Central Grasslands Research Extension Center

2020 Annual Report

Range - Forage - Livestock

NDSU | NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

NDSU | EXTENSION

Summary of the Year

Welcome to the 2020 CGREC Annual Report

The year 2020 marked my fourth year as the interim director. The growing season for 2020 was much different from 2019.

We started the growing season dry (April – June: 55% of normal precipitation), received some much-needed rain in August (July – August: 88% of normal) and then ended with a severe drought starting in September (September – December: 16% of normal). The wet fall of 2019 saved us from experiencing drought conditions during the 2020 grazing season.

Accomplishments for 2020:

- We survived COVID-19! We continue to follow safe guidelines to maintain a safe working environment. To date, we have had no cases of COVID-19 at the center and we conducted all research experiments as planned in 2020. We did have major adjustments within our Extension programming but still delivered numerous Extension programs virtually using Zoom and Microsoft Teams.
- We completed the first cycle of the patch-burn grazing study. Results to date show:
    - ◊ Patch-burn grazing is the best treatment for livestock performance (average daily gain), compared with continuous and rotational grazing.
    - ◊ Patch-burn grazing created the highest flowering densities and longest display of flowering, creating greater pollinator habitat, compared with continuous grazing.
    - ◊ Patch-burn grazing created greater heterogeneity in structure, compared with continuous grazing, thus attracting more upland nesting bird species.
- We published five peer-reviewed journal articles associated with the patch-burn grazing trials to date.
    - ◊ We graduated five master of science graduate students from these trials to date:
        - Megan Dornbusch (Range Science, major adviser Ryan Limb)
        - Brooke Karasch (Range Science, major adviser Torre Hovick)
        - Haley Johnson (Range Science, major adviser Limb)
        - Micayla Lakey (Range Science, major adviser Devan McGranahan)
        - Leslie Gerhard (Soil Science, major adviser Caley Gasch)
    - ◊ We have six active graduate students associated with the patch-burn grazing and rotational grazing projects:
        - Cameron Duquette (Ph.D., Range Science, major adviser Hovick)
        - Michael Hamel (M.S., Range Science, major adviser Limb)
        - Megan Wanchuk (M.S., Range Science, major advisers McGranahan and Sedivec)
        - Hayley Hilfer (M.S., Range Science, major adviser Limb)
        - Erin Gaugler (Ph.D., Range Science, major advisers Sedivec and Miranda Meehan)
        - Hailey Keen (M.S., Range Science, major advisers Hovick and Ben Geaumont)
    - ◊ We have four graduate students starting in 2021 associated with patch-burn and rotational

grazing projects, thanks to funding from the U.S. Department of Agriculture (USDA):

    - Justin Clarke (Ph.D., studying upland birds, Range Science, major adviser Hovick)
    - Beth Roberton (Ph.D., studying pollinators, Range Science, major advisers Hovick and Jason Harmon)
    - Elly Johnson (M.S., studying monarch butterflies, Range Science, major advisers Hovick and Harmon)
    - Esben Kjaer (Ph.D., plant community dynamics, Range Science, major adviser Limb)

- We started collecting soil microbial data on the grazing trials in 2020. This is a collaborate project with the Microbiology Department at NDSU and associated with the Agrobiome Initiative funded during the 2019-2021 legislative session. This project has one graduate student:
    - Lennel Camuy-Velez (Ph.D., microbial populations and greenhouse gases, Microbiology, major advisers Samiran Banerjee and Sedivec)
- We conducted a new precision agriculture study looking at drone imagery in 2020. This is a collaborate project with the Department of Agricultural and Biosystems Engineering and funded by a precision agriculture grant in 2020. This project has one graduate student:
    - Dylan Bartels (M.S., Range Science, major advisers Sedivec and Michael Undi)
- We started a new integrated livestock cropping system project with the Animal Sciences Department, thanks to funding by USDA-Sustainable Agriculture Research and Education. This is an Extension project that involves six ranches, the Central Grasslands REC and Main Station Beef Unit. This project has two graduate students:
    - Tanner Hoffman (M.S., Natural Resource Management, advisers Meehan & Sedivec)
    - Erin Gaugler (Ph.D., Range Science, major advisers Sedivec and Meehan)
- We continue to focus on late-season grazing and feeding options, specifically bale grazing and supplementation.
    - ◊ We graduated one graduate student from these projects to date:
        - Jessalyn Bachler (M.S., Range Science, major advisers Sedivec and Undi)
- We continue to conduct basic and applied animal science projects with the NDSU Animal Sciences Department. We published 21 peer-reviewed journal articles related to minerals, energy, fetal programming, genomics, bull development and heifer development.
    - ◊ We graduated five graduate students from these trials to date:
        - Kacie McCarthy (Ph.D., Animal Sciences, major adviser Carl Dahlen)
        - Cierrah Kassetas (M.S., Animal Sciences, major adviser Dahlen)
        - Felipe A.C.C. da Silva (M.S., Animal Sciences, major adviser Dahlen)
        - Nicolas N. Pereira (Ph.D., Animal Sciences, major adviser Dahlen)
        - Jerica Hall (M.S., Animal Sciences, major adviser Alison Ward)
    - ◊ We have two active graduate students associated with the animal sciences projects:
        - Friederike Baumgaertner (Ph.D., Animal Sciences, major advisers Sedivec and

Christopher Schauer)
- Jennifer Hurlbert (M.S., Animal Sciences, major adviser Dahlen)

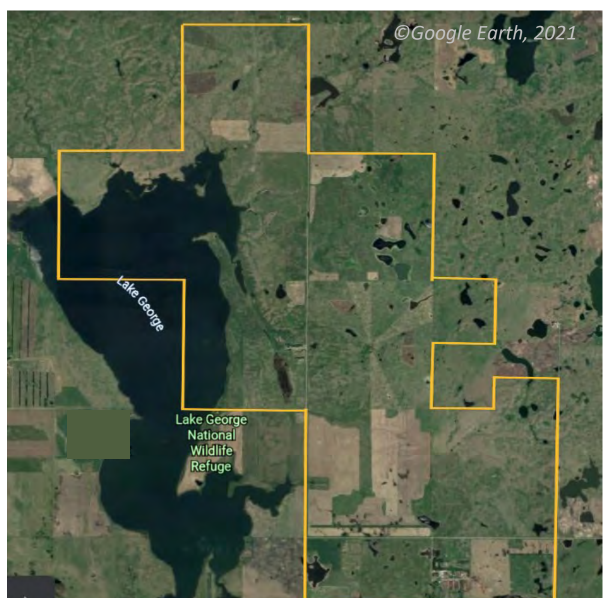
- Finally, we have expanded our forage research and Extension program the past two years, focusing on agronomic forage crops. We started trials associated with:
    - ◊ Annual cereal forage variety trial started in 2019 at the center and the tri-county agronomy plots near Wishek – a collaborative project with Carrington REC and three NDSU Extension agents (Logan, McIntosh, Emmons). This project has one graduate student:
        - Emily Leier (Extension agent - Emmons County, M.S., Range Science, major adviser Sedivec)
    - ◊ Cover crop species mixture trial in collaborations with the Plant Sciences Department. This project has one graduate student:
        - Kenneth Mozea (M.S., Plant Sciences, major adviser Marisol Berti)
    - ◊ Corn silage variety trial started in 2020. This project will be expanded to include a location with the Carrington REC
    - ◊ Winter cereal agronomy and grazing trial

The Central Grasslands REC 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 livestock herd phenotype, and work closely with the NDSU Main Station scientists (Range Science, Animal Sciences, Soil Science, Microbiological Sciences, Agricultural and Biosystems Engineering and Plant Sciences) and partner RECs (Carrington, Hettinger, Langdon, North Central) to conduct research and Extension programming in the areas of range and pastureland, forages, wildlife and pollinators, soil health and beef cattle in 2021.

We invite you to our 2021 annual field day on July 27. We will run two tours, one focusing on grazing management, forages and livestock from 10 a.m. to noon, and one focusing on wildlife, pollinators and prescribed burns from 1 to 3 p.m. We hope to provide lunch between the tours if COVID-19 guidelines allow.

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

Kevin Sedivec, Interim Director



Central Grasslands Research Extension Center

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Range - Patch-burn and Rotational Grazing

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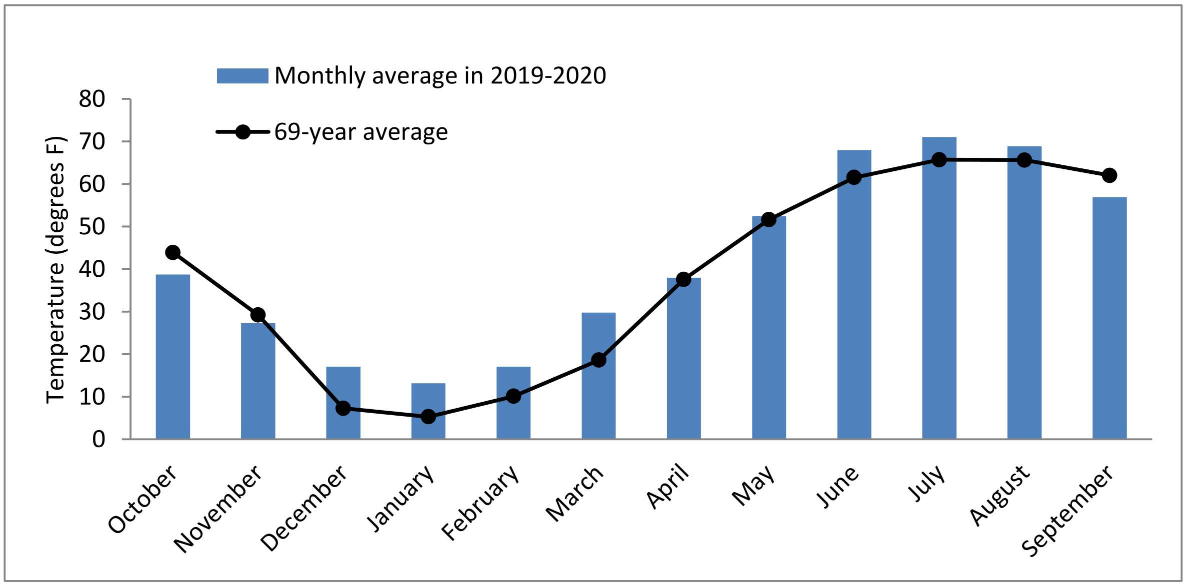
Animal Science

Forages and Cover Crops

Monthly Temperatures for the 2019-2020 Crop Year



Last spring frost: May 12 (26°F)
First fall frost: September 8 (31°F)
119 frost-free days

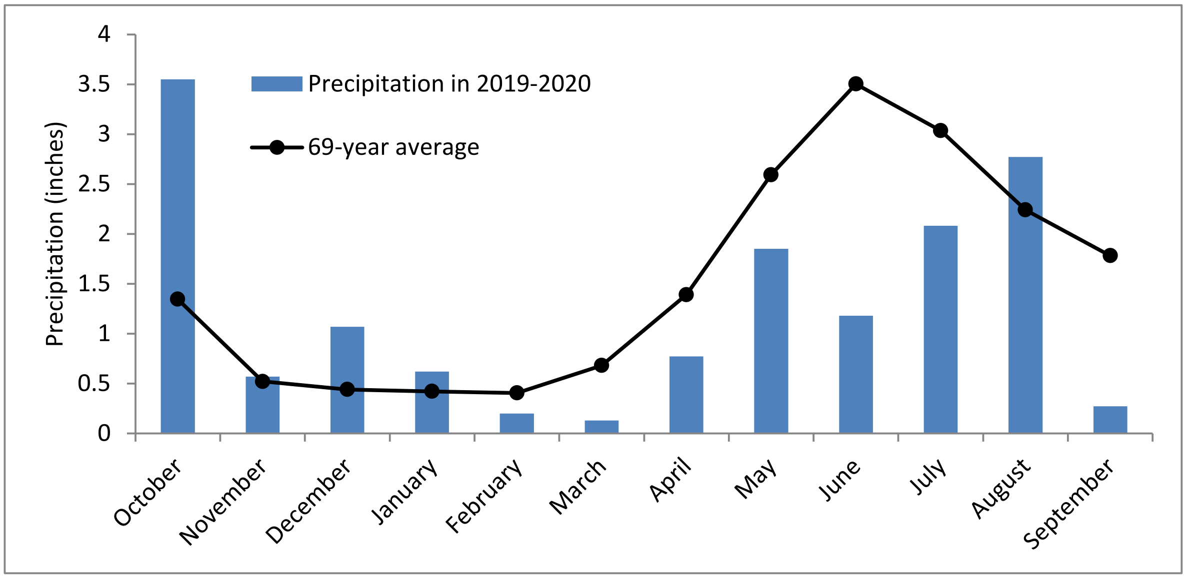
Average[1] last spring frost: May 13
Average first fall frost: September 22
Average: 132 frost-free days

[1] 1951 to 2020; 69 years

Month	Maximum temperature[2]	Minimum temperature	Average temperature	Long-term[1] average temperature	2019-2020 deviation from long-term average
October	73	14	38.8	43.9	-5.2
November	54	-7	27.3	29.2	-1.9
December	40	-16	17.1	7.3	9.8
January	39	-19	13.2	5.3	7.9
February	42	-18	17.1	10.1	7.0
March	57	0	29.8	18.6	11.2
April	72	5	38.0	37.6	0.4
May	78	24	52.5	51.6	0.8
June	91	44	68.0	61.5	6.4
July	93	54	71.1	65.7	5.4
August	90	45	68.9	65.6	3.2
September	85	31	56.9	62.0	-5.1

[2] Degrees F

Monthly Precipitation for the 2019-2020 Crop Year



Month	Precipitation[1]	Long-term[2] average precipitation	Deviation from long-term average	Accumulated precipitation	Accumulated long-term average	2019-2020 accumulated % of long-term average	Snow[3]
October	3.55	1.34	2.21	3.55	1.34	264.10	15.5
November	0.57	0.52	0.05	4.12	1.87	220.89	6
December	1.07	0.44	0.63	5.19	2.31	225.16	35.5
January	0.62	0.42	0.20	5.81	2.73	213.09	12.5
February	0.2	0.41	-0.21	6.01	3.13	191.89	3
March	0.13	0.68	-0.55	6.14	3.81	161.08	2
April	0.77	1.39	-0.62	6.91	5.20	132.84	6
May	1.85	2.59	-0.74	8.76	7.79	112.38	0
June	1.18	3.50	-2.32	9.94	11.30	87.98	0
July	2.08	3.03	-0.95	12.02	14.33	83.87	0
August	2.77	2.24	0.53	14.79	16.57	89.25	0
September	0.27	1.78	-1.51	15.06	18.35	82.06	0
Total	**15.06**	**18.37**	**-3.31**	**15.06**	**18.35**	**82.06**	**80.5**

[1] Rain and melted snow in inches [2] 1951-2020; 69 years [3] Depth in inches

Upland Sandpiper (*Bartramia longicauda*)
Photo by T.J. Hovick

Breeding Bird Community Composition in Patch-burn and Modified Twice-over Rotational Grazing Systems

Cameron Duquette and Torre Hovick
School of Natural Resource Sciences, North Dakota State University, Fargo, N.D.

We are evaluating the effects of patch-burn grazing and twice-over rotational grazing management strategies on avian breeding community composition. The results demonstrate the distinct preferences for vegetation structure in the breeding bird community.

Although species such as the chestnut-collared longspur prefer the patch-burn treatment, the dense vegetation in other treatments was preferred by species that need shrubs and thick litter for breeding. Community diversity is highest in the patch-burn pastures compared with the season-long (without burning) and twice-over rotational grazing pastures. Here we present results following four years of study, from 2017 through 2020.

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. These vegetation drivers are shaped by inherent (topoedaphic) and imposed (management-based) factors and their interactions.

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

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 low vegetation 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). Grasslands managed with patch-burn grazing 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 and density. We 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 compare patch-burn grazing with season-long grazing and twice-over rotational grazing, two traditional management practices in the area.

In addition, we want to evaluate the competing effects of topoedaphic and management heterogeneity on bird densities during the course of the treatment cycle. These results will enable managers to select a grazing system that will promote grassland bird conservation in a working landscape.

Procedures

Study Area

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

(*Heterostipa comata*) dominate the herbaceous community.

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 (15.9 inches) and an average annual temperature of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).


T.J. Hovick, NDSU

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 pasture) at a four-year return interval and (PBG40), (3) season-long grazing with dormant-season (one-eighth pasture) and growing season (one-eighth pasture) patch burning at a four-year return interval (PBG20), (4) modified twice-over rotational grazing (MTORG).

Annual burn plots in PBG20 are two adjacent 20-acre subpatches. Growing season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals mirror the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs graze freely within pastures from May 1 to Oct. 1each year at a moderate stocking rate designed to achieve 30% forage utilization. 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. This is the first time that patch-burn grazing management has been practiced on this site, so a full round of treatments was not implemented until the 2020 season, allowing us to study the relative importance of heterogeneity from different sources.

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 (512 surveys/year 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 1- by 0.5-m quadrat and modified Daubenmire cover classes (20 quadrats/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).

Quantifying Inherent Heterogeneity

For each patch in the PBG20, PBG40 and SLG treatments, we evaluated topographic roughness, the topographic wetness index, which determines relative rates of inflow and outflow, and the dominant soil type (NRCS).

Statistics

We calculated the density of detected bird species using the R package *unmarked* (Fiske and Chandler, 2011). For each year/ species combination, we used AIC model selection procedures (Burnham and Anderson, 1998) to evaluate relative support for inherent heterogeneity models versus imposed heterogeneity models. We used this information to evaluate the impacts of management-based versus inherent heterogeneity.

We used vegetation and management to describe variation in avian community composition. Significance of environmental variables was assessed using permutational analysis of variance (PERMANOVA, McArdle and Anderson, 2001). We used transect-level densities to compare differences between treatments.

Table 1. Relative influences of inherent (topoedaphic) versus imposed (management) heterogeneity on six species of grassland birds across PBG20, PBG40 and SLG treatments from 2017 to 2020.

Species	2017	2018	2019	2020
Bobolink	TE	TRT	TRT	TRT
Chestnut-collared longspur	TE	TE	TE	TE
Clay-colored sparrow	TRT	TE	TRT	TRT
Savannah sparrow	TE	TRT	-	TE
Western meadowlark	-	TE	TRT	TRT
Grasshopper sparrow	TE	-	TE	TRT

TE indicates that topoedaphic (inherent) heterogeneity was the main component driving species density that year.

TRT indicates that treatment-imposed (patch-burn grazing versus season-long without burn grazing) heterogeneity is the strongest driver of density that year.

Cells filled with **dashes** indicate that neither source of heterogeneity was associated with species density.

Results

Density

We found variable responses in bird species density through time with respect to inherent and imposed heterogeneity. From year two onwards, bobolink (*Dolichonyx oryzivorus*) density was more strongly influenced by imposed heterogeneity (Table 1). Chestnut-collared longspur (*Calcarius ornatus*) density was structured by inherent topoedaphic heterogeneity across all years (Table 1).

Clay-colored sparrow (*Spizella pallida*) density was more strongly affected by treatment structure (Table 1). Savannah sparrow (*Passerculus sandwichensis*) density also was not consistently associated with imposed or inherent heterogeneity features (Table 1).

Western meadowlark (*Sturnella neglecta*) density was weakly structured by inherent heterogeneity at the beginning of the study period and weakly associated with imposed heterogeneity by the latter half of the study period (Table 1). Grasshopper sparrow (*Ammodramus savannarum*) density was not strongly associated with levels of inherent or imposed heterogeneity at the scale studied but was more sensitive to treatment effects by the time our full treatment structure was implemented (Table 1).

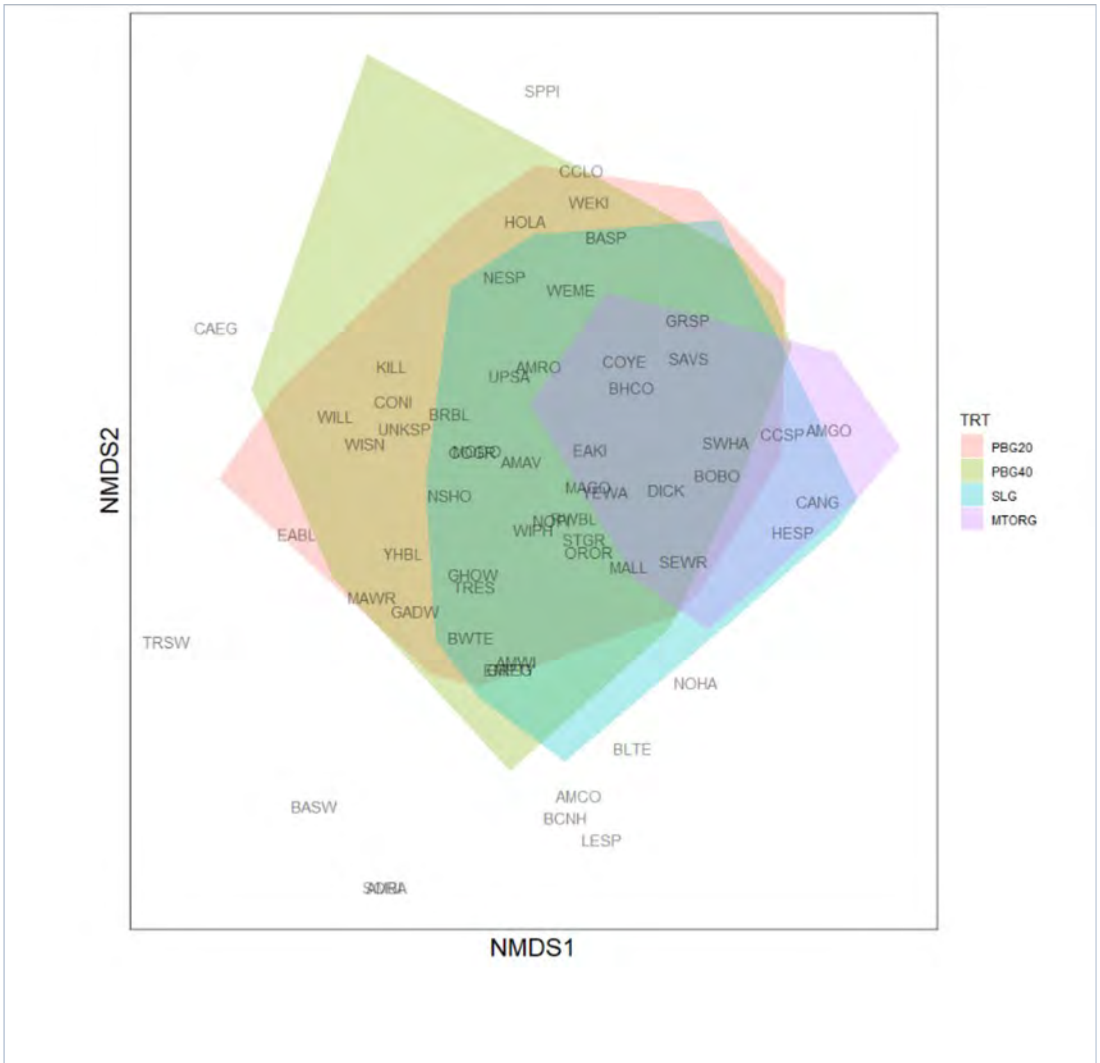


Figure 1. Nonmetric dimensional scaling (NMDS) ordination plot for abundances of grassland bird species in a landscape managed with patch-burn, season-long without burning and modified twice-over grazing treatments at the Central Grasslands Research Extension Center near Streeter, N.D. See Table 1 for species abbreviations.

Community

We see significant overlap in bird communities among treatments. However, the patch-burn communities are more diverse and variable than the SLG treatment, which is in turn more variable than the MTORG treatment (Figure 1). Detections of species by treatment are listed in Table 2 (next two pages).

Discussion

The results demonstrate the distinct preferences for vegetation structure in the breeding bird community. Although species such as chestnut-collared longspur prefer the patch-burn treatment, results also show that the dense vegetation in SLG and MTORG treatments are preferred by species that need shrubs and thick litter for breeding, such as bobolinks and clay-colored sparrows.

Community diversity is highest in the patch-burn pastures compared with the SLG and MTORG grazing pastures. We also see that treatment is the dominant source of heterogeneity affecting bobolink and clay-colored sparrow densities, while inherent landscape heterogeneity caused by topoedaphic features best explains chestnut-collared longspur density.

Together, these results suggest that a diversity of rangeland management strategies may be required to provide habitat structure for a full suite of grassland species, but patch-burn grazing management provides habitat for a diverse assemblage of breeding grassland birds on its own.

Table 2. Detections of species by treatment for patch-burn, season-long without burning and modified twice-over grazing treatments from 2017-2020.

Species	Code	PBG20	PBG40	SLG	MTORG
American avocet	AMAV	0	0	**3**	0
American bittern	AMBI	**1**	0	0	2
American coot	AMCO	**12**	2	0	0
American goldfinch	AMGO	3	1	3	**7**
American robin	AMRO	**6**	1	0	0
American wigeon	AMWI	0	0	**3**	**3**
Baird's sparrow	BASP	**1**	**1**	0	0
Barn swallow	BARS	0	0	**2**	0
Black-crowned night heron	BCNH	0	0	**2**	0
Brown-headed cowbird	BHCO	202	155	**380**	209
Black tern	BLTE	**21**	2	12	3
Bobolink	BOBO	60	61	**159**	83
Brewer's blackbird	BRBL	181	**344**	26	37
Blue-winged teal	BWTE	37	**46**	28	15
Cattle egret	CAEG	**6**	**6**	0	0
Canada goose	CAGO	0	0	**2**	1
Chestnut-colored longspur	CCLO	**108**	55	4	4
Clay-colored sparrow	CCSP	147	196	**345**	3
Common grackle	COGR	13	4	**38**	1
Common nighthawk	CONI	18	**20**	1	0
Common yellowthroat	COYE	9	6	**21**	0
Dickcissel	DICK	0	1	4	**18**
Eastern bluebird	EABL	0	0	**2**	0
Eastern kingbird	EAKI	24	**42**	37	20
Franklin's gull	FRGU	0	0	**2**	0
Gadwall	GADW	7	**14**	9	8
Great-horned owl	GHOW	0	0	**1**	0
Great egret	GREG	0	0	**1**	0
Green-winged teal	GWTE	0	0	**1**	0
Grasshopper sparrow	GRSP	257	**289**	268	98
Henslow's sparrow	HESP	0	0	**12**	0
Horned grebe	HOGR	0	0	**1**	0
Horned lark	HOLA	3	**6**	0	0

Bolded numbers are the treatment with the highest count. (*Continued on next page)*

Table 2 *(continued).* Detections by species by treatment for patch-burn, season-long without burning and modified twice-over grazing treatments from 2017-2020.

Species	Code	PBG20	PBG40	SLG	MTORG
Killdeer	KILL	31	**46**	16	8
LeConte’s sparrow	LESP	2	0	**4**	1
Lesser yellowlegs	LEYE	0	1	**2**	0
Marbled godwit	MAGO	11	7	**16**	1
Mallard	MALL	**10**	8	5	8
Marsh wren	MAWR	9	3	**10**	0
Mourning dove	MODO	**9**	7	7	3
Nelson’s sparrow	NESP	**1**	**1**	0	0
Northern harrier	NOHA	0	0	**4**	0
Northern pintail	NOPI	8	**17**	4	8
Northern shoveler	NSHO	**16**	11	6	3
Orchard oriole	OROR	0	2	**5**	0
Red-winged blackbird	RWBL	260	283	**331**	264
Ring-billed gull	RBGU	0	0	**1**	0
Ruddy duck	RUDU	**2**	1	1	0
Savannah sparrow	SAVS	101	**131**	109	96
Sedge wren	SEWR	5	2	**22**	8
Sora	SORA	**1**	0	0	0
Sprague’s pipit	SPPI	0	**2**	0	0
Sharp-tailed grouse	STGR	3	5	**22**	6
Swainson’s hawk	SWHA	0	0	**1**	0
Tree swallow	TRES	**10**	5	9	2
Upland sandpiper	UPSA	**21**	13	6	4
Western kingbird	WEKI	**4**	3	2	1
Western meadowlark	WEME	**139**	126	133	35
Willet	WILL	**11**	6	**11**	1
Wilson’s phalarope	WIPH	5	**13**	2	4
Wilson’s snipe	WISN	**12**	4	4	2
Yellow warbler	YEWA	0	0	**1**	0
Yellow-headed blackbird	YHBL	**43**	0	28	2
Total		1,830	1,949	**2,120**	1,330

Bolded numbers are the treatment with the highest count.

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Photos by Rick Bohn

Avian Nest Survival in a Patch-burn Grazing System

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Wilson's Snipe (*Gallinago delicata*)
Photo by C.A. Duquette

Summary

We are evaluating the effect of a patch-burn grazing management strategy on avian nest success. Results highlight the differences in preferred vegetation structure among grassland species. Combined with our community results, patch contrast seems to create more niches for nesting and breeding birds and enhances abundance and diversity of birds, compared with traditional range management. Our duck nest selection work shows that waterfowl benefit from areas managed with fire and grazing. These results cover four years, from 2017 through 2020.

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 (Vermeire 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. 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).

Woody species can increase the incidence of predation and cowbird parasitism and reduce nesting

Mourning dove (*Zenaida macroura*) Photo by C.A. Duquette cues for grassland species (Archer et al., 2017; Klug et al., 2010; With, 1994). 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 have been studying the use of experimental pastures by nesting birds during a time-since-fire-gradient by monitoring nest success, selection 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 from this study will help in the selection of grazing systems that improve management 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. Native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*) dominate the herbaceous community. 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 an average annual temperature of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Treatment Structure

Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight subpatches. The treatments are: (1) season-long grazing (SLG), (2) season-long grazing with dormant season patch-burning (one-fourth pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth pasture) and growing season (one-eighth pasture) patch-burning at a four-year return interval (PBG20). Annual burn plots in PBG20 are two adjacent 20-acre subpatches.

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

Cow-calf pairs graze freely within pastures from May 1 to Oct. 1 each year at a moderate stocking rate designed to achieve 30% forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Nest Searching

We designated a 4-hectare (ha) nest searching plot in each subpatch (one-eighth 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 nest by visual predators (Winter et al., 2003).

We candled two representative eggs from each nest to determine nest age (Lokemoen and Koford, 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.

We calculated waterfowl nest site selection for the different time-since-fire patches using Manly selection ratios (Duquette et al., 2020). To better understand the role of time since fire in duck nest site selection, we combined our nesting data with patch-burn duck nest data from the Hettinger Research Extension

Table 1. Summary of 2017-2020 nest sampling at CGREC near Streeter, N.D.

Species	PBG20	PBG40	SLG	Total
American Bittern	0	0	**2**	2
American Wigeon	6	4	**13**	23
Blue-winged Teal	**164**	91	128	383
Bobolink	1	1	**6**	8
Brewer's Blackbird	49	**70**	3	122
Canada Goose	0	0	**3**	3
Chestnut-collared Longspur	**36**	33	3	72
Clay-colored Sparrow	70	102	**121**	293
Common Nighthawk	**14**	6	0	20
Eastern Kingbird	0	0	**2**	2
Gadwall	39	28	**55**	122
Grasshopper Sparrow	**42**	29	31	102
Green-winged Teal	**1**	0	0	1
Horned Lark	2	**3**	0	5
Killdeer	**10**	3	0	13
Lesser Scaup	0	2	**4**	6
Mallard	**34**	19	20	73
Marbled Godwit	**3**	**3**	0	6
Mourning Dove	34	15	**39**	88
Northern Pintail	**52**	51	37	140
Northern Shoveler	27	**33**	20	80
Red-winged Blackbird	**15**	**15**	10	40
Savannah Sparrow	13	**18**	14	45
Sharp-tailed Grouse	3	**6**	3	12
Upland Sandpiper	**10**	4	5	19
Western Meadowlark	**100**	93	82	275
Willet	**7**	6	1	14
Wilson's Phalarope	**5**	3	0	8
Wilson's Snipe	**14**	9	5	28
Yellow-headed Blackbird	**1**	0	0	**1**
All species	**752**	**647**	**607**	**2006**

Center. Because we are interested explicitly in the role of time since fire, and an unburned area in a pasture without fire theoretically should have a different structure than an unburned area in a patch-burn pasture, we only used patch-burn grazing pastures for analysis.

Results

During the past four years, we have monitored 2,006 nests in our treatment structure, totaling 30 species. Many species have similar numbers of nests among treatments (Table 1), but others, such as the chestnut-collared longspur, prefer nesting in the patch-burn pastures. Future work will evaluate the effect of treatment structure on nest survival and patch-burn and nest-specific variables.

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.

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.

Species	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	Brown-headed Cowbird parasitism - Nest visual obstruction +
Grasshopper Sparrow	0.92	Stage + Nest vegetation height -
Western Meadowlark	0.95	Stage + 5m cool-season invasive grasses + 5m bluegrass + Nest visual obstruction -
Brewer's Blackbird	0.95	Julian day - Brown-headed Cowbird parasitism - 5m vegetation height + Nest cool-season invasive grass -

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 with brown-headed cowbird parasitism and nest-site cool-season grass cover. Nest survival increased with greater vegetation height.

Waterfowl Nest Site Selection

Blue-winged teal, gadwall and mallard preferred to nest in later time-since-fire patches, but these species also preferred burned patches to unburned patches. Northern pintail showed little preference for nesting with respect to time since fire (Figure 1).

Discussion

Results highlight the differences in preferred vegetation structure among grassland species. Combined with our community results, patch contrast seems to create more niches for nesting and breeding birds and enhance abundance and diversity of birds, compared with traditional range management. Our duck nest selection work shows that waterfowl benefit from areas managed with fire and grazing, and that later time-since-fire values differ ecologically from a waterfowl selection standpoint from unburned areas.

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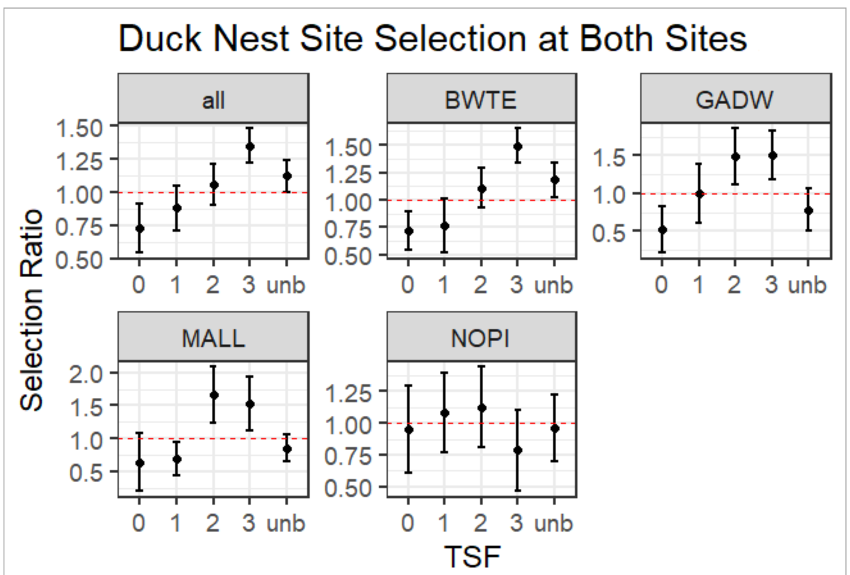

Figure 1. Duck nest site selection in proportion to availability of time since fire (zero to three years) and unburned at the Central Grasslands Research Extension Center and the Hettinger Research Extension Center from 2017-2020. A value less than 1 indicates ducks select nest sites in that time-since-fire category less often than would be expected given its availability on the landscape, while a value greater than 1 indicates the opposite.

BWTE = Blue-winged Teal, GADW = Gadwall, MALL = Mallard, NOPI = Northern Pintail.

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Cumulative Growth of Forage Production in a Patch-burn Grazing System

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Summary

Rotational grazing intervals of two, four and six weeks are evaluated in a patch-burn grazing system to understand the impact on cumulative forage production.

Introduction

Patch-burn grazing is the application of prescribed fire to focus livestock grazing on a portion of a grazing unit. The objective is to increase the diversity and structure of vegetation in a way that benefits wildlife and maintains livestock production. By burning on a portion of the acreage on an annual basis, a mosaic of heterogeneity can be created for grassland-dependent wildlife while also maintaining production and economic benefits for livestock producers.

The concept of grazing strategies dates back to the turn of the 20th century. Combined pressures of agricultural and livestock production, urbanization, deforestation and extreme weather events such as droughts generated an institutional and scientific response to severe rangeland degradation. The movement of livestock between two or more subunits of rangeland such that alternating periods of grazing and no grazing occur within a single growing season is defined as rotational grazing (Heitschmidt and Taylor, 1991).

Rotational grazing became established as the norm, and various direct and indirect benefits resulted when coupled with the ability of managers to observe and adapt (Briske et al., 2011). Prior to the 20th century, much of the Great Plains evolved with disturbances such as fire and grazing. While rotational grazing has continued to be modified and widely adapted, burning largely has been suppressed.

Research quantifying the impacts of using fire to benefit herbivores dates back to the 1960s. Scientists applied fire treatments to understand how fire influenced grazing behavior, animal growth and the plant community. Improvement to forage palatability and nutritive value, the abundance of herbaceous plants and weight gains of cattle were documented (Duvall and Whitaker, 1964; Hilmon and Hughes, 1965; Angell et al., 1986).

Despite a reduction in plant biomass when compared with unburned patches, post-fire forage growth was attractive to grazers because the plant material was higher in protein content and lower in fiber (Fuhlendorf et al., 2017; Sensenig et al., 2010). Current research has documented that fire and grazing could increase the productivity of important native forage species such as little bluestem (*Schizachrium scoparium*) and western wheatgrass (*Pascopyrum smithii*) (Vermeire et al., 2004; Limb et al., 2011).

Since the time of its institution, the merits of rotational grazing have been highly debated by researchers and livestock producers. The term born during a period of widespread range degradation was applied to many management concepts such as rest-rotation, deferred rotation and season-long grazing (Society for Range Management, 1998).

The persistence of the rotational grazing debate is due in part to terminological confusion. A review of literature would suggest that contrasting interpretations exist regarding the efficacy of rotational grazing (Briske et al., 2011). However, rotational grazing continues to be valued by producers (Budd and Thorpe, 2009).

Many popular news outlets, trade magazines and conservation agencies promote the application of rotational grazing for production, conservation and ecological benefits (Goodloe, 1969; Norton, 1998; Teague et al., 2004, 2008). A closer look at experimental evidence suggests that regional and local conditions have much to do with results achieved. Factors such as stocking rates, seasonal distribution of rainfall, soil type, topography and time between deferment periods may influence the outcome greatly (Sampson, 1951; Vermeire et al., 2008).

The detrimental or beneficial effects of grazing systems are largely determined by how, where and when grazing is used. Livestock play a major role in regulating forage production through the defoliation of plants (Huntly, 1991).

Defoliation can promote shoot growth; however, overgrazing can reduce plant production significantly

(Hyder, 1972; Rogler, 1951). In this study, rotational grazing intervals are evaluated in a patch-burn grazing system to understand the impact on cumulative forage production.

Procedures

A randomized block design was initiated in 2019 with three grazing treatments each replicated four times to monitor cumulative growth of forage production in a patch-burn grazing system at the Central Grasslands Research Extension Center. Rotational grazing intervals of two, four and six weeks (with an equivalent rest period) were assigned to treatments.

Caged grazing exclosures, measuring 8 by 16 feet, were located in a 20- or 40-acre patch burn that had been completed in the spring prior to grazing turnout. A control was established to represent non-grazed, season-long forage production.

Soil type and vegetation communities were similar among replicates, as defined by the Natural Resources Conservation Service's ecological site descriptions and equivalent land use histories. The loamy sites frequently consisted of Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), goldenrod (*Solidago* spp.), Flodman's thistle (*Cirsium flodmanii*) and more.

Cow-calf pairs grazed at a moderate stocking rate designed to achieve 30% utilization from May 22 to Oct. 23 and May 19 to Oct. 22 during 2019 and 2020, respectively. The degree of disappearance within the patch-burn area where the grazing exclosures were located, however, was 72% for graminoids and 11% for forbs during 2019, while the degree of disappearance during 2020 was 80% for graminoids and 69% for forbs.

Cumulative Growth of Forage Production

Herbage production was collected following each grazing interval from areas that were predetermined and marked with global positioning system (GPS) technology. Three 0.25-meter $(m)^2$ frames were used to estimate forage production per treatment in the grazing exclosure and its paired plot (grazed). Clippings were separated by graminoids and forbs, oven-dried at 122 F for 48 hours and weighed.

Upon collection of samples, the grazing exclosure was removed and installed at the nearby paired (grazed) plot, which then was allowed to recover from grazing (two, four or six weeks). The data collected at the end of each grazing interval represented forage production from in and out of the grazing exclosure, the difference of which is assumed consumed by livestock.

Consumption, regrowth and the final forage clipping, which was exposed to grazing for its assigned grazing period (two, four or six weeks), were compiled to determine cumulative forage production. The control was sampled every four weeks throughout the growing season.

Results and Discussion

The livestock at the Central Grasslands Research Extension Center express a preference for burned patches versus unburned patches, despite the burned patches having a lower amount of available forage at the beginning of the growing season. As the growing season progresses, cattle tend to use the recently burned areas less (Wanchuk and McGranahan, 2019).

A study conducted at the center during 2017-2018 indicated that livestock are attracted to burned patches because of increased forage quality (Lakey and McGranahan, 2018). The differences in forage quality between the burned and unburned patches are likely more noticeable during the beginning of the growing season.

Year One

Cumulative growth of forage production at the two- and four-week grazing intervals was statistically different (P = 0.0474) from the control during the 2019 growing season (Figure 1). Means followed by the same letter within Figure 1 are not different at P > 0.05.

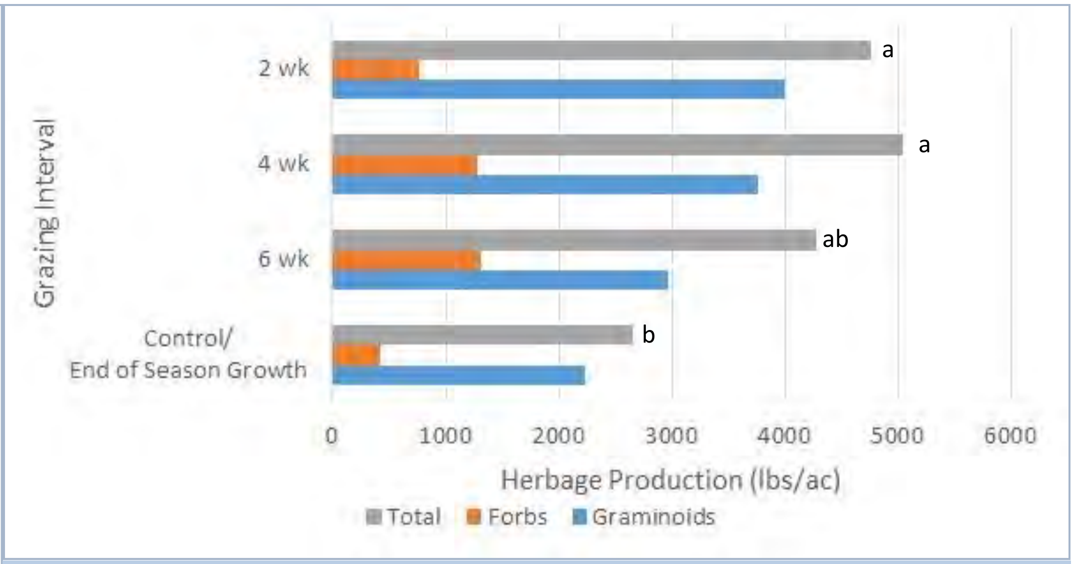

Figure 1. Cumulative growth of forage production in a patch-burn grazing system at the Central Grasslands Research Extension Center during 2019.

Year Two

Cumulative growth of forage production was not statistically different (P = 0.3474) for the grazing treatments during 2020 (Figure 2).

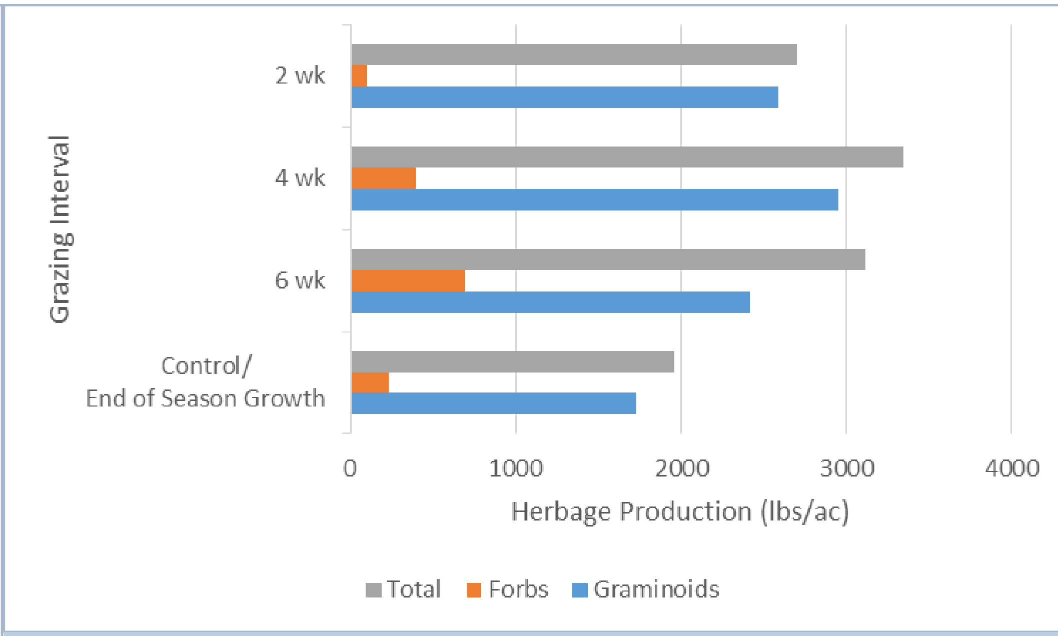

Figure 2. Cumulative growth of forage production in a patch-burn grazing system at the Central Grasslands Research Extension Center during 2020.

Disturbance-driven heterogeneity is important to maintain rangelands in the northern Great Plains that evolved with disturbances such as fire and grazing (Bowman et al., 2009; Kay, 1998). The response of herbage production to these disturbances may be decreased growth, equal growth or increased growth of graminoids and forbs.

While statistical differences occurred between grazing treatments during the 2019 growing season, the same level of significance was not maintained during the following season. What is important to note is that the growing season conditions during 2019 and 2020 were different (Table 1).

Rainfall during 2019 exceeded the 30-year average for each month during the growing season by a range of .06 to 2.40 inches. In direct contrast, the only month during 2020 where rainfall exceeded normal was August. Departures from normal during the 2020 growing season ranged from minus 0.64 to minus 2.06 inches of rainfall.

Table 1. Average monthly rainfall levels and seasonal totals (inches) by month and year at Central Grasslands Research Extension Center during 2019 and 2020 growing season.			
	Monthly Rainfall (inches)[1]		
Month	**2019**	**2020**	**30-year average**
May	2.99	1.81	2.45
June	3.47	1.35	3.41
July	4.15	2.13	3.20
August	2.52	2.73	2.31
September	4.44	.31	2.04
October	2.59	.22	1.36
Seasonal total	**20.16**	**8.55**	**14.77**

[1]Data obtained from the North Dakota Agricultural Weather Network, 2020

The differences in growing season conditions are apparent when evaluating forage production. The highest amount of cumulative forage production in a patch-burn grazing system at Central Grasslands during 2019 and 2020 was 5,052 and 3,349 pounds/acre, respectively. Although significant difference was not detected between grazing treatments during 2020, responses to grazing intervals appear to be a driver for plant response and cumulative growth.

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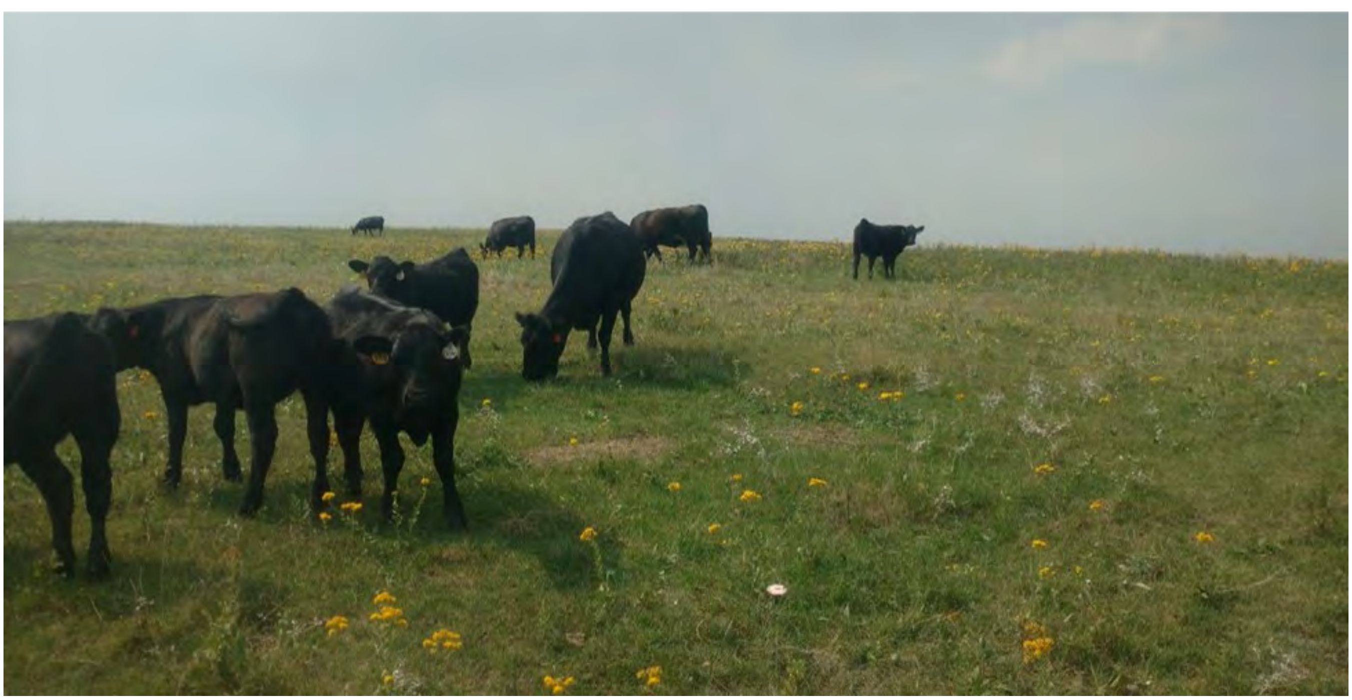
Photos by Erin Gaugler and Kevin Sedivec



Small Mammal Community Responses to Fire and Grazing in the Northern Mixed-grass Prairie

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Summary

Landscape heterogeneity is essential for ecosystem biodiversity. Historically, the interaction of fire and grazing, known as pyric-herbivory, created heterogeneity in the Great Plains capable of supporting a wide variety of wildlife and diverse small mammal communities.

Disturbances that vary spatially, temporally and in intensity create a wide array of habitat types. Present land management creates homogenous landscapes and habitat due to a lack of disturbances, which has led to a decrease in biodiversity of rangelands.

To determine how small mammal communities would react to reintroducing pyric-herbivory, we evaluated the differences in small mammal communities in a conventional season-long grazing treatment and two burn grazing treatments. Total species abundance was highest in patch-burn grazing treatments.

Deer mice (Peromyscus maniculatus) had the highest abundance of any species across treatments and was highest in patch-burn grazing treatments. Vole species (Microtus spp.) abundance decreased with time in the patch-burn grazing treatments while remaining stable in the season-long grazing treatment.

Using perMANOVA, we established that average pasture community composition was not different between treatments in 2017 ($P < 0.05$) but was different between the patch-burn grazing 40-acre treatment and the season-long grazing treatment in 2020 ($P < 0.05$). Species richness was highest in the patch-burn grazing treatments ($S = 8$) and lowest in the continuous grazing treatment ($S = 5$) during the course of the study.

Higher total species abundance and richness in patch-burn grazing treatments most likely can be attributed to the shifting mosaic landscape produced by the rotation of annual fires and focal grazing creating more variable habitat structure needed for various species. This suggests that patch-burn grazing could be used to create heterogeneous landscapes of variable habitat structure needed to support various small mammal species.

Introduction

Heterogeneity is essential to a biodiverse ecosystem (Ostfeld et al., 1997; Fox and Fox, 2000). The combination of inherent heterogeneity, caused by abiotic factors such as soil, climate, topography and nutrient availability, and disturbance-driven heterogeneity create habitat heterogeneity (Fuhlendorf et al., 2017). Historically in the Great Plains, the interaction between grazing and fire has been the main source of disturbance-driven heterogeneity, otherwise known as pyric-herbivory (Fuhlendorf et al., 2009).

Pyric-herbivory creates a shifting mosaic of plant communities due to the temporal and spatial interactions of fire and grazing (Fuhlendorf et al., 2009). This occurs when large herbivores, such as bison or cattle, preferentially graze recently burned areas because new plant growth is more palatable and nutritious (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009; Knapp et al., 1999; Vermeire et al., 2004). This allows patches that had been burned and grazed in previous growing seasons to recover (Fuhlendorf and Engle, 2001; Gates et al., 2017).

These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and probability of these patches burning again, repeating the cycle of the fire-grazing interaction (Fuhlendorf and Engle, 2001, 2004). This produces varying plant community composition and structure through space and time, which can sustain diverse wildlife communities (Fox, 1990; Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Heterogeneous habitat is crucial for supporting a variety of wildlife species at extreme ends of the habitat structure gradient (Fox and Fox, 2000; Fuhlendorf et al., 2009).

Due to present land management, the interaction between grazing and fire has been removed from the landscape, creating more homogenous ecosystems and habitat types. To counteract this, an effort has been made to develop land management strategies to reintegrate pyric-herbivory on the landscape. One such strategy is patch-burn grazing (Fuhlendorf and Engle, 2001, 2004).

Patch-burn grazing was developed to re-establish the historical fire-grazing relationship on the landscape. This framework creates a shifting mosaic of plant communities by establishing discrete patches of burned and nonburned patches within a pasture.

This cycle occurs every growing season, where previously nonburned patches subsequently are burned, while burned patches from the previous growing season experience a decrease in grazing intensity (Fuhlendorf and Engle, 2001). This interaction between burned and nonburned patches creates a heterogeneous landscape that varies in structure and composition, providing a wide variety of habitat for wildlife, such as small mammals (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016).

Small mammals fill an important niche in grassland ecosystems. They are a major food source for mesocarnivores, such as coyotes (Brillhart and Kaufman, 1995), and many raptor species, where *Microtus pennsylvanicus* (prairie voles) can make up to 41% of an owl's diet (Huebschman et al., 2000).

Researchers also have found that small mammals can influence plant community composition by reducing the number of native plant seedlings in post-disturbance ecosystems (Maron et al., 2012; Reed et al., 2004). *Peromyscus maniculatus* (deer mice), the most abundant small mammal in North America, are a granivore that prefers large-seeded native plants while avoiding small seeded exotics, such as *Bromus inermis* (smooth brome) (Everett et al., 1978; Witmer and Moulton, 2012). This has been found to limit re-establishment of native plant species in some cases (Everett and Monsen, 1990).

In previous studies, patch-burn grazing treatments were found to create spatial and temporal patterns of differing habitat types suitable to supporting diverse small mammal communities (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Because small mammals are an integral part of the grassland ecosystem, we need to study the effects of different grazing management systems on their community structures.

The objective of this study is to determine what effect land management has on small mammal communities using three treatments: two patch-burn grazing treatments that vary in size and season of fire, and a conventional season-long grazing treatment as a control treatment. We hypothesize that the patch-burn grazing treatments will create a shifting mosaic of plant communities that will support a diverse small mammal community, while the season-long grazing treatment will promote even grazing pressure, creating a uniform vegetation structure and decreased small mammal diversity.

Methods

Study Area

This study was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains.

This area is characterized by irregular, rolling plains and depressional wetlands. The climate is characterized as temperate and receives an average of 40.1 centimeters (cm) (15.8 inches) of precipitation a year and has an average temperature of 5 C (41 F) (1991-2020, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al., 2018).

Treatment Structure

Three treatments are applied to the study area, in which we compare four intervals of time since fire of the patch-burn grazing treatments (PBG), and a season-long grazing treatment (SLG). A total of 12 160-acre (approximately 65-hectare [ha]) pastures were used in this study, with four pastures (replicates) per treatment.

Pastures were split into eight 20-acre (8 ha) subpatches. All pastures are stocked with cow-calf pairs to achieve approximately a 40% to 60% degree of disappearance at a harvest efficiency of 30%.

(a) Patch-burn grazing 40-acre treatment (PB40) is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf and Engle, 2001). Prescribed fire was applied to two sub-patches (40 acres, 16 ha or one-fourth of the pasture) concurrently within each pasture every year for a total of eight subpatches being burned in the spring of each year.

(b) Patch-burn grazing 20-acre treatment (PB20) is similar to the previous patch-burn grazing treatment, in which two subpatches are burned every year. However, we wanted to observe what effect season and size of burn would have on small mammal communities. One 20-acre subpatch (one-eighth of the pasture) was burned in the spring while the other 20-acre subpatch was burned in the summer. Time-since-fire data from the PBG treatments was analyzed by zero-, one-, two- and three-years-since-fire, and by nonburned subpatches.

(c) Season-long grazing treatment (SLG) is intended to replicate a conventional cow-calf grazing management system and serves as a control treatment.

Data Sampling

Sampling of small mammals occurred from late May to late June. Each sampling period consisted of 25 days. Treatments were sampled concurrently to prevent biases associated with weather or time of day.

We established 40- by 40-meter grids of 25 Sherman live-traps (7.6- by 8.9- by 22.9-cm) spaced 10 meters apart per subpatch. In one day, 12 separate subpatches, one subpatch per pasture, were sampled (four subpatches/treatment). Three hundred traps were set per night, for a total of 4,200 traps set per sampling period.

Traps were baited with a combination of peanut butter and rolled oats. Sampled individuals were recorded by species and marked with ear tags – Style 1005-3 from the National Band and Tag Co. – to identify previously captured individuals.

Statistical Analysis

We estimated species abundances by subpatch using closed-capture Huggins models in Program MARK. Using PC ORD 6.0, we constructed PCA (Principal Components Analysis) ordinations based on estimated species abundances of our top six most abundant species to evaluate community composition of treatments from 2017-2020 and times-since-fire intervals using 2020 data. Utilizing permutational multivariate analysis of variance (PerMANOVA), changes in community composition by pasture from 2017-2020 were assessed.

Results

Ten small mammal species were recorded during the duration of this study (Table 1). The most abundant species in this study and in each treatment were deer mice (*Peromyscus maniculatus* - PEMA), which were most abundant in PB40 (Table 1). PB40 had the highest species richness of all treatments, with eight species, while PB20 had seven species and SLG had five species being recorded during the course of the study.

Table 1. Number of small mammal individuals captured by species in each treatment across all years of this study at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017-2020.

Scientific Name	Common Name	Species Code	Treatment		
			PB40	PB20	SLG
Peromyscus maniculatus	deer mouse	PEMA	87	74	46
Microtus ochrogaster	prairie vole	MIOC	9	6	18
Microtus pennsylvanicus	meadow vole	MIPE	4	5	5
Ictidomys tridecemlineatus	thirteen-lined ground squirrel	ICTR	6	10	
Urocitellus richardsonii	Richardson's ground squirrel	URRI	3	6	1
Zapus hudsonius	meadow jumping mouse	ZAHU	2		2
Thomomys talpoides	northern pocket gopher	THTA	2		
Mustela nivalis	least weasel	MUNI		1	
Peromyscus leucopus	white-footed mouse	PELE		1	
Blarina brevicauda	northern short-tailed shrew	BLBR	1		

From 2017 to 2020, relative abundance of deer mice did not change much in the PB40 or PB20 but did decrease in the SLG treatment due to a decrease in deer mouse abundance in 2020 (Figures 1 and 2). The biggest changes we see in the patch-burn grazing treatments (PBG) is the shift in relative abundance of specialist species.

Prairie vole (*Microtus ochrogaster* - MIOC) were not present in the 2020 PB40, as they were the second most abundant species in 2017, while relative abundance decreased slightly in the PB20, and stayed the same in the SLG (Figures 1 and 2). Meadow vole (*Microtus pennsylvanicus* - MIPE) relative abundance decreased in the PB40 but increased in the PB20 and SLG (Figures 1 and 2).

Thirteen-lined ground squirrel (*Ictidomys tridecemlineatus* - ICTR) relative abundance increased in both PBG treatments and were not present in the SLG in both years, while Richardson's ground squirrel (*Urocitellus richardsonii* - URRI) relative abundance increased in the PB40, as they were not present in 2017, stayed the same in the PB20 and no longer were present in the SLG in 2020 (Figures 1 and 2). While meadow jumping mice (*Zapus hudsonius* - ZAHU) were not present in 2017, they did make up about 10% of the population in the PB40 and SLG in 2020 but were not present in the PB20 (Figures 1 and 2).

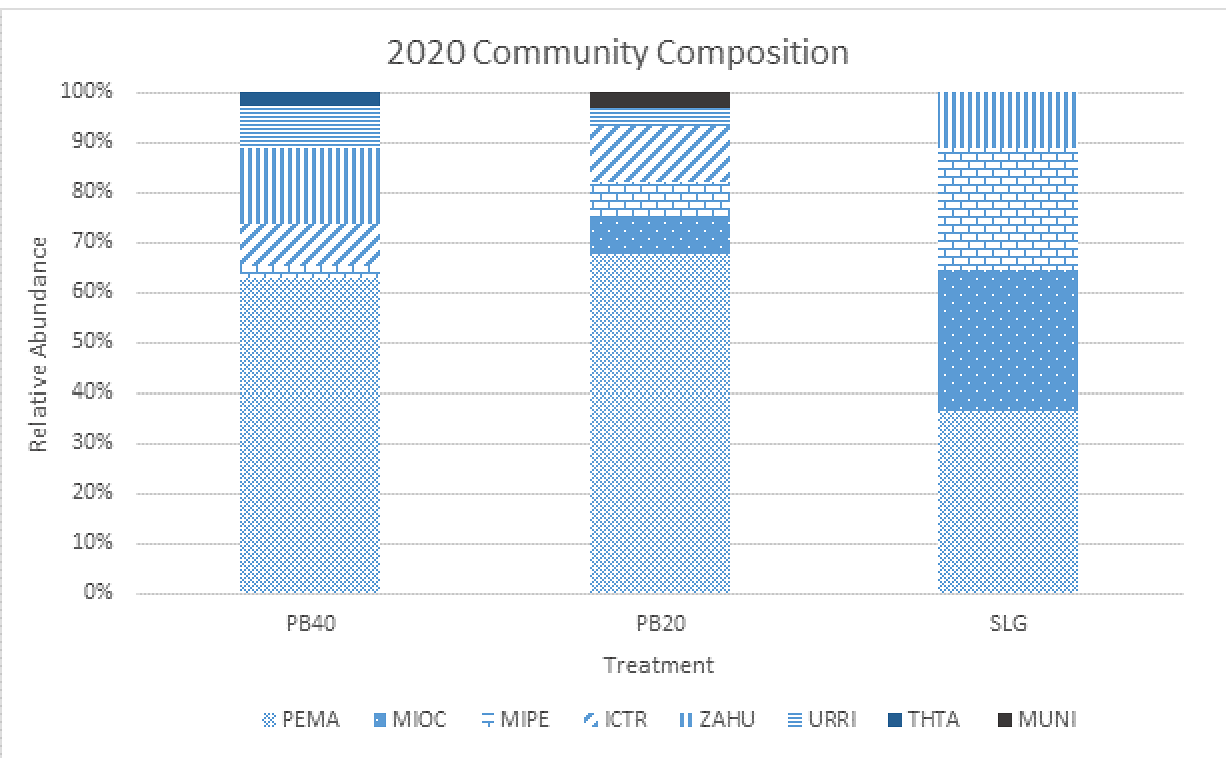

Figure 1. Relative abundance of small mammal communities according to treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020. Species codes are listed in Table 1.

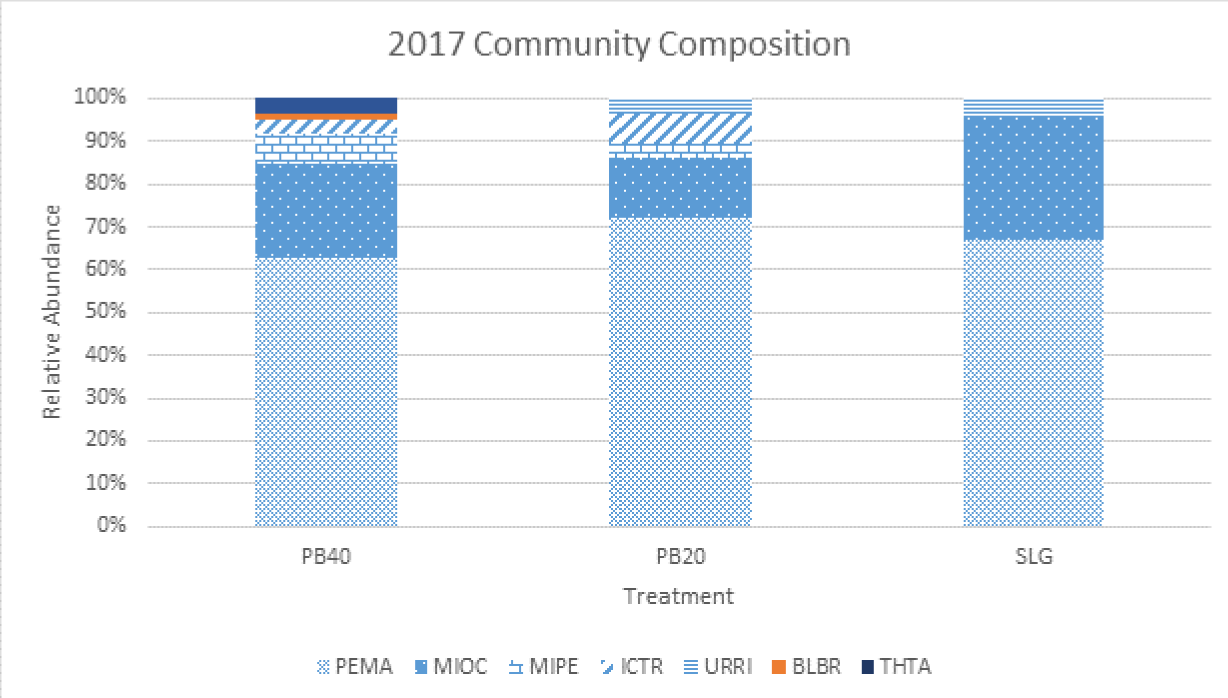

Figure 2. Relative abundance of small mammal communities according to treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017. Species codes are listed in Table 1.

PCA analysis of average pasture community composition indicated that year had a strong effect on community composition, especially in 2018 communities, where drought from the previous year combined with below-average cold temperatures and lack of snowpack in the winter of 2017-2018 likely caused communities in all treatments to contract (Figure 3, next page). After 2018, small mammal communities began to recover, with PBG treatments starting to become dissimilar from the SLG community in 2019 and 2020 (Figure 3). Using perMANOVA analysis, we established 2017 communities were not significantly different from each other, but PB40 and SLG treatments were different in 2020 ($p < 0.05$).

Time-since-fire PCA analysis illustrates the difference in community composition between recently burned subpatches (zero- and one-year-since-fire) and subpatches that had longer time-since-fire intervals (two- and three-years-since-fire), and how these communities are similar or dissimilar to communities in the SLG treatment (Figure 4). Recently burned subpatches were most dissimilar to the SLG communities, with communities having greater composition and being more diverse with time since fire, except in the three-year-since-fire subpatches, where communities were less diverse than the one- and two-year-since-fire communities (Figure 4). Of the different time-since-fire subpatches, one- and two-year-since-fire communities were the most diverse, but with increasing time since fire, communities become more similar to SLG communities (Figure 4).

Specialist species (animals that require unique habitat and resources) had different responses to time since fire. Vole species (*Microtus* spp.) were more associated with the SLG and the greater time-since-fire areas, while thirteen-lined and Richardson's ground squirrels were more associated with the most recently burned areas (Figure 4). In contrast, deer mice, a generalist species (animals that can occupy a wide variety of habitats), were not strongly associated with any of the time-since-fire intervals or the SLG treatment because they were prevalent across all sites (Figure 4).

Discussion

Relative composition of small mammal communities did not change greatly within treatment from 2017 to 2020 because the dominant species (deer mice) did not change in relative abundance except in the SLG treatment, where estimated abundance was 68% lower in 2020 than it was in 2017. Where we did see changes in community composition of treatments was

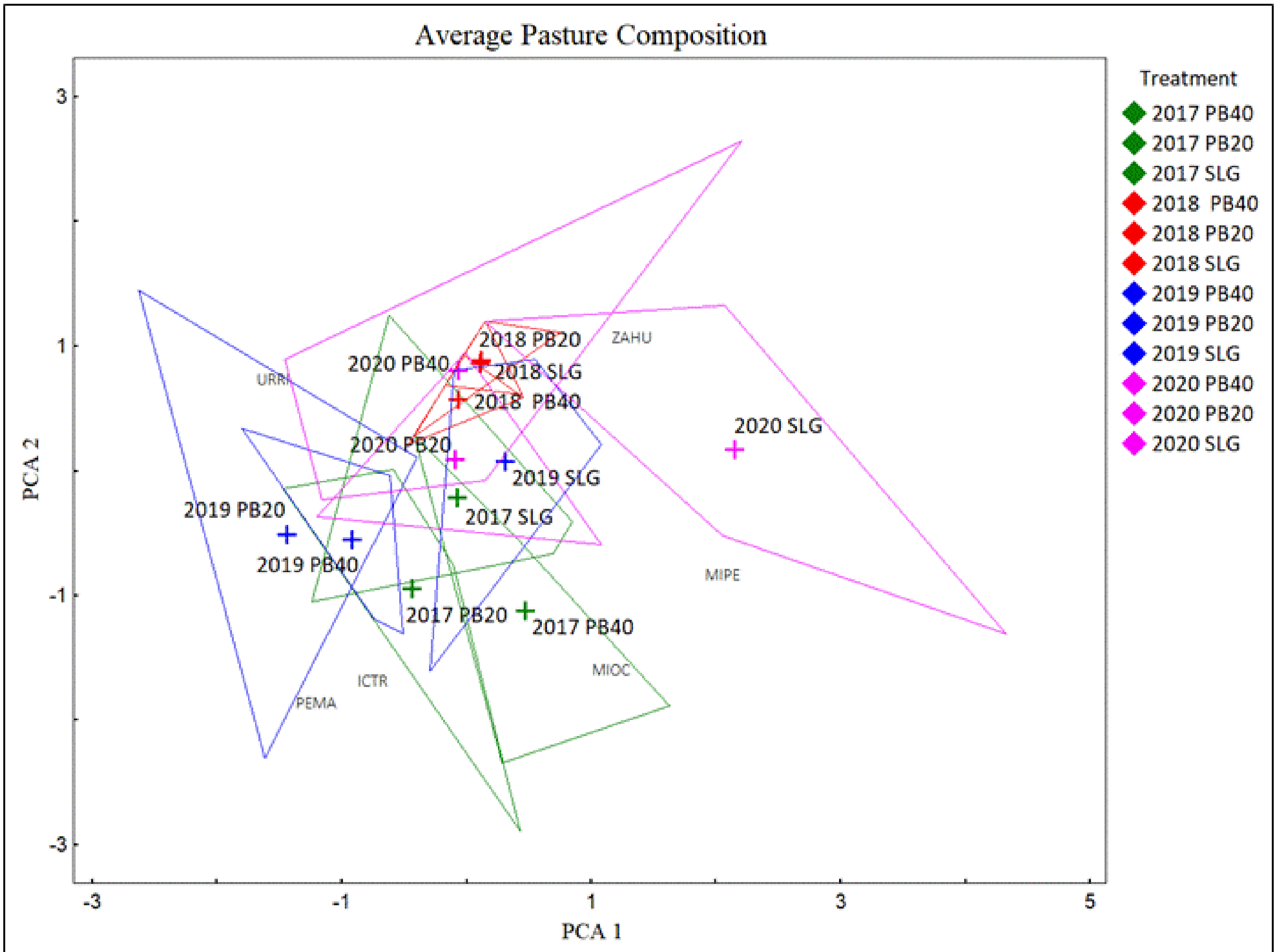

Figure 3. PCA ordination of average pasture small mammal communities at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017 to 2020. Polygons represent average pasture community composition by year of treatment. The four-letter species codes (see Table 1) are presented in the ordination to visualize relationships between species and treatments. Centroids of each polygon are represented by crosses.

in the specialist species, where vole species became less prevalent in the PB40 and to a lesser extent in the PB20.

This likely is due to a loss of habitat associated with high amounts of litter, which is needed by vole species (Ricketts and Sandercock, 2016). Species more associated with bare ground, such as thirteen-lined and Richardson's ground squirrels, increased in relative abundance in PBG treatments, likely in response to the increased bare ground that is associated with post-fire plant communities (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2010).

With time, small mammal communities of the PBG treatments and the SLG treatment began to diverge in composition. Although yearly weather can have a great effect on community composition (See Hamel et al., 2020, report), divergence in small mammal communities likely can be attributed to the differences in habitat created by time since fire in our PBG treatments.

After a full rotation of fire through the PBG pastures in 2020, a mosaic of patches was established with four different time-since-fire intervals and habitat types, which can explain why average pasture community composition in the PBG treatments differed with respect to the SLG treatment (Fuhlendorf et al., 2010).

Although we didn't find that PB20 pasture community composition was significantly different to that of the SLG pasture, this is not entirely surprising. At the time of sampling in June, only half of the 40-acre patches were burned (one 20-acre subpatch burned in spring, one 20-acre subpatch burned in summer), leaving the other half unburned, possibly acting as refugia for

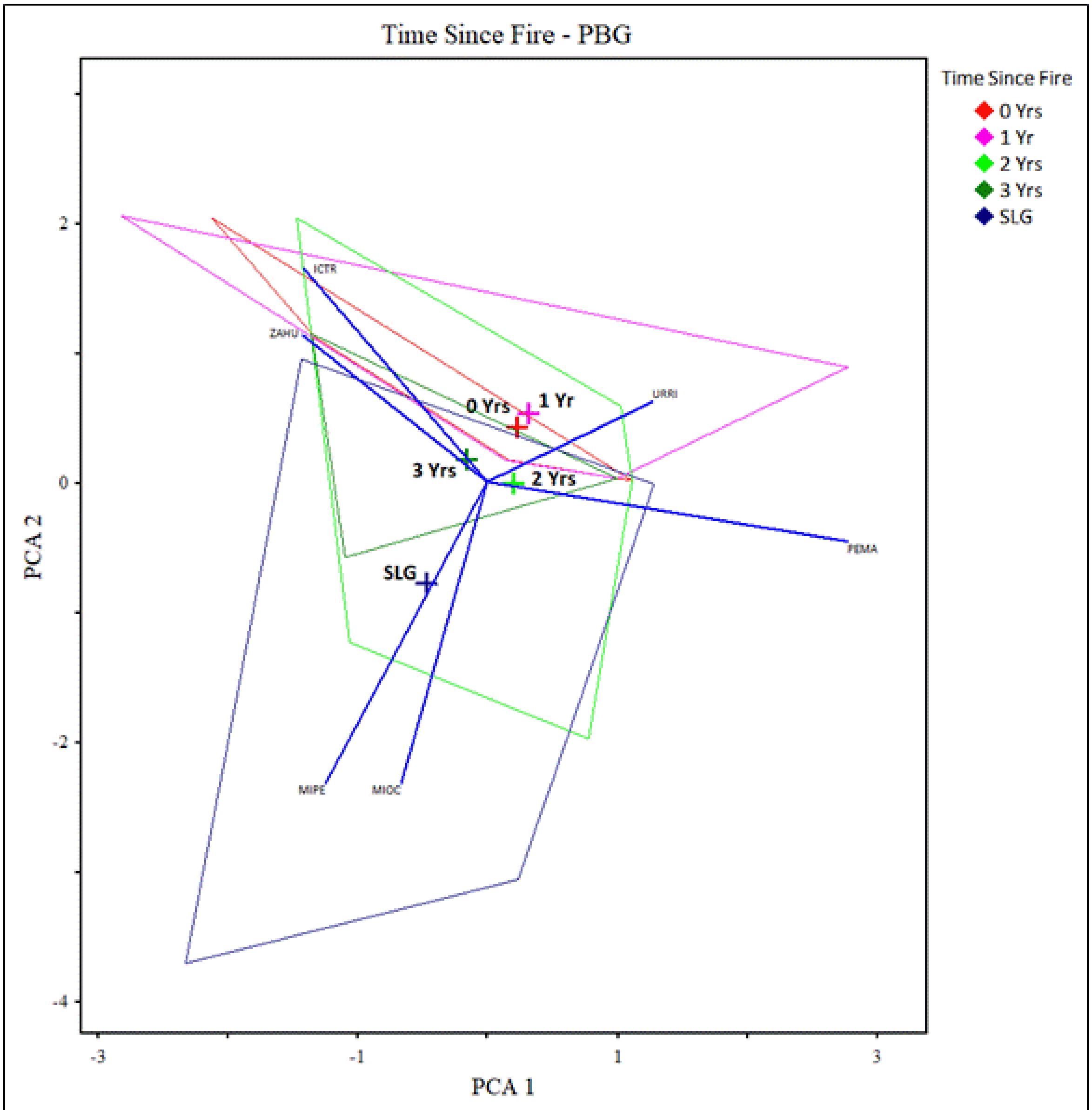

Figure 4. PCA ordination of average small mammal community compositions from PBG treatments arranged by time-since-fire intervals of subpatches compared with SLG community in 2020 at the Central Grasslands Research Extension Center near Streeter, N.D. The four-letter species codes (see Table 1) are presented in the ordination to visualize relationships between species and treatments. Centroids of each polygon are represented by crosses.

species that require more vegetative cover and litter, such as voles (Ricketts and Sandercock, 2016).

As discussed previously, species such as voles and ground squirrels can have specific habitat requirements. This is evident with time since fire as species more associated with bare ground (ground squirrels) were more abundant in recently burned areas, while species that require litter and canopy cover (voles) were more associated with areas that had greater time since fire and the SLG treatment.

Communities that occupied one- and two-year-since-fire subpatches were more diverse than those in the zero- and three-year-since-fire subpatches. This is because habitat within one- and two-year-since-fire subpatches is transitioning from areas with bare ground, needed for some species (ground squirrels), to areas begin accumulating litter and canopy cover, needed for other species (voles), causing more diverse communities (Ricketts and Sandercock, 2016).

Many of the results presented here are consistent with similar studies conducted in the tall grass prairie (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Patch-burn grazing shifted small mammal community composition in ways that season-long grazing couldn't by creating a mosaic of patches of differing habitat and time since fire. But because small mammal community responses to patch burning in the mixed-grass prairie are dynamic and are affected by more than management, further study is needed to better understand what effect this patch-burn grazing has on these communities.

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Plant Community Dynamics Under Multiple Land Management Strategies

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Summary

Fire and grazing are disturbances that interacted with each other to shape grasslands for millennia, creating mosaic landscapes with highly diverse plant communities. Present land management has removed fire from this ecosystem, creating homogenous landscapes that are dominated by invasive grass species, such as Kentucky bluegrass (Poa pratensis) and smooth brome (Bromus inermis).

To determine if reintroduction of the fire-grazing interaction (pyric-herbivory) and other land management strategies could promote more heterogeneous and diverse plant communities, we evaluated the differences in plant communities among a season-long grazing treatment, two patch-burn grazing treatments and a modified twice-over rest rotation treatment starting in 2017. We determined that average plant community composition between the season-long grazing treatment and the patch-burn grazing treatments were different ($P < 0.05$) and became increasingly different with time using nonmetric multidimensional scaling (NMDS) and permutational multivariate analysis of variance (perMANOVA).

We also found the patch-burn grazing treatments had higher diversity indices ($P < 0.05$) than the continuous grazing treatment in all treatment years, with difference in diversity indices between season-long grazing and patch-burn grazing increasing by approximately +.06 in each year. In 2020, diversity in all patch-burn grazing treatments and the modified twice-over rotation treatment was higher than in the season-long grazing treatment and varied by time since fire and pasture use type. This increase in diversity can be beneficial to plant communities because high-diversity plant communities have been found to be more resilient to drought and produce higher-quality forage for livestock.

These more diverse plant communities also can positively influence the diversity of higher trophic levels such as pollinators. Therefore, patch-burn grazing should be considered as a tool for conservation of grasslands and possibly as a replacement for conventional season-long livestock grazing.

Introduction

Fire and grazing are naturally occurring disturbances that, along with climate and topo-edaphic differences, have been shaping plant communities for millions of years (Bowman et al., 2009; Bond and Keeley, 2005; Fuhlendorf and Smeins, 1998, 1999). Fire and grazing historically interacted with each other, otherwise known as pyric-herbivory, in the Great Plains, creating spatial and temporal heterogeneity in plant communities (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009).

Pyric-herbivory occurs when large herbivores, such as bison or cattle, preferentially graze recently burned areas due to new growth being more palatable and nutritious (Knapp et al., 1999; Vermeire et al., 2004). Large herbivores focus their grazing efforts on recently burned patches, which allows patches that previously were burned and grazed to recover (Fuhlendorf and Engle, 2001; Gates et al., 2017).

These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and the probability that this patch will burn again, repeating the cycle of this fire-grazing interaction (Fuhlendorf and Engle, 2001, 2004).

Plant community composition and structure vary significantly in response to pyric-herbivory (Fuhlendorf and Engle, 2004). When fire burns across a grassland, it creates nonuniform, discrete patches of plant communities that vary in successional stages, forming a shifting mosaic of plant communities

through time and space, which produces an overall diverse landscape (Fuhlendorf et al., 2009).

Pyric-herbivory produces heterogeneous landscapes of various successional stages of plant communities that differ in structure and biomass, and creates an overall diverse plant community (Fuhlendorf and Engle, 2001, 2004). Recently burned and grazed sites see an increase in forbs, annual species and bare ground, with a reduction in litter and graminoid species.

Because large herbivores concentrate grazing in burn patches, this allows for graminoids in past burn patches to recover from the previous fire and grazing (Fuhlendorf and Engle, 2004). The changes in structure and composition of a plant community create heterogeneity on the landscape and in habitat, which in turn supports a diverse system of flora and fauna (Fox and Fox, 2000; Fuhlendorf et al., 2010; Ostfeld et al., 1997; Ricketts and Sandercock, 2016).

Present land management of grassland systems promotes uniform utilization that creates homogenous landscapes (Briske et al., 2003; Fuhlendorf et al., 2009). Due to present land management practices, fire and grazing have been decoupled, which has led to homogenous systems of non-native grasses, such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Dillemuth et al., 2009; Toledo et al., 2014). Although uniform moderate grazing can be beneficial to ground cover and soil disturbance, it fails to create heterogeneity of habitat structure essential for niche species at extreme ends of the habitat structural gradient (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016).

A solution to the decoupling of fire and grazing is the restoration of pyric-herbivory as a land management tool (Fuhlendorf and Engle, 2001). One such pyric-herbivory-based land management system is a patch-burn grazing system. It combines the historical elements of pyric-herbivory by creating discrete burned patches in a pasture that vary spatially and temporally, creating patches of recently burned, unburned and transitional areas (Fuhlendorf and Engle, 2001). This system of creating spatial and temporal changes on a landscape produces a shifting mosaic of plant communities, a wide variety of habitat structure and increased biodiversity.

To better understand the impacts of a patch-burn grazing system, we examine whether it can serve as a suitable conservation-based form of livestock management. This study used replicated treatments to examine plant community measurements, such as diversity, richness, evenness and standing crop biomass production, to evaluate what effect focal grazing and fire and rotational grazing with differing levels of grazing intensity have on these areas, and whether these grazing treatments create a shifting mosaic in the plant community and on a landscape level.

Methods

Study Area

This study was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains. This area is characterized by irregular, rolling plains and depressional wetlands.

The climate is characterized as temperate and receives an average of 40.1 centimeters (cm) (15.8 inches) of precipitation per year and has an average temperature of 5 C (41 F) (1991-2020, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al., 2018).

Treatment Structure

Four treatments were applied to the study area. We compared four intervals of time since fire and nonburned areas of the patch-burn grazing 40-acre treatment (PB40) and the patch-burn grazing 20-acre treatment (PB20); two intervals of four differing grazing intensities of heavy, full, moderate and rested of the modified twice-over rest rotation treatment (MTRR); and a season-long grazing treatment (SLG). Each treatment was replicated using four 160-acre pastures (approximately 65 hectares [ha]) split into eight 20-acre (approximately 8 ha) subpatches (patch = two subpatches) in the PBG and SLG treatments; 16- to 40-acre pastures with four grazed heavily, four grazed at full use, four grazed moderately and four rested; and four SLG pastures in the MTRR treatment. All pastures are stocked with cow-calf pairs to achieve approximately a 40% to 60% degree of disappearance at a harvest efficiency of 30%.

- *Patch-burn grazing 40-acre treatment* (PB40) is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf and Engle, 2001). Prescribed fire was applied to two subpatches (40 acres, 16 ha or one-fourth of the pasture) concurrently within each pasture every year for a total of eight plots being burned in the spring of each year. Data from this treatment was analyzed by zero, one, two and three years since fire and by nonburned plots.

- *Patch-burn grazing 20-acre treatment* (PB20) is a management technique similar to the previous patch-burn grazing treatment in which two subpatches are burned every year. However, because plant communities can respond differently to season of burn (Kral et al., 2018), we wanted to assess what effect season and size of burn would have on plant communities. One 20-acre subpatch (one-eighth of the pasture) was burned in the spring while the other 20-acre plot was burned in the summer.

- *Season-long grazing treatment* (SLG) is intended to replicate a conventional cow-calf grazing management system and serves as a control treatment.

- *Modified twice-over rest rotation grazing* (MTRR) was designed to be similar to the patch-burn grazing treatments in that it is designed to produce structural heterogeneity across a grazing unit. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilizes fencing to dictate cattle distribution and influence grazing. The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete subpastures that cattle cannot move among (without being purposefully moved) and are grazed from mid-May to late October. Across the subpastures, cattle are rotated through twice and allowed to graze for approximately 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy use (60% to 80% disappearance of graminoid species), full use (40% to 60% disappearance of graminoid species), moderate use (20% to 40% disappearance of graminoid species) and rested subpastures, respectively. The first rotation uses 40% of the grazing days and the second rotation 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, heavy-use will become the rested pasture, the rested becomes moderate -use pasture and the moderate-use becomes the full-use pasture. This rotation will create heavy disturbance in one subpasture but will avoid the annual heavy disturbance in the same location that could result in changes to forage quality and loss of plant species (Fuhlendorf et al., 2017).

Data Collection

All vegetation data was measured using ¼-meter $(m)^2$ frames. Species vegetation cover was measured using 60-meter permanent transects per each subpatch and sampling 31 measurements along each transect.

Plant community measurements were assessed using canopy cover. Standing crop biomass (alive and dead plant material) was collected by sampling four randomly located 1-m^2 exclosures per subpatch. Average standing crop biomass was calculated for each subpatch.

Three frames were sampled within each exclosure and outside of each exclosure. By measuring the difference between in- and out-of-exclosure biomass, we calculated the degree of disappearance.

Statistical Analysis

We analyzed differences in plant community composition of treatment pastures across all study years using permutational multivariate analysis of variance (perMANOVA) and nonmetric multidimensional scaling (NMS) procedures in PC-ORD 6.0.

Results: Update

Plant Community Response

One hundred sixty plant species were recorded during the duration of this study (2017-2020). Common plant species are listed in Table 1. Using NMS ordinations, we observed that average pasture plant community composition of PB treatments shift in size and placement within the ordinations space with time of treatment (Figure 1A & B). This can be seen better when comparing NMS axis 1 to axis 3, where a circular pattern of PB treatments with time can be seen (Figure 1B).

Using perMANOVA analysis, we determined average pasture composition differed in all years between the PB treatments and the SLG treatment, but not between the two PB treatments ($P < 0.05$). Although average pasture composition did vary with time, changes were not significantly different from 2017 to 2020 in the PB treatments (P < 0.05).

Using plant community data from 2020, we constructed an NMS ordination of time since fire in patch-burn grazing treatments (PBG) showing how plant communities vary with time since fire (Figure 2). Plant communities that were burned recently (0 and one year since fire) were more diverse when compared with previously burned plant communities (two and three years since fire), nonburned and SLG communities (Figure 2). Plant communities with increasing time since fire became more similar to SLG plant communities (Figure 2).

In the MTRR treatment, we found plant communities varied slightly with grazing use type, using data from 2020 (Figure 3). Of the four different use types in the MTRR treatment, the moderate use type communities were most similar to the SLG communities (Figure 3).

Diversity, richness and evenness of plant communities were all higher in the PB treatments within each year, compared with the SLG treatment (Figures 4A, 5 and 6). Although plant community measurements did not increase with time of treatment, we saw an increase in the difference between treatments with time (Figure 4B). Unlike diversity and evenness, richness of PBG treatments were slightly higher in 2020, compared with 2017, while SLG richness was similar in both years (Figure 5).

Table 1. USDA plant codes for common species encountered in this study and represented in Figures 1 and 7.

Plant Code	Scientific Name	Common Name
ACMI2	*Achillea millefolium*	common yarrow
AGCR	*Agropyron cristatum*	crested wheatgrass
AMPS	*Ambrosia psilostachya*	western ragweed
ANGE	*Andropogon gerardii*	big bluestem
ARLU	*Artemisia ludoviciana*	cudweed sagewort
ASOV	*Asclepias ovalifolia*	oval-leaf milkweed
ASSP	*Asclepias speciosa*	showy milkweed
ASSY	*Asclepias syriaca*	common milkweed
BOCU	*Bouteloua curtipendula*	sideoats grama
BOGR2	*Bouteloua gracilis*	blue grama
BRIN2	*Bromus inermis*	smooth brome
CALO	*Calamovilfa longifolia*	prairie sandreed
DIOLS	*Dichanthelium oligosanthes*	Scribner's rosette grass
GAAR	*Gaillardia aristata*	blanketflower
HECO8	*Hesperostipa comata*	needle and thread
LIIN2	*Lithospermum incisum*	narrowleaf stoneseed
MEOF	*Melilotus officinalis*	sweetclover
MURI	*Muhlenbergia richardsonis*	mat muhly
NAVI4	*Nassella viridula*	green needlegrass
OENU	*Oenothera nuttallii*	Nuttall's evening primrose
OLRI	*Oligoneuron rigidum*	stiff goldenrod
PASM	*Pascopyrum smithii*	western wheatgrass
POPR	*Poa pratensis*	Kentucky bluegrass
PRVI	*Prunus virginiana*	chokecherry
SCSC	*Schizachyrium scoparium*	little bluestem
SYOC	*Symphoricarpos occidentalis*	western snowberry

Biomass and Degree of Disappearance

In 2020, standing crop biomass for the SLG treatment averaged 4,120 pounds per acre (lbs/ac), while the PBG treatments ranged from 3,080 to 3,760 lbs/ac, increasing with time since fire (Table 2).

The degree of disappearance averaged 37% in the SLG treatment in 2020. The PBG degree of disappearance decreased with time since fire from an average of 75.3% in recently burned subpatches to 30.2% in the three-year post-fire subpatches (Figure 7). Subpatches that were burned two or three years ago experienced a slightly lower degree of disappearance than the average SLG degree of disappearance (Figure 7).

Discussion

The fire-grazing interaction has a dynamic effect on plant communities in grassland ecosystems (Fuhlendorf and Engle, 2004). With patch-burn grazing, we can see patterns developing in our plant communities according to time since fire and time exposed to the PBG treatment.

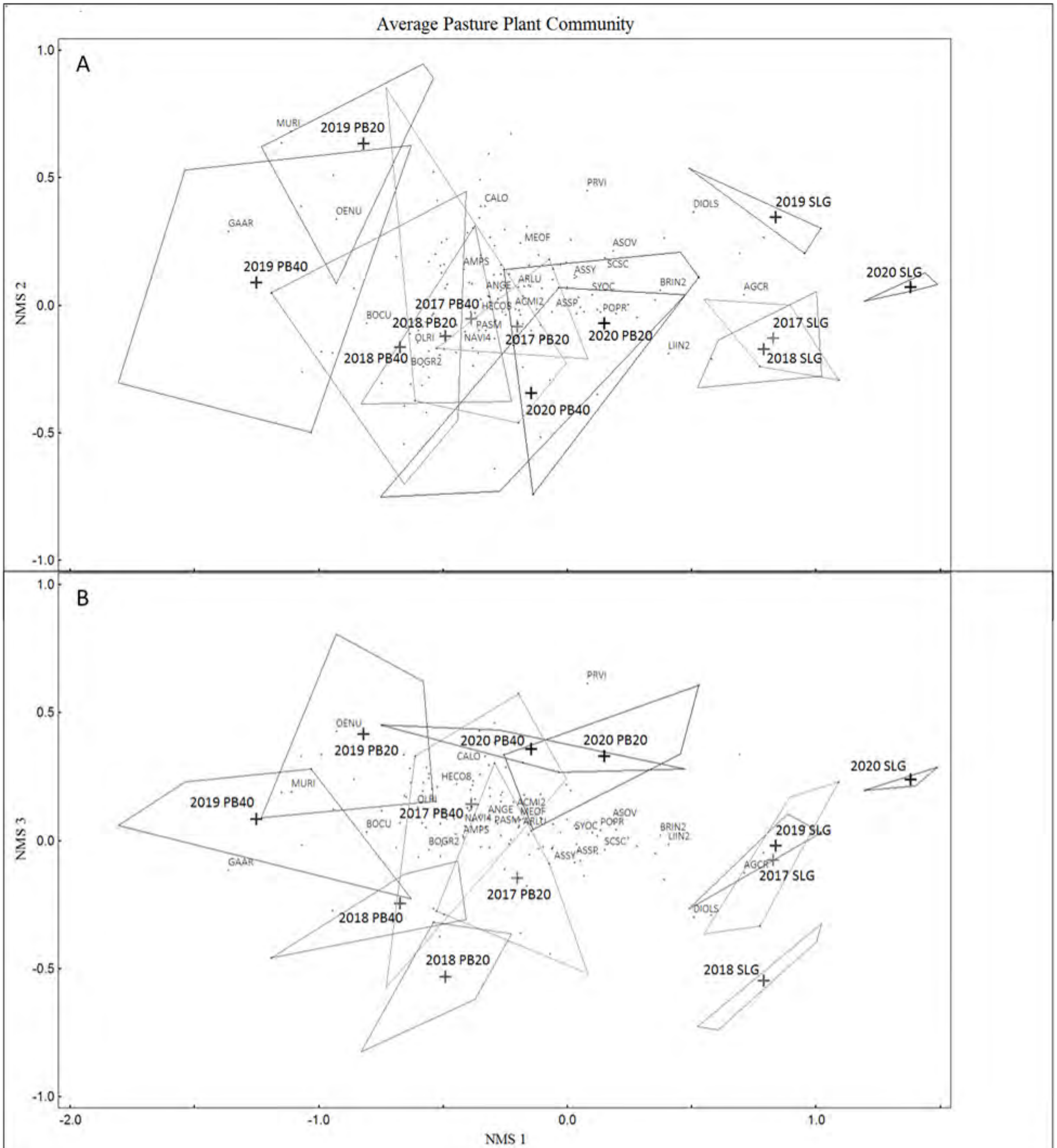

Figure 1. NMS ordination of plant community composition of species found across all years of the study. Polygons represent average pasture composition of patch-burn grazing 40-acre (PB40), patch-burn 20-acre (PB20) and season-long grazing (SLG) treatments from 2017 to 2020. Centroids of each polygon are represented by crosses. Points represent plant species denoted by USDA plant codes listed in Table 1. Axis 1 and 2 (A) and axis 1 and 3 (B) of the 3-dimensional ordination are plotted to visually represent spatial pattern within the ordination space of plant communities at the Central Grasslands Research Extension Center near Streeter, N.D.

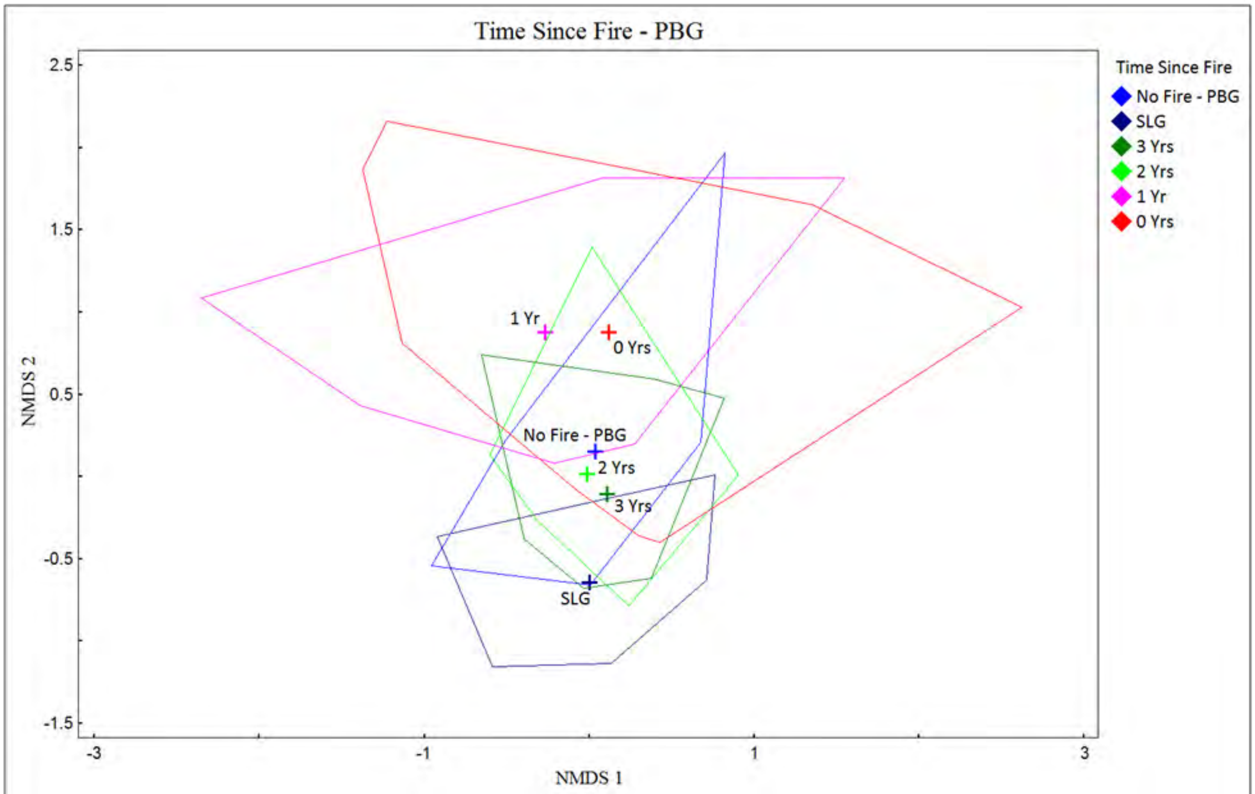

Figure 2. NMS ordination of plant community composition in 2020 arranged by time since fire intervals. Polygons represent average plant community composition of patches treated with season-long grazing (SLG), and patches within the patch-burn grazing system burned in 2017 (three years since fire), 2018 (two years), 2019 (one year) and 2020 (zero years). Patches within the patch-burn grazing treatment not subjected to fire are categorized as No Fire - PBG. Study conducted at the Central Grasslands Research Extension Center near Streeter, N.D. in 2020.

In our NMS ordinations, we observed that exposure to PBG not only shifts plant community compositions with time, but it also expands plant community composition, making them more diverse, while SLG communities contracted with time (Figure 1A and 2). Although SLG communities did shift with time in 2019 and 2020, this likely can be attributed to yearly difference in precipitation (Figure 1A).

In these NMS ordinations that plot treatment through years, average pasture composition of PBG treatments moved in a cycle toward its starting point in 2017. This likely can be attributed to difference in composition within the PBG pastures according time since fire. In two and three years since fire, plant communities will return to similar pre-fire conditions (Fuhlendorf and Engle, 2001).

In the final year of this study (2020), each PBG pasture had a mosaic of four patches with different time-since-fire intervals. Half of each pasture burned two or more years ago, with these patches resembling pre-fire conditions and nonburned plant communities of 2017 (Figure 1A & B).

This dynamic can be observed in data from 2020, where zero- and one-year-since-fire patches had more diverse composition than two- and three-years-since-fire patches, with two- and three-years-since-fire interval plant communities resembling nonburned communities and moving toward SLG communities (Figure 2). Zero- and one-year-since-fire communities also had higher diversity indices (2.32 and 2.40, respectively) than two- and three-years-since-fire communities (2.23 and 2.17, respectively) (Table 2), with two- and three-year indices resembling 2017 treatment indices (Figure 4A).

Although diversity of treatment by year did not show many clear trends, the differences between treatments by year does show a linear increase in diversity from year to year between PBG and SLG. Further study is needed to determine how plant community dynamics are affected by pyric-herbivory, and if these patterns of shifting plant communities continue with time in the northern mixed-grass prairie.

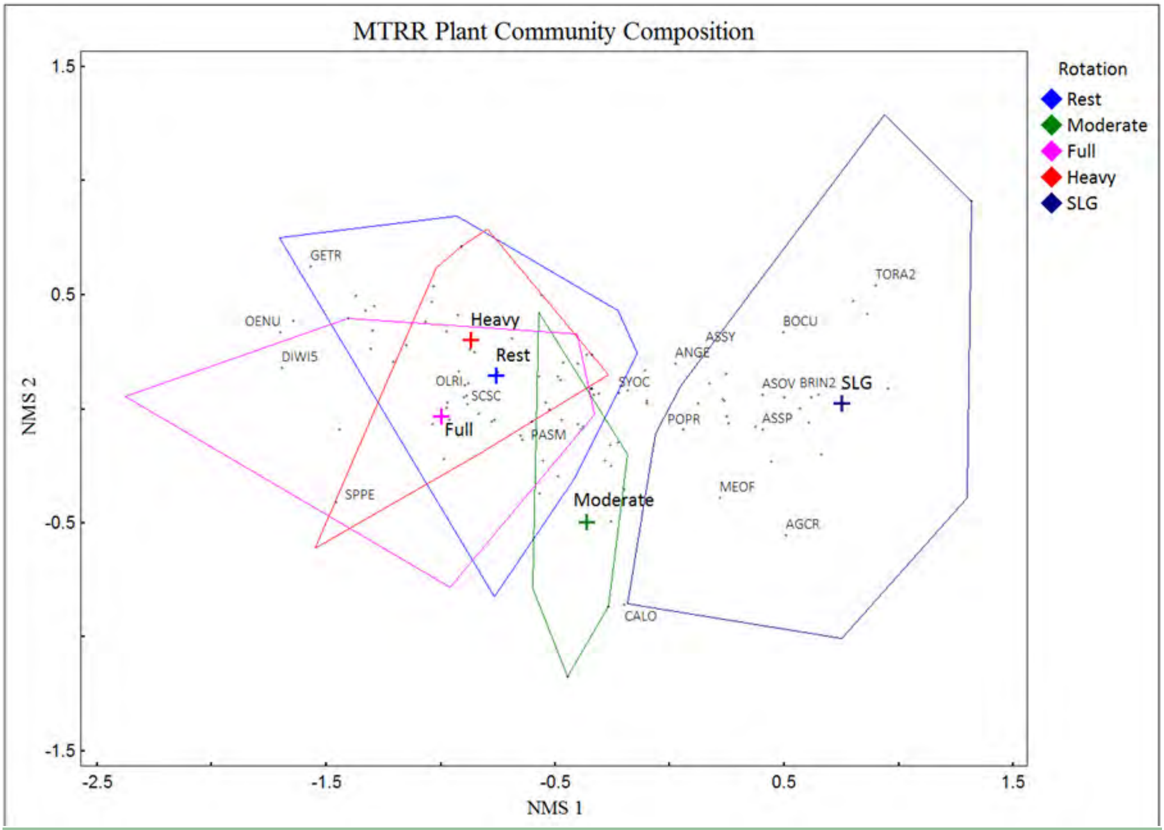

Figure 3. NMS ordination of plant community composition in 2020 of the modified twice-over rest rotation grazing treatment (MTRR) arranged by pasture use. Polygons represent average plant community composition of heavy-use pastures (Heavy), full-use pastures (Full), moderate-use pastures (Moderate) and rested pastures (Rest) within the MTRR treatment, compared to season-long grazing (SLG). Points represent different plant species, denoted by USDA plant codes listed in Table 1. Study conducted at the Central Grasslands Research Extension Center near Streeter, N.D. in 2020.

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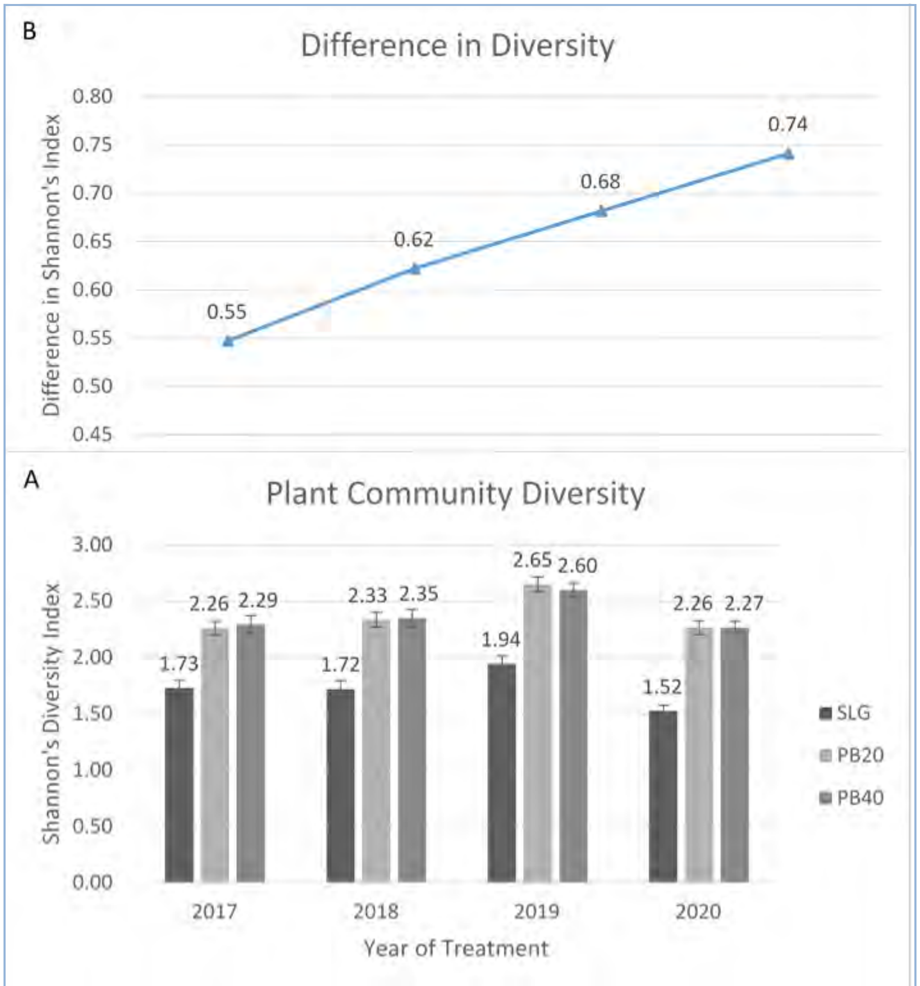

Figure 4 (A). Shannon-Weiner Diversity Index of treatments arranged by year (SLG = season-long grazing, PB20 = patch-burn grazing 20-acre and PB40 = patch-burn 40-acre). **(B)** Difference of Shannon Index between the average of patch-burn grazing treatments and the season-long grazing treatment in each year at the Central Grasslands Research Extension Center near Streeter, N.D. from 2017-2020.

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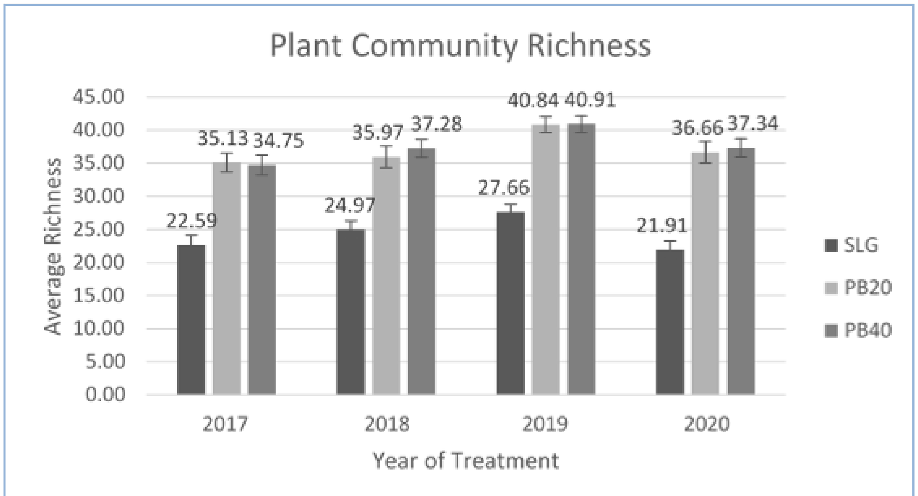

Figure 5. Plant community richness of each treatment arranged by year (SLG = season-long grazing, PB20 = patch-burn grazing 20-acre and PB40 = patch-burn grazing 40-acre) at the Central Grasslands Research Extension Center near Streeter, N.D. from 2017-2020.

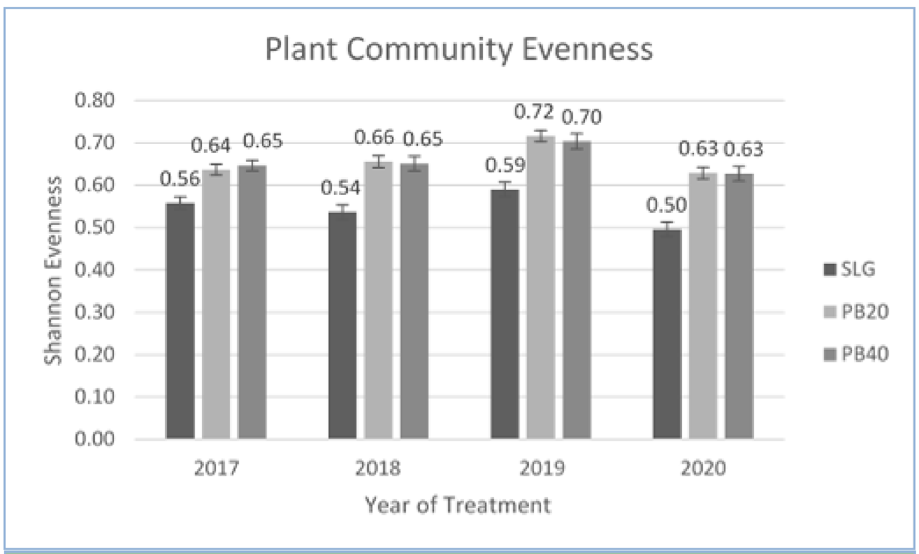

Figure 6. Plant community evenness of each treatment arranged by year (SLG = season-long grazing, PB20 = patch-burn grazing 20-acre and PB40 = patch-burn grazing 40-acre) at the Central Grasslands Research Extension Center near Streeter, N.D. from 2017-2020.

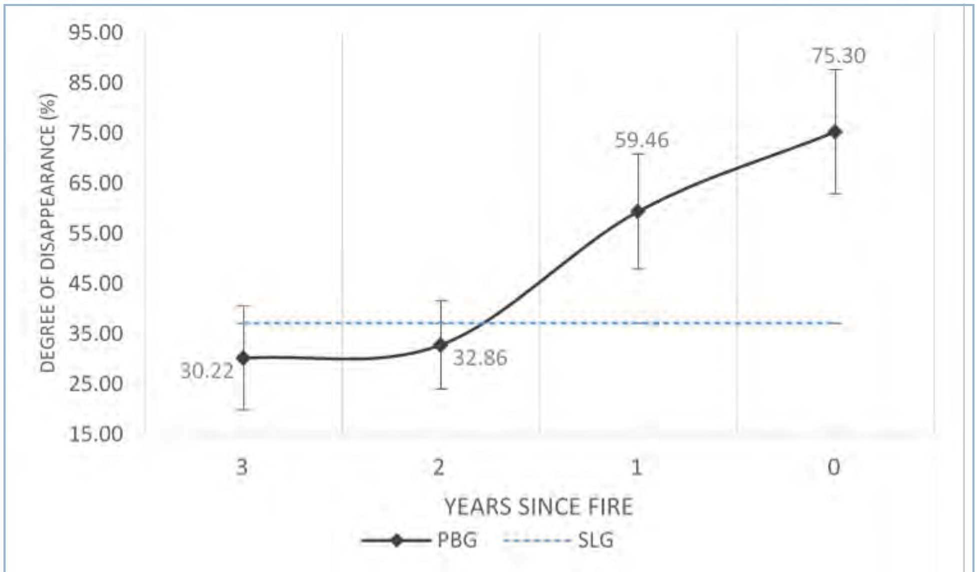

Figure 7. Average degree of disappearance of patches within patch-burn grazing treatments (PBG) arranged by time since fire with season-long grazing (SLG) degree of disappearance shown as a baseline. Study conducted at the Central Grasslands Research Extension Center near Streeter, N.D. in 2020.

Table 2. Mean effect of treatment on four plant community measurements, with patch-burn grazing and modified twice-over rest-rotation grazing split by years since fire and pasture use, respectively, at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020 (mean ± SE).

2020 Plant Community Measurements				
Treatment	**Diversity[1]**	**Richness**	**Evenness**	**Standing Crop Biomass (lbs/ac)**
Season Long Grazing	1.52 ± .52	21.9 ± 1.0	0.50 ± .01	4,120 ± 110
Patch-Burn Grazing Years Since Fire:				
0	2.32 ± 0.1	37.0 ± 2.1	0.64 ± .02	3,080 ± 140
1	2.40 ± .08	38.9 ± 1.8	0.66 ± .02	3,520 ± 180
2	2.23 ± .08	37.1 ± 1.2	0.62 ± .02	3,580 ± 150
3	2.17 ± .09	36.2 ± 2.2	0.61 ± .02	3,760 ± 140
Modified Twice-over Rest-rotation Grazing Pasture Use:				
Heavy	2.40 ± 0.07	38.4 ± 1.9	0.66 ± 0.01	n/a
Full	2.24 ± 0.12	37.6 ± 2.8	0.62 ± 0.02	n/a
Moderate	1.97 ± 0.08	34.0 ± 1.6	0.56 ± 0.02	n/a
Rest	2.31 ± 0.11	36.5 ± 3.1	0.65 ± 0.01	n/a

[1] Shannon-Wiener Diversity Index

Thatch Removal: A New Method for Managing Kentucky Bluegrass in the Northern Great Plains

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Summary

Kentucky bluegrass (Poa pratensis L.) engineers its environment to promote its success through the production of thatch, a tightly woven mat of roots, partially decomposed plant material, senesced stems and leaves, and live plants. Thatch suppresses the growth and establishment of native species through alterations in soil surface light availability and hydrology, posing a threat to grassland biodiversity and forage sustainability.

We conducted an experiment utilizing new methodology to remove Kentucky bluegrass thatch. We evaluated plant community composition in areas with historic thatch accumulation and in response to thatch removal using a skid-steer equipped with an angle broom attachment.

We found that thatch removal significantly reduced thatch depth and Kentucky bluegrass cover. Thatch removal also increased species evenness and diversity. This research provides insight about the effects of Kentucky bluegrass thatch on plant community composition and the role it plays in successful invasion.

Introduction

Inhibiting the expansion of invasive plant species worldwide is of great importance in an era of human-induced global change. Globally, invasion by one or two regionally non-native "ecosystem engineers" creates homogenous landscapes that no longer support historical biodiversity (Ehrenfeld, 2010; Richardson et al., 2000).

Ecosystem engineers utilize mechanisms to facilitate their spread and dominance while replacing local native species (Hobbs et al., 2006; Olden et al., 2004). Invasion by an ecosystem engineer triggers threshold development, and ecosystems can transition into an entirely new state where reversal to a pre-invaded condition may be difficult or impossible to achieve (Hobbs et al., 2006). Managing the spread of invasive species is of increasing importance to preserve ecosystem integrity, yet the effects of the mechanisms they utilize are not fully understood within a species- and scenario-specific context (Gong et al., 2020).

Kentucky bluegrass (*Poa pratensis* L.) is an ecosystem engineer whose dominance is facilitated by the presence of thatch, a tightly woven mat of roots, partially decomposed plant material, senesced stems and leaves, and live plants (Dornbusch et al., 2020; Ellis-Felege et al., 2013; Nouwakpo et al., 2019). Kentucky bluegrass (KBG) thatch reduces light availability and daily temperature fluctuations (Bosy and Reader, 1995; Gasch et al., 2019), the two primary mechanisms involved in germination cueing (Rice, 1985).

The ability of thatch to decrease light availability is the primary mechanism through which KBG suppresses the germination and growth of native species. Thatch also is associated with changes in soil surface hydrology (Gasch et al., 2019; Liang et al., 2017; Nouwakpo et al., 2019) and nutrient cycling (Chuan et al., 2020; Sanderson et al., 2017). These three mechanisms interact to create a positive feedback loop that favors the persistence of KBG while squandering the performance of native species.

KBG is a prolific invader in the Northern Great Plains (NGP). The temperate grasslands of the NGP historically were dominated by cool-season C_3 grasses (Toledo et al., 2014) and evolved with the interacting disturbances of periodic fire and grazing, processes which were altered upon European settlement (Fuhlendorf and Engle, 2001, 2004). Historic management practices, such as infrequent burning and grazing (Murphy and Grant, 2005; Printz and Hendrickson, 2015) or prolonged periods of rest (Kobiela et al., 2017), have further promoted homogeneity and increased the abundance of KBG (DeKeyser et al., 2013; Miles and Knops, 2009).

More recent management efforts aimed at controlling KBG spread, such as grazing, burning or chemical application, have mixed results. KBG's functional similarity as a C_3 grass makes it difficult to manage chemically without damaging the remaining native population (Kral et al., 2018). The location of KBG's apical meristems near the soil surface and below the thatch layer make it a grazing-tolerant grass (Hendrickson and Lund, 2010).

In addition, the tendency of thatch to hold excessive moisture also may decrease its susceptibility to fire as a viable management strategy (Czarniecka-Wiera et al., 2020; Kral et al., 2018). KBG invasion in the NGP provides an excellent example of an ecosystem engineer within the context of a human-modified landscape. New management strategies are required to address the creation of this novel ecosystem.

We propose that thatch is the primary mechanism utilized by KBG to facilitate its dominance. The goal of this research is to investigate the effects of removal of KBG thatch on a northern Great Plains grassland system.

Here we evaluate changes in plant community composition following removal of the thatch layer using an angle-broom attachment on a skid-steer for one growing season. Complete removal of the thatch layer in this way will provide insight about its role in KBG invasion and plant community composition, and will better inform future development of management methodologies aimed at preventing the spread of KBG.

Methods

Site Description

This experiment was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC). This center is positioned within the Missouri Coteau ecoregion, which is composed primarily of small glacial lakes and irregular rolling hills formed by the collapse of supraglacial sediment (U.S. Department of Agriculture - Soil Conservation Service [USDA-SCS], 1981).

The climate of the region is described as continental (USDA-SCS, 1981), with average temperatures ranging from minus 11 C in January to 21 C in July (North Dakota Agricultural Weather Network [NDAWN], 2020). Average annual precipitation is 407 millimeters, with 73% of the rainfall occurring between May and September, primarily during heavy thunderstorm events (NDAWN, 2020; USDA-SCS, 1981).

The vegetation of central North Dakota is typical of mixed-grass prairie, historically dominated by cool-season and warm-season native grasses such as green needlegrass (*Nasella viridula)*, western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*) and little bluestem (*Schizachyrium scoparium*), as well as a variety of sedges (*Carex* spp.) and forbs (Limb et al., 2018). Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), two non-native cool-season grasses, have come to dominate this region within the past half century and are responsible for many recent changes in biodiversity (Limb et al., 2018).

Experimental Design

We initiated a split-plot design in four approximately 16-hectare (ha) bluegrass-invaded pastures with two treatments (thatch removal and control), each replicated 10 times in April 2020. These pastures are part of a modified twice-over rest-rotation grazing system in which fencing is utilized to direct cattle distribution to increase habitat heterogeneity. For the purposes of this experiment, all four pastures will be subjected to the same grazing treatments each year across the three-year study period.

Plots are placed in one intensity grazing treatment only to reduce any potential grazing effects, and in pastures that were idle the previous year to maximize thatch cover and treatment effect. No other intentional treatments will be implemented in these plots during the study period.

Pastures were stocked with calf-cow pairs to achieve moderate use (20% to 40% disappearance of graminoid species) in 2020. A full-use grazing treatment (40% to 60% disappearance of graminoid species) will be used in 2021 and a heavy use treatment (60% to 80% disappearance of graminoid species) will be applied in 2022 (Table 1).

Table 1. Grazing treatments applied to the four pastures during the three-year period, with the number of grazing days utilized to achieve the respective degrees of disappearance.

Year	Grazing Treatment	Degree of Disappearance	Grazing Days
2020	Moderate use	20%-40%	54
2021	Full use	40%-60%	108
2022	Heavy use	60%-80%	155

To investigate the effects of thatch removal, a paired design with stratified random sampling was employed. Prior to treatment initiation, a visual survey of all four pastures was conducted to determine areas that were dominated by KBG and contained thick layers of thatch (100% litter cover). Areas of interest were dominated by grasses and still had some native vegetation component.

Ten 10- by 20-meter (m) plots then were placed in areas that had minimal topographical and vegetative variation. Each plot was further divided into two 10- by 10-m plots, which were assigned randomly to one of two treatments: thatch removal or control.

Edge effects were reduced by nesting a 5- by 5-m sampling plot within each treatment plot, creating a 2.5-m buffer zone around the measurement area (Figure 1). This size was chosen to be large enough to capture a plant community (Dornbusch et al., 2020), yet small enough to avoid attracting grazers.

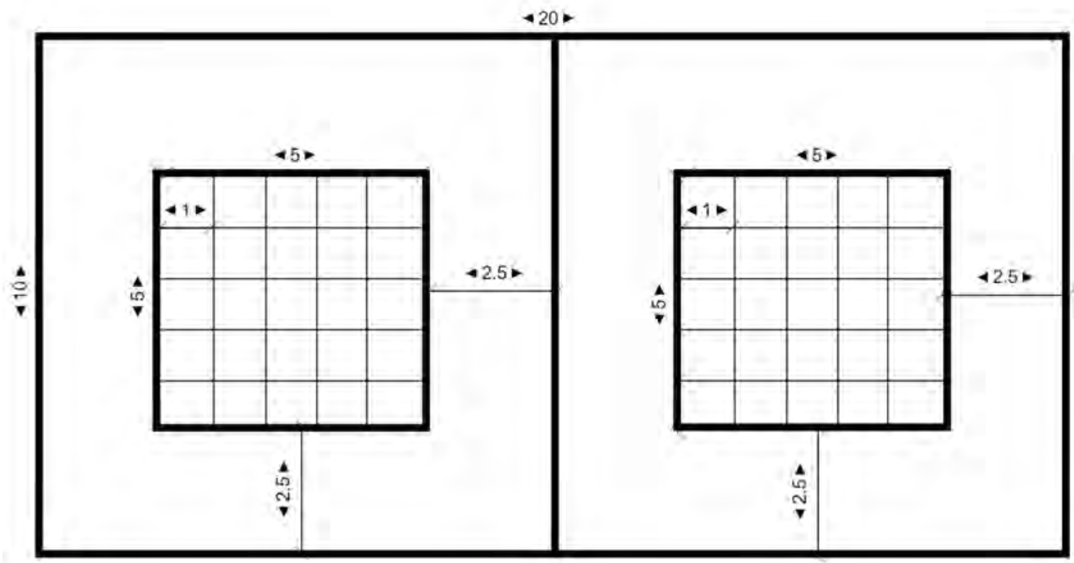

Figure 1. 10- by 20-m split-plot design, with each 10 m^2 half randomly assigned to treatment or control. For vegetation sampling, 25 m^2 plots are nested within each half and further gridded into the 1 m^2 subsamples utilized for Daubenmire cover class collection.

Thatch removal treatment was applied on May 20-21, 2020, using an 82-inch Titan Implement X-treme Skid-Steer Angle Broom Attachment connected to a SSV75 Kubota Skid-Steer (Figure 2a). Each treatment plot was brushed until the root-mat layer was clearly visible (Figure 2b).

Figure 2a. 82-inch Titan Implement X-treme Skid-Steer Angle Broom Attachment connected to a SSV75 Kubota Skid-Steer.

Figure 2b. Result of thatch removal split-plot, with thatch removal treatment on the left and control treatment on the right.

Photos by Hayley Hilfer

Data Collection and Analysis

Plant community composition data was collected the first two weeks in July during the peak growing season and will continue in 2021. Identification and canopy cover of each species of the entire 25 m^2 sampling plot was recorded within 1- by 1-m^2 frames using a modified Daubenmire cover class system (1 = trace-1%, 2 = 1%-2%, 3 = 2%-5%, 4 = 5%-10%, 5 = 10%-20%, 6 = 20%-30%, 7 = 30%-40%, 8 = 40%-50%, 9 = 50%-60%, 10 = 60%-70%, 11 = 70%-80%, 12 = 80%-90%, 13 = 90%-95%, 14 = 95%-98%, 15 = 98%-99%, 16 = 99%-100%) (Daubenmire, 1959).

All values were converted to midpoints and averaged across the 25 subsamples in each plot. Plant species richness, evenness and Simpson's diversity index were calculated using PC-ORD 7.0.

The effectiveness of the thatch removal treatment was determined by measuring thatch layer depth in the buffer zone of each treatment plot. Litter depth was measured at 10 locations within the buffer zones of each treatment plot in the week following treatment initiation.

A sod hole cutter with a 4.25-inch diameter was used at each location to remove a sample down to bare soil. The depth of the root mat and decomposing material was measured with a ruler. These measurements were combined for total depth and averaged within treatment and control plots for analysis. Additional depth measurements will be collected in May of the following years to assess changes in depth through time.

Data Analysis

The treatment effect was assessed by creating a distance matrix in PC-ORD 7.0 and comparing the similarity values for each treatment-control pair. The statistical analysis of plant community metrics (richness, evenness and diversity) consisted of the mean difference between treatment and control values.

We utilized one-tailed t-tests with a specified value of zero to investigate how univariate data responded to thatch-removal (SPSS Version 27; IBM Corp., 2020). Results were considered significant at $p \leq 0.05$.

Results

In the first year of our experiment, thatch removal treatment significantly reduced thatch depth by an average of 9.16 centimeters. We identified a total of 88 plant species across all plots in 2020, with an average of 30 species across all 10 plots.

The difference between treatment and control plots indicated a significant reduction in KBG cover (Figure 3). No effect of treatment ($p > 0.05$) was observed in smooth brome and native grass cover, with a slightly positive trend found in native forb cover ($p = 0.17$). Evenness and Simpson's diversity increased ($p \leq 0.05$) with thatch removal (Figure 4).

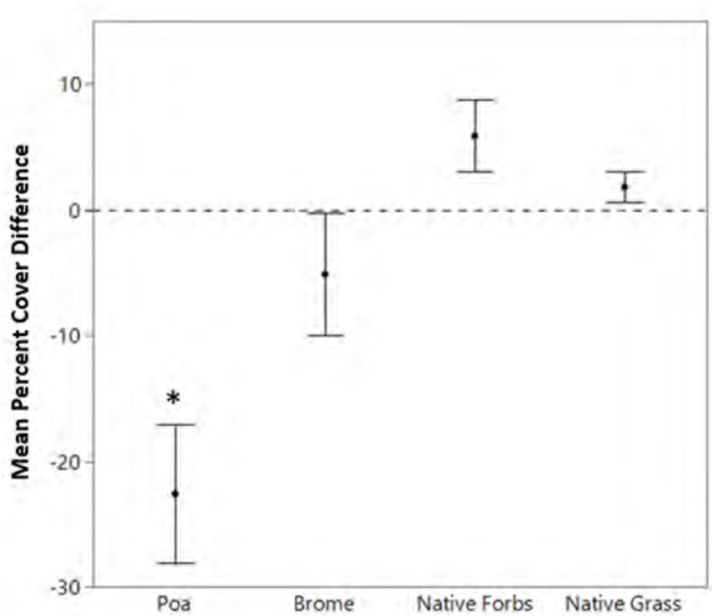

Figure 3. Mean percent cover differences due to thatch removal of Kentucky bluegrass (Poa), smooth brome (Brome), native forbs and native grasses between paired treatment and control plots (n = 10) in 2020. No difference between treatment and control is represented by the dashed line. The asterisk represents a statistical difference from the control plot average ($p < 0.05$). Error bars represent standard error of the mean.

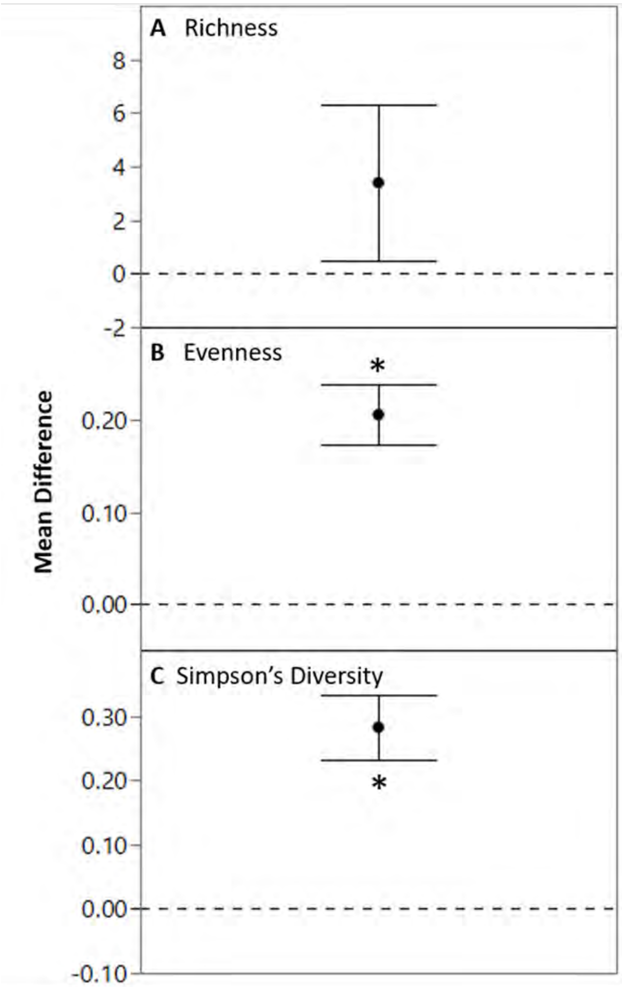

Figure 4. Mean differences due to thatch removal between paired treatment and control plots in plant species richness (A), evenness (B) and Simpson's diversity index (C) in 2020 (n = 10). No difference between treatment and control is represented by the dashed line. Asterisks represent a statistical difference from the control plot average ($p < 0.05$). Error bars represent standard error of the mean.

Discussion

Our data show significant differences in thatch depth and KBG cover immediately following treatment initiation. Alternative management strategies, such as alternative grazing management and burning, have proven successful at preventing increases in KBG cover but unsuccessful at producing any meaningful declines through time (Dornbusch et al., 2020; Kobiela et al., 2017).

The nature of our methodology specifically targets the thatch layer and likely disrupts the positive feedback loop to a greater extent than these strategies. Although performance of native species did not improve within the first year, we saw a slightly positive increase in native forb performance.

We also observed significant increases in species evenness and Simpson's diversity, indicating that removal of the thatch layer provided adequate conditions for improved performance of already established species. Data collection one-year post-treatment application may provide more time for the establishment of newly dispersed species or allow those already present in the seedbank to respond to the new environmental conditions (Bosy and Reader, 1995; Molinari and D'Antonio, 2020; Nouwakpo et al., 2019).

The consequences of KBG in the northern Great Plains are severe, with impacts on local biodiversity eventually impacting ecosystem services such as pollinator populations and livestock forage production (Toledo et al., 2014). KBG has been found to have poor digestibility overall and tends to go dormant quickly during the hot, dry summers typical of the NGP (Hockensmith et al., 1997; Toledo et al., 2014).

Higher species richness produces increased forage quality (French, 2017) and greater forage resistance to environmental stress. The propensity of KBG to create monocultures not only creates vast areas of poor forage, but also reduces forage sustainability. We anticipate that the outcomes of this species- and scenario-specific research will better inform management decisions directed at the reduction of KBG and foster the development of new methodologies targeted at reducing the spread of ecosystem engineers more broadly.

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Photo by Caley Gasch

Quantifying the Role of Shelterbelts (Tree Plantings) as Early-season Resources for Honey Production and Hive Growth of Managed Honeybees

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Summary

We are evaluating the use of shelterbelts as early season foraging resources for managed honeybee (<u>Apis</u> <u>mellifera</u>) hives. We monitored 48 hives at 24 sites with varying distance to and composition of shelterbelts between May and September 2020. Here we present preliminary results from the first year.

Introduction

Globally, native and managed pollinators are experiencing broad-scale population declines, causing a reduction in available pollination services (National Research Council et al., 2007; Potts et al., 2010). Pollinators, however, are extremely important for humans economically and for global food security (Gallai et al., 2009; Klein et al., 2006; Potts et al., 2010).

The European honeybee (*Apis mellifera*) is the primary commercial pollinator in North America and the most widely used and managed pollinator in the world. Since the mid-1900s, the U.S. Department of Agriculture has tracked and documented an overall decline in managed honeybee hives (National Research Council et al., 2007).

Similar to declines in other pollinators, factors including parasites, pests and pathogens interact, weakening populations (National Research Council et al., 2007; Potts et al., 2010). The declining population is unable to keep up with the demand for their pollination services (Aizen and Harder, 2009; Delaplane and Mayer, 2000; Kearns et al., 1998; McGregor, 1976).

In the U.S., honeybee pollination is estimated to be valued between $15 billion and $18.9 billion annually (National Research Council et al., 2007). In 2019 alone, 157 million pounds of honey were produced with a value of more than $309 million (U.S. Department of Agriculture, National Agricultural Statistics Service, 2020).

In addition to their importance throughout the U.S., honeybees are an important species for the northern Great Plains (NGP) region. After a mass transport of honeybee hives back to the region in early spring, the NGP hosts about 1 million honeybee hives and leads the country in honey production. Therefore, honeybee declines are of particular concern for the region (Otto et al., 2016; U.S. Department of Agriculture, National Agricultural Statistics Service, 2020).

Increasingly, land-use changes reduce forage availability for honeybees throughout the year and influence their survivorship (Smart et al., 2016). These changes limit forage and nutrient diversity necessary for honeybee survival and hive growth (Smart et al., 2016).

One potential solution to lessen future declines in honeybees is to promote forage diversity specifically at times when it is lacking (Decourtye et al., 2010; Dolezal et al., 2019). Early spring floral resources often are limited in grasslands, and flowering trees and shrubs could fill this niche and provide crucial resources in a time of need.

Around the world, trees and shrubs have been highly documented as important honeybee resources, especially during the spring (Brodschneider et al., 2019; Couvillon et al., 2014; Lau et al., 2019; Sponsler et al., 2020). Tree and shrub plantings in the NGP are commonly known as shelterbelts and were planted as windbreaks and to provide soil stability, as well as numerous services for human use (Gardner, 2009; Johnson and Beck, 1988).

The goal of our study is to determine if early flowering trees and shrubs planted in the NGP provide essential resources to fill early season forage gaps for honeybees. Specifically, our main objectives are: 1) identify tree species found in North Dakota shelterbelts that are used by honeybees and 2) quantify the relationship between honeybee hive growth and shelterbelt cover across varying spatial scales.

Study Area

This study took place near the Hettinger Research Extension Center (HREC) near Hettinger, N.D., in Adams County, and the Central Grasslands Research

Extension Center (CGREC) near Streeter, N.D., in Stutsman and Kidder counties. On average, annual temperatures are 43.5 F at the HREC and 41.3 F at the CGREC, with respective annual precipitations of 17.08 inches and 18.40 inches (Arguez et al., 2010).

Both regions are highly influenced by agriculture. In 2019, the leading land/crop categories in the three counties surrounding the centers were grass/pasture, spring wheat, soybeans and corn (U.S. Department of Agriculture, National Agricultural Statistics Service, 2019).

Honey producers and their relative apiary densities in the surrounding counties are high. Adams County has eight registered apiaries per 10,000 hectares (ha), with 13 per 10,000 ha in Stutsman County and 11 per 10,000 ha in Kidder (Otto et al., 2016).

Both regions contain shelterbelts that feature various deciduous and coniferous tree and shrub species. Shelterbelt tree species regularly include eastern cottonwood (*Populus deltoides*), elm (*Ulmus* spp.), Russian olive (*Elaeagnus angustifolia*), boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*) and various conifers. Common lilac (*Syringa vulgaris*) and common caragana (*Caragana arborescens*) also are frequently planted shelterbelt shrubs (Van Enk et al., 1980).

Methods

Site Selection

Honeybees may travel a range of distances to forage. Therefore, to test the use of shelterbelts as forage resources, we chose sites in western (HREC) and central (CGREC) North Dakota that varied in nearby tree cover densities at various distances (250 meters [m], 500 m, 1 kilometer [km], 2 km, 2.5 km and 3 km) around hives.

Using North Dakota Forest Service-mapped tree cover data, we chose sites in each region to fill a gradient of tree cover densities (high-low). We selected sites with a majority of anthropogenically planted tree and shrub cover to avoid largely natural tree cover associated with waterways.

Vegetation Surveys

We mapped all tree rows (clusters of more than two individual plants of typically one tree or shrub species) that fell within a one-mile radius of the apiary. Mapping included species types, individual counts and geographic locations.

Following site mapping, we conducted weekly drive-by surveys throughout the season at each site. During weekly drive-bys, we categorized tree and shrub rows by average floral resource percent of flowering categories (adopted from Brereton et al., 2004). We compiled these data to document species phenology by region and to record nearby tree and shrub composition.

Hive Scales

Using two hive scales per site (Solutionbee LLC, Raleigh, N.C.), we measured hourly hive weights. These weights are used as a proxy for hive growth and an index of honey production (McLellan, 1977). We uploaded and adjusted weights to account for anthropogenic weight gains or losses (adding or removing honeybee supers by beekeepers) to plot hive weight through time.

Pollen Traps and Pollen Collection

To gauge transitions in pollen foraging throughout the field season, we also equipped each site with two pollen traps to collect samples of corbicula pollen from returning bees (Smart et al., 2017b). Pollen traps consisted of two entrances, one that directed bees straight to the hive and one that brushed pollen off entering honeybees.

Weekly, we collected pollen from devices placed on each hive. We then placed collected pollen into labeled storage bags and froze the samples. As most tree species finished flowering (mid-July), we transitioned to a 72-hour every other week pollen trap opening period schedule. We collected and stored this pollen in the same way as previous pollen samples.

To prepare pollen samples, we cleaned, dried and ground 10 grams of each sample into a homogenized powder. Following pollen processing, we will send samples to a lab for floral species identification (Smart et al., 2017a).

Species composition within each sample will help us better understand weekly honeybee foraging habits. We later will compare these pollen sample species compositions with vegetation surveys to understand honeybee floral preference.

Results

During the 2020 field season (May-September), we monitored 48 hives at a total of 24 unique sites (apiaries) in North Dakota. That was 15 sites in the western region and nine sites in central North Dakota.

Hive Weights

Throughout the season, most hives showed similar overall weight change trends (Figure 1). Most hive

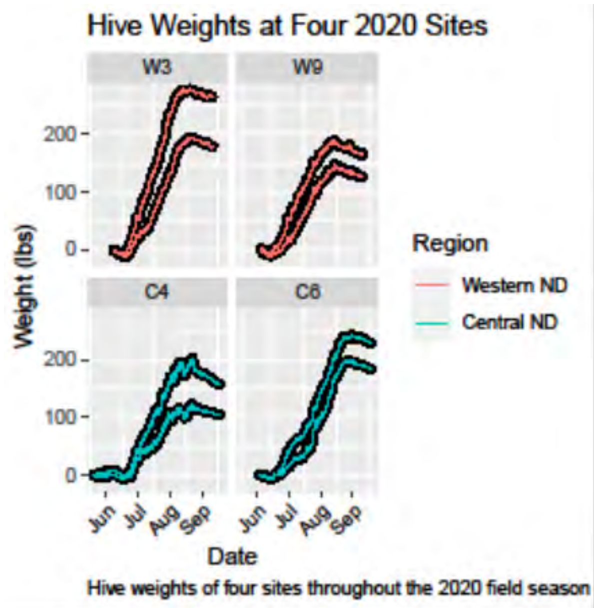

Figure 1. Individual graphs depict hive weights of two hives throughout the 2020 field season (May-September) at four of 24 total sites (two in western and two in central North Dakota). We collected hive weights by equipping honeybee hives with hive scales.

scales documented little weight change between May and July, large daily weight gains between July and mid-August and a slight overall weight loss following a mid-August peak. Figure 1 provides an example of these seasonal hive weight trends at four 2020 sites.

Our two hives at each site often differed in their hive weights throughout the season, with the overall net weight gain varying by hive. Six hives (three per region) had a net loss and five hives had net gains of more than 200 pounds.

Pollen Samples

Pollen samples are in the processing stage and will be analyzed and compared with vegetation surveys in the future.

Discussion

Hive Weight Analysis

Similar seasonal weight trends have been documented in previous NGP literature (Smart et al., 2017b). These overall hive weight trends are connected to photoperiod (daily light period), forage phenology and forage availability throughout the seasons (Couvillon et al., 2014).

Differences in hive weights may be attributed to the age and reproductive fitness of the hive's queen. A queen's age and physical characteristics affect her egg-laying capabilities (Tarpy et al., 1999). Discrepancies in these queen characteristics between hives may contribute to differences in hive composition and available foraging worker bees.

Worker bees forage for nectar and pollen, adding to the overall hive weight by themselves and from the resources they collect (Winston, 1987). A greater number of worker bees may allow some hives to gain weight faster than other hives at the same site, and hives may gain weight at different paces throughout the season.

Future Analysis

Hive weights will be analyzed further to compare tree cover surrounding sites with hive weight change throughout the season. We expect results to show hives near high-density and diverse tree plantings to display significant weight gain trends through time relative to hives in apiaries further from tree plantings.

Additionally, pollen samples will be analyzed further. Following pollen species analysis, we will compare species results with mapped tree cover at each site to understand if honeybees foraged on nearby trees and shrubs. We expect our pollen samples to show that honeybees are foraging on flowering trees and shrubs within nearby shelterbelts.

Challenges

Due to 2020 being the first field season of this study and the nature of the past year, some challenges arose during the 2020 field season. Challenges associated with the timing of data collection and equipment placement restricted the amount of data collected and site selection choices. These issues should not prohibit data collection in the coming seasons.

Conclusions

Our results will explain trends in honeybee hive health and honey production across a gradient of landscapes, which will help influence future apiary management in landscapes with limited early season forage resources.

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Bee research, NDSU photo gallery

Impacts of Patch-burn, Rotational and Continuous Grazing on Livestock Performance and Conception Rates on Kentucky Bluegrass-invaded Mixed-grass Prairie

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Introduction

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 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 concentrate 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, 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 started in 2017 and was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota (lat 46°46’N, long 99°28’W). As part of the North Dakota State Agriculture Experiment Station, the CGREC’s mission is to extend scientific research and Extension programming to the surrounding rural communities. It consists of 2,160 hectares (ha) 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 situated in the Missouri Coteau ecoregion of the northern Great Plains, which occupies 125 million hectares, of which approximately 40% is perennial rangeland grazed by livestock.

Irregular, rolling, rocky plains and depressional wetlands characterize the Missouri Coteau ecoregion. The climate is characterized as temperate and experiences an average yearly rainfall of 40.3 centimeters (cm) (Limb et al., 2018).

Vegetation at the 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 (*Poa pratensis* L.), and includes a diverse forb community that should support a diverse pollinator community.

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 for 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 grazing 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 (PBG1) with one season of burn, (b) patch-burn grazing (PBG2) with two seasons of burn, (c) modified twice-over rest rotation grazing (MTRG) and (d) season-long grazing (SLG).

(a) Patch-burn grazing (PBG1) - one season of burn is a management framework that is intended to mimic historic disturbance regimes where focal grazing occurs on recently burned areas while lightly grazed areas allow for accumulation of plant biomass (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 (approximately 65 ha each) are divided into four relatively equal-size patches (approximately 16 ha each), with one of the four patches being burned each spring. This four-year fire return interval is designed to mimic the historical disturbance regime of mixed-grass prairie.

(b) Patch-burn grazing (PBG2) - two seasons of burn. The season of burning 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 subpatch equal to one-eighth of a pasture, approximately 8 ha) is burned in the spring (same timing as PBG1) and the other subpatch 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 grazing unit. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilizes fencing to dictate cattle distribution and influence grazing. The grazing unit is divided into four relative equal subpastures using cross-fences and grazed with one herd of cattle, grazing one pasture at a time from mid-May to late October. Cattle are rotated through each subpasture twice for a total of 155 days, a total of 74, 54, 27 and zero days the heavy use (60% to 80% disappearance), full use (40% to 60% disappearance), moderate use (20% to 40% disappearance) and rested subpastures, respectively. The first rotation uses 40% of the grazing days and the second rotation uses 60% of the available grazing days.

In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, the heavy-use pasture will transition to the rested pasture, the rested pasture to the moderate use and the moderate use to the full use. This rotation will create annual heavy disturbance in one subpasture and reduce annual heavy disturbance in the same location that 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 fairly typical management approach in this area and it serves as an important comparison because it homogeneously applies the disturbance (grazing) throughout the entire pasture. Thus, it is expected to lack the heterogeneity and structure of other treatments, and therefore not benefit biodiversity.

Common among the PBG1, PBG2 and SLG treatments, cow-calf pairs graze within pastures from mid-May to late October each year at a full-use stocking rate (1.01 animal unit months/acre) in all treatments designed to achieve an average 40% to 50% degree of disappearance across the pasture. The MTRG also was stocked at an average 1.01 animal unit months/acre across a four-cycle, 1.27 animal unit months/acre/year. 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 uses 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 (U.S. Department of Agriculture-NRCS, 2018).

Vegetation quadrat samples of 0.25 meters $(m)^2$ were used to determine the cover of native and introduced grasses and forbs. We also measured heights of vegetation, litter and thatch layers using 10 quadrats per survey set.

To determine herbage production and degree of disappearance, three 0.25 m^2 plots were caged and paired with three uncaged plots at each monitoring location (six 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 late July, two new plots were picked to match each of the original uncaged plots and the original plots and clipped using the 0.25 m^2 quadrats.

One of each pair of new plots was caged and at the end of the grazing period the herbage from each remaining plot were clipped. Herbage production clipped from inside caged plots at peak growing season provided an estimate of peak biomass.

The difference 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 the peak. Samples were 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 using an average of two-day body weights. We quantified cow and calf performance by calculating daily weight gain of the calf and cow. This was determined by subtracting the average two-day weight at the beginning of the grazing season from the two-day weight at the end of the grazing season, then dividing by grazing days (about 155 days).

Results

Vegetation Degree of Disappearance

The degree of disappearance on the PBG treatments varies across the pasture based on timing of fire. The degree of disappearance ranged from 30.2% on the burn patches that were three-year post-fire to 75.3% on the new burns (Figure 1). Fairly high levels of disappearance occurred on the one-year post-fire sites at 59.5%. If all burn patches were similar in size, the average degree of disappearance on the PBG treatments would be 49.5%.

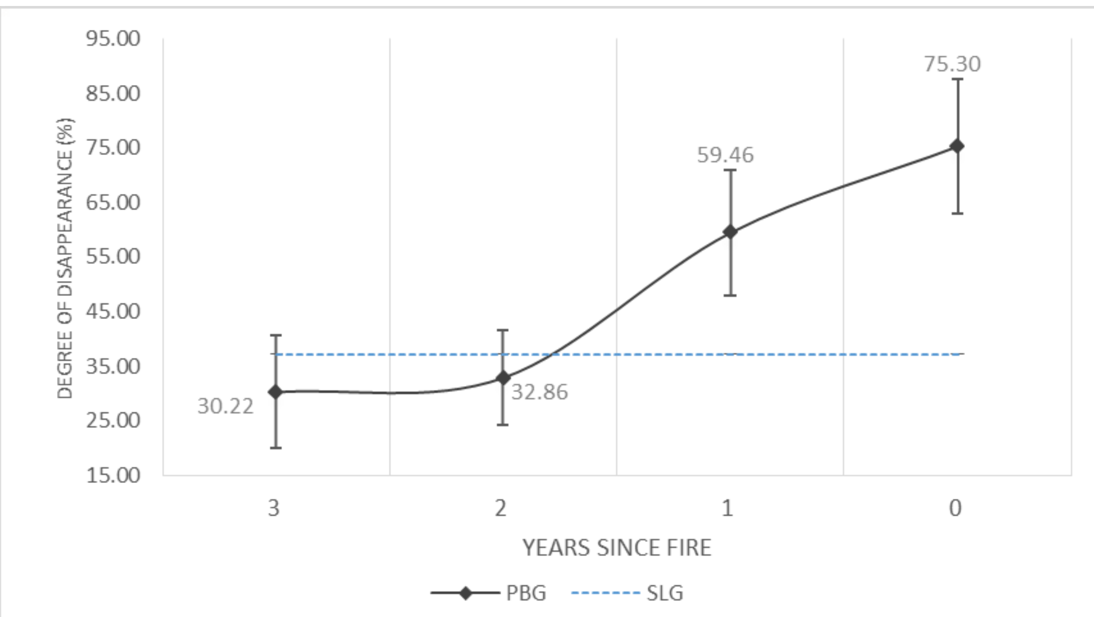

Figure 1. Average degree of vegetation disappearance of patches within patch-burn grazing treatments (PBG) arranged by time since fire, with season-long grazing (SLG) degree of disappearance shown as a baseline, at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

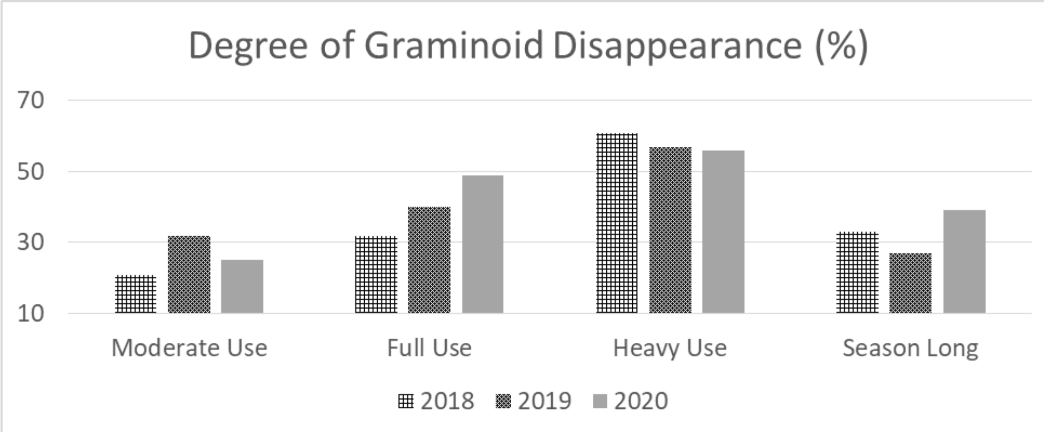

Figure 2. Degree of graminoid disappearance on the modified twice-over rotation and season-long treatments at the Central Grasslands Research Extension Center near Streeter, N.D.

The overall goal is to achieve an average degree of disappearance of 40% to 60% on the PBG, SLG and full-use pasture of the MTRG. We did meet this objective on the PBG and two years of the MTRG treatments but were slightly below the objective on SLG treatment during the four years at 37.2%.

The degree of disappearance of graminoid (grasses and sedges) on the modified twice-over rotation treatment was 21%, 32% and 61% in the moderate-, full- and heavy-use pastures in 2018, respectively (Figure 2). The degree of disappearance of graminoids was 32%, 40% and 59% in the moderate-, full- and heavy-use pastures in 2019, respectively.

The degree of disappearance of graminoids was 26%, 49% and 56% in the moderate-, full- and heavy-use pastures in 2020, respectively. Our full-use pasture was stocked to create a similar degree of disappearance as the SLG treatment, which averaged 33%, 27% and 39% in 2018, 2019 and 2020, respectively.

The 2018 and 2019 growing season precipitation was 127% and 136% of average, respectively (North Dakota Agricultural Weather Network, 2020). This additional precipitation resulted in higher than expected vegetation growth; thus, the degree of disappearance was below the targeted level.

In 2020, however, we were closer to achieving the desired degree on disappearance. We increased

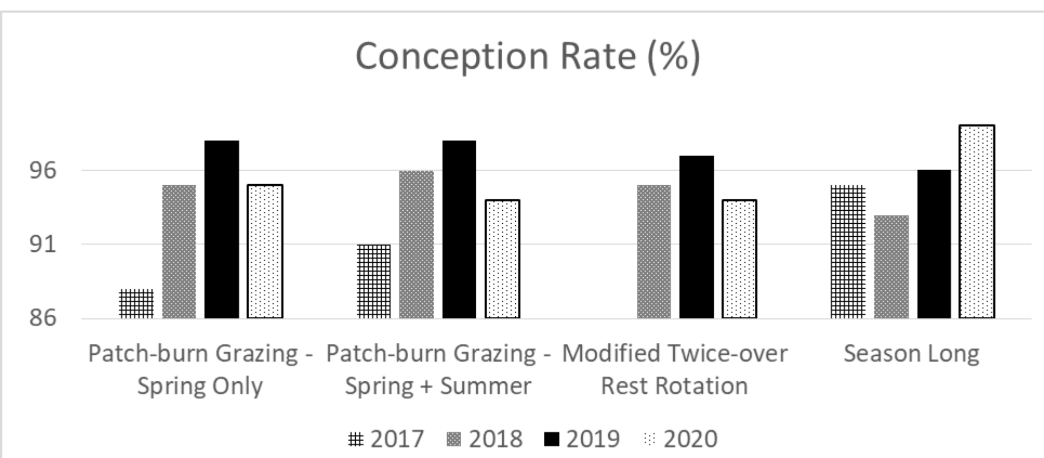

Figure 3. Conception rates of cows bred on pasture by grazing treatment at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017 to 2020.

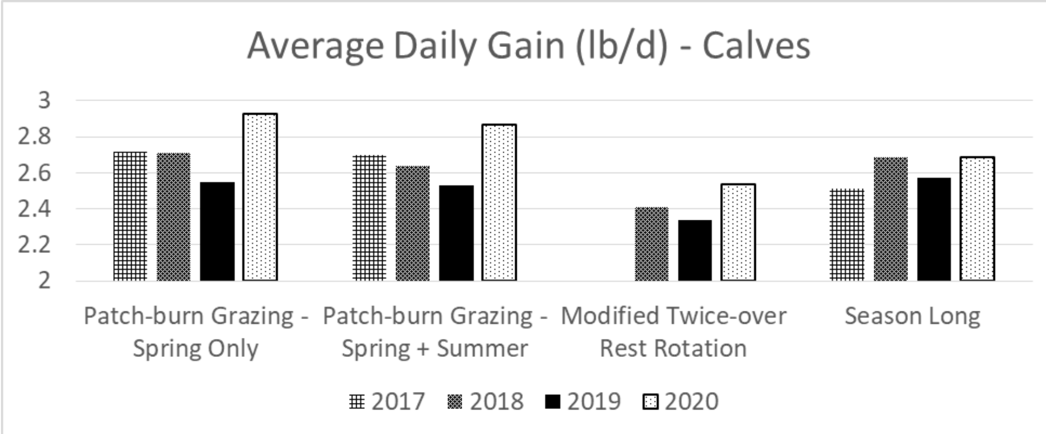

Figure 4. Calf average daily gain (pounds/day) by treatment at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017to 2020.

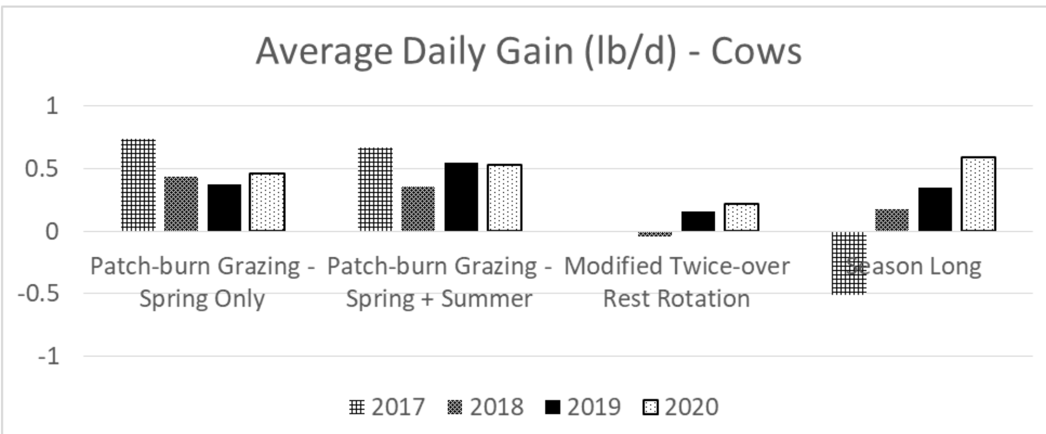

Figure 5. Cow average daily gain (pounds/day) by grazing treatment at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017 to 2020.

animal numbers on the SLG treatment, adjusted grazing days on the MTRG and had a drought during the growing season, with only 58% of average rainfall.

Livestock Reproduction and Performance

The percent of bred cows was similar ($P > 0.05$) among treatments in all years of the study, ranging from 88% to 96% in 2017, 92% to 96% in 2018, 94% to 99% in 2019 and 94% to 96% in 2020, (Figure 3). On average, conception rates were 94%, 95%, 95% and 96% for the PBG1, PBG2, MTRG and SLG, respectively.

Calf performance, in terms of average daily gain, was similar ($P > 0.05$) among treatments in all four years (Figure 4). On average, calf average daily gain (pounds/day) was 2.72, 2.69, 2.43 and 2.62 on the PBG1, PBG2, MTRG and SLG, respectively.

Cow performance, in terms of average daily gain, was greatest ($P < 0.05$) on the PBG1 and PBG2 treatments in 2017, compared with the SLG (Figure 5). That year, the PBG treatments had positive average daily gains (0.72 and 0.67 pound/day), compared with cows losing weight on the SLG treatment (minus 0.51 pound/day).

In 2018, daily gains were higher ($P \leq 0.05$) on the PBG1 and PBG2 than the MTRG and SLG. Daily gains on the PBG1, PBG2 and SLG were different ($P \leq 0.05$) from the MTRG in 2018 and 2019 when compared with zero gain. We found no difference between treatments in cow performance in 2020.

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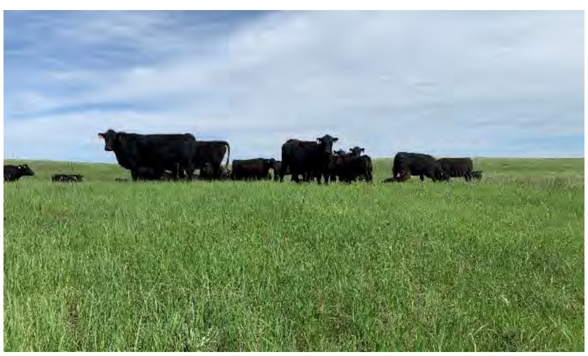

Photos by Megan Wanchuk and Kevin Sedivec

How Does a Grazing System Work? Above-ground Cumulative Production and Growth Efficiency with a Modified Twice-over Rest-rotation Treatment

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Summary

Above-ground cumulative production accounts for any additional plant growth that occurs from regrowth following a grazing event plus growth consumed by the animal during the grazing event.

Rotational grazing with a recovery period of 33 days from grazing between the first rotation and second rotation of the modified twice-over rest-rotation treatment (MTRR) increased the aboveground cumulative production and growth efficiency. On the heavy-use subpasture, cumulative production increased by 51.8%, 66.6% and 35.5% on the loamy and 50%, 54.3% and 47.9% on the shallow loamy ecological sites, compared with peak production from the nonuse exclosures in 2018, 2019 and 2020, respectively. The overall degree of disappearance was at 64.9%, 57.2% and 56.2% for those years, respectively.

On the full-use subpasture, we had an increased above-ground cumulative production of 40.8% and 24.7% on the loamy and 36.6% and 60.8% on the shallow loamy ecological site, compared with peak production from the nonuse exclosures in 2019 and 2020, respectively. This subpasture treatment received 60 days of recovery between the first and second rotation. The overall degree of disappearance was 39.8% and 49.7%, respectively, after the second rotation.

On the moderate-use subpasture, we had an increased above-ground cumulative production of 26.7% and 20.1% on the loamy and 29.7% and 30.1% on the shallow loamy ecological site, compared with peak production from the nonuse exclosures in 2019 and 2020, respectively. This subpasture treatment received 79 days of recovery between the first and second rotation. The overall degree of disappearance was 31.7% and 24.8% after the second rotation (end of grazing season).

The length of recovery period did not appear to be the driving factor in growth efficiency, but the degree of disappearance and the uniformity of use create greater regrowth across the pasture, thus increasing growth efficiency potential.

Kevin Sedivec

Introduction

Grazing systems differ from season-long grazing through the increased control over stocking rates, stocking density, and timing of grazing and livestock distribution (Holechek et al., 1998; Smart et al., 2010). Typically, season-long and rotational grazing systems differ in stocking rates and temporal and spatial manipulation of grazing (Savory, 1988), creating a high stock density.

Rotational grazing is believed to be a superior way to manage resources, especially at the ranching level on private lands (Ranellucci et al., 2012). However, relatively few studies support the concept that rotational grazing systems are superior to other management regimes (Hart et al., 1993; Manley et al., 1997; Briske et al., 2008).

Twice-over rotation grazing is promoted widely in the northern Great Plains and humid northeastern Great Plains (Sedivec and Barker, 1991; Biondini and Manske, 1996; Shepherd and McGinn, 2003;

Limb et al., 2018). Twice-over grazing, like many rotational grazing systems, is a practical application of the grazing optimization hypothesis (McNaughton, 1979).

Previous rotational grazing studies were designed to create a homogenous grazing pattern throughout the unit or system, attempting to create the greatest impact of the vegetation during the immature phenological growth stage, that is, prior to the heading stage (Briske et al., 2008; Smart et al., 2010). However, most of the studies lack the methodology or rigors of vegetative data collection to show how much regrowth occurred and how much forage was consumed throughout the grazing season (Briske et al., 2008).

To determine above-ground cumulative production, these parameters (regrowth and consumption) need to be assessed to truly determine the impact of rotational grazing on forage production potential and economic return.

Heterogeneity is the principal driver of biodiversity in rangeland ecosystems and frequently is correlated positively with population and community stability (Wiens, 1997; Hovick et al., 2015; McGranahan et al., 2016). As most rotational grazing systems used by ranchers today, and most published in the literature, were designed to create spatially uniform moderate grazing, they often failed 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).

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; Limb et al., 2010). Patch-type grazing is needed to create a structurally and compositionally heterogeneous landscape.

Therefore, this project will focus on determining the effect of heterogeneity-based management within an exotic perennial cool-season-invaded rangeland on: 1) above-ground cumulative production, 2) growth efficiency, 3) livestock performance and 4) plant community composition.

Study Area and Design

This study is conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota (lat. 46°46'N, long. 99°28'W). The CGREC's mission is to extend scientific research and Extension programming to the surrounding rural communities.

Vegetation at the 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 (*Poa pratensis* L.) and includes a diverse forb community that supports a diverse pollinator community.

Within this design framework, we compare four management treatments for their ability to optimize forage production (above-ground cumulative production) and livestock production while promoting plant pollinator and breeding bird interactions. Treatments are based on current management frameworks but use a combination of well-established and novel designs.

The four treatments are: patch-burn grazing (PBG, one season of burn), patch-burn grazing (PBG, two seasons of burn), modified twice-over rest-rotation grazing (MTRR) and season-long grazing (SLG). Each treatment is replicated four times using a block design. This article will focus on the MTRR treatment.

The MTRR treatment was designed to be similar to patch-burn grazing (PBG) in that it produces structural heterogeneity across a pasture. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilizes fencing to dictate cattle distribution and influence grazing.

The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete subpastures that cattle cannot freely move between and are grazed from mid-May to late October. Cattle are rotated twice across each of the subpastures and allowed to graze for a total 74, 54, 27 and zero days (total 155-day grazing season) in the heavy use (60% to 80% disappearance), full use (40% to 60% disappearance), moderate use (20% to 40% disappearance) and rested subpastures, respectively. Cattle start the grazing season in the heavy-use subpasture.

The first rotation uses 40% of the grazing days and the second rotation uses 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, the heavy -use pasture will transition to the rested pasture, the rested pasture to the moderate-use and the moderate -use to the full-use pasture. This rotation will create annual heavy disturbance in one subpasture 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).

Cow-calf pairs are grazed within pastures from mid-May to late October each year. The stocking rate is determined assuming a 30% harvest efficiency. Fresh water access from well water and mineral supplements are provided.

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).

Methodology

Vegetation quadrat samples are collected using 0.25 meter $(m)^2$ quadrats to determine production of standing crop, graminoids (grasses and sedges) and forbs. Samples are oven-dried to a constant weight and weighed.

To evaluate objectives, five cages are placed on two loamy and two shallow loamy ecological sites in each subpasture (heavy, full, moderate, rested) of the MTRR (20 cages total per subpasture).

Herbage production is determined during the first rotation using the pair-plot clipping technique, with one plot clipped in the cage and a paired plot outside the cage clipped at the end of each grazing period. The herbage production inside the cage represents the amount of the growth produced in the first rotation. The degree of disappearance and herbage production consumed by cattle is determined from the difference between growth in the caged plot and uncaged plot.

Herbage production is collected again after the rest period and prior to cattle grazing the second rotation by clipping inside the cage and from a new paired uncaged plot. This growth represents continued growth from the first clipping (first grazing event) without grazing (inside cage) and regrowth after grazing (outside cage).

At the end of the second rotation, herbage production is clipped for the third time inside the cage to represent total herbage production and outside the cage using a new paired plot to determine overall degree of disappearance and herbage production consumed by cattle during the second grazing period.

Herbage production is clipped monthly (June through October) during the third week of the month in the rested pasture to determine peak herbage production. Peak production is the highest amount of production present during the growing season. Net primary production is production at the end of the grazing season. If peak production occurs at the end of the grazing season, then peak production and net primary production are the same, meaning no senescence occurred during the grazing season.

Above-ground cumulative production is calculated for each grazing intensity level (subpasture) by totaling the herbage production at the end of the second grazing period (outside cage) with the amount of production consumed by cattle at the end of the second grazing period (inside cage minus outside cage) plus regrowth (second outside cage clipping minus first outside cage) plus the amount of production consumed by cattle at the end of the first grazing period (inside cage minus outside cage) plus senescence (peak production minus net primary production) (see below).

Cumulative production =

livestock consumption during first rotation
(production inside exclosure – production outside exclosure)

+ regrowth during the rest period
(production outside exclosure prior to second rotation – production outside exclosure after the first rotation)

+ livestock consumption during second rotation
(production inside exclosure – production outside exclosure)

+ senescence[1]
(peak production – net primary production)

[1] *If peak production occurred at the end of the grazing period, then it would be equal to net primary production, and senescence = zero.*

$$\textbf{Growth efficiency} = \frac{\text{cumulative production} - \text{peak production}}{\text{peak production}} \times 100\%$$

The above-ground cumulative production from each grazing intensity subpasture is compared with the peak herbage production from within the same grazing intensity subpasture to determine growth efficiency.

Results

In 2018, we determined above-ground cumulative production for only the heavy-use subpasture. Above-ground cumulative production was 51.8% and 50.0% greater than peak production from the non-grazed plots on the loamy and shallow loamy ecological sites, respectively (Figures 1 and 2).

In 2019 and 2020, all subpasture treatments (heavy, full and moderate) were studied to determine if grazing intensity impacts growth efficiency. Above-ground cumulative production on the heavy-use subpasture was 66.6% and 54.3% greater in 2019 and 35.5% and 47.9% greater in 2020, compared with peak production from the non-grazed plots on the loamy and shallow loamy ecological sites, respectively. (Figures 1 and 2).

Generally, growth efficiency declined with reduced grazing intensity. Above-ground cumulative production on the full-use subpasture was 40.8% and 36.6% greater in 2019, and 24.7% and 60.8% greater, compared with peak production from the non-grazed plots on the loamy and shallow loamy ecological sites, respectively (Figures 3 and 4).

Above-ground cumulative production on the moderate -use subpasture was 26.7% and 29.7% greater in 2019 and 20.1% and 30.1% greater in 2020, compared with peak production from the non-grazed plots on the loamy and shallow loamy ecological sites, respectively (Figures 5 and 6).

We achieved our targeted degree of disappearance for all years on the full and moderate-use subpasture. The degree of disappearance on the full-use subpasture (targeted use was 40% to 60%) was 39.8% and 49.7% in 2019 and 2020, respectively. The degree of disappearance on the moderate-use subpasture (targeted use was 20% to 40%) was 31.7% and 24.8% in 2019 and 2020, respectively.

We achieved the targeted degree of disappearance on the heavy-use subpasture (targeted use was 60% to 80%) only in 2018 at 64.9%. The degree of disappearance was 57.2% and 56.2% in 2019 and 2020, respectively.

The length of recovery period does not appear to be the driving factor in growth efficiency; instead, the higher degree of disappearance and the uniformity of use across the higher grazing intensity subpastures creates greater regrowth, thus increasing overall growth efficiency.

This study will continue for one more year. A fourth year will allow for comparison of a full cycle to assess growth efficiency and determine if a lag effect (impacts of growth due to previous years' grazing intensity) occurs on herbage production.

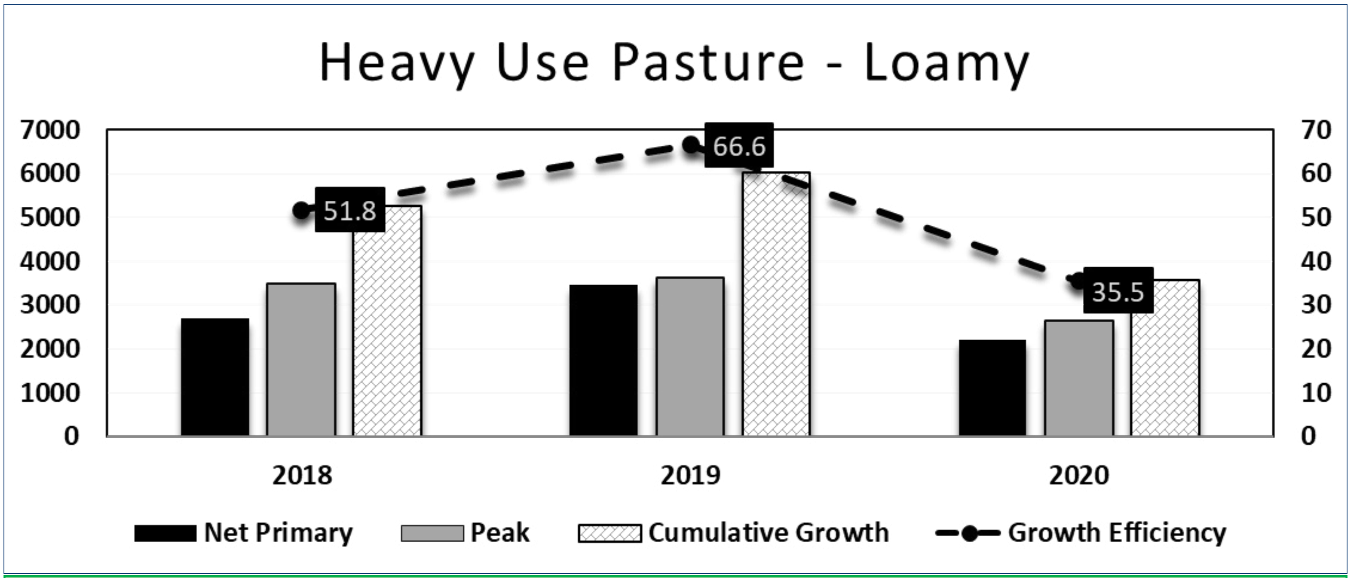

Figure 1. Above-ground net primary, peak and cumulative production on the heavy-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2018 to 2020.

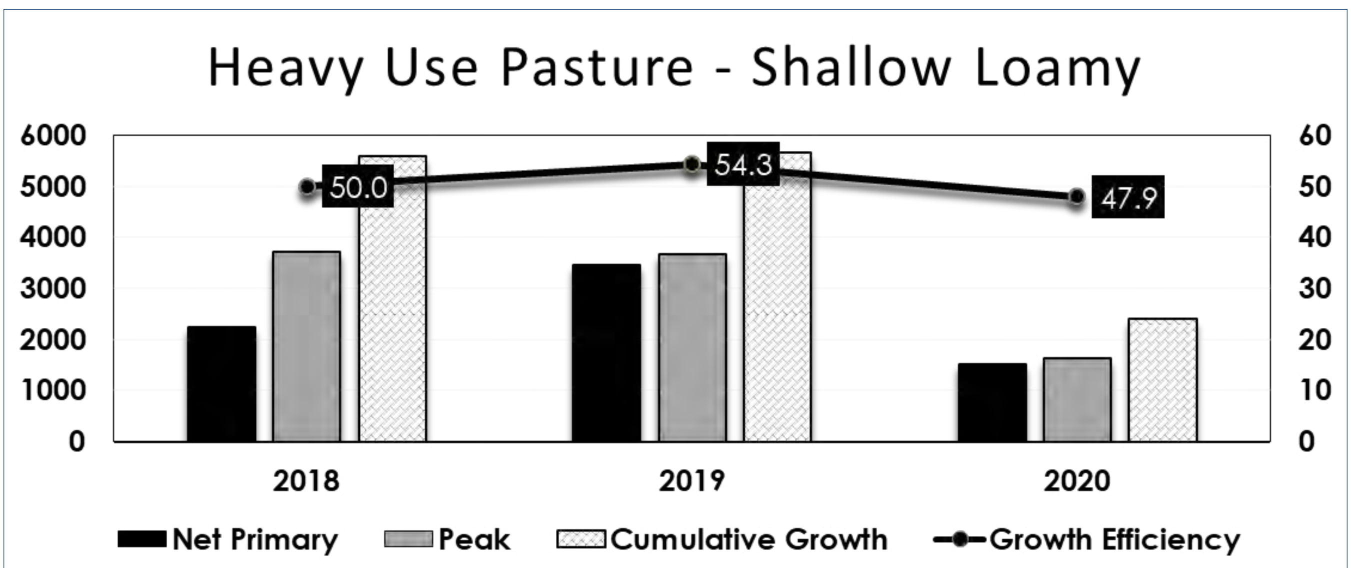

Figure 2. Above-ground net primary, peak and cumulative production on the heavy-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the shallow loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2018 to 2020.

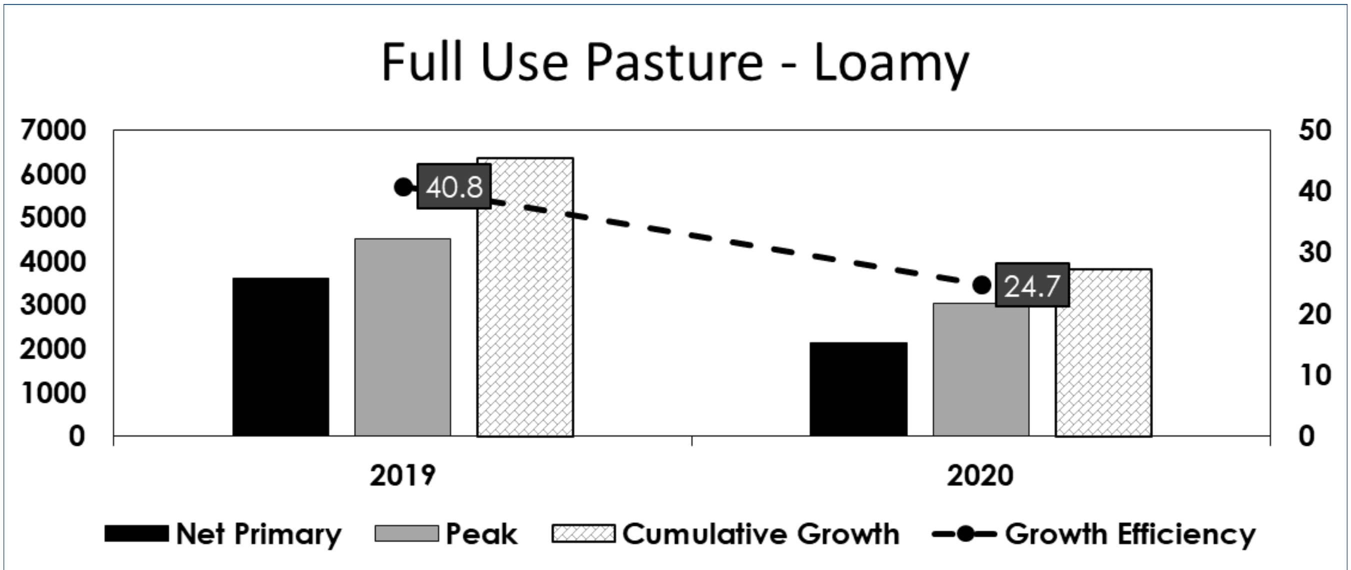

Figure 3. Above-ground net primary, peak and cumulative production on the full-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019 to 2020.

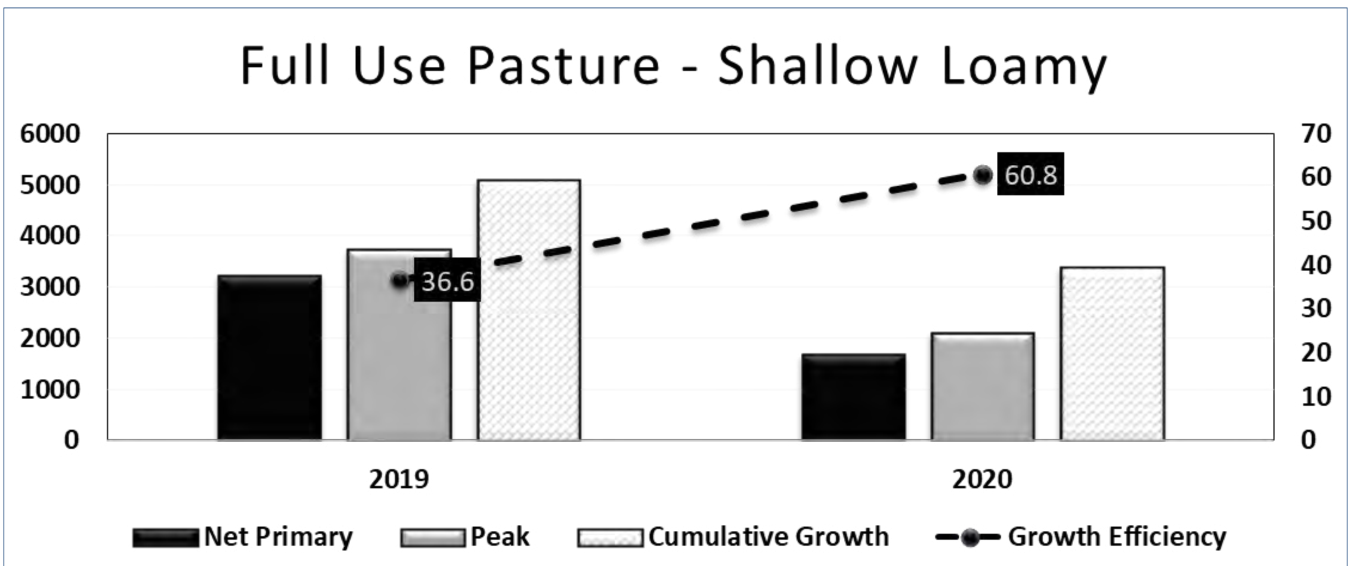

Figure 4. Above-ground net primary, peak and cumulative production on the full-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the shallow loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019 to 2020.

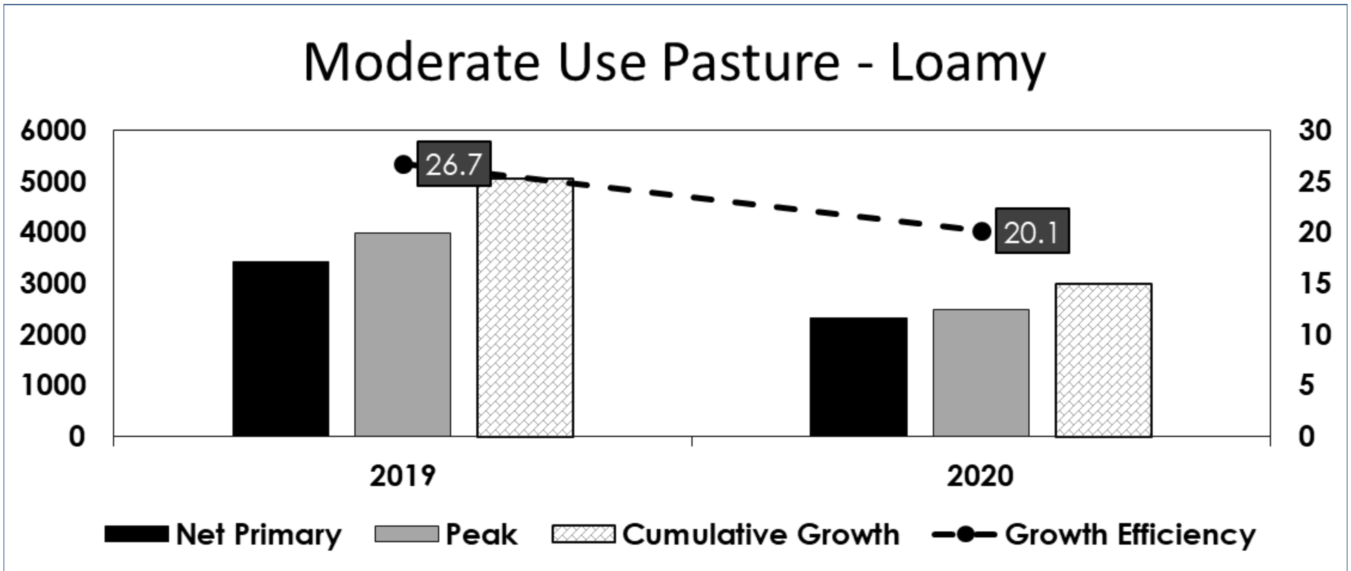

Figure 5. Above-ground net primary, peak and cumulative production on the moderate-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019 to 2020.

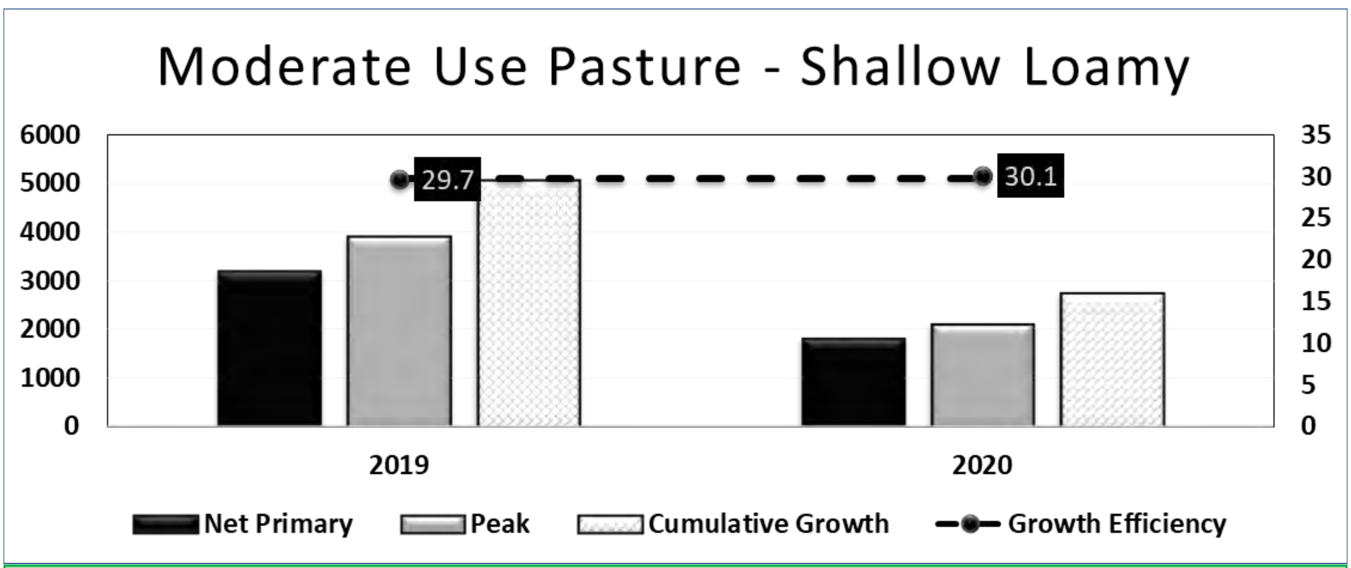

Figure 6. Above-ground net primary, peak and cumulative production on the moderate-use grazing intensity subpasture (pounds/acre, left y-axis) and growth efficiency (percent, right y-axis) from rotational grazing on the shallow loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019 to 2020.

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Photos by Erin Gaugler and Kevin Sedivec

Mineral Content of Forage With Patch-burn Grazing

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Summary

Patch-burn grazing is a livestock management practice that provides several benefits for conservation and livestock production. The mineral content of forage on grazing rangelands is useful for producers to know to ensure that livestock nutritional requirements are being met.

We collected forage samples from spring-burned areas and unburned areas during late spring and late summer. We then analyzed the samples for calcium, phosphorus, copper and zinc content. Forage mineral content was higher in burned areas than in unburned areas. Phosphorous, copper and zinc were higher in burned areas in late spring and summer, while calcium was only higher during the late summer.

Introduction

North Dakota rangelands evolved with fire and grazing, which are important for maintaining disturbance-driven heterogeneity. Patch-burn grazing is the combination of fire in discrete patches within a pasture and ungulate grazing.

The forage regrowth in the most recently burned patch is high in protein content and low in structural fibers, which attracts livestock. Fire and grazer attraction to the recently burned patch results in heterogeneity through contrasts in vegetation structure, quality and quantity. This offers several advantages for conservation through maintaining ecosystem functioning, wildlife habitat and species diversity (Fuhlendorf et al., 2017; Hobbs et al., 2009).

Patch-burn grazing also has benefits for livestock production. Managing for heterogeneity decouples the relationship between precipitation and livestock gains by buffering forage resource and providing high-quality regrowth, which stabilizes livestock production during drought years (Allred et al., 2014; Spiess et al., 2020).

Minerals are an essential part of livestock nutrition and must not be overlooked when assessing whether nutritional requirements are being met during the grazing season. Rangeland forage is not always able to satisfy the requirements of grazing cattle (McDowell, 1996).

Macro and trace minerals are important for reproduction, health and growth of livestock. Cattle almost always require supplementation, but needs vary with forage and water sources, age, stress, breed and gestational status of the animal (Paterson and Engle, 2005).

Although minerals are an important component of livestock nutrition, no studies have examined the impacts of patch-burn grazing management on mineral concentration of forage. With knowledge regarding the forage mineral content in patch-burn grazing systems, producers can ensure that their current supplementation strategy is meeting mineral requirements effectively.

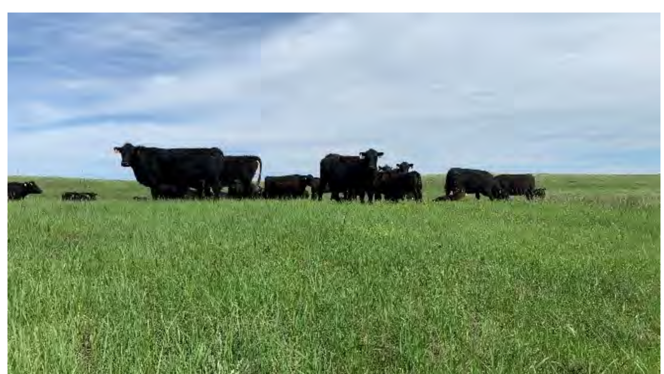
Objectives

Our objective was to determine if patch burning can increase mineral availability in rangeland pastures. We expect post-fire regrowth in patches following spring fire to have greater forage mineral content than vegetation in unburned patches.

Study Area

This study was conducted at the Central Grasslands Research Extension Center (CGREC). CGREC pastures are mixed-grass prairie consisting of native and introduced C_3 grasses, native C_4 grasses, forbs, legumes and shrubs.

Photos by Megan Wanchuk



Cows grazing on a recently burned patch.

Samples were collected in 2017 and 2018 on four pastures managed with patch-burn grazing. These pastures undergo a spring burning treatment in which a quarter of the pasture (15 hectares [ha]) is burned each spring, creating a four-year fire return interval.

Procedures

To determine forage mineral content at the beginning and end of the grazing season, above-ground biomass was clipped from a 25- by 25-centimeter (cm) frame during late spring (May-June) and late summer (August-September). All plant material above the crown was clipped to minimize contamination from soil and litter but still include the live and standing dead material.

Samples were from thin-loamy ecological sites to minimize the effect of different soil type on mineral content. We dried samples for 72 hours at 105 C and ground them with a Willey mill using a 1-millimeter (mm) screen. We analyzed all samples for calcium, phosphorus, copper and zinc content using wet-chemistry analysis at the North Dakota State University Animal Sciences laboratory.

Results and Discussion

Zinc and phosphorus content were greater during late spring and late summer in the forage regrowth after fire as compared with forage in unburned patches (Figure 1). In both years, calcium was only greater in the recently burned patch during late summer sampling.

Forage copper content in the recently burned patch was variable between years but still remained higher than unburned patches. Ash content was similar between patches, except in August 2017, when the burned patch had higher ash content than the unburned.

Overall, we found greater forage mineral content in recently burned patches compared with unburned patches (Figure 2). In Figure 2, values left of 0 would indicate that mineral content is decreased with fire. Values overlapping 0 would indicate no difference in mineral content between burned and unburned patches. Because all mineral content values are to the right of 0, this indicates fire has a positive effect on forage mineral content.

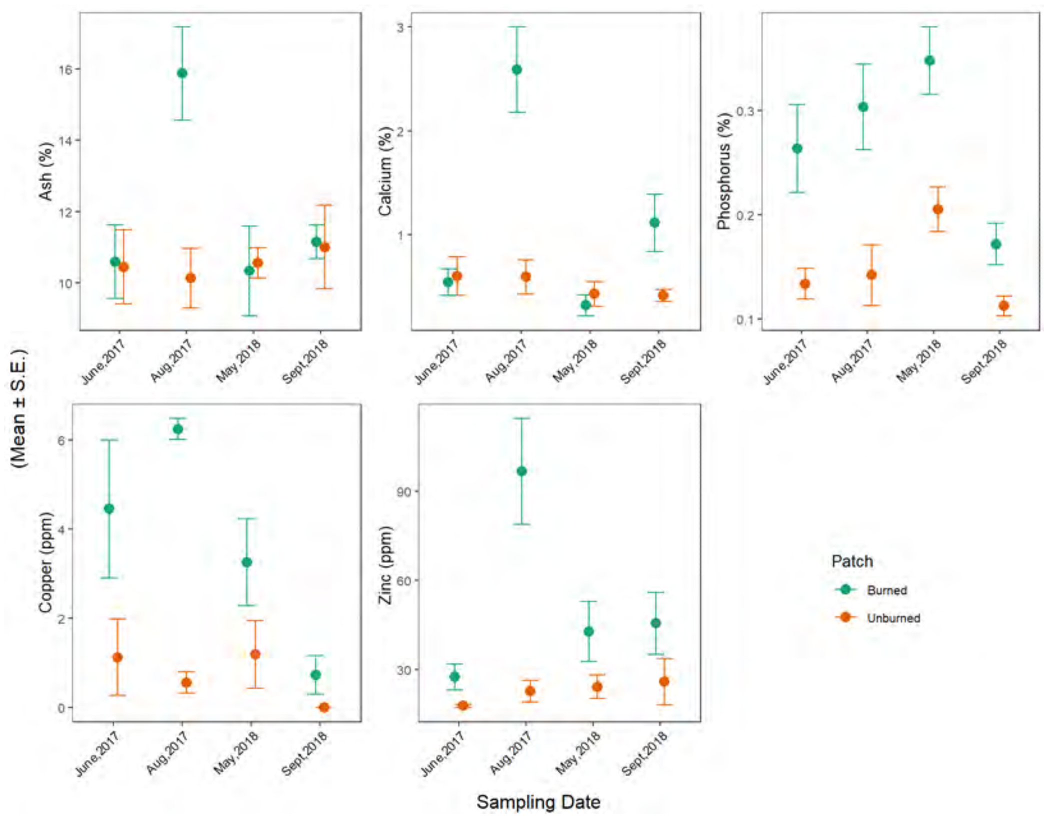


Figure 1. Ash, phosphorus, copper, zinc and calcium content in forage by sampling date in burned and unburned patches at CGREC in 2017 and 2018. Copper, zinc and phosphorus are greater in the burned patches compared with the unburned during the late spring and late summer. Calcium is greater in the burned patches during the late summer only.

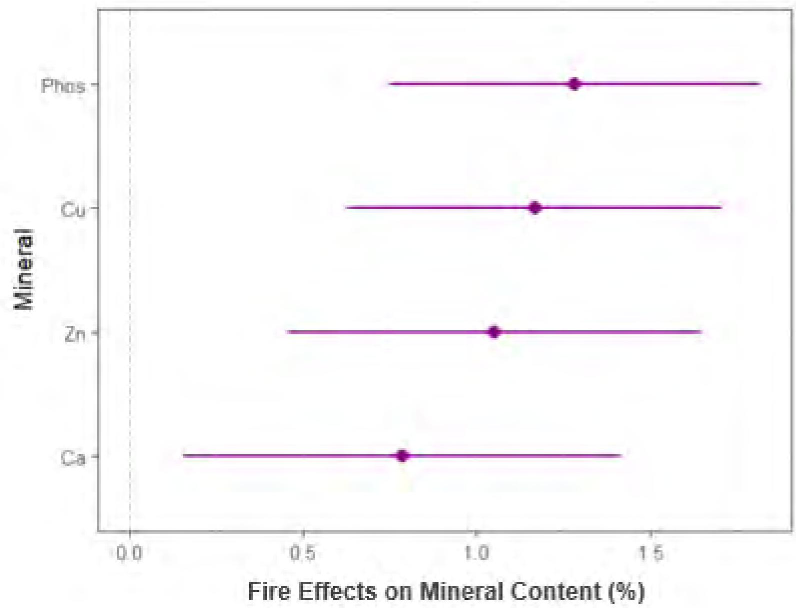


Figure 2. Phosphorus, copper, zinc and calcium content of forage is greater in the recently burned patches than unburned patches. Values to the right of 0 indicate that fire increases forage mineral content. Mineral values in this figure are expressed as percent dry matter.

The results seen in patch-burn grazing are consistent with studies using fire and excluding grazing (Van de Vijver et al., 1999). Higher mineral concentration in recently burned patches is caused by reduced age of plant tissue, increased leaf-to-stem ratio and nutrients distributed over less biomass of post-fire vegetation. Increased mineral content in forage appears to last longer with patch-burn grazing than just fire alone, likely due to grazing delaying plant maturity (Van de Vijver et al., 1999).

Increased mineral content of forage on burned areas relative to unburned areas is another benefit of patch-burn grazing management. Livestock production and producer profitability potentially can be increased through reduced mineral supplementation costs and increased cow performance from enhanced immune functioning and reproductive performance.

Conclusions

Recently burned patches in patch-burn grazing systems have greater forage mineral content than unburned patches for the four minerals tested. The next steps are to see if forage mineral content is greater in other minerals important for beef production and how long the increase lasts. With this information, producers can be sure that their mineral supplementation strategy is effectively meeting livestock requirements.

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Beef Cow-calf Performance on Bale-grazed Grass Hay Supplemented with Alfalfa Hay, a Liquid Supplement or Corn Dried Distillers Grains with Solubles (DDGS)

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The high cost of winter feeding, accounting for more than 60% of the total annual feed costs of a beef cow-calf operation, is associated with keeping cows in dry lots. Extending the grazing season through strategies such as bale grazing will reduce the cost of feeding, labor, fuel, machinery maintenance and repair, and manure removal. When bale grazing, ensuring that animals have adequate nutrition is important.

In line in with bale grazing, supplementation strategies that minimize or eliminate pasture visits will further the goal of minimizing winter feed costs. This study examines strategies for supplementing cows that are bale grazing grass hay.

Strategies evaluated include feeding grass hay in combination with alfalfa hay, a liquid supplement or corn dried distillers grains with solubles (DDGS). Results suggest that supplementation with good-quality alfalfa hay or a liquid supplement is not adequate in severely cold winters. Under such conditions, high-energy supplements such as DDGS will be required to meet the nutrient shortfall.

Summary

Methods of supplementing beef cows bale grazing grass hay were investigated in a study conducted for four winters, from 2016 to 2019, 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 optimal method of supplementation depends on environmental conditions during the winter. In severely cold winters, good-quality alfalfa hay or a liquid supplement is not adequate to meet requirements of pregnant beef cows in early to midgestation. 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 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 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). This study examines beef cow performance and cost effectiveness of bale grazing supplementation strategies.

Procedures

This study was conducted during four years, from 2016 to 2019, at the Central Grasslands Research Extension Center, Streeter, N.D. The bale grazing site was a 10.5-hectare (ha) field that historically was cropland in a corn and small-grain rotation.

In the two years prior to 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 site was divided into eight, 1.3-ha paddocks, which were separated using three-strand, high-tensile wire electric fencing. One water tank was installed between two paddocks to supply water to two groups of cows.

Windbreaks were placed in each paddock. In the fall of each year, 40 hay bales were placed in each paddock with two bales to a row. Net wrap was removed prior to feeding.

The study was conducted with nonlactating 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; 2019, n = 80, BW = 624 ± 33 kg). Starting in the fall of each year, cows were divided into eight groups of similar total body weight and randomly assigned to four bale grazing treatments.

The bale grazing treatments were as follows: a) grass hay (control), b) grass hay supplemented with alfalfa hay, c) grass hay supplemented with corn DDGS and d) grass hay treated with a liquid supplement. Bale grazing grass hay was expected to maintain body condition with no weight gains. Some weight and body condition score (BCS) changes were expected from supplemented diets.

Most of the grass 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. For alfalfa supplementation, one bale of alfalfa hay was fed for every three bales of grass hay.

Liquid supplementation involved pouring approximately 34 liters of liquid supplement (Quality Liquid Feeds Inc. - QLF) onto grass hay bales. This amount of liquid supplement was calculated to increase hay protein content by approximately 3 percentage points.

Cows in each treatment were allotted four bales per pasture at a time, and access to new bales was controlled using one portable electric wire. Cows were moved to a new set of bales when remaining feed was deemed insufficient. Cows had *ad libitum* access to water and a salt block.

Cow performance was assessed using body weight (BW) changes and body condition scores (BCS). Two -day body weights were taken at the start and end of the study. Body condition scores were assigned by

two observers using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988; Rasby et al., 2014) at the start and end of each grazing period.

Calf performance was assessed through birth weights and weaning weights. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Results

Temperatures during bale grazing are shown in Figure 1. Mean monthly temperatures of minus 14 C and minus 21 C in December and January 2016-2017 were below normal and lower, compared with other years. Normal temperatures for this time of year are minus 10 C and minus 13 C for December and January, respectively. Temperatures in the winter of 2018-2019 were higher than normal for the same period, averaging minus 7 C for December and January (Figure 1).

December 2016 and December 2019 were marked by heavy snowfall (Figure 2), with monthly totals of 81 and 90 centimeters, respectively. These two years also were marked by several blizzards, three in 2016 and two in 2019, during the bale grazing season.

Feeds

Nutrient composition of grass hay and grass hay supplemented with alfalfa hay, a liquid supplement or DDGS is shown in Table 1. Grass hay averaged 7.9% crude protein (CP) with a range of 7.6% to 8.8% and total digestible nutrient (TDN) content of 55.1%, with a range of 54% to 55.9%.

The addition of a liquid supplement increased CP of grass hay to 9%. Liquid supplementation did not increase TDN content.

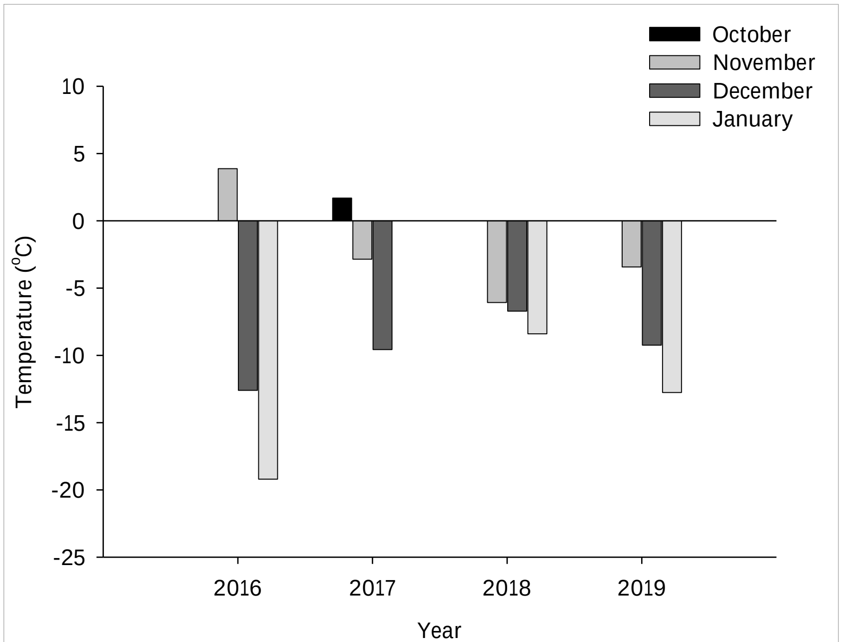

Figure 1. Average temperatures during bale grazing. Bale grazing dates were Nov. 4, 2016, to Jan. 12, 2017; Oct. 24 to Dec. 28, 2017; Nov. 17, 2018, to Jan. 10, 2019; Nov. 14, 2019, to Jan. 17, 2020. Data from North Dakota Agricultural Weather Network (2020).

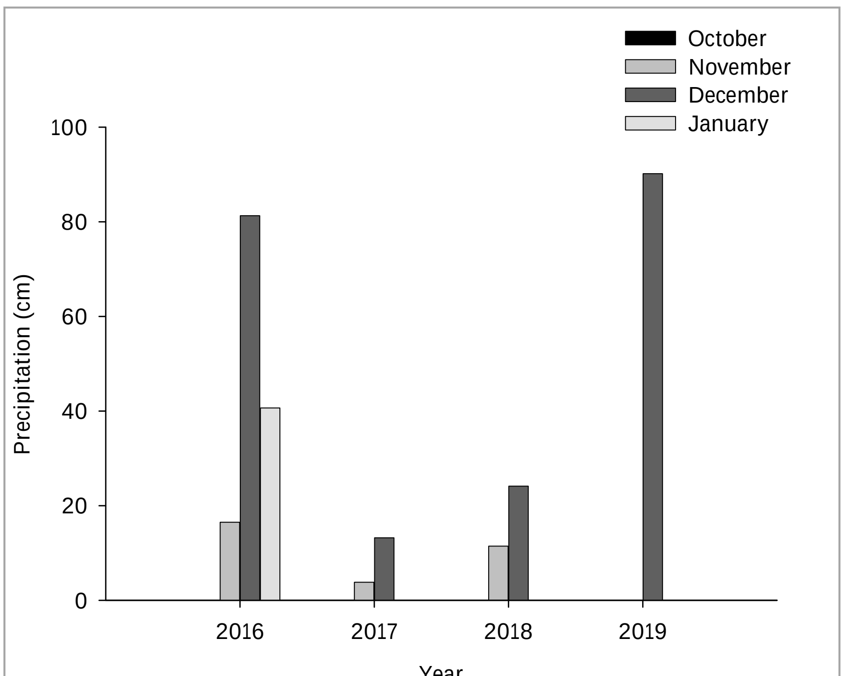

Figure 2. Snowfall (in cm) during bale grazing. Bale grazing dates were Nov. 4, 2016, to Jan. 12, 2017; Oct. 24 to Dec. 28, 2017; Nov. 17, 2018, to Jan. 10, 2019; Nov. 14, 2019, to Jan. 17, 2020. Data from National Oceanic and Atmospheric Administration (NOAA).

Table 1. Nutrient composition (mean ± SD; % dry-matter basis) of grass hay, and grass hay supplemented with alfalfa hay, a liquid supplement or DDGS during four grazing seasons.

Nutrient	HAY[1]	ALF[2]	QLF[3]	DDGS[4]
CP	7.9 ± 0.51	10.8 ± 0. 71	9.0 ± 0.44	11.5 ± 0.48
TDN	55.1 ± 0.45	56.3 ± 1.06	54.7 ± 0.56	59.1 ± 0.77
NDF	66.3 ± 0.69	62.4 ± 1.38	65.4 ± 0.81	60.7 ± 0.37
ADF	47.3 ± 1.96	45.1 ± 1.27	48.8 ± 3.09	42.5 ± 1.01
Ca	0.61 ± 0.04	0.89 ± 0.03	0.54 ± 0.05	0.53 ± 0.04
P	0.11 ± 0.04	0.13 ± 0.04	0.16 ± 0.02	0.24 ± 0.04
Mg	0.18 ± 0.02	0.23 ± 0.02	0.16 ± 0.01	0.22 ± 0.02
K	0.77 ± 0.50	1.2 ± 0.41	0.91 ± 0.03	0.85 ± 0.41

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

Supplementation with alfalfa hay increased diet CP content to 10.8% CP and TDN content to 56.3%. Supplementation with DDGS increased diet CP content to 11.5% and TDN content to 59.1% (Table 1).

Cow Performance

Initial cow BW were similar ($P > 0.05$) among treatments but differed on a yearly basis (Table 2).

Final BW were greater ($P < 0.05$) when cows were supplemented with DDGS and least when cows were not supplemented (Table 2).

The diet by year interaction ($P = 0.025$) for daily gain showed that response to supplementation was dependent on the type of supplement as well as the bale grazing season. In the 2016 season, only supplementation with DDGS resulted in positive daily

Table 2. Cow performance following bale grazing grass hay or grass hay supplemented with alfalfa hay, a liquid supplement or dried distillers grains with solubles.

	Diet					Year				
	HAY[1]	ALF[2]	QLF[3]	DDGS[4]	SE	2016	2017	2018	2019	SE
Initial BW, kg	621	623	620	621	9.0	593[c]	621[b]	644[a]	626[ab]	7.9
Final BW, kg	626[bc]	638[ab]	634[ab]	654[a]	9.5	583[b]	659[a]	663[a]	645[a]	8.5
Daily gain, kg/d	0.07[c]	0.24[b]	0.25[b]	0.52[a]	0.05	-0.14[c]	0.59[a]	0.34[b]	0.29[b]	0.05
Initial BCS	5.8	5.8	5.8	5.8	0.05	5.6[c]	5.4[d]	5.8[b]	6.5[a]	0.05
Final BCS	5.7[b]	5.8[ab]	5.8[ab]	5.9[a]	0.04	5.4[c]	5.6[b]	5.3[c]	6.9[a]	0.05
BCS change	-0.08[b]	0.03[ab]	0.04[a]	0.07[a]	0.04	-0.13[c]	0.22[b]	-0.42[d]	0.39[a]	0.04

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

Means with a different letter within row for diet (D) or within row for year (Y) differ significantly ($P \leq 0.05$).

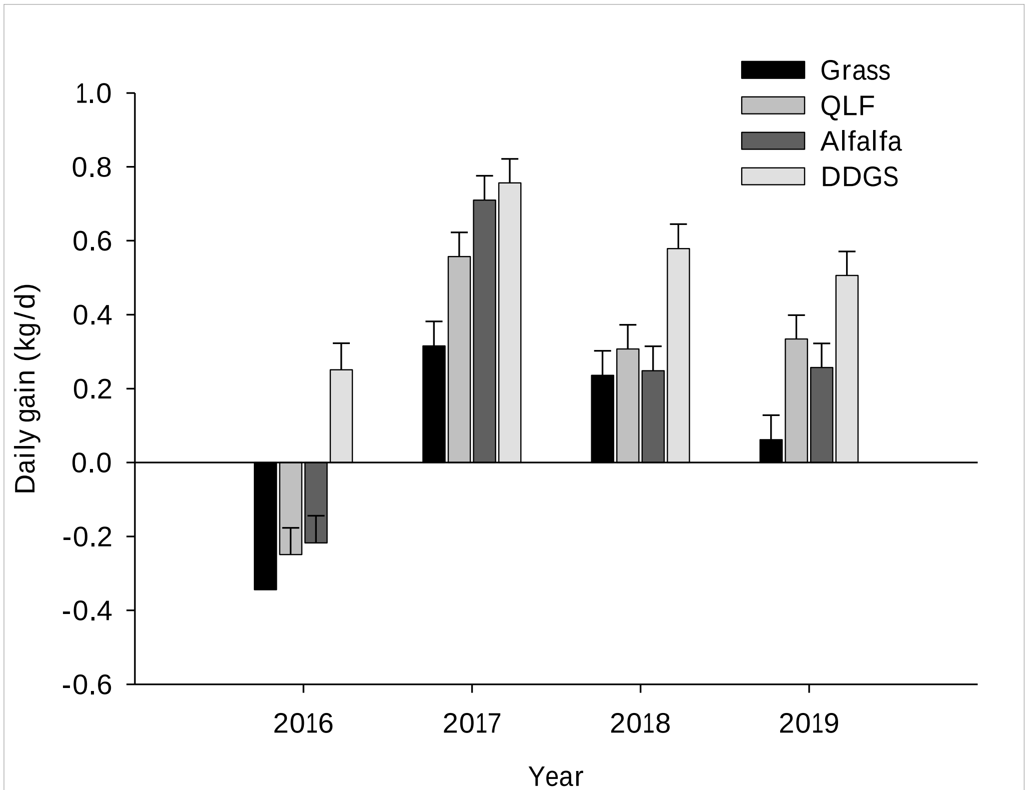

Figure 3. Cow daily gains following bale grazing grass hay or grass hay supplemented with alfalfa hay (alfalfa), a liquid supplement (QLF) or dried distillers grains with solubles (DDGS).

gains (Figure 3). Unsupplemented cows and cows supplemented with alfalfa and a liquid supplement lost weight during this grazing season.

In 2017, daily gains were positive on all diets but lowest on the unsupplemented grass hay diet. As in the 2016 grazing season, supplementation with DDGS resulted in greater daily gains in the 2018 and 2019 bale grazing seasons relative to other supplementation strategies (Figure 3).

Initial cow BCS were similar ($P > 0.05$) among treatments but differed on a yearly basis (Table 2). Final BCS were greatest ($P < 0.05$) when cows were supplemented with DDGS, intermediate following alfalfa or liquid supplementation and lowest in unsupplemented cows (Table 2). As well, final BCS differed ($P < 0.05$) on a yearly basis. Change in BCS was greatest in DDGS-supplemented cows (gain) and unsupplemented cows (loss).

Calf Performance

Calf birth weights, weaning weights and daily gains were not influenced ($P > 0.05$) by method of supplementation (Table 3). Calf weaning weights and daily gains differed ($P < 0.05$) on a yearly basis. Calf performance was similar for bull and heifer calves (Table 3).

Discussion

The length of the bale grazing period in each year of this study was approximately 60 days and efforts were made to ensure that the grazing period was similar across the years. As well, the study was conducted during the same period of the year, starting in mid-November and going into January.

Evaluating supplementation strategies during bale grazing during a four-year period for the same length of grazing period and at approximately the same time of year allowed us to relate animal response to supplementation under varying environmental conditions. Indeed, environmental conditions differed greatly on an annual basis.

The first year of bale grazing, 2016, had the lowest December and January temperatures. Temperatures for the remaining three grazing years were comparable.

Precipitation also differed significantly among bale grazing years. The 2016 and 2019 bale grazing

Table 3. Performance of calves from cows that bale grazed grass hay or grass hay supplemented with alfalfa hay, a liquid supplement or dried distillers grains with solubles.

	Diet					Year				
Heifer calves	**HAY[1]**	**ALF[2]**	**QLF[3]**	**DDGS[4]**	**SE**	**2016[5]**	**2017**	**2018**	**2019**	**SE**
Birth weight, kg	37	38	38	39	1.4	36[b]	36[b]	39[ab]	40[a]	1.4
Weaning wt, kg	256	255	261	261	7.3	248[bc]	245[c]	264[ab]	276[a]	7.3
Adj. weaning wt, kg	282	273	277	281	7.7	285[ab]	269[bc]	265[c]	294[a]	7.7
Age at weaning, d	187	190	191	189	3.2	177[c]	185[bc]	204[a]	190[b]	3.2
ADG, kg/d	1.2	1.2	1.2	1.2	0.04	1.2[a]	1.1[b]	1.1[b]	1.3[a]	0.04
Bull calves										
Birth weight, kg	40	40	40	41	1.4	39[ab]	42[a]	38[b]	41[a]	1.4
Weaning wt, kg	271	279	275	283	7.6	258[c]	254[c]	287[b]	308[a]	7.6
Adj. weaning wt, kg	294	299	296	304	7.6	297[b]	283[b]	289[b]	323[a]	7.6
Age at weaning, d	185	190	188	189	3.2	174[c]	180[c]	204[a]	194[b]	3.2
ADG, kg/d	1.2	1.3	1.3	1.3	0.04	1.3[b]	1.2[b]	1.2[b]	1.4[a]	0.04

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

[5]Calves were born in 2017, 2018, 2019 and 2020 following bale grazing in 2016, 2017, 2018 and 2019, respectively.

Means within a row for diet and year with a different letter differ significantly ($P \le 0.05$).

seasons were marked by stormy weather, with three blizzards occurring in 2016 and two in 2019. Despite heavy snow accumulation in paddocks following these weather events, cows were able to bale graze to the end of the bale grazing period in each grazing year.

The initial expectation was that grass hay would supply the required TDN and CP to maintain cow body condition and BW during bale grazing. Evaluation of the supplementation strategies using the CowBytes Beef Ration Balancing Program (Version 4, Alberta Agriculture, Food and Rural Development, Alberta, Canada) showed that the diets provided variable amounts of CP and TDN and that grass hay and liquid supplementation did not supply adequate amounts of CP and TDN to meet nutritional requirement of cows in early to midgestation.

Grass hay provided approximately 94% of the required CP and 86% of the required TDN. Similarly, liquid supplementation provided approximately 106% of the required CP but only 84% of the required TDN.

Supplementing with alfalfa hay increased diet CP and TDN and supplied approximately 126% and 98% of the required CP and TDN, respectively. The highest increase in diet CP and TDN occurred with DDGS supplementation, which supplied approximately 143% and 105% of the required CP and TDN, respectively.

Supplementation of grass hay increased final BW, BCS and change in BCS, with the greatest increase occurring following DDGS supplementation. Trends in daily gains were influenced by type of supplement used as well as environmental conditions.

The 2016 bale grazing season was particularly cold relative to other grazing seasons. Unsupplemented cows and cows supplemented with alfalfa or a liquid supplement lost weight. Only supplementation with DDGS resulted in positive daily gains. Clearly, below-average temperatures and stormy weather made 2016 a unique year when compared with the other grazing seasons.

Response to supplementation in the last four grazing seasons differed in degree but not trend, with supplementation showing positive daily gains. Grass hay resulted in the lowest daily gains, and supplementation with DDGS resulted in greater daily gains relative to other supplementation strategies.

This study shows that environmental conditions will play a part in determining the success of supplementing cows bale grazing grass hay in the winter. When winters were harsh, as occurred in 2016, grass hay did not contain adequate energy and protein to meet nutritional requirement of cows in early to midgestation.

During the 2016 winter, supplementation of grass hay with good-quality alfalfa hay or a liquid supplement did not provide nutrients to meet nutritional requirement of cows in early to midgestation. Supplementation with alfalfa and a liquid supplement was successful only under more moderate environmental conditions.

Supplementation with DDGS was successful in maintaining and improving cow performance under different environmental conditions. Despite difference in cow performance, supplementation strategies did not influence calf performance.

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Photos by Michael Undi, NDSU

Performance of Beef Cattle Housed in a Dry Lot or on Bale-grazed Pasture in Winter

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Cows in North Dakota typically are overwintered in dry lots to which feed, water and bedding are delivered on a regular basis. This practice of keeping cows in dry lots contributes greatly to winter feed costs, which are the single highest annual cost in a beef cow-calf operation. Allowing beef cattle to harvest their own forage potentially can decrease costs by reducing the cost of feeding, labor, fuel, machinery maintenance and repair, and manure removal.

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 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 evaluated in a study conducted during four winters, from 2016 to 2019, at the Central Grasslands Research Extension Center, Streeter, N.D. Keeping cows on pasture or in dry lot pens did not influence ($P > 0.05$) final body weight (BW) or body condition score (BCS).

However, daily gains and BCS change were greater ($P < 0.05$) in bale-grazed cows relative to cows kept in dry lot pens. Performance of calves from cows kept in the two overwintering environments was similar. Results show that bale grazing is a viable alternative to keeping cattle in dry lots in winter.

Introduction

The majority of beef cows in the northern Plains are housed in open dry lot pens in the winter (Asem-Hiablie *et al.,* 2016) and are exposed to extreme winter conditions. 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 the extreme minimum temperature of minus 51 C has been recorded (Enz, 2003).

In typical dry lots, cattle are fed mechanically harvested feeds. 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% 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 in winter allows animals to harvest their own food and decreases reliance on inputs such as machinery 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 bale grazing, swath 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 beef cows managed in two overwintering environments (pasture or dry lot) under south-central North Dakota winter conditions.

Procedures

This study extended for four years, from 2016 to 2019. The study was conducted with nonlactating pregnant Angus cows (2016, n = 32, body weight [BW] = 599 ± 68 kilograms [kg]; 2017, n = 40, BW = 620 ± 59 kg; 2018, n = 40, BW = 643 ± 47; 2019, n = 40, BW = 624 ± 30).

Starting in the fall of each year, cows were divided into four groups of similar body weight and randomly assigned to bale-grazing paddocks or dry lot pens. Cow performance was assessed using body weight changes and body condition scores (BCS). Two-day body weights were taken at the start and end of the study.

Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner *et al*., 1988; Rasby *et al*., 2014) at the start and end of each season. Calf performance was assessed from birth weights and weaning weights. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Bale Grazing

Two 1.3-hectare (ha) paddocks separated by three-strand, high-tensile wire electric fencing were used for bale grazing. A water tank installed between the paddocks supplied water. Each paddock had windbreaks.

In early fall of each year, 40 round grass hay bales were placed in each paddock with two bales to a row. Net wrap was removed prior to feeding. Cows were allotted four bales at a time, and access to new bales was controlled using one portable electric wire. Cows were offered a salt block and mineral supplement, and had *ad libitum* access to water.

Dry Lot

Two dry lot pens were used for this study. Each pen contained a hay feeder and a winterized water bowl (Richie Industries Inc., Conrad, Iowa). Dry lot cows were fed the same grass 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 and Discussion

Temperatures during the study are shown in Figure 1. Mean monthly temperatures of minus 14 C and minus 21 C in December and January of 2016-2017 were below normal and lower, compared with other years. Normal temperatures for this time of year are minus 10 C and minus 13 C for December and January, respectively. Temperatures in the winter of 2018-2019 were higher than normal for the same period, averaging minus 7 C for December and January (Figure 1).

December 2016 and December 2019 were marked by extremely heavy snowfall (Figure 2), with monthly snowfall totals in 2016 and 2019 of 81 and 90 centimeters, respectively. These two years also were marked by several blizzards, three in 2016 and two in 2019, during the bale grazing season.

Overwintering housing systems in this study were evaluated in a four-year period that had variable environmental conditions. Indeed, environmental conditions differed greatly on an annual basis.

The first year of bale grazing, 2016, had the lowest December and January temperatures. Temperatures for the remaining three grazing years were comparable.

Precipitation also differed significantly among bale grazing years. The 2016 and 2019 bale grazing seasons were marked by stormy weather, with three blizzards occurring in 2016 and two in 2019. Despite heavy snow accumulation in bale-grazed paddocks following these weather events, cows were able to bale graze to the end of the bale grazing period in each grazing year.

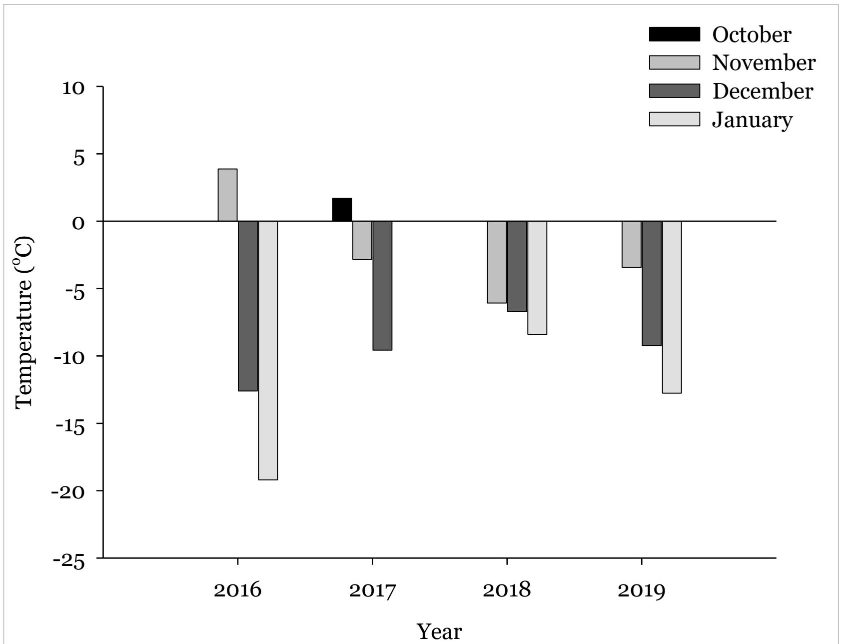

Figure 1. Average temperatures during bale grazing. Bale grazing dates were Nov. 4, 2016, to Jan. 12, 2017; Oct. 24 to Dec. 28, 2017; Nov. 17, 2018, to Jan. 10, 2019; Nov. 14, 2019, to Jan. 17, 2020. Data from North Dakota Agricultural Weather Network (2020).

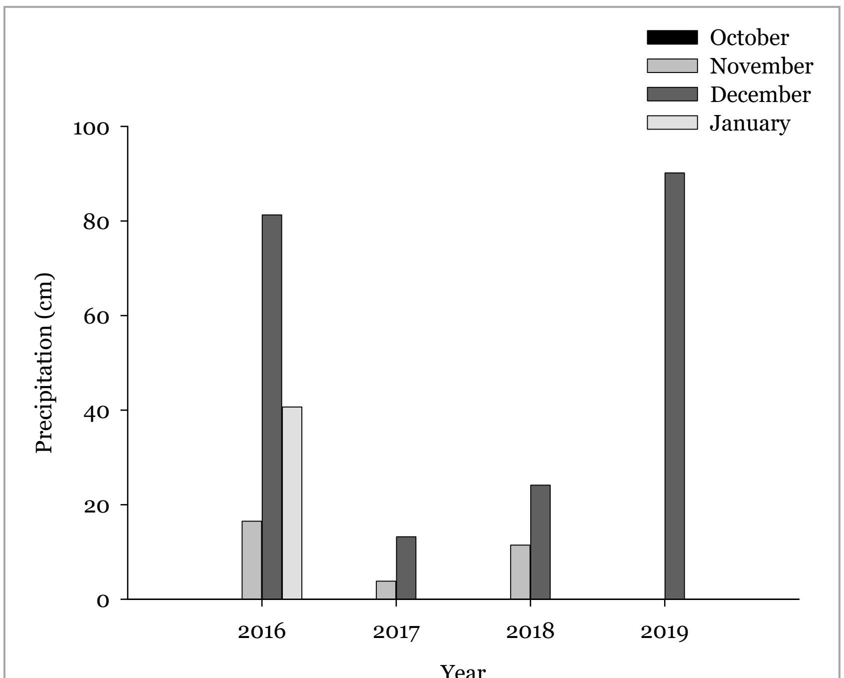

Figure 2. Snowfall (in cm) during bale grazing. Bale grazing dates were Nov. 4, 2016, to Jan. 12, 2017; Oct. 24 to Dec. 28, 2017; Nov. 17, 2018, to Jan. 10, 2019; Nov. 14, 2019, to Jan. 17, 2020. Data from National Oceanic and Atmospheric Administration (NOAA).

Table 1. Nutrient composition (mean ± SD; percent dry-matter [DM] basis) of grass hay offered to cows bale grazing on pasture or kept in a dry lot.	
Nutrient	**Percent DM**
Crude protein	7.9 ± 0.51
Total digestible nutrients	55.1 ± 0.45
Neutral detergent fiber	66.3 ± 0.69
Acid detergent fiber	47.3 ± 1.96
Calcium	0.61 ± 0.04
Phosphorus	0.11 ± 0.04

The challenge after storms was keeping water accessible to cows on pasture. In the first year of this study, the third blizzard made keeping water points open impossible to do and led to the termination of the study. This study 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.

We noted some interesting observations from blizzard events of 2016 and 2019 for bale-grazing cows on pasture. First, despite windbreaks, not all cows sought shelter during blizzards. Some cows simply would stand on the leeward side of hay bales, while others did not seek shelter at all and continued to graze.

Secondly, when water troughs were cleared of snow and refilled after each blizzard, not all cows visited water troughs immediately. 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).

Grass Hay

Nutrient composition of grass hay that was bale grazed and fed in dry lot in the four grazing seasons is shown in Table 1. Grass hay averaged 7.9% crude protein (CP) and a total digestible nutrient (TDN) content of 55.1%.

Cow Performance

Initial cow BW were similar ($P > 0.05$) between housing treatments (Table 2). Similarly, keeping cows on pasture or in dry lot pens in winter did not influence ($P > 0.05$) final BW. However, daily gains were greater ($P < 0.05$) in bale-grazed cows relative to cows kept in dry lot pens. Differences in daily gains could be due to differences in forage between bale-grazed cows and cows kept in dry lot pens.

Initial and final BCS were not influenced ($P > 0.05$) by type of overwintering system (Table 2). Although both groups lost body condition during winter, BCS change was greater ($P < 0.05$) in cows kept in dry lot pens relative to bale-grazed pasture (Table 2).

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

	Housing			Year				
	Pasture	Dry lot	SE	2016	2017	2018	2019	SE
Initial BW, kg	621	624	9.5	599[c]	615[bc]	646[a]	630[ab]	9.6
Final BW, kg	625	618	9.1	577[b]	635[a]	651[a]	623[a]	11.5
Daily gain, kg/d	0.07[a]	-0.08[b]	0.05	-0.33[c]	0.24[a]	0.10[ab]	-0.03[b]	0.07
Initial BCS	5.8	5.9	0.05	5.7[b]	5.4[c]	5.8[b]	6.5[a]	0.06
Final BCS	5.7	5.7	0.06	5.4[b]	5.4[b]	5.2[c]	6.7[a]	0.07
BCS change	-0.08[a]	-0.21[b]	0.04	-0.25[b]	0.05[a]	-0.57[c]	0.20[a]	0.06

Means with a different letter within a row for housing and within row for year differ significantly ($P \leq 0.05$).

Table 3. Performance of calves from cows kept on pasture or in a dry lot in winter.

Heifer calves	Housing			Year				
	Pasture	Dry lot	SE	2016[1]	2017	2018	2019	SE
Birth weight, kg	37	38	1.3	36	37	38	38	1.8
Age at weaning, days	186	186	3.1	173[b]	174[b]	203[a]	193[a]	5.2
Weaning weight, kg	255	247	7.8	237[b]	236[b]	258[a]	273[a]	10.9
205-d weaning wt, kg	276	268	6.6	280[a]	260[b]	260[b]	288[a]	9.3
ADG, kg/day	1.2	1.1	0.03	1.2[ab]	1.1[b]	1.1[b]	1.2[a]	0.04
Bull calves								
Birth weight, kg	40	41	1.4	39	41	40	44	2.0
Age at weaning, days	186	186	3.3	173[b]	176[b]	207[a]	188[a]	4.4
Weaning weight, kg	272	273	7.4	249[b]	244[b]	293[a]	303[a]	10.5
205-d weaning wt, kg	294	297	6.9	288[b]	277[b]	291[b]	327[a]	9.8
ADG, kg/day	1.2	1.3	0.03	1.2[a]	1.2[a]	1.2[b]	1.4[a]	0.05

[1]Calves were born in 2017, 2018, 2019 and 2020 following bale grazing in 2016, 2017, 2018 and 2019, respectively. Means with a different letter within a row for housing and within a row for year differ significantly ($P \leq 0.05$).

Calf Performance

Bull calf birth weights, weaning weights and daily gains were not influenced ($P > 0.05$) by type of housing (Table 3). As well, heifer calf birth weights and weaning weights were not influenced ($P > 0.05$) by type of housing. However, heifer calf daily gains tended ($P < 0.10$) to be greater in calves from bale-grazed cows (Table 3).

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.

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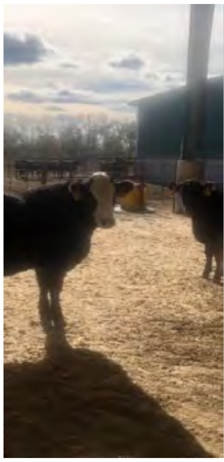
Photos by Michael Undi, NDSU



Effect of Rate of Gain During Early Gestation on Colostrum and Milk Composition in Beef Heifers

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The objectives of this study were to evaluate the impact of feeding an energy/protein supplement to replacement heifers to achieve a moderate rate of gain during the first trimester of gestation (84 days) on composition of colostrum and milk, and milk production. Developing heifers to a moderate rate of gain decreased somatic cell count in colostrum and increased the percent of protein in milk; however, no effects were observed on milk production measured via a weigh-suckle-weigh procedure in this study.

Summary

We hypothesized that the rate of gain during the first 84 days of gestation would affect composition of colostrum and milk, and increase milk production in moderate-gain heifers. At breeding, 45 Angus-based heifers received a basal total mixed ration allowing 0.63 pound/day of gain (low gain [LG], n = 23) or a basal diet plus starch-based supplement allowing 1.75 pounds/day of gain (moderate gain [MG], n = 22) for 84 days.

Heifers then were managed on a common diet until parturition. Colostrum samples (50 milliliters [mL]) were collected before first suckling. Milk samples (50 mL) were collected six hours after calf removal on days 62 ± 10 and 103 ± 10 postpartum.

Samples were collected by stripping each teat 15 to 20 times after discarding the first five strips. At day 103, sampling techniques were compared by collecting a second sample after 1 mL oxytocin administration and 90 seconds of lag time.

Data were analyzed using the GLM procedure of SAS. Fat, protein, somatic cell count (SCC), milk urea nitrogen and other solids were analyzed in colostrum for effect of treatment, whereas milk composition was evaluated for effects of treatment, day and their interaction.

Heifer was the experimental unit and significance was set at $P \leq 0.05$. Colostrum SCC was greater ($P = 0.05$) in LG (6,949 ± 739 cells × 10^3/mL) than MG (4,776 ± 796 cells × 10^3/mL). In milk, protein and other solids were greater ($P \leq 0.03$) in MG (3.02 ± 0.03 and 6.20 ± 0.02%, respectively) than LG (2.87 ± 0.03 and 6.14 ± 0.02%, respectively).

On day 103, oxytocin administration and extended lag time after teat stimulation (0.96 ± 0.05%) increased fat content in milk ($P < 0.01$) compared with immediate milk sample collection (0.34 ± 0.05%). We conclude that nutrition during early gestation had a sustained impact on milk composition, and techniques of oxytocin administration result in greater milk fat content.

Introduction

In cattle, the development of the mammary gland begins during embryonic development, with the majority of its growth occurring during the last trimester of gestation. By parturition, all components of the gland are established in the fetus, including vascular, lymphatic, connective and adipose tissues (Rowson et al., 2012).

In the heifer dam, the majority of apparent mammary growth occurs during the last trimester of gestation and is completed at parturition (Rowson et al., 2012; Davis, 2017). Therefore, optimal development and growth of the mammary gland during gestation is essential to ensure maximized milk production in future lactations (Meyer et al., 2011).

Additionally, the mammary gland is a key tissue ensuring the transfer of nutrients and immunoglobulins to the neonatal calf (Neville et al., 2010; Geiger, 2020). Because of the importance of a dam's milk production on her calf's weaning weight (Sapkota et al., 2020), optimizing milking potential is crucial.

Milk is produced in the secretory tissue of the alveoli; however, milk's nutritional constituents, and consequently composition, vary depending on place of storage in the udder. In contrast to casein micelles (protein), which are small enough to passive transfer from the alveoli into the cistern, milk fat globules are larger and require active expulsion from the alveoli. Therefore, fat content is greater in the alveoli than in the cistern, whereas protein content is similar across the two storage sites.

Milk letdown is initiated by oxytocin, which is released from the pituitary gland in response to tactile stimulation of the udder and causes the myoepithelial cells around the alveoli to contract and eject the milk stored there into the duct system and cistern (Bruckmaier and Blum, 1998; McKusick et al., 2002; Mačuhová et al., 2004). However, an approximate one- to two-minute lag period occurs between the release of oxytocin and milk expulsion (Bruckmaier and Blum, 1998).

Milk composition can be influenced by multiple factors, with milk fat being the component that can vary the most as a result of environmental and physiological factors, especially nutrition (Bauman and Griinari, 2001).

Fatty acids in milk can stem from two different sources. The short and medium chain fatty acids result from *de novo* synthesis in the mammary gland from carbon sources, including acetate, whereas the longer chain fatty acids originate from preformed circulating fatty acids in the blood (Bauman and Griinari, 2001; Wijesundera et al., 2003). When high-concentrate/low-fiber diets or diets high in plant oils are fed to cattle, ruminal biohydrogenation pathways of poly-unsaturated fatty acid may be shifted from *trans*-11 to *trans*-10 isomers (Fougère et al., 2018; Fougère and Bernard, 2019), with *trans*-10 isomers having an inhibitory effect in milk fat synthesis (Baumgard et al., 2000; Medeiros et al., 2010).

Based on the lack of information in the literature regarding maternal nutrition during early gestation and its effect on lactation, we evaluated the impacts of low and moderate gain during the first 84 days of gestation on composition of colostrum and milk, and milk production.

Experimental Procedures

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University.

Forty-five Angus-based heifers (initial body weight [BW] = 818.2 ± 8.7 pounds) were estrus synchronized using a Select Synch plus CIDR protocol and bred via artificial insemination to female-sexed semen from a single sire. At breeding, heifers were blocked by antral follicle count, ranked by BW and assigned to one of two treatments: 1) a basal total mixed ration (TMR; low gain [LG] 0.63 pound/day; n = 23) or 2) the basal TMR diet with the addition of a starch-based energy/protein supplement mixed into the diet (moderate gain [MG] 1.75 pounds/day; n = 25, Table 1).

Heifers were fed individually using the Insentec Feeding System (Hokofarm B.V., Marknesse, The Netherlands). Heifers were weighed on two consecutive days at the beginning and end of the feeding trial, and every 14 days throughout the 84-day period prior to morning feeding, then on days 164, 234, 262, and at the time of calving, pasture turnout and weaning.

Table 1. Dietary ingredients and nutrient composition of the total mixed ration fed to beef heifers during the first 84 days of gestation.

	Treatment	
Item	**LG[1]**	**MG[2]**
Ingredient, % of DM		
Corn silage	37	29
Prairie hay	53	41
DDGS	10	5
Energy/protein supplement	–	25
Chemical composition, %		
Ash	12.57	9.57
Crude protein	10.49	11.57
ADF	36.97	29.38
NDF	61.12	50.68
Fat	1.98	3.48
Calcium	0.95	0.78
Phosphorus	0.40	0.41

[1]Low gain; heifers fed a basal TMR containing a commercially available mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day, targeting gain of 0.63 pound/day.

[2]Moderate gain; heifer fed basal TMR plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 pounds/day.

At calving, a 50-mL colostrum sample was collected from each heifer, before calves suckled for the first time, and placed into a DHIA plastic milk vial. For sample collection, we stripped each teat 15 to 20 times after discarding the first five strips. Colostrum samples were mixed thoroughly to ensure equal distribution of the preservative in the vials throughout the samples, which then were stored at 4 C until further analysis.

At day 62 ± 10 postpartum, we estimated milk production using a 12-hour weigh-suckle-weigh procedure. Briefly, dams and calves were assigned to two groups of 23 and 22 pairs each. At midnight, we separated calves from their dams. At 6 a.m. the next morning, calves were allowed to nurse their dams until satiety (about 30 minutes) to establish similar milking status across the dams.

Then pairs were separated for two six-hour time periods. After each six-hour window, calves were weighed before and immediately after suckling until satiety (about 30 minutes). The difference between the pre- and post-suckling calf weights was recorded as the estimated milk production of the dam for each of the six-hour time periods.

To estimate 24-hour milk production, milk production for the two six-hour separation periods was added together and multiplied by 2 (Shee et al., 2016). Before allowing the calves to suckle their dams at 6 a.m., we collected a 50-mL milk sample into DHIA vials by stripping each teat 15 to 20 times after discarding the first five strips. Samples were mixed thoroughly and stored at 4 C until further analysis.

At day 103 ± 10 postpartum, dams and calves were separated for six hours and a 50-mL milk sample was collected following the same protocol used at day 62 postpartum. Immediately following the collection of the milk sample, we administered oxytocin (1 mL intramuscularly) to each dam and waited for 90 seconds before collecting another 50-mL milk sample to compare sampling protocols.

All samples were shipped to a DHIA milk laboratory (Stearns County DHIA Lab, Sauk Centre, Minn.) within 10 days (colostrum) and five days (milk) after sample collection for analysis of composition of colostrum and milk (fat, protein, somatic cell count [SCC], milk urea nitrogen [MUN] and other solids).

Statistical Analysis

Heifer BW was analyzed as repeated measures in time using the MIXED procedure of SAS for effects of treatment, day and a treatment × day interaction.

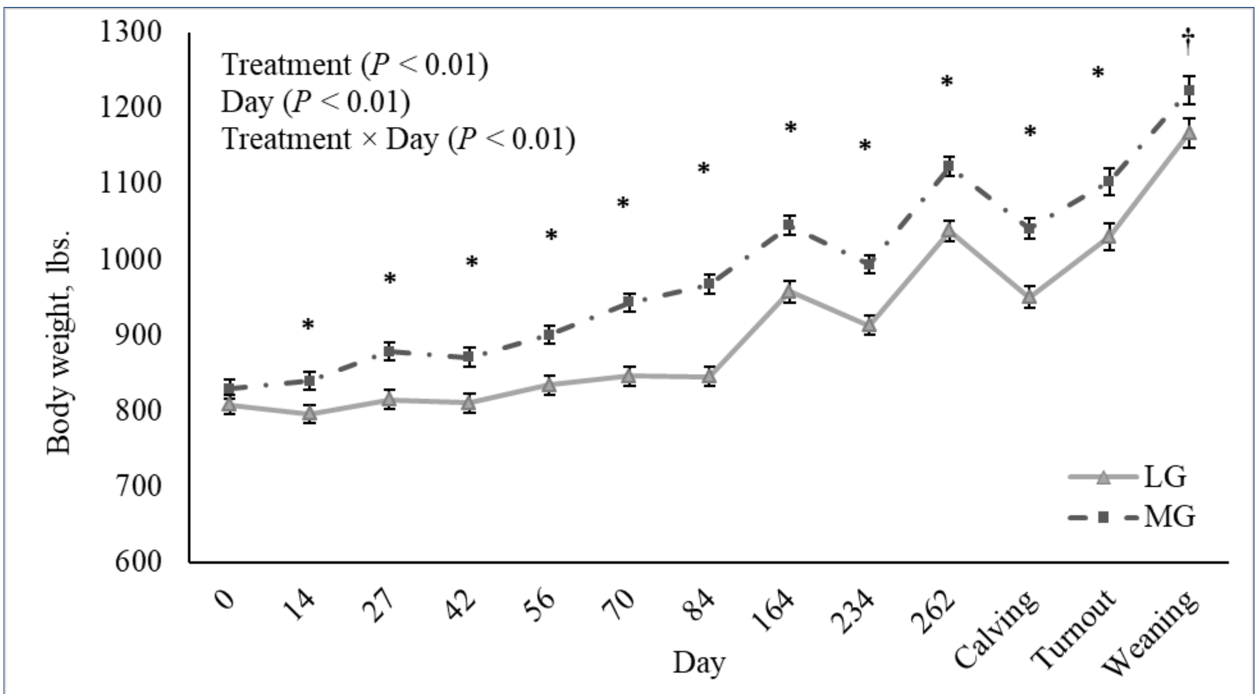

Figure 1. Impact of nutritional treatment on body weight of heifers managed at two rates of gain (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) for 84 days, followed by common management for the duration of gestation and lactation. *Within day treatments differ ($P < 0.01$), † with day treatment differ ($P = 0.04$).

Colostrum composition and milk production were analyzed using the GLM procedure of SAS. Milk composition at days 62 ± 10 and 103 ± 10 was analyzed using the GLM procedure of SAS for effects of treatment, day, and a treatment × day interaction.

Further, milk composition at day 103 ± 10 was analyzed using the GLM procedure of SAS for effects of treatment, oxytocin and a treatment × oxytocin interaction (SAS Inst. Inc., Cary, N.C.). Heifer was considered the experimental unit in all analyses and significance was set at $P \leq 0.05$.

Results and Discussion

Heifer BW was affected by a treatment × day interaction ($P < 0.01$), being similar at initiation of treatment, diverging by day 14 ($P = 0.01$) and was 122.1 pounds greater for MG heifers at day 84 ($P < 0.01$; Figure 1). Although heifers were managed as a single group beginning at day 85, the weight divergence continued throughout calving until weaning, at which time heifers in the MG treatment remained 90.4 pounds ($P < 0.01$) and 56.1 pounds ($P = 0.04$) heavier than LG heifers at calving and weaning, respectively.

In colostrum (Table 2), we observed an effect of maternal treatment on SCC ($P = 0.05$), which was lower in MG heifers than in LG heifers; however, the percent of fat ($P = 0.11$), protein ($P = 0.40$), other solids ($P = 0.17$) and MUN ($P = 0.29$) were not impacted by rate of gain during the first 84 days of gestation. Somatic cells in colostrum and milk include epithelial cells and leukocytes (macrophages, neutrophils and lymphocytes), with the majority of somatic cells in milk being leukocytes (Kelly et al., 2000).

Consequently, SCC is an indicator of colostrum and milk quality, and a measure of inflammation and infection in the udder. Somatic cell score is greater in colostrum than in milk, which may be caused by cells passing through leaky tight junctions present in the mammary epithelium, which close when milk production increases (Nguyen and Neville, 1998; McGrath et al., 2016).

The SCC in colostrum in this study was far greater than observed by others. For instance, values reported for SCC in beef cattle fed a control diet or a nutrient-restricted diet during the first 82 days of gestation were lower than values reported in the current study (1,276 and 1,043 cells × 10^3/mL for control and restricted, respectively; Noya et al., 2019).

The high SCC values could have been a result of the sampling protocol used, as we did not milk out the entire udder. However, similar to our study, Noya et al. (2019) did not observe any effect of maternal nutritional treatment during early gestation on percent of fat and protein in colostrum, either.

Maternal dietary treatment did not affect milk production on day 62 postpartum ($P = 0.67$;

Table 2. Colostrum composition of beef heifers as influenced by rate of gain (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) during the first 84 days of gestation.

	Treatment[1]			
Item	**LG**	**MG**	**SEM[2]**	***P*-value**
Fat, %	5.7	6.7	0.47	0.11
Protein, %	13.6	14.3	0.70	0.40
Somatic cell count, cells × 10^3/mL	6,949	4,776	796	0.05
Milk urea nitrogen, mg/dL	1.7	0.6	0.83	0.29
Other solids, %[3]	4.3	4.5	0.1	0.17

[1]Treatment: low-gain heifers (LG) fed a basal TMR containing a commercially available mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day, targeting gain of 0.63 pound/day; moderate gain-heifers (MG) fed basal TMR plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 pounds/day.

[2]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).

[3]Values for other solids include lactose and ash.

LG: 10.6 ± 0.91 pound/day; MG: 11.2 ± 0.92 pound/day), but influenced milk composition on days 62 and 103 postpartum (Table 3). Moderate-gain heifers had greater percentage of milk protein ($P < 0.01$) and other solids ($P = 0.03$) than LG heifers. Further, the percent of fat and other solids in milk decreased from day 62 to day 103 postpartum ($P < 0.01$), whereas the percent of protein in milk and MUN increased for the same time periods ($P < 0.01$).

Kennedy et al. (2019) used a portable milking machine to determine milk yield and milk composition at day 44 of lactation in beef cows receiving a control diet or the control diet plus dried distillers grains during late gestation. They did not observe differences in milk production or milk composition, but the percent of milk protein was similar to our values (3.08 ± 0.07% for control and 2.98 ± 0.07% for supplement; Kennedy et al., 2019).

At day 103 postpartum, using a sampling technique that included oxytocin administration and an extended lag time of 90 seconds after teat stimulation, we observed an increased percent of milk fat ($P < 0.01$) compared with collecting an immediate sample without oxytocin injection (Table 4). However, oxytocin administration and the extended lag time did not affect the percent of milk protein ($P = 0.98$).

Both observations make sense in regard to the anatomy of the mammary gland and the role that oxytocin plays in the milk ejection process. Regardless of the sampling technique used, milk fat concentrations were extremely low and do not appear representative of the milk fat that calves have access to when compared with results by Kennedy et al. (2019), who reported fat concentrations greater than 4% in beef cows (4.11 ± 0.33% for control and 4.21 ± 0.33% for supplement). Therefore, future sampling techniques should focus on milking at minimum an entire quarter to obtain a better representation of nutrients in milk.

Acknowledgments

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Table 3. Milk composition of beef heifers at days 62 ± 10 and 103 ± 10 postpartum as influenced by rate of gain (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) during the first 84 days of gestation.

	LG[1]		MG[2]			*P*-values		
Item	**d 62[5]**	**d 103[6]**	**d 62**	**d 103**	**SEM[3]**	**Treatment**	**Day**	**Treatment × Day**
Fat, %	0.55	0.35	0.45	0.34	0.044	0.23	<0.01	0.28
Protein, %	2.75	3.0	2.92	3.12	0.045	<0.01	<0.01	0.53
Somatic cell count, cells × 10^3/mL	36.65	88.09	33.59	57.9	28.76	0.55	0.18	0.63
Milk urea nitrogen, mg/dL	4.11	11.15	3.95	10.11	0.425	0.15	<0.01	0.29
Other solids, %[4]	6.20	6.08	6.26	6.13	0.027	0.03	<0.01	0.87

[1]Low gain; heifers fed a basal TMR containing a commercially available mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day, targeting gain of 0.63 pound/day.

[2]Moderate gain; heifers fed basal TMR plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 pounds/day.

[3]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).

[4]Values for other solids include lactose and ash.

[5]Milk sample collected at day 62 ± 10 postpartum.

[6]Milk sample collected at day 103 ± 10 postpartum.

Table 4. Percent of milk fat and protein in beef heifers at day 103 ± 10 postpartum as influenced by sampling technique and rate of gain (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) during the first 84 days of gestation

	LG[1]		MG[2]			*P*-values		
Item	Pre-Oxytocin[4]	Post-Oxytocin[5]	Pre-Oxytocin[4]	Post-Oxytocin[5]	SEM[3]	Treatment	Oxytocin	Treatment × Oxytocin
Fat, %	0.35	0.88	0.34	1.03	0.078	0.23	<0.01	0.28
Protein, %	3.00	3.00	3.12	3.12	0.043	<0.01	<0.01	0.53

[1]Low gain; heifers fed a basal TMR containing a commercially available mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day, targeting gain of 0.63 pound/day.

[2]Moderate gain; heifers fed basal TMR plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 pounds/day.

[3]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).

[4]Milk sample collected before injection of 1 mL of oxytocin and a 90 second lag time.

[5]Milk sample collected after administration of 1 mL of oxytocin and a 90 second lag time.

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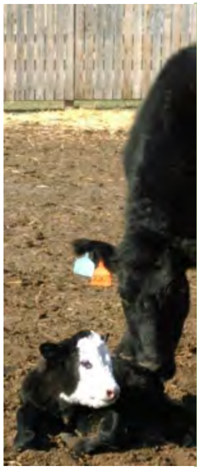

Vitamin and Mineral Supplementation and Rate of Gain in Beef Heifers: Effects of Concentration of Trace Minerals in Maternal and Fetal Liver at Day 83 of Gestation

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The objective of this study was to evaluate the effects of feeding vitamin and mineral supplement and two different rates of gain during the first 83 days of pregnancy on trace mineral concentrations in the maternal and fetal liver. Our results show that providing a vitamin and mineral supplement resulted in increased concentrations of selenium (Se), copper (Cu), manganese (Mn) and cobalt (Co) in fetal liver. Increased trace mineral stores in the liver may be beneficial for offspring health and productive performance.

Summary

The objective of this study was to evaluate the effects of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on trace mineral concentrations in the maternal and fetal liver. Thirty-five crossbred Angus heifers (initial body weight [BW] = 792.6 ± 15.7 pounds [lb.]) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplement (VTM or NoVTM) and rate of gain (GAIN; low gain [LG], 0.62 lb./day, vs. moderate gain [MG], 1.74 lb./day).

The VTM treatment (113 grams (g)/heifer/day) was initiated at least 71 days before artificial insemination (AI). At breeding, heifers were maintained on their respective diets (target gain of 0.62 lb./day) or fed a starch-based protein/energy supplement (target gain of 1.74 lb./day).

Heifers were ovariohysterectomized on day 83 of gestation and samples of maternal and fetal liver were collected. Samples then were analyzed for concentrations of Se, Mn, Cu, Co, molybdenum (Mo) and zinc (Zn). In maternal liver, a VTM × GAIN was observed for Se (P = 0.02) and Mn (P = 0.03). Se concentrations were greater for VTM-LG than all other treatments, while Mn were greater for VTM-MG than VTM-LG heifers.

Further, maternal liver from VTM had increased concentrations of Cu (P < 0.01) and Co (P = 0.04), whereas GAIN affected concentrations of Mo, with greater concentrations (P ≤ 0.02) in MG heifers. Greater concentrations of Se (*P* < 0.01), Cu (*P* = 0.01), Mn (*P* = 0.04) and Co (*P* = 0.01) were observed in fetal liver from VTM than NoVTM, while Mo (*P* ≤ 0.04) and Co (*P* < 0.01) were impacted by GAIN, with greater concentrations in fetal liver from LG than MG.

In conclusion, concentrations of Se, Cu, Mn and Co were greater in fetal liver from VTM dams, while greater concentrations of Mo were observed in the liver of fetuses from LG dams. Concentrations of Zn were not affected by any of the nutritional strategies evaluated. These data provide insights into how nutritional management of beef heifers affect fetal liver stores of trace minerals, which may be beneficial for offspring health and productive performance.

Introduction

The first trimester of gestation is a critical period for fetal development; it is when the placenta and all vital organs are developed. Many producers do not realize that at this stage, not only the dam, but also the fetus, require proper trace mineral nutrition.

However, several biological processes, such as carbohydrate, protein and lipid metabolism, and hormone and DNA synthesis are dependent on trace minerals (Van Emon et al., 2020). Further, the fetus is completely dependent on the dam for trace mineral supply; thus, an inadequate maternal trace mineral consumption can compromise reproduction and negatively affect embryonic and fetal development (Hostetler et al., 2003), which can have long-term consequences on offspring health and performance.

Therefore, developing studies evaluating how maternal nutritional strategies can affect the supply of trace minerals to the fetus is important. The current experiment characterized a research model we developed to evaluate the effect of managerial inputs on maternal and fetal trace mineral concentration. The primary aim of this study was to test the hypothesis that vitamin and mineral supplementation and rate of gain during the first trimester of gestation would impact the concentrations of trace minerals in the maternal and fetal liver.

Experimental Procedures

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

Thirty-five crossbred Angus heifers (initial BW = 792.6 ± 15.7 lb.) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplementation (VTM or NoVTM) and rate of gain [GAIN; low gain (LG) 0.62 lb./day or moderate gain (MG) 1.74 lb./day]. Briefly,

Table 1. Nutrient composition of total mixed ration and supplements provided to beef heifers during the first trimester of gestation.

Chemical Composition	Total Mixed Ration[1]	Supplements		
		NoVTM[2]	VTM[3]	Starch-based protein/energy[4]
Dry matter (DM), %	53.0	86.6	89.6	87.7
Ash, % DM	11.5	5.3	25.1	2.4
Crude protein, % DM	9.9	15.6	14.8	17.5
Neutral detergent fiber, % DM	65.9	41.9	27.6	19.4
Ether extract, % DM	1.5	-	-	9.1
Nonfiber carbohydrates, % DM	11.1	37.2	32.5	51.6
Mineral Content				
Calcium, g/kg DM	5.74	2.47	50.62	0.30
Phosphorus, g/kg DM	2.05	8.94	22.82	4.59
Sodium, g/kg DM	0.26	0.12	19.44	0.24
Magnesium, g/kg DM	2.83	4.47	5.20	1.96
Potassium, g/kg DM	15.81	14.22	13.15	6.05
Sulfur, g/kg DM	2.25	2.41	4.84	2.57
Manganese, mg/kg DM	121.2	103.9	953.4	26.0
Cobalt, mg/kg DM	0.36	0.14	3.38	0.05
Copper, mg/kg DM	4.8	13.7	285.8	3.6
Selenium, mg/kg DM	0.3	0.4	7.0	0.3
Zinc, mg/kg DM	28.4	130.2	1051.8	35.0

[1]Proportion of ingredients: prairie grass hay (55%), corn silage (38%) and dried distillers grains plus solubles (7%).

[2]NoVTM: No vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day with no added vitamin and mineral supplement.

[3]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day (consisting of 113 grams [g] of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).

[4]An energy/protein supplement formulated with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea; targeting gain of 1.74 lb./day for moderate-gain and 0.62 lb./day for low-gain heifers.

the VTM supplement was initiated at least 71 days before artificial insemination.

At breeding, heifers were maintained on their respective diets (LG) or fed a starch-based protein/ energy supplement (MG). This resulted in the following treatment combinations: 1) No vitamin and mineral supplement, low gain (NoVTM-LG; n = 9); 2) No vitamin and mineral supplement, moderate gain (NoVTM-MG; n = 9); 3) Vitamin and mineral supplement, low gain (VTM-LG; n = 9); 4) Vitamin and mineral supplement, moderate gain (VTM-MG; n = 8). Heifers were fed individually in Calan gates, and supplements were top dressed over the total mixed ration (Table 1).

Heifers were ovariohysterectomized on day 83 ± 0.27 of gestation. Liver biopsies were obtained from all heifers at surgery day. Following ovariohysterectomy, fetuses were harvested and dissected, and samples of fetal liver were collected. Samples were placed in 2 milliliter microtubes and snap frozen on dry ice and stored at minus 80 C for subsequent trace mineral analysis.

Concentrations of Se, Mn, Cu, Co, Mo and Zn were determined via inductively coupled plasma mass spectrometry at the Veterinary Diagnostic Laboratory of Michigan State University. Data were analyzed using the MIXED procedures of SAS for effects of VTM, GAIN and a VTM × GAIN interaction. Differences were considered significant at a P- value ≤ 0.05.

Results and Discussion

In the maternal liver (Table 2), a VTM × GAIN interaction was observed for Se (P = 0.02) and Mn (P = 0.03). Se concentrations were significantly greater for VTM-LG than all other treatments, while Mn were significantly greater for VTM-MG than VTM-LG heifers. Further, maternal liver from VTM had increased concentrations of Cu (P < 0.01) and Co (P = 0.04), whereas GAIN affected concentrations of Mo, with greater concentrations (P ≤ 0.02) in MG heifers.

In the fetal liver (Table 3), greater concentrations of Se (P < 0.01), Cu (P = 0.01), Mn (P = 0.04) and Co (P = 0.01) were observed in the fetal liver from VTM than NoVTM dams, while Mo (P ≤ 0.04) and Co (P < 0.01) were impacted by GAIN, with greater concentrations in the fetal liver from LG than MG dams.

We would expect greater concentrations of all trace minerals in the maternal and fetal liver in response to vitamin and mineral supplementation. However, that was not the case for two of the six trace minerals

Table 2. Concentrations of trace minerals in the liver of beef heifers at day 83 of gestation as influenced by vitamin and mineral (VTM) supplementation and rate of gain (GAIN; low rate, 0.62 lb./day [LG] or moderate rate, 1.74 lb./day [MG]) in early gestation.

Mineral concentration, ug/g dry	NoVTM[1]		VTM[2]		SEM[4]	*P*-value		
	LG	MG[3]	LG	MG[3]		VTM	GAIN	VTM × GAIN
Selenium	1.64[c5]	1.54[c]	2.87[a]	2.26[b]	0.11	<0.01	<0.01	0.02
Copper	39.35	27.35	196.27	184.21	14.64	<0.01	0.39	0.99
Manganese	9.94[ab]	9.86[ab]	8.46[b]	10.85[a]	0.58	0.66	0.04	0.03
Cobalt	0.20	0.19	0.24	0.21	0.01	0.04	0.26	0.41
Molybdenum	3.58	3.85	3.39	3.95	0.17	0.76	0.02	0.36
Zinc	119.49	120.73	121.95	123.93	6.04	0.63	0.78	0.95

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at a 0.99 lb./heifer/day with no added vitamin and mineral supplement.

[2]VTM: Vitamin mineral supplement was a pelleted product fed at a 0.99 lb./heifer/day (consisting of 113 g of a mineral and vitamin supplement, formulated to deliver similar levels of vitamins and minerals that were fed pre-breeding, and 337 g of a carrier).

[3]Heifers fed a pelleted blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea, targeting a gain of 1.74 lb./day.

[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).

[5] Means within a row and without a common superscript differ significantly (P ≤ 0.05) with respect to VTM × GAIN interaction.

Table 3. Concentrations of trace minerals in fetal liver at day 83 of gestation as influenced by maternal vitamin and mineral (VTM) supplementation and rate of gain (GAIN; low rate, 0.62 lb./day [LG] or moderate rate, 1.74 lb./day [MG]) in early gestation.

Mineral concentration, ug/g dry	NoVTM[1]		VTM[2]		SEM[4]	*P*-value		
	LG	MG[3]	LG	MG[3]		VTM	GAIN	VTM × GAIN
Selenium	4.23	4.25	6.25	6.39	0.46	<0.01	0.86	0.89
Copper	246.01	277.84	298.21	348.91	22.75	0.01	0.08	0.68
Manganese	5.09	4.78	5.19	6.03	0.32	0.04	0.39	0.07
Cobalt	0.07	0.05	0.09	0.06	0.01	0.01	<0.01	0.27
Molybdenum	0.37	0.33	0.36	0.33	0.02	0.79	0.04	0.81
Zinc	440.61	448.24	541.2	563.76	85.35	0.21	0.85	0.93

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at 0.99 lb./heifer/day with no added vitamin and mineral supplement.

[2]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day (consisting of 113 g of a mineral and vitamin supplement, formulated to deliver similar levels of vitamins and minerals that were fed pre-breeding, and 337 g of a carrier).

[3]Heifers fed a pelleted blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea, targeting a gain of 1.74 lb./day.

[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).

evaluated, Mo and Zn; those concentrations were not affected by VTM supplementation.

Interestingly, heifers with moderate rates of gain had greater liver concentrations of Mo than LG heifers, but the opposite relationship was observed in the fetal liver. We may speculate that the protein/energy supplement provided to MG heifers already was providing enough minerals to reach fetal requirements, therefore, unsupplemented heifers (LG) had to mobilize more nutrients to the developing fetus to ensure an adequate supply and consequently liver storage.

Fetal liver stores of trace minerals are important for the neonate because the bovine milk is poor in essential trace minerals (Abdelrahman and Kincaid, 1993). Additionally, an adequate trace mineral reserve is crucial in early life to maintaining health status (Van Emon et al., 2020).

In conclusion, concentrations of Se, Cu, Mn and Co were greater in the fetal liver from VTM dams, while greater concentrations of Mo were observed in the liver of fetuses from LG dams. Concentrations of Zn were not affected by any of the nutritional strategies evaluated. These data provide insights into how nutritional management of beef heifers affect fetal liver stores of trace minerals, which may be beneficial for offspring health and productive performance.

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Forage Production, Quality and Cost Comparison for Selected Varieties of Forage Oats, Forage Barley, Forage Wheat, and Spring Triticale

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Summary

Annual cool-season cereal forages are excellent feed sources for livestock. Determining which forage type to plant becomes the question. Forage oats were the highest-producing cereal crop in 2019, ranging from 2.6 to 3.7 tons/acre. During the drought year in 2020, no differences were found between the forage types: oats, barley, wheat, and triticale.

On average, the spring triticale varieties had the highest crude protein content, with all over 11% at the early dough stage in 2019 and all but BYS FT in 2020. Among the oat varieties, only the forage oat Goliath had a crude protein content greater than 11% in 2019. The forage oats, barley and wheat had a crude protein content between 10 and 11% in 2020.

The forage barley varieties, along with BYS FT spring triticale, contained the lowest levels of acid detergent lignin: less than 4% in 2019 and 2020 with all forage oats less than 4% in 2020. Total digestible nutrients also were highest in the forage barley varieties and BYS FT spring triticale in 2019 and highest in the forage wheat in 2020. The forage oat varieties were the lowest cost forages to produce based on seed cost in 2019, with the Everleaf 126 the lowest at $9.05 per ton of forage. However, in 2020 forage oat, barley and wheat were the lowest cost forage types, with M120 forage oat and Hayes forage barley lowest at $11.03 and $11.93, respectively.

Introduction

Annual forages are a common feedstuff for the livestock industry and are planted each year in North Dakota. Approximately 2.65 million acres of hay were harvested in North Dakota in 2018 (U.S. Department of Agriculture - National Agricultural Statistics Service, 2019), with alfalfa comprising 1.47 million acres and other hay types 1.2 million acres. Annual cereal crops are a popular hay type planted for spring and summer forages.

The awnless forage barley was developed for drier climates in the late 1970s and 1980s. Forage barley can produce good-quality hay but tends to be lower quality than oats and triticale. Barley can be established on well-drained soils and is considered to be the earliest maturing small grain.

Forage oats have been popular in cover crop mixtures and can make exceptional hay with good tonnage and high quality. Oats can be established on well-drained, fertile soils. Many varieties of forage oats have been developed for the northern Plains, with the age of maturity varying among varieties.

Spring triticale is a hybrid developed by crossing wheat and rye. Drought tolerance is the primary advantage spring triticale has over other spring cereal forage crops. Trials conducted in Alberta, Canada, showed spring triticale to be higher yielding than barley or oats from 1995 to 2000 (Salmon et al., 2001).

Study Area

This study was conducted on the Central Grasslands Research Extension Center (CGREC) in 2019 and the Tri-county Agronomy Plot near Wishek in 2020.

Forage oats in the annual cereal forage variety trial near Wishek, ND in 2020. *Photos by Kevin Sedivec*

Table 1. Precipitation and average temperature during the study period May through August at the Central Grasslands Research Extension Center in 2019 and 2020 (NDAWN, 2020).

	Precipitation (inches)		Percent of Normal		Average Temperature (°F)		Departure from Average (°F)	
Month	2019	2020	2019	2020	2019	2020	2019	2020
May	2.99	1.81	122	74	49	51	-5	-3
June	3.47	1.35	102	39	64	67	0	4
July	4.15	2.13	130	66	69	71	-1	2
August	2.52	2.73	109	118	64	69	-4	1

Experimental plots at CGREC were on soils of the Hecla-Ulen soil series, classified as loamy fine sands; and plots at Wishek on soils of the Lehr-Bowdle soil series and classified as loamy (USDA, Natural Resources Conservation Service, 2020). Precipitation was at or above average for May through August in 2019 and well below average for May through July in 2020 (Table 1). In 2019, average temperature was 1 to 5 degrees F cooler than the long-term average for the duration of the study, except in June; and in 2020, 1 to 4 degrees F warmer than the average for the duration of study, except in May (Table 1).

Procedures

- The trial was planted on May 28, 2019, on 25- x 50-foot plots that previously were left fallow, and May 12, 2020, on 5- x 25-foot plots that were previously seeded to wheat.
- All plots at CGREC have been no-till for five years or more. All plots were sprayed with 1 quart of glyphosate + 1 ounce of Sharpen/acre to kill volunteer yellow foxtail (*Setaria pumila*) on the same day the plots were seeded. All plots at Wishek have a history of tillage.
- In 2019, the following varieties were studied: four varieties of forage oats (Goliath, 4010 Everleaf 126, Mustang 120, BYS FO), four varieties of spring triticale (Bunker, Merlin, BYS FT, 141) and three varieties of forage barley (Haymaker, Axcel, Hayes). The Hayes forage barley was heavily invaded by ground squirrels and was not included in the final analysis.
- In 2020, the varieties included: four varieties of forage oats (Goliath, 4010 Everleaf 126, Mustang 120, BYS FO), seven varieties of spring triticale (Bunker, Merlin, BYS FT, Surge, Thor, Flex 719, Exp. 2063) and three varieties of forage barley (Haymaker, Axcel, Hayes), and one variety of forage wheat.
- In 2019, all varieties were seeded at 90 lb/acre.
- In 2020, all forage oat varieties were seeded at 64 lb/acre except Everleaf 126 (80 lb/ac). All forage barley and triticale were seeded at 90 lb/acre except Bunker (100 lb/ac).
- The targeted harvest stage was early dough.
- All nutritional analysis was conducted at the North Dakota State University Nutrition Lab using AOAC standards (AOAC, 2019).
- Total digestible nutrients were determined using acid detergent fiber and the energy equation for grass (98.625-[1.048*ADF]).
- Study design was a randomized block design with four replications and was analyzed used a general linear model in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.). Means were separated using the post hoc test Duncan's Multiple Range Test (Duncan, 1955).

Results

Forage oats were the highest-producing cereal forages in 2019 (Table 2). Everleaf 126 and Goliath were the highest-producing forage oat. We found no difference in yield between the spring triticale and forage barley varieties (Table 2). All forage oat varieties and spring triticale Merlin Max had the best stand establishment, and forage oat varieties Everleaf 126, Goliath and BYS FO were best at suppressing weeds, with yellow foxtail the most common weed.

We found no difference in yield among all forage types and varieties in 2020, except Haymaker forage

Table 2. Days to early dough, plant height, harvest date, and yield for selected varieties of forage oats, forage barley, spring triticale and forage wheat at Central Grasslands Research Extension Center in 2019 and Wishek Tri-county Agronomy Plot in 2020.

		Days to Early Dough		Plant Height (inches)		Harvest Date		Yield (100% DM)[2] (ton/ac)	
Cereal Crop[1]	Variety	2019	2020	2019	2020	2019	2020	2019	2020
FO	Everleaf 126	66	64	41	26	Aug. 8	July 15	3.68[a]	1.99[ab]
FO	Goliath	50	57	48	32	July 23	July 8	3.24[ab]	1.71[ab]
FO	Mustang 120	50	57	48	35	July 23	July 8	2.67[bc]	2.03[ab]
FO	BYS FO	50	57	44	30	July 23	July 8	2.57[bcd]	1.65[ab]
ST	BYS FT	50	57	36	33	July 23	July 8	1.88[cde]	1.69[ab]
ST	Merlin Max	50	57	37	28	July 23	July 8	1.75[de]	1.51[ab]
ST	Bunker	50	57	39	32	July 23	July 8	1.41[e]	1.40[b]
ST	141	50	57	41	---	July 23	July 8	1.31[e]	------
FB	Axcel	56	57	27	23	July 24	July 8	1.45[e]	2.00[ab]
FB	Haymaker	56	57	31	27	July 24	July 8	1.34[e]	2.17[a]
FB	Hayes	---	57	---	24	---------	July 8	-------	1.93[ab]
ST	Flex 719	---	64	---	39	---------	July 15	-------	1.46[ab]
ST	Surge	---	57	---	32	---------	July 8	-------	1.58[ab]
ST	Thor	---	57	---	34	---------	July 8	-------	1.44[ab]
ST	Exp. 2063	---	64	---	31	---------	July 15	-------	1.88[ab]
FW	3099	---	64	---	25	---------	July 15	------	1.80[ab]

[1] FO = forage oat, ST = spring triticale, FB = forage barley, FW = forage wheat.
[2] Varieties with the same letter (a, b, c, d, e) in a column are not statistically different (P>0.05).

barley was greater than Bunker triticale (Table 2).

Forage barleys Axcel and Haymaker, and spring triticale BYS FT had the highest total digestible nutrient (TDN) levels in 2019 (Table 3). Forage wheat had the highest TDN content in 2020 (Table 3).

The Everleaf 126 forage oat was the poorest-performing forage in terms of crude protein, with Bunker triticale the superior forage in this trial in 2019. All the triticale varieties except 141 had a crude protein content greater than 11% in 2019 and BYS FT in 2020 (Table 3).

The forage barley varieties contained the lowest levels of acid detergent lignin, followed by forage oat BYS FO; all three were less than 4% in 2019 and 2020 (Table 3).

All forage cereal varieties provided the minimum requirements of phosphorus for 1,200-pound gestating and early lactating beef cattle in both years (National Research Council, 2016).

All forage cereal varieties were deficient of calcium for the minimum requirements for gestating 1,200-pound beef cattle (National Research Council 2016) in 2019 (Table 3). However, all the oat and barley varieties, and triticale varieties Merlin Max and Flex 719 provided the minimum levels in 2020.

All forage cereal varieties were analyzed for potassium nitrate to determine if toxic levels occurred. With 2020 considered a drought year, nitrate toxicity in feeds fed to livestock can be more common in cereal forages, especially oats.

Forages with potassium nitrate levels in a range of 0 to 7,220 ppm are considered safe for livestock (Block,

Table 3. Forage quality content for selected varieties of forage oats, forage barley, spring triticale and forage wheat at Central Grasslands Research Extension Center in 2019 and Wishek Tri-county Agronomy Plot in 2020.

		Crude Protein[1] (%)		Acid Detergent Fiber[1] (%)		Acid Detergent Lignin[1] (%)		Total Digestible Nutrients[2] (%)		Calcium[3] (%)		Phosphorus[3] (%)	
Cereal Crop[1]	Variety	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
FO	Everleaf 126	8.8^{b}	10.5^{d}	35.2^{ab}	32.9^{bcd}	4.6^{a}	3.8^{fgh}	61.9^{ab}	64.8^{abc}	0.27	0.40^{a}	0.21	0.26^{bcde}
FO	Mustang 120	9.5^{ab}	10.1^{d}	35.2^{ab}	34.2^{abcd}	4.2^{ab}	3.9^{efg}	61.8^{ab}	63.9^{abcd}	0.24	0.29^{bcde}	0.21	0.19^{h}
FO	BYS FO	9.9^{ab}	10.0^{d}	35.5^{ab}	34.9^{abc}	4.0^{b}	3.8^{fgh}	61.4^{ab}	63.8^{bcd}	0.27	0.33^{b}	0.27	0.23^{efgh}
FO	Goliath	11.0^{ab}	10.0^{d}	37.2^{a}	32.1^{cd}	4.5^{ab}	3.7^{ghi}	59.7^{b}	65.4^{ab}	0.22	0.29^{bcde}	0.21	0.20^{gh}
ST	BYS FT	11.0^{ab}	10.2^{d}	33.7^{ab}	34.2^{abcd}	4.3^{ab}	4.0^{edf}	63.4^{ab}	63.9^{abcd}	0.23	0.22^{fg}	0.27	0.24^{cdef}
ST	Bunker	12.0^{a}	11.2^{bcd}	35.8^{ab}	34.6^{abcd}	4.3^{ab}	4.4^{bc}	61.1^{ab}	63.6^{abcd}	0.22	0.25^{ef}	0.27	0.24^{cdef}
ST	Merlin Max	11.4^{ab}	11.9^{bc}	36.6^{ab}	35.3^{abc}	4.7^{a}	4.6^{b}	60.2^{ab}	63.1^{bcd}	0.27	0.31^{bcd}	0.27	0.28^{bc}
ST	141	10.4^{ab}	--------	36.7^{a}	-----	4.4^{ab}	----	60.2^{b}	------	0.25	-----	0.23	-----
FB	Axcel	10.5^{ab}	10.4^{d}	32.3^{b}	32.3^{bcd}	3.5^{c}	3.5^{hi}	64.8^{a}	65.2^{abc}	0.28	0.42^{a}	0.22	0.22^{efgh}
FB	Haymaker	9.7^{ab}	10.7^{cd}	33.4^{ab}	34.4^{abcd}	3.4^{c}	3.4^{i}	63.7^{ab}	63.8^{abcd}	0.28	0.40^{a}	0.22	0.21^{fgh}
FB	Hayes	-------	10.3^{d}	-------	33.1^{abcd}	-----	3.4^{i}	-------	64.7^{abcd}		0.32^{bc}		0.24^{defg}
ST	Flex 719	-------	13.5^{a}	-------	32.6^{bcd}	-----	4.2^{cd}	-------	65.0^{abc}		0.32^{bc}		0.35^{a}
ST	Surge	-------	12.3^{ab}	-------	35.9^{ab}	-----	4.4^{bc}	-------	62.7^{cd}		0.26^{cdef}		0.28^{bc}
ST	Thor	-------	12.3^{ab}	-------	35.6^{abc}	-----	4.1^{cde}	-------	62.9^{bcd}		0.26^{def}		0.29^{b}
ST	Exp. 2063	-------	11.0^{cd}	-------	36.8^{a}	-----	5.0^{a}	-------	62.1^{d}		0.21^{fg}		0.27^{bcd}
FW	3099	-------	11.0^{cd}	-------	30.9^{d}	-----	4.2^{cde}	-------	66.2^{a}		0.19^{g}		0.24^{cdef}

[1] FO = forage oat, ST = spring triticale, FB = forage barley, FW = forage wheat.
[2] Varieties with the same letter (a, b, c, d, e, f, g, h) within a column are not statistically different (*P*>0.05).
[3] We found no difference (*P*>0.05) among varieties in calcium or phosphorus content in 2019.

Table 4. Nitrate toxicity (potassium nitrate) levels for selected varieties of forage oats, forage barley, spring triticale and forage wheat at the Wishek Tri-county Agronomy Plot in 2020.

Cereal Crop[1]	Variety	Potassium Nitrate (ppm)[2]
FO	Everleaf 126	4500[cd]
FO	Goliath	5500[bcd]
FO	Mustang 120	8500[ab]
FO	BYS FO	9500[a]
ST	BYS FT	<2500[d]
ST	Merlin Max	3380[d]
ST	Bunker	<2500[d]
FB	Axcel	2750[d]
FB	Haymaker	5880[abcd]
FB	Hayes	3750[d]
ST	Flex 719	4000[d]
ST	Surge	4630[cd]
ST	Thor	4750[cd]
ST	Exp. 2063	7750[abc]
FW	3099	<2500[d]

[1] FO = forage oat, ST = spring triticale, FB = forage barley, FW = forage wheat.

[2] Varieties with the same letter (a, b, c, d) are not statistically different (*P*>0.05).

2020). Forage varieties with a mean potassium nitrate level over 7,220 in 2020 included forage oats Mustang 120 and BYS FO, and triticale Exp. 2063 (Table 4).

Because input costs were the same for planting and harvesting all forage cereal crops studied in 2019 and 2020, the only variable would be seed cost. The cost to produce 1 ton/acre of forage was lowest for all four forage oat varieties in 2019, ranging from $9.05 per ton for Everleaf 126 forage oats to $12.61 per ton seed cost for BYS FO forage oats. The seed cost to produce 1 ton/acre of Merlin Max spring triticale was $12.37. All other varieties ranged from $19.15 to $34.35 per ton for seed cost (Figure 1).

In 2020, cost associated directly from seed price to produce a ton of forage per acre was lowest for oats and barley (Figure 2). Only the triticale variety Merlin Max was at similar costs to oats and barley in 2020.

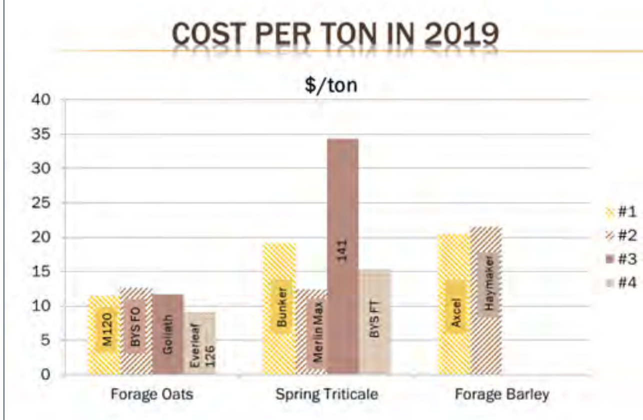

Figure 1. Cost to produce a ton of forage based on seed price in 2019.

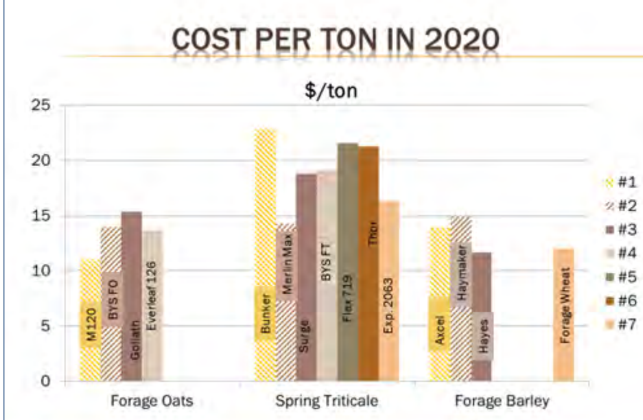

Figure 2. Cost to produce a ton of forage based on seed price in 2020.

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Forage Production and Quality for Selected Varieties of Corn Silage

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Summary

Corn silage is an important feedstuff for North Dakota cattle producers economically and nutritionally. However, deciding which variety to grow can be difficult without local data. The 26 corn silage varieties in this trial ranged in dry-matter yield from 6,717 to 7,885 pounds/acre.

The highest-producing variety was Dairyland 3808, while the variety with the highest dry-matter percentage was Mycogen 0526AM. The crude protein levels among all varieties ranged from 8.4% to 9.5%, and the highest-performing variety was Mycogen TMF91Q.

We found varietal differences ($P \leq 0.05$) for calcium, phosphorus, magnesium and potassium but not sulfur. Total digestible nutrients (TDN) ranged from 71.6% to 73.6%, and the two varieties with the highest TDN were Dairyland 3099RA and Pioneer P9998Q.

Introduction

Cattle production is a very important part of the North Dakota economy. Production has been stable at about 1.8 million cattle, including calves (U.S. Department of Agriculture, National Agriculture Statistics Service [USDA NASS], 2020).

The largest expense for most cattle producers in North Dakota and across the northern Great Plains is winter feed. Producers not only need to provide enough dry matter but also need to provide forage of adequate quality.

Many producers in North Dakota choose to produce high-quality feed for their livestock in the form of silage. In 2019, approximately 140,000 acres of silage were harvested, producing 2.73 million tons of feed (USDA NASS, 2020) at a value of $122.9 million.

Just as a farmer selects wheat, grain corn or soybean varieties based on yield data, a good cattle producer should be selecting silage varieties based on field trial studies. The issue with this concept is that most of the published corn silage data does not come from North Dakota, creating decisions based on findings that may not fit the region. The intent of this trial was to provide producers with accurate, local silage data gathered in North Dakota.

Study Area

This corn silage trial was conducted at the NDSU Central Grasslands Research Extension Center near Streeter, N.D. Experimental plots were grown on Wabek-Appam soils, which are classified as gravelly sandy loam soils on 6% to 9% slopes (USDA, Natural Resource Conservation Service, 2021). Monthly precipitation was 62% below the long-term average, and below average four of the five months of the trial (Table 1). Average monthly temperature ranged from 3 degrees below average to 4 degrees above average, with three out of the five months having temperatures above average (North Dakota Agricultural Weather Network [NDAWN], 2020).

Table 1. Monthly precipitation and average monthly temperature during the corn silage variety trial at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020. (NDAWN, 2020)

Month	Precipitation	Departure from Average	Average Temperature	Departure from Average
	-------------inches-------------		----------------F°---------------	
May	1.81	-0.64	51	-3
June	1.35	-2.06	67	+4
July	2.13	-1.07	71	+2
August	2.73	+0.42	69	+1
September	0.31	-1.73	57	0
Total	**8.33**	**-5.08**	**63**	**+0.5**

Methods

- The trial was planted on May 28, 2020, using a John Deere 1700 MaxEmerge Plus (eight rows, 30-inch spacing). Seeds were planted 2 inches deep at a population of 26,000/acre.
- Nutrients were supplied based on soil testing and required started fertilizer (40 pounds of phosphorus and 20 pounds of potassium per acre) and an application of 200 pounds/acre of urea.
- Plots consisted of two rows, 400 feet in length, which is equal to 0.05 acre. Twenty-six varieties were replicated four times (Table 2).
- Weed control was accomplished through herbicides because we practice no-till farming at the station. Preplant burn-down was accomplished by applying 1 quart of glyphosate with 1 ounce of Sharpen® (BASF Corp.) per acre. In-season weed control consisted of 1 quart of glyphosate with 15 ounces of Armezon® PRO (BASF Corp.) per acre.
- Plots were harvested on Sept. 7, 2020. Plots were harvested with a two-row Gehl corn chopper that shot the silage directly into a Knight mixer/feed wagon equipped with a digital scale. The silage was mixed with the reel as the plot was harvested. After chopping the whole plot into the wagon, the tractor was stopped and weight was recorded. A composite sample of each plot was taken as the wagon was unloaded and used to determine forage quality.
- Samples were sent to Dairyland Laboratories Inc. for nutritional quality testing using wet chemistry analysis.
- Data were analyzed as a completely randomized design using the general linear model in SAS 9.4 (SAS Institute, Cary, N.C.). Significant differences of least square means at the $P \le 0.05$ level were separated using t-tests.

Results

Corn varieties were analyzed for harvest weight, yield, moisture, dry matter (DM), crude protein (CP), acid detergent fiber (ADF), calcium, phosphorus, magnesium, potassium, sulfur, total digestible nutrients (TDN), net energy for growth (NeG), net energy for maintenance (NeM), and net energy of lactation (Nel 3x). We found significant differences among varieties for all tested parameters except sulfur.

Table 2. List of varieties with company and relative maturity (RM).

Company	Variety	RM
Croplan	CP 3300 SRR	93
Croplan	CP 5000 SAS3122	110
Croplan	CP 4100 SVT2P	101
Croplan	CP 3899 VT2P	98
Pioneer	P 9608Q	96
Pioneer	P 9998Q	99
Pioneer	P 0157 AMXT	101
Pioneer	P 0031Q	103
NK	E095D3	95
NK	E105	105
NK	NK 0440	104
Integra	5500 STP	105
Integra	4810 STP	98
Integra	4550 STP	95
Integra	5191	101
Legacy	L4545	100
Legacy	L5467	104
Legacy	L4567	100
Dairyland	3808	108
Dairyland	4545Q	105
Dairyland	3211	111
Dairyland	3099RA	98
Mycogen	TMF91Q	91
Mycogen	0526AM	95
Mycogen	TMF94L37	94
Mycogen	1247AMXT	102

Table 3 presents all of the harvest and yield data. The top 11 varieties ranged in yield from 6,717 to 7,885 pounds/acre. Variety 3808 was the highest yielding and posted the highest harvest weight; however, it had the third lowest dry-matter content. Variety 3808 yielded 7,885 pounds/acre and was not different (P > 0.05) from the next 10 highest yielding varieties. The three highest yielding varieties were 3808, P998Q and CP3899VT.

Table 3. Least significant means of wet weight yield, dry matter yield and moisture.

Variety	Wet Weight Yield[a]	100% Dry-matter Yield	Moisture Content
	----------------------Pounds/acre----------------------		-----%------
3211	25,145 a	6,409 cdefgh	69.1 abc
3808	25,435 a	7,885 a	69.2 abc
5191	22,898 abc	6,539 bcdefg	67.5 abc
0526AM	16,522 f	6,306 defgh	60.0 d
1247AMXT	20,942 abcdef	6,410 cdefgh	64.4 abcd
3099RA	17,754 def	7,180 abcde	62.8 cd
4545Q	22,029 abcd	6,091 efgh	66.5 abcd
4550STP	19,420 bcdef	5,654 gh	64.7 abcd
4810STP	21,667 abcde	7,069 abcdef	64.4 abcd
5500STP	20,652 abcdef	6,506 bcdefg	65.2 abcd
CP3300SRR	20,507 abcdef	7,247 abcd	64.5 abcd
CP3899VT2P	21,522 abcde	7,516 abc	67.0 abc
CP4100SVT2P	23,696 ab	6,147 defgh	67.7 abc
CP5000SAS3122	22,826 abc	6,071 efgh	67.8 abc
E095D3	18,261 cdef	6,717 abcdefg	63.2 bcd
E105	22,102 abcd	5,340 h	70.6 a
L4545	16,957 ef	7,103 abcdef	64.7 abcd
L4567	22,029 abcd	7,318 abcd	66.7 abcd
L5467	20,072 bcdef	6,264 defgh	62.6 cd
NK0440	22,536 abcd	6,041 fgh	69.7 ab
P0031Q	19,928 bcdef	6,248 defgh	65.3 abcd
P0157AMXT	21,087 abcdef	6,575 bcdefg	65.6 abcd
P9608Q	20,942 abcdef	6,876 abcdef	64.1 abcd
P9998Q	18,551 cdef	7,610 ab	62.8 cd
TMF91Q	19,493 bcdef	6,415 cdefgh	65.0 abcd
TMF94L37	18,841 bcdef	6,873 abcdef	63.3 bcd
LSD	**226.68***	**1167.6***	**6.54668***

[a] Values in the same column followed by the same letter are not significantly different by the t-test at the 95% level of confidence.

Table 4 (next page) presents a selection of feed quality parameters tested for each variety. Crude protein (CP) content ranged among varieties from 8.4% to 9.5% of dry matter, with a least significant difference (LSD) of 0.66. Variety TMF91Q had the highest CP and was greater ($P \leq 0.05$) than the two lowest varieties. Varieties L4567 and 3099RA had the second and third highest CP levels, respectively, but were only greater ($P \leq 0.05$) than CP4100SV, which had the lowest CP content.

Acid detergent fiber (ADF) ranged from 20.32% to 23.21%, with an LSD of 2.25 (Table 4). The top three varieties with the lowest ADF content were 3099RA, P9998Q and P0157AMXT, respectively. The ADF content of these three varieties was lower ($P \leq 0.05$) than the four highest ADF varieties: 4550STP, TMF91Q, 4810STP and 5500STP.

The silage varieties were tested for composition of five minerals and we found significant varietal differences for all minerals except sulfur. Table 4 shows the mean of each variety for calcium, phosphorus, magnesium and potassium. Calcium means ranged from 0.20% (1247AMXT) to 0.29% (E105), with an LSD of 0.071. E105 was only significantly greater ($P \leq 0.05$) than the five lowest performing varieties for calcium composition.

Phosphorus, magnesium and potassium all showed higher levels of variability among varieties. Varieties P0031Q and NK0440 had the highest phosphorus levels and were greater ($P \leq 0.05$) than the lowest 12 varieties.

With magnesium, variety TMF91Q had the highest level and was greater ($P \leq 0.05$) than the lowest 12 varieties; however, the second highest variety was only greater ($P \leq 0.05$) than the three lowest varieties.

Potassium showed the greatest differences among variety, where CP3300SR was greater than 23 of the 26 varieties. Varieties TMF91Q and 4810STP, which had the second and third highest potassium levels, were greater than the 10 lowest varieties.

Varieties 3099RA and P9998Q had the highest levels of total digestible nutrients (TDN). However, these varieties were only greater ($P \leq 0.05$) than the three lowest varieties. TDN values ranged from 71.59% to 73.62%, with an LSD of 1.47.

Net energy was tested for lactation, growth and maintenance. We saw varietal differences with all three measurements of energy, but we decided to report only net energy of growth (NeG). The varieties P0157AMX, 3099RA, E095D3, E105 and CP5000SA had the highest NeG levels at 48.04, 48.01, 47.64, 47.62, and 47.62 mega calories per hundredweight (Mcal/cwt), respectively.

The NeG values ranged from 45.27 to 48.04 Mcal/cwt, with an LSD of 1.14. The top two performing varieties were greater ($P \leq 0.05$) than the lowest eight varieties, while the next three top varieties are only greater ($P \leq 0.05$) than the lowest three.

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Photos by Kevin Sedivec

Table 4. Means for crude protein (CP), acid detergent fiber (ADF), calcium, phosphorus, magnesium, potassium, TDN and NeG.

Variety	CP	ADF	Calcium	Phosphorus	Magnesium	Potassium	TDN	NeG
	----------% Dry Matter----------							---Mcal/cwt---
3211	9.30 ab[a]	22.25 abcd	0.24 abc	0.21 abcd	0.22 bcd	1.17 bcd	72.27 abcd	46.90 abc
3808	8.91 abc	22.18 abcd	0.28 abc	0.21 abcde	0.24 abc	1.12 bcde	72.34 abcd	47.01 abc
5191	9.03 abc	22.85 abc	0.25 abc	0.19 de	0.24 abc	1.22 bc	71.84 bcd	46.35 bcd
0526AM	9.18 ab	21.26 abcd	0.21 bc	0.21 abcd	0.19 cd	0.98 e	72.96 abcd	47.54 ab
1247AMXT	8.78 bc	21.12 abcd	0.20 c	0.20 bcde	0.21 bcd	1.17 bcd	73.06 abcd	47.36 abc
3099RA	9.33 ab	20.32 d	0.25 abc	0.20 bcde	0.23 abcd	1.12 cde	73.62 a	48.01 a
4545Q	9.13 ab	21.54 abcd	0.24 abc	0.20 abcde	0.21 bcd	1.21 bc	72.76 abcd	46.98 abc
4550STP	8.98 abc	23.21 a	0.22 abc	0.18 e	0.21 bcd	1.17 bcd	71.59 d	46.45 bcd
4810STP	9.05 abc	23.11 ab	0.20 bc	0.19 e	0.22 abcd	1.30 ab	71.66 cd	46.01 cd
5500STP	8.91 abc	22.98 ab	0.25 abc	0.22 ab	0.24 ab	1.20 bc	71.76 cd	46.39 bcd
CP3300SRR	9.08 abc	22.83 abc	0.22 abc	0.21 abcde	0.22 abcd	1.44 a	71.86 bcd	45.99 cd
CP3899VT2P	8.86 abc	20.73 bcd	0.25 abc	0.21 abcde	0.23 abcd	1.01 de	73.33 abc	47.59 ab
CP4100SVT2P	8.40 c	22.35 abcd	0.25 abc	0.18 e	0.20 bcd	1.06 cde	72.20 abcd	46.29 bcd
CP5000SAS3122	8.90 abc	21.22 abcd	0.25 abc	0.20 bcde	0.21 bcd	1.09 cde	72.99 abcd	47.62 ab
E095D3	9.12 abc	21.15 abcd	0.27 abc	0.21 abcd	0.20 bcd	1.09 cde	73.04 abcd	47.64 ab
E105	9.17 ab	22.23 abcd	0.29 a	0.21 abcde	0.22 abcd	1.09 cde	72.28 abcd	47.62 ab
L4545	9.20 ab	20.97 abcd	0.22 abc	0.20 bcde	0.21 bcd	1.23 bc	73.17 abcd	47.56 ab
L4567	9.40 ab	22.41 abcd	0.21 bc	0.19 e	0.23 abcd	1.20 bc	72.15 abcd	46.95 abc
L5467	8.81 abc	21.95 abcd	0.23 abc	0.20 bcde	0.23 abcd	1.02 de	72.48 abcd	46.95 abc
NK0440	9.09 abc	21.24 abcd	0.26 abc	0.23 a	0.23 abcd	1.13 bcde	72.97 abcd	47.54 ab
P0031Q	9.23 ab	21.20 abcd	0.24 abc	0.23 a	0.21 bcd	1.10 cde	73.00 abcd	47.38 abc
P0157AMXT	9.28 ab	20.43 cd	0.20 bc	0.22 abc	0.19 d	1.12 bcde	73.54 ab	48.04 a
P9608Q	9.00 abc	21.46 abcd	0.23 abc	0.19 cde	0.19 cd	1.16 bcd	72.82 abcd	47.29 abc
P9998Q	8.96 abc	20.36 d	0.24 abc	0.21 abcd	0.22 abcd	1.07 cde	73.59 a	47.62 ab
TMF91Q	9.46 a	23.17 ab	0.28 ab	0.21 abcde	0.26 a	1.31 ab	71.62 cd	46.42 bcd
TMF94L37	9.33 ab	22.00 abcd	0.23 abc	0.20 bcde	0.22 abcd	1.14 bcde	72.44 abcd	45.27 d
LSD	0.66*	2.25*	0.071*	0.027*	0.044*	0.14*	1.47*	1.14*

[a] Values in the same column followed by the same letter are not significantly different by the t-test at the 95% level of confidence.

Forage Production, Livestock Performance, Soil Nutrients and Cost Comparison for Cover Crops Using a Livestock/Cropping Integrated System

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Summary

The 2020 drought had a dramatic negative impact on cover crop forage production. Due to low production, hay production and the grazing stocking rate were affected negatively, creating a year when both were not economical options, compared with traditional alternatives. However, both grazing use treatments added nitrogen and organic matter to the soil profile after one season of grazing.

This project will be repeated in 2021 to assess a longer-term economic impact as well as assess soil health benefits, physical and chemical. The final year of the study will assess the impacts of integrated grazing cover crops on farmland and its impact on a cash crop in 2022.

Introduction

Cover crops have gained popularity as a practice implemented by producers across the U.S. According to the U.S. Department of Agriculture's Census of Agriculture, 15.4 million acres were planted to cover crops in 2017, up 50% from the 10.3 million acres in 2012 (UDSA 2019; USDA, 2014).

North Dakota is no exception to this trend, with producers incorporating cover crops to improve soil health and increase crop production (USDA, 2019; Conservation Technology Information Center [CTIC], 2017). Despite the ecological benefits of incorporating cover crops into a system, the economic benefits may not be realized if livestock are not incorporated into the system (Costa et al., 2014; Franzluebber and Stuedemann, 2015).

The benefits of integrated crop and livestock systems (ICLS) include enhanced nutrient cycling as well as reduced inputs and livestock feeding costs. Livestock management decisions, such as stocking rates, stock density and utilization, have the potential to impact the environmental and economic sustainability of ICLS.

The majority of research evaluating ICLS has been conducted in regions characterized by humid climates, and little information is available to producers in the northern Great Plains to help make these management decisions. This producer-led demonstration project will aid in the development of best management practices for managing grazing livestock in ICLS to enhance soil health, livestock production, crop production and economic sustainability.

Our study objective is to determine the impact of an ICLS using two years of grazed winter cereal followed by grazed cover crop with two different stocking rates followed by a cash grain crop on soil health, livestock performance and economic return.

Study Area

This study was conducted on the Central Grasslands Research Extension Center (CGREC) in 2020. Experimental plots at the CGREC were on gravelly sandy loam soils (USDA-Natural Resources Conservation Service, 2020). Precipitation was below normal (May and June) prior to seeding the cover crop and below normal while the cover crop grew in July 2020 (Table 1). The average temperature was 3 F cooler than the long-term average in May and above average from June through August (Table 1).

Table 1. Precipitation and average temperature during the study period May through September at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020 (North Dakota Agricultural Weather Network, 2020).

Month	Precipitation (inches)	Percent of Normal	Average Temperature (°F)	Departure from Average (°F)
May	1.81	74	51	-3
June	1.35	39	67	4
July	2.13	67	71	2
August	2.73	118	69	1
September	0.31	15	57	-1
Total	**8.33**	**63**		

Procedures

- Four treatments – grazing at two stocking rates (50% use and 70% use), haying and non-use – were tested on a nine-way cover crop mixture seeded after a winter cereal crop that was grazed from May 11-June 8 (see Winter Cereal Crop article, Sedivec et al.).
- The study design is a randomized block design, with a split plot design imposed on the non-use treatment, creating an even split for the non-use and hayed treatment.
- The nine-way cover crop mixture was seeded on nine 10-acre fields on June 13, 2020, with each treatment replicated three times.
- The nine-way cover crop mixture included forage oats (18 pounds/acre), sorghum sudangrass (3 pounds/acre), German millet (2 pounds/acre), sunflowers (1.5 pounds/acre), forage radish (1 pound/acre), kale (0.75 pound/acre), hybrid turnip (0.75 pound/acre), brown flax (2 pounds/acre) and forage peas (10 pounds/acre).
- We analyzed for significance using a general linear model in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.). Means were separated using the post hoc test Duncan's Multiple Range Test (Duncan, 1955).
- All fields have been in no-till for 14 years or more. No fertilizer was applied and all fields were sprayed with 1 quart of glyphosate + 1 ounce of Sharpen/acre to kill the winter cereal and any volunteer yellow foxtail (*Setaria pumila*) prior to seeding.
- Each field was grazed with yearling pregnant heifers from Aug. 25 through Sept. 22, 2020.
- All fields were clipped using six 0.25 meter^2 frames spread evenly across each field (54 frames total) on Aug. 21, 2020, to determine forage production and stocking rate.
- The stocking rate for the 50% and 75% use treatments was 0.87 heifer per acre. The fields with the 50% degree of use had a higher average forage production at 1,854 pounds/acre versus the 75% degree of use, having an average of 1,380 pounds/acre.
- Livestock performance was determined by collecting two-day weights prior to turnout and after grazing ended.
- The hayed treatment was cut Sept. 24 (103 days after planting, 72 days after germination) and baled Sept. 26, 2020.
- End-of-season residue and degree of use was determined by clipping each grazed field using six 0.25 m^2 frames spread evenly across each field (36 frames total) on Sept. 23, 2020.
- Soils samples were collected: 1) Sept. 6, 2019 – just prior to seeding the winter cereals, 2) May 5, 2020 – prior to cattle grazing the winter cereals, and 3) Nov. 6 – six weeks after the cattle finished grazing the cover crop and pre-soil freezing.

Results

Average forage production for the cover crop mixture prior to implementing the grazing treatments was 1,617 pounds/acre (Figure 1). The degree of use was 38% and 56% on the 50% and 75% degree of use treatments, respectively (Figure 1). We missed our targeted grazing use levels by 24% and 25% on the 50% and 75% degree of use treatments, respectively. Yearling heifer performance was surprisingly high for both treatments. Heifers gained 1.98 and 1.61 pounds/day on the 50% and 75% grazing use treatments, respectively (Figure 2). Both grazing use treatments also improved body condition by at least a 0.4 score.

Hay production averaged 1,430 pounds/acre. Total cost for the cover crop stand was $72.01, with no economic return (Figure 3). If we put the total costs to hay production, the breakeven was $93.52/ton. Because the degree of use treatments were stocked at the same rate (rates were adjusted by field forage production), cost per head was $74.24, or $2.65 per head/day for each treatment (Figure 3).

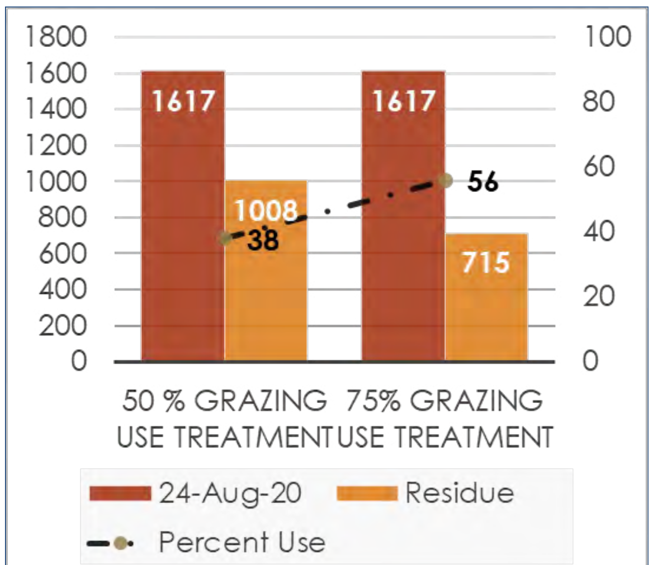


Figure 1. Forage production (lb/ac), residue after grazing (lb/ac) and degree of use (percent) by cover crop grazing treatment at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

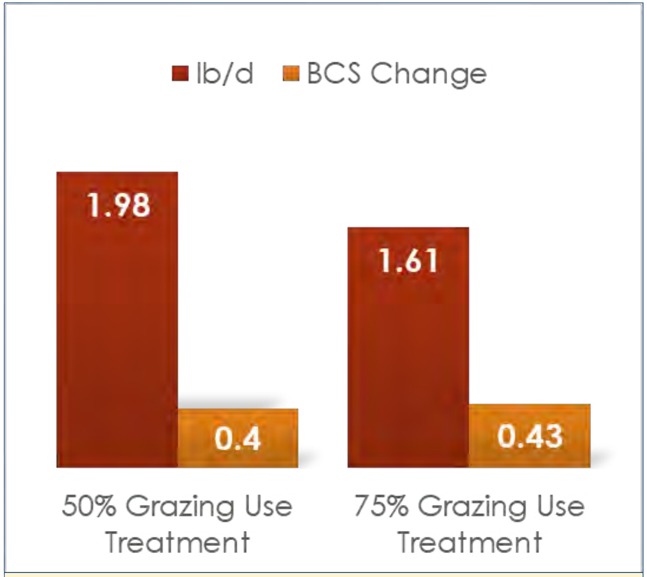


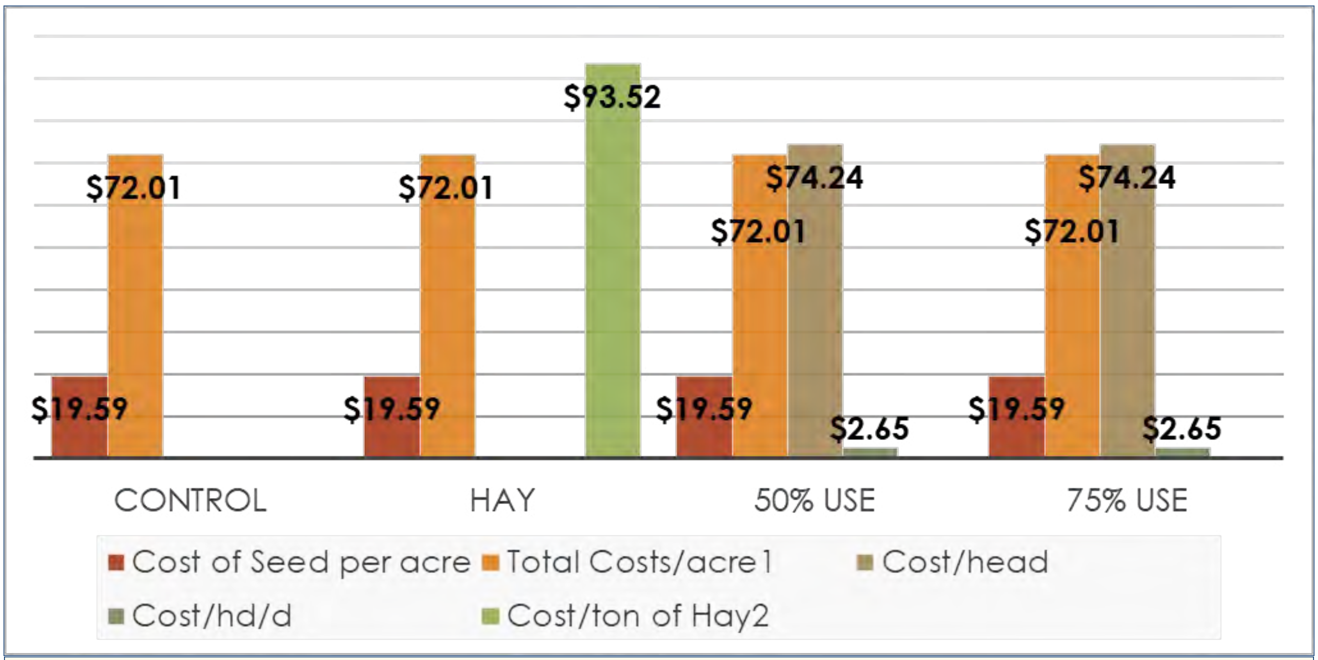
Figure 2. Yearling heifer performance and change in body condition score (BCS) by degree of grazing use treatment (28-day grazing period) at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

Although neither hay nor livestock production were economical, based on the value of the hay (about $50/ton; AllHay.com) or cost to dry lot feed a heifer ($2.05/day; Lardy, 2018), they did provide an income versus planting a cover crop without use.

Potassium increased on all treatments from an average 126 parts per million (ppm) to 229 ppm from Sept. 6, 2019, to Nov. 6, 2020. Phosphorus also increased on all treatments from Sept. 6, 2019, (treatment averages were 9 ppm) through May 5, 2020 (treatment averages were 32 ppm); however, phosphorus declined on all treatments except the 50% degree of use treatment by Nov. 6, 2020 (treatment averages were 25 ppm).

Nitrogen declined on all treatments from Sept. 6, 2019, through May 5, 2020 (Figure 4). However, nitrogen increased on both grazing treatments from May 5, 2020, through Nov. 6, 2020, while decreasing on the non-use and hayed treatments (Figure 4).

Organic matter increased on all treatments except the hayed treatments throughout the study period (Figure 5). Organic matter on the hayed treatment was the same (2.9%) on Sept. 6, 2019, and Nov. 6, 2020.



[1] Total costs per acre includes custom no-till seeding rate ($17.80/acre), custom herbicide application ($6.57/acre), actual cost of herbicide (glyphosate + Sharpen; $5.60/acre), land rent ($22.45/acre) and seed cost ($19.59/acre; USDA, National Agricultural Statistics Service.

2020). Land rental rate would be $44.90/acre. We dedicated 50% of the cost toward the winter cereal, 50% for the second crop (cover crop). Grazing period: Aug. 25-Sept. 22 (28 days).

[2] Cost per ton of hay includes total costs per acre + cost for swathing ($9.66/acre) and baling ($9.47/acre).

Figure 3. Costs of seed per acre, total costs per acre, production cost of hay (tons/acre), production cost per head of cattle and cost to graze a cow per day (head/day) at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

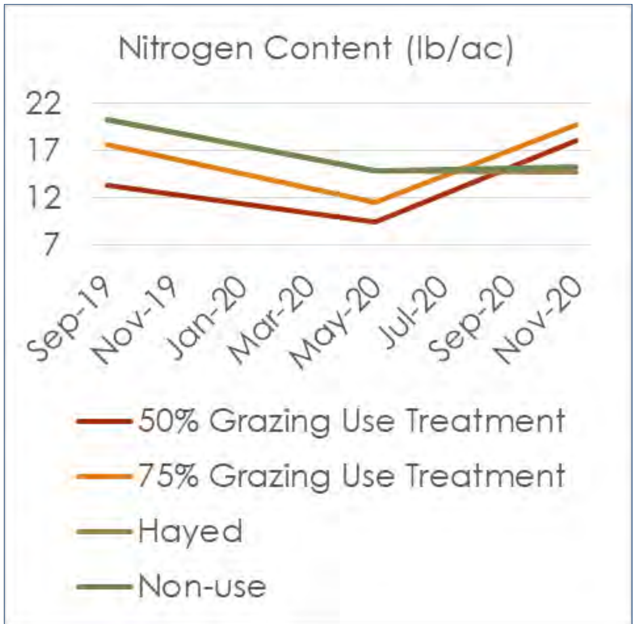


Figure 4. Nitrogen content (pounds/acre) pretreatment in September 2019 through the completion of the cover crop grazing in November 2020 by treatment at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

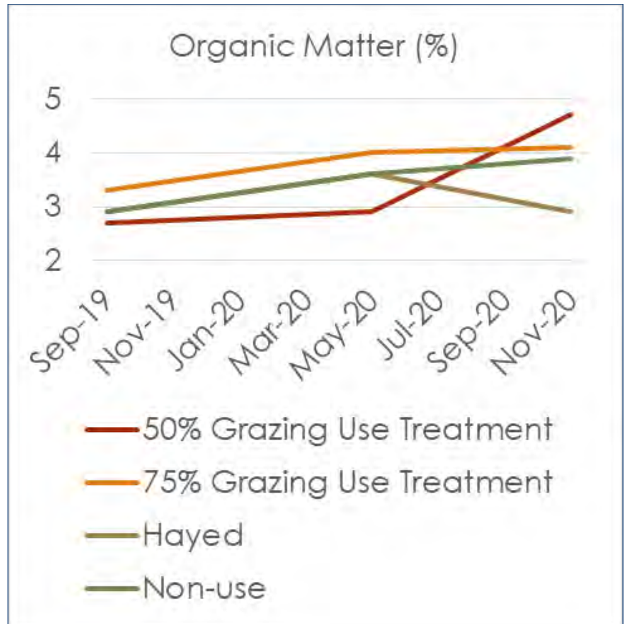


Figure 5. Organic matter (%) pretreatment in September 2019 through the completion of the cover crop grazing in November 2020 by treatment at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

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Grazing Management Practices to Enhance Soil Health in the Northern Great Plains

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Summary

The objective of this project is to identify the impacts of livestock grazing management on the environmental and economic sustainability of an integrated crop and livestock system. Our focus is on the influence of stock density and forage utilization on 1) soil physical and chemical properties, 2) crop production, 3) livestock production and 4) economics.

Introduction

Cover crops have gained popularity as a practice implemented by producers across the U.S. According to the U.S. Department of Agriculture (USDA) Census of Agriculture, 15.4 million acres were planted to cover crops in 2017, up 50% from the 10.3 million acres in 2012 (USDA, 2019; USDA, 2014). North Dakota is no exception to this trend, with producers incorporating cover crops to improve soil health and increase crop production (USDA, 2019; Conservation Technology Information Center [CTIC], 2017). Despite the ecological benefits of incorporating cover crops into a system, the economic benefits may not be realized if livestock are not incorporated into the system (Costa et al., 2014; Franzluebber and Stuedemann, 2015).

The benefits of integrated crop and livestock systems (ICLS) include enhanced nutrient cycling as well as reduced inputs and livestock feeding costs. The majority of research evaluating ICLS has been conducted in regions characterized by humid climates. Research on the ecological impacts of ICLS in semi-arid ecosystems, such as the northern Great Plains, is limited (Faust et al., 2018).

Livestock management decisions, such as stocking rates, stock density and utilization, have the potential to influence the environmental and economic sustainability of ICLS. Limited information is available to producers in the northern Great Plains to help make these management decisions. This producer-led demonstration project will aid in the development of best management practices for managing grazing livestock in ICLS to enhance soil health, livestock production, crop production and economic sustainability.

Procedures

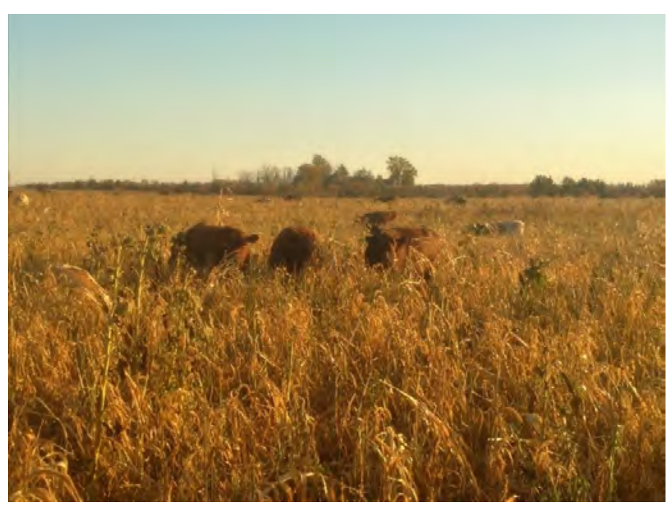
A three-year ICLS project was initiated during the spring of 2020. NDSU Extension collaborated with producers to establish six demonstration sites in central North Dakota, along with a host site on the main campus of NDSU. An annual forage crop was subjected to two grazing density treatments: 1) moderate and 2) high.

Additionally, two forage utilization rates were evaluated: 1) 50% and 2) 75%. A non-grazed treatment served as the control. Treatments will be imposed for two years, followed by a cash crop.

Each location was developed to test grazing density treatments in a split-plot design. Three producers demonstrated the high stock density at two utilization rates (50% and 75%), while three producers demonstrated the moderate stock density at the same two utilization rates. The Fargo location provided a study of all treatments and utilization rates.

Forage Establishment

The annual forage crop planted by mid-June 2020 and 2021 included and will include oats, sorghum sudangrass, foxtail millet, sunflowers, radish, kale, turnip, flax and forage pea seed seeded at a rate of 18, 3, 2, 1.5, 1, 0.75, 0.75, 2 and 10 pounds/acre, respectively. Following two years of an annual forage crop, the planned cash crop will be corn planted in the spring of 2022.



Livestock and Grazing Management

Cattle were assigned randomly to grazing density treatments and carrying capacities were determined based on available forage production and estimated utilization. Stocking rates were determined by dividing the available forage by anticipated dry-matter intake per day, then dividing by 30 days of planned grazing to predict the number of cows per plot.

The available forage for 50% and 75% utilization treatments was calculated at 35% and 50% of the total forage produced, respectively (Meehan et al., 2018). The estimated dry-matter intake was based on recommendations in the Beef Cattle Handbook (National Research Council, 2016). The moderate stock density was based on the recommended stocking rate for a 30-day period.

The high stock density was set at double the moderate stock density and the grazing period reduced so as to ensure the treatment was not overgrazed. During 2020, turnout dates ranged from late August to early October.

Electric poly-wire and temporary posts were utilized as portable cross-fence to limit-graze livestock and maintain grazing efficiency. Each treatment was divided into four sections. Windbreak shelters were available for use and continued access to water was provided.

Soil Sampling

Soil samples were collected to characterize physical, chemical and biological properties. Soil physical properties included bulk density, infiltration and soil aggregate stability collected pre- and post-treatment.

Six subsamples were collected from a similar soil series within each treatment prior to seeding of an annual forage crop. Samples also were collected from a nearby location that was managed as part of a traditional cash crop system. Soil chemical properties included soil nutrients, pH and organic matter collected annually with assessment of nutrient distribution occurring pre- and post-treatment only.

Subsamples for nutrient distribution were collected from each 1-acre subplot, whereas once yearly levels were extracted from a similar soil series within each treatment. Above-ground residue was removed gently at each sampling site prior to conducting the sampling technique.

A soil core sampler with hammer attachment was used to measure bulk density at a depth of 0 to 6 inches. In calculating bulk density, the weight of the oven-dried soil was divided by the volume of the ring to determine pounds/foot^3.

Soil infiltration was determined by utilizing the Cornell Sprinkle Infiltrometer system (van Es and Shindelbeck, 2003). It consists of a portable rainfall simulator that is placed onto a single 9.5-inch inner diameter infiltration ring and allows for application of a simulated rainfall event.

Field-saturated infiltrability reflects the steady-state infiltration capacity of the soil after wet-up. It is based on the data collected at the end of the measurement period, or whenever steady-state conditions occur. Because the apparatus has a single ring, conversion factors from Reynolds and Elrick (1990) are needed to account for the three-dimensional flow at the bottom of the ring.

Soil aggregate stability samples were collected with a tiling spade to a depth of 0 to 6 inches. A manual wet sieving method by Six et al. (1998) was used to develop an automated method for assessing aggregate stability. Due to variation in soil across locations, the sand correction procedure by Mikha and Rice (2004) was applied to each sample to remove the sand fraction from the water stable aggregates total.

Soil nitrate nitrogen (NO_3-N), carbon (C), phosphorus (P), potassium, pH, organic matter (OM), sulfate-sulfur (SO_4-S), zinc and copper (Cu) were determined from samples collected at 0 to 6 and 6 to 12 inches with a 0.7-inch-diameter soil probe. Soil nitrates (Vendrell and Zupancic, 2008) were measured using the Brinkmann PC910 Colorimeter. This colorimeter also was used to determine levels of P after applying the Olsen Test (Nathan and Gelderman, 2015).

Potassium was measured using an atomic absorption spectrophotometer. Zinc and copper were extracted with diethylene triamine penta acetic acid and also measured with an atomic absorption spectrophotometer (Nathan and Gelderman, 2015). Recommended chemical soil test procedures for the North Central Region (Nathan and Gelderman, 2015) were used to analyze C, pH, OM and SO4-S.

Forage Production and Utilization

Forage production and utilization of the annual crop was estimated by clipping six 59-inch-diameter hoops per experimental treatment. Clipping for peak biomass production occurred during the week prior to grazing, and turnout dates ranged from late August to early October. Clipping to determine forage utilization occurred upon removal of cattle from the grazing treatments.

Livestock Performance

A two-day body weight and body condition score was collected for the beef cattle at the Fargo location pre- and post-treatment; whereas, cattle at the demonstration sites were scored for body condition only. A visual scoring system developed by Wagner et al. (1988) was used to assess body condition.

Results and Discussion

Year One

Growing season conditions (Table 1) and field preparation appeared to impact germination of annual forage species and production (Table 2). Stocking rates were adjusted for locations with a significant amount of weed competition because forage utilization likely was reduced.

We also noted that seeding depth impacted germination of brassica species. Any location that seeded the annual forage crop to a depth greater than ¾ inch experienced little to no germination of brassicas.

Grazing start dates ranged from late August to early October 2020. The annual forage mix was designed

Table 1. Average monthly precipitation levels and seasonal totals (inches) by month at each project location during the 2020 growing season.

		Month						
Location	**Rainfall (inches)**	**May**	**June**	**July**	**August**	**Sept.**	**October**	**Seasonal Total**
Fargo[1]	Total	1.5	2.6	5.3	4.8	0.9	0.9	**16.0**
	Normal total	2.8	3.9	2.8	2.6	2.6	2.2	**16.9**
Jamestown[1]	Total	2.2	0.4	3.5	2.4	0.2	0.4	**9.1**
	Normal total	2.7	3.5	3.3	2.1	2.3	1.7	**15.6**
McKenzie[1]	Total	.7	0.9	3.5	0.7	0.5	0.5	**6.8**
	Normal total	2.4	3.2	2.9	2.3	1.6	1.3	**13.7**
Napoleon[2]	Total	2.0	1.5	2.8	2.0	0.7	0.5	**9.5**
	Normal total	2.8	3.5	3.0	2.2	1.7	1.6	**14.8**
Lehr[1]	Total	1.7	1.6	3.1	2.9	0.7	0.2	**10.2**
	Normal total	2.6	3.0	2.7	2.0	1.3	1.6	**13.2**
McClusky[2]	Total	1.0	2.0	2.4	3.8	0.2	0.4	**9.8**
	Normal total	2.4	3.2	2.6	2.1	1.6	1.4	**13.3**
Tappen[1]	Total	1.5	2.4	2.3	4.0	0.3	0.2	**10.7**
	Normal total	2.6	3.2	3.2	2.2	2.0	1.5	**14.7**

[1] Data obtained from the North Dakota Agricultural Weather Network (2020) from or near specific locations.

[2] Data obtained from National Weather Service (2020).

Table 2. Average forage production (pounds/acre [lbs/ac]), carrying capacity (animal unit months [AUM]/acre), number of grazing days and degree of use (%) by grazing treatment and location during 2020.

	Treatment					
Location	**Stock Density**	**Grazing Utilization (%)**	**Peak Production (lbs/ac)**	**Carrying Capacity (AUMs/ac)**	**Number of Grazing Days**	**Degree of Use (%)**
Fargo	High	50	4,892	1.40	11	38
		75	5,671	2.32	18	58
	Moderate	50	6,940	1.99	28	63
		75[1]	6,249	2.56	35	64
	Control	0	3,914			
Jamestown[2]	High	50	7,181	2.06	33	44
		75	6,490	2.66	33	52
	Control	0	6,548			
McKenzie	High	50	9,333	2.68	36	53
		75	7,714	3.16	41	68
	Control	0	8,079			
Napoleon[3]	High	50	5,593	0.72	30	52
		75	4,917	0.91	37	66
	Control	0	4,669			
Lehr	Moderate	50	12,725	3.65		51
		75	11,017	4.52		55
	Control	0	14,437			
McClusky[4]	Moderate	50	7,164	2.06	24	34
		75[5]	6,893	0.99	24	40
	Control	0	6,375			
Tappen[6]	Moderate	50	10,536	3.02	18	39
		75	8,782	3.60	18	56
	Control	0	6,444			

[1]Livestock pulled early due to inclement weather and limited feed.
[2]Livestock pulled early due to inclement weather and limited feed.
[3]Forage production consisted of 50% to 60% weeds. Stocking rate was adjusted accordingly.
[4]Livestock pulled early due to inclement weather.
[5]Forage production consisted of 65% weeds. Stocking rate was adjusted accordingly.
[6]Livestock pulled early due to issues with water.

Degree of use is based on the first two sections within each treatment.

to not only meet nutrient requirements of beef cattle, but also to maintain or improve ecological benefits.

These objectives are difficult to achieve when growing season conditions or field preparation negatively impact brassica germination. An early September frost also slowed or halted plant growth, which influenced the forage quality available to livestock. In year two, we hope to maintain a consistent depth of seeding across locations and begin grazing the treatments by mid- to late August.

Soil samples were collected to characterize physical, chemical and biological properties in both ICLS sites and nearby cash crop systems. Baseline data for soil nutrients is reported in Table 3 (next page). Data associated with soil physical characteristics still is being processed. Information collected in year one will serve as a baseline for evaluating response to treatments.

Livestock performance data was collected and will be provided in secondary reports. The best way to share this information is still being determined because the type of cattle (for example, cow-calf pairs, bred heifers, fall calving cows) used for grazing was and will continue to be variable.

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Photos by Erin Gaugler

Table 3. Soil nutrient and biological analysis at 0 to 6 and 6 to 12 inches (in) sampled within a similar soil series at each project location.

Location	Cropping System	Soil Ecological Type	Depth (in)	NO_3-N (lbs/ac)	P (ppm)	K (ppm)	pH	OM (%)	SO_4-S (lbs/ac)	Zn (ppm)	Cu (ppm)
Tappen	ICLS	Very droughty loam	0-6	20	7.5	243	7.5	3.9	7.1	1.37	0.54
			6-12	12	6.0	162	7.8	2.0	5.5	0.42	0.55
	Annual crop		0-6	12	14.7	348	7.9	3.1	6.8	1.68	0.45
			6-12	8	2.7	195	8.1	2.3	5.3	0.66	0.48
Napoleon	ICLS	Droughty loam	0-6	20	11.8	205	6.2	3.6	10.0	0.91	0.73
			6-12	9	4.0	137	6.6	2.8	5.4	0.40	0.69
	Annual crop		0-6	14	6.3	138	6.4	4.7	6.0	1.01	0.72
			6-12	9	3.0	84	6.8	3.5	7.5	0.40	0.61
Wishek	ICLS	Loam	0-6	17	7.2	256	7.3	4.3	93.8	0.96	0.95
			6-12	7	2.6	173	7.6	2.9	86.2	0.57	0.96
	Annual crop		0-6	6	4.0	220	7.7	2.6	3.0	0.76	0.80
			6-12	10	1.7	143	7.8	2.0	17.2	0.37	0.69
Jamestown	ICLS	Loam	0-6	5	16.9	248	6.6	3.5	59.3	1.26	0.78
			6-12	5	4.9	139	7.1	2.2	86.1	0.53	0.70
	Annual crop		0-6	12	23.5	290	6.4	4.0	7.8	1.53	0.59
			6-12	13	7.7	177	6.7	2.5	6.5	0.68	0.58
McKenzie	ICLS	Loam	0-6	14	4.2	215	5.8	2.6	6.1	0.56	0.51
			6-12	8	2.2	110	5.9	1.7	6.9	0.25	0.52
	Annual crop	Very droughty loam	0-6	15	2.8	124	6.0	2.4	4.7	0.63	0.45
			6-12	9	1.2	71	6.9	1.5	6.2	0.25	0.45
McClusky	ICLS	Loam	0-6	31	9.7	427	7.0	3.9	27.1	1.04	0.61
			6-12	16	5.0	285	7.4	2.9	6.7	0.39	0.66
	Annual crop		0-6	22	11.3	328	6.8	3.9	5.5	0.56	0.83
			6-12	12	4.3	216	7.1	3.4	4.7	0.30	0.81
Fargo	ICLS	Clayey subsoil	0-6	7	8.5	315	7.3	5.3	14.1	0.90	2.19
			6-12	5	5.0	244	7.7	3.8	35.0	0.50	2.80
	Annual crop		0-6	53	22.4	385	7.3	5.7	11.4	1.22	2.79
			6-12	17	11.6	278	7.4	3.9	16.6	0.63	2.90

Biomass Yield and Quality of Annual Forage Mixtures Compared With Sorghum Monocrops

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Summary

Annual forage mixtures are a good source of forage with high nutritional value for ruminant consumption. Determining what forage mixture to use for ruminant grazing is important. Treatment 7 (a mixture of oats, phacelia, faba beans, peas and Brachytic sorghum) had the highest biomass yield of 0.8 ton/acre. No difference ($P > 0.05$) in forage yield was found between the monocrops and mixtures, excluding a late-planted brassica mix.

Sorghum x sudan monocrop had the highest total digestible nutrients (TDN) at 43%, and differences ($P \leq 0.05$) in total digestible nutrients (TDN) were observed between the monocrops (Treatments 8 to 12) and mixtures (Treatments 1 to 7). Crude protein ranged from 9% to 17% in the mixtures and 14% to 18% in monocrops. Acid detergent lignin was less than 7% in all the treatments.

Introduction

Annual forage mixtures are a valuable biomass feed source for ruminants (Smith et al., 2014). Annual forage mixtures also extend the grazing period of livestock (Acuña and Villamil, 2014). Other benefits such as increasing plant biodiversity and improving the soil micro fauna and flora are attributed to annual forage mixtures (Rodriguez et al., 2009).

Biomass yield of forage mixtures can be optimized using proper agronomic practices (Foster et al., 2013). The seeding rate is considered the biggest factor affecting forage yield (Vlachostergios et al., 2018). Seeding a variety of high-yielding forage crops in the appropriate proportion balances the botanical composition of the mixture (DeHaan et al., 2010; Bonin and Tracy, 2012).

Environmental factors, animal grazing and management practices change the botanical composition of a mixture during a period of time (Belesky et al., 2002). This change in botanical composition impacts nutritive value and makes maintaining diverse crop mixtures difficult (Sleugh et al., 2000).

Methodology

The study was a randomized complete block design conducted at the Central Grasslands Research Extension Center near Streeter, N.D. The soil type was Hecla-Ulen loamy fine sands with low water storage and 0% to 6% slope (U.S. Department of Agriculture, Natural Resources Conservation Service, 2020). Rainfall was below average through the duration of the study in 2020 except in August (Table 1).

The experiment was planted May 19, 2020, using an eight-cone continuous plot drill with row spacing of 6 inches for mixture treatments and 12 inches for monocultures. Experimental areas have been in no-till for five years or more. All plots were fertilized with 71 pounds of N/acre and 89 pounds of P_2O_5/acre before seeding.

Table 1. Rainfall and average temperature between May and August 2020 at Central Grasslands Research Extension Center near Streeter, N.D. (North Dakota Agricultural Weather Network, 2020).

Month	Mean temperature	Soil temperature	Total rainfall	Departure from normal total rainfall
	--------------- °F --------------		---------------------- inches ----------------------	
May	50.98	49.47	1.81	-0.64
June	67.43	66.19	1.35	-2.06
July	71.23	73.84	2.13	-1.07
August	68.65	71.44	2.73	0.42

Seventeen forage species ranging from cool-season and warm-season varieties and brassicas were used to develop 12 annual forage treatments (Table 2, next page). Seven treatments (Treatments 1 to 7) were mixtures and five treatments (Treatments 8 to 12) were monocrops. The majority of the experiment was impacted by invasive weeds and ground squirrels, impacting forage production.

Hand weeding was done on June 2, June 16, June 24 and Aug. 13, 2020. The harvest date was Aug. 19, 2020. Plots were harvested with a flail forage harvester; the wet weight was recorded and a sample was taken to determine moisture. The fresh sample was dried and after it was dry, the percentage of dry weight was calculated to calculate the dry weight of the total plot.

Nutritional analysis of samples was conducted at the North Dakota State University Nutrition Lab using AOAC standards (AOAC, 2019). The wet chemistry data was calibrated for biomass mixtures using near-infrared (NIR) spectroscopy equipment. Total digestible nutrients (TDN) were determined using the formula developed by the National Research Council, 2001:

$$TDN = [(NFC \times 0.98) + (CP \times 0.93) + (FA \times 0.97 \times 2.25) + (NDF \times (NDFD/100)-7)]$$

where the parameters were nonfiber carbohydrate (NFC), crude protein (CP), fatty acid (FA), neutral detergent fiber (NDF) and neutral detergent fiber digestibility (NDFD).

The design was a randomized complete block design with four replicates. Data analyzed used a general linear model in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.) (Duncan, 1955). Means were separated using the least significant differences (LSD) at 5% significance.

Results

Treatment 7 had the highest biomass yield of 0.8 ton/acre (Figure 1). Treatment 2 biomass yield was lower than all other treatments ($P \leq 0.05$). However, no difference ($P > 0.05$) in yield was found between the monocrops and mixtures (Figure 1).

The TDN contents of monocrops (Treatments 8 to 12) were statistically higher ($P \leq 0.05$) than those of the mixtures (Treatments 1 to 7). The sorghum x sudan monocrop (Treatment 12) had the highest TDN at 43% (Figure 1).

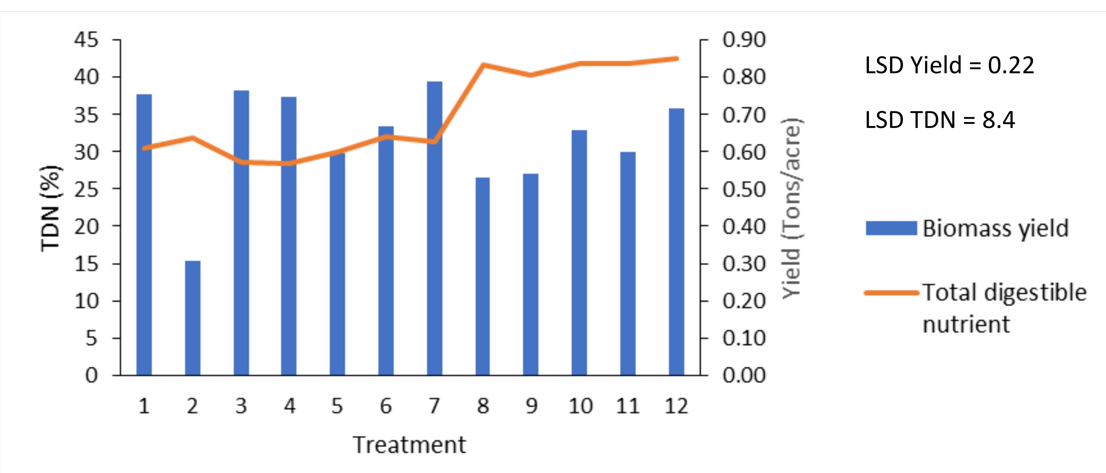

Figure 1. TDN and biomass yield of the 12 treatments at the Central Grasslands Research Extension Center in 2020.

Table 2. Seeding rate of annual forage mixtures.

Treatment	Crop	Cultivar	Seeding rate lbs/acre
1	Annual ryegrass Chicory Plantain Red clover	Crusader Choice Tonic Relish	12 2 3 3
2	Hybrid brassica Turnip	Winfred New York	2 2
3	Hybrid brassica Oats Forage peas Forage sorghum blend Foxtail millet	Winfred Paul Arvika Pampa Legion Siberian	2 5 5 2 2
4	Turnip Forage sorghum blend Forage peas Hybrid brassica Oats Faba beans Forage pearl millet	New York Pampa Tribuno Arvika Winfred Paul Sampo Pampa mijo II BMR6	1 2 5 1 2 2 2
5	Forage pearl millet Hybrid brassica	Pampa mijo II BMR6 Winfred	5 2
6	Sorghum x sudan Radish	ADSGS6504 Graza	2 2
7	Oats Phacelia Forage peas Faba beans Brachytic sorghum BMR	Paul VNS Arvika Sampo AF7101	5 1 5 5 3
8	Forage sorghum blend	Pampa Legion	10
9	Forage pearl millet	Pampa mijo II BMR6	10
10	Pearl millet	Platino non-BMR	10
11	Brachytic sorghum BMR	AF7101	10
12	Sorghum x sudan	ADSGS6504	10

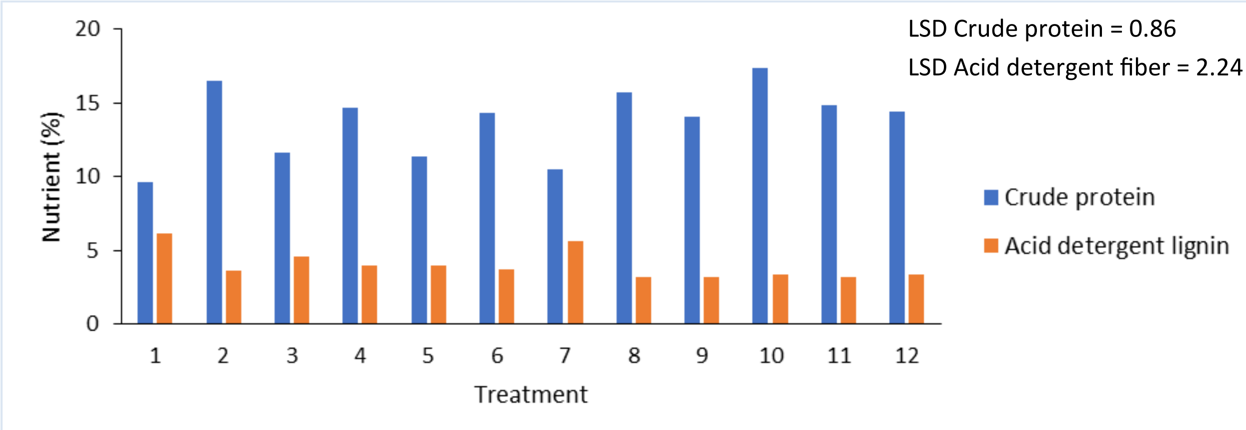

Figure 2. Acid detergent lignin and crude protein of the 12 treatments at the Central Grasslands Research Extension Center in 2020.

The highest CP content was 18% (Treatments 2 and 10) and lowest just under 10% (Treatment 1) (Figure 2). No difference (*P* > 0.05) was found among treatments 2, 4, 6, 8, 10, 11 and 12 in CP (Figure 2). Acid detergent lignin was less than 7% in all the treatments (Figure 2).

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Forage Production and Quality, Livestock Performance and Cost Comparison for Winter Cereal Forages

Kevin Sedivec, Scott Alm, Michael Undi and Justin Leier
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Summary

Three winter cereal forages for cattle grazing and hay production were evaluated at the Central Grasslands Research Extension Center (CGREC). Our objective was to determine the forage production potential and heifer beef cow performance of the winter cereals rye, triticale and wheat.

Winter rye produced the greatest amount of forage in May, and was the most cost effective for grazing heifers and producing hay. Willow Creek winter wheat had the highest nutritional quality in May, but was the poorest forage producer and lowest in livestock performance.

Winter rye and winter triticale had an acid detergent lignin (ADL) content greater than 5% by June 8. Usually we recommend grinding hay with an ADL content greater than 4% to increase intake efficiency.

All three winter cereal forage types had a calcium-to-phosphorus ratio less than 1.2:1 throughout the grazing period. An imbalance in the calcium-to-phosphorus ratio can lead to potential health issues unless calcium is supplemented.

Based on the results from this study, winter rye was the superior winter cereal for grazing cattle during May and early June. Winter triticale appears to be the best option for producing good-quality hay if the planned harvest is early June. Willow Creek winter wheat would not be recommended as a spring grazing winter cereal, but it is the best option if producing hay in mid to late June.

Introduction

Annual forages are a common feedstuff for the livestock industry and are planted each year in North Dakota. Approximately 2.65 million acres of hay were harvested in North Dakota in 2019 (U.S. Department of Agriculture - National Agricultural Statistics Service, 2020).

Annual cereal crops, including winter cereals, are popular hay types for forages. Winter cereals also are popular for cover crops to protect the soil from erosion.

Winter cereal forages are biennial cereal crops sown in late summer to early fall. In this experiment, we tested three winter cereal types, rye, triticale and wheat – Willow Creek.

Winter rye is considered the most winter-hardy of all cereal grains and is fast-growing the following spring. Winter triticale is a hybrid developed by crossing winter wheat and winter rye.

Winter triticale is considered more winter-hardy than winter wheat but less than winter rye, and often is considered superior to rye for silage, hay and pasture. Winter wheat – Willow Creek has good winter-hardiness, is later maturing than rye and triticale, and is considered a high-quality forage.

Our study objective was to compare the forage production potential and heifer beef cow performance of three winter cereals: rye, triticale and wheat – Willow Creek.

Photos by Kevin Sedivec

Table 1. Precipitation and average temperature during the growing seasons of the study period September 2019 through June 2020 at the Central Grasslands Research Extension Center near Streeter (North Dakota Agricultural Weather Network, 2020).

Month	Precipitation (inches)		Percent of Normal		Average Temperature (F)		Departure from Average (F)	
	2019	2020	2019	2020	2019	2020	2019	2020
September	4.44		218		58		1	
October	2.59		136		36		-8	
April		0.64		59		37		-5
May		1.81		74		51		-3
June		1.35		39		67		4

Study Area

This study was conducted at the CGREC from September 2019 to June 2020. Experimental plots at the CGREC were on gravelly sandy loam soils (USDA, Natural Resources Conservation Service, 2020). Precipitation was above normal when we seeded the winter cereals and during the fall growth period in September and October 2019 but below normal during the spring growing period in 2020 (Table 1). The average temperature was 8 degrees below normal in October 2019 and 3 to 5 degrees F cooler than the long-term average in April and May 2020 (Table 1).

Procedures

- We tested winter rye, winter triticale and winter wheat – Willow Creek.
- Each species was seeded in a 10-acre field, with three replicated fields per forage type totaling nine 10-acre fields.
- The study design was a randomized block design and analyzed using a general linear model in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.). Means were separated using the post hoc test Duncan's Multiple Range Test (Duncan, 1955).
- Each study field was fertilized with 73.1 pounds/acre of nitrogen (urea, MAP), 19.2 pounds/acre of phosphorus (MAP) and 12 pounds/acre of potassium (potash) in May 2019, then seeded to spring triticale. The spring triticale was harvested for hay in July 2019.
- All fields have been in no-till for 14 years or more. All fields were sprayed with 1 quart of glyphosate + 1 ounce of Sharpen/acre to kill volunteer yellow foxtail (*Setaria pumila*) on the same day each field was seeded.
- The winter cereals were seeded Sept. 5, 2019.
- All varieties were seeded at 90 pounds/acre.
- Each field was grazed with yearling heifers from May 11 through June 8, 2020.
- The stocking rate was projected using the May 8, 2020, clipping. Winter rye was stocked at 2.49 heifers per acre, winter triticale at 1.45 heifers per acre and winter wheat at 1.43 heifers per acre.
- Livestock performance was determined by collecting two-day weights prior to turnout and after grazing ended.
- Hay from winter rye and triticale were harvested at the milk to soft dough stage June 8, 2020.
- All nutritional analysis was conducted at the North Dakota State University Nutrition Lab using AOAC standards (AOAC, 2019).
- Total digestible nutrients were determined using acid detergent fiber content and the energy equation for grass (98.625-[1.048*ADF]).

Results

Winter rye was the highest-producing cereal on June 1 at 3,610 pounds/acre, followed by winter triticale and winter wheat at 3,177 and 1,771 pounds/acre, respectively (Figure 1). Winter rye was also the most productive May 8 and May 22 (Figure 1).

Crop residue after grazing was lowest in the winter wheat – Willow Creek treatment, mainly due to lower production in May (Figure 1).

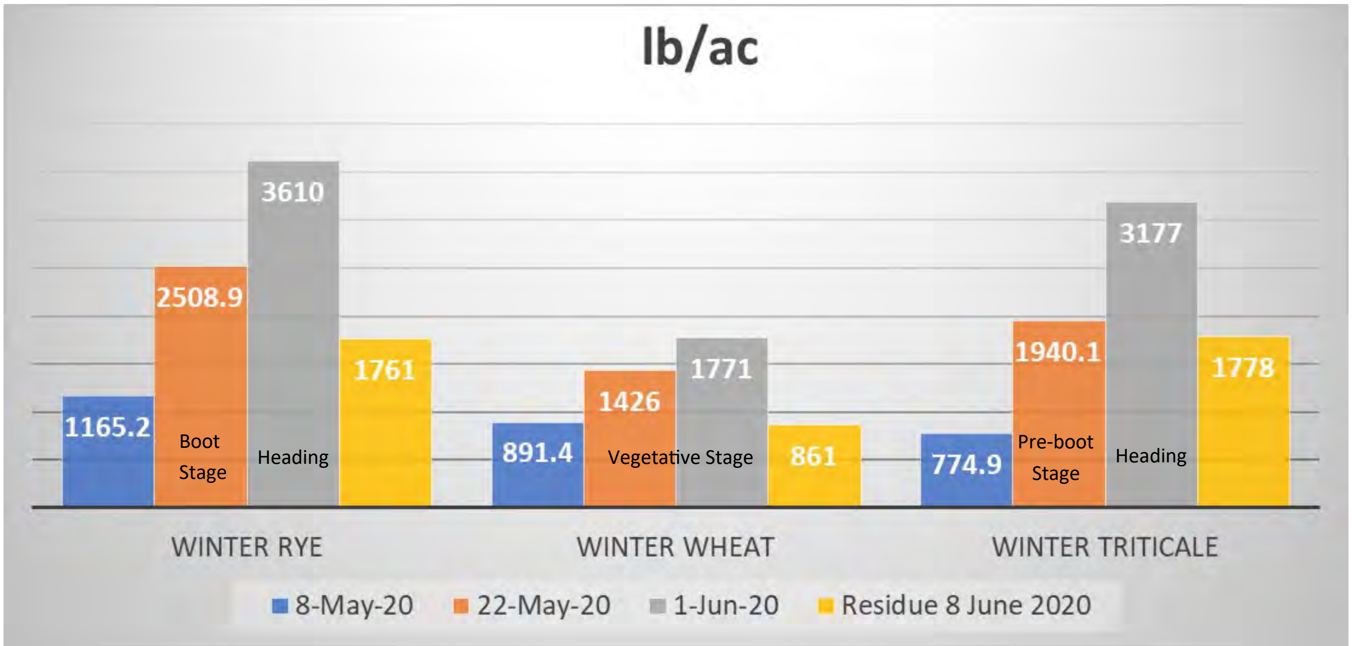

Figure 1. Forage production by winter cereals on May 8, May 22 and June 1 at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

The percent of crop residue was 49%, 49% and 56% for winter rye, wheat and triticale, respectively.

Willow Creek winter wheat was highest in crude protein and total digestible nutrients (TDN) throughout May (Table 2). Winter triticale and Willow Creek were below 3% acid detergent lignin (ADL) in May (Table 2). Winter rye and winter triticale were above 5% ADL by June 8, indicating a low palatable hay at this time (Table 2).

All winter cereal types provided the minimum requirements of phosphorus for a yearling heifer when grazing in May and early June (National Research Council, 2016). However, all three winter cereals were deficient in calcium by the end of May (National Research Council, 2016).

The calcium-to-phosphorus ratio ranged from 0.5:1 to 0.65:1 on May 22 for the winter cereals, and ranged from 0.67:1 to 0.85:1 on June 1. All winter cereals were below the minimum recommended threshold of 1.2:1 calcium-to-phosphorus ratio for cows grazing at this period (National Research Council, 2016).

Winter rye performed best for livestock performance. Heifers gained 0.97 pound/day on the winter rye (Table 3). Heifers on the winter triticale gained 0.04 pound/day, while on the winter wheat – Willow Creek, they lost 0.06 pound/day.

The Willow Creek performance can be explained due to lack of available forage throughout the grazing period. The stocking rate for all three winter cereals was based on a fast growth rate in May. Willow Creek

Table 2. Forage quality content for winter rye, winter triticale and winter wheat – Willow Creek at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

Winter Cereal Crop	Crude Protein (%)			Acid Detergent Lignin (%)			Total Digestible Nutrients (%)			Calcium (%)		Phosphorus (%)	
	May 22	June 1	June 8	May 22	June 1	June 8	May 22	June 1	June 8	May 22	June 1	May 22	June 1
Rye	8.7	6.7	6.6	2.4	4.2	5.6	68.6	61.2	58.0	0.20	0.19	0.39	0.28
Triticale	10.4	7.8	7.8	2.3	2.8	5.2	70.8	65.7	59.0	0.25	0.20	0.40	0.27
Wheat, Willow Creek	12.3	9.2	N/A	2.4	2.5	N/A	71.4	69.2	N/A	0.30	0.22	0.46	0.26

Table 3. Heifer average daily gain (pounds/day) by winter cereal type grazed from May 11 through June 8, 2020, at Central Grasslands Research Extension Center near Streeter, N.D.

Winter Cereal Crop	Average Daily Gain
Rye	0.97
Triticale	0.04
Wheat, Willow Creek	-0.06

grows much slower in May (see Figure 1) than winter rye and triticale, so the stocking rate would be too high for May grazing.

The cost to graze heifers on the winter rye was $1.02 per day and much cheaper than winter triticale and winter wheat – Willow Creek (Figure 2). The cost to graze heifers on the winter triticale was $2.03/head per day, with the higher costs, compared with winter rye, a function of less forage produced and cost of seed. Due to the slow growth rate of Willow Creek in May, the costs to graze heifers on this forage type was also high due to lower forage production.

The cost to produce hay was $51.27, $65.85 and $110.96 per ton for winter rye, triticale and wheat, respectively, when harvested June 1 (Figure 2).

Due to Willow Creek's slow growth in May, harvesting for hay on June 1 would not be recommended. Willow Creek was still in the vegetative growth stage on June 1 and would be much more economical to harvest in mid to late June.

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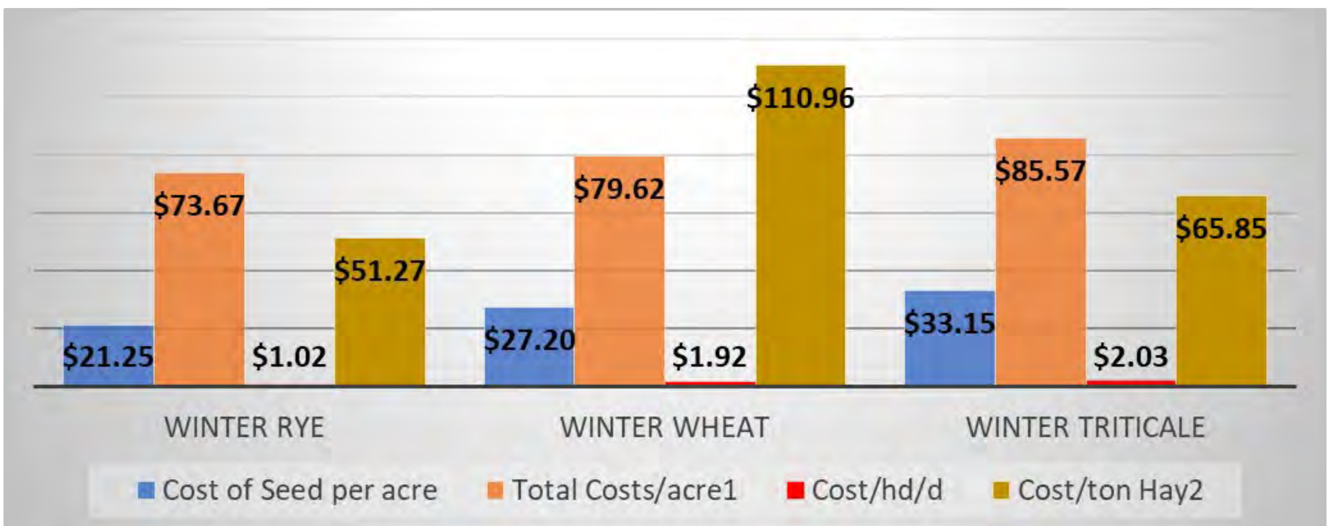

[1] Total costs per acre includes custom farm rates (USDA, Agricultural Statistics Service, 2020) for no-till seeding rate ($17.80/acre), custom herbicide application ($6.57/acre), actual cost of herbicide (glyphosate + Sharpen; $5.60/acre), land rent ($22.45/acre) and seed cost (winter rye - $21.25/acre, winter wheat - $27.20/acre, winter triticale - $33.15/acre). Total land rental rate would be $44.90/acre (USDA, Agricultural Statistics Service, 2020); however, we dedicated 50% of the cost toward the winter cereal, 50% for the second crop (cover crop). Grazing period May 11-June 8 (29 days).

[2] Cost per ton of hay includes total costs per acre + cost for swathing ($9.66/acre) and baling ($9.47/acre).

Figure 2. Total costs per acre, cost to graze heifers per day and cost to harvest hay by winter cereal type at Central Grasslands Research Extension Center near Streeter, N.D., in 2020.

CGREC Staff, Graduate Students and Advisory Board

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Sandi Dewald	Administrative Assistant
Scott Alm	Farm Operations Manager/ Forage Specialist
Timothy Long	Beef Herdsman
Lisa Pederson	Extension Livestock – Beef Quality Assurance Specialist
Erin Gaugler	Range Research Specialist
Stephanie Becker	Animal Science Technician
Cody Wieland	Livestock Technician
Rick Bohn	Range Technician
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Robert Weigel, Kintyre
Jeff Williams, Streeter

The CGREC Annual Field Day is held in July and is open to the public. The Advisory Board meets that day as well as on the second Thursday of November.

Summer 2020

Back: Hayley Hilfer, Morgan Gallagher, Bruce Tempel, Michael Hamel, Cody Wieland, Bruce Erdmann, Tim Long, Cameron Duquette, Scott Alm, Kevin Sedivec.
Middle: Sandi Dewald, Jacob Yetter, Allison Shorter, Michael Undi, Erin Gaugler, Laura Smith, Justin Leier, Carson Kephart, Rick Bohn, Lisa Pederson.
Front: Megan Wanchuk, Levi Norton, Kaitlyn Dix, Makayla Paul, Stephanie Becker, Noami Hegwood, Emma Weaver, Paige Harman.
Missing: Emily Alm, Rike Baumgaertner, Tanya Metz, Janet Patton.

Photos by Kevin Sedivec, Janet Patton and Rick Bohn

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