Central Grasslands Research Extension Center

2018 Annual Report

Range—Forage—Livestock

NDSU | NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

NDSU | EXTENSION

Summary of the Year

Welcome to the 2018 CGREC Annual Report

The growing season for 2018 was much better than 2017, with the station receiving 125 percent of normal precipitation during the growing season.

We produced ample hay from our perennial hay fields and our annual forage crops, and produced almost two years' supply of corn silage. We are like many ranchers in North Dakota with old hay fields that need rejuvenating or reseeding (another new study).

We completed two years of patch burn studies (part of an eight-year study) with some cool results coming in on impacts on the plant community, soil physical properties, enhancement in flowering forbs that have increased pollinator and bird habitat, and increases in livestock performance. We also started the modified twice-over rest-rotation grazing study this year.

These trials will be compared with the season-long grazing pasture. We are working collaboratively with the range science faculty on the NDSU campus, including Torre Hovick, Ryan Limb and Devan McGranahan.

Michael Undi completed his third year of research on the bale grazing study and corn/cover crop trial. We plan to run a fourth year on the bale grazing study, then summarize the impacts on livestock performance, economic and soil health.

We continue to conduct studies on beef cattle reproduction, cattle genetics and the interaction of nutrition on reproduction in the cow herd. Almost all of our steers went on trials for the Main Station campus or Carrington Research Extension Center (REC) in a genomic study or bedding study.

Our researchers even kept 36 bull calves intact and used them on two studies: one (12 head) on a methods study looking at predicting potential daily sperm production and fertility in the bull using the testis, and a second study (24 head) looking at the effects of feeding 60 percent dried distillers grains plus solubles or the equivalent sulfur as calcium sulfate on hydrogen sulfide gas production in the rumen. We are working collaboratively with the Animal Sciences faculty on the main campus, including Carl Dahlen, Alison Ward and Lauren Hannah, and Bryan Neville at the Carrington REC.

We were able to fill two of our vacant positions in 2018. We hired Cody Wieland as our livestock technician and Erin Gaugler as our range research specialist. Lisa Pederson was hired in 2018 as the center's new Extension livestock and beef quality assurance specialist.

As I reported in last year's annual report, we lost Rodney Schmidt, the center's herdsman and an employee since 1999, to an ATV accident May 12, 2018. Rodney was the face of our livestock unit, and we truly miss him. He was the most humble, kind-hearted man I have ever met.

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

Congratulations to Megan Dornbusch, Haley Johnson and Felipe Alves Correa Carvalho Da Silva. All three graduated with their M.S. degrees in range science or animal sciences in 2018.

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 continue to improve our infrastructure and will work closely with the NDSU Main Station scientists (Range Science, Animal Sciences, Soil Science and Plant Sciences) and partner RECs (Carrington, Hettinger, Langdon, Minot) to conduct research in the areas of rangeland, forage, wildlife and pollinators, soil health and beef cattle research in 2019.

We invite you to our 2019 annual field day on July 8 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 are always welcome to stop by and visit.

Kevin Sedivec, Interim Director

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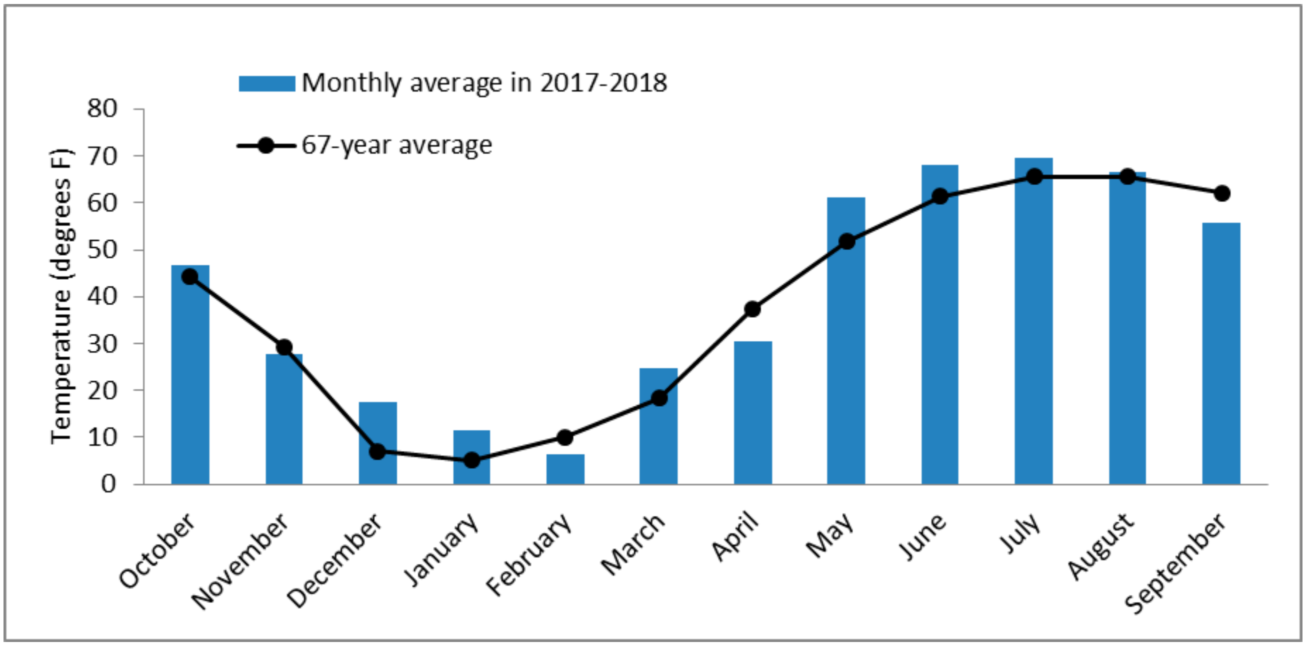
Monthly Temperatures for the 2017-2018 Crop Year



Last spring frost: May 11, 2018 (32°F)

Average[2] last spring frost: May 13

First fall frost: Sept. 28, 2018 (29°F)

Average first fall frost: Sept. 22

140 frost-free days

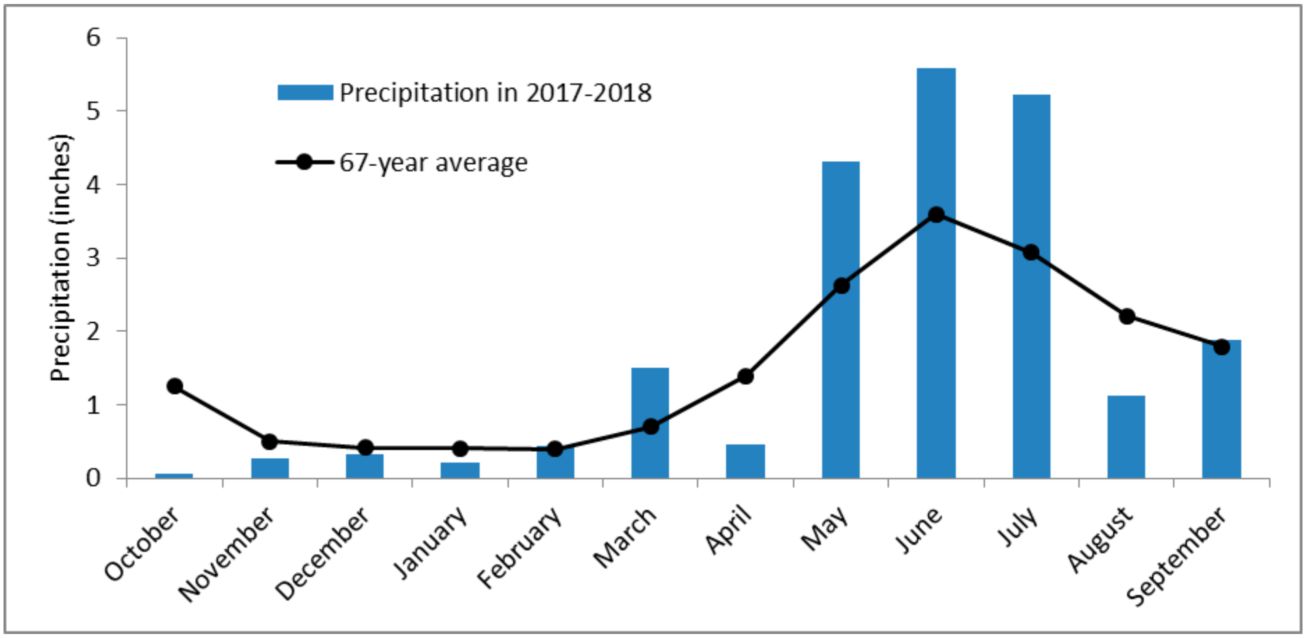
Average: 132 frost-free days

Month	Maximum temperature[1]	Minimum temperature	Average temperature	Long-term[2] average temperature	2017-2018 deviation from long-term[2] average
October	75	17	46.7	44.2	2.5
November	61	2	27.7	29.3	-1.6
December	51	-26	17.5	7.1	10.4
January	41	-29	11.6	5.1	6.5
February	40	-19	6.5	10.0	-3.5
March	43	-5	24.8	18.3	6.5
April	77	-5	30.5	37.4	-6.9
May	90	32	61.2	51.8	9.4
June	87	46	68.1	61.4	6.6
July	91	49	69.6	65.5	4.0
August	96	46	66.7	65.5	1.2
September	88	29	55.8	62.1	-6.4

[1] Degrees F.

[2] 1951 to 2018; 67 years

Monthly Precipitation for the 2017–2018 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	2017-2018 accumulated percent of long-term[2] average	Snow[3]
October	0.06	1.25	-1.19	0.06	1.25	4.79	0
November	0.27	0.50	-0.23	0.33	1.76	18.79	1.5
December	0.33	0.42	-0.09	0.66	2.17	30.37	5.2
January	0.21	0.40	-0.19	0.87	2.58	33.75	5
February	0.44	0.40	0.04	1.31	2.98	43.98	8
March	1.50	0.70	0.80	2.81	3.68	76.29	22.5
April	0.46	1.39	-0.93	3.27	5.07	64.44	6.5
May	4.31	2.63	1.68	7.58	7.71	98.36	0
June	5.58	3.60	1.98	13.16	11.31	116.39	0
July	5.23	3.08	2.15	18.39	14.38	127.86	0
August	1.12	2.21	-1.09	19.51	16.59	117.60	0
September	1.88	1.79	0.09	21.39	18.38	116.36	0
Total	21.39	18.35	3.04	21.39	18.38	116.36	48.7

[1] Rain and melted snow; in inches

[2] 1951-2018; 67 years

[3] Depth in inches

Supplementation of Beef Cattle Bale Grazing Grass Hay in Winter: Effects on Animal Performance and Soil Nutrients

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

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. Results suggest that supplementation with good-quality alfalfa hay or a liquid supplement will not meet requirements of pregnant beef cows in early to mid-gestation in severely cold winters. Under such conditions, 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

Methods of supplementing beef cows bale grazing poor-quality grass hay were investigated in a study conducted during three winters, from 2016 to 2018, at the Central Grasslands Research Extension Center, Streeter, N.D. Methods evaluated were a) grass hay supplemented with good-quality alfalfa hay, b) grass hay supplemented with corn DDGS and c) grass hay treated with a liquid supplement.

Results show that the method of supplementation depends on environmental conditions during the winter. In severely cold winters, good-quality alfalfa hay or a liquid supplement are not adequate to meet the requirements of pregnant beef cows in early to mid-gestation. Under such conditions, supplements such as corn DDGS will be needed to meet animal requirements. 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 Plains typically graze poor-quality forages in the 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). The 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).

Cost-effective supplement delivery methods help minimize feed costs by reducing supplement delivery frequency (Schauer et al., 2005; Canesin et al., 2014; Gross et al., 2016) or eliminating pasture visits (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 the winter. The study examined beef cow performance and cost effectiveness of bale grazing supplementation strategies.

Procedures

This study extended for two years, from 2016 to 2017. Starting in the fall of each year, non-lactating pregnant Angus cows (2016, n = 64, body weight [BW] = 595 ± 65 kilograms [kg]; 2017, n = 80, BW = 621 ± 59 kg; 2018, n = 80, BW = 643 ± 45 kg) were divided into eight groups of similar total body weight and kept on bale-grazing pasture in the 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 historically was cropland, using a corn and small-grain rotation. In the two years prior to the 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, which was planted in early May 2016. The field then was divided into eight three-acre paddocks using three-strand, high-tensile wire electric fencing.

Table 1. Composition of grass hay and hay supplemented with alfalfa hay (ALF), a liquid supplement (QLF) or dried distillers grains with solubles (DDGS).

	Control[1]	ALF[2]	QLF[3]	DDGS[4]
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.

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 one portable electric wire. 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 DDGS were fed 1.8 kg of DDGS/head/day twice weekly. Approximately 34 liters of liquid supplement (Quality Liquid Feeds Inc.) was poured onto upright bales. This amount of liquid supplement was calculated to increase hay protein content by approximately 3 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. One bale of alfalfa hay was fed for every three bales of poor-quality hay.

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 the study. Two observers assigned body condition scores (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.

Soil samples were collected at two depths, 0 to 15 centimeters (cm) and 15 to 30 cm, and from three distance points, bale center, 10 feet from the bale center and 20 feet from the bale center. As well, soil samples were collected from bale grazed and ungrazed areas.

Results

Initial cow BW and BCS were similar ($P > 0.05$) among treatments in both years. Final BW and BCS were not influenced ($P > 0.05$) by treatment. The diet by year interaction ($P < 0.001$) for daily gain (Table 2) shows that response to supplementation was dependent on the type of supplement used, as well as environmental conditions.

In the first year, cows supplemented with DDGS had positive daily gains, while supplementation with alfalfa hay or liquid resulted in weight loss (Figure 1). In the second year, more favorable environmental conditions resulted in similar performance in supplemented cows, whereas in the third year, DDGS supplementation clearly was superior to the other supplementation strategies (Figure 1).

In the first year, supplementation did not influence ($P > 0.05$) soil organic matter, nitrate-N, ammonium-N, phosphorus (P) and potassium (K) at two soil depths (Table 3). As well, the distance from the center of the bale did not influence ammonium-N, P and K. However, nitrate-N content decreased linearly with increasing distance from the bale center. We found no difference in soil nutrients between bale grazed and ungrazed areas.

Table 2. Animal performance following bale grazing poor-quality grass hay supplemented with alfalfa hay, a liquid supplement or dried distillers grains with solubles (DDGS).

	Diet (D)					Year (Y)				P-value		
	HAY[1]	ALF[2]	QLF[3]	DDGS[4]	SE	2016	2017	2018	SE	D	Y	D x Y
Initial BW, kg	621	620	620	618	11.4	594^{b}	622^{a}	643^{a}	7.8	0.997	<0.001	0.729
Final BW, kg	624	635	632	651	12.1	583^{b}	661^{a}	662^{a}	8.9	0.165	<0.001	0.455
Daily gain, kg/d	0.07^{c}	0.25^{b}	0.21^{bc}	0.53^{a}	0.053	-0.13^{c}	0.58^{a}	0.34^{b}	0.045	<0.001	<0.001	0.009
Initial BCS	5.6	5.6	5.5	5.6	0.05	5.5b	5.4c	5.8a	0.04	0.939	<0.001	0.278
Final BCS	5.4	5.5	5.7	5.5	0.17	5.4	5.6	5.5	0.11	0.377	0.346	0.261
BCS change	-o.19	-0.11	0.12	-0.04	0.16	-0.08b	0.19a	-0.27b	0.11	0.298	<0.001	0.595

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

[a-c]Means within diet and within year with a different letter differ (P ≤ 0.05).

Discussion

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 select places, cows were able to bale graze for 70 days before the termination of the study. The trial was terminated because cows no longer were able to reach the water source due to the heavy snowfall.

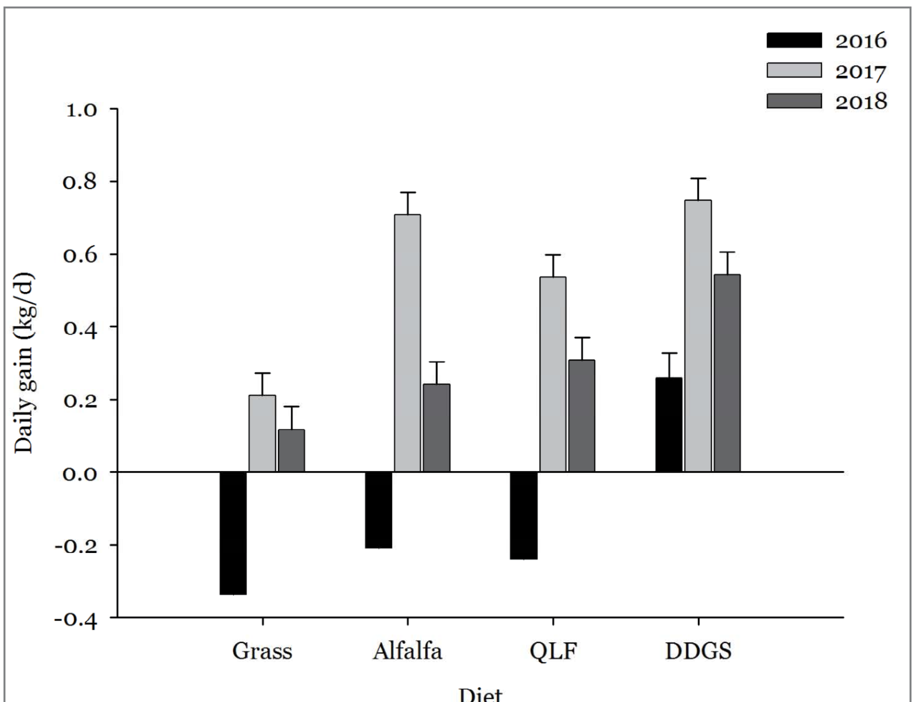


Figure 1. Cow daily gains following bale grazing grass hay supplemented with alfalfa hay (alfalfa), a liquid supplement (QLF) or dried distillers grains with solubles (DDGS).

Environmental conditions will play a part in determining the success of supplementing cows bale grazing grass hay in the winter. When winters are harsh, poor-quality grass does not contain adequate amounts of energy, protein and phosphorus to meet nutritional requirement of cows in early to mid-gestation.

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 in the second year, supplementation with alfalfa hay, a liquid supplement or DDGS improved animal performance.

Results suggest that poor-quality grass hay does not contain adequate energy, protein and phosphorus to meet requirements of pregnant beef cows in early to mid-gestation when winters are severely cold. 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. Supplementation with good-quality alfalfa hay or grass hay treated with a liquid supplement may be an option during mild winters.

Table 3. Soil concentrations[1] of organic matter, ammonium-N, nitrate-N, phosphorus and potassium following bale grazing poor-quality hay supplemented with DDGS, alfalfa hay or a liquid supplement.

	Treatment (T)					Distance (D)				P-value			Distance effect	
	HAY	QLF	ALF	DDG	SE	0	10	20	SE	T	D	T x D	L	Q
Depth (0 – 15 cm)														
OM, %	0.58	0.46	0.62	0.59	0.070	0.53	0.57	0.57	0.014	0.267	0.039	0.020	0.033	0.107
NO_3-N, kg/ha	1.35	1.30	1.48	1.46	0.246	1.52[a]	1.64[a]	1.03[b]	0.151	0.862	0.009	0.511	0.012	0.024
NH_4-N, kg/ha	1.31	1.17	1.26	1.34	0.100	1.36	1.21	1.25	0.097	0.513	0.284	0.432	0.246	0.245
P, kg/ha	1.49	1.31	1.23	1.14	0.146	1.22	1.28	1.38	0.079	0.255	0.176	0.417	0.074	0.728
K, kg/ha	2.76	2.64	2.66	2.61	0.134	2.65	2.72	2.62	0.069	0.718	0.405	0.212	0.704	0.208
Depth (15 – 30 cm)														
OM, %	0.48	0.37	0.50	0.41	0.046	0.43	0.43	0.47	0.039	0.064	0.493	0.698	0.288	0.698
NO_3-N, kg/ha	1.12	0.98	1.21	1.09	0.229	1.33[a]	1.23[a]	0.74[b]	0.077	0.785	0.001	0.034	0.001	0.019
NH_4-N, kg/ha	1.18	1.22	1.20	1.41	0.104	1.34	1.20	1.22	0.061	0.269	0.133	0.246	0.145	0.161
P, kg/ha	1.31	1.16	0.99	0.86	0.274	1.11	1.06	1.08	0.103	0.478	0.901	0.733	0.787	0.724
K, kg/ha	2.59	2.51	2.51	2.51	0.087	2.52	2.53	2.53	0.050	0.770	0.973	0.242	0.840	0.909

[a-b]Means within treatment and within distance with a different letter differ ($P \leq 0.05$).

Linear and quadratic orthogonal polynomial contrasts.

[1]Log_{10} values for all means.

Acknowledgments

The excellent technical assistance provided by the late Rodney Schmidt, as well as Dwight Schmidt, Scott Alm, Megan Gross, Elisabeth Gnitka, Cody Wieland, Felipe Silva, Nico Negrin, Cheyanne Klein, Thomas Mittleider, Rick Bohn, Tom Lere (QLF) and Curt Lahr (QLF) is gratefully acknowledged.

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Photos by Michael Undi, NDSU

Performance of Beef Cattle Overwintered on Bale-grazed Pasture or in a Dry Lot in South-central North Dakota

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

Allowing beef cattle to harvest their own forage potentially can decrease production costs by reducing reliance on inputs such as labor and machinery required for forage harvest. This study assesses the performance of beef cattle kept on pasture to bale graze or in dry-lot pens during the winter in North Dakota. Results show that bale grazing may be a viable alternative to keeping cattle in dry lots 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.

Summary

The performance of beef cows managed in two overwintering environments (pasture or dry-lot pens) was assessed in a study conducted during three winters, from 2016 to 2018, at the Central Grasslands Research Extension Center, Streeter, N.D. Starting in the fall of each year, nonlactating pregnant Angus cows were divided into four groups of similar body weight (BW) and kept on pasture to bale graze or in dry-lot pens in the winter.

Keeping cows on pasture or in dry-lot pens in the winter did not influence ($P > 0.05$) their final BW and final body condition score (BCS). However, daily gains were greater ($P < 0.05$) in bale-grazing cows relative to cows kept in a dry lot. Although both groups lost BCS, the loss was greater ($P < 0.05$) in cows kept in a dry lot.

Results show that bale grazing is a viable alternative to keeping cattle in dry lots 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.

Introduction

Winters in the northern Plains are characterized by cold temperatures, low wind chills, freezing rain and snow. A large portion of winter (40 to 70 days) averages minus 18 C, although extreme minimum temperatures of minus 51 C have been recorded (Enz, 2003).

The majority of beef cows in the Northern Plains is housed in open dry-lot pens during the winter (Asem-Hiablie *et al.,* 2016) and is exposed to these extreme winter conditions. In typical dry lots, 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 dry lots, make up more than 60 percent of total feed costs for most beef cow-calf operations (Taylor and Field, 1995). Thus, 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 be assessed against 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 dry lot) under south-central North Dakota winter conditions.

Procedures

This study extended for three years, from 2016 to 2018. Starting in the fall of each year, nonlactating pregnant Angus cows (2016, n = 32, body weight [BW] = 599 ± 68 kg; 2017, n = 40, BW = 620 ± 59 kg; 2018, n = 40, BW = 643 ± 47) were divided into four groups of similar BW and kept on pasture to bale graze or kept in dry-lot pens in the winter.

Pastured cows were kept in paddocks separated by three-strand, high-tensile wire electric fencing. Dry-lot pens contained a hay feeder and a water tank. Cows in both housing scenarios were offered the same Conservation Reserve Program (CRP) hay (Table 1), free choice.

Two-day body weights were taken at the start and end of the study. Two independent observers assigned body condition scores (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.

Bale Grazing

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

Nutrient	%DM
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

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 Round-up in late April, after which meadow brome was planted in early May. Three-acre paddocks were separated using three-strand, high-tensile wire electric fencing. One water tank was placed between two paddocks. Wind breaks 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]) were placed in each paddock in two rows approximately 15 meters apart. Cows were allotted four bales in one grazing session; access to new bales was controlled using a single portable electric wire.

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 10 10 centimeters (cm). Cows had *ad libitum* access to fresh water, mineral supplement and salt blocks.

Dry Lot

Two groups of cows were kept in dry-lot pens. Each pen contained a two-bale hay feeder and a Richie water tank. Dry-lot cows were fed the same CRP hay as the bale-grazed cows. Like the bale grazed cows, dry-lot 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 (Table 2). Keeping cows on pasture or in dry-lot pens in the winter did not influence ($P > 0.05$) final BW and final body condition score (BCS). However, daily gains were greater ($P < 0.05$) in bale-grazing cows relative to cows kept in a dry lot.

Although both groups lost BCS, the loss was greater ($P < 0.05$) in cows kept in a dry lot (Table 2). Whether on pasture or in dry-lot pens, cows lost body weight and condition in the first year but maintained or gained weight and BCS in the second year (Figure 1).

Discussion

The first year of the study was marked by three blizzards, which led to huge snow accumulations. Despite snow depths being greater than 50 cm in selected places, cows were able to bale graze for 70 days before the termination of the study.

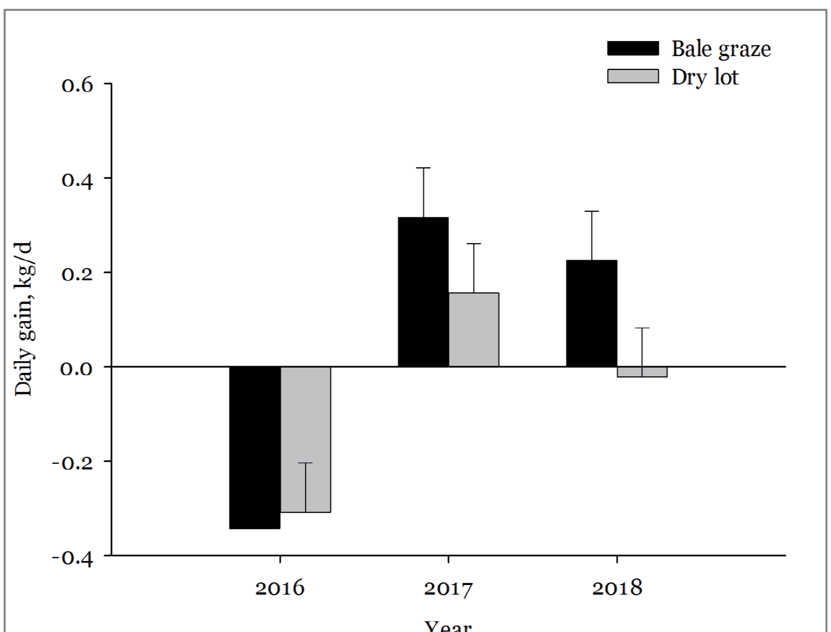

Figure 1. Average daily gains of cows (2016, n = 32; 2017, n = 40) kept on pasture or in a dry lot in the winter during two winters.

Table 2. Performance of cows kept on pasture or in a dry lot in the winter.

	Housing (H)			Year (Y)				P-value		
	Pasture	Dry Lot	SE	2016	2017	2018	SE	H	Y	H x Y
Initial BW, kg	621	623	11.5	600[b]	618[b]	647[a]	9.8	0.883	0.002	0.784
Final BW, kg	623	618	11.7	577[b]	636[a]	650[a]	12.5	0.656	<0.001	0.803
Daily gain, kg/d	0.07	-0.06	0.062	-0.33[b]	0.24[a]	0.10[a]	0.075	0.052	<0.001	0.202
Initial BCS	5.6	5.7	0.053	5.7[a]	5.4[b]	5.8[a]	0.062	0.090	<0.001	0.728
Final BCS	5.4	5.3	0.060	5.4[a]	5.4[a]	5.2[b]	0.071	0.700	0.001	0.144
BCS change	-0.20[a]	-0.31[b]	0.051	-0.25[b]	0.06[a]	-0.58[c]	0.060	0.027	<0.001	0.235

The study 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.

Here are some interesting observations from blizzard events of 2016: First, despite windbreaks, not all cows sought shelter during the blizzards. Some simply would 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 refilled, not all cows visited the water troughs immediately, as anticipated. However, we observed what seemed to be a "catch up" period of several days following 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 likely a combination of hay quality and environmental conditions. The hay was low in energy, protein and phosphorus (P) content and did not supply these nutrients to meet the requirements of cows in mid-gestation (National Research Council, 1996), particularly during adverse weather conditions as encountered in 2016. The positive animal performance in the second and third years may be attributed to more favorable environmental conditions.

Overall, daily gains were numerically greater in cows kept on pasture. The smaller-size dry-lot pens would be expected to give dry-lot 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, over and above 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 dry-lot pens in the 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 is a viable alternative to keeping cattle in dry lots 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, the late Rodney Schmidt, Cody Wieland, Thomas Mittleider and Rick Bohn is gratefully acknowledged.

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Supplementing Cattle Grazing Corn Residue with a Lick Tub

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Methods of supplementing grazing cattle in the winter should aim to reduce winter feed costs, which are the single highest annual cost in a cow-calf operation. Eliminating pasture visits in the winter can reduce labor and fuel costs. This study evaluated a lick tub as a strategy for supplying extra nutrients to cattle partially overwintered on corn residue. Results suggest that corn residue can be a sole forage source for beef cattle in early winter. Supplementation may be beneficial as corn residue quality and quantity decline with advancing winter.

Summary

This study evaluated the use of a lick tub (Crystalyx® HE-12%) as a source of extra nutrients for beef cattle partially overwintered on corn residue. Non-lactating pregnant Angus cows grazed corn residue or corn residue plus a lick tub during two winters starting in 2017. Supplementation with a lick tub did not impact animal performance, suggesting that early winter supplementation of cattle grazing corn residue may not be beneficial.

Introduction

Corn residue is a readily available feed resource for grazing cattle in the winter in North Dakota. However, corn residue is a low-quality feed that can be improved by targeted supplementation. Beef cattle grazing corn residue mostly have been supplemented with distillers grains with solubles (DDGS) (Warner et al., 2011; Jones et al., 2015; Gross et al., 2016).

Supplementation methods that reduce labor and fuel costs by eliminating pasture visits are of interest to beef producers. A recent study at the CGREC (Gross et al., 2016) showed that pasture visits in the winter can be minimized by delivering loose DDGS every third day versus daily supplement delivery.

Cattle lick tubs are a great way to supplement protein, minerals and vitamins to grazing beef cattle when pastures are deficient in these essential nutrients (Vitti, 2010). Lick tubs are convenient to producers because they minimize pasture visits (Jones et al., 2015). Strategic placement of lick tubs allows effective pasture utilization. The objective of this study was to evaluate a lick tub as a method of supplementing cows grazing corn residue for part of the winter.

Procedures

This two-year study was conducted on a 24-hectare field planted to corn. The field was divided into six 4-hectare paddocks using high-tensile wire electric fencing.

Starting in the fall of each year, non-lactating pregnant Angus cows (n = 60, 2017, body weight [BW] = 632 ± 32 kilograms [kg]; 2018, BW = 617 ± 31 kg) were divided into six groups of similar total body weight and allowed to graze corn residue or corn residue supplemented with a lick tub (Crystalyx® HE-12%). The lick tub contained 12 percent crude protein (CP) and consisted of a nutrient-dense blend of molasses solids, protein meals, hydrolyzed vegetable oil, vitamins and minerals and trace minerals (Crystalyx.com).

Cows were allotted a portion of the corn field, and access to new sites was controlled by using one portable electric wire. Two-day body weights were taken at the start and end of the study. Two observers assigned body condition scores (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, cob and stalk have low CP content, but neutral detergent fiber (NDF) is high. In vitro dry-matter digestibility (DMD) is lowest in the cob and stalk and highest in grain (Table 1).

Table 1. Composition of whole corn and components.

			Component (mean ± SD; %DM)				
	Whole	Residue[1]	Grain	Leaf	Husk	Cob	Stalk
CP	7.8±1.06	3.0±0.05	9.3±0.92	7.2±0.14	2.9±0.04	2.3±0.54	2.7±0.07
NDF	39.2±12.71	68.3±1.83	30.0±6.73	66.6±9.15	83.3±3.96	86.0±4.30	77.6±7.89
ADF	19.8±6.36	41.3±0.61	3.3±0.70	36.9±4.00	43.2±1.50	44.7±0.79	50.0±7.07
Ca	0.11±0.03	0.33±0.01	0.02±0.00	0.88±0.31	0.15±0.04	0.02±0.00	0.26±0.04
P	0.23±0.06	0.08±0.01	0.28±0.07	0.14±0.02	0.09±0.02	0.06±0.00	0.08±0.01
IVDMD	78.0±1.79	59.9±0.18	92.4±2.69	59.7±2.86	66.4±3.28	44.2±0.45	49.0±11.55

[1]Whole plant minus grain.

Table 2. Performance of cows grazing corn residue.

	Treatment (T)			Year (Y)			P-value		
	Residue	Tub	SE	2017	2018	SE	T	Y	T x Y
Initial BW, kg	626	624	6.3	631	618	6.3	0.854	0.029	0.626
Final BW, kg	638	641	7.9	660[a]	619[b]	7.9	0.789	<0.001	0.646
Daily gain, kg/d	0.32	0.39	0.11	0.69[a]	0.02[b]	0.11	0.521	<0.001	0.952
Initial BCS	5.6	5.6	0.04	5.5[b]	5.7[a]	0.04	0.968	<0.001	0.871
Final BCS	5.5	5.5	0.05	5.7[a]	5.4[b]	0.05	0.858	<0.001	0.426
BCS change	-0.08	-0.07	0.04	0.19[a]	-0.34[b]	0.04	0.855	<0.001	0.405

[a,b]Means within housing and within year followed by a different letter differ ($P \leq 0.05$).

Initial cow BW and BCS were similar (P > 0.05) between treatments in both years (Table 2). We found a significant difference (P < 0.05) between years in daily gains and BCS change (Table 2).

Cattle lick tubs are meant to supplement protein, minerals and vitamins to grazing beef cattle when pastures are deficient in these essential nutrients. Supplementation with a lick tub did not influence (P > 0.05) final BW and average daily gains. As well, we found no difference (P > 0.05) in final BCS and BCS change between treatments (Table 2).

The nonresponse to supplementation suggests that corn residue can be a sole source of forage for beef cattle in the fall/early winter. Supplementation may not be beneficial because corn residue quality and quantity decline as winter advances.

Grazing residue in the winter can result in considerable cost savings. Corn residue is a cost-effective source of feed for cattle in the winter because its production is paid for by the grain operation (McCutcheon and Samples, 2015).

We calculated the value of grazing corn residue based on feeding similar quality or average grass hay, as suggested by McCutcheon and Samples (2015). Using this simple model, we calculated that grazing corn residue in this study resulted in average savings of $1.14/head/day during a 50-day grazing period. This value was calculated on average cow weight of 625 kg, hay intake of 2.5 percent of BW, including a 10 percent hay loss, and a hay price of $60/ton.

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Photos by Michael Undi, NDSU

Comparison of Forage Sampling Strategies to Monitor Native Range Pasture Chemical Composition, Forage Intake and Digestibility During the Grazing Season

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Pasture forage sampling normally is accomplished by hand clipping. This two-year study compares hand clipping and rumen evacuation as forage sampling strategies to monitor changes in pasture chemical composition, forage intake and digestibility during the grazing season. Sampling strategy had the biggest impact on forage crude protein (CP) content and in vitro dry-matter digestibility (IVDMD), which were greater in samples collected through rumen evacuation. However, positive linear relationships between hand clipped and masticate samples suggest that hand clipping provides reasonable estimates of pasture forage quality during the grazing season. Rumen evacuation may be a more suitable sampling strategy when a wide range of pasture conditions are anticipated.

Summary

Hand clipping and rumen evacuation were compared as pasture forage sampling strategies to monitor changes in native range pasture chemical composition, forage intake and digestibility during the grazing season. Forage samples were collected by hand clipping or rumen evacuation in four periods in the first year and one period in the second year. Rumen evacuations were conducted with ruminal cannulated Angus heifers (n = 8, body weight [BW] = 597 ± 64 kilograms [kg], year one; n = 9, BW = 602 ± 76 kg, year two) that were kept in continuously-grazed pastures. Hand clipped and masticate samples were collected on the same day. Forage CP content was greater ($P \leq 0.05$; 11.7 vs. 7.6 ± 0.44 percent) in masticate samples relative to clipped samples. Forage CP content declined ($P \leq 0.05$) with advancing season. Regression analysis showed a significant linear relationship ($r^2 = 0.61$; $P \leq 0.05$) in CP content from the two sampling strategies.

Forage neutral detergent fiber (NDF) and acid detergent fiber (ADF) content were not influenced ($P > 0.05$) by sampling strategy and increased linearly ($P \leq 0.05$) with advancing season. Masticate samples had greater ($P \leq 0.05$) acid detergent lignin (ADL) content relative to hand clipped samples (6.3 vs. 5.5 ± 0.16%) and ADL contents from sampling strategies were correlated ($r = 0.72$; $P \leq 0.05$).

In vitro dry-matter digestibility (DMD) was greater ($P \leq 0.05$) in masticate samples relative to hand clipped samples and decreased linearly ($P \leq 0.05$) with advancing season. Dry-matter intake estimated from masticate samples had a greater range (4.1 - 14.3 vs. 4.9 - 8.1 kg/day) and variability (CV; 37.7 vs. 13.2 percent) relative to estimates from hand clipped samples.

Sampling strategy by period interaction ($P \leq 0.05$) in dry-matter intake (DMI) showed that decline in DMI with advancing season was more pronounced in masticate samples relative to hand-clipped samples. Although sampling strategy had the biggest impact on forage CP content and IVDMD, hand clipping can provide useful estimates of pasture forage quality and nutrient changes during the grazing season, provided differences in forage chemical composition and IVDMD are considered. Sampling strategy should be taken into account when evaluating pasture quality.

Introduction

Beef producers in North Dakota depend largely on mixed-grass prairie as the primary forage source for cattle throughout much of the year (Johnson et al., 1998). Pasture productivity of mixed-grass prairie, measured by changes in crude protein content, fiber content and forage digestibility, declines with advancing season (Johnson et al., 1998; Cline et al., 2009; Cline et al,. 2010), the rate of decline depending on time of the year, forage species and environmental conditions (McDowell, 1996). Thus, pasture productivity should be monitored periodically so that decisions for optimal pasture use and cattle management are based on accurate information. In many cases, evaluation of pasture productivity is hindered by the inability to collect a representative sample mainly due to diverse plant communities and the rugged terrain of grazing lands (Holechek et al., 1982).

Pasture forage samples can be collected through several methods. Esophageal fistulation has been evaluated in several studies (Rama Rao et al., 1973; Vavra et al., 1978; Coffey et al., 1991; Olson, 1991) and provides the most representative sample of forage consumed by grazing animals (Holechek et al., 1982). Although sample collection through esophageal fistulation requires less labor, compared with other methods, esophageal fistulated cattle are expensive and difficult to maintain (Coffey et al., 1991).

Pasture sampling through rumen evacuation also has been used to obtain representative pasture samples (Olson, 1991; Hughes et al., 2010). Compared with esophageal fistulation, rumen fistulated animals are easier to maintain and representative samples can be collected during longer collection periods (Olson, 1991). A major limitation of rumen evacuation includes time and labor to evacuate and clean the rumen, as well as depressed digestibility if evacuations are repeated frequently (Olson, 1991).

Nutritional management decisions for cattle often are based on pasture productivity estimated from hand-clipped forage samples (Hughes et al., 2010). Unlike sampling through esophageal fistulation or rumen evacuation, hand clipping requires less equipment and time and also produces sample free of salivary contamination (Holechek et al., 1982). However, hand clipping may misrepresent forage consumed because this strategy does not take into account diet selection (Holechek et al., 1982).

Despite these setbacks, clipping likely will remain the most practical strategy for pasture sampling. This study was conducted to compare hand clipping and rumen evacuation as sampling strategies for monitoring seasonal variation in forage intake, digestibility and forage chemical composition of mixed-grass prairie pastures.

Procedures

This two-year study was conducted at the North Dakota State University Central Grasslands Research Extension Center near Streeter, N.D. Animal handling and care procedures in this study were approved by the North Dakota State University Animal Care and Use Committee. The study was conducted with ruminal cannulated Angus heifers (n = 8, BW = 597 ± 64 kg, year one; n = 9, BW = 652 ± 91 kg, year two) that were kept in continuously grazed pastures and were co-grazed with cow-calf pairs (year one) and heifers (year two).

The grazing season was divided into four collection periods corresponding to May, June, July and August in the first year. Logistics resulted in late pasture turnout in the second year (2018), resulting in sample collection in July and August. Hand-clipped samples were collected by walking diagonally across pastures and hand clipping forage from 20 different locations in the pasture. The samples were clipped to a height of 3.75 centimeters (cm) above ground. Masticate samples were collected through a rumen evacuation technique described by Cline et al. (2010).

Results

The effect of sampling strategy on pasture forage nutrients, intake and IVDMD in year one is shown in Table 1. Masticate samples had greater ($P \leq 0.05$) CP content relative to hand-clipped samples. As well, forage CP content declined quadratically ($P \leq 0.05$) with advancing season (Table 1; see next page). The tendency toward a sampling strategy by period interaction ($P = 0.09$) suggests that the magnitude of change in CP content with advancing season depended on sampling strategy (Figure 1).

Forage NDF and ADF content were not influenced ($P > 0.05$) by sampling strategy but increased linearly ($P \leq 0.05$) with advancing season (Table 1). Hand-clipped samples had lower ($P \leq 0.05$) ADL content relative to masticate samples (Table 1). Also, forage ADL content increased linearly ($P \leq 0.05$) with advancing season.

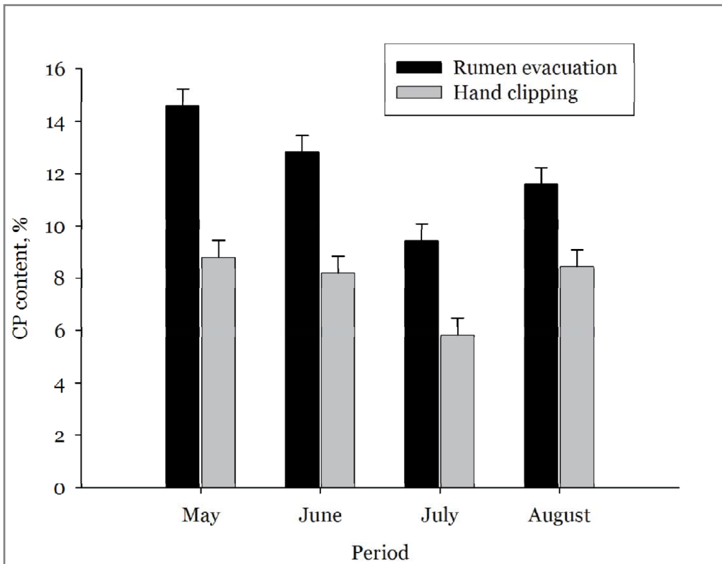

Figure 1. Change in forage CP content with advancing season estimated from forage samples collected by hand clipping or rumen evacuation.

In vitro DMD was greater ($P \leq 0.05$) in masticate samples relative to hand-clipped samples. In vitro DMD decreased linearly ($P \leq 0.05$) with advancing season (Table 1) but the rate of decline tended ($P = 0.09$) to depend on sampling strategy. The sampling strategy by period interaction ($P \leq 0.05$) in DMI shows that the linear decline in DMI with advancing season was more pronounced in masticate samples relative to hand-clipped samples (Figure 2).

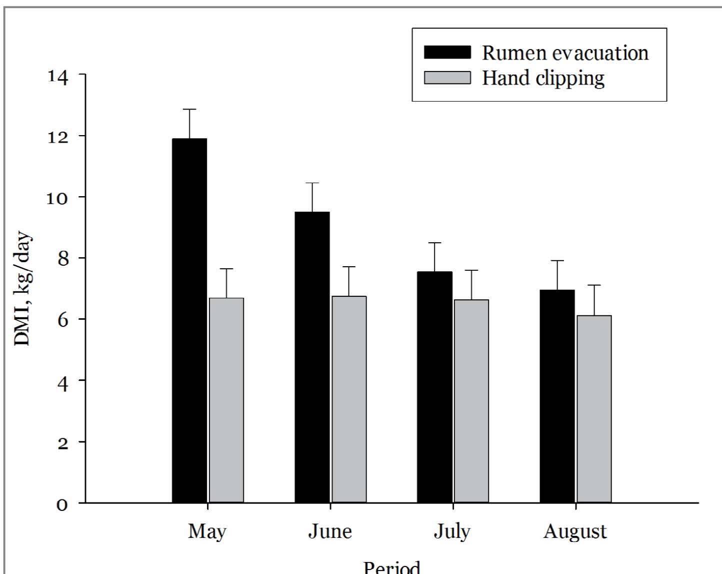

Figure 2. Change in DMI with advancing season estimated from forage samples collected by hand clipping or rumen evacuation.

Late pasture turnout in the second year limited sampling to only one period (Table 2). Masticate samples had greater ($P \leq 0.05$) CP content relative to hand-clipped samples. We found no differences ($P > 0.05$) in NDF, ADF and ADL content, as well as IVDMD, between masticate and hand-clipped samples.

Table 1. Pasture chemical composition, intake and digestibility estimated from forage samples collected by hand clipping or rumen evacuation (year 1).

	Strategy (S)[1]			Period (P)[2]					P-value			Period effect[3]	
Item	HC	RE	SE	E-Jun	L-Jun	E-Aug	L-Aug	SE	S	P	S x P	L	Q
CP, %	7.8^{b}	12.1^{a}	0.32	11.7^{a}	10.5^{a}	7.6^{b}	10.0^{a}	0.46	<0.001	<0.001	0.089	0.008	<0.001
NDF, %	66.2	65.3	1.06	63.8^{b}	61.8^{b}	67.9^{a}	69.7^{a}	1.50	0.412	0.003	0.237	0.004	0.115
ADF, %	37.5	36.2	0.69	35.8^{b}	34.5^{b}	38.2^{a}	39.1^{a}	0.98	0.087	0.005	0.624	0.010	0.155
ADL, %	5.6^{b}	6.4^{a}	0.16	5.7^{b}	5.1^{c}	6.4^{a}	6.6^{a}	0.23	0.002	0.001	0.221	0.006	0.048
IVDMD, %	59.9^{b}	61.4^{a}	0.79	65.1^{a}	64.5^{a}	54.5^{b}	56.6^{b}	1.11	0.015	<0.001	0.091	<0.001	0.1333
DMI, kg/d	6.6^{b}	8.9^{a}	1.02	9.3^{a}	8.1^{ab}	7.1^{bc}	6.5^{c}	0.51	0.027	<0.001	<0.001	<0.001	0.406

[1]Sampling strategies were hand clipping (HC) and rumen evacuation (RE).

[2]Periods were early June (June 7), late June (June 27), early August (Aug. 2) and late August (Aug. 30).

[3]Linear (L) and quadratic (Q) orthogonal polynomial contrasts.

$^{a-c}$ Means within sampling strategy and within period with a different letter differ ($P \leq 0.05$).

Table 2. Pasture chemical composition and digestibility estimated from forage samples collected by hand clipping or rumen evacuation (year 2).

	Strategy[1]			
Item	HC	RE	SE	P-value
CP, %	6.9[b]	10.1[a]	0.48	0.023
NDF, %	63.0	68.3	3.35	0.253
ADF, %	33.8	35.6	2.61	0.577
ADL, %	5.2	5.9	0.55	0.329
IVDMD, %	51.1	52.4	5.31	0.896

[1]Sampling strategies were hand clipping (HC) and rumen evacuation (RE).

[a – b] Means within sampling strategy with a different letter differ ($P \leq 0.05$).

When year one and two samples were pooled, forage CP content of masticate forage samples ranged from 8.6 to 15.1 percent, with a mean CP content of 11.7 percent, which was greater ($P \leq 0.05$) than the CP content of hand-clipped samples (Table 3; see next page). Forage CP content resulting from the two sampling strategies were highly correlated ($r = 0.81$; $P \leq 0.05$), and regression analysis showed a significant linear relationship ($r^2 = 0.61$; $P \leq 0.05$) between masticate and hand-clipped samples.

Pooled masticate and hand-clipped samples had similar ($P > 0.05$) forage NDF and ADF content (Table 3). Pooled masticate samples had greater ($P \leq 0.05$) ADL content relative to hand-clipped samples (Table 3), but ADL content were correlated ($r = 0.72$; $P \leq 0.05$; Table 3).

In vitro DMD of masticate and clipped samples were highly correlated ($r = 0.91$; $P < 0.005$; Table 3), and regression analysis showed a significant linear relationship ($r^2 = 0.81$; $P \leq 0.05$) between the two sampling strategies. Dry-matter intake estimated from masticate samples had a greater range relative to estimates from hand-clipped samples (Table 3). As well, DMI estimates from masticate samples were more variable as indicated by relatively greater CV. Dry-matter intakes estimated from the two sampling strategies were not correlated (Table 3).

Discussion

Nutritional management decisions for cattle often are based on pasture productivity estimated from hand-clipped forage samples (Rama Rao et al., 1973; Dubbs et al., 2003; Hughes et al., 2010). This study compared rumen evacuation and hand clipping as sampling strategies to monitor seasonal nutritional quality changes of mixed-prairie pasture.

In this study, hand clipping followed normal practice as would be practiced by grazers, with no attempt to identify specific areas of the pastures where the animals were grazing. Hand clipping requires less equipment and time, and also produces samples free of salivary contamination (Holechek et al., 1982). However, hand clipping may misrepresent forage consumed because this strategy does not take into account diet selection (Holechek et al., 1982). Despite these limitations, we anticipate that hand clipping will remain a method of choice for most grazers because it does not require cannulated animals.

Pasture sampling through rumen evacuation has been used to obtain representative pasture samples (Olson, 1991; Hughes et al., 2010) since samples collected represent forage consumed by animals. Rumen evacuation requires cannulated animals, and the process of collecting masticate samples can be labor-intensive (Olson, 1991). In the present study, four individuals took at least six hours to collect masticate samples from nine cannulated heifers during each sampling cycle.

Forage CP content declined with advancing season as previously reported in the northern Great Plains (Johnson et al., 1998; Cline et al., 2009; Cline et al., 2010). The difference between sampling strategies was in magnitude of change in CP content (Figure 3). Forage CP content was 54 percent greater in masticate samples relative to clipped samples.

Studies that have reported greater CP content in esophageal collected (Rama Rao et al., 1973; Coffey et al., 1991) or masticate samples (Dubbs et al., 2003; Hughes et al., 2010) relative to clipped samples attributed the lower CP content in clipped samples to failure of clipped samples to mimic grazing by not accounting for animal selection.


Sandi Dewald, NDSU

Coupled with a greater CP content range of masticate samples (8.6 - 15.1 percent), results from this study suggest that grazing cattle have the ability to select forage with higher CP content and will likely select forage with greater CP forages, even when forage quality is declining. This likely would occur only in cases where forage availability is not a limiting factor. A significant correlation between masticate and clipped CP values suggests that, despite limitations of clipping, this strategy still has value and can be used in situations where masticate samples cannot be obtained.

Table 3. Pooled[1] data comparing forage sampling strategies to estimate pasture chemical composition, dry-matter intake and digestibility.

	Sampling strategy	Statistics					Correlation	
Item		T-test	SD	CV	Min.	Max.	HC[2]	RE[2]
CP, %	Rumen evacuation	11.7[a]	2.18	18.86	8.6	15.1	0.81**[3]	-
	Hand clipping	7.6[b]	1.24	16.18	5.8	9.2	-	0.81**
	SE	0.44						
NDF, %	Rumen evacuation	65.9	4.58	6.95	58.0	72.2	0.44NS	-
	Hand clipping	65.6	2.98	4.55	60.6	70.1	-	0.44NS
	SE	1.34						
ADF, %	Rumen evacuation	36.1	2.39	6.63	32.2	38.6	0.56NS	-
	Hand clipping	36.8	2.54	6.91	32.6	40.9	-	0.56NS
	SE	0.73						
ADL, %	Rumen evacuation	6.3[a]	0.64	10.22	5.3	7.0	0.72*	-
	Hand clipping	5.5[b]	0.70	12.81	4.7	6.5	-	0.72*
	SE	0.16						
IVDMD, %	Rumen evacuation	59.5[a]	6.44	10.83	48.8	67.2	0.91**	-
	Hand clipping	57.3[b]	6.00	10.46	46.7	64.5	-	0.91**
	SE	0.84						
DMI, kg/day	Rumen evacuation	7.4[a]	2.49	37.91	4.1	14.3	0.23NS	-
	Hand clipping	6.6[b]	1.14	13.17	4.9	9.7	-	0.23NS
	SE	0.39						

[1]Pooled year one and two data (n= 10) except DMI (n = 16).

[2]Sampling strategies were hand clipping (HC) and rumen evacuation (RE).

[3]*P ≤ 0.05; **P ≤ 0.005; NS, P ≥ 0.05.

[a - b] Means in within t-test and within item followed by a different letter differ (P ≤ 0.05).

Contrary to studies that have reported greater NDF and ADF content in clipped samples relative to masticate (Dubbs et al., 2003; Hughes et al., 2010) samples, NDF and ADF contents of masticate and clipped samples in this study were similar. Differences between this and others studies could be due to clip sampling location where samples were collected in the same location as grazing animals or across pastures.

Forage NDF and ADF content increased with advancing grazing season, which previously has been reported in the northern Great Plains (Johnson et al., 1998; Cline et al., 2009; Cline et al., 2010) and reflects the association of advancing forage maturity with increased cell wall constituents (Van Soest, 1982).

Forage ADL content increased with advancing season mainly due to advancing forage maturity, which is associated with increased cell wall constituents including lignin (Van Soest, 1982). The lower ADL content in clipped relative to masticate samples was unexpected and contrary to studies (Rama Rao et al., 1973; Coffey et al., 1991) that have shown greater ADL content in clipped samples.

In vitro DMD of masticate samples was greater than IVDMD from clipped samples and the two sampling strategies were highly correlated. A similar trend was reported in bahiagrass pastures where in vitro digestible organic matter (OM) of masticate samples were greater (60 percent) than hand-clipped samples (48.7 percent; Hughes et al., 2010). Decline in IVDMD with advancing grazing season also has been reported in other studies in the northern Great Plains (Johnson et al., 1998; Cline et al., 2009; Cline et al., 2010).

Typically, nutrition of ruminants grazing rangelands is complicated by diverse plant communities, changing topography and large seasonal and yearly variations in quantity and quality of available forage (Wofford et al., 1985). Precise estimation of forage intake by cattle on pasture depends on accurate determination of consumed forage components because chemical composition of consumed forage may differ from that of available forage resulting from animal selectivity and other processes involved with ingestion and mastication (Coffey et al., 1991). This is why determining a sampling strategy that provides a reliable estimate of consumed forage is important.

Forage samples for intake estimation can be obtained by following grazing animals for short durations and sampling grazed area (Wilson et al., 2010) or through rumen evacuation (Cline et al., 2010). A comparison of the two sampling strategies in this study shows that dry-matter intakes estimated from masticate samples were greater than estimates from hand clipped samples.

As well, masticate samples showed a greater DMI range and variability relative to clipped samples, indicating the ability of rumen evacuation to capture animal differences. Clearly, forage sampling strategy during individual animal DMI estimation on pasture will have an impact on intake estimations, and use of cannulated animals for forage sampling will provide more realistic DMI estimations.

This study suggests that hand clipping can provide reasonable estimates of pasture forage quality during the grazing season, provided you account for differences in CP, ADF content and IVDMD. Further, hand clipping can be a useful strategy in simple swards while rumen evacuation may be more suitable when a wide range of pasture conditions are anticipated.

Acknowledgments

The excellent technical assistance provided by the late Rodney Schmidt, as well as Dwight Schmidt, Scott Alm, Megan Gross, Elisabeth Gnitka, Cody Wieland, Felipe Silva, Nico Negrin, Cheyanne Klein and Rick Bohn is gratefully acknowledged.

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Alfalfa Variety Trial

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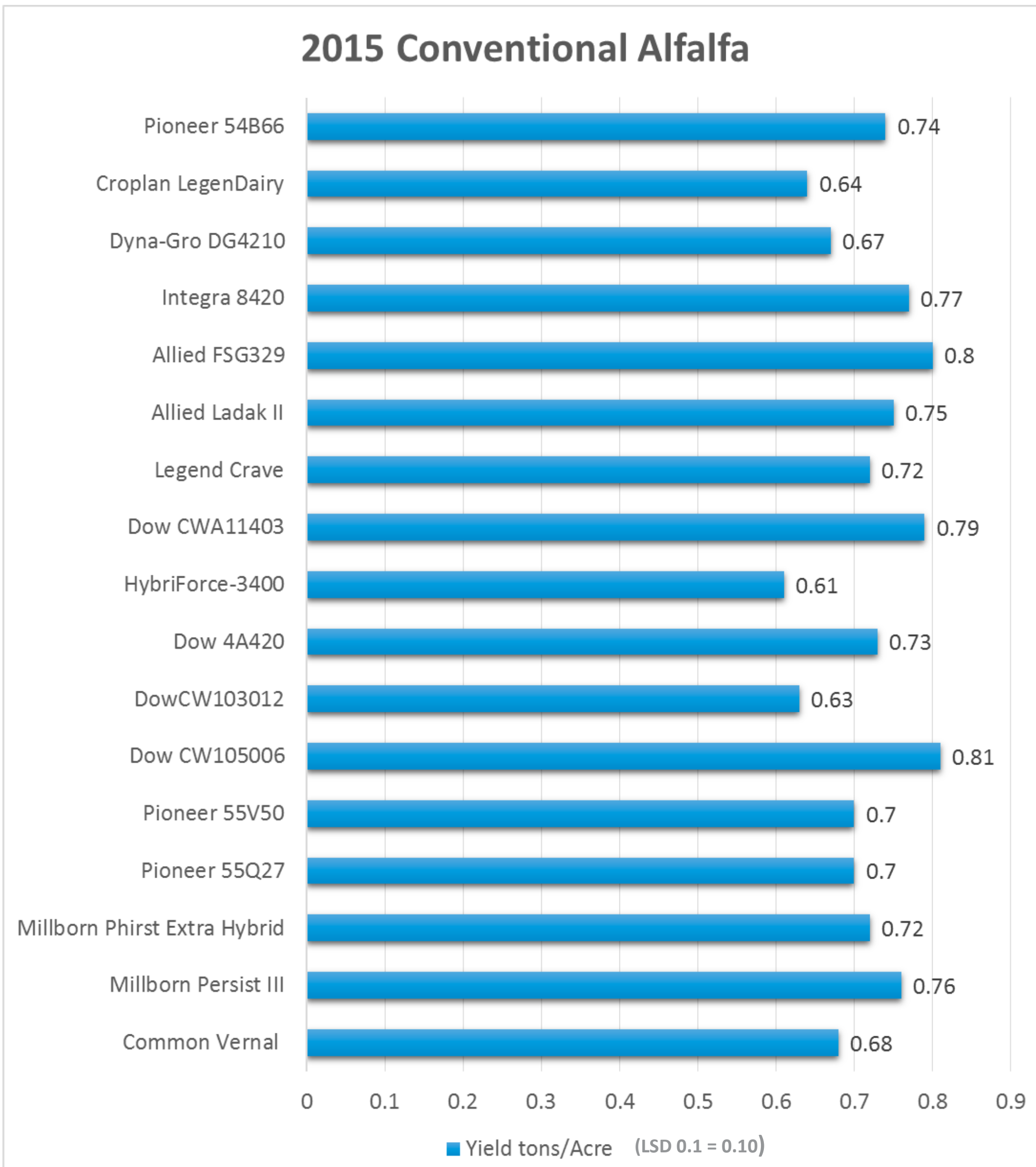
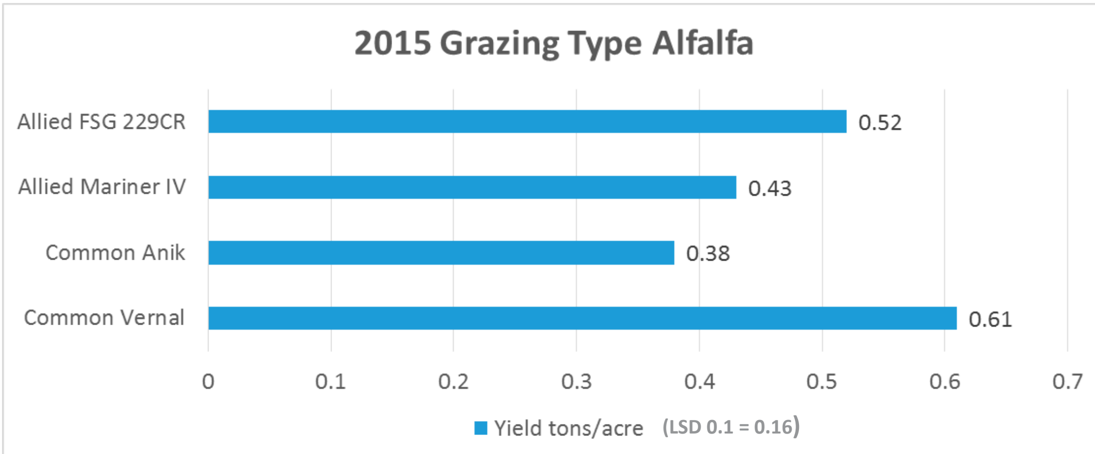
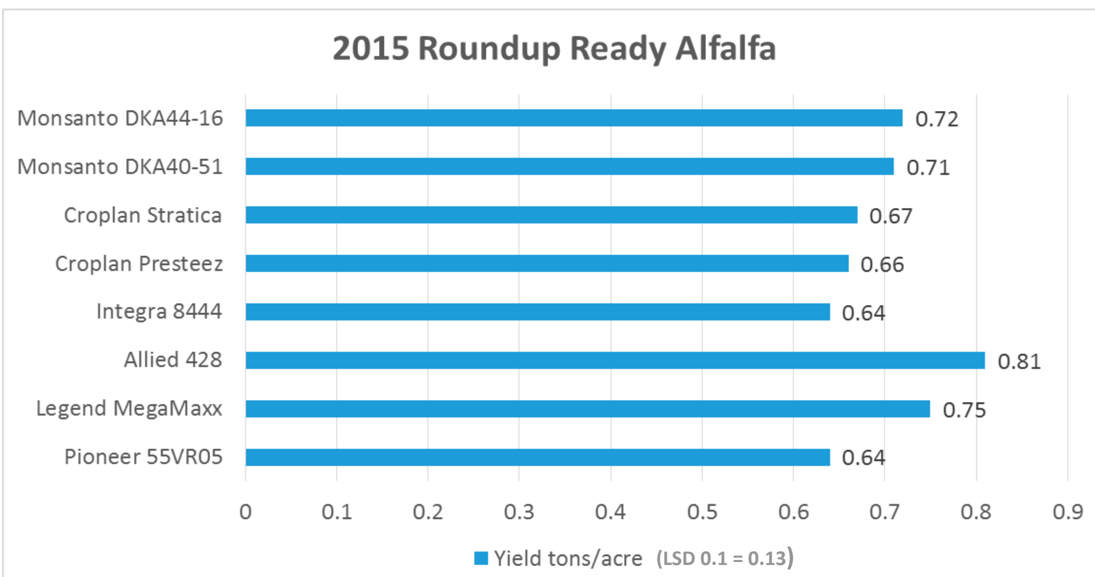
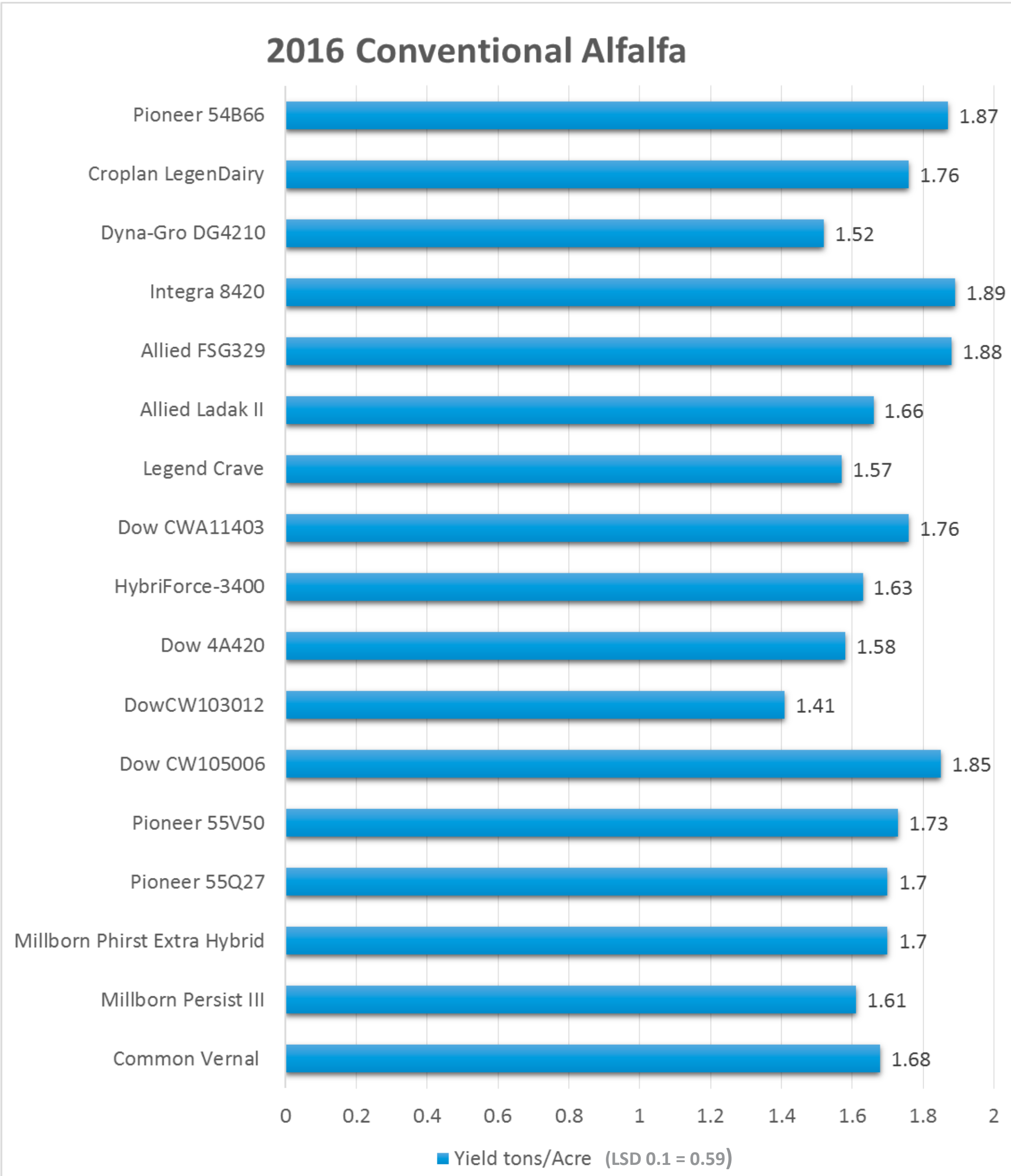
Central Grasslands Research Extension Center, Streeter, N.D.

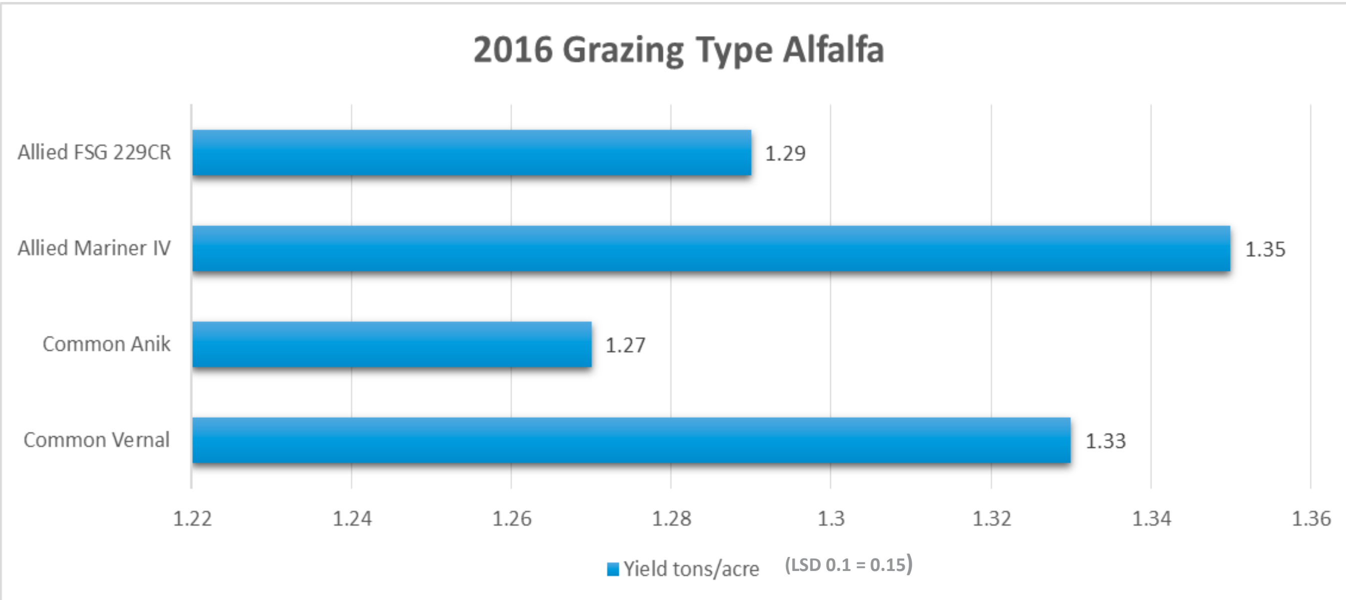
The current alfalfa variety trial being conducted at the Central Grasslands Research Extension Center contains three alfalfa classes including Conventional, Roundup Ready and Grazing type. Planted in 2015; yield is the primary interest in this trial.

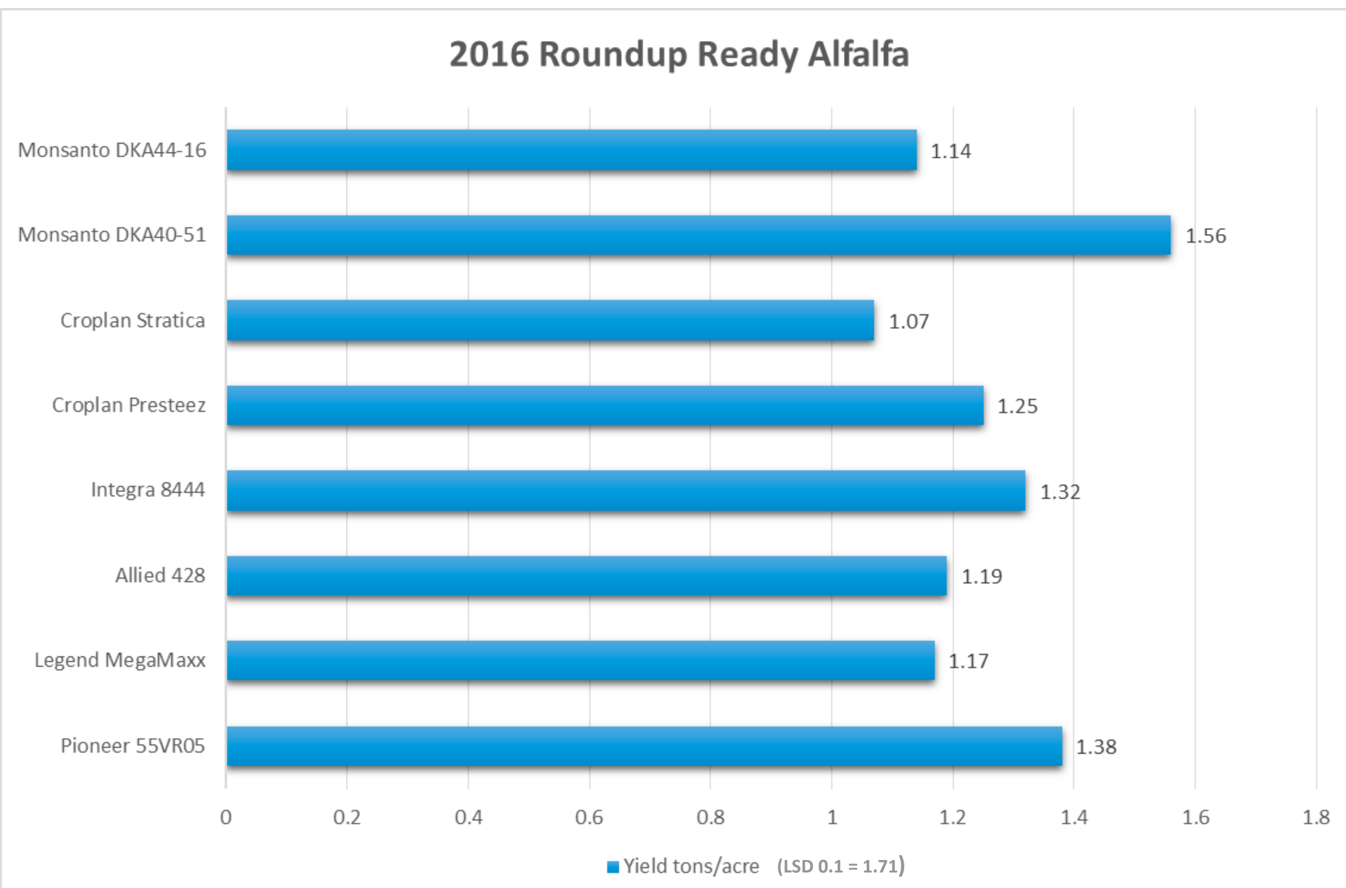


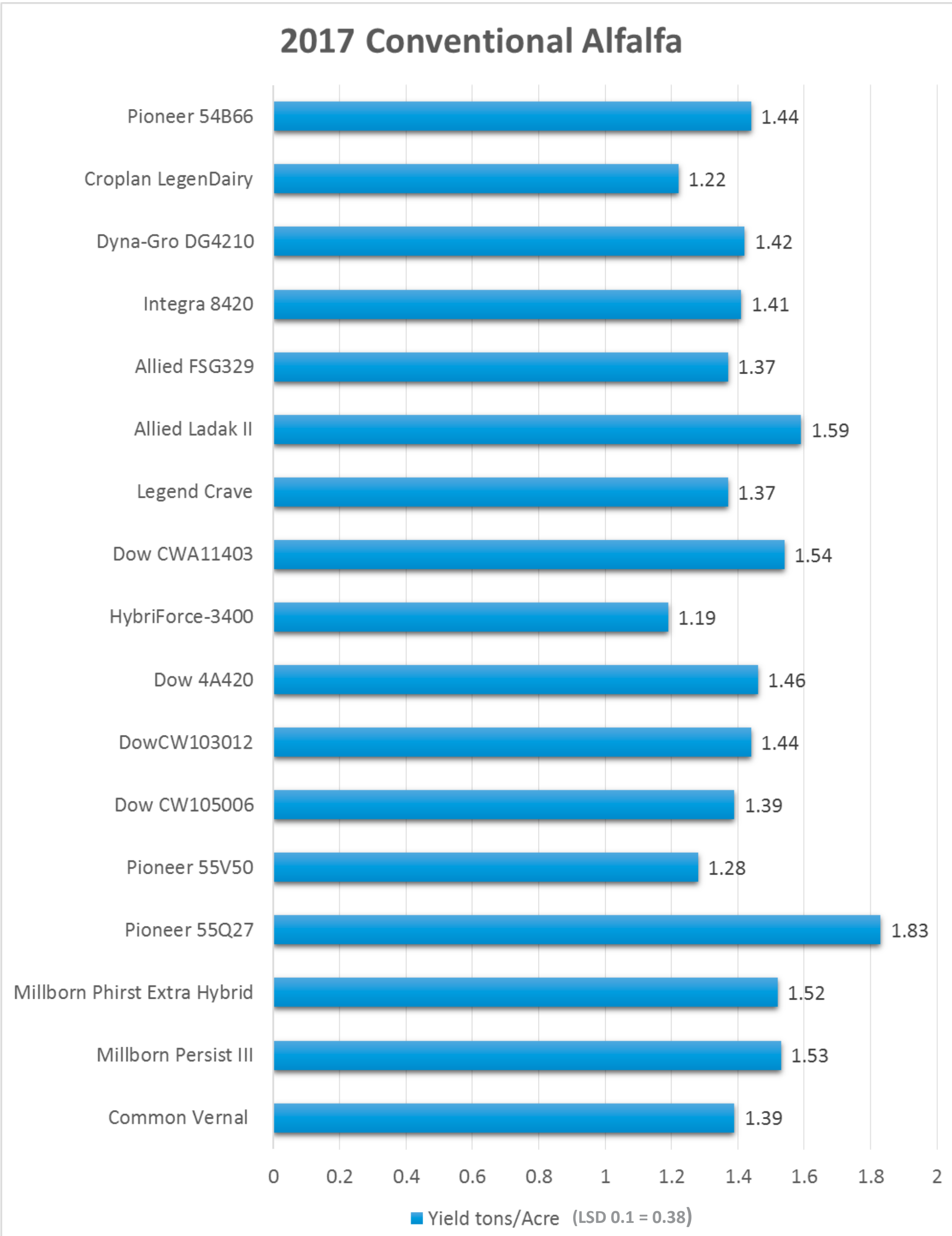

2015 Grazing Type Alfalfa
Allied FSG 229CR
Allied Mariner IV
Common Anik
Common Vernal
0.52
0.43
0.38
0.61
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Yield tons/acre (LSD 0.1 = 0.16)


2015 Roundup Ready Alfalfa
Monsanto DKA44-16
Monsanto DKA40-51
Croplan Stratica
Croplan Presteez
Integra 8444
Allied 428
Legend MegaMaxx
Pioneer 55VR05
0.72
0.71
0.67
0.66
0.64
0.81
0.75
0.64
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Yield tons/acre (LSD 0.1 = 0.13)

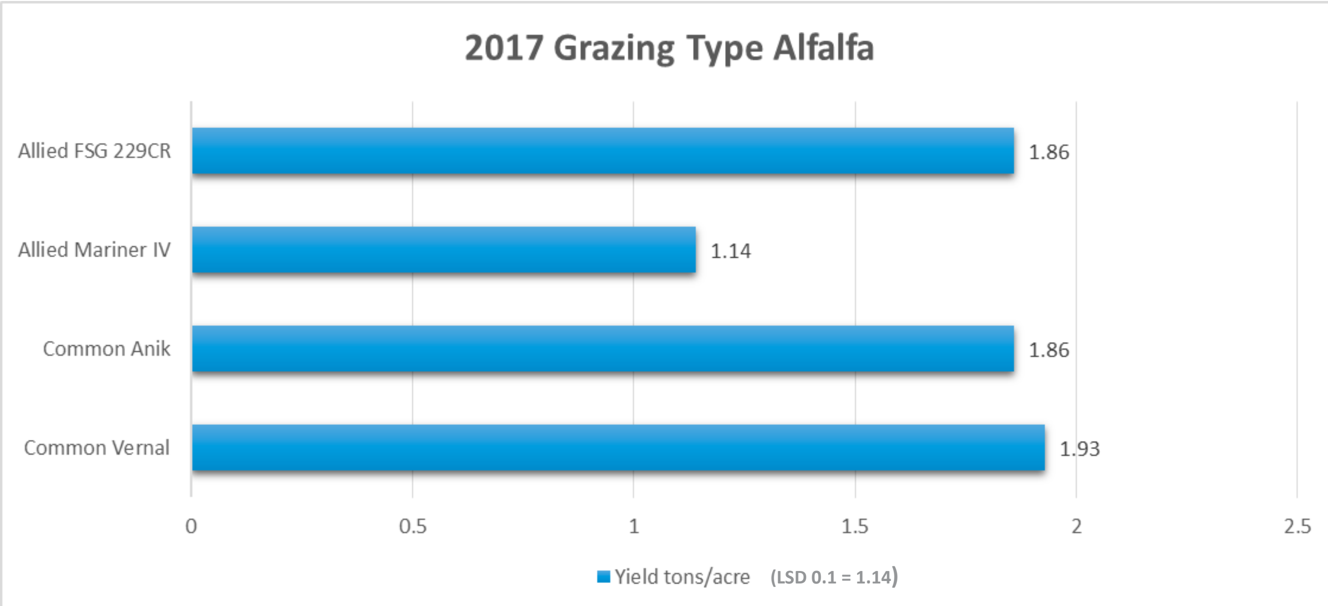

2016 Conventional Alfalfa
Pioneer 54B66
1.87
Croplan LegenDairy
1.76
Dyna-Gro DG4210
1.52
Integra 8420
1.89
Allied FSG329
1.88
Allied Ladak II
1.66
Legend Crave
1.57
Dow CWA11403
1.76
HybriForce-3400
1.63
Dow 4A420
1.58
DowCW103012
1.41
Dow CW105006
1.85
Pioneer 55V50
1.73
Pioneer 55Q27
1.7
Millborn Phirst Extra Hybrid
1.7
Millborn Persist III
1.61
Common Vernal
1.68
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Yield tons/Acre (LSD 0.1 = 0.59)

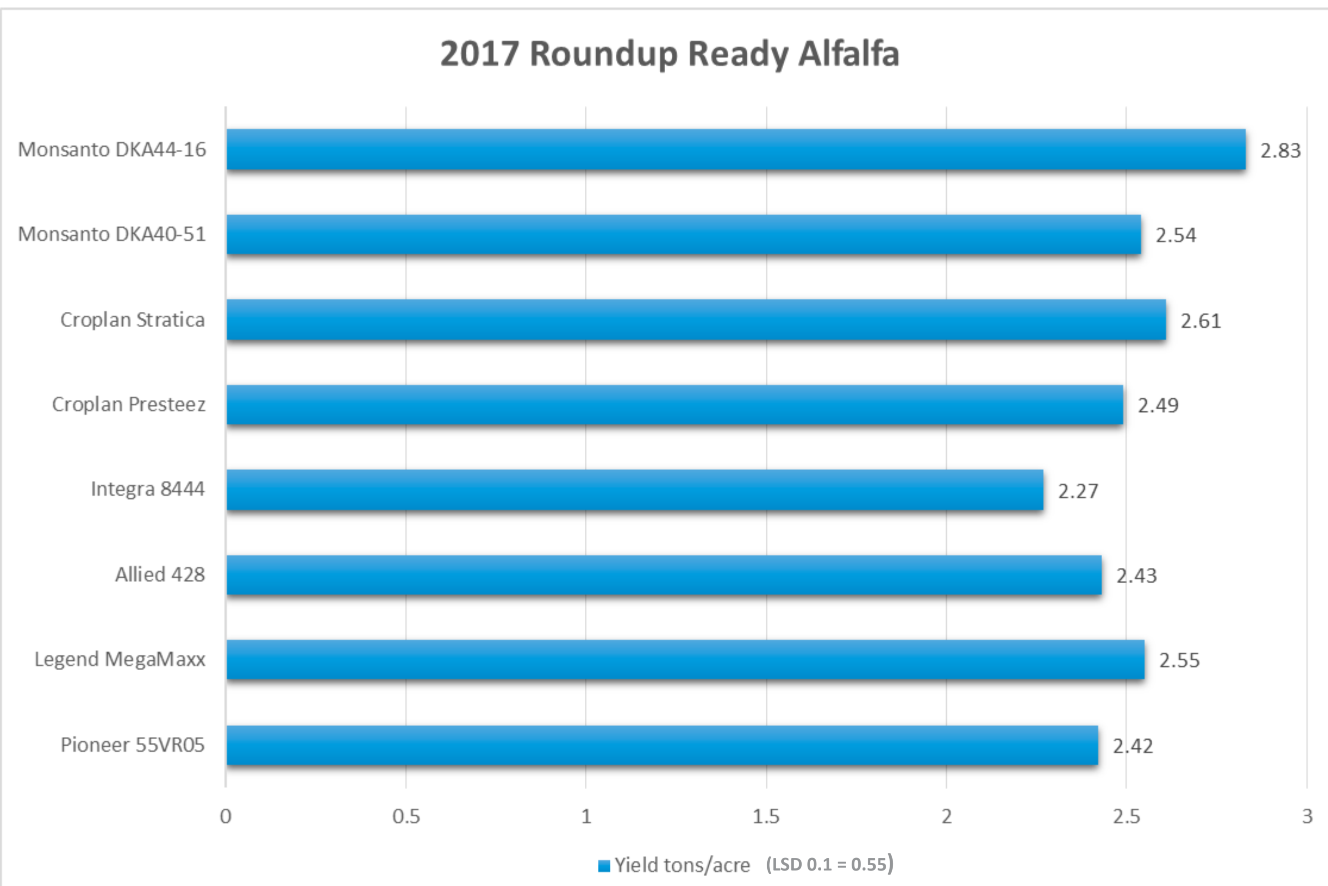

2016 Grazing Type Alfalfa
Allied FSG 229CR
Allied Mariner IV
Common Anik
Common Vernal
1.29
1.35
1.27
1.33
1.22
1.24
1.26
1.28
1.3
1.32
1.34
1.36
Yield tons/acre
(LSD 0.1 = 0.15)

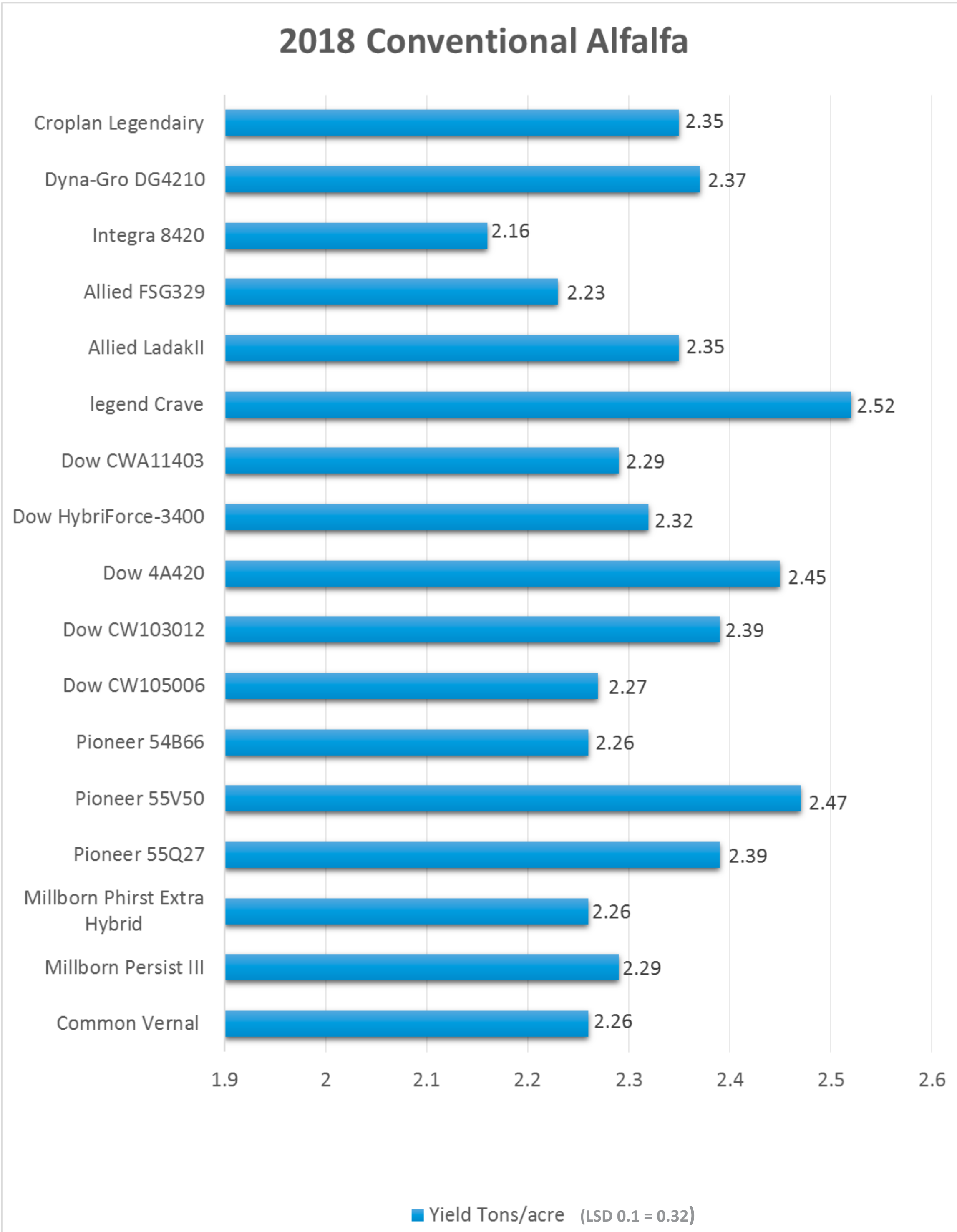

2016 Roundup Ready Alfalfa
Monsanto DKA44-16
Monsanto DKA40-51
Croplan Stratica
Croplan Presteez
Integra 8444
Allied 428
Legend MegaMaxx
Pioneer 55VR05
1.14
1.56
1.07
1.25
1.32
1.19
1.17
1.38
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Yield tons/acre
(LSD 0.1 = 1.71)



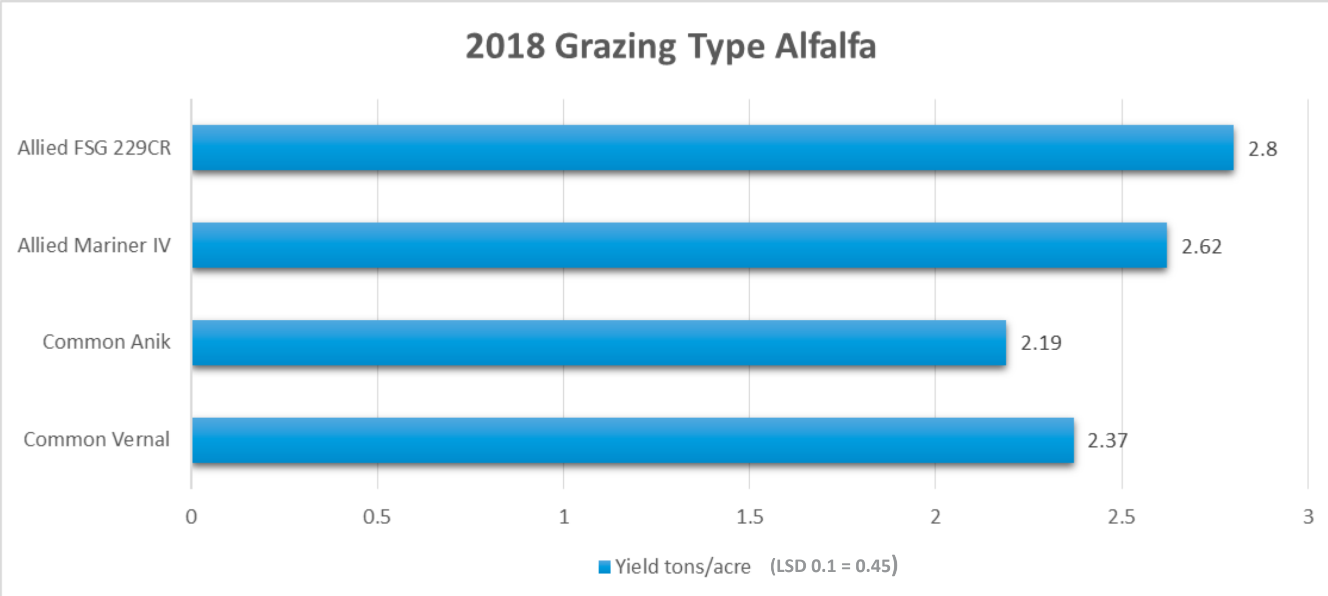
2017 Conventional Alfalfa
Pioneer 54B66
Croplan LegenDairy
Dyna-Gro DG4210
Integra 8420
Allied FSG329
Allied Ladak II
Legend Crave
Dow CWA11403
HybriForce-3400
Dow 4A420
DowCW103012
Dow CW105006
Pioneer 55V50
Pioneer 55Q27
Millborn Phirst Extra Hybrid
Millborn Persist III
Common Vernal
1.44
1.22
1.42
1.41
1.37
1.59
1.37
1.54
1.19
1.46
1.44
1.39
1.28
1.83
1.52
1.53
1.39
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Yield tons/Acre (LSD 0.1 = 0.38)


2017 Grazing Type Alfalfa
Allied FSG 229CR
Allied Mariner IV
Common Anik
Common Vernal
1.86
1.14
1.86
1.93
0
0.5
1
1.5
2
2.5
Yield tons/acre (LSD 0.1 = 1.14)

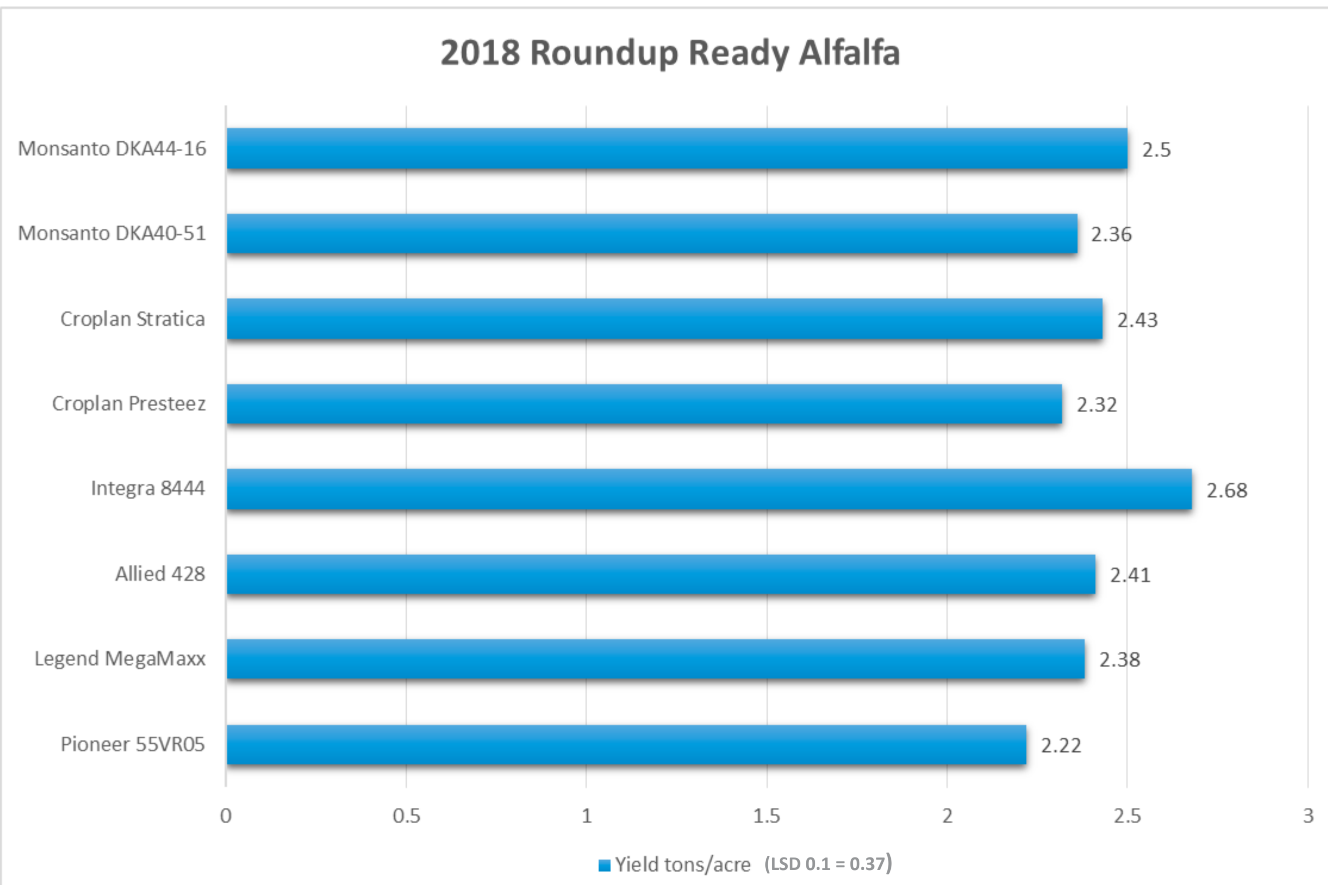

2017 Roundup Ready Alfalfa
Monsanto DKA44-16
Monsanto DKA40-51
Croplan Stratica
Croplan Presteez
Integra 8444
Allied 428
Legend MegaMaxx
Pioneer 55VR05
2.83
2.54
2.61
2.49
2.27
2.43
2.55
2.42
0
0.5
1
1.5
2
2.5
3
Yield tons/acre (LSD 0.1 = 0.55)



2018 Conventional Alfalfa
Croplan Legendairy
2.35
Dyna-Gro DG4210
2.37
Integra 8420
2.16
Allied FSG329
2.23
Allied LadakII
2.35
legend Crave
2.52
Dow CWA11403
2.29
Dow HybriForce-3400
2.32
Dow 4A420
2.45
Dow CW103012
2.39
Dow CW105006
2.27
Pioneer 54B66
2.26
Pioneer 55V50
2.47
Pioneer 55Q27
2.39
Millborn Phirst Extra Hybrid
2.26
Millborn Persist III
2.29
Common Vernal
2.26
1.9
2
2.1
2.2
2.3
2.4
2.5
2.6
Yield Tons/acre (LSD 0.1 = 0.32)



2018 Grazing Type Alfalfa
Allied FSG 229CR
Allied Mariner IV
Common Anik
Common Vernal
2.8
2.62
2.19
2.37
0
0.5
1
1.5
2
2.5
3
Yield tons/acre (LSD 0.1 = 0.45)



2018 Roundup Ready Alfalfa
Monsanto DKA44-16
Monsanto DKA40-51
Croplan Stratica
Croplan Presteez
Integra 8444
Allied 428
Legend MegaMaxx
Pioneer 55VR05
2.5
2.36
2.43
2.32
2.68
2.41
2.38
2.22
0
0.5
1
1.5
2
2.5
3
Yield tons/acre (LSD 0.1 = 0.37)

Winter Grazing Beef Cows on Swath Corn

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Corn is a high-yielding crop that can create a late-season grazing alternative by cattle grazing it as it stands or as swathed feed. We chose to swath the corn in the R3 (milk) stage to reduce the risk of founder. The study objectives were to 1) evaluate herbage production of two selected varieties, 2) compare costs of production by variety and 3) and compare livestock performance using a swath-grazing technique. The corn varieties Ray Brothers Forage Corn (BMR Forage Corn) and Canamaize CM440 Hybrid (CM440) were planted June 26 and swathed Sept. 6, 2018. Eighty -seven nonlactating pregnant Angus X cows (average turnout weight was 1,548 pounds) grazed from Nov. 26 through Dec. 18 (23 days) on 18 acres. BMR Forage Corn and CM440 produced 5.01 and 7.09 tons/acre, respectively, at a cost of $20.48 and $18.84/ton of dry matter, respectively. The cost to feed was $1.13 and $1.02/day for BMR Forage Corn and CM440, respectively. Cows lost 1.1 pounds/day during the 23 days; however, they did not lose any body condition score. The results indicate corn for late-season swatch grazing is a viable, economic alternative to the cost of dry lot feeding, which averages $1.25 per pregnant nonlactating cow at Carrington (Anderson et al., 2013).

Introduction

Corn is an option livestock producers may be interested in when looking to extend the grazing season and reduce feed costs per cow per day (Lardner et al., 2012). Advances in plant breeding have led to hybrid varieties that require less heat and contain lower lignin content, creating varieties that can be good in short growing season areas and high in palatability as standing forage.

Interest in grazing corn has increased in North Dakota; however, concerns of founder have kept many producers from grazing corn. This new interest in grazing corn led to the Central Grasslands Research Extension Center (CGREC) conducting a grazing corn study with two varieties in 2018. To reduce the risk of founder, the corn was swathed at the milk stage (R3) of development.

Procedures

The study site was an 18-acre field on the CGREC near Streeter, N.D. In late May, the field was split into two nine-acre plots. Soils comprised of a Zahl-Williams loam (82 percent) and Zahl-Max-Bowbells loam (15 percent) with slopes of 6 to 9 and 6 to 35 percent, respectively (USDA, NRCS 2019).

Prior to seeding, the site was sprayed for weeds using 1 quart/acre of Glyphosate, 1 ounce/acre of AIM EC and 6 ounces/acre of Destiny HC. Granular nitrogen (N) fertilizer (urea) was applied on May 27 at a rate of 100 pounds of urea/acre or 46 pounds of N/acre.

On June 6, two grazing corn varieties were solid-seeded using a no-till drill with 15-inch spacing. These varieties were seeded at a rate of 40,000 seeds/acre at a depth of 1.5 inches. The field was sprayed with Glyphosate on June 11 at a rate of 1 quart/acre. The varieties were BMR Forage Corn and CM440.

The corn was swathed Sept. 6 using a hay bine. The corn was in the milk R3 stage of development at the time of swathing and lay in the original position until cattle were place on the land to graze.

Precipitation

The CGREC received 18.4 inches of rainfall during the growing season (April 15 through Oct. 15, 2018), which provided excellent growing conditions (NDAWN, 2019). The long-term 30-year average annual rainfall for this time period is 14.8 inches; thus, we received 125 percent of average. Although precipitation was 44 percent of long-term average through May 15, precipitation ranged from 126 to 153 percent of the long-term average during the corn-growing period.

Methods

Forage Production

Forage production was collected at six locations evenly distributed across the plot for each corn variety just prior to swathing. Each collection site was a rectangular frame 6 feet long and two rows wide. The conversion rate for this dimension is 8.92 (8.92 times grams of forage dried to 100 percent; Meehan and Sedivec, 2017).

Corn was clipped from within the frame, bagged, weighed (to determine moisture content) and dried at 105 F for seven days. Forage production for each variety was determined by averaging the six frames.

Animal Performance

The livestock average daily gain was determined by collecting two-day weights just prior to grazing turnout and collecting a one-day weight directly after terminating the grazing. Body condition score (BCS, Encinias and Lardy, 2000) also was determined for each cow prior to the grazing turnout data and immediately after cattle were removed from the project. Body condition score was collected by two individuals and averaged. The same two people did pre- and post-scoring.

Economic Measurements

Crop production costs were calculated for each variety. A combination of actual expenses (seed, fertilizer, and herbicide), suggested retail prices for fencing and material, and custom rates for North Dakota were used (Haugen, 2017).

Results and Discussion

Yield

Each corn variety was swathed Sept. 6, 2018. Dry-matter yield was 5.01 tons/acre for the BMR Forage Corn variety and 7.09 tons/acre of the CM440 variety (Table 1). Both varieties were grazed at the same time with one herd. The BMR Forage Corn and CM440 varieties comprised 41 and 59 percent of the carrying capacity, respectively.

Grazing

Both varieties were grazed at the same time with 87 bred, non-lactating Angus X cows. These cows were in their second trimester of pregnancy. The average starting weight of the cows was 1,548 pounds and the average BCS was 6.04 (Table 1). Twenty-three days of grazing occurred from Nov. 26 to Dec. 18, 2018. Grazing termination was based on a visual estimation of 75 to 80 degrees of disappearance of the swaths. Cattle were limit fed for eight days, with the last rotation of seven days. Cattle were able to graze previous section after each move.

The average weight of the cows was 1,522 pounds at the end of the project, and the average BCS was 6.18 (**Table 1**). We found no change ($P > 0.05$) in livestock performance (average daily gain) or body condition score after 23 days of grazing.

Table 1. Forage production, pre- and post-grazing treatment for cow weight and body condition score by corn variety at the Central Grasslands Research Extension Center in 2018.

Corn Variety	Forage[1] Production (ton/ac)	Average[2] Pre-weight	Average Post-weight	Average Daily Gain	Average[2] Pre-body Condition Score	Average Post-body Condition Score	Daily Change (-/+)
BMR Forage Corn	5.01 +/- 0.43 SD[a]	1,548 +/-193 SD[x]	1,522 +/- 187 SD[x]	-1.1 lb/d	6.04 +/- 0.52 SD[x]	6.18 +/- 0.64 SD[x]	0.006
CM440	7.09 +/- 0.48 SD[b]						

[1] Varieties with same letters (a, b) are not significantly different ($P > 0.05$).
[2] Weights and body condition scores with the same letters (x, y) are not significantly different ($P > 0.05$)

Economics

Total crop expenses ranged from $102.59 to $133.59/acre (Table 2). What is important to note is that costs will vary from operation to operation. Producers are encouraged to calculate costs according to their individual situation.

The cost per cow per day was calculated by dividing the crop production costs per acre by the grazing days per acre. The cost to feed a cow in this study was $1.02 to $1.13/head/day for BMR Forage Corn and CM440, respectively (Table 2).

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Table 2. Crop production expenses by corn variety at the Central Grasslands Research Extension Center in 2018.

Expenses (per acre)	BMR Forage Corn	CM440
Seed	$29.00	$60.00
Fertilizer (100 lb urea/ac, $345/ton	$17.25	$17.25
Herbicide (1 qt/a Glyphosate, 1 oz/a AIM EC, 6 oz/a Destiny)	$10.59	$10.59
Seeding	$17.63	$17.63
Fertilizing	$6.39	$6.39
Spraying	$6.57	$6.57
Swathing	$12.54	$12.54
Portable fence with charger (pro-rated across 5-years	$2.62	$2.62
TOTAL	$102.59/ac	$133.59/ac
Grazing days/acre	91	131
$/HEAD/DAY	$1.13	$1.02

Note: Land rent is not included in the calculations above; $40/acre cash rent would increase costs by $0.43 and $0.30/head/day for **BMR Forage Corn** and **CM440,** respectively.

Conclusion

Both varieties produced good yields and were of suitable quality to meet nutrient requirements of grazing beef cows. The CM440 variety produced greater yields; however, we found no difference in livestock performance, compared with BMR Forage Corn. Swathing the corn prevented any instances of founder; the cows showed no signs of illness or founder while grazing swathed corn in the kernel blister stage.

Grazing days per acre were greater and cost/head/day lower in the **CM440** variety. Further research needs to be conducted to determine palatability, production potential and costs among new corn hybrids.

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Alternative Grazing Management Strategies Combat Invasive Kentucky Bluegrass Dominance

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Maintaining native biodiversity is essential to ensure the long-term sustainability of livestock production in the Great Plains. This is especially important in the northern Great Plains where Kentucky bluegrass (Poa pratensis, hereafter bluegrass), a cool-season invasive species, is actively displacing native prairie species with consequences for several ecosystem services.

Reducing or controlling the abundance of bluegrass is necessary to manage the deleterious effects of its invasion, but no evidence is available to recommend effective grazing management. Therefore, we examined the effects of traditional and alternative grazing management practices on bluegrass-invaded pastures.

We found that traditional season-long (SL) grazing increased the influence of bluegrass on plant community composition after four years of treatment. Two alternative management strategies, early-intensive (EI) and patch-burn (PB) grazing, on the other hand, reduced its influence without negative effects on the two most dominant native cool-season grasses or forage production.

These results suggest that livestock producers in the northern Great Plains may need to transition away from traditional grazing management to alternative strategies to combat bluegrass invasion. Moreover, our results add to the growing body of evidence supporting the use of rangeland management practices, such as patch-burn grazing, that mimic historic disturbances to promote native biodiversity.

Introduction

Kentucky bluegrass (*Poa pratensis*; hereafter bluegrass) invasion is actively reducing the abundance of native plant species and developing novel ecosystems throughout the northern Great Plains (Toledo et al., 2014). Its origin in the U.S. is not clear (Carrier et al., 1916), but bluegrass was not a part of the region's historic plant community (Barker et al., 1986).

Bluegrass is a cool-season perennial grass that begins growth in early spring and develops a dense root and thatch layer that restricts the establishment and growth of other species. Changes in vegetation structure and community composition from bluegrass invasion have developed novel ecosystems throughout the northern Great Plains that may be irreversible (Toledo et al., 2014).

The development of novel bluegrass-invaded grasslands in the northern Great Plains has gone unnoticed, likely because bluegrass can provide adequate forage for livestock production, especially during early spring and wet years (Toledo et al., 2014). However, bluegrass goes dormant with heat and water stress experienced during the summer and drought conditions (Hockensmith et al., 1997), as it does in a front lawn.

Therefore, as bluegrass increases in a pasture, the forage supply becomes increasingly susceptible to climate change and drought. A diverse prairie community, on the other hand, provides adequate forage across a wider range of conditions.

An area of a season-long (SL) grazed pasture on CGREC property that has been taken over by Kentucky bluegrass.

Grasslands managed for livestock production utilize strategic livestock grazing strategies that traditionally promote uniform distribution and forage utilization (Fuhlendorf and Engle, 2001, 2004) such as season-long (SL) or rotational grazing (Bailey et al., 1998). Uniform disturbances simplify plant community composition because they do not allow the development of areas with varying levels of disturbance intensity or frequency (Fuhlendorf and Engle, 2004).

Bluegrass increases under SL grazing regardless of grazing intensity in the absence of fire (Murphy and Grant, 2005; Limb et al., 2018), which implies that its invasion expands under uniform disturbance regimes. Combatting bluegrass invasion will require a change in grazing management practices in the northern Great Plains.

Empirical evidence is lacking at this time to suggest effective grazing management strategies for bluegrass control in the cool-season mixed-grass prairie ecoregion. Early-intensive (EI) grazing, combined with annual burning, can stabilize or decrease bluegrass populations in warm-season prairie (Smith and Owensby, 1978) and may reduce its productivity (Bryan et al., 2000) but has not been tested for bluegrass control in cool-season mixed-grass prairie.

The northern Great Plains is a fire-adapted system, and evidence suggests that fire alone has the potential to control bluegrass dominance in the tallgrass (Anderson et al., 1970) and mixed-grass prairie. However, reductions are highly dependent on precipitation and soil type (Engle and Bultsma, 1984) and are short term in mixed-grass prairie (Bahm et al., 2011; Kral et al., 2018).

Therefore, grazing bluegrass after burning with patch-burn (PB) grazing management could extend bluegrass reductions in the mixed-grass prairie, but this option remains uninvestigated.

Analyzing the effects of EI and PB grazing management strategies on bluegrass-invaded pastures of the northern mixed-grass prairie is relevant to determine if they can control bluegrass dominance where traditional SL grazing does not.

In our study, we hypothesized that traditional (SL) and alternative grazing management strategies (EI and PB) would generate differences in plant community metrics (richness, evenness and diversity), composition, bluegrass cover, cover of the two most dominant native cool-season grasses and production. Because native Great Plains plants evolved with fire and grazing (Samson et al.. 2004), we also hypothesized that alternative management would increase or maintain the cover of native cool-season grasses without reducing above-ground biomass production.

Procedures

We initiated a completely randomized design experiment in 2014 on nine approximately 40-acre bluegrass-invaded pastures with three grazing treatments each replicated three times (n = 3). Each grazing treatment involved stocking yearling mixed-breed heifers moderately at the same number of animal unit months (1.85 AUM/hectare). The experiment continued through the 2017 growing season for a total of four years of treatment.

Grazing treatments emulated practices typical of, or alternative to, those used in the northern Great Plains. Traditional grazing management involves stocking pastures for the duration of the growing season. Thus, we stocked pastures annually in early May for 12 weeks to establish a season-long (SL) grazing treatment.

Our alternative grazing management treatments consisted of early -intensive (EI) and patch-burn (PB) grazing. EI grazing involved stocking pastures at triple stock density for the first third of the growing season (four weeks, early May to early June). PB grazing combined the SL grazing strategy with a prescribed-fire regime in which we burned a different fourth (10 acres) of each PB-grazed pasture annually after a hard frost. The first fire occurred in October 2014. At the end of the study (2017), each fourth of the PB pastures had a different time-since-fire.

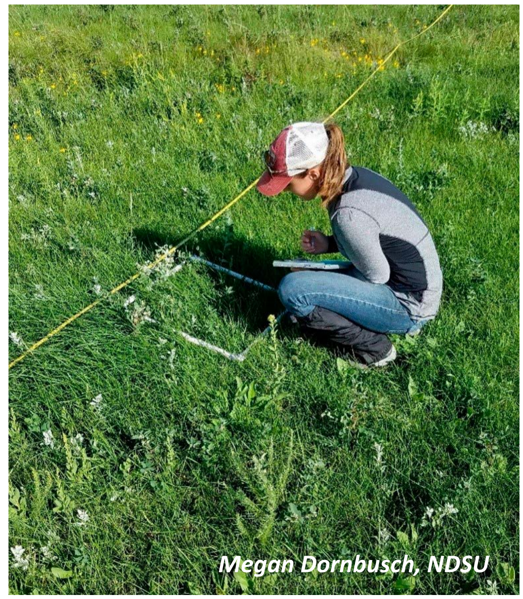
We standardized sampling intensity among pastures by arbitrarily dividing each pasture into four equal patches based on the PB treatment. Data from 2014 revealed that plant community metrics and composition were not different among treatments at the study's initiation ($p > 0.05$, data not shown). Thus, experimental plant community and forage production monitoring occurred in 2015, 2016 and 2017 to monitor for changes among treatments.

Plant Community Monitoring

To compare plant community composition among grazing treatments, we performed vegetation surveys every two meters along one 40-meter transect in each patch of every pasture (20 surveys per transect; 80 per pasture) during peak production (late July to early August). Each survey involved identifying all plant species within a 0.5- by 0.5-meter quadrat and visually estimating each species' canopy cover with a Daubenmire cover class system (Daubenmire, 1959). Plant nomenclature, status and distribution followed the U.S. Department of Agriculture's National Plant Database (USDA-NRCS 2018).

Forage Production Monitoring

We monitored forage production annually by collecting biomass samples also during peak production from three randomly placed 2- by 2-meter (m) caged grazing exclosures in each patch of every pasture (12 cages per pasture). We collected samples by clipping all standing biomass to the soil surface from one random 0.5- by 0.5-m quadrat placed within each exclosure. All samples were oven dried to constant weight.



Statistical Analyses

We determined mean species richness, evenness, Simpson's diversity and forage production (pounds per acre [lb/ac]) for each pasture and compared treatments using ANOVA and post hoc Tukey's B means separation in SPSS (Version 25; IBM Corp. 2017). We evaluated 2015 and 2016 means as trends and only tested for differences among treatment means in 2017 to allow the full implementation of the PB treatment when time-since-fire differed for each of the four patches.

We analyzed differences in plant community composition among grazing treatments within and across study years using permutation-based nonparametric multivariate analysis of variance (perMANOVA) and non-metric multidimensional scaling (NMS) procedures in PC-ORD 6.0. We also compared 2017 ordination scores and mean canopy cover of bluegrass and native cool-season grasses, green needlegrass and western wheatgrass to investigate differences among treatments.

Results

Plant Community Monitoring

We recorded 123 plant species across the study's 12 pastures throughout three years of monitoring (2015, 2016 and 2017). Grazing treatments did not differ in species richness, evenness or diversity at the end of the study (Figure 1). However, the perMANOVA analysis indicated differences across years, treatments and the year by treatment interaction.

The NMS analysis of all plant species, across all years and treatments, indicated year had the strongest influence on plant community composition, with grazing management strategy having a secondary effect. Moreover, the NMS ordination revealed that plant community composition was similar among all treatments in 2015 and 2016 but not 2017 when alternative communities separated from traditional (Figure 2a).

The perMANOVA analysis of 2017 plant species data alone confirmed a treatment effect on plant community composition at the end of the study (p = 0.01). Therefore, plant community composition shifted through time according to year and treatment (Figure 2b).

We found bluegrass within every individual quadrat each year. Our NMS analysis revealed that year primarily influenced bluegrass. while grazing strategy exerted a secondary effect. The NMS analysis of 2017 revealed that bluegrass was strongly correlated with traditional management (-0.909), while green needlegrass (0.785) and western wheatgrass (0.727) were strongly correlated with alternative management strategies upon the full implementation of the PB treatment.

Therefore, the trajectory of changes in plant community composition shifted toward bluegrass dominance with SL grazing

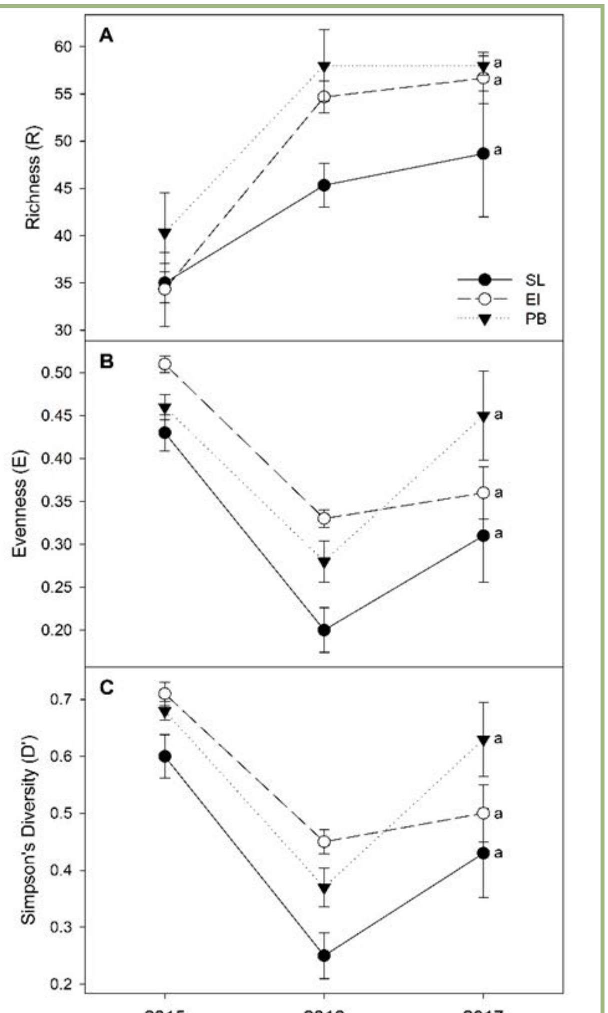


Figure 1. Richness (A), evenness (B) and Simpson's diversity (C) averages for pastures treated with season-long (SL), early-intensive (EI) and patch-burn (PB) grazing from 2015 through 2017. Note different scaling among graphs.

and shifted away with alternative EI and PB grazing strategies (Figure 2b). Likewise, bluegrass canopy cover differed among traditional and alternative grazing treatments in 2017 (p = 0.003).

Mean bluegrass cover with alternative EI and PB grazing management was approximately 18 and 21 percent lower than the traditional SL grazing treatment mean (48 percent), respectively (Figure 3a). Across years, trends reveal that bluegrass cover was highest for each individual treatment in 2016 when precipitation was above average (Figure 3a). Interestingly, bluegrass cover in 2017 was similar to 2015 levels in PB and EI grazed pastures but was approximately 160 percent greater than 2015 levels in SL-grazed pastures.

In contrast, grazing treatments did not differentially influence the canopy cover of the two most dominant native cool-season grasses or forage production at the study's end. Canopy cover of green needlegrass (Figure 3b) and western wheatgrass (Figure 3c) did not differ among treatments in 2017.

Above-ground biomass production followed the same trend (Figure 4). Production was highest with above-average (2016) and lowest with below-average (2017) annual precipitation (Figure 4).

Discussion

Kentucky bluegrass invasion is actively developing novel ecosystems in northern Great Plains grasslands with consequences for several ecosystem services (Toledo et al., 2014). Little evidence is available to recommend best management practices for bluegrass-invaded rangelands, so we compared vegetation responses to traditional (SL grazing) and alternative grazing management strategies (EI and PB grazing) in the northern Great Plains.

With regard to controlling bluegrass invasion, we found that traditional management increased the influence of bluegrass on community composition through time, while alternative management did the opposite and increased the influence of other species, including oval-leaf milkweed (*Asclepias ovalifolia*), bearded wheatgrass (*Elymus caninus*) and needle and thread (*Hesperostipa comata*).

Interestingly, we did not observe differences among grazing strategies in richness, evenness or diversity indices at the end of the study (Figure 1), but we did see changes in community composition (Figure 2). Growing-season precipitation drives grassland composition and production (Biondini et al., 1998). Accordingly, shifts in plant community composition were influenced primarily by year-to-year variation, with treatment having a secondary effect.

Community composition changed the most for PB, followed by EI grazing, and least for SL grazing through time (Figure 2b). SL grazing increased the influence of bluegrass on community composition, whereas EI and PB decreased it. Our study agrees with others that SL grazing increases bluegrass abundance (Figure 3a) (Murphy and Grant, 2005; Limb et al., 2018), which likely amplified its influence on plant community composition in our study.

EI grazing reduces the early productivity of bluegrass (Bryan et

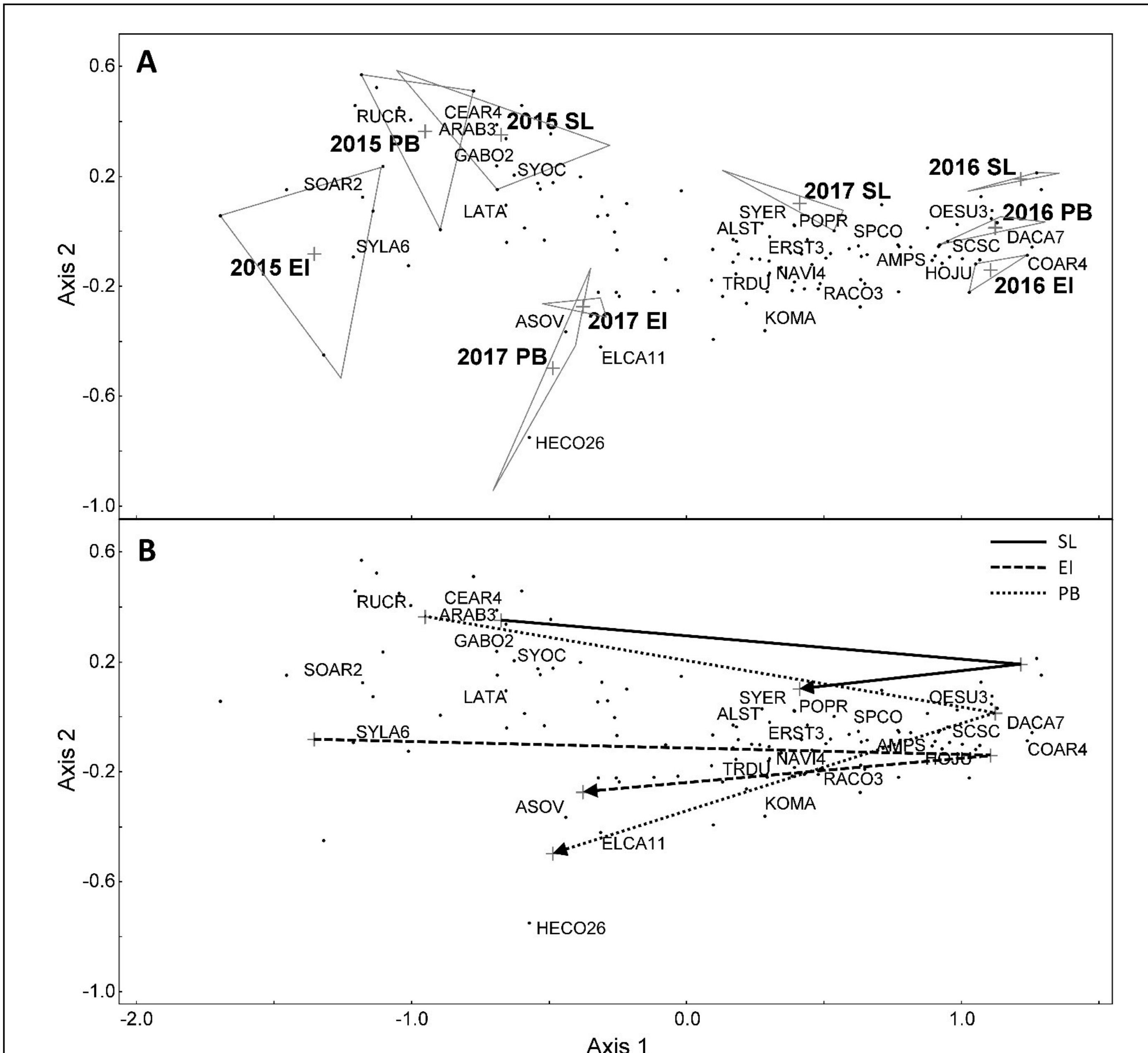


Figure 2. NMS ordination of plant community composition with all species found across all years for pastures treated with season -long (SL), early intensive (EI) and patch-burn (PB) grazing. *Triangles* represent average plant composition for each treatment by year (A) and *vectors* represent the trajectory of changes in plant composition through time for each treatment (B). *Points* represent individual plant species.

Symbol	Scientific name	Common name
ALST	*Allium stellatum*	wild prairie onion
AMPS	*Ambrosia psilostachya*	western ragweed
ARAB3	*Artemisia absinthium*	wormwood
ASOV	*Asclepias ovalifolia*	oval-leaf milkweed
CEAR4	*Cerastium arvense*	field chickweed
COAR4	*Convolvulus arvensis*	field bindweed
DACA7	*Dalea candida*	white prairie clover
ELCA11	*Elymus caninus*	bearded wheatgrass
ERST3	*Erigeron strigosus*	daisy fleabane
GABO2	*Galium boreale*	northern bedstraw
HECO26	*Hesperostipa comata*	needle and thread
HOJU	*Hordeum jubatum*	foxtail barley
KOMA	*Koeleria macrantha*	prairie Junegrass

Symbol	Scientific name	Common name
LATA	*Lactuca tatarica*	blue lettuce
NAVI4	*Nassella viridula*	green needlegrass
OESU3	*Oenothera suffrutescens*	scarlet gaura
POPR	*Poa pratensis*	Kentucky bluegrass
RACO3	*Ratibida columnifera*	upright prairie coneflower
RUCR	*Rumex crispus*	curly dock
SCSC	*Schizachyrium scoparium*	little bluestem
SOAR2	*Sonchus arvensis*	field sowthistle
SPCO	*Sphaeralcea coccinea*	scarlet globemallow
SYER	*Symphyotrichum ericoides*	white heath aster
SYLA6	*Symphyotrichum lanceolatum*	white panicle aster
SYOC	*Symphoricarpos occidentalis*	western snowberry
TRDU	*Tragopogon dubius*	yellow goat’s beard

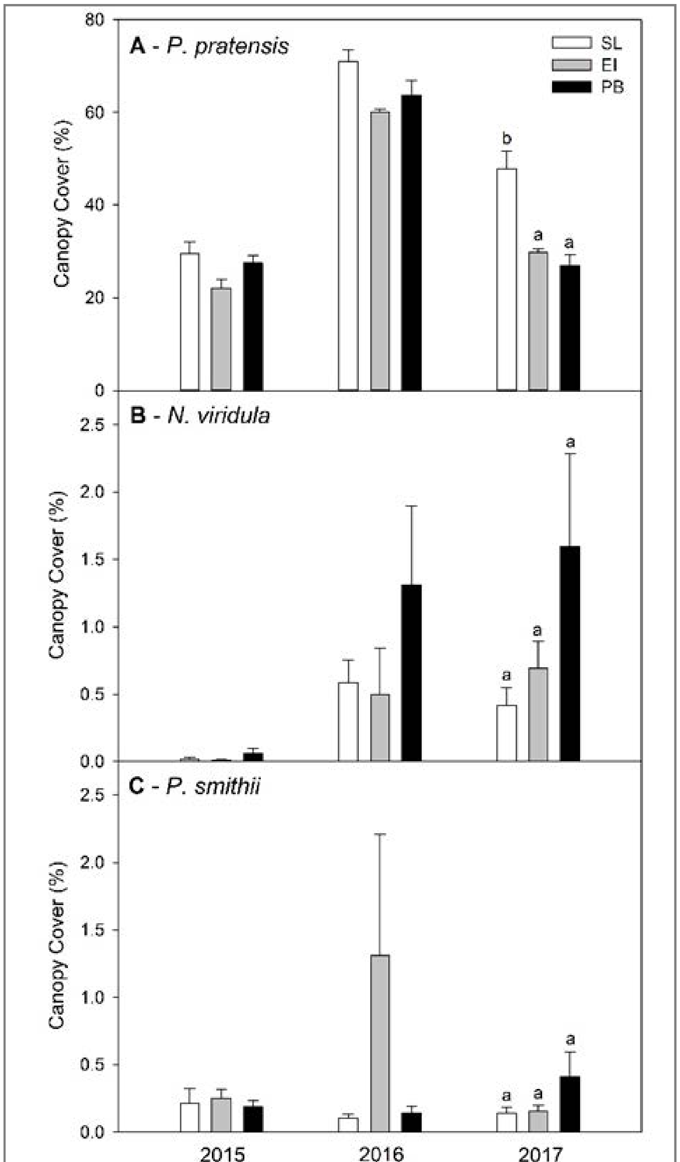


Figure 3. Mean canopy cover of invasive Kentucky bluegrass (*Poa pratensis*) (A), green needlegrass (*Nassella viridula*) (B) and western wheatgrass (*Pascopyrum smithii*) (C) of pastures treated with season-long (SL), early-intensive (EI) and patch-burn (PB) grazing.

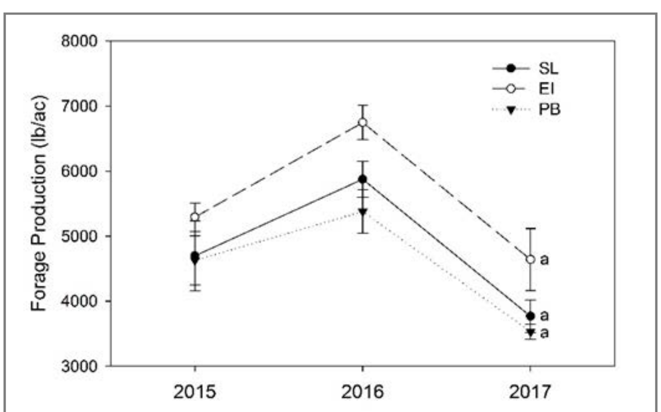


Figure 4. Mean forage production (measured as annual above-ground biomass production) of pastures treated with season-long (SL), early-intensive (EI) and patch-burn (PB)

al., 2000), and increased grazing intensity reduces dead biomass accumulation (Biondini et al., 1998). Thus, EI grazing may have stunted the early growth of bluegrass and limited its ability to establish a thickened thatch layer before the emergence of native species.

Burning also releases native plants from the inhibitory effects of bluegrass by removing accumulated thatch (Kral et al., 2018), and regrowth increases grazing pressure in recently burned patches (Fuhlendorf and Engle, 2004). Thus, we propose that increased grazing intensity following prescribed burning may have limited thatch accumulation post-fire and continued to release more later-emerging species from its inhibiting effects. Therefore, grazing after burning may decrease the influence of bluegrass on composition throughout more of the growing season and following seasons than burning alone.

Four years of treatment did not elicit differences among grazing treatments in the cover of green needlegrass or western wheatgrass at the end of the study (Figure 3b,c). Native mixed-grass prairie species evolved with variations in climate, fire and grazing (Fuhlendorf and Engle, 2001), so no effect or an increasing effect was expected. Although not significant, observed differences in their cover in 2017 warrants further investigation into the potential for both species to increase during extended periods of time with PB grazing management.

Year-to-year variation strongly influenced bluegrass cover, with treatment exerting a secondary influence through time (Figure 3a). Above-average precipitation in 2016 likely elicited an increase in bluegrass cover in all treatments by intensifying its rhizome production more than native species (Dong et al., 2014). Notably, bluegrass cover returned to first-year levels under EI and PB grazing the following year, while it remained high under SL grazing (Figure 3a).

Grazing during drought can reduce the growth potential and vigor of bluegrass (Dong et al., 2014). Below-average precipitation in 2017 may have provided a competitive advantage for native plants that were released from bluegrass inhibition with burning (Kral et al., 2018) and EI grazing (Biondini et al., 1998).

We also found that patch burning did not differentially influence average above-ground biomass production in grazing exclosures at the end of our study (Figure 4). Therefore, patch burning mixed-grass prairie invaded by bluegrass neither reduced nor increased average annual forage availability for livestock after four years of treatment.

Management Implications

Our study suggests that transitioning away from traditional SL grazing management to alternative strategies may be necessary to combat bluegrass invasion in the northern Great Plains. Alternatives PB and EI grazing, however, may affect livestock production differently, although they had similar effects on plant community metrics in our study. Studies have revealed that EI grazing management results in decreased livestock weight gains (Grings et al., 2002), while PB grazing weight gains are unchanged or improved (Limb et al., 2011), as compared with weight gains associated with SL grazing in mixed-grass prairie.

The fact that average above-ground biomass production was not affected by patch burning in our study also attests to the resilient nature of the mixed-grass prairie to fire. Patch burning can increase the consistency in above-ground biomass production across years (McGranahan et al., 2016), which will become increasingly important for producers as climate change continues to alter precipitation patterns (Alexander et al., 2006).

Additional research is necessary to confirm these findings through extended timespans and identify management specifics in bluegrass-invaded mixed-grass rangelands. Nevertheless, our results join a growing body of evidence that suggests PB grazing is a viable management strategy that can meet economic and biological objectives simultaneously in fire-dependent grassland ecosystems such as those invaded by bluegrass in the northern Great Plains (DeKeyser et al., 2013).

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Fuel Characteristics of a Kentucky Bluegrass Monoculture Indicate Potential Changes in Invaded Fuel Beds

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Land managers are increasingly restoring natural fire regimes using prescribed fire to promote native species in invaded grasslands. Exotic grass invasions can transform fuel characteristics and alter fire behavior in grasslands, but possible changes associated with Kentucky bluegrass (Poa pratensis, hereafter bluegrass) invasion in the northern Great Plains remain unknown. A hallmark of bluegrass invasion is the development of a thickened thatch layer of dead plant material on the soil surface. Surface fuels, like those of rangeland ecosystems, are regarded as having uniform fuel arrangement. This may not be the case with bluegrass invasion because thatch appears visually denser than standing fuels above it. Therefore, we conducted a field study to quantify the fuel characteristics of a bluegrass monoculture in the northern Great Plains. Our aim was to determine if bluegrass thatch and standing bluegrass fuels are different fuel components by comparing their bulk density and fuel moisture content under wet and dry environmental conditions.

We found that bluegrass thatch was denser and drier than standing bluegrass fuels regardless of environmental conditions. Furthermore, prevailing environmental conditions influenced the fuel moisture content of thatch but not standing bluegrass fuels. Thatch moisture content also was less affected by hourly changes in relative humidity than standing bluegrass fuels. Therefore, bluegrass thatch and standing bluegrass fuels possess different fuel characteristics, and bluegrass invasion likely is altering fuel arrangement in the northern Great Plains. Land managers need to be aware of these differences because they have the potential to affect fire behavior differently during prescribed burn operations.

Introduction

Frequent fires of varying intensity, scale and origin formed and maintained North American rangelands (Axelrod, 1985). Alterations to natural fire regimes since European establishment have reduced and simplified the face of rangeland ecosystems (Samson and Knopf, 1994).

Invasive species, among other anthropogenic alternations, are further altering rangelands and reducing native biodiversity (Twidwell et al., 2016). In severe cases, novel ecosystems have emerged with no historical precedent to guide management (Hobbs et al., 2009). Managers are increasingly recognizing the importance of restoring natural fire regimes for biodiversity conservation, but many questions remain regarding specific effects and proper implementation (Driscoll et al., 2010).

Prescribed fire is a cost-effective tool that managers can use to impose a fire regime (Kelly et al., 2015). Predicting fire behavior is necessary for safe and effective management (Johnson and Miyanishi, 1995) and requires an understanding of the effects of invasive species on fuel characteristics. Research has documented the effects of exotic species changes in fuel arrangement of canopy fuels (biomass that's at least 2 meters above the ground, as in forests) but not North American surface fuels, such as those found in rangelands, to our knowledge.

Fuel particles are considered uniformly arranged, or evenly distributed, throughout rangeland fuel beds in North American fuel models. This does not account for changes in litter. Increased litter, also known as thatch, associated with Kentucky bluegrass (*Poa pratensis*; hereafter bluegrass) invasion is developing novel ecosystems in the northern Great Plains and displacing native prairie species (Toledo et al., 2014).

Thatch is a tightly interwoven layer of dead plant material that lies between the soil surface and plant canopy. Thatch not only reduces light penetration of the understory but also acts as a buffer that moderates environmental conditions experienced at the soil surface (Murray and Juska, 1977).

Differences in fuel particle distribution in bluegrass-invaded rangelands appear substantial as thatch accumulates but have not been quantified. Therefore, bluegrass invasion provides a relevant case study to test for alterations in fuel arrangement in a rangeland ecosystem.

The purpose of this study was to investigate Kentucky bluegrass (*Poa pratensis*; hereafter bluegrass) invasion in the northern Great Plains as a model of an invasive exotic grass potentially altering surface fuel arrangement. In a bluegrass monoculture on idle rangeland, we quantified fuel characteristics separately for bluegrass thatch and standing bluegrass fuels.

Our objectives were to compare their average bulk densities, moisture content under wet and dry conditions, and the influence of hourly changes in relative humidity (RH) on their moisture content under different prevailing conditions. This information can help improve fire behavior predictions and enhance the restoration of natural fire regimes for biodiversity conservation in novel ecosystems such as those invaded by bluegrass.

Methods

We quantified fuel bed characteristics in a bluegrass monoculture on idle rangeland at the Central Grassland Research Extension Center (CGREC) during the 2017 and 2018 growing seasons. We selected a 20– by 20-meter (m) fenced site excluded from grazing for the previous three years where bluegrass dominated the community composition. On each of four different days, we collected bluegrass thatch and standing bluegrass fuels as separate fuel sample types. Fuels were sampled during wet and dry conditions during the growing season.

We collected wet samples immediately following precipitation events in excess of 0.5-inch in total and dry samples when the site received less than 0.5-inch total precipitation during the previous 72 hours. Data collection occurred on the following dates: Aug. 3, 2017 (wet); May 27, 2018 (dry); July 4, 2018 (wet); and Aug. 17, 2018 (dry). We retrieved all weather data from the Streeter (6NW), N.D., Agricultural Weather Network station (NDAWN, 2018).

Thatch sample collection in an idle bluegrass monoculture.

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Sampling began the hour of sunrise (dry) or the hour after precipitation ceased (wet) and ended the hour of sunset on each of the four sampling days. Grasses are classified as one-hour fuels because they are less than 1/4 inch in diameter. Thuse, we collected hourly samples because the moisture content of one-hour fuels is expected to change hourly with corresponding changes in relative humidity (RH) (Rothermel, 1972).

We sampled bluegrass thatch and standing bluegrass fuels separately each hour from 10 random points characterized by a bluegrass monoculture. At each point, we sampled standing bluegrass fuel by measuring the height of and clipping all aboveground biomass (including live and dead fuels) to the top of the thatch layer within a 10.8-centimeter (cm) diameter area.

We then cut a 10.8-cm diameter thatch-fuel core from the same point, measured thatch depth and separated thatch (including live and dead material) from the mineral soil. All samples were placed immediately in plastic bags and weighed wet, and then were oven dried to constant weight and weighed dry.

Approximately 6.5-inch-deep Kentucky bluegrass (*Poa pratensis*) thatch sample collected during the 2018 growing season.

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Statistical Analyses

To accomplish our first objective, we calculated bulk density for each fuel sample type by dividing dry weight (g) by volume (cm^3, calculated as a cylinder with a 10.8-cm diameter and height determined by height of the respective sample). We measured bulk density because it influences the oxygen supply available for combustion and, therefore, can affect fire behavior (Rothermel, 1972).

Bulk density measurements were averaged for each sampling day, regardless of environmental conditions, because moisture content has no influence on this measurement. Thus, this analysis included four repetitions (n = 4). We tested for differences in the bulk density of bluegrass thatch and standing bluegrass fuels with one-way analysis of variance (ANOVA) procedures in the IBM-SPSS Statistics software package (Version 25; IBM Corp.).

Next, we determined percent fuel moisture for each fuel sample type with the following formula: [(wet weight – dry weight)/dry weight] × 100. Fuel moisture is influenced by environmental conditions, and our second objective was to test for differences in fuel moisture content between bluegrass thatch and standing bluegrass fuels.

Therefore, fuel moisture content for each fuel sample type was averaged within environmental conditions, so we analyzed two repetitions (n = 2) for samples collected on wet and dry days. We used ANOVA procedures and Tukey's B mean separation in the IBM-SPSS Statistics software package (Version 25; IBM Corp.) to compare averages across fuel sample types and conditions.

Finally, we used regression analysis to test for differences among fuel sample types in their relationship between fuel moisture content and hourly RH on wet and dry days. All observations (10 samples of each fuel type collected hourly) were treated as independent samples. Hourly RH values were obtained from the

Streeter (6NW), N.D., Agricultural Weather Network station (NDAWN 2018).

We used regression analysis (IBM-SPSS Version 25; IBM Corp.) to determine the strength of the relationship (r^2) between relative humidity (RH) and fuel moisture for bluegrass thatch and standing bluegrass fuels under wet and dry conditions. A significant regression slope indicated a relationship between fuel moisture (dependent variable) and RH (independent variable).

Results

Bulk density and moisture content differed between bluegrass thatch and standing bluegrass fuels. Bluegrass thatch had approximately 290 times the bulk density of standing bluegrass fuels (Figure 1).

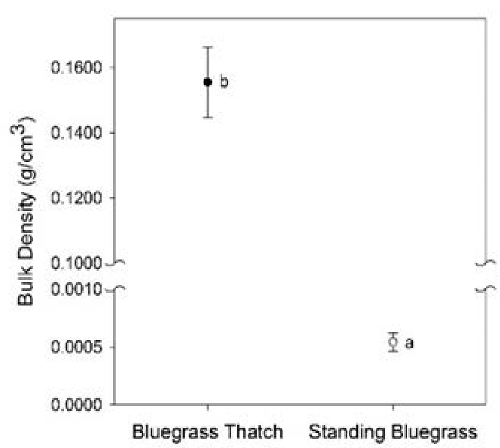

Figure 1. Bluegrass thatch and standing bluegrass fuel mean bulk density (g/cm3, n = 4 daily averages) of an idle bluegrass monoculture sampled on four random days (n = 4). Note the y-axis break and different scaling pre- and post-break.

Moisture content differed among fuel types under both environmental conditions, and the difference was more pronounced under dry (34.11 ± 1.10 percent) than wet conditions (15.53 ± 1.15 percent) (Figure 2). Wet conditions resulted in higher bluegrass thatch moisture than dry conditions, while conditions (wet or dry) did not influence average standing bluegrass fuel moisture (Figure 2).

The data revealed a positive relationship between fuel moisture content and RH for bluegrass thatch and standing bluegrass fuels under wet and dry conditions (Figure 3). Moisture content of both fuel types declined throughout the day as RH declined. The relationship was strongest for bluegrass thatch ($r^2 = 0.33$) and standing bluegrass fuel moisture ($r^2 = 0.34$) under wet conditions (Figure 3a).

The data also revealed a stronger influence of RH on standing fuel moisture than thatch fuel moisture in both scenarios (Figure 3b). Moreover, standing fuel moisture changed at a rate that was 187 and 420 percent that of bluegrass thatch under wet and dry conditions, respectively. Thatch fuel moisture was nearly constant under dry conditions (Figure 3b).

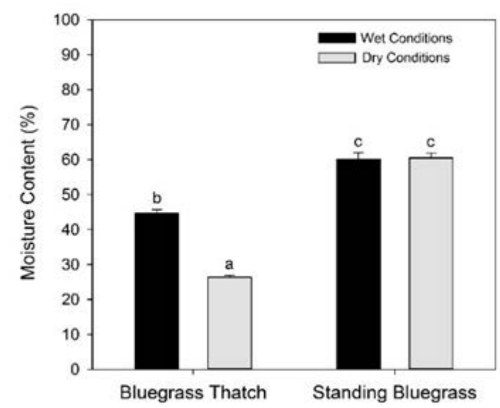

Figure 2. Bluegrass thatch and standing bluegrass fuel mean moisture content (%) under wet and dry conditions (each

Discussion

Effective restoration of fire regimes in fire-prone grassland ecosystems can aid efforts to control invasive species spread and maintain native biodiversity (Kelly et al., 2015). However, invasive species can complicate the success of prescribed burn management where they alter fuel bed characteristics (D'Antonio and Vitousek, 1992; McGranahan et al., 2012). Bluegrass invasion in the northern Great Plains is developing a thickened thatch layer on the soil surface, but research has not investigated its influence on fuels, fire behavior or prescribed fire management (Toledo et al., 2014).

Our results indicate that bluegrass thatch and standing bluegrass fuels differ in bulk density, moisture content and their fuel moisture relationship with hourly RH. Consequently, our results may be the first to suggest that an exotic grass invasion has the potential to alter fuel arrangement in a rangeland ecosystem.

We found that bluegrass thatch was roughly two orders of magnitude more dense than standing bluegrass fuels (Figure 1), indicating lower oxygen concentration for combustion in bluegrass thatch. North American surface fuel models assume that fuel particles are uniformly distributed throughout the fuel bed (Rothermel, 1972; Pastor et al., 2003), but our findings provide no support for this assumption in idle bluegrass-invaded rangelands. Thus, we propose that bluegrass likely is altering fuel arrangement where it has invaded rangelands through the development of a thickened thatch layer.

Fire spread declines as bulk density of a fuel bed increases, while maximum temperature and burning time increase (Grootemaat et al., 2017). The percentage of fuel combustion also declines as fuels become more tightly packed (Gillon et al., 1995). Therefore, bluegrass thatch may burn slower and longer than standing bluegrass fuels and its combustion may be limited as its density increases.

The moisture content of bluegrass thatch was always less than that of standing fuels, regardless of environmental conditions (Figure 2). We also found that as RH declines throughout the day, the moisture content of standing bluegrass fuels declines nearly twice as fast as bluegrass thatch under wet conditions (Figure 3a).

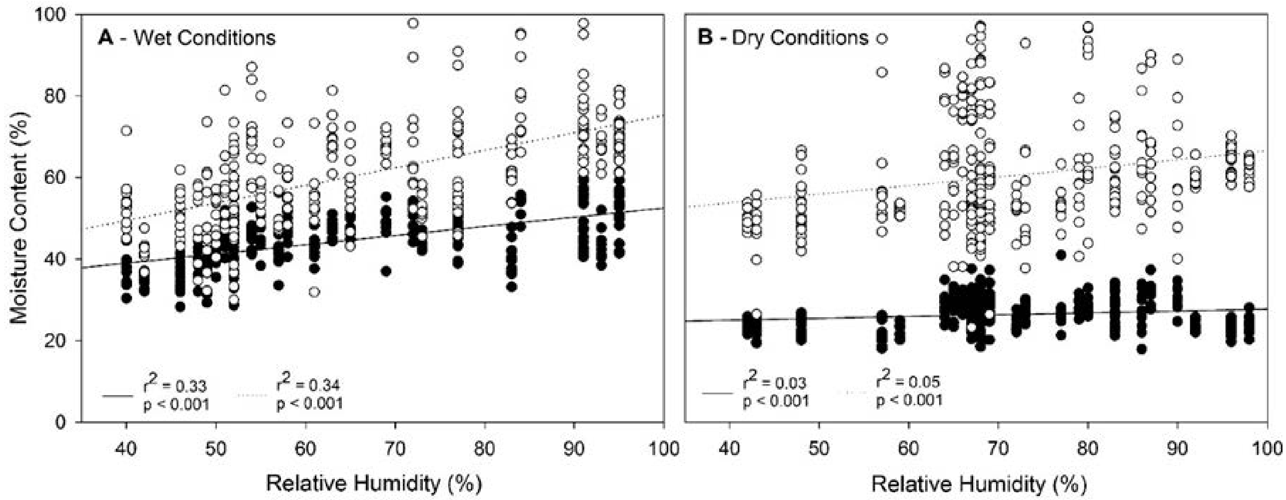

Figure 3. Fuel moisture content of bluegrass thatch and standing bluegrass fuels along a gradient of relative humidity (RH) in a bluegrass monoculture under wet (A) and dry (B) growing season conditions. Solid circles and solid lines represent bluegrass thatch, while open circles and dashed lines represent standing bluegrass fuels (wet, bluegrass thatch y = 30 + 0.23x; wet, standing bluegrass y = 32.31 + 0.43x; dry, bluegrass thatch y = 12.17 + 0.05x; dry, standing bluegrass y = 45.3 + 0.21x).

Moreover, RH had almost no influence on the moisture content of bluegrass thatch during dry conditions (Figure 3b).

Minor changes in fuel moisture can elicit drastic changes in fire behavior (Jolly, 2007). Therefore, we propose that observed differences in moisture dynamics between bluegrass thatch and standing bluegrass fuels also have the potential to elicit differences in fire behavior characteristics in bluegrass-invaded rangelands.

Management Implications

Research on the use of prescribed fire as a management tool for bluegrass invasion in the northern Great Plains indicates that it has the potential to control bluegrass, but management specifics remain largely unknown and the success often is short-lived (Bahm et al., 2011; Kral et al., 2018). Furthermore, reductions often are dependent upon precipitation and soil type (Engle and Bultsma, 1984). We argue that differences in fuel behavior among bluegrass thatch and standing bluegrass fuels also may play an important role in the success of prescribed burns for bluegrass control and require consideration.

For instance, bluegrass thatch may burn slower and longer than standing bluegrass fuels, and the difference may be more pronounced during wet conditions when fuel moisture declines more slowly for bluegrass thatch than standing fuels as RH declines by the hour. Therefore, burning when the weather is the driest may be necessary to remove bluegrass thatch accumulations effectively.

In agreement with this argument, evidence suggests that conducting prescribed burns during the summer, when bluegrass is dormant, can reduce bluegrass cover without negatively affecting native species by removing the inhibiting effects of thatch (Kral et al., 2018).

Determining how invasive species alter ecosystem properties, such as fuel bed characteristics, will aid in developing management strategies that conserve biodiversity and maintain valuable ecosystem services. As a whole, our findings reinforce the importance of research investigating the effects of invasive species on fuel bed and fire behavior characteristics.

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Standing dead bluegrass falls over and contributes to thatch, which makes walking through heavily invaded areas difficult.

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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 consists of four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-quarter of pasture) at a four-year return interval and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval. Here we present preliminary results following two years 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 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 for 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 increase 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, N.D., (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 centimeters (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 consists of four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-fourth of pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval (PBG20).

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 will graze freely within pastures from May 1 to Oct. 1 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 the Natural Resources Conservation Service's ecological site descriptions and equivalent land use histories.

Nest Searching

We designated a 4-hectare nest-searching plot in each subpatch (one-eighth of pasture) for a total of 96 plots. We searched each plot four times from May 19 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 nests by visual predators (Winter et al., 2003).

We candled two representative eggs from each nest to determine nest age (Lokemoen et al., 1996). 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).

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).

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 between time-since-fire groupings.

Results

In 2018, we monitored 7,385 nests from 27 species (Table 1).

Daily Survival Rate

We were able to run nest survival metrics on every species with 20 or more nests per year (six species total; Table 2).

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 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*) daily nest survival was 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.

Brewer's blackbird (*Euphagus cyanocephalus*) daily survival probability was 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.

Nesting	
Nest Total	385
Total Species	27
PBG20	127
PBG40	149
SLG	109
CCSP	72
WEME	53
BWTE	42
NOPI	30
GRSP	23
BRBL	37
MALL	21
CCLO	20

Table 1. Nesting species monitored and number of nests by species and treatment for individuals monitored at the Central Grasslands Research Extension Center, May-August 2018.

Discussion

After two years of data collection, early results highlight the differences in preferred vegetation structure among grassland species. We discovered that new burns create habitat for blackbirds and is reflected in blackbird density and blackbird 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.

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	0.94	Stage+, nest vegetation height-
Western meadowlark	0.95	Stage+, 5m C3 invasive grasses+, 5m bluegrass+, nest visual obstruction-
Brewer's blackbird	0.95	Time2-, 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 2018. BHCO = brown-headed cowbird; C3 = cool-season.

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We are evaluating the effect of a patch-burn grazing management strategy on avian breeding community composition. Our

Breeding Bird Community Composition in a Patch-burn Grazing System

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treatment structure consists of four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-fourth of pasture) at a four-year return interval, (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval, and (4) twice-over rotational grazing. *Here we present preliminary results following two years 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. is privately owned and, thus, often undergoes 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-burn 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 evaluate the impacts of patch-burn grazing on breeding season avian community composition using density estimates. We will evaluate the densities of grassland species in each treatment, as well as study changes in the structure of the community among treatments and through time.

We also will compare patch-burn grazing with season-long grazing and twice-over rotational grazing, two traditional management practices in the area. 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, N.D., (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 centimeters (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 consists of four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-fourth of pasture) at a four-year return interval (PBG40), (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval (PBG20), and (4) twice-over rotational grazing (2xROT).

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 will graze freely within pastures from May 1 to Oct. 1 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 Resource 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 the individual’s 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. Additionally, at each plot, a Robel pole was used to quantify visual obstruction in each cardinal direction (Robel, 1970).

Statistics

We calculated the abundance of detected bird species using the R package *lme4*. We analyzed differences in the breeding-season community using nonmetric dimensional scaling using the R package VEGAN (Dixon 2003). We used vegetation and management to describe variation in avian community composition.

The significance of environmental variables was assessed using permutational analysis of variance (PERMANOVA, McArdle and Anderson, 2001). We used transect-level abundances to compare differences among treatments.

Results

In 2018, we had 1,324 detections from 57 species.

Abundance

After two years of data collection, we tested for differences in abundance estimates among treatments. Brown-headed cowbird abundance was higher in twice-over rotational grazing pastures, compared with season-long grazing, and PBG40 pastures had lower brown-headed cowbird abundance. Transect-level abundance in PBG20, PBG40 and 2xROT was lower than in SLG pastures.

Bobolink abundance was lowest in PBG20 pastures, followed by PBG40, 2xROT and SLG pastures (Figure 1). Brewer's blackbird abundance was higher in both patch-burn pastures than the 2XRot and SLG pastures.

Chestnut-collared longspur (*Calcarius ornatus*) abundance was higher in both patch-burn treatments, compared with the rotational grazing and season-long grazing pastures. Clay-colored sparrow abundance was lower in either patch-burn pasture, compared with season-long and rotational-grazing pastures, which were similar.

Grasshopper abundance was lower in 2XROT pastures, compared with season-long grazing and both patch-burn pastures. Western meadowlark abundance followed a similar pattern. Savannah sparrow abundance did not vary among treatments.

Cover Variables Affecting Abundance

Grasshopper sparrow abundances increased with increasing litter depth. Bobolink abundance increased with the cover of cool-season grasses. Brewer's blackbird and Savannah sparrow abundance increased with bare ground.

Clay-colored sparrow abundance increased with increasing cover of woody vegetation. Western meadowlarks responded positively to increasing litter depth. Finally, chestnut-collared longspurs increased with increasing bare ground and shorter vegetation (Table 1 and Figure 2).

Discussion

Following two years of data collection, we demonstrate distinct preferences for vegetation structure in the breeding bird community. 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.

We expect to find a divergence in the breeding community as our treatment structure is further implemented (Pillsbury et al., 2011).

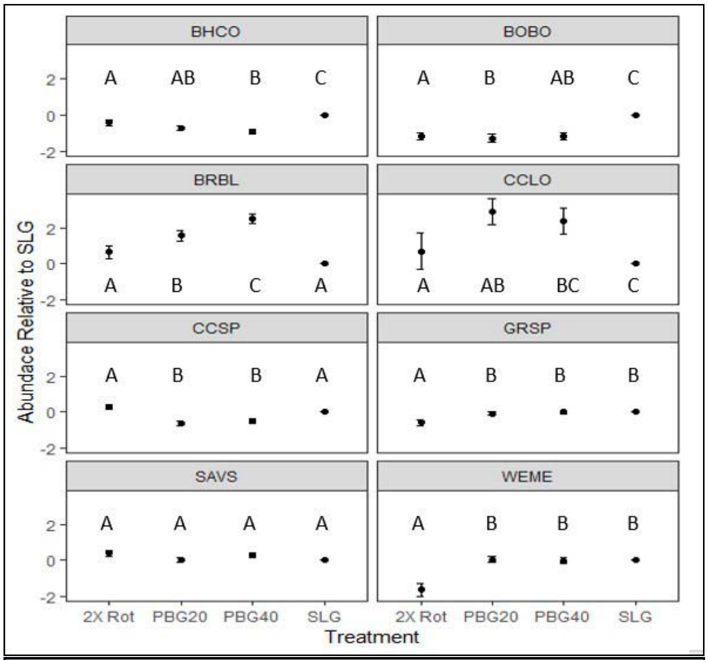

Figure 1. Estimates of the abundances of eight grassland bird species at the Central Grasslands Research Extension Center northwest of Streeter, N.D., in 2017 and 2018.

Species	Density Model
Grasshopper Sparrow	Litter Depth +
Bobolink	Cool-season Grasses +
Brewer's Blackbird	Bare Ground +
Savannah Sparrow	Cool-season Grasses +
Clay-colored Sparrow	Woody Vegetation +
Western Meadowlark	Litter Depth +
Chestnut-Collared Longspur	Bare Ground + Vegetation Height -

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 and 2018.

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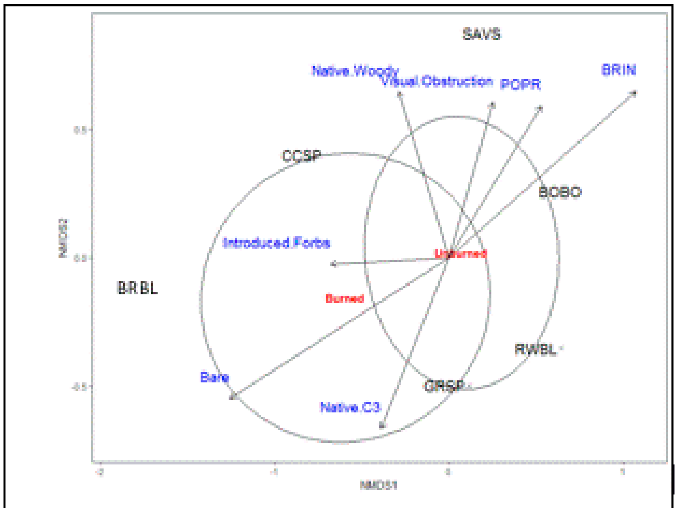

Figure 2. Nonmetric dimensional scaling (NMDS) ordination plot for abundances of six grassland bird species in a landscape managed with patch-burn grazing at the Central Grasslands Research Extension Center near Streeter, N.D. Abbreviations for environmental variables are as follows: BRIN: smooth brome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

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Bumblebee Resource Use in Rangelands Managed With Patch-burn Grazing

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We are evaluating the effect of a patch-burn grazing management strategy on bumblebee resource use and network assembly. Our treatment structure is four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-quarter of pasture) at a four-year return interval and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval. Here we present preliminary results following one year of study.

Introduction

Bumblebees are key components of temperate pollinator networks. They exclusively pollinate more than 20,000 plant species worldwide, and their large size and thermoregulatory ability uniquely permit foraging in climatic and weather conditions unavailable to most pollinators (De Luca and Vallejo-Marin, 2013; Sapir et al., 2017).

However, modern trends in agricultural intensification and rangeland management threaten this role. Most current cattle grazing practices focus on even grazing pressure and have homogenized vegetation structure and composition at broad scales (Fuhlendorf and Engle, 2001). The associated lack of floral diversity contributes to decreased abundances and diversity of bumblebees and other native pollinators while raising concerns for agriculture and biodiversity conservation (Öckinger and Smith, 2006).

The use of modern rangeland management techniques such as patch-burn grazing can enhance rangeland plant diversity and heterogeneity (Fuhlendorf and Engle, 2001). Within this management framework, the phenology of a patch is closely tied to its successional state (Devoto et al., 2013) and, thus, patch-burn grazing has the potential to stabilize the temporal availability of flowers through patch contrast (McGranahan et al., 2012).

One consequence of low flowering plant diversity is the accompanying lack of phenological diversity in the flower community (Wolf et al., 2017). Anthropogenic climate change also has the potential to alter flowering plant phenology, creating a mismatch between bee resource demands and resource availability (Papanikolaou et al., 2016; Arfin Khan et al., 2018)

The long active flight period of bumblebees outlasts the full flowering period of any one species. Thus, low diversity in grassland flora and peak flowering time can create periods of food resource limitation regardless of average seasonal floral abundance (Ebeling et al., 2008; Isbell et al., 2017).

Survival rates and resource availability of bumblebees are highly temporally variable (Goulson et al., 2010; Hemberger and Gratton, 2018). This variability depends on the season and colony life stage.

For example, in the spring, new queens provision most of the nectar for the colony, in addition to incubating eggs and building the nest, resulting in high colony vulnerability (Baer and Schmid-Hempel, 2003). Thus, queens select dense nectar sources during this critical period to increase foraging efficiency (Galpern et al., 2017).

Pollen and nectar restriction during this period has the most severe effects on colony growth, and colonies may be vulnerable to climate-induced asynchrony in plant-pollinator seasonal emergence (Rotheray et al., 2016; Schenk et al., 2017). Nectar and pollen resources also may be limiting to survival in late summer because colonies reach their period of maximum resource demand and many flowering plants have begun to senesce (Rotheray et al., 2016).

Bumblebees store limited amounts of pollen and honey, compared with other apian pollinators, and, thus, are particularly vulnerable to short-term resource shortages (Shelly et al., 1991; Williams and Christian, 1991; Pelletier and McNeil, 2003). In addition to managing for high total seasonal diversity, understanding how bumblebees use floral resources at fine temporal scales is essential to determine ecological "pinch points" and the temporal distribution of resources (Maron et al., 2015).

In addition to differences in floral availability, bee species turnover also is emerging as an important factor structuring seasonal networks (Winfree et al., 2018). Pollinator networks (i.e., the diagrammed associations of pollinator species and their host plants) allow researchers to document several traits known to preserve mutualistic plant-pollinator communities.

The modularity of pollinator networks (i.e., the tendency for the division of a network into subgroups that have densely connected nodes within but are sparsely connected to each other) recently emerged as an important factor for understanding resource availability for bees (Jha and Kremen, 2012; Spiesman and Gratton, 2016). Network plasticity grants pollinator communities resilience in the face of stochastic conditions across the course of the season, but pollinator research traditionally relies on averaged interaction networks during the course of the season.

These methods commonly are used because they are easy to work with and interpretable. However, resource use at a broad temporal scale may not accurately describe conditions that the organism is experiencing, much less the factors that are limiting to a species (Tanner et al., 2016). This mismatch may hamper grassland pollinator conservation efforts by focusing management on increased overall flower abundance and diversity without alleviating seasonal discontinuities in resources.


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In this study, we will establish the relationship between bumblebee communities and prairie forbs at fine temporal scales, while also investigating how floral resources change during the course of a season.

We then will investigate how a restored interacting fire and grazing disturbance regime regulates these changes. Rangeland fire can increase floral density and extend the late-season availability of flowers (Wrobleski et al., 2003). Increasing the temporal stability of resources for bumblebees will improve community diversity and reduce colony mortality.

Our specific objectives are to 1) monitor the abundance of floral resources at one-week intervals across a fire gradient and 2) use floral visitor surveys to construct fine temporal resolution plant-pollinator interaction networks and assess how best to characterize bumblebee use of available resources. Together, these results will be used to assist in bumblebee management and fine-tune knowledge of pollinator-habitat relationships during the course of a season. Knowledge of when flowers are limiting bee abundance and diversity, as well as how fire and grazing can manipulate resources at these times can help managers meet conservation objectives.

Procedures

Study Area

The Central Grasslands Research Extension Center (CGREC) is in Kidder and Stutsman counties, N.D., (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 centimeters (cm) (15.9 inches) and average annual temperatures of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Landscape context is important for structuring pollinator communities and seasonal abundances, especially the amount and diversity of surrounding cropland (Rundlof et al., 2007; Persson and Smith, 2013). The surrounding landscape is primarily rangeland, with pastures of corn (*Zea mays*), soybeans (*Glycine max*), canola (*Brassica rapa*) and wheat (*Triticum aestivum*).

The study plots have a history of cattle grazing and limited exploratory agriculture. Additionally, the study plots do not have a recent history of burning. Thus, our treatments may incur a lag effect as we establish the treatment structure.

Treatment Structure

Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-quarter of pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth of pasture) and growing-season (one-eighth of pasture) patch burning at a four-year return interval (PBG20).

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 mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs will graze freely within pastures from May 1 to Oct. 1 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.

Methods

Assessing Pollinator Plant-Pollinator Networks

Within each 8-hectare (ha) subpatch, we will conduct a 20-minute visual encounter survey in two 50- by 50-meter (m) plots (128 plots/round, Devoto et al., 2013). Initially, the plot will be walked in three systematic transects. Each bumblebee visiting the reproductive parts of a flower will be collected, identified and subsequently released.

The species of plant that the bumblebee is visiting also will be recorded. If bumblebees cannot be identified to species in the field, they will be collected for identification in the laboratory using a dissecting scope.

Following the completion of a systematic walk-through, the remainder of the survey time will be spent performing a focused search for bumblebees, biasing search effort toward areas of dense floral resources. The length of time spent surveying is designed to approach an exhaustive sample of the plot, and will be adjusted if initial surveys demonstrate an abundance of unsurveyed bumblebees.

We will conduct surveys only between the hours of 9 a.m. and 5 p.m. on rain-free days (CaraDonna et al., 2017). Focused network surveys will not allow us to calculate pollinator densities among treatments, but because our treatment structure is small scale, we are more interested in the resources that our treatments provision within the greater foraging landscape of bumblebees (Knight et al., 2005).

To capture temporal changes in plant-pollinator networks, we will conduct a full round of network sampling every three to four weeks. This will allow us three sampling periods per season to capture a range of floral phenologies. Climate variables will be collected using an on-site North Dakota Agricultural Weather Network (NDAWN) weather station.

Analysis

We will use the R package bipartite to analyze plant-pollinator networks (Dormann et al., 2008; Peralda et al., 2017). Network generality and nestedness will be calculated for each sampling period, as well as the rate of species turnover and network switching during the course of the season for each time since the fire period.

Network nestedness is a measure of the extent to which specialist network interactions are a subset of generalist interactions (i.e, whether specialist interactions are unique). A nested network should be more resistant to stochastic perturbation.

Network nestedness has been shown to change with increased land use intensity and landscape degradation, and nestedness has been hypothesized to increase with active disturbance regimes (Burkle, et al., 2013; Moreira et al., 2015; Brown et al., 2016). Network specialization, as measured by the H2 index, measures the overall degree of specificity exhibited by pollinators and flowers in a network.

Robustness measures the extent to which network collapse will occur if random members are removed from the network.

Assessing Floral Availability

We will use floral surveys to plot the flowering period of forbs for a range of time since fire and assess resource discontinuities through time. Every week, we will perform floral resource surveys using 300 m belt transects centered within each one-eighth pasture subpatch (DeBano et al., 2016).

Along each transect, we will tally all flowering ramets within 1 m of the transect that are usable by bumblebees (Moranz et al., 2014). Although at a finer resolution than bumblebee surveys, floral abundance surveys will occur simultaneously to allow for comparison. Two transects in each subpatch will be sampled, for a total of 192 transect surveys per round.

Analysis

The lengths of flowering periods, as well as the diversity and abundance of flowers, will be compared among treatments using generalized linear models using the lmer package in R (R Core Development Team). Prior research demonstrates that fire can prolong the flowering period of rangeland forbs, as well as enhance the flower set of individual plants (Wroblenski and Kaufmann, 2003; Mola et al., 2018).

Results

Assessing Pollinator Plant-Pollinator Networks

In 2018, our networks included nine bumblebee species, 28 flower species and 1,319 plat/flower interactions (Figure 1). Season-long grazing pastures had nine bumblebee species and 16 flower species. PBG40 pastures had nine bumblebee species and 21 flower species, while PBG 20 pastures had seven bumblebee species and 25 flower species.

In general, bumblebee/flower network statistics were similar among the three treatments. All bumblebee networks were unspecialized. They also were moderately nested, and plant and bumblebee halves were robust to extinction events (Table 1).

Assessing Floral Availability

Our weekly surveys culminated in 15 rounds from May 21 to Sept. 3, 2018. We documented 120 flowering plant species and 658,182 flowering heads. We found that flowering plant abundance and diversity was higher in both patch-burn grazing treatments, compared with season-long grazing (Figure 2).

Additionally, we found differences in species-specific flowering plant phenology among treatments. For example, rigid goldenrod (*Solidago rigida*) reached its peak abundance more than two weeks later, compared with season-long grazing (Figure 3).

Among fire-age classes, western snowberry (*Symphocarpos occidentalis*) reached peak flowering more than three weeks later in new burns, compared with unburned patches and one year-since-fire patches (Figure 3).

Discussion

What should be noted is that we are unable to make statistical comparisons among treatments with our networks statistics after only one year of data

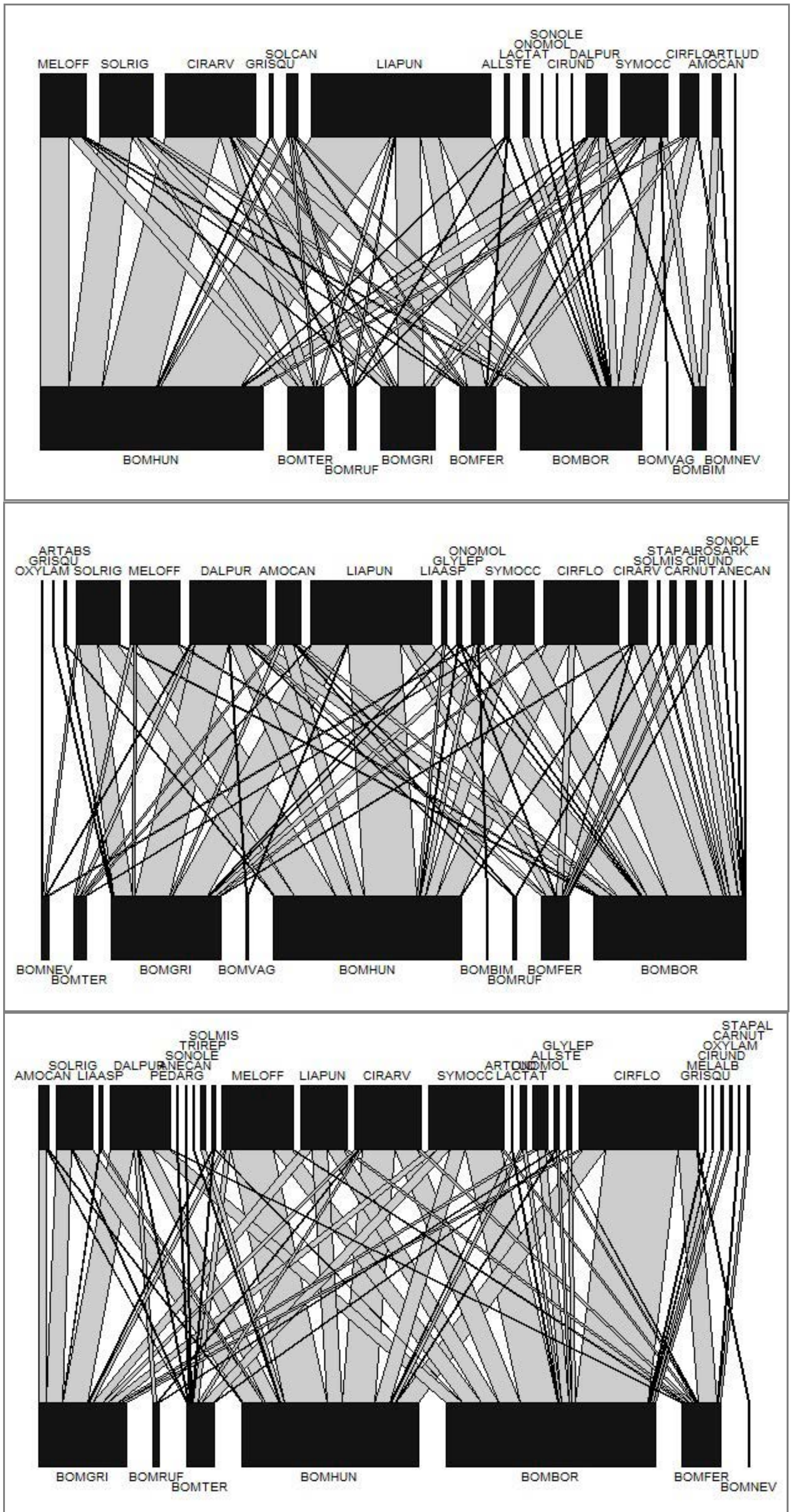

Figure 1. Bumblebee-flower network interactions under three management paradigms at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018. Top) Season-long grazing (SLG); Middle) Patch-burn grazing with spring fires (PBG40); Bottom) Patch-burn grazing with spring and summer fires

collection. However, patch-burn grazing does not seem to be disruptive to bumblebee resource use and network assembly.

At the same time, patch-burn grazing increases floral availability and diversity. Even in species that did not extend their phenology under patch-burn grazing, a diversification of phenology within a species increases temporal stability of that resource under patch-burn management (Figure 3).

	PBG20	PBG40	SLG
Bee Species	7	9	9
Flower Species	25	21	16
H2	0.21	0.20	0.18
Nestedness	0.58	0.69	0.49
Robustness Flowers	0.85	0.82	0.84
Robustness Bees	0.69	0.74	0.73

Table 1. Network characteristics of a flower/bumblebee interaction network across three management treatments at t he Central Grasslands Research Extension Center near Street, N.D., in 2018. PBG20 = Patch-burn grazing with two seasons of fire, PBG40 = Patch-burn grazing with one season of fire. SLG = Season-long grazing with no fire.

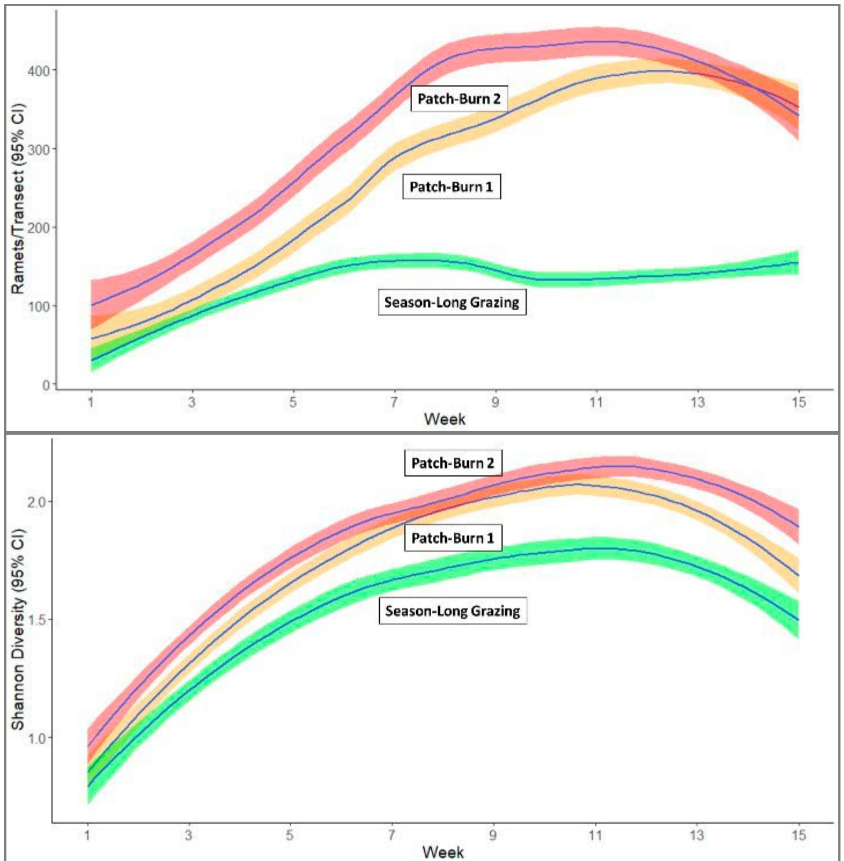

Figure 2. Total flower abundance (top) and Shannon diversity (bottom) of pastures managed with season-long grazing, patch burning with one season of fire, and patch burning with two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018.

In light of these conclusions, patch-burn grazing appears to be an effective conservation tool for those seeking to increase resource availability for native rangeland pollinators.

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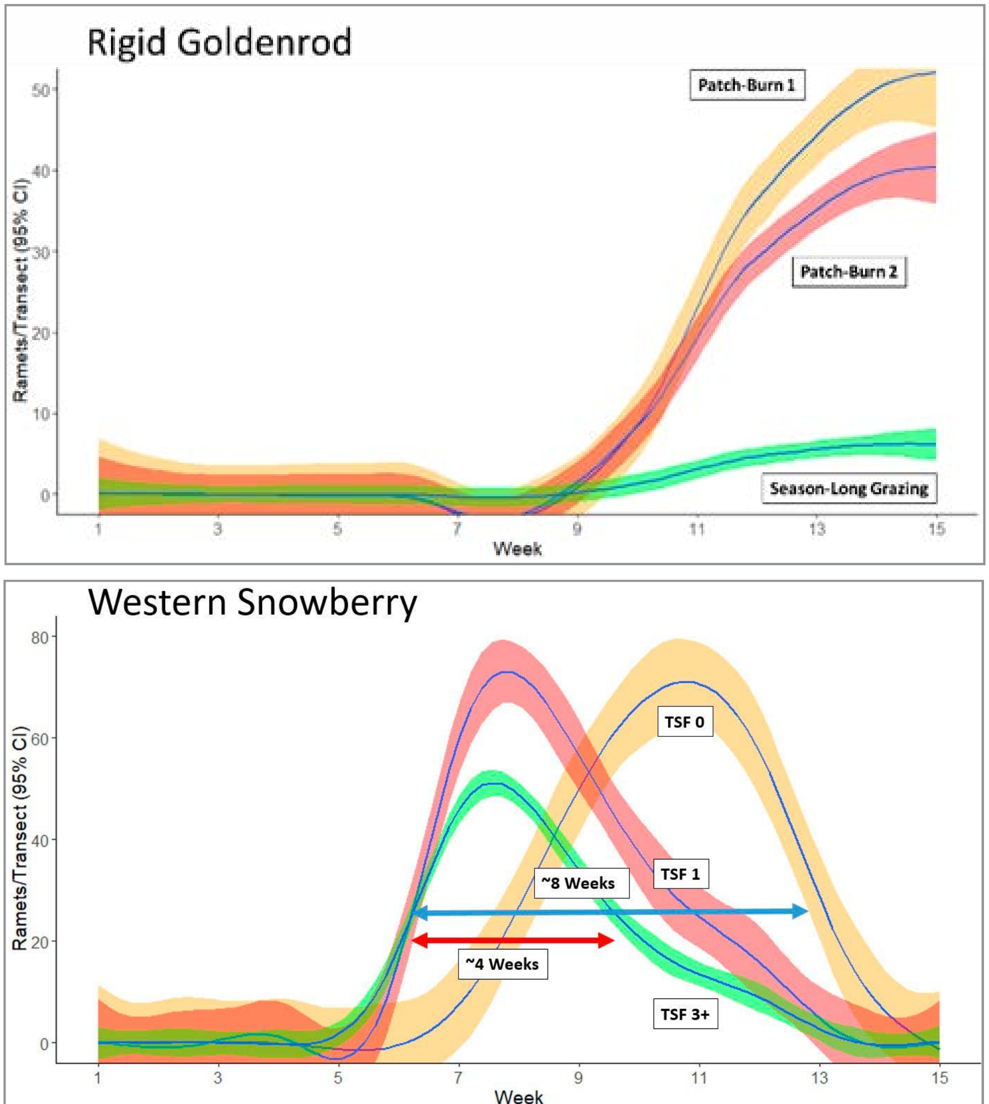

Figure 3. (Top) Rigid goldenrod abundance among season-long grazing, patch burning with one season of fire, and two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018. (Bottom) Western snowberry flower expression among season-long grazing, patch burning with one season of fire, and two seasons of fire at the Central Grasslands Research Extension center near Streeter, N.D., in 2018, illustrating the resource benefits provided by patch-burn grazing via phenological heterogeneity.

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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 season-long 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 years one and two 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 can be 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 season-long grazing.

Procedures

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

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. The survey period corresponds with the butterfly flight period, and surveys in both years took place between June 1 and Aug. 15.

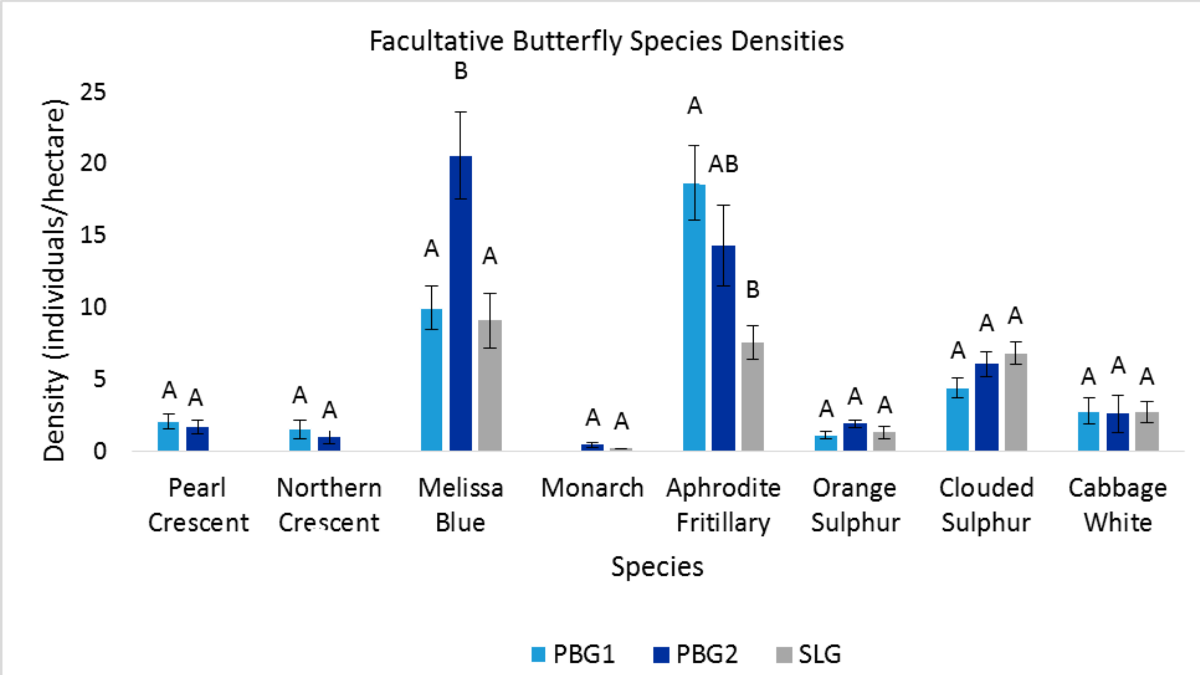
We also are collecting floral resource data along the same transects. This involves identifying and recording all forbs and legumes in flower within 1 meter of the transect line during butterfly surveys.

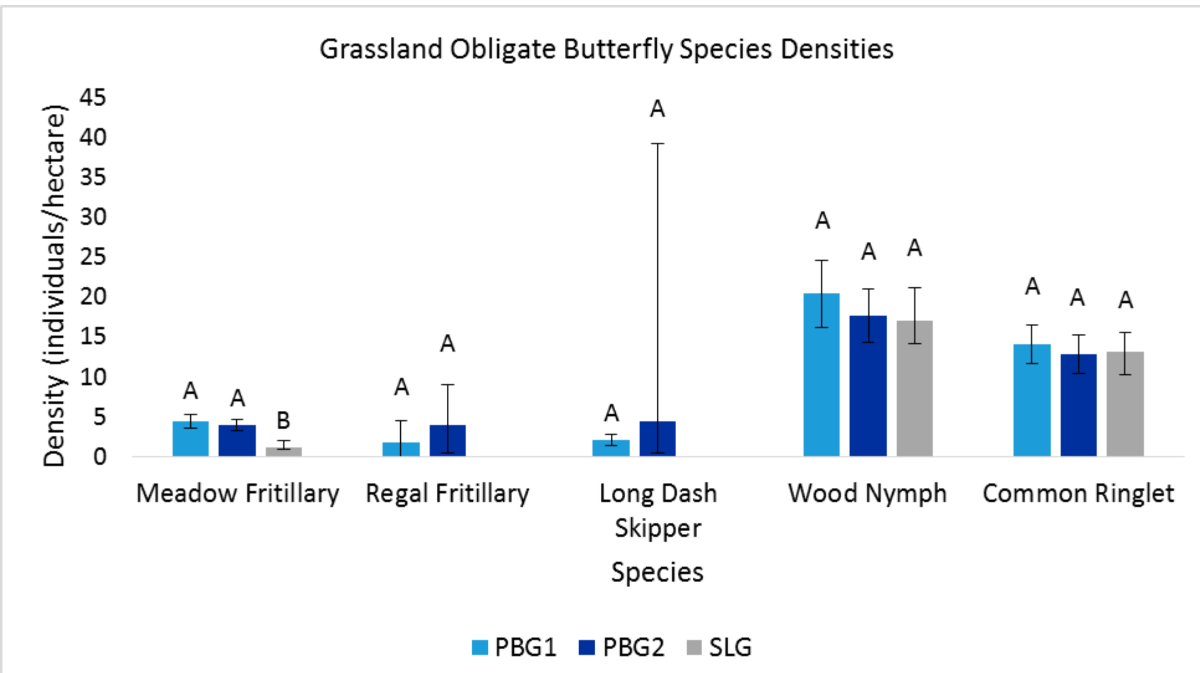
Statistics

We used the statistical program Distance 7.1, release 1 (Thomas et al., 2010) to calculate densities for all butterfly species with a minimum of 60 detections.

Results

In the 2017 and 2018 field seasons, we recorded a total of 4,856 butterflies, representing 44 species, across the three cattle management treatments (Table 1). We also recorded 91,800 total flowering plants of 128 species.





Figures 1a-1b. These graphs show the density per hectare of 13 butterfly species. They are grouped by habitat specialization, with facultative species being those that are habitat generalists, and grassland obligate species being those that require grassland habitats for their entire life cycle. Letters indicate significant differences among the three treatments within each species.

Butterfly Abundance

In 2018, butterfly total abundance was highest in the patch-burn grazing with two seasons of fire, which had 33.4 detections/transect (SE ± 3.5). Abundance was similar in the patch-burn grazing treatment with one season of fire, with 28.6 detections/transect (SE ± 2.6). The season-long grazing treatment had 24.3 detections/transect (SE ± 2.4).

Butterfly Density

We had 13 species with a minimum of 60 detections for analysis in program Distance. Eight of these species showed higher densities in at least one of the treatments involving fire rather than season-long grazing. The remaining five species had similar densities across all three treatments. (Figures 1a and 1b).

Floral Diversity and Abundance

Floral species richness was highest in the patch-burn grazing with two seasons of fire treatment, with a total of 88 flowering species, followed by the patch-burn grazing with one season of fire at 77 species, and lastly the season-long grazing treatment with 62 species.

Floral abundance in patch-burn grazing with two seasons of fire was the highest of the three treatments, with 251.9 flowering stems/transect (SE ± 32.6). Patch-burn grazing with one season of fire had an average of 164.1 flowering stems/transect (SE ± 13.6). Season-long grazing had the fewest flowering stems of the three treatments at 82.3 per transect (SE ± 6.6).

Discussion

Our results show that butterfly species respond differently to the reintroduction of fire and grazing. What is important to note is that no species showed a negative response to fire; that is, no species had a lower density in both of the treatments including fire than in the treatment without fire.

One factor that could be driving some species to respond positively to treatments including fire is that floral abundance was higher in these treatments. In fact, all three treatments were significantly different from one another, with patch-burn grazing with two seasons of fire having the greatest floral abundance, and season-long grazing having the least. Many butterfly species rely on floral forb resources not only for adult feeding, but for oviposition and larval feeding as well.

Although we still have one season of data collection before this study is completed, what is apparent from the current data is that the butterfly community benefits from the inclusion of fire in this grassland landscape. Previous studies have found that butterflies responded neutrally or negatively to fire (Kral et al. 2017), but our results are in contrast.

No butterfly species that we analyzed had a negative response, and more than half of the species (8 of 13) had higher densities in areas including fire. This could be because our fires are relatively small, and most of each pasture is left unburned each year. These unburned areas may be refuges for low-mobility larvae, which then recolonize the burned areas after metamorphosing into adult butterflies.

We suggest that future research focus on long-term studies, which will provide a more complete picture of how butterflies respond as fire becomes a management legacy, and more importantly, on spatiotemporally varied application of fire to the landscape.

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Monarch and Regal Fritillary Behaviors in Grasslands with Restored Fire Regimes

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We are evaluating the behavior of two butterfly species within a patch-burn grazing framework. Our focal species are monarchs (Danaus plexippus) and regal fritillaries (Speyeria idalia). The main goals of this study are to describe species' behavior generally and to determine species' use of the landscape. Here we present year one of a two-year study.

Introduction

Conservation management research typically focuses on species richness and abundance. However, behavior also can be an important component in assessing the efficacy of management for conservation purposes. The way an animal uses the landscape contributes to determining if that landscape is a valuable area for conservation.

Butterflies are a good organism to examine for this purpose. Butterflies often are considered indicators because of their short generation times and wide life history requirements (Samways 2007). Additionally, researchers rarely study butterfly behavior in the field, but this could provide important insight into their use of the landscape (Carleton and Schultz 2013).

We have chosen to monitor the behavior of two species of butterfly: the monarch (*Danaus plexippus*) and the regal fritillary (*Speyeria idalia*). These are species of conservation concern but may differ in their behavior due to differing life histories and habitat requirements. Monarchs are generalist butterflies and may occur in many habitats, while regal fritillaries are grassland specialists, which require grasslands for their entire life cycle.

The main objectives of this study are to quantify butterfly behavior in the field and determine if these behaviors can predict an individual's status as resident or transient.

Procedures

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

The study area is subject to a set of experimental treatments. In one treatment, season-long grazing, the pastures are stocked with cow-calf pairs for the duration of the growing season. In the second treatment, the pastures are similarly stocked, but also have a 40-acre patch burned each spring. The third treatment also has moderately-stocked cow-calf pairs, and has a 20-acre burn each spring, followed by a 20-acre burn each summer.

We conducted time-budget surveys to collect data on butterfly behavior. Whenever an individual of the target species was located, the observer followed it and recorded each behavior as it occurred for up to 15 minutes. Observations were between 10 and 15 minutes in length.

Behaviors include resting, basking, ovipositing, nectaring, mating, patrolling, foraging, chasing, and fleeing (Table 1). We also recorded the plant during events of resting, basking, ovipositing or nectaring, and we recorded the other organism in events of mating, chasing, and fleeing.

Statistics

We calculated total proportions of time spent in each behavior by averaging the time in each behavior across individuals. We categorized groups by species and sex.

We also categorized individuals into groups by philopatry status. Any individual that was mating or ovipositing is considered a resident. Males that chased conspecifics for any length of time are also residents.

Individuals whose full observations consisted of 95 percent or more of flying are considered transient. To determine time spent flying, we added patrolling and foraging together. Any individuals that did not meet any of the above criteria are of unknown philopatry status.

We were limited in our ability to conduct thorough statistical tests due to the small sample size from one year of data. Results are largely presented as anecdotal at this time.

Results

In 2018, we observed 35 monarchs (15 females and 20 males) and 21 regal fritillaries (10 females and 11 males).

Proportion of Time in Behaviors

We were unable to perform statistical tests reliably to indicate any differences due to the small sample size obtained from only one year of data collection. However, proportions of time spent in each of our nine behaviors by males and females of both species are presented in Figure 1.

Philopatry Status

We were able to determine philopatry status for 17 of the total 56 observations. Of these, 15 were residents and 2 were transients. Eight of the residents were monarchs (five males and three females). The remaining seven residents were regal fritillaries (four males and three females). One of the two transients was a male monarch and the other was a female regal fritillary.

Discussion

With a total of only 56 complete detections, which must be split into four groups for species and sex, making any strong conclusions is difficult. We anticipate that a second year of data

Behavior	Description	Citation
Resting	Sitting on vegetation or substrate; wings closed	Clench 1966
Basking	Sitting on vegetation or substrate; wings open	Clench 1966
Foraging flight/nectaring	Flight above vegetation canopy, occasionally stopping to sit on open flower with proboscis extended	Curtis et al. 2015
Mating	Two butterflies, typically in flight, connected at the abdomen	Rutowski 1982
Ovipositing: monarchs	Female on *Asclepias* spp., occasionally pausing to flex her abdomen and deposit an egg	Ladner and Altizer 2005
Ovipositing: regal fritillaries	Female in low flight, occasionally dipping below the vegetation canopy, walking through senesced vegetation occasionally flexing her abdomen to deposit an egg	Kopper et al. 2000
Chasing	Flighted pursuit of any organism; will be separated into conspecific, misc. Lepidoptera, other insect, or vertebrate	Kemp 2000
Fleeing	Flight closely followed by any organism; will be separated into conspecific, misc. Lepidoptera, other insect, or vertebrate	Kemp 2000
Patrolling	Flight that appears to follow a pattern and cover a specific area; likely to be broken up by bouts of chasing	Peixoto and Benson 2009
Courtship	Unlikely to be observed, but may consist of male pursuit of female	Pliske 1975

Table 1 shows the behaviors we expect to observe, as well as an explanation of how each behavior will be quantified and at least one source.

collection will help alleviate this issue.

Despite the lack of statistical power currently possible in this study, we still can make observations on the data available. For instance, what is apparent is that female regal fritillaries spend a greater amount of time ovipositing than do female monarchs. This is likely because of their life history traits; monarchs oviposit quickly, almost while in flight, and regal fritillaries land and walk around in senesced vegetation to oviposit (Casagrande and Dacey 2007; Kopper et al. 2000).

We also can see that all four groups spend a lot of time nectaring, but male regal fritillaries spend less time foraging than the other groups. This may be because male regal fritillaries are very territorial (Kopper et al. 2001). Rather than nectaring consistently and briefly taking foraging flights between flowers, as the other groups do, male regal fritillaries appear to stop along their patrolling flights and nectar for shorter periods of time. This also is reflected in their proportion of time spent patrolling, which appears to be slightly higher than the other three groups.

Determining philopatry status also is largely anecdotal at this point in the study. We are unable to perform tests to see if either species or either sex is more likely to be counted as a resident or transient, and we are unable to compare behaviors in residents and transients. After the second year of data collection, we hope to analyze the influence of vegetation variables on individuals' philopatry status; i.e., are regal fritillaries more likely to be residents in areas with high floral diversity?

Having only one year of data collection, we are unable to present conclusive results. However, we expect that the present trends will continue, and we should be able to present statistical evidence to support these trends after the coming field season. After the completion of the study, we will provide further evidence that behavior should be considered an important part of conservation monitoring.

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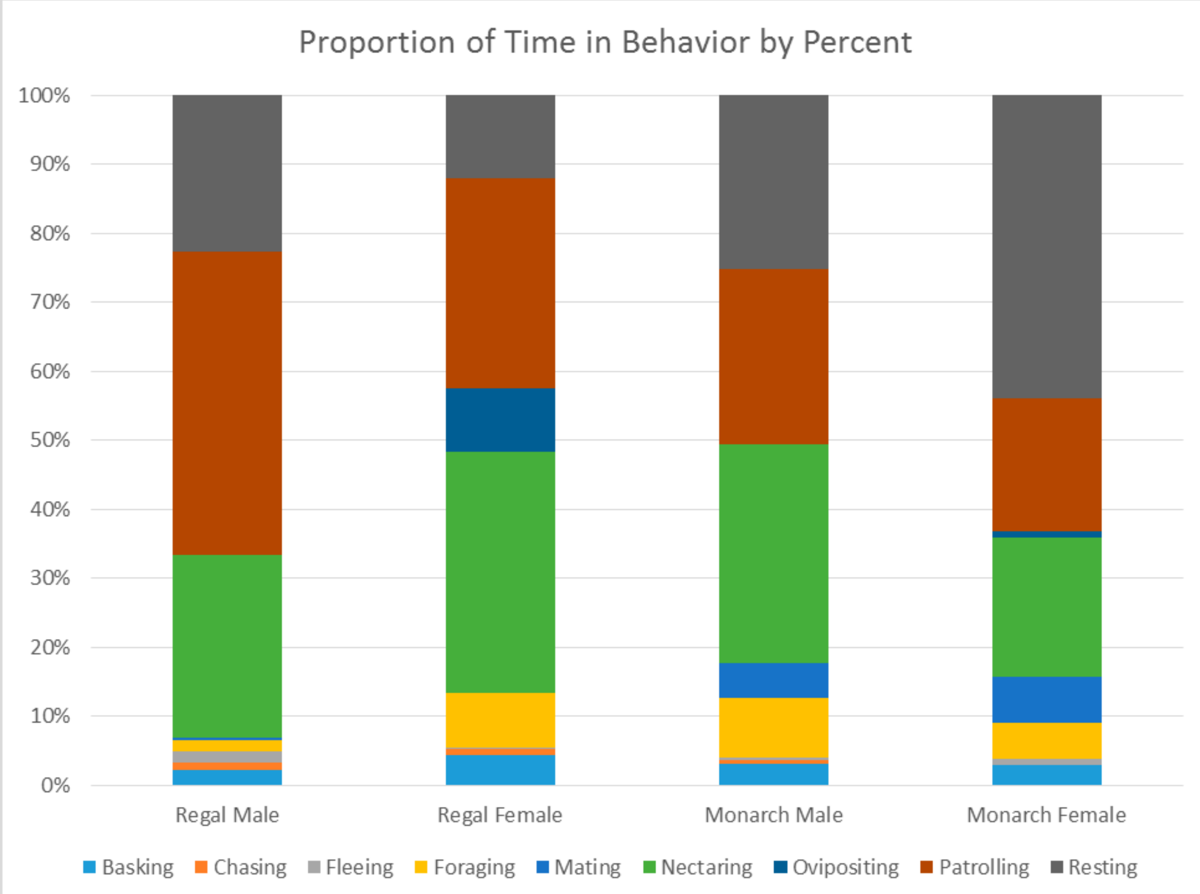

Figure 1. This graph shows the percent of time spent in each behavior by male and female monarchs and regal fritillaries. "Regal fritillary" is shortened to "regal" for aesthetic purposes.

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Soil Nutrient and Microbial Response to Kentucky Bluegrass Invasion and Land Management Techniques

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The overall objective of this research was to examine below-ground characteristics under accumulated Kentucky bluegrass conditions and in response to management with fire and grazing. We present results from treatments of idle management, resulting in Kentucky bluegrass monocultures, compared with those that were burned in the spring and grazed throughout the growing season.

Introduction

The fact that invasive species are a contributing factor to the decline of grasslands in the northern Great Plains has been well documented (Cully et al., 2003). Kentucky bluegrass (*Poa pratensis L.*) is one of the main invasive species encroaching on endemic species in these ecosystems. The species has expanded rapidly in the last 30 years (DeKeyser et al., 2009) and is present in 82 percent of most areas of North Dakota (U.S. Department of Agriculture, 2014).

Kentucky bluegrass (hereafter referred to as bluegrass) is an effective competitor and produces abundant litter, which, in turn, creates a thick thatch layer of living and dead plant material between the soil surface and the plant canopy. Dominance of bluegrass, and the resulting accumulation of thatch, has the potential to reduce provisioning ecosystem services and functions (Toledo et al., 2014).

If bluegrass continues to invade remaining grasslands at its current rate, biodiversity will diminish at rates that may not be reversible. Biodiversity is one of the most important factors influencing primary productivity (Tilman et al., 2012), so maintaining species diversity in forage-producing rangelands is particularly important. The pervasiveness of bluegrass is likely to increase if adaptive land management techniques are not adopted.

In the northern Great Plains, patch-burn grazing is being explored as a land management technique. This disturbance-driven management model can help reduce the bluegrass thatch layer and promote the regeneration of native plant species. Seasonal prescribed fire is shown to reduce bluegrass cover up to nearly 30 percent one growing season post-fire (Kral et al., 2018). Additionally, this management model helps promote heterogeneity and diversity across the landscape.

While bluegrass and patch-burn grazing are often thought of as primarily above-ground issues, many below-ground impacts often are overlooked. Research has shown that bluegrass has the potential to disrupt soil nutrient cycling, surface hydrology and structure (Taylor and Blake, 1982; Wedin and Tilman, 1990; Herrick et al., 2001). Depending on the disturbance regime, fire and grazing have varying and interactive impacts on soil nutrient budgets, hydrology and microbial populations (Hobbs et al., 1991; Zhao et al., 2017; Alcañiz et al., 2018).

Kentucky bluegrass thatch
Megan Dornbusch, NDSU

With these below-ground impacts in mind, we hypothesized that the dominance of bluegrass and development of thatch may lead to a different soil microclimate, as well as organic-matter inputs, that are different in quality and quantity than on land managed with a combination of fire and grazing. These differences in microclimate and organic matter inputs may, in turn, affect soil nutrient and microbial dynamics. Additionally, fire and grazing may have direct impacts on these soil properties.

Methods

This research was conducted at the Central Grasslands Research Extension Center (CGREC) in the mixed-grass prairie typical of central North Dakota. We established replicate sites, distributed across the research center, in pastures that are managed with a patch-burn grazing model. We selected ecologically similar site locations based on soil series descriptions (USDA, 2017a) and ecological site descriptions (USDA, 2017b) to minimize environmental variation.

Our treatments consisted of 12 replicate sites in total. Eight of the sites received moderate season-long grazing and were burned in the spring. These management practices help reduce bluegrass and promote native grass, and forb species expression and/or germination (DeKeyser et al., 2009).

Half of the managed replicate sites were burned in the spring of 2017 (*2017 Mgmt.*), allowing for a year of native vegetation recovery post-disturbance. The other half were burned in the spring of 2018 (*2018 Mgmt.*) to account for immediate and in-season effects of management practices on soil properties.

The remaining four replicate sites were located in exclosures that had not been burned or grazed in recent management history

(*Bluegrass*). The extreme idle management resulted in the formation of bluegrass monocultures and the accumulation of a thick thatch layer.

Composite soil samples were collected from each treatment across all replicates at the beginning of the 2018 growing season. We divided soil samples into depths of 0 to 5 centimeters (cm) and 5 to 15 cm for analysis of surface and near-surface soil conditions.

To understand direct impacts of fire and grazing on soil properties, we collected subsequent soil samples from the sites burned in the spring of 2018 throughout the growing season. We sampled these sites immediately following the 2018 spring fire event, and then at time steps of one month and three months post-fire.

The soil was analyzed for labile and stable fractions of carbon and nitrogen pools, and for microbial abundance and community structure.

Soil carbon pools were analyzed for total carbon, organic carbon and permanganate oxidizable carbon (POX C). POX C represents the most labile fraction of carbon, which is readily accessible to microbial populations, and was expected to be the fraction most sensitive to shifts in vegetation structure and management practices (Culman et al., 2012).

Soil nitrogen pools were analyzed for total nitrogen, ammonium (NH4-N), nitrate (NO3-N) and potentially mineralizable nitrogen (PMN). Ammonium and nitrates are forms of nitrogen easily taken up by plants, while PMN is an indicator of the nitrogen mineralization capacity of the microbial community (Cornell University, 2017).

Lastly, we analyzed soil microbial population abundance and community structure. Microbial biomass carbon (MBC) is an indicator of the carbon abundance within the cells of living soil organisms (Vance et al., 1987). Relative microbial community structure was determined using phospholipid-derived fatty acid (PLFA) analysis. The PLFA method estimates microbial groups at a broad taxonomic level, and it is an effective method for detecting shifts in microbial communities across treatments (Ramsey et al., 2006).

We analyzed differences among treatments using the Kruskall-Wallis test with Wilcoxon pairwise post-hoc tests used for mean comparisons. Significant differences were determined at a $p \leq 0.05$.

Results

Soil carbon, nitrogen and microbial population analyses are detailed in Figures 1-3, respectively. Predictably, no differences were detected in the more stable fractions of either nutrient pool. We did, however, detect differences in the most highly dynamic and labile fractions of the soil carbon and nitrogen pools.

POX C and NH4-N showed differences in both sampled depths. However, based on the timing of the detected changes throughout the season, determining with certainty that treatment differences were the cause is difficult.

Excluding the 5 to 15 cm depth for POX C, no differences were detected between *Bluegrass*, *2017 mgmt.* and *2018 mgmt.* pre-fire samples. This suggests that the changes observed subsequently throughout the growing season were likely a result of abiotic environmental fluctuations in soil moisture and temperature. Microbial community distributions showed no differences across treatments or throughout the season.

Conclusion

In preliminary analysis of data, this research showed no conclusive evidence that bluegrass dominance or associated land management techniques strongly influence soil carbon and nitrogen pools, or microbial community structure and abundance. Soil abiotic characteristics, such as moisture and temperature, may be more important than litter chemistry in driving soil nutrient pools and microbial populations.

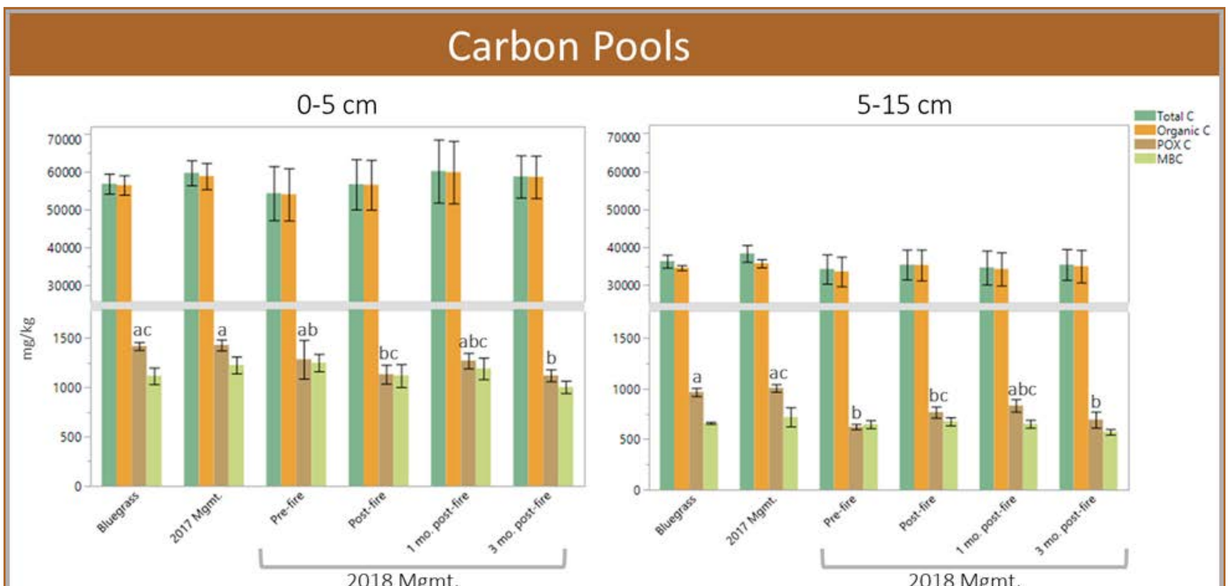

Fig. 1 Effect of management on mean soil carbon fractions (n=4 for each property measured). Different letters indicate significant differences across treatments, within a depth.

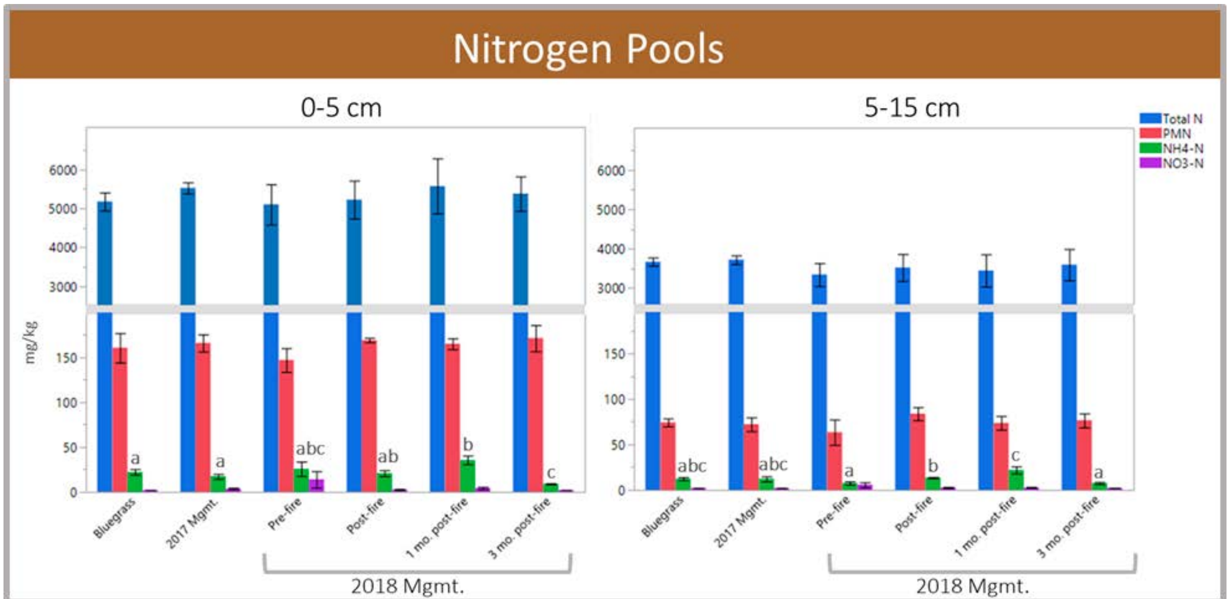

Fig. 2 Effect of management on mean soil nitrogen fractions (n=4 for each property measured). Different letters indicate significant differences across treatments, within a depth.

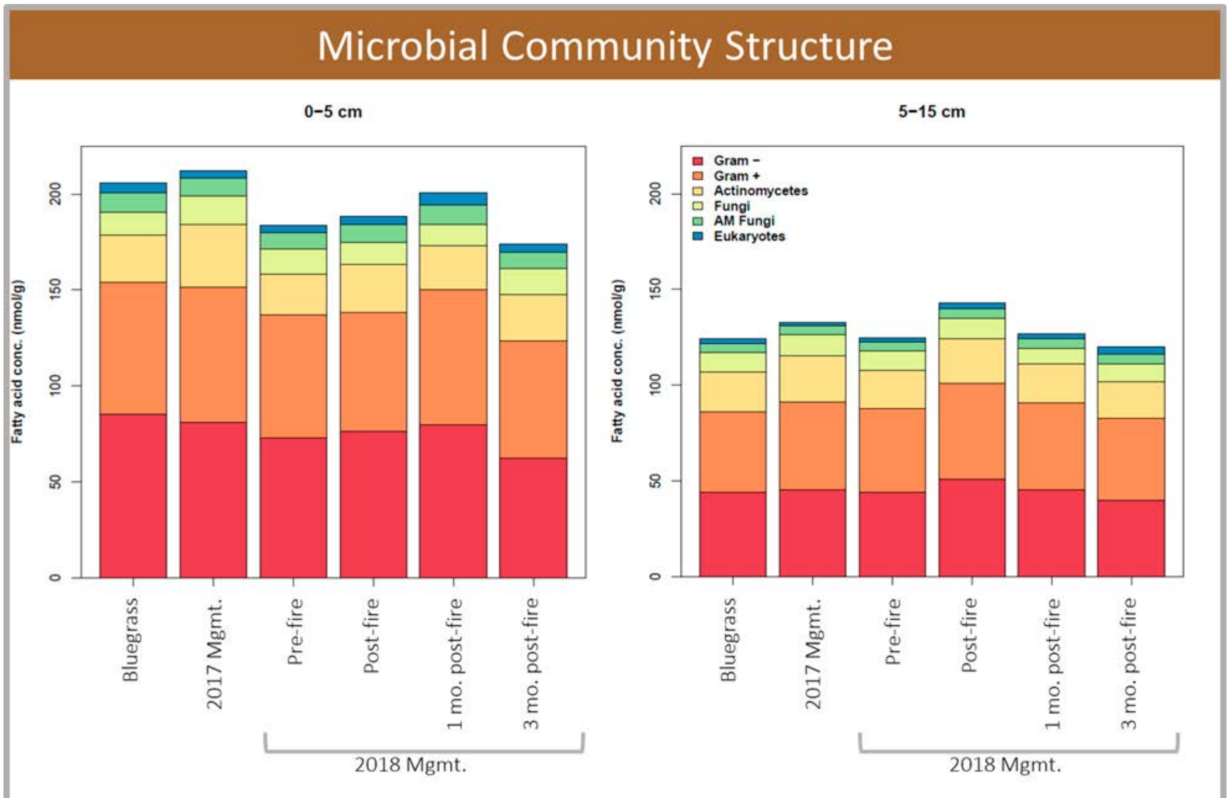

Fig. 3 Microbial community distribution for each treatment and depth based on absolute abundance of membrane lipids. Group means were not statistically different across treatments, within a depth.

Future directions for this research include analysis of decomposition rates among treatments through in-situ litterbag incubations. Decomposition is an important ecosystem function that links below-ground and above-ground processes. Results may provide insight into whether the function of the soil microbial community is impacted by bluegrass dominance or land management practices.

Despite no clear indication from this research that bluegrass is affecting soil nutrient or microbial properties, the larger ecological threat from bluegrass remains the widespread loss of above-ground biodiversity. Understanding of how bluegrass effects below-ground properties remains limited and certainly warrants additional research.

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Cattle Respond to Higher-quality Forage Under Patch-burn Grazing on Kentucky Bluegrass-invaded Rangeland

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Heterogeneity in forage quality and quantity can enhance rangeland quality for livestock and wildlife. We seek to increase heterogeneity by applying a rotational patch-burn grazing treatment to pastures with season-long grazing. High forage quality in recently burned patches attracts livestock during the season. We present data following two years of treatment comparing forage quality across three different grazing management types.

Introduction

Disturbance-driven heterogeneity is important to maintain rangelands that evolved with disturbances such as fire and grazing (Bowman et al., 2009; Kay, 1998). Heterogeneity can stabilize forage availability during the growing season, and the forage bank created by heterogeneous disturbance can benefit cattle by giving them patches of available forage even during drought, thus maintaining cattle weights during stressful times (McGranahan et al., 2016; Allred et al. 2014).

Historically, rangeland management in the Great Plains has minimized disturbance or made it spatially even. By combining season-long grazing with a yearly rotation of spatially discrete fires, patch-burn grazing creates contrast in forage quality and forage quantity between recently burned and unburned patches within a pasture (Fuhlendorf et al., 2017).

Grazers often are 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 and grazer occupancy during a four-year patch-burn rotation, which began in the spring of 2017. We expect to see high forage quality, measured here by crude protein percentage, with the highest at low plant biomass (on the most recent burns).

We also expect to see consistently higher forage quality and higher grazing density on the most recently burned patches. In addition, we anticipate that patch burning will produce better forage and higher cattle weight gains when compared with conventional or rotational grazing systems.

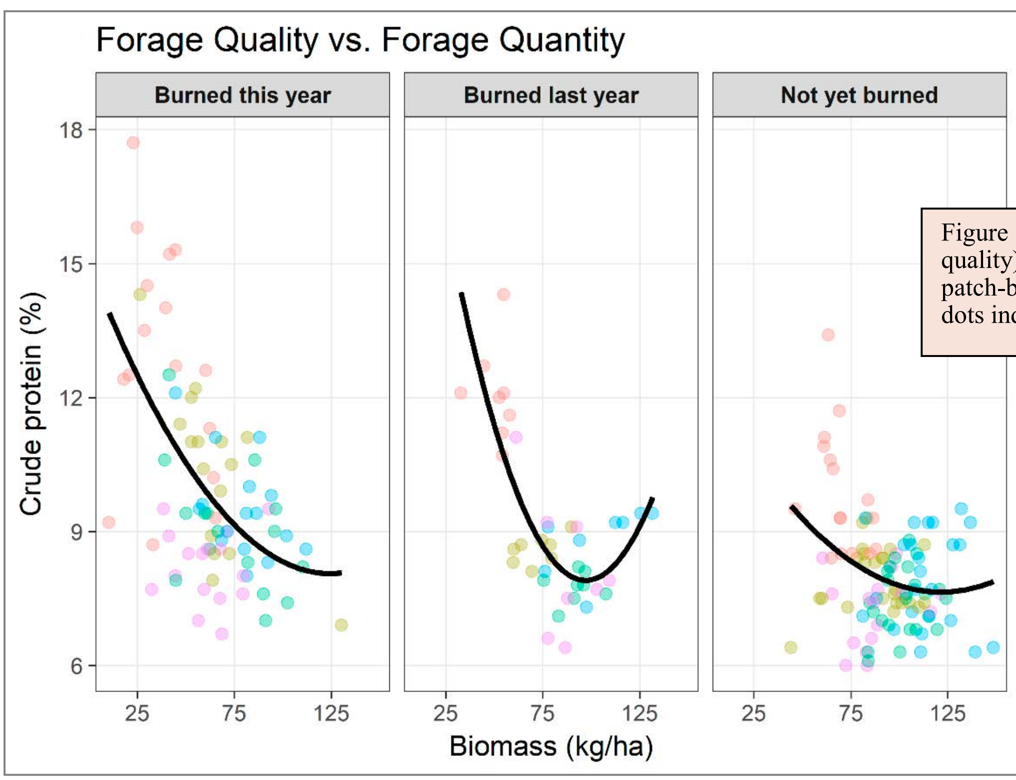

Figure 1. Crude protein percentage (forage quality) versus biomass (forage quantity) on patch-burn grazed pastures in 2018. Colored dots indicate different sampling months.

Procedures

We sampled 16 pasture replicates at the CGREC: four continuously grazed, four rotationally grazed and eight patch-burn grazed (PBG). Four PBG pastures received an entire 40-acre patch burn in the spring, while the other four received a 20-acre patch burn in spring and a 20-acre patch burn in late summer. Cow-calf pairs grazed each pasture at a 30 percent forage utilization rate from May to October.

We clipped above-ground biomass once per month from 25- by 25 -centimeter (cm) quadrats at predetermined points along transects in each patch per pasture. At each sampling point, we counted fecal pats within 5 meters (m) of the point to determine grazer usage.

All forage samples were dried for 48 hours in a 60 C drying oven, weighed and ground in a Wiley mill through a 1-millileter (mm) screen. We used near infrared spectroscopy (NIR) to determine crude protein and fiber content based on a custom calibration for mixed rangeland. Here we use crude protein as our measure of forage quality.

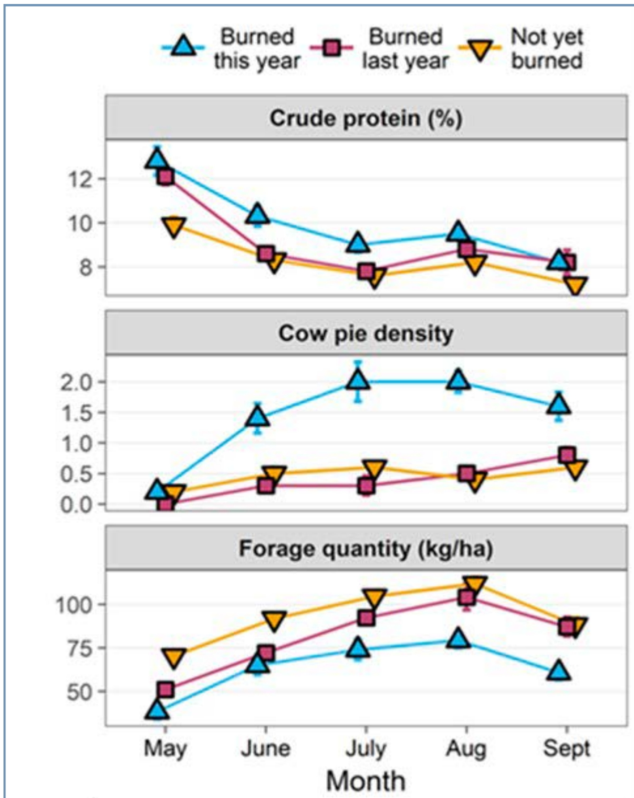

Figure 2. Changes in crude protein percentage, cow pie density, and forage quantity on patch burn grazed pastures over the 2018 growing season.

Results

Forage quality decreases as biomass increases, regardless of time since fire, and this relationship is more pronounced on the most recent burns (Figure 1). The percent of crude protein is consistently highest in the recently burned patches, and we observed a general trend of declining forage quality during the season (Figure 2).

By looking at cow pie density, we can see that cattle show a pronounced attraction to the burned patches that increases during the season. This gives evidence for the "magnet effect": Cows will continue to be attracted to the recently burned patches vs. the unburned patches, even as forage quality decreases. The burned patches provide substantial forage for most of the season, and all patches exhibit general declines in late summer, which is an expected characteristic of cool-season stands (Figure 2).

Cattle on the patch-burn grazing pastures had consistent gains in both years (Figure 3). The continuously grazed pastures showed annual variability in the average daily gains, but that variability was not significantly different from zero.

With the one year of data we have from the rotationally grazed pastures, we see a nonsignificant trend toward weight loss. The most notable aspect of this is the stability of cattle weights on the patch-burn pastures.

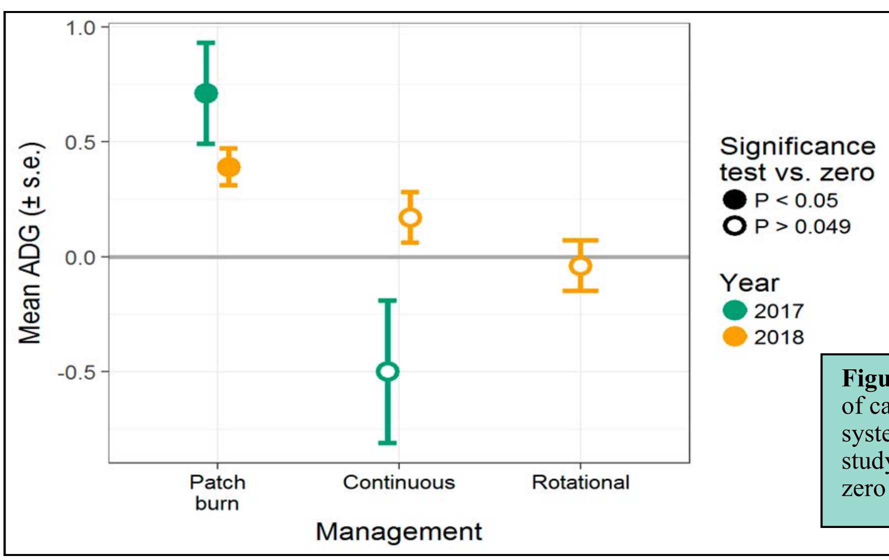

Figure 3. Mean average daily gains of cattle on all three management systems during both years of the study. Significant differences from zero are shown.

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 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 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.

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 and quantity, driven by this gradient in time-since-fire. We also 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.

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GPS Collars Allow Cattle to Tell Us How They Use Their Pasture

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Rangeland scientists and managers often want to know how livestock behave in their pastures, but commercial systems for tracking animal activity are costly. I constructed a do-it-yourself (DIY) system that can be strapped to livestock and takes GPS readings at fixed intervals for a little more than a month for only about $125. We ran about 40 of these units at the CGREC throughout the 2018 grazing season, collecting fine-scale information about where and when cattle choose to graze. We found they responded very well to patch burning and often concentrate their grazing in recently burned patches.

Introduction

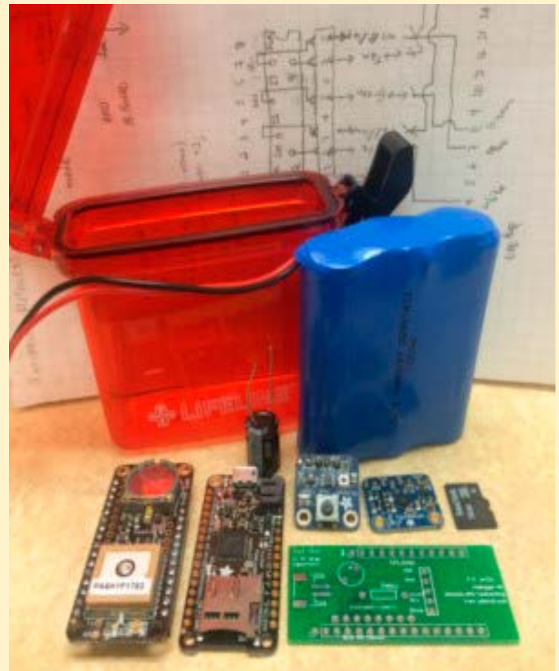
At first glance, a cow's life doesn't seem terribly complex: Her main objective is to find enough grass to keep her belly full, punctuated with taking a few drinks of water and standing still long enough for her calf to nurse. But in rangeland pastures, she's faced with a surprising amount of choice: what grass to eat, where to get those drinks of water, and where to loaf around to feed her calf and chew, chew, chew that cud.

Taken together, all the grazing, stomping and loafing of a whole herd of cows can have substantial effects on the range in terms of soil compaction and nutrient deposition, forage removal and productivity, and the height and density of vegetation that rangeland wildlife count as their habitat. Range managers have put a lot of research and effort into coming up with ways to help steer cows around the pasture, so to speak: water and mineral distribution, fencing systems even patch burns such as in the research at the CGREC.

But do these schemes work? Does cattle behavior actually respond to management? We can monitor all the potential impacts - soil health, forage production, plant species composition - but to really attribute those patterns to livestock behavior requires insight into how they use their pasture.

As in so many cases, the techie types have come up with several solutions to spy on our herds. Livestock can be fitted with all sorts of monitoring and tracking devices that record when they get close to specific sensors, such as at water or a creep feeder, or even where they are at any point in time, using Global Positioning Systems technology (GPS). But strapping sensitive electronics onto an animal for a season on the range requires ruggedness and extended battery life all in a small package. Thus, commercial GPS livestock tracking systems are expensive ($700 to $1,500/head).

I built a low-cost GPS data-logging collar from parts I found on the internet. A unit costs about $125, and I have built them so that the batteries last about 40 to 50 days. I tested them in the summer of 2017 out at the Hettinger REC, and they worked well (McGranahan et al., 2018).



The individual components soldered together to make a GPS data logger unit, plus the battery (blue) and the waterproof case it all goes into (red) before being strapped to a cow's neck.

Here I describe a full-bore roll-out of the DIY GPS collars at the CGREC in 2018. At any given time, we had about 40 units logging the positions of two to three cattle in each of our experimental pastures: the eight patch-burn grazing trials, the four continuously grazed refuge pastures, and the four pastures in the twice-over rotational grazing pastures.

The collars were on the pastures the whole time the cows were. We fit the collars when the animals were weighed and randomly assigned to pastures in mid-May, and the last collars came off when the cattle were moved off in mid-October.

Taking GPS Collars from the Lab to the Field

The Brains of the Operation

That definitely was not me, or even Kevin. I'm talking about the ATSAMD21G18 ARM Cortex M0 microprocessor. This is a cheap but powerful little computer chip that is widely used by electronics and robotics hobbyists. As part of the open-source movement that seeks to make technology and information freely available to users without hefty licensing fees, an Italian group developed Ardunio, a simple system of electronics and computer code that lets users program simple sensors and data loggers.

A summer technician fits cow with a freshly duct -taped GPS unit in the field.

I got my components from Adafruit Industries, a start-up in Brooklyn, N.Y., that sells small, portable Arduino electronics hardware aimed at hobbyists and artists. I soldered it all together in the lab on campus and re-wrote existing computer code available online to create a custom program to read GPS information at set intervals and store them on a removable SD (secure digital) card.

Deployment and Recovery in the Field

At the headgate, we plugged in a charged battery, sealed the waterproof case with duct tape and fastened the device to a triple-ply collar with hose clamps. We wrapped the cases in stretchy, insulated electrical tape for shock absorption, and we used lots of duct tape.

About monthly, Carl Dahlen's team ran the cattle through the chute, and we were there to swap out batteries, download data and replace any malfunctioning units.

Interpreting the Results

The GPS collars brought in a lot of data. By the end of the grazing season, I had nearly 10 million individual datapoints. So much information gives us an opportunity to look into how cattle choose where to graze based on ecological sites, distance to water and, of course, which grazing system they are in. We also have the opportunity to see how these decisions change throughout the season. As the plant community changes, or droughts come and go, do cows make different decisions on where and when they will graze?

For now, we can answer the simple question that got me interested in designing my own DIY system: Do cattle tend to concentrate their grazing in recently burned patches? It appears that they do, which is consistent with our observations that recently burned patches have higher-quality forage emerge after fire, which stays high quality throughout the season as long as cattle keep grazing it and maintaining a juvenile state in the grass sward.

But they also spend more time outside of the burned areas than cattle in the southern Plains do, which might be because our fires were more patchy and we have more cool-season grasses up here. Cool-season grasses generally are more palatable, even without having been burned.

Conclusions

The DIY GPS collars worked pretty well at the CGREC. I'll admit I was pleasantly surprised, especially for as little as each unit cost (about $125). Thanks to a few cows with GPS collars, we were able to confirm that very often, cattle chose to graze in recently burned patches. Further analysis will reveal how grazing site selection decisions vary through the season, and research in additional years will provide more information as burning and precipitation patterns change.

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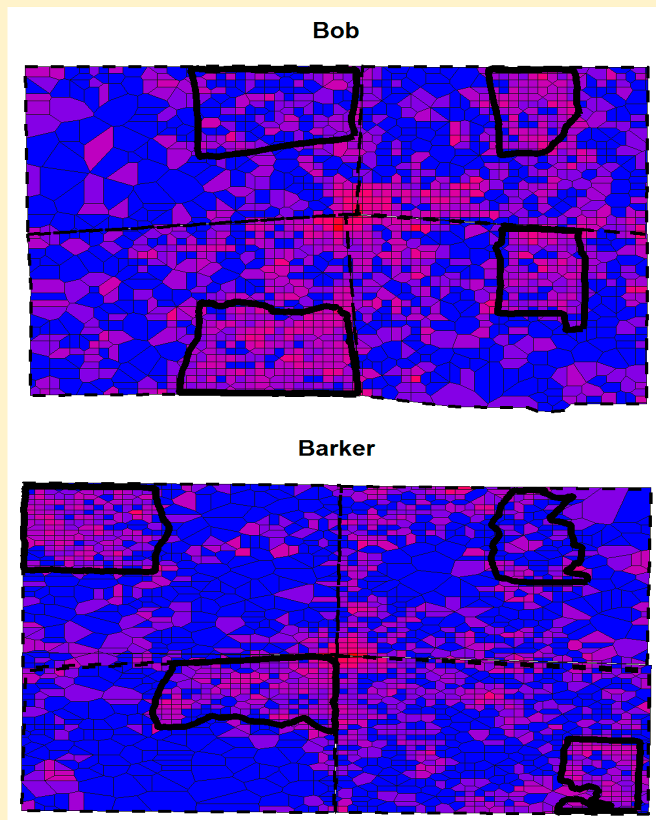

An example of how GPS positions are used to understand cattle behaviour. The red zones are areas that collared cows spent a lot of time in through June 2018; very few positions were recorded in blue areas. Each image has four 160-acre pastures, and burned areas are outlined in bold. The water source is in the center. Cows were definitely attracted to burned areas, although not so

Examining Marker-assisted Management as a Strategy in Precision Agriculture to Maximize Carcass Traits in Beef Cattle

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We are looking to assess how different implant strategies interact with the GALR2 genotype to affect carcass traits as a means of better understanding the biological mechanisms influencing differences in muscle and fat growth. Our ultimate goal for this research is to develop marker assisted management strategies utilizing the GALR2 genotype to improve production efficiency and carcass characteristics in finishing cattle. Cattle on the study were selected from the Central Grasslands Research Extension Center cow herd based on specific genomic markers and fed at the North Dakota State University, Beef Cattle Research Complex and will be harvested during mid-May, early June 2019. At harvest carcass data including, hot carcass weight, ribeye area, back fat, yield grade, quality grade and marbling score, will be collected. The strip loin of each animal will be collected at harvest and brought to NDSU for further meat quality analysis including shear force, ether extract values, meat color, cook loss and pH to determine if any effects on meat quality can be attributed to genotypic differences.

Introduction

Marker-assisted management has become a growing practice in many successful feedlot production systems by assisting in identifying more efficient and profitable cattle. Feedlots have the opportunity to capitalize on increased profit margins by producing more uniform body composition of feeder cattle. Regardless of whether cattle are marketed on a live weight, carcass weight or grid basis, increased muscling and marbling are key to increasing profit for product. It is because of these market incentives with this study we are looking into the effects of a target for genetic marker assisted management on finishing cattle production.

In addition, value-based markets provide a premium price for well marbled carcasses. These are the reasons that marker-assisted management has become a growing practice in many successful feedlot production systems. There is an opportunity cost of underfed animals when uniform pen weights are not achieved (Woronuk et al., 2012). The North American beef industry provides premiums for well-marbled carcasses without excessive fat cover (DiCostanzo and Dahlen, 2000). These market incentives are the reason why with this study we are looking into the effects of a target for genetic marker-assisted management on finishing cattle production.

Galanin receptor 2 (GALR2) is a neuropeptide receptor that is associated with feeding behavior, insulin release, and growth hormone secretion (Smith et al., 1997; Waters and Krause,2000). A previous study in cattle examined the effect of a mutation in GALR2 (GALR2c.-199T>G) on carcass characteristics (Duncombe et al., unpublished). The GG genotype was associated with greater rib-eye area, whereas the TT genotype was associated with increased marbling score. This divergence in muscle and fat growth between the genotypes presents a unique opportunity for marker-assisted management.

Utilizing different management practices based on genotype, such as conservative versus aggressive implant strategies, could improve carcass uniformity and therefore, profitability, for beef producers. Additionally, gaining insight into the biology and mechanisms of how the GALR2 genotype affects muscle growth and fat deposition can point toward additional management strategies that could be implemented to improve beef production. Previous research demonstrated that the GALR2 genotype affects rib-eye area and marbling of cattle. An inverse relationship exists between muscle growth and fat deposition, with the GG genotype resulting in greater rib-eye area, but the TT genotype having a greater marbling score, with TG being intermediate.

The goal of this research is to study the underlying mechanism of how the GALR2 affects muscle and fat growth. This will support our ultimate goal of developing a marker-assisted management strategy, utilizing different implant strategies depending upon the GALR2 genotype to maximize rib-eye area and marbling while improving carcass uniformity.

Marker-assisted management is the concept of genotyping cattle for a genetic marker and employing different management practices based on genotype to improve production outcomes.

An example of this is a mutation in the gene leptin (LEPc.73C>T). Leptin is a hormone that affects the appetite pathway. Cattle with of the leptin TT genotype have increased body weight, back fat and marbling, compared with CC cattle (Kononoff et al., 2005; Woronuck et al., 2012).

A commercial test is available for cattle, which some commercial feedlots use to sort their cattle based upon genotype. To improve carcass uniformity each genotype is finished with a different number of days on feed, with CC cattle being fed for more days to reach the same degree of finish as TT cattle. This improved uniformity improves profitability and reduces inefficiencies caused by over- or under-finishing.

Galanin is a neuropeptide that is involved in appetite regulation and insulin secretion (Lang et al., 2007). Galanin acts through binding to the receptor GALR2, which is widely expressed throughout the nervous system and in other tissues including the kidneys and lungs (Waters and Krause, 2000). This large tissue distribution and association with feeding behavior make GALR2 a promising candidate gene for carcass traits in beef cattle. In previous research (Duncombe et al., unpublished) a mutation in GALR2 (GALR2c.-199T>G) has been found to be associated with differences in rib-eye area and fat deposition in beef cattle. Treatments were designed with 1000 implanted steers and 1000 non-implanted steers finished in a commercial feedlot. In implanted steers, the GG genotype was associated with significantly (P <0.01) greater rib-eye area than TT steers, with TG being intermediate (TT = 83.74, TG = 84.32 and GG = 86.90

Table 1. The effect of GALR2 genotype on marbling score and back fat thickness in implanted and non-

	Marbling Score		Back Fat (mm)	
Genotype	GG	TT/TG	GG	TT/TG
Implanted	378.3[a]	397.8[b]	7.3[a]	8.4[b]
Non-implanted	430.9[a]	463.5[b]	9.1[a]	10.2[b]

centimeters^2). Conversely, there was no difference in rib-eye area in the non-implanted steers. Effects of the GALR2 genotype were observed in implanted and non-implanted steers for marbling score and back fat thickness. Steers of the GG genotype had significantly ($P < 0.01$) less back fat and lower marbling score than the TT and TG genotypes (Table 1). These results suggests that implant strategy had potential as a marker assisted management tool, with the GALR2 genotype to target rib-eye area in finishing cattle.

Procedures

Materials and Methods

All steer calves were selected from the Central Grasslands Research Extension Center beef cow herd based on genomics and arrived at the Beef Cattle Research Complex by Nov. 8th, 2018. Each steer was given time to train up to Insentec feeding systems. Of the 96 steers brought to the BCRC 94 began on the study starting Nov. 20, 2018 which was classified as day zero. Treatments were equally distributed across pens. The steer calves were allocated randomly to one of two implant strategies: one implant vs two implant. The implant strategies are: 1) Revalor-S (Merk Animal Health, Summit, NJ) on d 77 of finishing (1X) or 2) Revalor-S on d zero and d 77 of finishing (2X). Forty-seven of the steers were assigned randomly to the two implant strategy as illustrated in Table 2.

The cattle are being fed a standard feedlot ration and are projected to finish to a final body weight of approximately 1,400 pounds. Two weeks prior to slaughter, a muscle biopsy will be collected from the ribeye (longissimus muscle) of each steer. The procedure has been performed successfully on feedlot cattle in our lab in previous research with no adverse effects. The area will be surgically prepared (shaved and scrubbed) and a local anesthetic will be injected to numb the area. A small (approximately 1 inch) incision will be made through the skin and a muscle biopsy will be collected using a 10 millimeter Bergstrom biopsy needle. The biopsy will be preserved in RNA later. The incision will be sutured and injections of an antibiotic and a pain reliever will be administered.

The biopsies will be used to measure the expression of genes involved in muscle growth and fat deposition. RNA will be extracted and then reverse transcribed to cDNA. Gene expression will be measured via qPCR using SYBR green chemistry.

All steers are being weighed to track average daily gain, and blood samples are being collected every 28 days. The calves are projected to be finished on approximately a 180-day schedule with two separate slaughter dates due to the wide spread weight distribution at weaning and logistics of travel to the slaughter facility. Carcass data, including hot carcass weight, ribeye area, back fat, yield grade, quality grade and marbling score, will be collected at the slaughter plant. The strip loin will be purchased for further analysis of meat quality including shear force, ether extract values, meat color, cook loss and pH to determine if any effects on meat quality can be attributed to genotypic differences.

Statistical Analysis

Treatment assignment is a completely randomized designed with a 3x2 factorial as displayed in Table 2. Genotype and implant strategy act as fixed effects while pen and slaughter date are considered random effects. Significance will be set at P <0.05.

Results and Discussion

Cattle are currently on study, slaughter dates are projected for mid -May and early June. The long-term goal of this research is to develop marker-assisted management strategies utilizing the GALR2 genotype to improve production efficiency and carcass characteristics in finishing cattle. The immediate objective of this

Table 2. Genotype and implant distribution by pen.

	Pen 1			Pen 2			Pen 3			Pen 4		
Implant Strategy	GG	TG	TT	GG	TG	TT	GG	TG	TT	GG	TG	TT
1 -Implant	1	6	5	3	5	5	2	3	5	4	4	2
2-Implants	3	3	5	2	5	4	3	6	4	1	5	7

project is to determine how different implant strategies interact with the GALR2 genotype to affect carcass traits and better understand the biological mechanisms influencing differences in muscle and fat growth.

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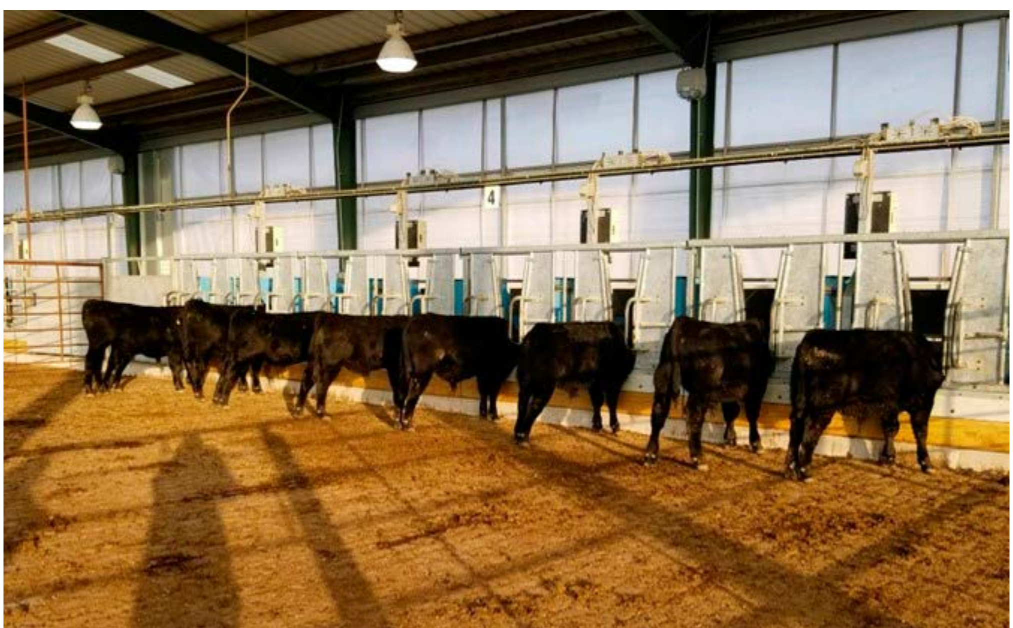

Week two of study steer calves eating from Insentec Feeding System.

Utilizing an Electronic Feeder and Ear Tag Accelerometer to Measure Mineral and Energy Supplement Intake and Reproductive Behavior in Beef Heifers Grazing Native Range

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The objectives of this study were to develop a mobile cow command center (MCCC) to 1) examine the relationship between mineral and energy supplementation on intake and feeding behavior on native range and 2) examine reproductive behavior of heifers on native range utilizing the CowManager system. The MCCC paired two commercially available technologies - a SmartFeed device, which monitors intake, and a CowManager system, which monitors cow reproductive, feed-related and health -associated data - in a single trailer unit that can be transported and function anywhere cattle are managed.

Our results clearly show that the feed-controlling portion of the MCCC can be used for precision feeding of individuals in expansive group-managed scenarios. Further, the estrus and health alert functions of the CowManager system were found to be unreliable triggers for management responses that could lead producers to inappropriate conclusions about the status of their herds.

Summary

Crossbred Angus yearling heifers (n = 60) at the Central Grasslands Research Extension Center (Streeter, N.D.) were used to evaluate an electronic feeder and ear tag accelerometer to measure mineral and energy supplement intake and reproductive behavior in heifers grazing native range. Heifers 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.) from which supplements were delivered.

Heifers were assigned randomly to one of three dietary treatments: 1) no access to feed supplements (**CON**; n = 20); 2) free-choice access to mineral supplement (**MIN**; Purina Wind and Rain Storm [Land O'Lakes Inc.], n = 20); or 3) free-choice access to energy supplement (**NRG**; Purina Accuration Range Supplement [Land O'Lakes Inc.], n = 20). Heifers also were fitted with a CowManager tag that uses the RFID tags and additional sensors to monitor cow reproductive (estrus alerts), feed-related (eating, rumination and activity level) and health-associated (body temperature) data.

Heifers were artificially inseminated utilizing sexed semen and turned out to graze at the initiation of the study. Consecutive weights were taken at the beginning and end of the study, along with blood and liver biopsy samples. Heifers in the NRG treatment (819.5 ± 85.0 grams per day [g/d]) consumed more ($P <$ 0.001) energy supplement, compared with CON (3.7 ± 85.0 g/d) or MIN (0.5 ± 85.0 g/d) heifers.

We found no differences in initial liver mineral concentrations among treatments ($P > 0.50$). Final cobalt (Co) levels were lower in CON heifers, compared with MIN or NRG heifers; however, selenium (Se), iron (Fe), copper (Cu), zinc (Zn), molybdenum (Mo) and manganese (Mn) were not different among treatments ($P > 0.13$). The MCCC units were deployed successfully and serve as portable units that use solar power to run individual feeders and upload data to cloud-based data acquisition platforms.

Introduction

As technology is advancing at an amazing rate, some sectors of agriculture are implementing new innovations with the utmost fervor. However, the beef industry is lagging behind other industries in the rate of adoption.

Several reasons likely exist for this adoption lag, foremost of which are the lack of comprehensive technological solutions that can be implemented in expansive pasture settings, and the lack of solutions from which management decisions can be made during the life of the individual. Each individual in a herd of cattle is unique, and differences can be found in variations in stage of production, specific nutritional needs and health status within herds.

These variations change throughout not only the production year, but the life cycle of the individual. Activities reported herein are aimed at pairing technologies to design and test a system that would allow for precision management of individuals within a herd to optimize production efficiency, improve animal health and enhance profitability.

This research explores the possibility of identifying and monitoring feed intake, estrus behavior and health status remotely while cattle are being managed in extensive pastures. This information could lead to targeted management strategies for cows with distinct nutrient needs (high and low body condition scores or mixed groups of cows and heifers) while being managed in common pastures. The project also contributes to the long-term goal of developing precision management strategies during the lifetime of cattle in our herds.

The concept of the mobile cow command center (MCCC) is to pair two commercially available technologies into a single trailer unit that can be transported and function anywhere cattle are managed. The two technologies are the SmartFeed device, which monitors intake, and the CowManager system, which uses RFID tags and additional sensors to monitor cow reproductive, feeding-related and health-associated data.

Therefore, our objectives were to develop a mobile cow command center (MCCC) for 1) examining the relationship between mineral and energy supplementation on intake and feeding behavior on native range and 2) examining reproductive behavior of heifers on native range utilizing the CowManager system.

Procedures

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

Mobile Cow Command Center Units

Two MCCCs were developed by pairing two commercially available technologies into single-trailer units that can be transported and function anywhere cattle are managed. The first technology is the SmartFeed device (C-lock Inc., Rapid City, S.D.; see www.c-lockinc.com), which is a self-contained system designed to measure supplement intake and feeding behavior from individual cattle in group settings.

The system is solar powered and includes a radio frequency identification (RFID) reader, weigh scales, access control gate, a feed bin and a cloud-based interface that continuously logs feed intake and feeding behavior data.

The second technology in the MCCC was the CowManager system (distributed by Select Sires in the U.S.; see www.cowmanager.com/en-us), which uses RFID tags and additional sensors to monitor cow reproductive (estrus alerts), feeding-related (eating, rumination and activity level) and health-associated (body temperature) data.

Data were received by a router attached to a computer in each MCCC that automatically uploaded the data for viewing on any device with an internet connection. Two SmartFeed units and controlling hardware and the CowManager systems were placed in each of two enclosed trailers with open feed-access areas and retractable wheels for easy transport.

Training Period

One hundred twenty-six crossbred yearling Angus heifers were managed for two weeks in dry lots at the Central Grasslands Research Extension Center (CGREC). Heifers were split into two pens (n = 63), where they all were given access to one SmartFeed trailer.

Each trailer contained two SmartFeed units that provided corn silage in each of the feed bins. The units were set at training mode, which locked the gate in the lowest position to allow easy access to feed in the bins. The radio frequency identification (RFID) reader and antenna recorded heifer RFID and intakes during the training period.

Heifer Selection

All heifers were estrus synchronized using a controlled internal drug release (CIDR; Zoetis) protocol, with heifers receiving 2 cc of GnRH (Factrel; Zoetis, Parsippany, N.J.) intramuscularly and a CIDR insert on day zero. Seven days later, the CIDR insert was removed and a single injection of $PGF_{2\alpha}$ (5 cc intramuscularly; Lutalyse; Zoetis, Parsippany, N.J.) was administered, followed by GnRH and artificial insemination approximately 60 hours later (seven-day CO-Synch plus CIDR protocol).

All heifers received an Estrotect patch to determine heat state. On the day of artificial insemination (AI), heifers were selected on the following basis: 1) patch score, 2) classification as "eater" or not and 3) exposure to feeders as calves on a previous study. All MCCC heifers (n = 60) were AI bred using sexed semen (Tehama Tahoe B767) and pregnancy checked via rectal ultrasonography (7.0-MHz transducer, 500 V Aloka, Wallingford, Conn.) 34 days after AI.

Grazing Period

Sixty crossbred yearling Angus heifers were managed as a single pasture group with free access to native range grazing at the Central Grasslands Research Extension Center (CGREC). Heifers were assigned randomly to one of three dietary treatments: 1) no access to feed supplements (**CON;** n = 20); 2) free-choice access to mineral supplement (**MIN**; Purina Wind and Rain Storm [Land O'Lakes Inc.], n = 20); or 3) free-choice access to energy supplement (**NRG**; Purina Accuration Range Supplement [Land O'Lakes Inc.], n = 20).

The MIN and NRG supplements were delivered via the MCCC SmartFeed units and only heifers assigned to the respective treatments were allowed access to the feeders through the web-based controlling interface. Feed intake data were summarized from the time of MCCC deployment (July 25, 2018) until removal from pasture (Sept. 19, 2018; Figure 1). The relationship between supplement intake reported with the SmartFeed units and activity reported with the CowManager system was evaluated during the 57-day period when heifers were actively consuming supplements (July 25 to Sept. 19, 2018).

Estrus-related events were generated via the CowManager system and were listed as in heat, potential or suspicious. Heifers were monitored for return to estrus after AI, and ultrasound was used to confirm pregnancies.

A retrospective analysis was conducted to determine the accuracy of estrus-related alerts generated via the CowManager system versus a known pregnancy status. Similarly, a retrospective analysis was conducted to evaluate the accuracy of health events that were flagged via the CowManager system (reported as sick, very sick or no movement) by comparing with treatment logs generated by the animal care staff at the CGREC.

Samples of liver were collected on the first and final day of monitoring via biopsy from a subset of heifers from each respective treatment (n = 24; eight per treatment). Heifers were restrained in a squeeze chute and the hair between the 10th and 12th ribs was clipped.

Liver biopsy samples were collected using the method of Engle and Spears (2000) with the modification that all heifers were given an intradermal 3 milliliter (mL) injection of Lidocaine Injectable-2% (MWI, Boise, Idaho) at the target biopsy site. A stab incision then was made between the 10th and 11th intercostal space at an intersection with a line drawn horizontally from the

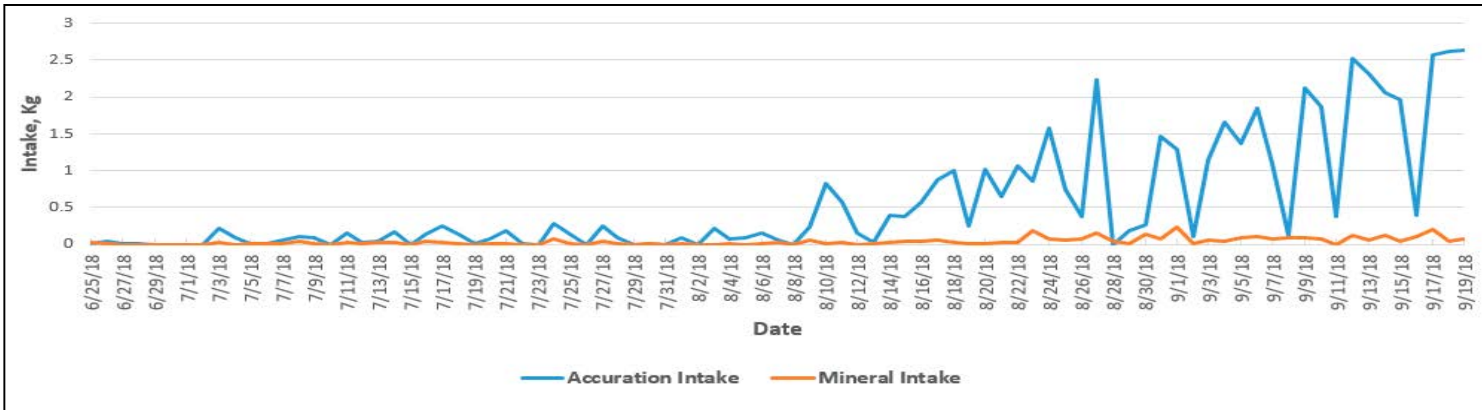

Figure 1. Intake of mineral and energy supplements during the grazing period.

greater trochanter. A core sample of liver was taken via the Tru-Cut biopsy trochar (14 g; Becton Dickenson Co., Franklin Lakes, N.J.).

After obtaining liver biopsies, a staple and topical antibiotic (Aluspray; Neogen Animal Safety, Lexington, Ky.) was applied to the surgical site and an injectable NSAID (Banamine; Merck Animal Health, Madison, N.J.) was administered. Biopsy samples were stored in vacuum tubes designed for trace mineral analysis (potassium EDTA; Becton Dickinson, Rutherford, N.J.) and stored at minus 20 C until further analysis. Liver samples were sent to the DCPAH at Michigan State University and were evaluated for concentrations of minerals using inductively coupled plasma mass spectrometry.

Analysis

Data were analyzed in SAS (9.4, SAS Inst. Inc., Cary, NC) for supplement intake, behavior and liver mineral concentrations via PROC GLM with significance at $P < 0.05$.

Results and Discussion

Intake of energy and mineral supplements was very low during the early portion of the grazing season but began to increase in mid-August as the quality of native range declined (Figure 1). From July 25, 2018, until Sept. 19, 2018, heifers in the MIN treatment (47.2 ± 3.4 g/d) consumed more ($P < 0.001$) mineral, compared with heifers in the CON (1.2 ± 3.4 g/d) and NRG treatments (2.1 ±3.4 g/d), and heifers in the NRG treatment (819.5 ± 85.0 g/d) consumed more ($P < 0.001$) energy supplement, compared with CON (3.7 ± 85.0 g/d) or MIN (0.5 ± 85.0 g/d) heifers.

Activity data from the CowManager tags indicate that time spent eating, ruminating, not active or active were not impacted by treatment ($P \geq 0.16$, Table 1). However, heifers in the NRG treatment spent 20 more ($P = 0.02$) minutes on a daily basis being highly active, compared with heifers in the other treatments (Table 1). The additional time NRG heifers spent being highly active likely was related to competition for energy supplements at feeders, where 20 heifers were competing for two feeding spaces. Interestingly, treatment did not impact weight gain ($P = 0.93$) during the monitoring period, with heifers gaining an average of 0.47 kilogram per day (kg/d).

Evaluation of estrus data revealed that 16 of 28 heifers confirmed pregnant via ultrasound (57 percent) were identified incorrectly as displaying estrus behavior (two reported as in heat, 11 reported as potential and three reported as suspicious). Additionally, 146 health alerts were generated, but only 13 heifers needed clinical treatment. An additional nine heifers required treatment but did not generate an alert.

We found no differences in initial liver mineral concentrations among treatments ($P > 0.50$; Table 2). Final Co levels were lower in CON heifers, compared with MIN or NRG heifers; however, Se, Fe, Cu, Zn, Mo and Mn were not different among treatments

Table 1. Activity of heifers monitored using CowManager ear tags.

	Treatment				
Parameter	**CON**	**MIN**	**NRG**	SE	*P*-Value
Eating, min/d	560.9	562.1	483.8	32.4	0.16
Ruminating, min/d	350.7	350.8	368.6	24.19	0.83
Not active, min/d	181.1	176.0	214.7	16.02	0.19
Active, min/d	210.7	212.2	214.1	29.33	0.99
Highly active, min/d	138.3^{x}	139.7^{x}	159.8^{y}	5.71	0.02

^{x,y} means with uncommon superscripts differ ($P = 0.01$).

($P > 0.13$).

According to Kincaid (2000), liver mineral concentrations for Fe, Zn, Mo and Mn are considered adequate for heifers among treatment groups. Adequate liver Cu concentrations are defined as 125 to 600 micrograms per gram (ug/g) dry matter (DM) (Kincaid, 2000) and normal is defined as greater than 100 ug/g DM (Radostits et al., 2007).

Therefore, heifers would be considered marginal (33 to 125 ug/g DM; Kincaid, 2000) to adequate or normal for liver Cu concentrations. Selenium concentrations in the liver for heifers were classified as adequate (1.25 to 2.50 ug/g DM; Kincaid, 2000).

Liver Co levels at 0.08 to 0.12 ug/g DM or more indicate satisfactory Co status (McNaught, 1948), and the heifers in this study were above satisfactory levels. Overall, heifers in their respective treatment groups had adequate liver mineral concentrations. In conclusion, the MCCC units were deployed successfully and serve as portable units that use solar power to run individual components and upload data to cloud-based data acquisition platforms. SmartFeed units were able to control the intake of individual animals assigned to different treatments in a group pasture scenario.

Our results clearly show that the feed-controlling portion of the MCCC can be used for precision feeding of individuals in expansive group-managed scenarios. The CowManager system was able to detect divergence in highly active behavior among treatment groups but also reported many false health and estrus-related alerts.

Acknowledgments

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Table 2. Liver mineral concentrations of heifers grazing native range and provided access to a mineral or energy supplement.

	Treatment[1]				
Item	**CON**	**MIN**	**NRG**	**SE**	***P*-value**
Initial					
Co	0.22	0.20	0.21	0.01	0.53
Mn	9.46	9.13	9.70	0.63	0.82
Mo	3.26	3.16	3.51	0.22	0.52
Zn	130.63	118.27	138.88	12.73	0.52
Cu	162.88	137.90	155.98	28.66	0.82
Fe	299.01	299.88	307.16	21.70	0.96
Se	1.68	1.53	1.69	0.11	0.50
Final					
Co	0.131[x]	0.303[y]	0.29[y]	0.04	0.01
Mn	9.73	8.89	9.80	0.65	0.55
Mo	3.73	3.87	3.62	0.22	0.71
Zn	101.90	100.75	107.74	6.84	0.74
Cu	82.72	99.55	92.25	16.79	0.78
Fe	191.12	211.99	258.48	23.10	0.13
Se	1.43	1.58	1.66	0.11	0.35

[xy] Means differ at $P < 0.05$.

[1] Treatment: **CON**, no access to feed supplements; **MIN,** free-choice access to mineral supplement; or **NRG**, free-choice access to energy supplement.

The Effects of Injectable Trace Mineral Supplements in Donor Cows at the Initiation of a Superovulation Protocol on Embryo Production and Pregnancy Rates in Recipient Females

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Objectives of this study were to determine the effects of an injectable trace mineral supplement (Multimin® 90) administered to donor beef cows at the initiation of a superovulation protocol on embryo production (i.e. quality and quantity) and pregnancy rate in recipient females. The injectable trace mineral increased the concentration of selenium in the liver; however, in this study no effects were observed on embryo production or pregnancy rates of recipients receiving those embryos.

Summary

We evaluated the effects of administering injectable trace mineral supplements at the initiation of a superovulation protocol on embryo outcomes (Exp 1) and pregnancy rates (Exp 2). In Exp 1, 35 crossbred Angus cows were randomly assigned to one of two treatments at initiation of a 16 d superovulation protocol; 1) cows received 90 mg Cu, 60 mg Mn, 30 mg Se, and 360 mg Zn as an injectable TM supplement (6 ml Multimin 90 s.q.; ITM); or 2) were untreated (CON). All donors were exposed to a common superovulation protocol, embryos were recovered 7 d after AI, graded for quality and developmental stage, and frozen until transfer. A replicated crossover design was used and each cow was flushed 4 times, with 120 d between flushes (total n = 70 for CON and 69 for ITM). In Exp 2, crossbred beef females were synchronized to receive embryos, and females with a CL 7 d after induced ovulation randomly assigned to receive an embryo originating from; 1) donors exposed to ITM (n =196); or 2) donors exposed to CON (n = 212). Embryo recovery data were analyzed using PROC MIXED of SAS for main effects of treatment, period, and their interaction, whereas the GLIMMIX procedure of SAS was used to analyze recipient pregnancy rates. In Exp 1 number of viable embryos recovered from cows responding to superovulation was similar ($P = 0.94$) among ITM (4.53 ± 0.63) and CON cows (4.46 ± 0.63). Moreover, number of degenerate, unfertilized, and total ova collected ($P \geq 0.67$), and number of embryos in respective developmental stages or quality grades ($P \geq 0.24$) were not affected by treatment. In Exp 2 pregnancy rates to embryo transfer were similar ($P = 0.52$) among CON (49.1%) and ITM (45.9 %) treatments. In this study, ITM administration failed to enhance embryo outcomes or pregnancy rates.

Introduction

Embryo transfer (ET) is an exceptional method of improving genetics in cattle herds. After superovulating and flushing, genetically superior calves can be gestated and raised by recipient females of different genetics. However, cost of ET can be prohibitive. Technologies and techniques that improve success rates and efficiencies in ET (i.e. reduce cost) have the potential to be widely adopted by producers who currently use ET, and also have the potential to expand the utilization of ET to a new audience of producers.

Proper nutritional status is paramount to optimal reproductive rate in cattle, and this concept extends to proper nutrition of embryo donor females (Lamb, 2010). Inclusive in recommendations for donor female nutrition are discussions about trace mineral status. In scenarios of artificial insemination (Mundell et al, 2012) and timed embryo transfer of recipient females (Sales et al., 2011) administration of injectable trace mineral supplements improved overall pregnancy rates. Though free choice trace mineral source did not impact embryo production in donor females (Lamb et al., 2008), a small preliminary study by Boas et al. (2017), showed that donors treated with ITM had a tendency (P = 0.15) to have fewer unfertilized oocytes per collection. Though promising, these preliminary results need to be tested on a larger scale.

Therefore, the objectives of this study were to evaluate the impact of administering injectable trace mineral supplements in embryo transfer programs on:

1) Number of embryos recovered, embryo quality, and developmental stage

2) Pregnancy rates of recipients receiving embryos originating from donors either receiving or not receiving injectable trace mineral supplements

Experimental Procedures

All procedures for this experiment were approved by the North Dakota State University Animal Care and Use Committee.

In Exp 1, 35 multiparous crossbred Angus cows (BW = 1274 ± 20 lbs, BCS 5.75 ± 0.11) were selected from Central Grassland Research and Extension Center (CGREC), Streeter, ND to serve as embryo donors. Donors were randomly assigned to one of two treatments at initiation of a 16-day superovulation protocol; 1) cows received 6 ml Multimin®90 s.c.; ITM; or 2) were untreated (CON).

All females were exposed to a common superovulation protocol and a single sire was used for all inseminations. Cows were kept in pens at CGREC and were fed to meet NRC requirements. In addition, all donors were offered 4 ounces/head daily of Purina® Wind and Rain® Storm® 7.5 CP Avalia® 4 Original XPC Altosid®. Liver biopsies were collected at the beginning of the superovulation protocol and at embryo recovery. Embryos were recovered via uterine flush and graded prior to being frozen and stored in liquid nitrogen.

In Exp 2, 380 crossbred Angus cows (BCS = 6.03 ± 0.06, DPP = 85.6 ± 0.94 days) and 117 crossbred Angus heifers (BCS = 5.74 ± 0.03) were selected from the CGREC herd to serve as embryo recipients. Recipients were randomly assigned to receive an embryo originating from 1) donors exposed to ITM (n = 196); or 2) donors exposed to CON (n = 212).

Females had equal access to native range pastures and free choice access to Purina® Wind and Rain® Storm® 7.5 CP Avalia® 4 Original XPC Altosid® in mineral feeders located near waterers in the pastures for at least 30 days before transfer protocol started. Females were synchronized for fixed-time embryo transfer (FTET) using a 7-day Co-Synch + CIDR estrus synchronization protocol. Seven days after the final working event of synchronization females were presented for ovarian evaluation and those females having a corpus luteum received an embryo transferred into the uterine horn on the side of the CL. Liver (n = 21) and blood (n = 336) samples were collected from a subsample of cows at embryo transfer. Pregnancy rate to embryo transfer was determined by transrectal ultrasonography 36 days after transfer in cow recipients and 48 days after transfer in heifer recipients.

Results and Discussion

Administering ITM increased ($P < 0.0001$) concentrations of Se in the liver compared with CON cows (Table 1), but did not impact ($P \geq 0.17$) concentrations of Cu or Mn. In contrast, change in concentrations of Zn was greater ($P = 0.02$) in CON cows compared with ITM cows. Pogge et al. (2012) observed increases in Se, Mn, and Zn after ITM administration, and perhaps some of the disparity among reports is related to shipment of our donor females from CGREC to Fargo for embryo collection.

There was no treatment effect ($P = 0.96$) on the number of viable embryos produced per cow when respective analysis compared all cows in the experiment (Table 2), or when comparing only those cows responding to superovulation (CON = 4.46 ± 0.63 and ITM = 4.53 ± 0.63). In addition, treatment with ITM did not influence the number of degenerate ($P = 0.75$) or unfertilized ($P = 0.54$) embryos. Moreover, number of embryos in each respective grade and developmental stage were similar ($P \geq 0.19$) among treatments (Table 2). It is noteworthy that donors were offered minerals to meet NRC requirements and were not in a deficient status. Thus, an increase in TM status given trough ITM seemed to not influence superovulatory response and embryo development. Similarly, Lamb et al. (2008) observed that free choice mineral source (either organic or inorganic) did not impact embryo production in donor females. A recent report with limited numbers; however, showed that 9 dairy heifers given ITM at the beginning of superovulation tended (P = 0.15) to have fewer unfertilized embryos compared with the 9 control heifers (Boas et al., 2017).

Literature has shown conflicting results regarding the effects of ITM supplementation in reproductive processes. Though several reports have shown enhanced pregnancy rates when ITM was administered to cows receiving AI or to females receiving embryos (Sales et al., 2011; Mundell at al., 2012; Brasche et al., 2014; Kirchhoff, 2015; Stokes et al., 2017), pregnancy rates in Exp 2 were similar ($P = 0.52$) among recipient females that received embryos from donors in CON (49.1 %) and ITM (45.9 %) treatments, respectively (Table 3). A major difference between the current report and previous research was that recipients in our study did not receive ITM directly. We were essentially testing whether there was a lasting effect of ITM before superovulation which could enhance pregnancy rates, not whether administration

Table 1. Change in liver trace mineral concentration at day 16 in cows receiving control (CON) or injectable trace mineral (ITM) at d 0 of superovulation.

		Period			
	Treatment	d 0	d 16	Change[1]	*P* – value
		mean ± SE , ug/g DM			
Selenium	CON	2.72 ± 0.20	2.77 ± 0.17	0.04 ± 0.15[a]	< 0.0001
	ITM	2.79 ± 0.18	3.89 ± 0.30	1.09 ± 0.15[b]	
Copper	CON	193.86 ± 18.84	187.62 ± 17.44	- 6.2 ± 18.9[a]	0.17
	ITM	187.55 ± 17.15	224.66 ± 24.69	37.1 ± 18.9[a]	
Manganese	CON	12.03 ± 0.40	12.03 ± 0.77	0.002 ± 0.71[a]	0.97
	ITM	12.53 ± 0.49	12.43 ± 0.34	-0.10 ± 0.71[a]	
Zinc	CON	109.31 ± 3.92	139.59 ± 7.66	30.27 ± 7.4[a]	0.02
	ITM	127.99 ± 9.37	132.65 ± 6.07	4.66 ± 7.4[b]	

[1] Change reflects the increase or decrease in mineral concentration from d 0 to d 16.

Table 2. Embryo production in all treated donor cows receiving control (CON) or injectable trace mineral (ITM) at d 0 of superovulation.

	Treatment		*P* - value
	Control (CON)	Multimin (ITM)	
No. cows	70	69	
	(mean ± SE)		
Viable embryos, no.	3.37± 0.52	3.39 ± 0.52	0.96
Degenerate embryos, no.	0.75 ± 0.22	0.65 ± 0.22	0.75
Unfertilized oocytes, no.	2.60 ± 0.60	3.07 ± 0.60	0.54
Total ova/embryo, no.	6.79 ± 1.13	7.04 ± 1.13	0.80
Grade 1	3.12 ± 0.50	3.10 ± 0.50	0.96
Grade 2	0.11 ± 0.04	0.11 ± 0.04	0.97
Grade 3	0.12 ± 0.07	0.17 ± 0.07	0.67
Morula[1]	1.92 ± 0.32	1.66 ± 0.32	0.52
Compact morula[2]	1.20 ± 0.26	1.15 ± 0.26	0.91
Blastocyst[3]	0.18 ± 0.14	0.31 ± 0.14	0.50
Expanded blastocyst[4]	0.01 ± 0.07	0.15 ± 0.07	0.19

[1] Stage 4, [2] Stage 5, [3] Stage 6, [4] Stage 7.

Table 3. Pregnancy rates in beef females after transfer of embryos from dams receiving control (CON) or injectable trace mineral (ITM) treatments at the initiation of superovulation protocol.

	Treatment		
	CON	ITM	*P* - value
	--------% (no. of no.)--------		
Heifer recipients	43.4 (23 of 53)	49.01 (25 of 51)	0.56
Cow recipients	50.9 (81 of 159)	44.8 (65 of 145)	0.28
All recipients	49.1 (104 of 212)	45.9 (90 of 196)	0.52

of ITM directly to a recipient would improve pregnancy outcomes. We failed to detect an improvement in pregnancy outcomes due to the enhanced TM status from ITM that occurred before and during the first 7 days of embryo development.

In summary, Multimin® 90 increased concentrations of selenium in the liver; however, in this experiment no effects were observed on embryo production or pregnancy rates of recipients receiving those embryos.

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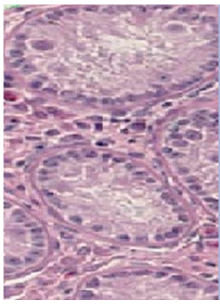

Comparison of Fine-needle Aspiration and Tissue Sections to Determine Sertoli and Germ Cell Counts in Prepubertal Beef Bulls

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At present, no methodology can predict potential daily sperm production and fertility in the bull. The size of the Sertoli cell (SC) population established in the testis before puberty is one of the most important determinants of daily sperm production in the bull. Fine-needle aspiration (FNA) has been used for many decades as a diagnostic tool, but its value to determine Sertoli and germ cell counts in bulls remains unexplored.

The objective of this study was to compare three sampling techniques (22G needle FNA vs. tissue samples collected using a 14G needle with vacuum pressure [14G ASP] and tissue cuts) and two stains (immunohistochemistry with GATA4 [IHC] vs. HE) to determine SC density in prepubertal bulls.

Fourteen age-matched prepubertal Angus bulls from the Central Grasslands Research Extension Center near Streeter, N.D., were castrated and testicular parenchyma samples were obtained for cytology. At castration, body weight, scrotal circumference, and testicular and dissected testicular weights were determined. From the same testis side, parenchyma samples for histology were collected using tissue sections and 14G ASP, and smears were produced using 22G FNA.

Two smears and tissue sections of each sampling method were stained using immunohistochemistry with anti-GATA4 as a specific SC marker (IHC-GATA4) and two with conventional HE. Complementary mirrored tissue sections were produced and stained with IHC-GATA4 and HE for individualized ST cross section cell count comparison.

Scrotal circumference was highly correlated with intact (P = 0.010) and dissected testicular weights (P = 0.018). Furthermore, intact and dissected testicular weights were correlated with IHC-GATA4 SC density determined in mirrored tissue sections (P = 0.018 and P = 0.016, respectively).

A high correlation was observed between stains for SC (P < 0.0001) and GC (P < 0.0001) counts performed on individualized ST cross sections. A significant correlation existed between GC counts and SC counts (P = 0.027) and density (P = 0.032) in IHC-GATA4 mirror tissue sections.

Nevertheless, no significant correlation existed between techniques for SC density in IHC-GATA4 sections (P =0.587). The high correlation observed between scrotal circumference and testis weight underlines the importance that scrotal circumference has as a routine measurement in breeding bulls.

The use of mirrored tissue sections allowed us to specify individual ST and assess the value of GATA4 as a SC marker. No significant correlation existed for SC density performed in IHC-GATA4 22GFNA, 14G ASP and tissue sections; nevertheless, a high correlation was observed between GC and SC cross section counts and density, highlighting the role SC play in determining the number of GC in the testis of prepubertal bulls.

Introduction

Potential daily sperm production of the bull is determined by the size of the Sertoli cell (SC) population in the testicle (Berndston, 1987). Sertoli cells replicate at specific windows of time during the life of the individual (Moura and Erickson, 1997).

Once puberty is reached, SC stop multiplying, fixing the ceiling of daily sperm production of the bull (O'Shaughnessy and Fowler, 2011). The incorporation of an accurate assessment method of SC population size could identify those subfertile individuals that escape current detection in routine breeding soundness exams (BSE) (Rajak et al., 2013).

Fine-needle aspiration (FNA) has been used for many decades as a diagnostic technique for neoplasms (Martin, 1930), reproductive pathologies (Aridogan et al., 2003), and infertility in humans (Craft et al., 1977) and animals (Leme and Papa, 2010). When compared with open biopsy, FNA presents several advantages, such as low invasiveness and no complications (Heath et al., 2001).

We hypothesized that Sertoli cell density determined using 22G needle FNA vs. 14 G with vacuum pressure vs. tissue sections are highly correlated. The objectives were to compare three sampling techniques (22G FNA vs. 14G needle with vacuum pressure and tissue sections) and two stains (HE vs. IHC-GATA4) to determine SC density in prepubertal bulls.

Materials and Methods

Fourteen aged-matched crossbred Angus bulls of 90 to 97 days of age and a bodyweight (±SEM) of 159.82 ± 3.67 kilograms (kg) were castrated surgically using an open-knife surgical procedure (IACUC #A18077). Fine-needle aspiration samples and tissue sections were collected from the same testis side. The following stains were performed:

2 slides x 22G smears with HE

2 x 22G smears with IHC-GATA4

2 x 14G tissue sections with HE

2 x 14G tissue sections with IHC-GATA4

1 x conventional tissue section with HE

1 x conventional tissue section with IHC-GATA4

For stain comparison, mirrored tissue cuts were produced, allowing cell counts in complementary seminiferous tubule cross sections (Figure 1).

Immunohistochemistry-GATA4 and HE images from tissue sections and smears were captured using a Zeiss Imager M2 epifluorescence microscope equipped with a Zeiss piezo automated stage and AxioCam HRm camera (Carl Zeiss International, Jena, Germany). From each IHC and HE smear and tissue section, five different images from randomly chosen fields were captured at 20-x magnification. Cell counts were performed using the Image Pro Premier 3-D software (Media cybernetics, Rockville, Md.).

Statistical Analysis

Data for birthweight, testicular parameters and cytology were analyzed using the PROC CORR and PROC REG procedure in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.).

Significance levels for all data comparison were determined and considered significant when $P<0.05$.

Results and Discussion

A high significant correlation was observed between GC HE counts per ST cross sections and intact (r = 0.607; $P = 0.021$) and dissected testicular weight (r = 0.594; $P = 0.024$). Furthermore, intact and dissected testicular weights were correlated with IHC-GATA4 SC density determined in mirrored tissue sections (r = 0.616; $P = 0.018$) and (r = 0.628; $P = 0.016$, respectively).

Sertoli cell counts conducted in the same individual ST cross section using IHC-GATA4 and HE were highly correlated for automatic ($P < 0.0001$) and manual counts ($P < 0.0001$) (Table 1), showing the usefulness and value of GATA4 as a specific SC marker (Figure 2). A similar scenario was found for GC, with highly correlated counts per ST cross sections for IHC and HE ($P < 0.0001$).

Sertoli cells are the only somatic cells within the ST that provide the hormonal, nutritional and physical support to germ cells (Moura and Erickson, 1997). In agreement with this, significant correlations existed between automatic and manual SC and GC counts done per ST cross sections on IHC-GATA4 ($P = 0.027$) and HE sections ($P = 0.041$) (Table 1).

When GATA4+ cell density determined in smears obtained by 22G FNA was compared with GATA4+ cell density done on tissue sections or in 14G ASP sections, no significant correlation was found ($P = 0.587$). The absence of ST micro-anatomical

Table 1. Pearson's correlation coefficient and significance levels between Sertoli and germ cell counts per seminiferous tubule cross section on IHC-GATA4 or HE in prepubertal beef bulls (90 to 97 days of age).

	Pearson's correlation coefficient			
Parameter	SC IHC auto	SC HE count	GC IHC count	GC HE count
SC IHC auto[a]		0.945***	0.587*	0.550*
SC HE count[b]			0.526*	0.447
GC IHC count[c]				0.948***
GC HE count[d]				

[a]SC IHC auto = SC automatic count per ST cross section on IHC-GATA4 mirror section.

[b]SC HE count = SC manual count per ST cross section on HE mirror section.

[c]GC IHC count = GC count per ST cross section on IHC-GATA4 mirror section.

[d]GC HE count = GC count per ST cross section on HE mirror section.

*P<0.05; **P<0.01; ***P<0.0001.

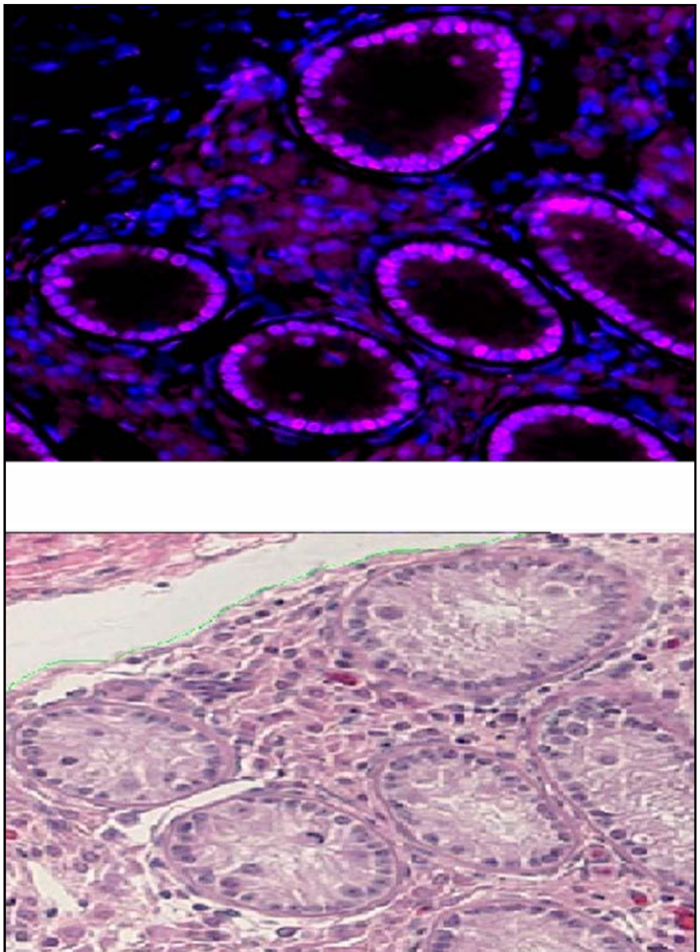


Figure 1. Images correspond to complementary mirror tissue sections stained with IHC-GATA4 (top) and HE (bottom). Stars of the same color correspond to the same ST cross section.

between smears and tissue sections.

Furthermore, intrinsic aspects of technique, such as uneven application of vacuum, syringe and needle control, and hand force might be causing the lack of consistency observed between FNA samples for SC density (Haseler et al., 2011).

Conclusions

The high correlation observed between SC and HE counts done in the same ST cross sections using IHC-GATA4 and HE confirms the value of GATA4 as a specific SC marker in prepubertal bulls.

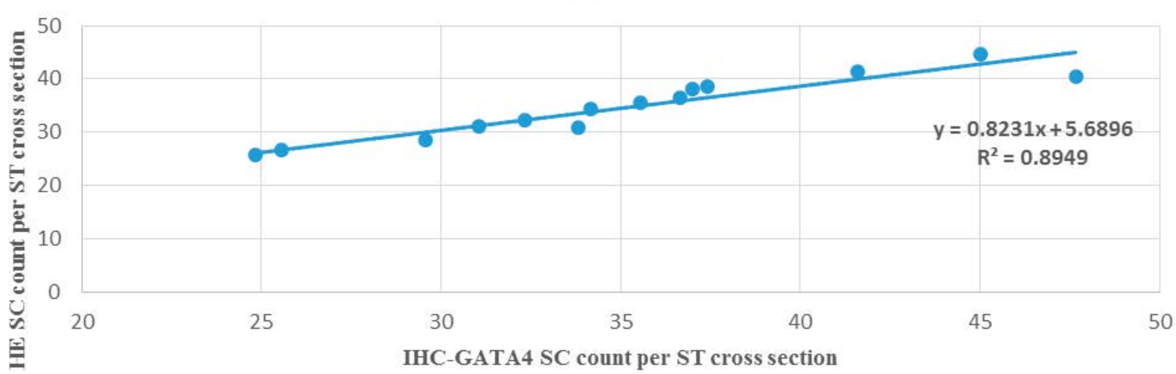
The high correlations seen between manual and automatic SC and GC counts performed on the same individual ST reflects the high accuracy of the automatic cell count using an image processing software tool.

The significant correlation detected between SC counts done in individual ST cross sections or as SC density with GC counts highlights the important role SC play in determining GC counts in prepubertal bulls.

The role of SC population size as a determinant of potential daily sperm production in the bull was confirmed by the relationship observed between SC densities and testis weights.

The lack of significant correlations for SC density among IHC-GATA4 22G FNA, 14G ASP and tissue sections observed in the present study reflects differences in cell counts among the sampling methods.

Figure 2. The relationship between Sertoli cell (SC) counts done on seminiferous tubule (ST) cross sections stained with immunohystochemistry with GATA4 (IHC-GATA4) and hematoxylin and eosin (HE) in prepubertal beef bulls (90 to 97 days of age).



references hindering the cytological reconnaissance of immature SC combined with the heterogeneous distribution and mixture of different types of loose cells observed in 22G FNA smears might contribute to the absence of significant correlations for SC density

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Evaluation of eyelid pigmentation and udder traits in Hereford cross cattle

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Introduction

Hereford cattle, along with other breeds with white pigmented faces, have increased risk of bovine ocular squamous cell carcinoma (aka cancer eye). Older studies have shown that Hereford cattle with more eyelid pigmentation had less chance of developing cancer eye (e.g., Anderson, 1991). Recent work has investigated how to quantify eyelid pigmentation in Hereford and Hereford cross cattle (Davis et al., 2015), but additional sample sizes are needed to take this a step further for genetic characterization.

Although cancer eye could be a reason a Hereford or Hereford cross cow could leave the herd, udder quality traits are also an important factor. Newborn calves need to nurse unassisted, particularly in range conditions where assisting those calves may not be feasible. Calves have difficulty nursing when the dams have poor udder attachment or teat sizes of either extreme (Wythe, 1970; Edwards, 1982; Ventorp and Michanek, 1992). Calf mortality rates were higher when dams had large teats and pendulous udder suspension (Frisch, 1982). Thus, improving udder quality can be beneficial to producers by reducing the amount of labor associated with assisting calves to nurse and increasing the number of calves weaned per cow, an important measure of efficiency. Furthermore, by improving udder quality, cows remained in the herd longer, resulting in the need for fewer replacement heifers (e.g., Greer et al., 1980; Frisch, 1982), thereby reducing replacement costs. Little current literature has investigated genetic inheritance of udder quality traits or tried to map genomic regions of influence in Hereford or Hereford cross cattle.

The objective of this project is to 1) collect face and eyelid pigmentation photographs of Hereford cross calves and 2) collect udder photographs and scores for udder support and teat size. Data collected will be shared and utilized in a multistate project investigating genetic inheritance of eyelid pigmentation and udder quality.

Materials & Methods

Animals. Data was collected on calves at weaning age from Central Grasslands Research Extension Center (CGREC) that were either sired by Hereford or whose dam was sired by Hereford and possessed a white face. White-faced heifers retained or that will be retained at CGREC for breeding were also utilized for the years they are present at CGREC and produce calves. All procedures involving animals were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Data Collection and Traits. White-faced calves at weaning were used to capture facial and eye photos following Davis et al. (2015). Each calf had blood drawn via jugular venipuncture for white blood cell extraction. White blood cell pellets have been stored long term in an ultralow freezer until funding becomes available for DNA extraction and genotyping. White-faced heifers that were retained for breeding and produced calves had photographs of body and udder taken as well as udder suspension and teat size recorded at calving, mid-lactation and weaning time following Beef Improvement Federation (2018) recommendations.

Results & Discussion

The number of calves used for eyelid study and females with scores captured since 2015 are shown in Table 1. White-faced females that had udder characteristics scored on their first calf were culled from the CGREC cow herd due to reproductive failure rather than udder characteristics (see Table 1 2015 born females). Udder types are diverse (Figure 1), which will add nicely to the multistate data set for genetic characterization. Hereford sires were used heavily in the 2018 breeding season; therefore, additional white-faced calves are being produced (n ≥ 100) and will be used for eyelid and face pigmentation photographs in fall 2019.

Table 1. Number of animals captured in photographs for eyelid and face pigmentation as well as udder traits scored and photographed since 2015.

		Eyelid and face		
Year captured	Year born	Male	Female	Udder traits[1]
2015	2015	26	23	--
2016	2015	--	--	--
	2016	36	29	--
2017	2015	--	--	19
	2016	--	--	--
	2017	56	39	--
2018	2015	--	--	18
	2016	--	--	14
	2017	--	--	--
	2018	3	7	--
Total records		121	98	51

[1]Udder traits included udder suspension and teat size according to Beef Improvement Federation (2018) recommendations. Scores and photographs were captured at calving, mid-lactation and weaning. Numbers present in this column are individual cow per year, where cows are repeated across years if retained by CGREC.

Figure 1. Udder photos captured at mid-lactation in 2018 on 2015 and 2016 white-faced cows.

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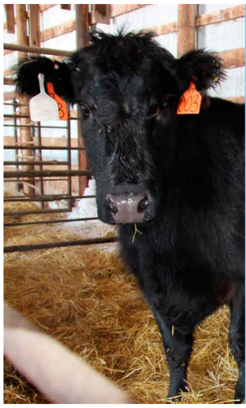

Evaluation of methods to measure temperament in cattle and their impacts on predictions of genetic merit

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Introduction

Measuring temperament, defined as the reaction of the animal to human handling (Burrow and Dillon, 1997; Fordyce et al., 1982), in beef cattle has been of industry-wide interest. Calmer cattle result in less stress and safer work environments for the handler as well as that animal and its contemporaries (Grandin, 1989). The reduction of stress on both animals and humans can result in more efficient production of beef and reduced costs due to health reasons (e.g., King et al., 2006; Cooke et al., 2009a, 2009b, 2011). This is particularly true as wilder, more excitable temperaments alter immune responses in cattle (reviewed by Burdick et al., 2011).

Temperament, among other similar traits of production importance, is challenging to measure. 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, requires specific equipment and skills to measure the characteristic. It has been shown that there is only moderate persistence of flight speed over a day (Vetters et al., 2012). Additionally, there are questions about what aspects of temperament (e.g., nervousness, flightiness, gregariousness, aggressiveness, etc.) flight speed really accounts for, but little research has been conducted to understand this. Furthermore, purely objective methods often lack the ability to capture the various aspects of temperament.

Subjective methods are 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 perception of that trait. In the case of temperament, several subjective methods have been identified, 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), docility score (Beef Improvement Federation, 2018), as well as a method based around behavioral attributes (Sant'Anna and Paranhos da Costa, 2013). A purely research-based scoring method also has been described (Boldt, 2008; Hulsman Hanna et al., 2014). Due to the impact of temperament on production characteristics, breed associations have implemented docility score into their genetic evaluation programs (e.g., Hyde, 2010; Northcutt and Bowman, 2010).

Subjective methods rely on the evaluator's perception of the animal's reaction to human handling. Due to this, there is potential for evaluator bias either between evaluators or across days of evaluation (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 (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 between evaluators for any given method. Even fewer actually compare these repeatability measures across methods.

Because temperament is a complex trait and often highly influenced by environmental cues, it is important to assess current and new methods for their effectiveness in capturing this trait of interest, especially if these methods are used for selection purposes. Findings related to temperament scoring methods have further-reaching implications as 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 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 & Methods

Animals. Calves at weaning age from 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, 2018). The cow herd producing these calves was comprised of approximately 425 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 have been stored long-term in an ultralow freezer until funding becomes available for DNA extraction and genotyping. Data was 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 = 4 evaluators per method). This was constructed to determine the level of differences between evaluator perceptions of temperament (i.e., 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 over those years; however, a subset was only involved in specific years. Replacements typically had similar backgrounds or experiences, where this difference also is being investigated as part of the long-term objective. Furthermore, novel objective methods of measuring temperament also were investigated to determine usefulness in measuring temperament.

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-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 choose an intermediate score.

3) Docility score (Beef Improvement Federation, 2018). 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 marker placed on its tail head. A second red 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 marker from the permanent red marker was captured to understand movement as a possible measure of temperament.

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 were only recorded 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 over time (records multiple times per second). Measures used from this data included the standard deviation of a set number of records and the coefficient of variation of this standard deviation (Yu, 2016). Additional measures using the scale data are being investigated.

Temperament Index (TI). 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 (i.e., 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. Attributes of QBA across the four years per evaluator were run through the PRINCOMP procedure of SAS to produce the TI.

Statistical Analysis. Phenotypes (scores and attributes) were evaluated using a mixed model procedure in SAS (SAS Institute Inc., Cary, NC) for the appropriate fixed effect model. Fixed effects being considered include: evaluation day (n = 2 per year), birth year (n = 4), evaluator (n = 11 total), breed composition or type (n = 8 or 2) and other environmental effects (e.g., sequence of evaluation). The average score for each method on each calf will be used for an aggregate value to compare against evaluators and across methods, particularly for project objective 3.

Genetic Predictions. Predictions of genetic merit will be produced using an animal model ASReml software (Gilmour et al., 2017). This approach uses the fixed effects identified, random effect of calf with relationship based on pedigree for additive genetic merit, and random effect of calf without pedigree relationship to account for maternal permanent environmental effects. Analysis will be conducted as single traits and in pairs to identify heritability and genetic correlations. Predictions will be generated and used for comparison of method efficacy and evaluator impacts on animal rankings.

Results & Discussion

Initially, concern existed that drawing blood prior to temperament scores in the four-platform scale and evaluation pen would cause issues with comparisons. In the first year (2014), this was investigated by randomly assigning sets of five calves as they came through the working facilities to either have blood draw conducted before or after evaluation. The effect of blood draw was found to be unimportant (Hulsman Hanna et al., 2017). A full -length publication is pending submission this year on this topic.

Using four years of data, the evaluator effect was again found to be significant for subjective methods (Celestino Jr. et al., 2019), where investigation of evaluator effect showed that some scales had minor differences (i.e., less than 15% of the scale) and others had major differences (i.e., more than 60% of the scale). Estimates of heritability and other genetic parameters have been produced (Celestino Jr. et al., 2019). Heritability (h^2) ranged from 0.00 ± 0.00 (TI) to 0.29 ± 0.05 (QBA calm). Maternal permanent environmental effects (c^2) ranged from 0.00 ± 0.00 (TI) to 0.36 ± 0.05 (TS), where several traits were found to have moderately high values (e.g., over 0.25 and included DS, agitated, calm, distressed, and irritated). The impact of evaluator on these estimates and ranking of genetic merit as well as the relationship of these scales to each other genetically is ongoing.

Outcomes from QBA analysis in SAS indicate that very different outcomes can occur across populations (*Bos indicus* vs. *Bos taurus* breeds) and evaluators (Hieber, 2016; Yu, 2016). Due to this, additional methods to characterize the QBA attributes is warranted. This currently is being done by pursuing a factor analytic model using multivariate approaches (Henderson and Quaas, 1976).

Lastly, the relationship of infrared thermography has been investigated with DS, TS, QBA attributes, and four-platform standing scale measures (Ogdahl et al., 2019). Low relationships of methods were found with thermal eye temperature values, indicating that prediction of temperament using infrared thermography may not be useful. Additional investigations of thermal images and VIA data are ongoing.

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Central Grasslands Research Extension Center Herd Performance from 2012 to 2017

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Data from breeding, pregnancy determination, calving, and weaning from the Central Grasslands Research Extension Center (REC) were compiled to represent production cycles beginning with breeding in 2011 (i.e., 2012 calf crop) and continuing until breeding of 2016 (i.e., 2017 calf crop). Once aligned within individual females, data were analyzed across years to evaluate trends over time. In addition, performance of calves sired by artificial insemination (AI) and natural service were compared. Calf birth weights peaked in 2013 with an average of 89.6 lbs., with lower ($P < 0.001$) birth weights observed in 2014, 2015, and 2017, and lowest ($P < 0.001$) birth weights observed in 2016 (77.8 lbs.). A steady increase ($P < 0.001$) in weaning weight was observed beginning in 2015 and continuing yearly through 2017, with an increase of nearly 110 lbs. In addition, 205-day adjusted weaning weight had a steady increase ($P < 0.001$) from 2014 to 2017, with a magnitude of nearly 130 lbs. Comparing AI with natural service revealed a nearly 4 lb. reduction ($P < 0.001$) in birth weight and an increase ($P < 0.001$) in weaning weight (+74.4 lb.), adjusted weaning weight (+27 lb.), and average daily gain (+0.12 lb./day) for calves sired by AI. Overall, the CGREC has observed enhanced growth performance over time, and some of that impact is due to inclusion of AI into their commercial beef herd. Further evaluations will evaluate performance of calves from females born from AI and natural service, as well as longevity and lifetime productivity.

Introduction

Since 2011, our research group has been conducting efforts related to enhancing productivity of cow-calf production systems. One of the common elements of this work has been inclusion of artificial insemination (AI) in a majority of the females at the CGREC. Though several different efforts have been conducted, the goal of this brief report is to summarize total herd performance from the calf crops of 2012 to 2017 and compare performance among years. In addition, a comparison of calves sired by AI and calves sired by natural service is presented.

Experimental Procedures

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

Information from spreadsheets established at breeding, pregnancy checking, calving, and weaning was compiled for each year beginning with breeding in 2011 (i.e., 2012 calf crop) until 2016 (i.e., representing 2017 calf crop). Data collected on breeding spreadsheets included heifer/cow age, previous calving date, breeding date, and AI sire. Data collected at pregnancy examination included whether female was pregnant to AI or to a herd bull. Data collected at time of calving included date, calf sex, calving ease, and birth weight (BW). Data collected at weaning included date and weaning weight (WW). All data were compiled within a yearly production cycle and aligned to each female present at breeding to follow her calf performance through birth and weaning.

Calculations included gain from birth to weaning (WW – BW), calf age at weaning (weaning date – birth date) and average daily gain (gain ÷ calf age at weaning). An adjusted 205-day weaning weight (205 d. Adj WW) also was calculated according to the Beef Improvement Federation's Uniform Guidelines (2010) to account for calf weaning with respect to variation in calf birthdate within a calving season and the variation in age of females weaning calves:

$$\text{Adj. 205-Day Weaning Weight} = (WW-BW)/\text{Weaning Age} \times 205 + BW + \text{Age of dam Adj.}$$

Age of dam adjustments were as follows:

Data were analyzed using the GLM procedure of SAS to compare respective performance (BW, WW, Gain, average daily gain (ADG), 205 d. Adj WW) across years from calf crops of 2012 to 2016. An additional model was developed to compare performance of calves sired by AI sires with those calves sired by cleanup bulls.

	Calf Sex	
Age of Dam at Birth of Calf	Male	Female
2	+60	+54
3	+40	+36
4	+20	+18
5 – 10	0	0
11+	+20	-18

Adapted from BIF, 2010

Results

Birth Weight

Calf birth weights peaked in 2013 with an average of 89.6 lbs., with lower ($P < 0.001$) birth weights observed in 2014, 2015, and 2017, and lowest ($P < 0.001$) birth weights observed in 2016 (77.8 lbs.; Figure 1).

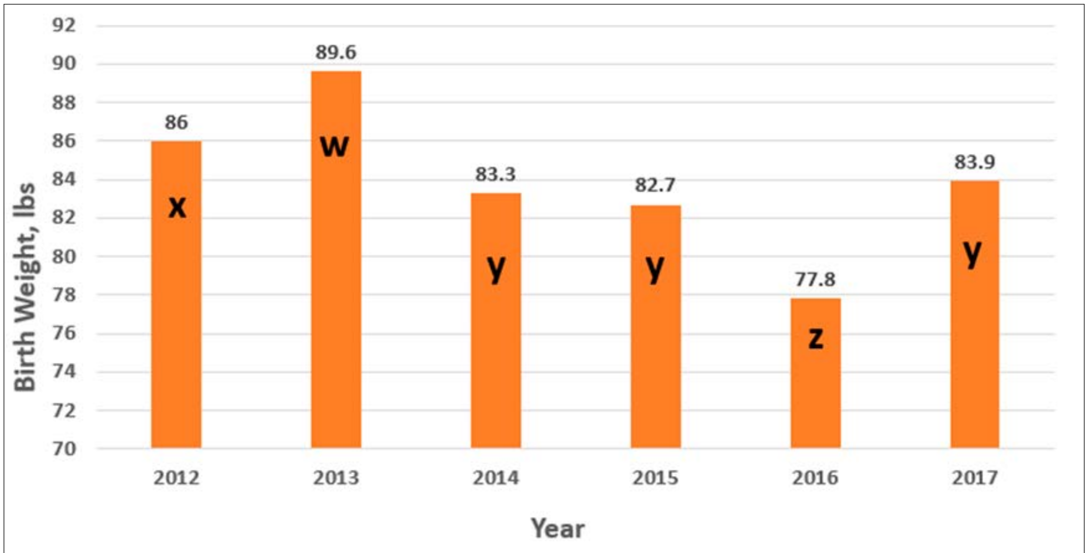

Figure 1. Calf birth weights at CGREC from 2012 to 2017

Weaning Weight

A steady increase ($P < 0.001$) in weaning weight was observed beginning in 2015 and continuing yearly through the end of the evaluation period (Figure 2). By 2017, weaning weights had increased by nearly 110 lbs. compared with the average weaning weights from 2012 to 2014.

205-day adjusted weaning weights

The adjusted weaning weights were calculated to account for age differences among calves and for changing age structures of females in the herd. Here, too, we observed a steady increase ($P < 0.001$) from 2014 to 2017, with a magnitude of nearly 130 lbs (Figure 3).

Impact of Artificial Insemination

The model that compared performance of calves sired by AI with those sired by herd cleanup bulls revealed major changes associated with implementing reproductive technologies. Birth weight of AI-sired calves was nearly 4 lbs. lighter ($P < 0.001$) than those sired by natural service bulls (Table 1). Weight traits, however, were all greater ($P < 0.001$) for calves sired by AI compared with natural service, with a WW advantage of 74.4 lbs., an adjusted WW advantage of 27 lbs., and an ADG advantage of 0.12 lbs/day. The cause of specific changes resulting from AI is likely due to a combination of factors: bulls used for AI may have favorable expected progeny difference (EPD) values, accuracy associated with EPDs of AI bulls is greater than that of cleanup bulls, and calves born from AI are older at weaning compared with calves born from cleanup bulls.

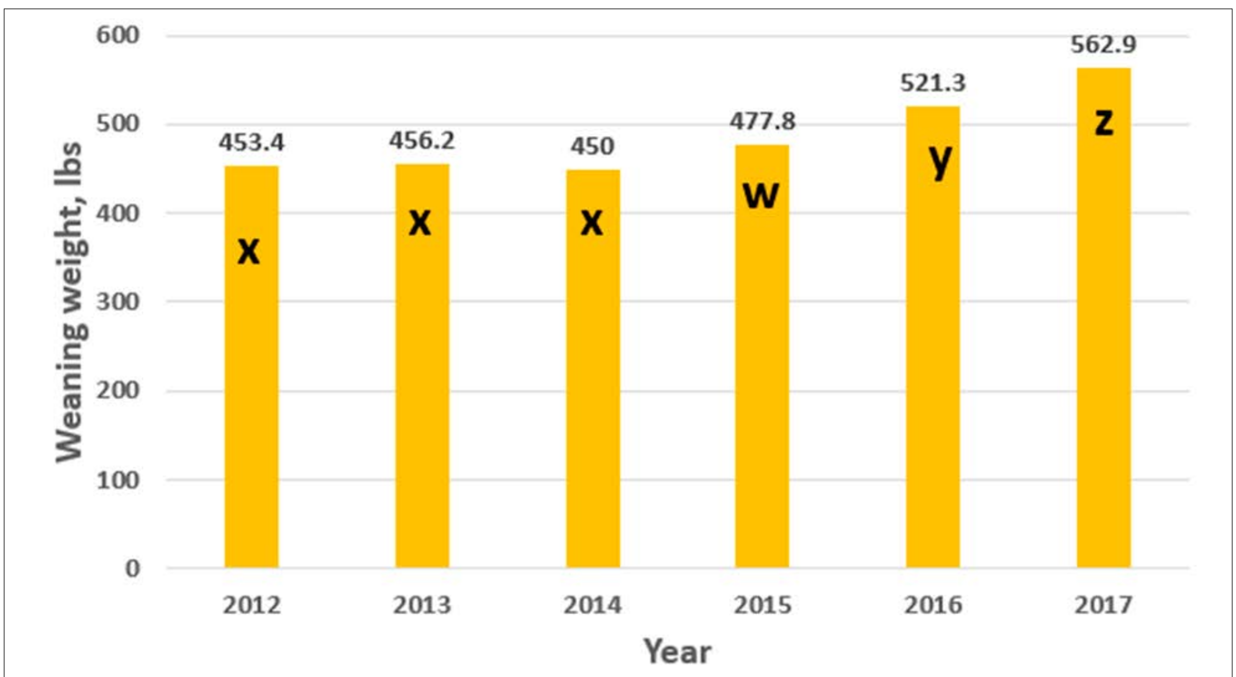

Figure 2. Calf weaning weights at CGREC from 2012 to 2017

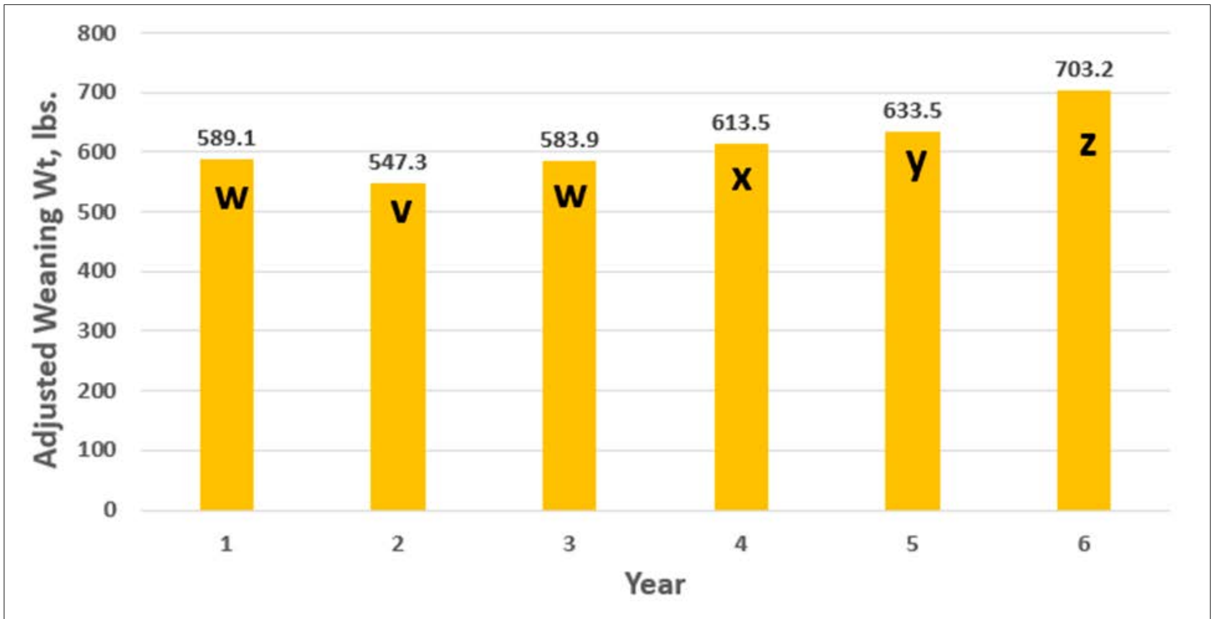

Figure 3. Adjusted 205-day weaning weights at CGREC from 2012 to 2017

Table 1. Impact of artificial insemination on herd performance characteristics -- summary of 2012 to 2017 calf crops.

Item	Natural Service	Artificial Insemination	SE	P-Value	Difference
Birth Weight, lbs.	86.0	82.1	0.38	<0.001	-3.9
Weaning Weight, lbs.	447.5	521.9	1.96	<0.001	+74.4
Gain from Birth to Weaning, lbs.	361.4	439.9	1.96	<0.001	+78.5
Average Daily Gain, lbs./d	2.42	2.54	0.01	<0.001	+0.12
205 d Adj. Weaning Weight, lbs.	596.3	623.3	2.40	<0.001	+27

Data presented in this report are just the beginning of a thorough evaluation of changes over time and the impacts of artificial insemination into a commercial beef herd. This dataset also contains information related to female body condition score, days postpartum, gestation length, and calving distribution that can be helpful in understanding why specific changes are occurring. In addition, as data continue to be generated, the long-term impacts of implementing AI can become clearer. Items such as reproductive and calf performance from females sired by AI vs. natural service and longevity of the respective groups of females in the herd continue to be monitored as they are critical components of overall herd profitability.

Using prescribed fire and rotational grazing to create heterogeneity in grazing patterns and assess plant community changes on Kentucky bluegrass-invaded mixed-grass prairie

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Introduction

Heterogeneity is the principal driver of biodiversity in rangeland ecosystems and is frequently positively correlated with population and community stability (Wiens 1997, Hovick et al. 2015, McGranahan et al. 2016). Rangelands are described as inherently heterogeneous, where composition, productivity and vegetation structure vary with disturbances, topo-edaphic features, and species interactions at multiple spatial and temporal scales (Patten and Ellis 1995, Fuhlendorf and Smeins 1998, 1999, Fuhlendorf and Engle 2001, Limb et al. 2010a). Conserving resources and promoting biodiversity are imperative to the long-term sustainability of rangeland resources, particularly on private lands where profitable livestock production is a primary objective (West 1993). The traditional view within rangeland management is that proper grazing management requires spatially uniform moderate grazing, therefore minimizing excessively grazed and non-grazedareas (Vallentine 2001). While spatially uniform moderate grazing may minimize soil disturbance and increase ground cover, and might improve habitat for some faunal species, spatially uniform moderate grazing often fails to create sufficient habitat heterogeneity to support species with requirements at both extremes of the vegetation structure gradient thus constraining potential biodiversity (Knopf 1994; Fuhlendorf et al. 2006).

Biological invasions occur when non-native species are introduced to a new ecosystem where they establish and spread (Mack et al. 2000; Andersen et al. 2004). Anthropogenic disturbance, such as land fragmentation due to urbanization and cultivation, and improper rangeland management, disrupts natural ecosystem function and aids in the establishment of invasive plant species (Cully et al. 2003). Establishment of invasive plant species consequently leads to lower crop production, increased herbicide use, decreased forage quantity and quality, lower diversity and richness, and degraded wildlife habitats (Grant et al. 2009). Biodiversity declines may be particularly detrimental in imperiled ecosystems such as grasslands that now comprise only 0.1% or less of their native range (Samson et al. 2004).

Kentucky bluegrass (*Poa pratensis*; hereafter bluegrass) invasion is threatening grassland ecosystems of the northern Great Plains (Toledo et al. 2014). Increased bluegrass abundance (Miles and Knops 2009) is threatening the biodiversity of grasslands and is associated with declines in the abundance of native plant species (Cully et al. 2003). The invasion occurred rapidly over the past 30 years, likely in response to land management practices that allow or promote its proliferation through alterations to the region's historic grazing and fire regimes (Toledo et al. 2014). Increases in growing-season length, atmospheric CO_2 concentrations, and above-average precipitation also may contribute to its increased dominance (DeKeyser et al. 2015). Its origin in the United States is not clear (Carrier and Bort 1916), but bluegrass was not a part of the region's plant community historically (Barker et al. 1986).

At this time, there is a lack of empirical evidence to suggest how bluegrass-invaded communities respond to grazing management in the northern Great Plains and how working landscapes respond to grazing after burning. The influence of both grazing and fire on the evolution of the Great Plains grassland ecosystem is widely recognized (Fuhlendorf et al. 2009; Samson et al. 2004). Also, patch-burn grazing management can promote structural and compositional diversity (Fuhlendorf and Engle 2001, 2004). Studies in the tallgrass (Anderson et al. 1970; Owensby and Smith 1979; Smith and Knapp 1999) and mixed-grass prairie (Bahm et al. 2011; Engle and Bultsma 1984; Kral et al. 2018) ecoregions indicate that burning can decrease bluegrass. However, the benefits of burning bluegrass are highly dependent on precipitation and soil type (Engle and Bultsma 1984), and reductions in mixed-grass prairie are short term (Bahm et al. 2011; Kral et al. 2018). Analyzing the effects of management (both grazing and continued burning) after burning, therefore, is relevant to determine if it can provide effective bluegrass control.

Controlled livestock distribution and reduced grazing intensity can be implemented to enhance wildlife habitat and promote conservation of certain landscapes and some wildlife species. However, traditional approaches to rangeland management to enhance conservation are generally thought to reduce profits from livestock grazing enterprises because traditional approaches reduce the number of grazing animals (Dunn et al. 2010). Current rangeland management decouples fire from grazing. Further, the decoupling decreases feedbacks created through disturbances leading to homogeneity in rangeland ecosystems. When these disturbances are suppressed, restricted vegetation succession creates stagnant and homogeneous landscapes. Homogeneity reduces the number of structural and compositional habitats needed to sustain plant and animal populations, resulting in loss of biological diversity. Therefore, conservation-based livestock grazing practices that are both profitable and promote biodiversity are clearly needed (O'Connor et al. 2010).

Combining the spatial and temporal interaction of fire and grazing (pyric-herbivory) is a conservation-based approach to management that increases rangeland biodiversity trophic levels and taxonomic orders by creating heterogeneous vegetation structure and composition (Fuhlendorf et al. 2006; Churchwell et al. 2008; Coppedge et al. 2008; Engle et al. 2008; Fuhlendorf et al. 2010). Discrete fires shifting in time across a landscape concentrates grazing while leaving unburned portions of the landscape largely undisturbed. The undisturbed areas have relatively tall and dense vegetation. Focal grazing on the recently burned areas maintains relatively short vegetation, and transition areas recovering from focal disturbance support diverse vegetation. The three different patch-types create a structurally and compositionally heterogeneous landscape (Fuhlendorf and Engle 2001 and 2004). Conservation-based livestock grazing and restoration practices that are profitable, reduce exotic plant species and promote biodiversity are clearly needed (O'Connor et al. 2010). Therefore, this project will focus on **1)** Developing methods to reduce exotic grass species and restore native species on Northern Great Plains rangelands, and **2)** Determine the effect of heterogeneity-based management on livestock production.

Methods: General Design

This study is conducted at the North Dakota State University Central Grassland Research Extension Center (CGREC) in south-central North Dakota (lat 46°46'N, long 99°28'W). As part of the North Dakota Agricultural Experiment Station, CGREC's mission is to extend scientific research and Extension programming to the surrounding rural communities. It consists of 2,160 hectares of native grassland and annual crops. The study area is representative of much of the Great Plains ecoregion with large tracts of native grassland used for livestock production intermixed with annual small-grain and row-crop agriculture. The CGREC is in the Missouri Coteau ecoregion of the northern Great Plains that occupies 125 million hectares, of which approximately 40% is perennial rangeland grazed by livestock. The Missouri Coteau ecoregion is characterized by irregular, rolling, rocky plains and depressional wetlands. The climate is temperate and experiences an average yearly rainfall of 40.3 cm

(Limb et al. 2018).

Vegetation at CGREC has been sampled recently and in the past (Limb et al. 2018). It is typical of a Northern mixed-grass prairie that has been invaded by Kentucky bluegrass, which includes a diverse forb community that could support a diverse pollinator community. While we are currently sampling that pollinator diversity at CGREC, preliminary data suggests numerous pollinator species, capturing 33 bee and 27 butterfly species from June to August 2015. This and more recent sampling suggest that bee and butterfly diversity still exists within the mixed-grass region in and around the proposed research sites. Thus, our efforts will allow for pollinator colonization and even population expansion.

Agro-ecosystem management strategies that promote sustainable production and ecosystem services are dependent on practical solutions based on sound ecological principles. In rangelands, this research is complicated by the need for large-scale replication that is allowed to take place over multiple years. We have the unique situation of being able to take advantage of a tremendous amount of work (and financial cost) that already has been used to create four management treatments that have each been replicated four times, each at a relatively large spatial scale (65 ha replicates).

Within this design framework, we compare four management treatments in their ability to optimize livestock production while promoting plant-pollinator interactions. Treatments are based on current management frameworks but use a combination of well-established and novel designs. The four treatments are *(a) patch-burn grazing (PBG 1 season of burn (SOB)), (b) patch-burn grazing (PBG 2 seasons of burn), (c) modified twice-over rest-rotation grazing (MTRG), and (d) season-long grazing (SLG).*

(a) Patch-burn grazing (PBG) 1 season of burn is a management framework intended to mimic historic disturbance regimes where focal grazing occurs on recently burned areas while lightly grazed areas allow for accumulation of plant biomass (i.e., fuel) for future fires (Fuhlendorf and Engle 2001). Fires will occur in the spring of each year when fuel moisture levels have decreased sufficiently for fire to carry. Patch-burn pastures (appx. 65 ha each) are divided into four relatively equal-size patches (appx. 16 ha each) with one of the four patches being burned each spring. These fire-return intervals are designed to mimic the historical disturbance regime of mixed-grass prairie.

(b) Patch-burn grazing 2 seasons of burn. Season of burn can differentially alter how the plant community responds to fire (Kral et al. 2018). Moreover, considering multiple seasons can be important for promoting floristic diversity in grasslands and overcoming logistical challenges of spring-only fires (McGranahan et al. 2016). The second treatment is similar to the previous PBG treatment in that one quarter of each pasture will be burned each year. However, in this case, half of a patch (a sub-patch equal to one eighth of a pasture,- appx. 8 ha) is burned in the spring (same timing as PBG 1 SOB), and the other half of that patch (the sub-patch=1/8 of a pasture) is burned in the summer.

(c) Modified twice-over rest-rotation grazing (MTRG). Our third treatment is similar to the PBG treatments in that it is designed to produce structural heterogeneity across a pasture. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilized fencing to dictate cattle distribution and influence grazing. Pastures are divided into four relative equal patches and cross fenced to create four discrete sub-pastures that cattle cannot move between (without being purposefully moved). Across the sub-pastures, cattle are rotated through twice and allowed to graze for a total 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy, moderate, light, and rest sub-pastures, respectively. In subsequent years, grazing intensity will be rotated to different patches such that the non-grazed patch will become the heavy-use pasture, the heavy-use pasture will transition to the non-grazed, the moderate to the light and the light to moderate grazing. This rotation will create annual heavy disturbance in one sub-pasture and reduce annual heavy disturbance in the same location, which could result in changes to forage quality and loss of plant species (Fuhlendorf et al. 2017).

(d) Season-long grazing (SLG) is intended to reflect status quo management for the region and will serve as a controlled comparison for the other treatments. This is a typical management approach for this region, and it serves as an important comparison because it homogeneously applies the disturbance (grazing) throughout the entire patch. Thus, it is expected to lack the heterogeneity and structure of other treatments and therefore not benefit livestock.

Common among the four treatments, cow/calf pairs grazed within pastures from mid-May to late October each year at a full-use stocking rate (2.47 animal unit months/ha) in all treatments designed to achieve 40% to 60% degree of disappearance. Stocking rates were determined using a 25% and 30% harvest efficiency on the season-long and managed treatments, respectively. All treatments provide fresh water access and mineral supplements for cattle. With the exception of MTRG, all treatment units (pastures) have exterior fencing only with no interior fences to separate individual patches. The MTRG used interior fencing to separate patches and maintain livestock at a particular stocking rate throughout the year. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service (NRCS) ecological site descriptions and equivalent land-use histories (USDA-NRCS 2018).

Vegetation quadrat samples will be performed using 0.5 x 0.5m quadrats to determine the cover of native and introduced grasses and forbs. We also will measure heights of vegetation, litter and thatch layers, and we will use 10 quadrats per survey set. To evaluate objectives, three 0.25 m^2 plots were caged and paired with three uncaged plots at each monitoring location (6 total plots/monitoring site, 24 total plots per pasture) prior to the onset of grazing. At the peak of forage production for the year in mid-July, two new plots were picked to match each of the original uncaged plots, and the original plots were clipped. One of each pair of new plots was caged, and at the end of the grazing period, the herbage from each remaining plot will be clipped. Herbage clipped from inside caged plots at peak growing season provides an estimate of peak biomass. Differences between biomass in the caged plots at the end of the grazing period and uncaged plots from the peak sampling represent the growth (or disappearance) from peak. Samples are oven-dried to a constant weight and weighed to determine the amount of herbaceous production and percent utilization of the forage.

All cattle were weighed before they went on the pastures and again when they were removed. We quantified their performance management treatments by measuring weight gain of both calf and cow. Calves were weighed within 24 hours of birth and again when weaned at the end of the growing season. The difference in those weights provided calf total and daily weight gain. Two-day individual body weights of cows were measured at the beginning and the end of the grazing season, with that difference providing a measurement of cow weight gain.

Results: Update

Vegetation Production, Degree of Disappearance and Plants Species Change

Standing crop ranged from 3,800 to 4,500 lb/ac on the season-long and patch-burn treatments in 2017 and 2018 (Figure 1). Biomass (no litter) production on the modified twice-over rotation rest-rotation treatment ranged from 2,780 to 2,840 lb/ac in 2018 (Figure 2).

The goal of a patch-burn grazing and modified rotational grazing treatment is to create heterogeneity in disturbance and structure across the landscape. Livestock grazing on the season-long treatment averaged 33% in 2017 and 2018. Within the patch-burn grazed spring burn treatment, degree of disappearance averaged 43% in the non-burned areas compared to 48% and 59% on the burned patches in 2017 and 2018, respectively (Figure 3). In the patch-burn grazed spring+summer burn treatment, degree of disappearance averaged 43% in the non-burned areas compared to 51% and 54% on the burned patches in 2017 and 2018, respectively (Figure 3).

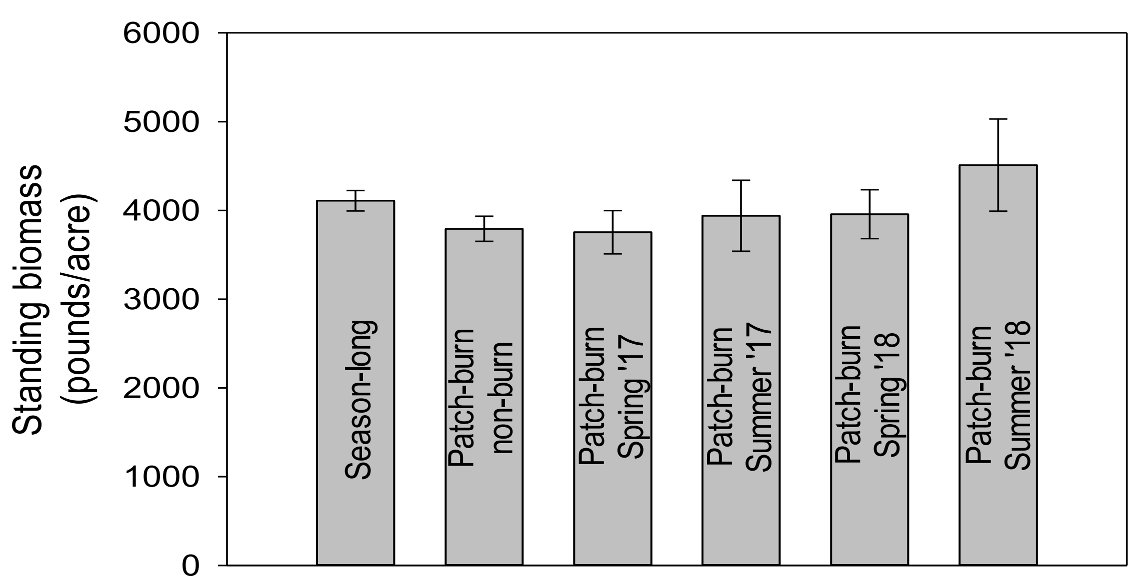

Figure 1. Standing crop at or near the end of the grazing season on the season-long and patch-burn treatments at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

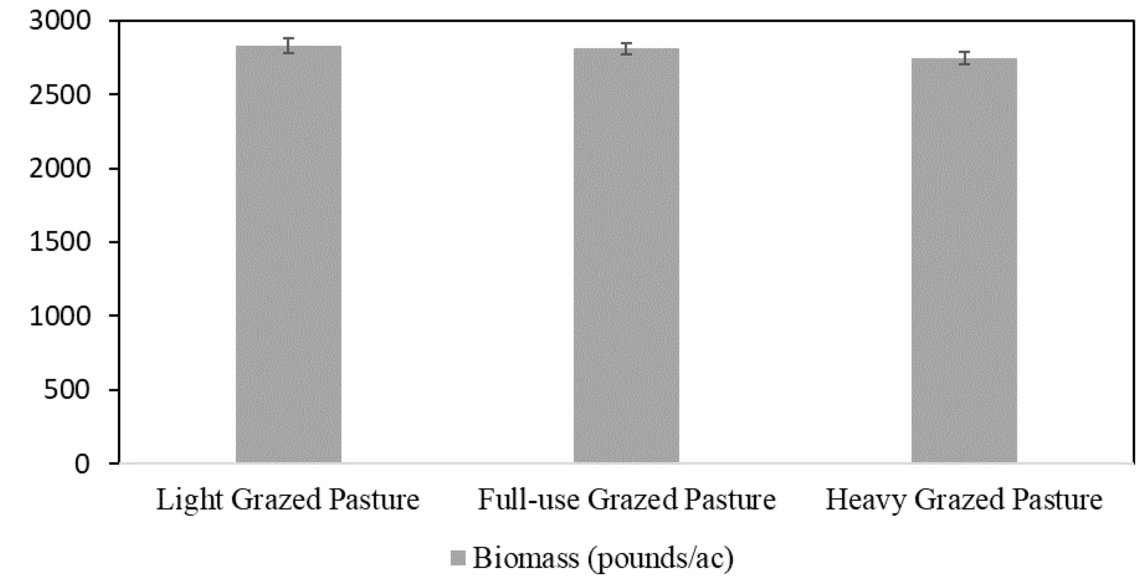

Figure 2. Biomass (no litter) produced at the end of each grazing period on the modified twice-over rotation-rest rotation treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2018.

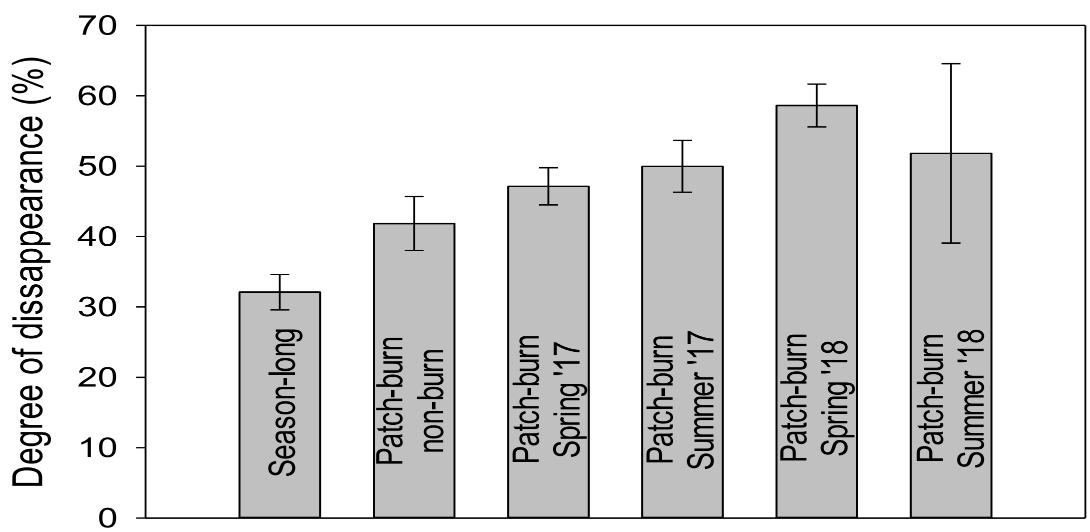

Figure 3. Degree of disappearance on the season-long and patch-burn treatments at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

Within the modified twice-over rotation rest-rotation treatment, degree of disappearance was 21%, 32% and 61% in the light, full and heavy use pastures in 2018, respectively (Figure 4). The full-use pasture was stocked to create a similar degree of disappearance as the season-long treatment, which averaged 33%. The goal is to achieve a degree of disappearance on the season-long treatment and full-use pasture of 40% to 50%; however, the 2018 growing-season precipitation was 127% of average. This additional precipitation created higher-than-expected vegetation growth, thus, degree of disappearance was below the targeted level.

There was no change (P > 0.05) in species richness (Figure 5), species evenness (Figure 6) or species diversity (Figure 7) after one year of treatment. Species richness and diversity were higher on the patch-burn treatments pretreatment compared to the season -long.

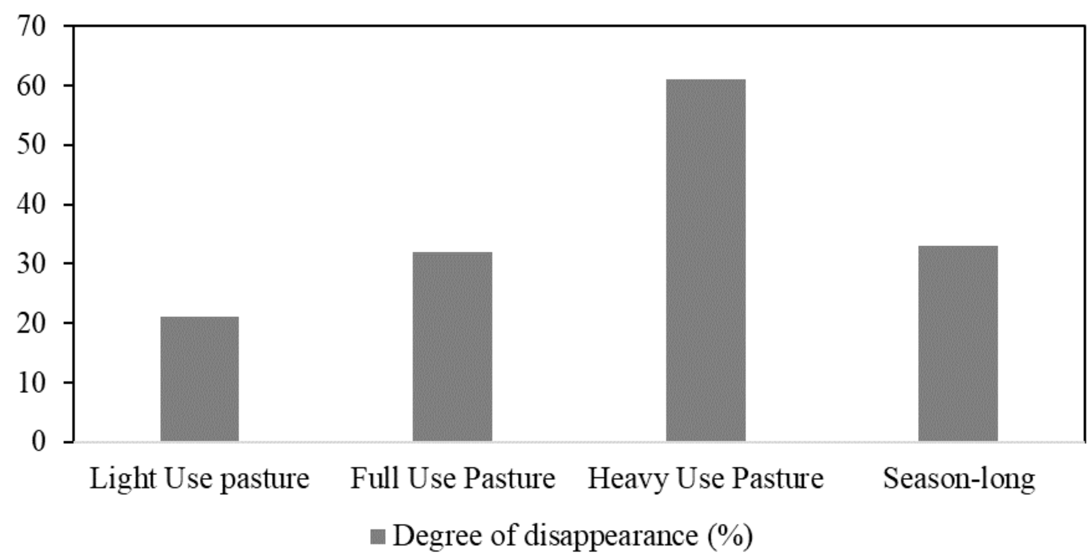

Figure 4. Degree of disappearance on the modified twice-over rotation rest-rotation treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2018.

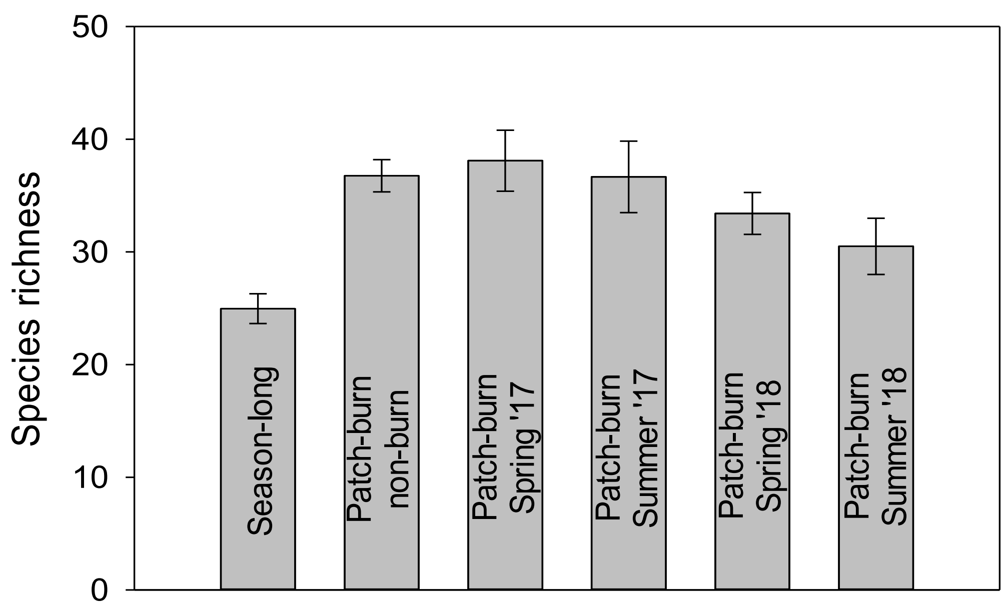

Figure 5. Species richness by treatment and year on the season-long and patch-burn treatments at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

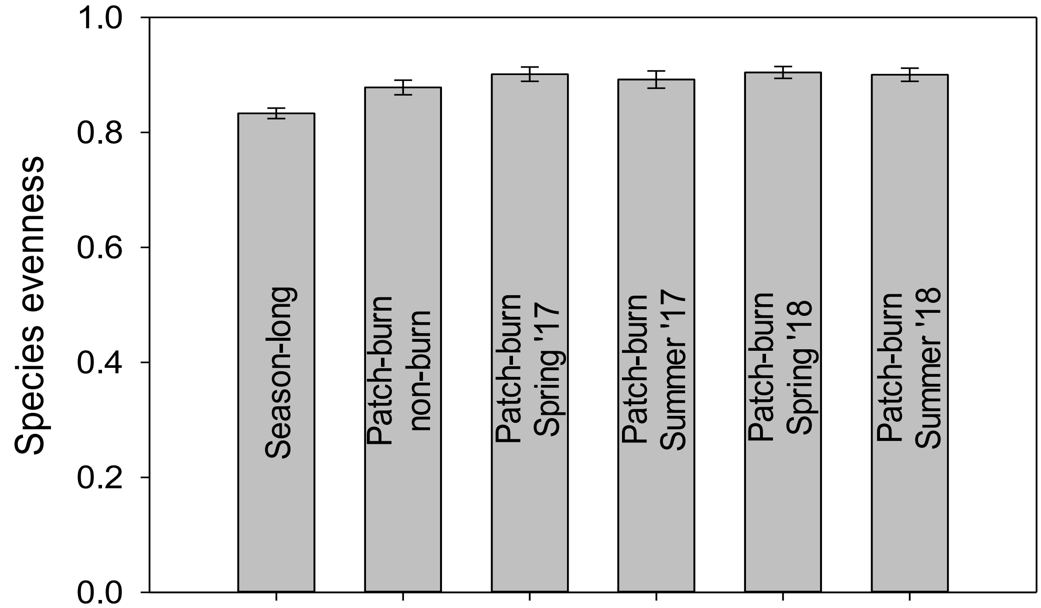

Figure 6. Species evenness by treatment and year on the season-long and patch-burn treatments at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

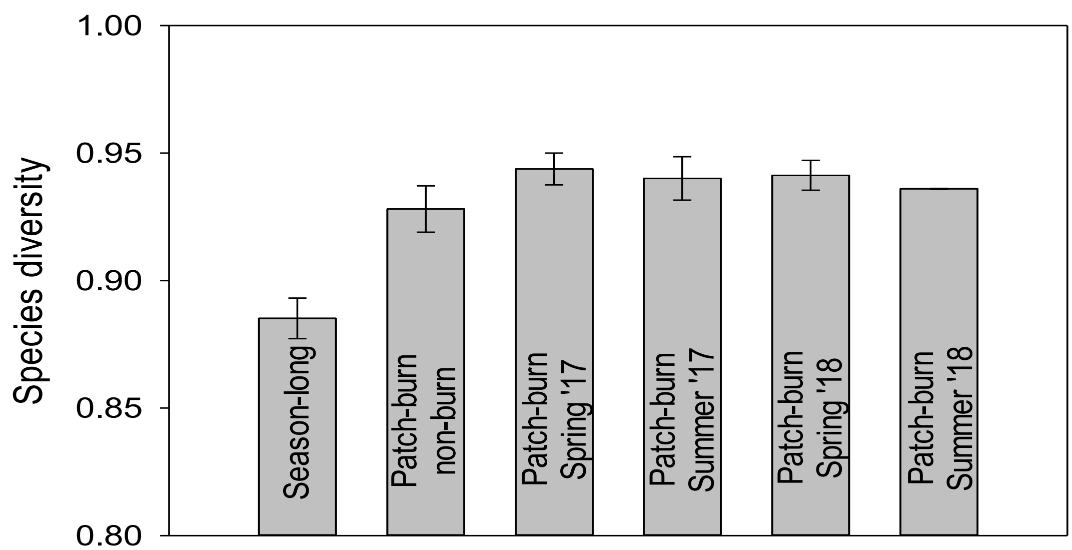

Figure 7. Species diversity by treatment and year on the season-long and patch-burn treatments at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

Livestock Reproduction and Performance

Percent bred cows was similar (P > 0.05) among treatment in 2017 and 2018, ranging from 88% to 96% in 2017, and 92% to 96% in 2018 (Figure 8). Interestingly, 98.2% were bred during the first two cycles in 2018.

Calf performance, in terms of average daily gain, was similar (P > 0.05) among treatments in 2017 and 2018 (Figure 9). Calf average daily gain (lb/day) ranged from 2.41 on the modified twice-over rest rotation treatment in 2018 to 2.72 on the spring patch burn grazing treatment in 2017.

Cow performance, in terms of average daily gain, was greatest (P ≤ 0.05) on the patch-burn graze treatments in 2017 compared to the season-long (Figure 10). The patch-burn grazing treatments both had positive average daily gains (0.72 and 0.67 lb/day) compared to cows losing weight on the season-long treatment (-0.51 lb/day). There was no difference between treatments in cow performance in 2018 (Figure 10).

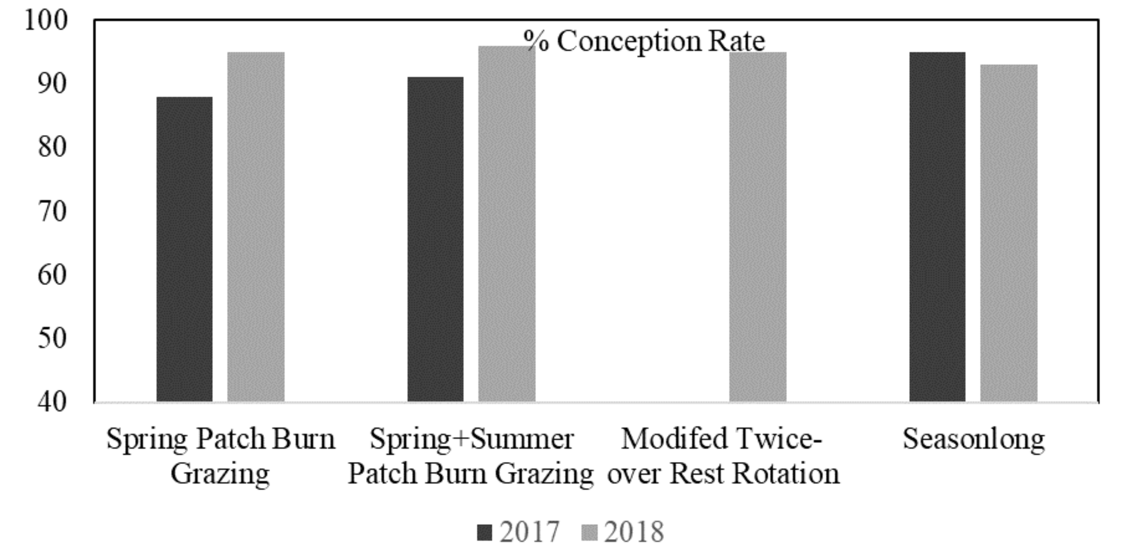

Figure 8. Conception rates of cows bred on pasture by treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2018.

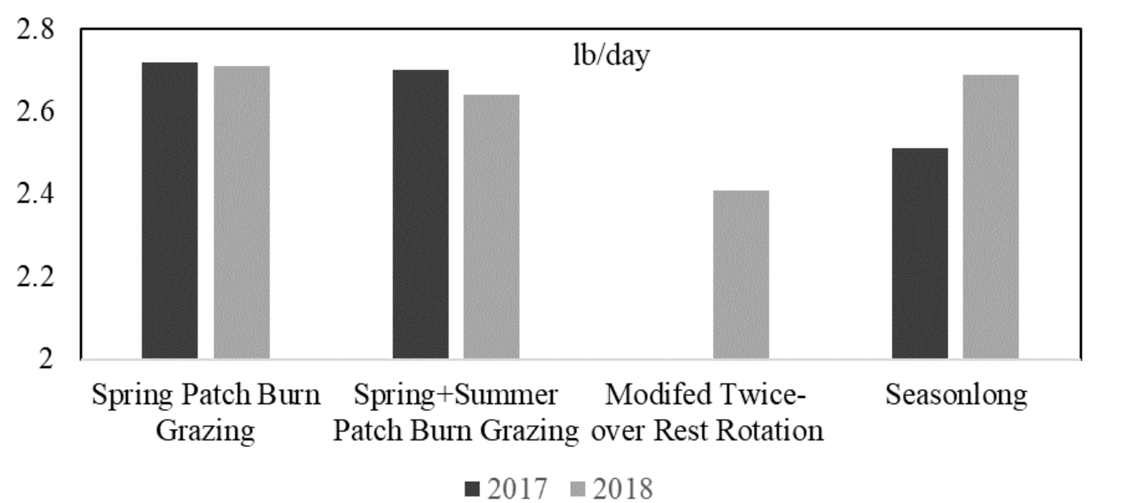

Figure 9. Calf average daily gain (lb/day) by treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

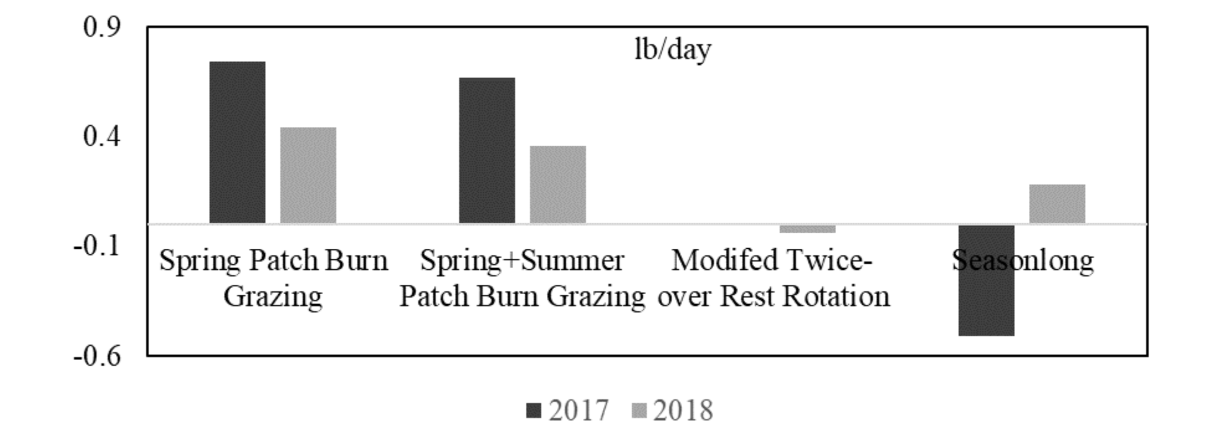

Figure 10. Cow average daily gain (lb/day) by treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2017 and 2018.

Vegetation Growth Responses from Grazing and Recovery

We looked at new plant growth, as it relates to recovery, following a grazing event versus non-grazing paired plots. This only was conducted on the heavy-use pasture of the modified twice-over rotation rest rotation treatment in 2018. A total 33 days recovery occurred between the first and second rotations of grazing. Vegetation that was grazed and had the 33-day recovery grew 72% and 94% more new grass, and 12% and 14% more new forbs on the shallow loamy and loamy ecological sites, respectively, compared to the non-grazed paired plots (Figure 11). The first rotation occurred from May 23 to June 22.

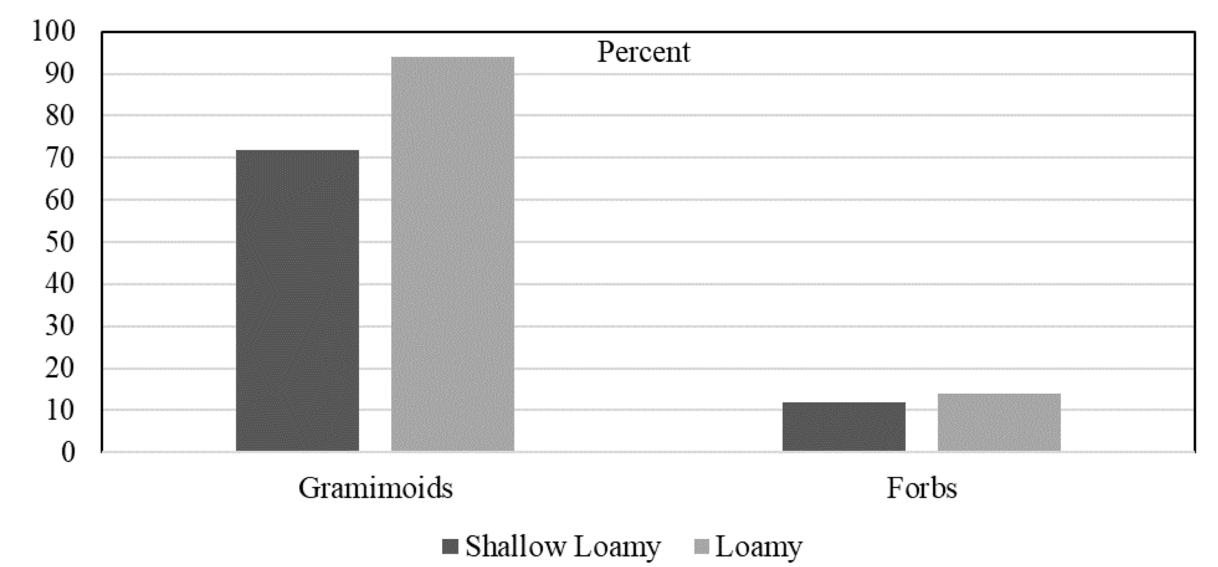

Figure 11. Percent new growth on grazed plots of the heavy-use pasture compared to non-grazed plots on the modified twice-over rotation rest rotation treatment at the Central Grasslands Research Extension Center near Streeter, ND, in 2018.

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CGREC Current Staff - 2019

Kevin Sedivec	Interim Director
Michael Undi	Animal Scientist
Scott Alm	Forage Specialist/ Manager of Operations
Dwight Schmidt	Farm Manager
Timothy Long	Herdsman
Erin Gaugler	Range Specialist
Lisa Pederson	Extension Livestock Specialist
Sandi Dewald	Administrative Secretary
Rick Bohn	Range Technician
Stephanie Becker	Animal Science Technician
Cody Wieland	Livestock Technician
Janet Patton	Research Technician
Tanya Metz	Office Maintenance

Current Graduate Students

Cameron Duquette, PhD	Range Science
Michael Hamel, MS	Range Science
Brooke Karasch, MS	Range Science
Micayla Lakey, MS	Range Science
Leslie Gerhard, MS	Soil Science
Friederike Baumgaertner, PhD	Animal Sci.
Kacie McCarthy, PhD	Animal Science
Nicolas Negrin Pereira, PhD	Animal Science
Jerica Hall, MS	Animal Science

2018 Graduated Students

Megan Dornbusch, MS	Range Science
Haley Johnson, MS	Range Science
Felipe Carvalho Da Silva, MS	Animal Science

Summer Staff

Sam Vanderheiden, Megan Gross, Jarrett Lardy, Joel Milos, Mike Hamel, Levi Bassett, Maxwell Williams, Cheyanne Klein, Emily Green, Allyson Gelinas, Hannah Schley, William Price

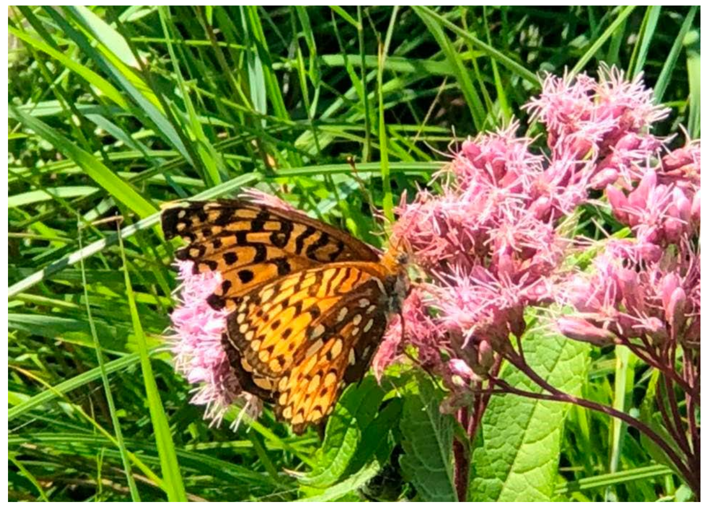
Back: Dwight Schmidt, Nico Negrin, Sam Vanderheiden, Megan Gross, Cody Wieland, Jarrett Lardy, Joel Milos, Cameron Duquette, Mike Hamel, Kevin Sedivec.
Middle: Sandi Dewald, Scott Alm, Karen Schmidt, Michael Undi, Brook Karasch, Micayla Lakey, Megan Dornbusch, Levi Bassett, Maxwell Williams.
Front: Cheyanne Klein, Lisa Pederson, Emily Green, Allyson Gelinas, Hannah Schley, Rick Bohn.
Missing: Janet Patton, Stephanie Becker, Felipe Silva, William Price, Kacie McCarthy, Leslie Gerhard, Maureen Puffer.

Current Advisory Board

Gary Aichele, Steele
Jay Doan, Sterling
Charlotte Heim, Bismarck
Richie Heinrich, Medina
Cody Kreft, Streeter
Martin Marchello, Bismarck
Darrell Oswald, Wing
Krista Reiser, Washburn
Arlyn Scherbenske, Steele
David Toledo, Mandan
Robert Weigel, Kintyre

Advisory Board meetings are held on the day of Field Day in July and on the second Thursday of November.



Photos by Sandi Dewald, Kevin Sedivec and Rick Bohn

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