buckbrush (*Symphoricarpos occidentalis* Hook.) expansion in the Northern Great Plains.

Western snowberry is a native cool-season shrub with an early growing season and resprouting growth characteristics. This means that it can regrow easily following control methods such as mowing and fire. The use of herbicide is effective, but it can be cost-prohibitive and detrimental to other vegetation.

Grazing can be effective for herbaceous plant management, but it often is ineffective for woody plant control because low palatability reduces browsing (Briggs et al., 2002; Weber and Jeltsch, 2000). Manipulating forage quality characteristics can be an effective mechanism to encourage large grazing animals to consume undesirable species (Cummings et al., 2007).

Western snowberry regrowth that has been browsed, and one plant reaching flowering stage.

Forage quality characteristics include forage palatability, digestibility, nutrient content and intake, and are influenced by climate, season, plant characteristics, structure, maturity and disturbance (Renecker and Hudson, 1988). The structural and chemical makeup of a plant changes as it grows, with lignin, cellulose and fiber content in the plant cell increasing, while nutritive values and palatability decrease (Schindler et al., 2004).

Prescribed burning has been used to remove mature plant material and promote immature plant growth (Cook et al., 1994; Raynor et al., 2015; Anderson et al., 2007). Further, patch-burn systems allow for portions of a pasture to be burned, resulting in concentrated grazing in burned areas and changing the grazing selections from specific plant species to selection of the patch as a whole (Cummings et al., 2007). Limited evidence suggests that prescribed burning could promote the consumption of woody species regrowth by livestock (Debyle, 1989; Cook et al., 1994; Schindler et al., 2004).

The objectives of this study were to: 1) estimate the percentage of western snowberry that was browsed by cattle under early intensive, seasonlong and patch-burn grazing management and 2) create a timeline showing nutrient content of regrowth following a spring prescribed burn, mature shrubs one year post-burn and unburned mature shrubs.

Based on cattle grazing preferences and the effect of burning on plant structure and nutrient content, we hypothesized that cattle will graze western snowberry regrowth more readily following prescribed fire, compared with mature unburned western snowberry, due to an initial increase in palatability and nutritive content following the prescribed burn.

Procedures

Grazing treatments included seasonlong grazing, patch burn with seasonlong grazing, early intensive grazing and idle management (no grazing or burning), each replicated three times in 12 16-hectare (ha) (40-acre) pastures. Seasonlong and patch-burn pastures were stocked at 3.04 animal unit months (AUMs)/hectare (1.23 AUMs/acre) and grazed May 1 to Sept. 5.

Patch burning began in 2014 on a four-year burn rotation in which one-fourth of each pasture was burned annually during the dormant season. Early intensive pastures were grazed at the same stocking rate but double the stocking density starting May 1, and cattle were removed after 1.2 months, approximately mid-June. This grazing management achieves similar grazing pressure as seasonlong and patch-burn grazing pastures by grazing more cattle for a shorter period of time.

Percent Browsed

To estimate western snowberry browsed per grazing treatment, we established four 100-meter (m) transects in each pasture and recorded the number of individual stems and browsed stems within a 1- by 1-m quadrat at 5-m intervals.

Nutrient content

Western snowberry samples taken for nutritional and digestibility analysis were clipped from idle pastures to represent unburned western snowberry, from patch-burn pastures the first growing season following burns and one-year post-burn at weekly intervals from mid-May to mid-September. All samples were clipped to ground level, separated into old and new growth, and weighed wet and oven-dried.

The forage quality categories determined were: percent dry matter (DM), crude protein (CP), acid detergent lignin (ADL), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash, calcium (Ca), phosphorus (P), in-vitro dry matter digestibility (IVDMD) and in-vitro organic matter digestibility (IVOMD).

Crude protein content represents the total nitrogen (N) in the feedstuff because CP is equal to N times 6.25 percent. Forage nutritive content of all samples was analyzed by the NDSU Animal Science Nutrition Lab.

Results

The percentage of western snowberry browsed (Figure 1) increased following the spring prescribed fire. Browsing occurred more within the patch-burn graze treatment (25.70 percent ± 6.71) than seasonlong (5.59 percent ± 1.54) and early intensive (8.32 percent ± 1.60) grazing treatments. The percentage browsed was not different between the seasonlong and early intensive grazing treatments. No browsing was detected within the idle treatment.

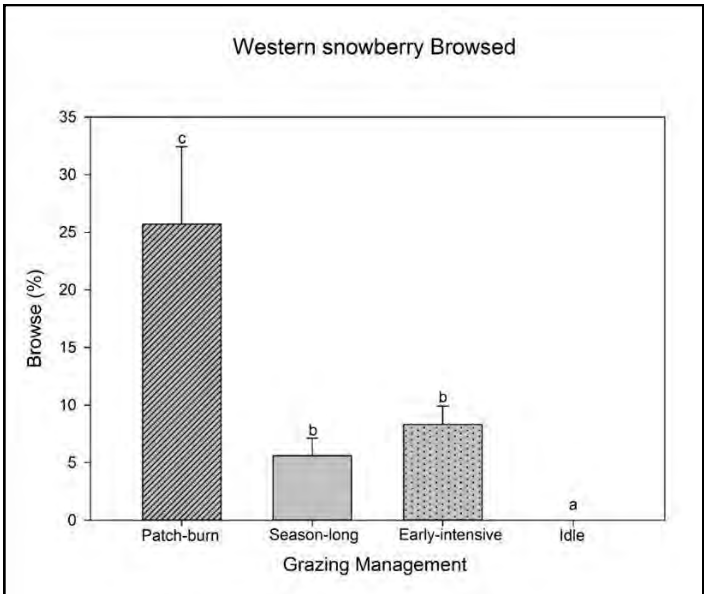

Figure 1. Percentage of western snowberry stems browsed within patch-burn and seasonlong grazing treatments and idle control at the CGREC in 2017.

The fibrous content (ADF and NDF) and acid detergent lignin (ADL) of western snowberry were different between old and new growth for the duration of the sampling period (Figure 2). The ADF content (Figure 2A) of 2017 post-burn regrowth (12.58 percent ± 1.86) and one-year post-burn new growth (15.24 percent ± 0.27) was lower than in nonburn new growth (18.22 percent ± 0.32) at three weeks post-burn.

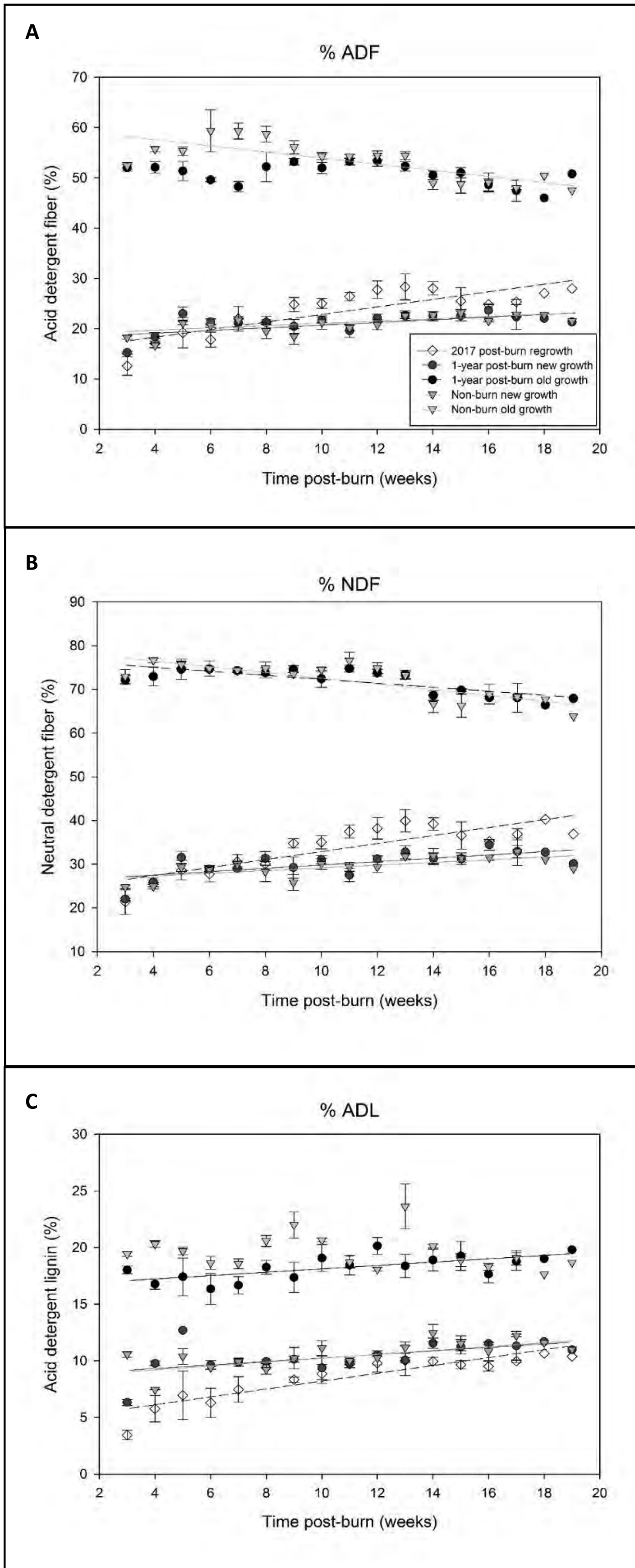

Figure 2. Acid detergent fiber, neutral detergent fiber and acid detergent lignin content of western snowberry for each treatment, with the sampling period starting once regrowth began following the 2017 spring prescribed burn at the CGREC. Lines indicate a significant regression.

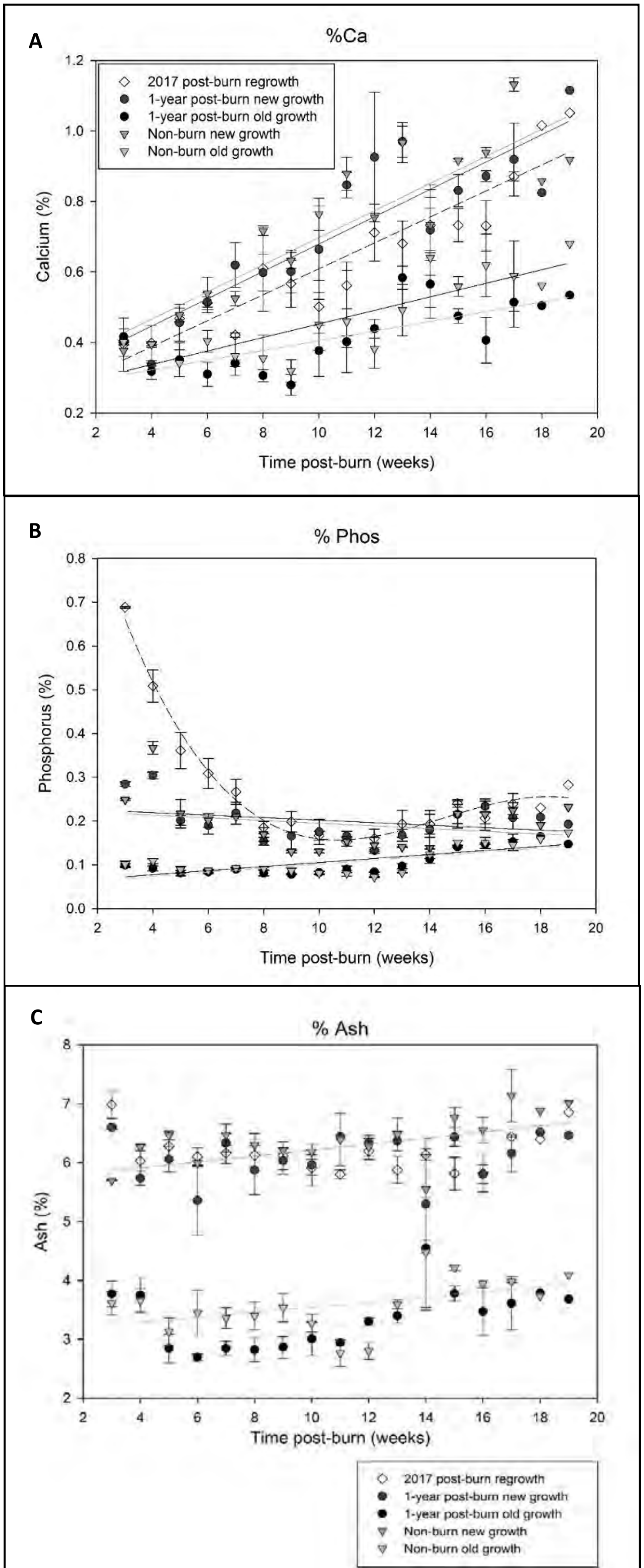

Figure 3. Calcium, phosphorus and ash content of western snowberry for each treatment, with the sampling period starting once regrowth began following the 2017 spring prescribed burn at the CGREC. Lines indicate a significant regression.

The NDF content (Figure 2B) of 2017 post-burn regrowth was higher than for the one-year post-burn and nonburn new growth at 11 through 14 weeks post-burn. The ADL content (Figure 2C) of 2017 post-burn regrowth (3.44 percent ± 0.44) was lower than for the one-year post-burn regrowth (6.32 percent ± 0.28) and nonburn new growth (10.56 percent ± 0.24) at three weeks post-burn.

The elements calcium (Ca) and phosphorus (P) changed inversely of each other through time (Figure 3). Calcium content of western snowberry increased within all growth types and treatments (Figure 3A). We found no consistent treatment differences, indicating a seasonal influence.

The P content (Figure 3B) of western snowberry 2017 post-burn regrowth was higher than it was one year post-burn and nonburn three through six weeks post-burn. The micro-mineral content (ash) of western snowberry 2017 post-burn regrowth (6.99 percent ± 0.23) and one-year post-burn new growth (6.44 percent ± 0.02) was higher than for nonburn new growth (5.74 percent ± 0.004) (Figure 3C).

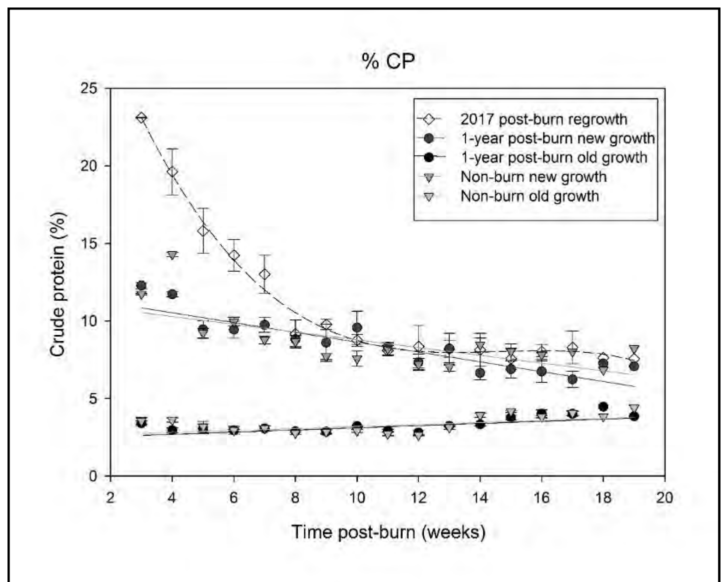

Figure 4. Crude protein of western snowberry for each treatment, with the sampling period starting once regrowth began following the 2017 spring prescribed burn at the CGREC. Lines indicate a significant regression.

The CP content of western snowberry new growth was higher than in old growth (Figure 4). The 2017 post-burn regrowth CP content was higher than for one-year post-burn and nonburn new growth from three through seven weeks post-burn.

The IVOMD and IVDMD of western snowberry (Figure 5; next page) was different between old and new growth for the duration of the sampling period. The IVOMD of 2017 post-burn regrowth (74.89 percent ± 1.55) (Figure 5A), one-year post-burn new growth (71.50 percent ± 0.10) and nonburn new growth (66.84 percent ± 0.22) all were different at three weeks post-burn.

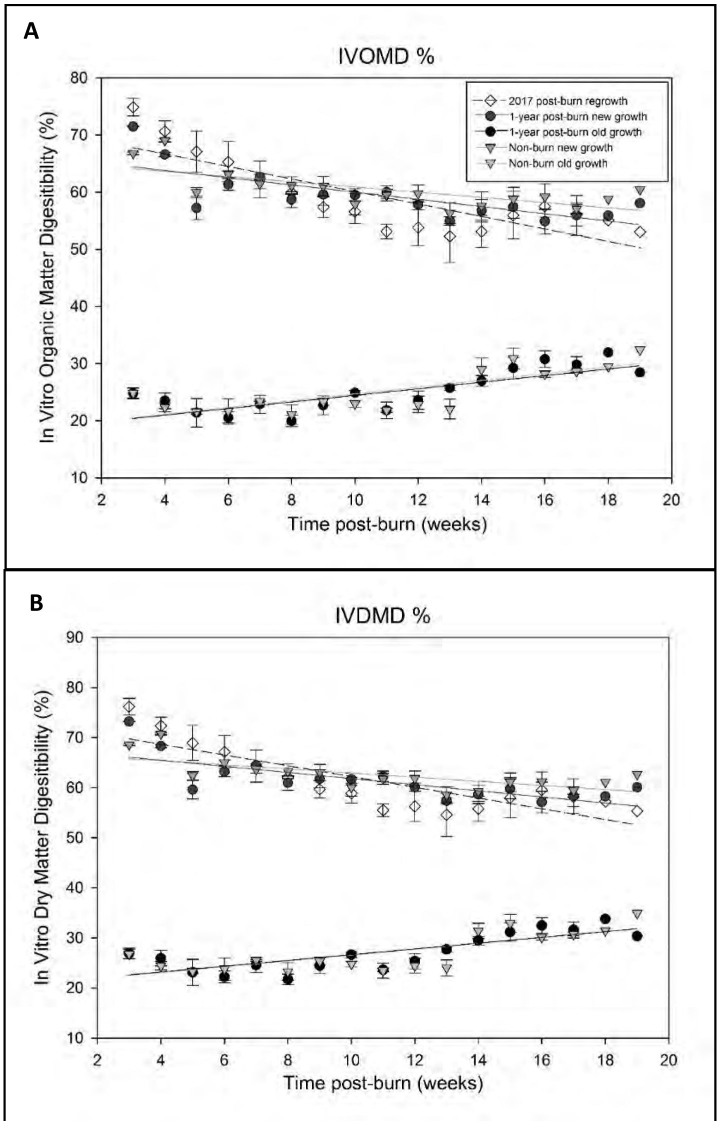

Figure 5. In vitro organic and dry-matter digestibility of western snowberry for each treatment, with the sampling period starting once regrowth began following the 2017 spring prescribed burn at the CGREC. Lines indicate a significant regression.

Discussion

Woody encroachment in grassland ecosystems results in alterations of rangeland plant community composition and productivity (Pelton, 1953; Archer, 1989). In a Northern Great Plains ecosystem invaded by western snowberry, we compared the percentage of shrub browsed by livestock under early intensive grazed, seasonlong grazed, patch-burn grazed and idle managements. Our study revealed that patch-burn grazing increased western snowberry browse three and five times greater, compared with browse in early intensive and seasonlong grazed pastures, respectively.

Fire removes mature plant material and debris, and effectively resets the growth cycle of vegetation, allowing new growth that is higher in palatability, nutrients and digestibility (Plumb and Dodd, 1993; Seastedt and Knapp, 1993; Cook et al., 1994; Anderson et al., 2007; Mbatha and Ward, 2010; Raynor et al., 2015). Our results and other research (Schindler et al., 2004; Saura-Mas and Lloret, 2009; Hejcman et al., 2016) suggest that a combination of changes in nutrient composition and concentrated grazing in the burned area (Cummings et al., 2007) contributed to the increased percentage of western snowberry browsed within the patch-burn graze management.

We found that as the shrubs matured, fibrous content increased and digestibility, crude protein and internal ash content decreased, regardless of treatment. Western snowberry new growth, including 2017 post-burn regrowth, was on average 30 and 41 percentage points lower in ADF and NDF content than old growth. This is consistent with traditional herbaceous forages; when ADF and NDF concentrations rise, the proportion of digestible plant tissue is reduced (Cook et al., 1994; Dufek et al., 2014; Raynor et al., 2015).

Crude protein of 2017 post-burn regrowth was 23 percent at three weeks post-burn and declined to 9 percent by eight weeks post-burn, at which point it was no different than for one-year post-burn and nonburn new growth, and the rate of decrease slowed. This same pattern of high crude protein with a rapid decline and leveling out approximately mid-way through the growing season has been seen for herbaceous vegetation as whole samples, and for other individual desirable and undesirable species (Defek et al., 2014; McGranahan et al., 2014).

The internal ash content of 2017 post-burn regrowth was 7.0 percent at four weeks post-burn; this is the average content of legume-grass forages (Platače and Adamovičs, 2014), and only slightly decreased with time post-burn. Internal ash is the total mineral content within a forage that would be present in hay or silage; it can be essential for meeting the dietary needs of livestock without supplementation, but at high levels, it may decrease feed intake.

Calcium and phosphorus, macro-minerals, change inversely of each other. Calcium increased, similarly to what has been documented for herbaceous forage species (Sinclair et al., 2006). Phosphorus content was highest in the 2017 post-burn regrowth until seven weeks post-burn, at which point it was not different than in other treatment new growth, closely following the same trend as crude protein.

Haley Johnson, NDSU

Cow-calf pairs grazing in a burned patch.

Western snowberry regrowth

Four weeks post-burn

About ten weeks post-burn

One year post-burn

Photos by Haley Johnson, NDSU

Prescribed burning altered the growth cycle of western snowberry, ultimately making it utilizable as a forage for livestock consumption. It can be inferred that post-burn regrowth and new growth had a greater chance of being consumed instead of old growth due to higher palatability and digestibility.

Patch-burning altered the selectivity of cattle grazing preferences from plant-specific to patch-specific (Cummings et al., 2007). Increased crude protein, coupled with higher digestibility and palatability, following patch burning made western snowberry a desirable consumable within the patch; therefore, it was a contributor to grazing cattle diets.

Following a disturbance, livestock return to graze the area frequently due to higher nutrient content being prolonged during the growing season (Allred et al., 2011). Disturbances such as prescribed burning can be used to manipulate the structure of undesirable vegetation, promoting consumption by livestock and potentially aiding in control of the undesired species (Smart et al., 2007; Dufek et al., 2014).

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CGREC office

CGREC office and livestock unit

Butterfly Community Response to Cattle Management Strategies

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We are assessing the influence of three cattle management regimes on butterfly species richness and abundance. Our three regimes are seasonlong grazing without fire, meant to mirror traditional management practices, and two forms of patch-burn grazing, which are meant to mimic the natural heterogeneity in vegetation structure in grasslands. One of our patch-burn grazing treatments has a single season of fire, and the other has two seasons of fire. Here we present results from year one of a multiyear study.

Introduction

Pollinators provide valuable ecosystem services worldwide. Native pollinators provide up to $3.07 billion in the U.S. in agricultural pollination (Losey and Vaughn, 2006), in addition to preserving biodiversity through native plant pollination (Allen-Wardell et al., 1998).

However, pollinator populations are in decline worldwide (Potts et al., 2010). The drivers of this decline include climate change (Peterson et al., 2004), pesticide-induced mortality (Rortais et al., 2005) and habitat degradation through mismanagement (Potts et al., 2010).

To combat these declines, creating land management plans that account for native pollinators is important. In the Great Plains, such a plan should reinstitute the natural disturbances of fire and grazing, alongside which native species evolved (Anderson, 2006).

When combined in a patch-burn grazing framework, fire and grazing create a "shifting mosaic" of patches, where grazers utilize the most nutritious forage in the most recently burned patch (Allred et al., 2011; Fuhlendorf and Engle, 2001). This allows for a variety of vegetation structure, including forb diversity, deep litter and bare ground throughout the patches (Fuhlendorf and Engle, 2004).

Different pollinator species have different habitat requirements, so this variety of vegetation could prove beneficial for many native pollinators throughout their life cycles.

Previous research into the influence of patch-burn grazing on pollinators has focused on tallgrass prairie in the southern Great Plains (Debinski et al., 2011; Moranz et al., 2012) and not the mixed-grass prairie in the northern Great Plains. Additionally, past research has included only one season of fire, and our work will include dormant and growing-season prescribed burns to determine how this influences the butterfly community.

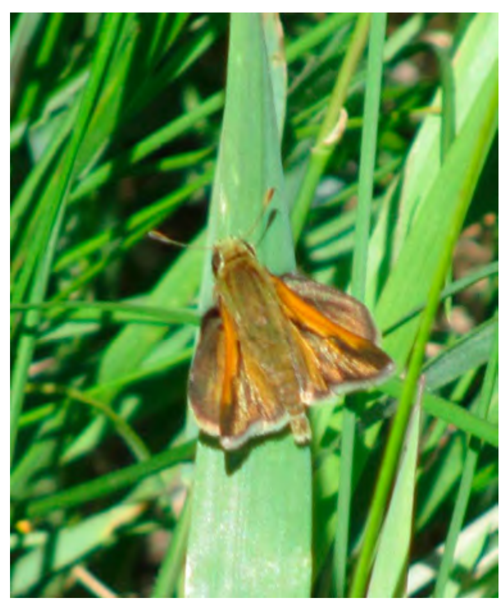
Further, studying the butterfly response to management practices could provide important insight into other native insects because butterflies sometimes are used as indicator species (Brereton et al., 2010; New. 1997).

As such, our main objective for this study is to assess the butterfly community response to three treatment types. Our three treatments are patch-burn grazing with one season of fire, patch-burn grazing with two seasons of fire and seasonlong grazing.

Photos by Brooke Karasch, NDSU

Aphrodite fritillary (*Speyeria aphrodite*)

Gorgone checkerspot (*Chylosyne gorgone*)



Long dash skipper (*Polites mystic*)

Procedures

Our research takes place in the Missouri Coteau ecoregion. The region is typified by mixed-grass prairie and a semiarid climate. Specifically, we are using the Central Grasslands Research Extension Center in central North Dakota, which is managed by North Dakota State University.

Each of our three treatment types has four replicates for a total of 12 pastures, each 160 acres. The patch-burn grazing treatments with one season of fire have a 40-acre prescribed burn applied each spring. The patch-burn grazing treatments with two seasons of fire have a 20-acre patch burned each spring, and an adjacent 20-acre patch burned in late summer or early fall. The spring prescribed burns are dormant-season burns, and the late summer or early fall burns are growing-season burns.

All pastures are moderately stocked with mixed-breed cow-calf pairs from mid-May to mid-September for 30 percent forage utilization. Cattle in each treatment may freely roam within their treatment but do not have access to other treatments or replicates.

Each pasture has eight permanent 150-meter transects for conducting butterfly surveys, for a total of 96 transects. We conducted line-transect distance sampling using these transects, wherein we walked each transect and recorded the species and distance perpendicular from the line for each adult butterfly seen.

Observers walked each transect three times throughout the butterfly flight season to capture the most accurate data across the season. In 2017, surveys took place from June 5 to Aug. 9. We then pooled data from all three sampling periods and used this to obtain density estimates.

We also are collecting floral resource data along the same transects. This involves identifying and recording all forbs and legumes in flower within 1 meter of the transect line during butterfly surveys.

Statistics

Butterfly species richness was calculated as the total number of species present in each treatment. Total abundance was calculated as the average number of detections per transect within each treatment.

We calculated floral species richness and abundance in the same way. We also used the statistical program Distance 6.2, release 1 (Thomas et al., 2010) to calculate densities for all butterfly species detected a minimum of 60 times.

Results

In the 2017 field season, we recorded a total of 2,031 butterflies, representing 39 species, across the three cattle management treatments (Table 1). We also recorded 60,019 total flowering plants of 92 species.

Butterfly Species Richness

Butterfly species richness was highest in the patch-burn grazing with two seasons of fire (33 species), followed by the patch-burn grazing with one season of fire (30 species) and, finally, the seasonlong grazing treatment (22 species). Species composition varied among treatments, and a total of 39 species were observed in 2017.

Butterfly Abundance

Butterfly total abundance was highest in the patch-burn grazing with one season of fire, which had 32.3 detections/transect (SE ± 1.7). Abundance was similar in the patch-burn grazing treatment with two seasons of fire, with 26.1 detections/transect (SE ± 1.9). The seasonlong grazing treatment had 12.1 detections/transect (SE ± 1.1).

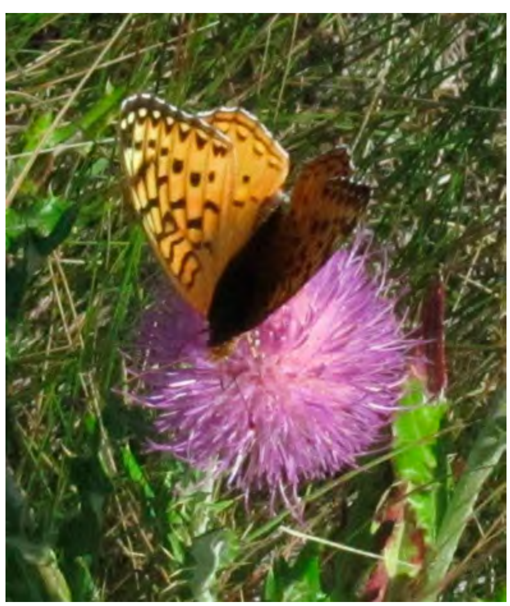
Butterfly Density

Of the six species analyzed, three had higher densities in both of the patch-burn grazing treatments, and only one species had a higher density in the seasonlong grazing treatment than either of the patch-burn grazing treatments (Figure 1A-C).

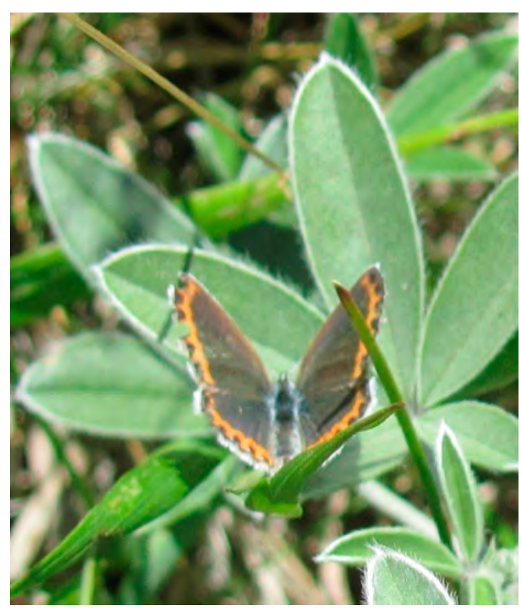
Floral Diversity and Abundance

Floral species richness was highest in the patch-burn grazing with two seasons of fire treatment (22.4 species/transect SE ± 1.3), followed by the patch-burn grazing with one season of fire (20.1 species/transect SE ± 0.9) and lastly the seasonlong grazing treatment (16.4 species/transect SE ± 0.9).

Floral abundance in the seasonlong grazing treatment was 423.7 (SE ± 33.7) blooming flowers/transect; in the patch-burn grazing with one season of fire it was 430.7 (SE ± 40.5) blooming flowers/transect. The patch-burn grazing with two seasons of fire had 510.5 (SE ± 47.7) blooming flowers/transect.



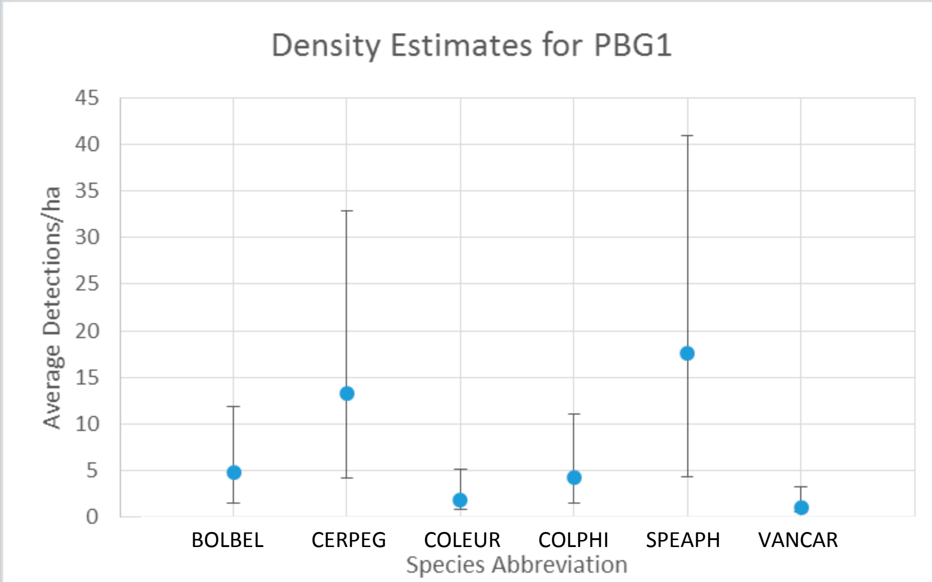
Silver-bordered fritillary (*Boloria selene*)

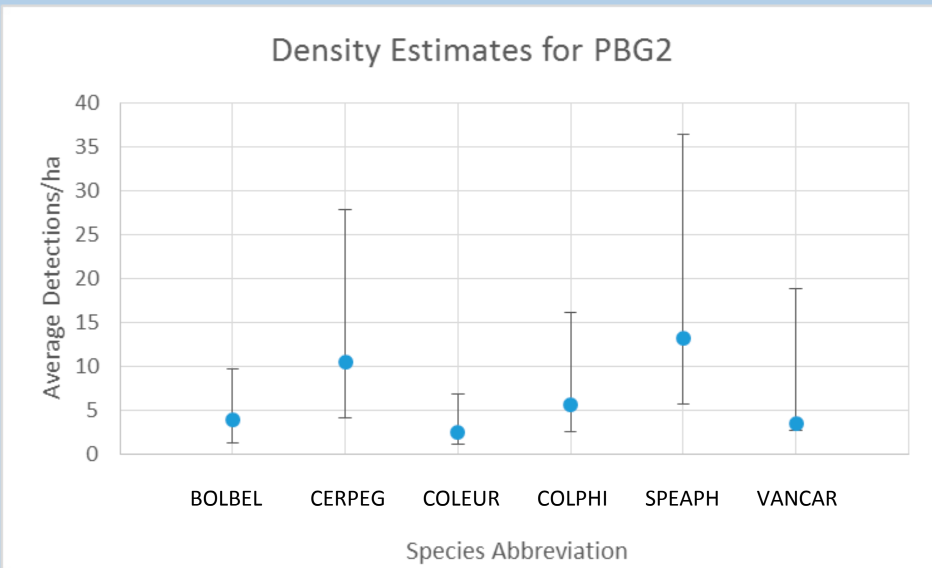


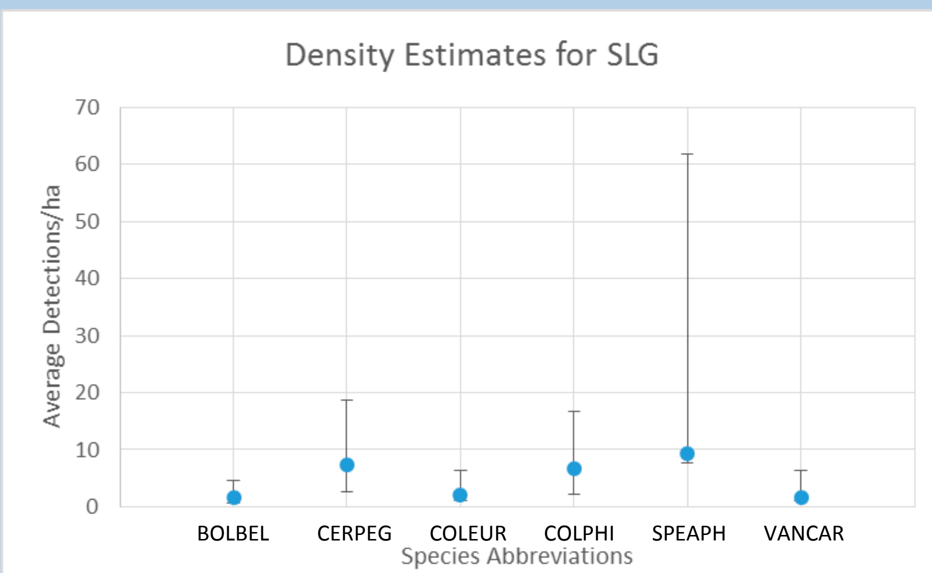
Melissa blue (*Lycaena melissa*)

Common Name	Scientific Name	Detections in PBG1	Detections in PBG2	Detections in SLG
Meadow fritillary	*Boloria bellona*	82	65	26
Silver-bordered fritillary	*Boloria selene*	26	16	6
Summer azure	*Celestrina neglecta*	11	7	8
Wood nymph	*Cercyonis pegala*	141	97	62
Gorgone checkerspot	*Chylosyne gorgone*	3	1	0
Common ringlet	*Coenonympha tullia*	76	82	3
Orange sulphur	*Colias eurytheme*	27	27	31
Clouded sulphur	*Colias philodice*	58	55	75
Monarch	*Danaus plexippus*	6	7	6
Silver-spotted skipper	*Epargyreus clarus*	0	0	1
Variegated fritillary	*Euptoieta claudia*	23	23	8
Eastern tailed blue	*Cupido comyntas*	0	1	0
Silvery blue	*Glaucopysche lygdamus*	12	27	5
Viceroy	*Liminitus archippus*	3	3	0
Gray copper	*Lycaena dione*	2	0	0
Purplish copper	*Lycaena helloides*	1	2	1
Bronze copper	*Lycaena hyllus*	0	1	0
Melissa blue	*Lycaena melissa*	80	83	22
American copper	*Lycaena phlaeas*	1	0	0
Eastern tiger swallowtail	*Papilio glaucas*	0	1	0
Black swallowtail	*Papilio polyxenes*	0	2	0
Tawny crescent	*Phyciodes batesii*	0	7	0
Northern crescent	*Phyciodes selenis*	4	4	0
Pearl crescent	*Phyciodes tharos*	8	5	0
Cabbage white	*Pieris rapae*	35	37	36
Long dash skipper	*Polites mystic*	7	6	2
Peck's skipper	*Polites peckius*	1	0	0
Tawny-edged skipper	*Polites themistocles*	0	0	1
Checkered white	*Pontia protodice*	1	5	8
Common checkered skipper	*Pyrgus communis*	4	0	1
Eyed brown	*Satyrodes eurydice*	14	2	1
Coral hairstreak	*Satyrium titus*	0	1	0
Aphrodite fritillary	*Speyeria aphrodite*	175	140	62
Great spangled fritillary	*Speyeria cybele*	3	6	0
Regal fritillary	*Speyeria idalia*	39	46	11
Gray hairstreak	*Strymon melinus*	0	1	0
Red admiral	*Vanessa atalanta*	1	1	0
Painted lady	*Vanessa cardui*	18	10	11
American lady	*Vanessa virginiensis*	3	7	1
Total detections	39	865	778	388

Table 1. Butterfly species detected at the CGREC in 2017 and the number of detections in each treatment. Patch-burn grazing with one season of fire is denoted as "PBG1," patch-burn grazing with two seasons of fire is denoted as "PBG2" and seasonlong grazing is denoted as "SLG."







Figures 1A-1C. Density estimates for the six species with the required number of observations to calculate for all three treatments at the CGREC in 2017. Abbreviations are: BOLBOL (meadow fritillary), CERPEG (wood nymph), COLEUR (orange sulphur), COLPHI (clouded sulphur), SPEAPH (aphrodite fritillary) and VANCAR (painted lady). Treatments are denoted by PBG1 (patch-burn grazing with one season of fire), PBG2 (patch-burn grazing with two seasons of fire) and SLG (seasonlong grazing).

Discussion

In year one of this study, we found that the patch-burn grazing treatment with one season of fire and the patch-burn grazing treatment with two seasons of fire had similar butterfly species richness and abundance. This is likely because the summer prescribed fire in the patch-burn grazing treatment with two seasons of fire took place after the surveys had ended, so the two patch-burn treatments were structurally similar in the first year of the study.

Both of these treatments had higher butterfly species richness and abundance than did the seasonlong grazing treatment, which had less than half as many detections as the patch-burn grazing treatments. This likely was driven by floral diversity and abundance, which were higher in the patch-burn grazing treatments. Many butterfly species rely on a specific host plant (for example, Kopper et al., 2000), which in many cases may have been more available in the patch-burn grazing treatments than the seasonlong grazing treatment.

An interesting component of the year one results is that along with the variation in total species richness, we also found some variation of community composition among treatments. All three treatments had at least one species that was found only in that treatment and was not detected elsewhere.

Although these may be misidentifications, having all 12 species unique to a treatment be misidentified every time seems unlikely. Instead, what is more likely is these species have some habitat requirement that is best filled by their treatment of choice. If this difference in species composition continues throughout the study, this would suggest that a variety of cattle management regimes would be the best to promote the highest biodiversity in butterflies.

Although these results appear to show that patch-burn grazing – with one and two seasons of fire – creates the best habitat for supporting the most diverse and abundant butterfly community, we must stress that this is year one of a multiyear study. These results may differ year to year as more prescribed burns are applied, and the "shifting mosaic" becomes more apparent in the pastures. Particularly, in future years, we expect to see further differentiation between the two patch-burn grazing treatments once surveys can occur in patches with the different seasonal burns applied and an increasing number of times-since-fire in patches.

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Avian Nest Survival in a Patch-burn Grazing System

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We are evaluating the effect of a patch-burn grazing management strategy on avian nest success. Our treatment structure includes four replicates of the following: (1) seasonlong grazing, (2) seasonlong grazing with dormant-season patch-burning (one-fourth of the pasture) at a four-year return interval and (3) seasonlong grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch-burning at a four-year return interval. Here we present preliminary results following one year of study.

Introduction

Common range management practices focus on even utilization of forage by grazers. This grazing strategy produces a homogeneous vegetation structure and composition centered on the middle of the disturbance gradient (Fuhlendorf and Engle, 2001). In contrast, grassland species have evolved with a shifting mosaic of disturbance through the interaction of fire and grazing (Fuhlendorf and Engle, 2004).

In intact disturbance regimes, grazers preferentially select for high-quality forage in patches regenerating after fire (Vermiere et al., 2003). Selection for newly burned areas by grazers releases unburned patches from grazing pressure, resulting in biomass accumulation. This, in turn, increases the propensity of unburned patches to carry fire and perpetuate the fire cycle (Fuhlendorf and Engle, 2004).

In fire-adapted rangeland systems, an intact natural disturbance regime creates a heterogeneous vegetation structure across the landscape. This diversity in habitat conditions maintains or promotes biodiversity in plants, arthropods, small mammals and birds (Doxon et al., 2011; Fuhlendorf et al., 2006; Fuhlendorf et al., 2010).

Patch-burn grazing also increases the temporal stability of grassland avian communities (Hovick et al., 2015). Through a shifting mosaic of vegetation structure, the application of fire and grazing (hereafter, patch-burn grazing) can provide habitat for species relying on diverse aspects of the disturbance gradient to complete their life histories (Fuhlendorf et al., 2009).

Traditional range management can be especially limiting to avian species that rely on vegetation structure characteristic of the far ends of the grazer utilization spectrum as part of their nesting strategy. Some examples include mountain plovers, which rely on sparse ground cover, and Le Conte's sparrows, which use areas with thick litter as part of their nesting strategy (Graul, 1975; Hovick et al., 2014).

When using a traditional management strategy, managers often achieve uniform grazing pressure through fencing and rapid rotation of grazers (Briske et al., 2011). This increased intensity of use by grazers during short time periods increases the risk of nest trampling (Bleho et al., 2014; Churchwell et al., 2008).

Woody encroachment also threatens rangeland systems subject to an inactive disturbance regime. Woody species can increase the incidence of predation and cowbird parasitism, and reduce nesting cues for grassland species (Archer et al., 2017; Klug et al., 2010; With, 1994).

In grassland avian species, woody encroachment has been shown to impact landscape-level species diversity and nesting success (Bakker, 2003; Coppedge et al., 2001; Sirami et al., 2009). Increases in grassland shrub cover also result in decreases in arthropod richness and abundance, which may impact the initiation timing and success of nesting attempts (van Hengstum et al., 2013).

We will study the use of experimental pastures by nesting birds during a time-since-fire gradient by monitoring nest success and density, as well as associated vegetation characteristics. Increases in within-patch homogeneity with accompanying heterogeneity between patches may create spatially explicit nesting habitat for a higher diversity of species, in turn creating more source habitat for grassland birds (Davis et al., 2016).

In addition, imposed heterogeneity should allow species to select for vegetation structure that maximizes nest success. Results will inform conservation of grassland bird species of conservation concern such as the grasshopper sparrow (*Ammodramus savannarum*), Sprague's pipit (*Anthus spragueii*) and upland sandpiper (*Bartramia longicauda*).

Procedures

Study Area

The Central Grasslands Research Extension Center (CGREC) is in Kidder and Stutsman counties in North Dakota (46° 42' 56" N, 99° 27' 08" W), in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella* *viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present.

The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago spp.*), yarrow (*Achillea millefolium*) and Flodman's thistle (*Cirsium flodmanii*) (Rogers et al., 2005).

The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 cm (15.9 inches) and average annual temperatures of 4.94 °C (40.9 °F) (1991-2016, North Dakota Agricultural Weather Network).

Treatment Structure

Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) seasonlong grazing, (2) seasonlong grazing with dormant-season patch-burning (one-fourth of the pasture) at a four-year return interval and (3) seasonlong grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch-burning at a four-year return interval.

Annual burn plots in treatment 3 are two adjacent 20-acre subpatches. Growing-season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals are designed to mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs graze freely within pastures from mid-May to mid-Sept. each year at a moderate stocking rate designed to achieve 30 percent forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Nest Searching

We designated a 4-hectare (ha) nest-searching plot in each subpatch (one-eighth of the pasture) for a total of 96 plots. We searched each plot four times from May 20 to July 15. We searched for nests via hand-dragging a 30-meter (m)-long rope with aluminum can bundles attached every 2.5 m.

Upon flushing a bird, we searched the immediate area for a nest. If the bird displayed a nesting behavior, such as chipping, a broken-wing display or a refusal to leave the immediate area, we marked the location and searched the area again within three days (Hovick et al., 2012).

We recorded the coordinates of each nest, and flagged vegetation 5 m north and south of the nest to avoid the association between markings and nest by visual predators (Winter et al., 2003). We candled two representative eggs from each nest to determine nest age (Lokemoen et al., 1996).


B.M. Karasch, NDSU

We also assessed parasitism rates by brown-headed cowbirds (*Molothrus ater*) because cowbird parasitism may lower nest success in grassland species (Shaffer et al., 2003). We monitored active nests every two to four days until depredation, completion or abandonment. We considered nests successful if at least one conspecific individual fledged.

Vegetation Monitoring

We standardized the collection date of all nest vegetation data to the actual or expected fledge date of each nest (McConnell et al., 2017). At each nest and at 5 m in each cardinal direction, we assessed the cover of vegetation functional groups using a Daubenmire frame and Daubenmire cover classes, as well as assessed visual obstruction and litter depth (Daubenmire, 1959; Dieni and Jones, 2003).

We included Kentucky bluegrass and smooth brome as separate functional categories because they are nonnative and of management interest (Madden et al., 2000).

Statistics

We analyzed nest survival in the RMark interface (Laake, 2013). Daily nest survival was modeled using a logit function in a generalized linear model (Rotella et al., 2004).

Species	Number of Nests
Clay-colored sparrow	77
Western meadowlark	48
Grasshopper sparrow	37
Blue-winged teal	33
Common grackle	33
Northern pintail	27
Mallard	24
Red-winged blackbird	19
Savannah sparrow	16
Gadwall	15
Chestnut-collared longspur	11
Common nighthawk	6
Mourning dove	6
Upland sandpiper	5
Bobolink	3
Northern shoveler	3
Sharp-tailed grouse	2
American wigeon	1
Common snipe	1
Eastern kingbird	1
Killdeer	1
Lesser scaup	1
Wilson's phalarope	1
Yellow-headed blackbird	1

Table 1. Nesting species monitored and number of nests by species for individuals monitored at the Central Grasslands Research Extension Center, May-August 2017.

For each species, we constructed a continuous model for daily survival, as well as a scale-based hierarchical model detailing the effects of vegetation and management (Dinsmore and Dinsmore, 2007; Hovick et al., 2012; Winter et al., 2003). The first model step evaluates the effects of cowbird parasitism, time-since-fire and incubation stage (laying, incubating or brooding).

The second step considers the effects of local (5 m) vegetation. The final modeling step includes nest-site vegetation measurements.

We used nonmetric dimension scaling to evaluate the divergence of avian nesting communities along a time-since-fire gradient using the VEGAN package in R (Oksanen, 2009). We used the anosim function to test for differences among time-since-fire groupings.

Species (n ≥ 20)	Daily Survival Probability	Model Coefficients
Blue-winged teal	0.96	Nest shrub -
Northern pintail	0.96	5m shrub+, Nest Bare -
Clay-colored sparrow	0.94	BHCO Parasitism-, nest visual obstruction +
Grasshopper sparrow	0.92	Stage +, nest vegetation height -
Western meadowlark	0.95	stage +, 5m C3 invasive grasses +, 5m bluegrass +, nest visual obstruction -
Common grackle	0.95	$time^2$ -, BHCO parasitism -, 5m vegetation height +, nest C3 grass -

Table 2. Daily nest survival rates and final hierarchical model coefficients and directionality for grassland bird species at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017. BHCO = brown-headed cowbird; C3 = cool-season.

Nest density per plot was adjusted for nest detectability based on modeled survival for each species in a Bayesian generalized linear mixed-model framework (Conkling et al., 2017). We then assessed total nest density across treatments and compared with seasonlong control pastures.

Results

In 2017, we monitored 381 nests from 24 species (Table 1).

Daily Survival Rate

We were able to run nest survival metrics on every species with 20 or more detections (six species, total; Table 2). We were not able to compare nest survival among treatments this year because with only two time-since-fire categories established, no overlap in nesting communities occurred across treatments. However, we were able to assess the effect of local and microsite vegetation structure.

Blue-winged teal (*Anas discors*) had a constant daily survival rate of 0.96. This corresponds to a total survival rate of 0.38. Greater cover of woody vegetation at the nest site decreased overall survival.

Northern pintails (*Anas acuta*) also had a constant daily survival rate of 0.96, corresponding with a total survival rate of 0.39. Shrub cover enhanced nesting success at the microsite-scale, and nesting success was decreased by bare ground cover at the nest site.

Clay-colored sparrows (*Spizella pallida*) had a daily nest survival rate of 0.94, corresponding with a total survival rate of 0.29. Their nest success was decreased by brown-headed cowbird parasitism and positively correlated with visual obstruction at the nest site.

Western meadowlark (*Sturnella neglecta*) had a daily nest survival rate of 0.95, with a total survival rate of 0.20. Western meadowlark survival was higher in the nestling stage, as well as in areas with a greater cover of smooth brome at the nest site and bluegrass at the microsite level. Nesting success decreased with increasing visual obstruction.

Common grackle (*Quiscalus quiscula*) had a daily survival probability of 0.95, corresponding to a total survival rate of 0.20. Their survival decreased during the course of the nesting season, and with brown-headed cowbird parasitism and nest-site cool-season grass cover. Nest survival increased with greater vegetation height.

Discussion

After one year of data collection, early results highlight the differences in preferred vegetation structure among grassland species. We hypothesize that local topoedaphic features drive selection for vegetation structure.

Additionally, we discovered that new burns create habitat for grackles and is reflected in grackle density and grackle selection for unburned areas for nesting.

In upcoming years, additional times-since-fire will allow for bird species to exhibit selection for vegetation characteristics at an experimental patch level. We will test to see if patch contrast creates more niches for nesting and breeding birds and enhances abundance and diversity of birds, compared with traditional range management.

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Photos by Rick Bohn, NDSU

T.J. Hovick, NDSU

Breeding Bird Community Composition in a Patch-burn Grazing System

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We are evaluating the effect of a patch-burn grazing management strategy on avian breeding community composition. Our treatment structure includes four replicates of the following: (1) seasonlong grazing, (2) seasonlong grazing with dormant-season patch-burning (one-fourth of the pasture) at a four-year return interval and (3) seasonlong grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch-burning at a four-year return interval. Here we present preliminary results following one year of study.

Introduction

Broad-scale threats to grassland birds include habitat loss, agricultural intensification and climate change (Hill et al., 2014; McCauley et al., 2017; Pool et al., 2014). However, at finer scales, patch area and local vegetation structure are important factors governing grassland bird communities (Hovick et al., 2015; Davis, 2004). Specifically, diversity in vegetation structure mediates grassland bird density, abundance and diversity.

The majority of remnant grasslands in the U.S. are privately owned and thus often undergo managed grazing by herbivores (Ribic et al., 2009). Many privately owned grasslands use a rotational grazing system designed to achieve a uniform foraging distribution (Briske et al., 2008). This minimizes selection by grazers and results in homogenization of vegetation structure and composition toward the middle of a disturbance gradient (Fuhlendorf and Engle, 2004).

A loss of structural heterogeneity causes associated declines in the diversity and stability of breeding bird communities (Hovick et al., 2015). Uniform grazing pressure can reduce the occurrence of bare patches on the landscape (Derner et al., 2008), which are important for migratory grassland species, most of which are insectivorous.

The absence of fire in grassland landscapes also can cause the expansion of woody cover. Many obligate grassland birds are less likely to use patches with woody vegetation due to declines in food resources and increased predation risk (Grant et al., 2004; Thompson et al., 2016).

The interaction of fire and grazing can prevent woody plant encroachment, as well as provide vegetation structure for grassland generalists and those that specialize on either end of the disturbance spectrum (Hovick et al., 2014; Ratajczak et al., 2012). Patch-burned grazing grasslands are more likely to be source habitats for grassland birds and retain a higher temporal stability in community structure (Davis et al., 2016; Hovick et al., 2015).

In this study, we are evaluating the impacts of patch-burn grazing on breeding season avian community composition using density estimates. We are evaluating the densities of grassland species in each treatment, as well as studying changes in the structure of the community among treatments and through time. Results will allow managers to promote grassland bird conservation in a working landscape.

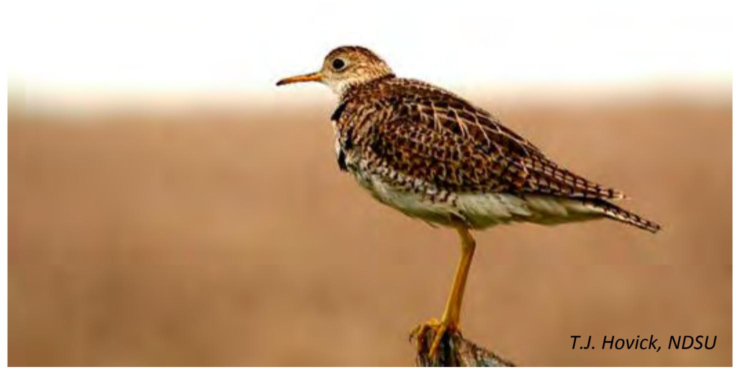
Procedures

Study Area

The Central Grasslands Research Extension Center (CGREC) is in Kidder and Stutsman counties in North Dakota (46° 42’ 56” N, 99° 27’ 08” W) in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at the CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present. The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago spp.*), yarrow (*Achillea millefolium*) and Flodman’s thistle (*Cirsium flodmanii*) (Rogers et al., 2005).

The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 cm (15.9 inches) and average annual temperatures of 4.94 °C (40.9 ºF) (1991-2016, North Dakota Agricultural Weather Network).



T.J. Hovick, NDSU

Treatment Structure
Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) seasonlong grazing, (2) seasonlong grazing with dormant season patch-burning (one-fourth of the pasture) at a four-year return interval and (3) seasonlong grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch-burning at a four-year return interval. Annual burn plots in treatment 3 will be two adjacent 20-acre subpatches.

Growing season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals are designed to mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs graze freely within pastures from mid-May to mid-Sept. each year at a moderate stocking rate designed to achieve 30 percent forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Community Monitoring
From June 1 to July 15, we monitored the breeding season avian community in each of our experimental pastures. In each subpatch (one-eighth of a 160-acre pasture), we conducted a 150-meter (m) transect survey four times during the season (384 surveys total). Each time a bird was detected, we recorded the species, sex and behavior of the bird, as well as its straight-line distance from the transect. Detections greater than 50 m from the transect were censored from analysis.

Vegetation Monitoring
Along each community transect, we performed vegetation surveys. On each side of the transect, we measured the cover of vegetation functional groups using a Daubenmire frame (20 frames/transect; Daubenmire, 1959). The cover of vegetation functional groups was recorded.

Kentucky bluegrass and smooth brome were included as separate categories because they have a unique vegetation structure and are of management interest. Additionally, at each plot, a Robel pole was used to quantify visual obstruction in each cardinal direction (Robel, 1970).

Statistics
We calculated the density of detected bird species using the unmarked package in R. We calculated breeding bird density using a constant density model, and then evaluated the effects of vegetation and treatment using an AICc modeling framework (Burnham and Anderson, 1998; Marques et al., 2007). We analyzed differences in the breeding season community using nonmetric dimensional scaling in the VEGAN package in R (Dixon, 2003).

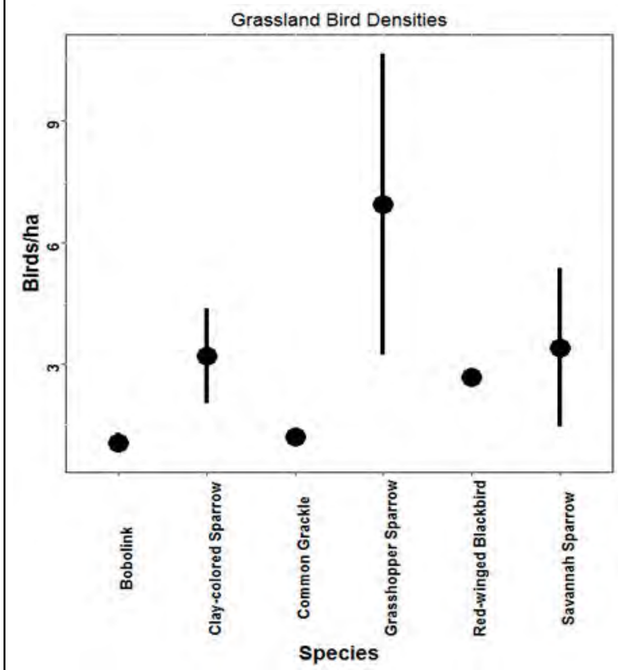


Figure 1. Estimates of the breeding season densities of six grassland bird species at the Central Grasslands Research Extension Center northwest of Streeter, N.D. in 2017.

Species	Density Model
Grasshopper sparrow (GRSP)	Litter depth +
Bobolink (BOBO)	Smooth brome +
Common grackle (COGR)	Bare ground +
Savannah sparrow (SAVS)	Kentucky bluegrass +
Clay-colored sparrow (CCSP)	Woody vegetation +
Red-winged blackbird (RWBL)	Litter depth +

Table 1. Variables and directionality of the top-performing univariate models influencing breeding season bird density at the Central Grasslands Research Extension Center near Streeter, N.D. in 2017.

We used vegetation and management to describe variation in avian community composition. Significance of environmental variables was assessed using permutational analysis of variance (PERMANOVA, McArdle and Anderson, 2001). We used the anosim function in VEGAN to assess the difference between communities in burned and unburned patches.

Results
In 2017, we had 1,910 detections from 48 species.

Density
We were able to calculate density metrics on every species with 60 or more detections (six species total; Figure 1). The density of grasshopper sparrows (*Ammodramus savannarum*) was 6.93 ±

3.72 birds/hectare (ha). The density of grasshopper sparrows increased with increasing litter depth (Table 1).

Bobolink (*Dolichonyx oryzivorus*) occurred at a density of 1.06 ± 0.25 birds/ha, and density increased in areas with a greater cover of smooth brome. Common grackles (*Quiscalus quiscula*) occurred at a density of 1.19 ± 0.24 birds/ha, and density increased with the cover of bare ground.

Savannah sparrows (*Passerculus sandwichensis*) occurred at a density of 3.40 ±1.96 birds/ha and occurred at a greater density in areas with a high cover of Kentucky bluegrass. Clay-colored sparrows (*Spizella pallida*) occurred at a density of 3.20 ±1.18 birds/ha and were more dense in areas with a higher cover of woody vegetation. Red-winged blackbirds (*Agelaius phoeniceus*) occurred at a density of 2.68 ± 0.04 birds/ha and density increased with increasing litter depth.

After one year of data collection, we found no statistically significant differences in the avian community in burned and unburned areas.

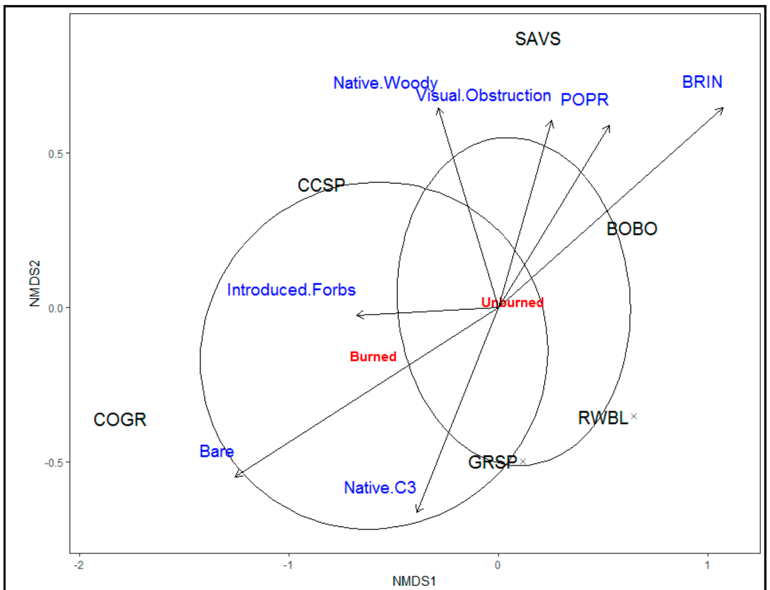


Figure 2. Nonmetric dimensional scaling (NMDS) ordination plot for abundances of six grassland bird species in a landscape managed with patch-burn grazing at the Central Grasslands Research Extension Center near Streeter, N.D. Abbreviations for environmental variables are as follows: BRIN: smooth brome (*Bromus inermis*), POPR: Kentucky bluegrass (*Poa pratensis*), Native C_3: native cool-season grasses. Bird species are those listed in Table 1.

Discussion

Following one year of data collection, we demonstrated distinct preferences for vegetation structure in the breeding bird community. Bobolink and savannah sparrow density increased with the cover of smooth brome and Kentucky bluegrass, respectively (Figure 2). These nonnative grasses likely provide the most common dense graminoid vegetation structure due to their dominance.

As we further implement our treatment structure, we will look for changes in vegetation community composition in burned plots and whether birds switch preferred vegetation groups through time.

For similar reasons, we were unable to detect a stratification in the bird community by time since fire. Our treatment structure consists of patches burned this year and patches that were not burned at all.

Newly burned patches benefit a unique suite of species (Powell, 2008), and all species unable to exploit these new burns likely used unburned areas. We expect to find a divergence in the breeding community as our treatment structure is further implemented (Pillsbury et al., 2011).

Grasshopper sparrow

Clay-colored sparrow

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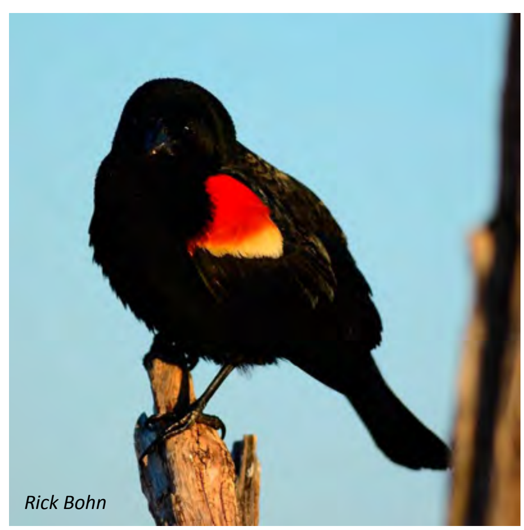
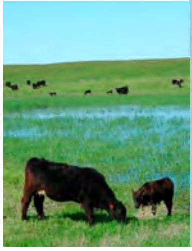
Common grackle



Red-winged blackbird



Utilizing an Electronic Feeder to Measure Mineral Intake, Feeding Behavior and Growth Performance of Cow-calf Pairs Grazing Native Range

Kacie McCarthy[1], Michael Undi[2] and Carl Dahlen[1]

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Individual animal mineral supplement intake measurements allow specific animal responses to be evaluated. Current supplementation practices do not allow measurement of individual animal mineral intake; as a result, mineral intake is reported on a group basis. The objective of this study was to evaluate an electronic feeder to monitor individual animal mineral intake and feeding behavior, and their relationship with growth performance and concentrations of mineral in the liver. The results indicate that mineral intake by grazing cattle is variable and mineral intake corroborated with concentrations in the liver.

Summary

Crossbred Angus cow-calf pairs (n = 28 pairs) at the Central Grasslands Research Extension Center (Streeter, N.D.) were used to evaluate an electronic feeder to monitor mineral intake and feeding behavior, and their relationship with growth performance and concentrations of mineral in the liver. Cows and calves were fitted with radio frequency identification (RFID) ear tags that allowed access to an electronic feeder (SmartFeed system; C-Lock Inc., Rapid City, S.D,) containing mineral (Purina Wind and Rain Storm, Land O'Lakes Inc., Arden Hills, Minn.).

Mineral intake, number of visits, time of visits and duration at the feeder were recorded for a 95-day monitoring period while pairs were grazing native range. Liver biopsies were conducted on cows on the final day of monitoring and analyzed for mineral concentrations.

Data were analyzed in SAS, with mineral intake and feeding behavior compared among cows and calves with the GLM procedure, correlations calculated among cow feeding behavior, calf intake and growth performance analyzed with the CORR procedure, and a comparison of liver mineral concentrations among cows of HIGH (greater than 90 grams per day [g/d]) and LOW (less than 90 g/d) mineral intake made with the GLM procedure.

Mineral intake was greater ($P < 0.01$) in cows (81.1 ± 8.2 g/d) than in calves (44.2 ± 8.6 g/d), but both classes of cattle attended the mineral feeders a similar ($P = 0.71$) proportion of the days during the experiment (overall mean of only 20 percent, or once every five days). Interestingly, the daily mineral feeding recommendation (113.4 g) was exceeded by calves on days they visited the feeders (222.3 ± 27.3 g), and calves had lower ($P < 0.01$) intake on mineral feeding days compared with cows (356.2 ± 26.2 g).

During the grazing period, calves gained 1.17 ± 0.02 kilograms per day (kg/d), whereas cows lost 0.35± 0.02 kg/d, but cow mineral intake and feeding behavior were not correlated ($P \geq 0.12$) with calf intake, feeding behavior or average daily gain (ADG).

Cows with HIGH mineral intake had greater ($P < 0.01$) concentrations of selenium (Se) (2.92 vs. 2.41 micrograms per gram [ug/g]), copper (Cu) (247.04 vs. 115.57 ug/g) and cobalt (Co) (0.506 vs. 0.266 ug/g), compared with LOW mineral intake cows, but liver concentrations of iron (Fe), zinc (Zn), molybdenum (Mo) and manganese (Mn) did not differ ($P \geq 0.22$).

We were able to monitor mineral intake and feeding behavior successfully with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of mineral in the liver.

Introduction

Diet alone does not supply sufficient amounts of minerals; therefore, supplementation is necessary to optimize animal health and performance (NASEM, 2016). Supplementation of cattle grazing poor-quality range vegetation will improve forage utilization and animal performance (Köster et al., 1996 Caton and Dhuyvetter, 1997).

For effective supplementation, animals must consume the target amount of mineral to ensure desired mineral intake. Research clearly has documented that intakes of minerals are variable among animals, with some cattle overconsuming or under consuming supplements (Greene, 2000).

Mineral intakes will vary depending on the season of the year, individual animal requirements, animal preference, availability of fresh minerals, mineral palatability, physical form of minerals, salt content of water, mineral delivery method, soil fertility and forage type, forage availability and animal social interactions (Bowman and Sowell, 1997; McDowell, 2003). Individual animal mineral supplement intake measurements allow specific animal responses to be evaluated.

Current supplementation practices do not allow measurement of individual animal mineral intake; as a result, mineral intake is reported on a group basis. Furthermore, the use of electronic monitoring systems in the beef industry has been limited and primarily has been used in research settings to examine the effects on feed intake in relation to cattle growth performance (Islas et al., 2014), health status (Wolfger et al., 2015) or animal movement in extensive pasture settings (Schauer et al., 2005).

These technologies could be adapted easily for use in beef cattle production systems to monitor activity, feeding or drinking behavior, or as tools for monitoring inventories in intensive or extensive production systems. Therefore, our objective was to evaluate an electronic feeder to monitor individual animal mineral intake and feeding behavior, and their relationship with growth performance and concentrations of mineral in liver.

Procedures

All animal procedures were conducted in accordance to the rules of the Institutional Animal Care and Use Committee at North Dakota State University.

Electronic Feeder Device

The SmartFeed system used to deliver mineral supplement and measure intake was developed by C-Lock Inc. (Rapid City, S.D.). SmartFeed is a portable, self-contained feeding device. It features a stainless steel feed bin suspended on two load cells, a radio frequency identification (RFID) tag reader and antenna, an adjustable framework to allow access to one animal at a time, and a data acquisition system that records RFID tags and feed bin weights at 1 hertz (Reuter et al., 2017).

The SmartFeed must be placed on level ground and firmly anchored because the animals will move it if possible. Previous research with the system developed algorithms to process the raw data signals from SmartFeed to account for rapid animal exchanges at the feeder and noise in the weight signal that results from animals pushing on the feed bin (Reuter et al., 2017).

The current feeder was fastened securely to the fence line to ensure that the animals would not push the feeder around in the pasture. The feeder was covered with a plywood shell to protect the feed bin and equipment from wind and rain. Mineral was monitored visually and through the online portal, where intake and monitoring of the device can be done remotely.

Animal Measurements

Crossbred Angus cow-calf pairs (n = 28) at the Central Grasslands Research Extension Center (Streeter, N.D.) were used to evaluate an electronic feeder to monitor mineral intake and feeding behavior, and their relationship with growth performance and concentrations of mineral in liver. Initial two-day body weights and body condition scores were collected prior to cattle being released onto pasture.

Cow-calf pairs were weighed every 28 days during the course of the grazing season. Final two-day body weights and body condition scores were collected on pasture prior to weaning.

Cows and calves were fitted with RFID ear tags that allowed access to the SmartFeed system that contained mineral (Purina Wind and Rain Storm, Land O'Lakes Inc., Arden Hills, Minn.). Mineral intake, number of visits, time of visits and duration at the feeder were recorded during a 95-day monitoring period while pairs were grazing native range.

Samples of liver were collected on the final day of monitoring via biopsy from a subset of cows with the greatest and least attendance at the mineral feeder throughout the grazing period.

Liver biopsy sites were clipped of hair, scrubbed twice with betadine and cleaned with gauze between scrubbings. Then we applied alcohol to the area, and the area was wiped with gauze until the gauze was clean after wiping. We then applied a final coating of alcohol and allowed it to air-dry.

Following that, we administered local anesthetic at the target biopsy site. After applying the anesthetic, we sprayed alcohol on the area and allowed it to air-dry.

We obtained a liver biopsy on the right side of the animal through an incision made between the 10th and 11th intercostal space at an intersection with a line drawn horizontally from the greater trochanter. We took a core sample of liver via Tru-Cut biopsy trochar (14 g; Becton Dickenson Co., Franklin Lakes, N.J.).

After obtaining liver biopsies, we applied a topical antibiotic (Aluspray; Neogen Animal Safety, Lexington, Ky.) to the surgical site and administered an injectable NSAID (Banamine; Merck Animal Health, Madison, N.J.). We stored biopsy samples in vacuum tubes designed for TM analysis (potassium EDTA; Becton Dickenson, Rutherford, N.J.) at minus 20 C° until further analysis.

Liver samples were sent to the Michigan State Diagnostic Laboratory and were evaluated for concentrations of minerals. Results were used to evaluate whether mineral feeder attendance was related to liver mineral content.

Analysis

Data were analyzed in SAS (SAS Inst. Inc., Cary, N.C.), with mineral intake and feeding behavior compared among cows and calves via PROC GLM with significance at $P < 0.05$. Correlations were calculated among cow feeding behavior, and calf intake and growth performance with PROC CORR. Comparisons of liver mineral concentrations among cows of HIGH (greater than 90 g/d) and LOW (less than 90 g/d) mineral intake were analyzed with PROC GLM.

Results and Discussion

Mineral intake was greater ($P < 0.01$) in cows (81.1 ± 8.2 g/d) than in calves (44.2 ± 8.6 g/d), but both classes of cattle attended the mineral feeders a similar ($P = 0.71$) proportion of the days during the experiment (overall mean of only 20 percent, or once every five days). Mineral intakes fall within the range of 56 to 114 g/d per animal suggested by Greene (2000) as a target for free-choice mineral supplements.

Interestingly, the daily mineral feeding recommendation (113.4 g) was exceeded by calves on days they visited the feeders (222.3 ± 27.3 g/d), and calves had reduced ($P < 0.01$) intake on feeding days, compared with cows (356.2 ± 26.2 g). During the grazing period, calves gained 1.17 ± 0.02 kg/d, whereas cows lost 0.35±

0.02 kg/d, but cow mineral intake and feeding behavior were not correlated ($P \geq 0.12$) with calf intake, feeding behavior, or ADG.

Comparatively, steers that had access to a GrowSafe system supplying mineral supplement and were grazing spring-season and fall-season pastures (36 ± 2d) consumed 96.3 and 85.4 g/d of mineral, respectively (Manzano et al., 2012). These steers consumed more mineral than the cows and calves in the current study but overall still fell within the suggested target range.

Furthermore, greater intake by cows vs. calves may be due to social interactions of dominant animals that often consume large amounts of supplement and prevent other animals from consuming desired amounts (Bowman and Sowell, 1997). With the proportion of days during the experiment that cattle were consuming mineral, the location of the mineral feeder and grazing behavior may explain variation in intake during the grazing period.

Mineral feeders were located down the fence line in a corner of the pasture away from the water source. However, further observations of cattle movements would need to be determined to understand frequency of attendance at the mineral feeder.

Concentrations of mineral in liver of cows with divergent mineral intake are reported in Table 1. Cows with HIGH mineral intake had greater ($P < 0.01$) concentrations of Se (2.92 vs. 2.41 ug/g), Cu (247.04 vs. 115.57 ug/g) and Co (0.506 vs. 0.266 ug/g), compared with LOW mineral intake cows, but liver concentrations of Fe, Zn, Mo and Mn did not differ ($P \geq 0.22$).

Selenium liver concentrations for HIGH cows showed levels of high adequate classification (greater than 2.50 ug/g dry matter [DM]; Kincaid, 1999) and for LOW mineral intake cows, levels were adequate (1.25 to 2.50 ug/g DM; Kincaid, 1999).

Liver Cu concentrations are defined as adequate at 125 to 600 ug/g DM by Kincaid (1999) or normal, greater than 100 ug/g DM by Radostits et al. (2007). HIGH and LOW cows would be considered adequate to normal for liver Cu concentrations.

Liver Co levels for HIGH and LOW cows were adequate (0.10 to 0.40 ug/g DM). As defined by Kincaid (1999), liver mineral concentrations for Fe, Zn, Mo and Mn were adequate for HIGH and LOW groups.

In conclusion, we were able to monitor mineral intake and feeding behavior successfully with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of mineral in the liver.

Table 1. Concentrations of mineral in liver of cows with divergent mineral intake[1] (high or low).

	Intake Category			
Item	**High**	**Low**	**SE**	**P-Value**
Se, ug/g	2.92^{x}	2.41^{y}	0.10	0.0027
Fe, ug/g	202.31	220.0	21.90	0.5757
Cu, ug/g	247.04^{x}	115.57^{y}	21.57	0.0005
Zn, ug/g	110.70	118.68	16.51	0.7371
Mo, ug/g	3.98	3.75	0.29	0.5948
Mn, ug/g	9.74	8.84	0.497	0.2168
Co, ug/g	0.506^{x}	0.266^{y}	0.045	0.0018

^{x,y}Means within row lacking common superscript differ significantly.
[1]Divergent mineral intake classified cows as HIGH (greater than 90 g/d) or LOW (less than 90 g/d) mineral intake.

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The Relationship between Creep Feeder Appearance Pre-weaning and Calf Intake, Gain and Feed Efficiency Post-weaning

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The objectives of this study were to determine the effect of preweaning creep feeding behavior on post-weaning feeding behavior, performance and carcass characteristics.

Summary

Suckling crossbred Angus steers (n = 32) at the Central Grasslands Research Extension Center (Streeter, N.D.) were fitted with transmission beacons on collars to determine the effect of preweaning creep feeding behavior on post-weaning feeding behavior, performance and carcass characteristics. Preweaning data included number of days visiting creep feeders and total minutes at the feeder.

Calves then were weaned and acclimated to finishing diets and an Insentec feeding system (which recorded feed intake and behavior) for a 24-day transition period, followed by a 172-day finishing period. Carcass characteristics were collected upon slaughter at a commercial abattoir.

Steer attendance at creep feeders was categorized as FREQUENT (attending greater than 80 percent of days) or INFREQUENT (attending less than 80 percent of days). Post-weaning feeding behavior data were summarized by 1) ration transition period (24 days) and 2) first 28 days on the finishing ration.

The effects of creep feeder attendance on post-weaning feeding behavior and carcass characteristics were analyzed using the GLM procedure of SAS. During the 24-day transition period, frequent creep feeder visitors ate more meals ($P = 0.05$) but had reduced time per meal, intake per meal and dry-matter intake (DMI) ($P \leq 0.03$), compared with infrequent visitors.

During the first 28 days of finishing, frequent creep feeder visitors spent more time eating and ate more meals, compared with infrequent visitors ($P \leq 0.01$), but infrequent visitors ate more DMI per meal and ate faster ($P \leq 0.04$). The frequency of creep feeder attendance had no impact on DMI, average daily gain (ADG), gain-to-feed (G:F) during the feeding period, or on carcass weight, marbling or loin-eye area ($P \geq 0.19$).

However, backfat and yield grade were greater for frequent visitors ($P \geq 0.03$), compared with infrequent steers. Overall, data indicate that preweaning creep feeder attendance influenced postweaning feeding behavior and carcass characteristics.

Introduction

Supplementing nursing calves has been used to increase preweaning weight gains (Tarr et al., 1994; Loy et al., 2002), reduce grazing pressure and improve intake at weaning (Reed et al., 2006). Increased weaning weights of calves can increase the gross income of many cow-calf production systems that sell calves at weaning (Martin et al., 1981; Tarr et al., 1994).

Additionally, creep feeding has been found to alter behavior by training calves to recognize milled feed and availability of feed from mechanical devices (Pritchard, 2013). Utilization of such devices can help producers understand feeding behavior and monitor calf performance in grazing settings.

Electronic ID systems have been used largely to qualify calves for export programs and, to a lesser extent, manage calves in feedlot scenarios. However, systems that integrate electronic identification on a ranch level into future decisions about cattle management are not available. Development of such systems could result in many improvements in management of cattle and could result in management or feeding approaches to improve the efficiency of production of calves and of beef.

The use of electronic monitoring systems in the beef industry has been limited and primarily has been used in research settings to examine the effects on feed intake in relation to cattle growth performance (Islas et al., 2014), health status (Wolfger et al., 2015) or animal movement in extensive pasture settings (Schauer et al., 2005). These technologies could be adapted easily for use in beef cattle production systems to monitor activity, feeding or drinking behavior, or as tools for monitoring inventories in intensive or extensive production systems.

Tremendous potential exists for utilizing these types of technologies to predict cattle performance that will allow for the development of precision management programs. Therefore, the objectives of this study were to evaluate the effect of preweaning creep feeding behavior on post-weaning feeding behavior, performance and carcass characteristics.

Animal Procedures

Suckling crossbred Angus steers (n = 32) at the Central Grasslands Research Extension Center (Streeter, N.D.) were fitted with transmission beacons on collars. Each beacon contained an accelerometer, and upon movement, transmitted data to receiver gateways placed at the feeders. All calves had access to creep feeders equipped with beacon gateways that sent data through a cellular network to a cloud platform.

Pre-weaning data included number of days visiting creep feeders and total minutes at the feeder. Only 32 working beacons were recorded for the creep feeding period (24 days) prior to the steers being shipped to the Beef Cattle Research Complex (BCRC) in Fargo, N.D.

Upon weaning, weights were recorded and calves were shipped to the BCRC. Steers were acclimated to finishing diets and an Insentec feeding system (Hokofarm Group B.V., the Netherlands), which recorded feed intake and behavior during a 24-day transition period, followed by a 172-day finishing period.

Upon completion of the trial, data from the Insentec feed system were combined with the creep feeder beacon data. Feed intake and behavior were summarized by day for each individual steer. Steer attendance at creep feeders was categorized as FREQUENT (attending greater than 80 percent of days) or INFREQUENT (attending less than 80 percent of days). Post-weaning feeding behavior data were summarized by 1) ration transition period (24 days) and 2) first 28 days on finishing ration.

Carcass characteristics were collected upon slaughter at a commercial abattoir; hot carcass weight data were obtained following animal slaughter, whereas marbling score, backfat, longissimus area, kidney, pelvic, heart fat (KPH) and yield grade were taken after carcasses were chilled in the cooler.

All procedures were conducted in accordance to the rules of the North Dakota State University Institutional Animal Care and Use Committee.

Analysis

All data were analyzed for the effects of creep feeder attendance on post-weaning feeding behavior and carcass characteristics using the GLM procedure of SAS (9.4; SAS Institute Inc., Cary, N.C.). Differences were determined using the least square means and considered significant at $P < 0.05$.

Results and Discussion

For October, beacons were recording appearance or the number of visits per calf at the creep feeders. The number of visits for the duration of the month can be observed in Figure 1 (see next page). Overall, the feeders were visited at least 28 times during a period throughout the day. The maximum number of visits was 99 times in one day.

Data for feeding behavior are reported in Table 1. Steers in the frequent category attended feeders an average of 90.6 percent of days; whereas, steers in the infrequent category attended feeders an average of 62.5 percent of days. During the 24-day transition period (Table 2), frequent creep feeder visitors ate more meals ($P = 0.05$) but had reduced time per meal, intake per meal and DMI ($P \leq 0.03$), compared with infrequent visitors. Steers that were more frequent visitors to the creep feeder attended the feedlot bunks within the first seven days upon arrival to the BCRC a greater percentage of time, compared with infrequent visitors (59 vs. 37 percent, respectively).

During the first 28 days of finishing, frequent creep feeder visitors spent more time eating and ate more meals, compared with infrequent visitors ($P \leq 0.01$), but infrequent visitors ate more DMI per meal and ate faster ($P \leq 0.04$). Frequency of creep feeder attendance had no impact on DMI, ADG, G:F over the feeding period, or on carcass weight, marbling or loin-eye area ($P \geq 0.19$).

Studies of creep feeding calves for 28 days showed no advantage to feedlot performance and carcass characteristics or when calves were on creep feed for longer amounts of time (Tarr et al., 1994). Data for carcass characteristics are reported in Table 3. Backfat and yield grade were greater for frequent visitors ($P \geq 0.03$), compared with infrequent steers. Studies of calves gaining similarly to the calves in this study have shown mixed results regarding backfat thickness, with increased time on creep feed resulting in greater fat thickness (Tarr et al., 1994).

Overall, data indicate that preweaning creep feeder attendance influenced post-weaning feeding behavior and carcass characteristics.

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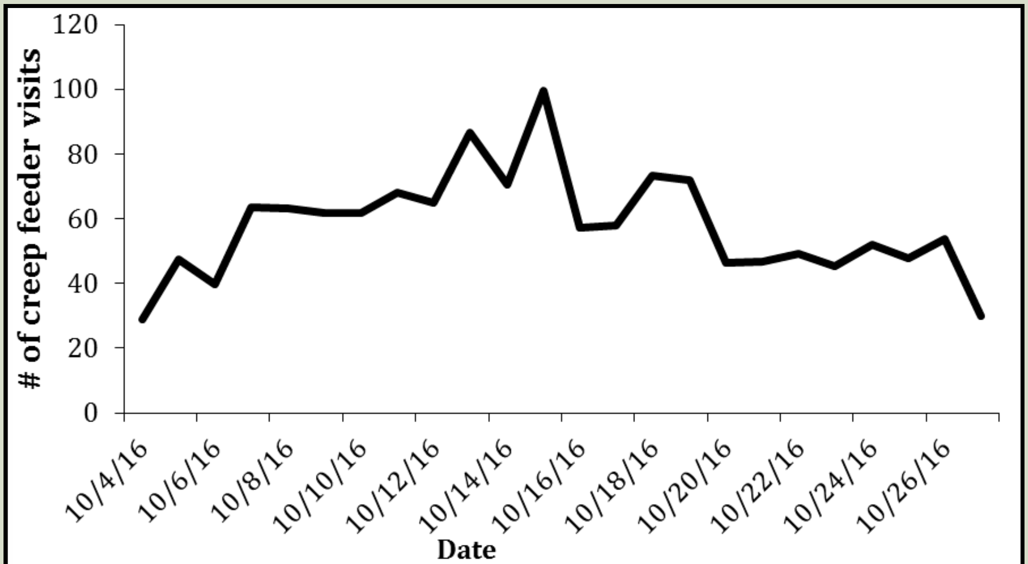

Figure 1. Number of creep feeder visits by suckling crossbred Angus steers.

Table 1. Impact of frequency of creep feeder visits on growth performance and feeding behavior in crossbred Angus steers during the first 28 days on feed.

	Visiting frequency category[1]			
Item	**Frequent**	**Infrequent**	**SE**	***P*-Value**
No. of steers	13	11		
DMI[2], kg	6.41	6.53	0.298	0.768
ADG[3], kg	0.99	0.90	0.149	0.663
G:F	0.153	0.130	0.149	0.446
Time spent eating, min.	158.4	126.4	7.91	0.009
Visits	33.8	27.2	3.17	0.153
Meals	12.7	10.7	0.52	0.014
Time per visit, min.	5.86	6.83	0.80	0.406
Time per meal, min.	13.31	12.61	1.03	0.635
Kg per visit	0.248	0.371	0.037	0.031
Kg per meal	0.852	1.053	0.064	0.037
Kg per minute	0.066	0.086	0.003	<0.001

[1]Steers in the Frequent category attended feeders an average of 90.6 percent of days, whereas steers in the Infrequent category attended feeders an average of 62.5 percent of days.

[2]DMI = dry-matter intake

[3]ADG = average daily gain

Table 2. Impact of frequency of creep feeder visits on transition period feeding behavior of crossbred Angus steers.

	Visiting frequency category[1]			
Item	**Frequent**	**Infrequent**	**SE**	***P*-Value**
No. of steers	13	11		
Count 7 days	4.15	2.6	0.45	0.024
Count 17 days	17	16.9	0.06	0.264
Count 24 days	21.2	19.5	0.47	0.021
% Attend 7 days	0.59	0.37	0.06	0.024
% Attend 17 days	1.00	0.99	0.004	0.264
% Attend 24 days	0.88	0.81	0.02	0.264
Training (24 d)				
DMI[2], kg	5.29	6.15	0.26	0.031
Time spent eating, min.	93.12	102.08	6.98	0.375
Visit	39.3	33.4	3.07	0.200
Meal	13.97	12.43	0.52	0.048
Time per visit, min.	2.34	3.47	0.29	0.014
Time per meal, min.	6.55	8.33	0.54	0.029
Kg per visit	0.135	0.215	0.021	0.015
Kg per meal	0.371	0.507	0.024	0.001
Kg per minute	5.65	3.26	1.58	0.297

[1]Steers in the Frequent category attended feeders an average of 90.6 percent of days, whereas steers in the Infrequent category attended feeders an average of 62.5 percent of days.

[2]DMI = dry-matter intake

Table 3. Impact of frequency of creep feeder visits on carcass characteristics of crossbred Angus steers.

	Visiting frequency category[1]			
Item	**Frequent**	**Infrequent**	**SE**	***P*-Value**
No. of steers	13	11		
HCW[2], kg	367.1	356.4	8.6	0.389
Marbling score	487.4	445.3	21.7	0.186
Backfat, cm	1.40	1.02	0.09	0.013
Longissimus area, cm^2	84.13	84.83	1.93	0.800
KPH[3], %	2.02	1.88	0.052	0.067
Calculated yield grade	3.24	2.66	0.176	0.031

[1]Steers in the Frequent category attended feeders an average of 90.6 percent of days, whereas steers in the Infrequent category attended feeders an average of 62.5 percent of days.

[2]HCW = hot carcass weight

[3]KPH = kidney, pelvic and heart fat

Evaluation of Methods to Measure Temperament in Cattle and Their Impacts on Predictions of Genetic Merit

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The objectives of this study are to: 1) characterize subjective and objective measurements of temperament in cattle, 2) identify evaluator impact on subjective measurements relative to genetic predictions, and 3) determine the feasibility and practicality of objective methods being characterized. The long-term goal is to identify a practical measure of temperament to use in genetic evaluation programs. This report describes the approach and current status of the project.

Introduction

Livestock behavior, particularly the human and animal interactions, is an important consideration because it can influence productivity as well as welfare of the animal (Hemsworth, 2003). Measuring temperament, often defined as the reaction of the animal to human handling (Burrow and Dillon, 1997; Fordyce et al., 1982), in beef cattle has been of industrywide interest because calmer cattle result in less stress and safer work environments for the handler, as well as for that animal and its contemporaries (Grandin, 1989).

The reduction of stress on animals and humans can result in more efficient production of beef, along with reduced costs due to health reasons (for example, King et al., 2006; Cooke et al., 2009a, 2009b, 2011). This is particularly true as wilder, more excitable temperaments alter immune responses in cattle due to increased stress levels (reviewed by Burdick et al., 2011).

Temperament, among other similar traits of production importance, is challenging to measure. Often, using an objective scale or collecting data in an objective manner can be cost prohibitive for a producer. For example, flight speed (Burrow et al., 1988), which is based on the premise that calmer animals leave the chute at a slower rate than their unruly contemporaries, eliminates having evaluators score each animal but requires specific equipment and skills to measure the characteristic.

Researchers have shown that only moderate persistence of flight speed occurs on a given day (Vetters et al., 2012). Additionally, questions have been raised about what aspects of temperament (for example, nervousness, flightiness, gregariousness, aggressiveness) flight speed really accounts for, but besides repeatability, not much research has been conducted to understand that aspect.

Furthermore, purely objective methods often lack the ability to capture the different aspects of temperament. This makes the use of subjective scoring methods appealing because the scales can be adapted to capture multiple descriptors of temperament.

Subjective methods are often more cost-efficient for the producer and can be utilized to capture various attributes of a complex trait. Subjective methods, however, rely on the evaluator's or evaluators' perception of that trait.

In the case of temperament, several subjective methods, including flight distance (Fordyce et al., 1982), crush score (also called temperament score; Hearnshaw and Morris, 1984), movement score (Fordyce et al., 1982, 1988; adapted by Grandin, 1993) and docility score (Beef Improvement Federation, 2010), as well as a different scoring method also called temperament score (Sant'Anna and Paranhos da Costa, 2013), have been identified.

A purely research-based scoring method also has been described for use in identifying biological mechanisms involved in cattle temperament through candidate gene searches and association studies (see Boldt, 2008, and Hulsman Hanna et al., 2014a). In addition, a few breed associations even have incorporated docility scores into their genetic evaluation programs (for example, Hyde, 2010; Northcutt and Bowman, 2010).

Lastly, Wemelsfelder et al. (2000, 2001) utilized free choice profiling techniques to identify behavioral attributes that would signify different aspects of animal welfare in pigs. This technique has been used extensively in food sensory studies to understand what attributes different food products have (for example, chocolate flavor intensity, smoke flavor intensity, fish taste, color), but studies by Wemelsfelder et al. (2000, 2001) were some of the first attempts to transition the technique into use for measuring attributes related to animal behavior.

Sant'Anna and Paranhos da Costa (2013) adapted the work of Wemelsfelder et al. (2000, 2001) and their procedure outlined in Welfare Quality® protocol (Welfare Quality® Consortium, 2009) to fit into the cattle production setting by using a set of behavior attributes in a method called Qualitative Behavior Assessment (QBA). This method sought to capture behavior attributes by using cattle body language in a quantitative fashion. In their study, Sant'Anna and Paranhos da Costa (2013) took those behavior measurements and, through principle component analysis, transformed them into a single score for each animal termed the Temperament Index (TI).

Although measuring the behavior attributes for the QBA requires subjective assessment, the use of principal component analysis converts these measurements, which may have correlation, to a set of values that are linearly uncorrelated (the principal components). The TI is the first principal component, meaning that it accounts for the largest amount of variation in the data, and each following component is uncorrelated to the TI.

This is particularly interesting because it may negate or reduce the impact the evaluator has on the behavior measurements. If this is true, then allowing producers to conduct a QBA for their animals and reporting those to breed associations for analysis may provide a cost- and time-efficient method to improve selection criteria that can replace current methods being used.

The primary challenge to Sant'Anna and Paranhos da Costa (2013) is that they employed a single evaluator to conduct the QBA method and it was utilized only on Nellore cattle, which are typically very expressive in their behavior.

In any case, these methods rely on the evaluator's perception of the animal's reaction to human handling. Due to this, the potential exists for evaluator bias among evaluators or across days of evaluation (see Vetters et al., 2012).

Very little is known of the actual impact of evaluators on these subjective scoring methods. Rather, a limited number of studies have reported repeatability of scores on animals (for example, Vetters et al., 2012; Jones, 2013), which provides an indication of usefulness in the production setting but not necessarily an indication of what variation could be expected among evaluators for any given method. Even fewer studies compare these repeatability measures across methods.

Because temperament is a complex trait and often highly influenced by environmental cues, assessing current and new methods for their effectiveness in capturing this trait of interest is important, especially if these methods are used for selection purposes. Findings related to temperament scoring methods have farther-reaching implications because they also could be translated to other difficult-to-collect traits such as fertility and reproductive performance.

Therefore, a **long-term objective** of this project is to identify a practical measure of temperament to use in genetic evaluation programs. Current **short-term project objectives** of this study are to: 1) characterize subjective and objective measurements of temperament, 2) identify evaluator impact on subjective measurements relative to genetic predictions, and 3) determine the feasibility and practicality of objective methods being characterized. This report describes the approach and current status of the project.

Materials and Methods

Animals

Calves at weaning age from the Central Grasslands Research Extension Center (CGREC) were evaluated for temperament using subjective and objective scoring systems. Weaning age is recommended to reduce influences on temperament evaluation due to past experiences (BIF, 2010).

The cow herd producing these calves consisted of approximately 450 females (mature cows and heifers) with primarily Angus and/or Hereford influence that were bred to Angus or Hereford bulls. Each calf had blood drawn via jugular venipuncture for white blood cell extraction.

White blood cell pellets are being stored long term in an ultralow freezer until funding becomes available for DNA extraction and genotyping. Data were collected on weaning-age calves from 2014 to 2017, resulting in approximately 1,542 calves with records available.

Data Collection and Traits

During weaning time, temperament was evaluated by randomly assigning evaluators (n = 6) to two of three subjective scoring methods (n = four evaluators per method). This was constructed to determine the level of differences between evaluator perceptions of temperament (evaluator bias) without introducing bias due to stress of scoring three scales.

Efforts were taken to keep evaluators consistent across years. Many evaluators were involved during all four years and kept the same two scoring systems during those years; however, a subset was involved only in specific years. Replacements typically had similar backgrounds or experiences, and differences are being investigated as part of the long-term objective. Furthermore, novel objective methods of measuring temperament also were investigated.

Subjective evaluation methods include:

1) Qualitative Behavior Assessment (QBA; Sant'Anna and Paranhos da Costa, 2013) - The QBA method uses 12 behavioral attributes: active, relaxed, fearful, agitated, calm, attentive, positively occupied, curious, irritated, apathetic, happy and distressed. Evaluation occurs as the animal leaves the chute and enters a working pen. Evaluators interpret the body language of the animal and score each attribute independently on a 136-millimeter (mm) line, where the far left of the line is no expression and the far right of the line is full expression. The score is the distance (in mm) of the mark from the left side.

2) Temperament score (Sant'Anna and Paranhos da Costa, 2013) - Like QBA, temperament score is used to evaluate the animal as it leaves the chute and enters a working pen. It is a 1 to 5 scale with whole numbers, where a score of 1 is a calm animal and a score of 5 is a wild animal. The middle value (3) is not included to avoid having evaluators chose an intermediate score.

3) Docility score (BIF, 2010) - Docility score is evaluated when the animal is in the squeeze chute with its head restrained, but body movement is not restricted. Each calf is scored on a 1 to 6 scale, where 1 indicates a docile, easily handled animal, and 6 indicates a very aggressive, wild animal.

Objective evaluation methods include:

1) Video image analysis (VIA) - Video was captured on each calf from the top as it entered the silencer chute in 2016 and 2017. Prior to entering the chute, the calf had a red tape marker placed on its tail head. A second red tape marker was present at a designated location within the chute. The video clip was reduced to a 10-second window for each calf in the same time frame of being in the chute for consistency. Deviations of the calf's red tape marker from the permanent red marker will be used to determine movement and possible measure of temperament for that calf.

2) Pupil dilation and thermal imaging - After the head of the calf was caught in the silencer chute but before blood draw, an infrared picture of the calf's left eye was taken for pupil dilation and a thermal image reading of the calf's face was recorded as two additional measures of temperament. These records also were recorded only in 2016 and 2017.

3) Four-platform standing scale (Pacific Industrial Scale, British Columbia, Canada) - Immediately after being evaluated in the squeeze cute for docility score, the animal was placed on a custom four-platform standing scale for a minimum of 45 seconds to record weight borne on each quadrant through time (records multiple times per second).

Qualitative Behavior Assessment (QBA) Attributes

Sant'Anna and Paranhos da Costa (2013) investigated these traits using principle component analysis. Our preliminary analysis of records from 2014 and 2015 also investigated using this statistical approach to create the temperament index (TI).

The results of this investigation indicate that very different outcomes can occur across populations (*Bos indicus* vs. *Bos taurus* breeds) and evaluators. Due to this, additional methods to characterize the QBA attributes are warranted. We are pursuing a factor analytic model using multivariate approaches (Henderson and Quaas, 1976).

Statistical Analysis

Phenotypes (scores and attributes) are being evaluated using a mixed-model procedure in SAS (SAS Institute Inc., Cary, N.C.). Fixed effects of evaluation day, birth year, evaluator and other environmental effects (for example, sequence of evaluation) are being evaluated for significance. The average score for each method will be used for an aggregate value to compare against evaluators and across methods, particularly for project objective 3.

Genetic Predictions

The current focus of this project is genetic predictions using a traditional animal model in ASReml software (Gilmour et al., 2015). Analysis will be conducted as single traits and in pairs to meet project objectives.

Both approaches predict genetic merit and estimate heritability for that trait. Analyzing two traits together allows for genetic correlations between traits to be estimated, while having nearly 2,000 animal records typically is necessary for reasonable estimates. Predictions will be generated and used for comparison of method efficacy and evaluator impacts on animal rankings.

Results

Data from 2014 and 2015 have been analyzed collectively, which resulted in a sample size of 802 calves. Preliminary analyses of data from 2014 and 2015 calves have found that temperament scores are influenced by date of evaluation and calf sex, and that temperament scores differ by evaluators ($P < 0.05$).

These models prove that evaluator differences are present, and preliminary analysis of genetic predictions indicate this causes re-ranking of animals. As these are based on pedigree relationships, however, the sample size needs to be larger for formal conclusions to be made and for project objectives to be met.

Discussion

Four years of data have been collected. As several of the methods to measure temperament are novel, many procedures on how to process the large amount of data and turn them into formal scores or measures to use have been challenging. The research team is working to finalize data processing and entry for all four years and begin formal analysis to meet project objectives.

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CGREC - 2017

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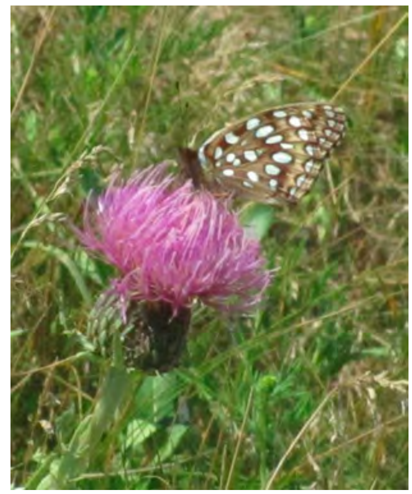

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