

AN ASSESSMENT OF ANNUAL FORAGES TO EXTEND GRAZING FOR BEEF CATTLE
IN SOUTH CENTRAL NORTH DAKOTA

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Erin Marie Gaugler

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By

Erin Marie Gaugler

The Supervisory Committee certifies that this *disquisition* complies with North Dakota State
University's regulations and meets the accepted standards for the degree of

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SUPERVISORY COMMITTEE:

Dr. Kevin K. Sedivec

Co-Chair

Dr. Bryan W. Neville

Co-Chair

Dr. Jack E. Norland

Dr. Aaron L.M. Daigh

Approved:

April 30, 2015

Date

Dr. Francis Casey

Department Chair

ABSTRACT

This study was designed to test 3 grazing treatments using 2 cropping systems during 2012 to 2014. Angus crossbred beef heifers in mid-gestation were assigned to treatments from mid-October to late November or early December. Single- and dual-crop systems were subjected to the following grazing treatments: 1) full use, 2) 50 percent degree of disappearance and 3) no use. A drylot served as the control. Herbage production, livestock performance, economic efficiency and soil health were monitored. Costs associated with the cocktail mixture ranged from \$37.56 to \$44.50/hectare. Average daily gain was highest in the drylot and was the only treatment to provide a positive return per head per day for all years. Returns of the full use grazing treatment were positive 2 of the 3 years and losses were limited compared to other grazing treatments. Grazing provided either neutral or positive soil health characteristics compared to no use.

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PREFACE

Chapter 2 was written as a manuscript that will be submitted to *The Professional Animal Scientist*, a peer-reviewed journal. The chapter will follow the style and guidelines of the journal in which it intended to be submitted.

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LIST OF ABBREVIATIONS

ADG	average daily gain
BCS	body condition score
BW	bodyweight
Cl	chloride
cm	centimeter
CP	crude protein
Cu	copper
d	day
Db	bulk density
DC	dual-crop
DM	dry matter
DMI	dry matter intake
EC	electrical conductivity
g	gram
GMD	geometric mean diameter
ha	hectare
hd	head
hr	hour
K	potassium
kg	kilogram
K_{sat}	saturated hydraulic conductivity
min	minute

mm millimeter
MWD mean weight diameter
NO₃-N nitrate
ODS oven dried soil
oz ounce
P phosphorus
ppm parts per million
qt quart
S sulphur
SC single-crop
T ton
TC total carbon
WSSI whole soil stability index
Zn zinc

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CHAPTER 1. THE POTENTIAL USE OF ANNUAL FORAGES FOR BEEF CATTLE GRAZING IN THE NORTHERN GREAT PLAINS

Introduction

Production costs and other economic uncertainties continue to challenge livestock producers. Though it is unlikely to alter market prices, strategies can be implemented to reduce production costs associated with a livestock enterprise (Adams et al., 1996; Walker, 2010). The use of extended grazing to reduce production costs have been studied, and to varying degrees proven to be the most cost effective method (D'Souza et al., 1990; Adams et al., 1994; McCartney et al., 2009). The selection of forage-type is an important management decision and is influenced by many variables.

The input costs associated with annual forages are considerably higher than perennials, but in years of below-average precipitation the grazing potential of annuals exceeds that of perennials (Kilcher and Heinrichs, 1961). An advantage of perennial forages is they do not require annual seeding and associated costs; however, warm season annual forages can peak in biomass production later than perennials (McCartney et al., 2008b). Some annual crops can serve as cover crops by providing physical, chemical and biological improvements to the soil (Fageria et al., 2005). The ability to immobilize nutrient flow by creating a demand for soluble nitrogen is also a major advantage (Entz et al., 2002). As producers strive to improve the efficiency and effectiveness of their operation, the advantages of annual forages become significant. This review considers the potential of cool and warm season annual forages to extend the grazing season for beef cattle by exploring historical and current research conducted in the northern Great Plains.

Nutrient Requirements of Beef Cattle

An important component of meeting herd production and profitability goals for a beef cattle enterprise is meeting nutrient requirements. Adequate nutrition is important for all classes of cattle at various stages of the production cycle. Factors that influence nutrient requirements include but are not limited to the following: age, sex, breed, level of activity, pest load and environment (Pond et al., 2005). Each of the listed factors has an additive effect on nutrient requirements. By knowing and anticipating any changes in nutritional needs, producers can more effectively manage and mitigate costs.

The nutritional requirements of cattle are dynamic because the production cycle is not static (National Research Council, 2000; Pond et al., 2005). Generally, a mature cow experiences periods of growth, gestation, lactation and maintenance. Growth can be considered as the recovery of body tissue energy not associated with gestation. Nutrition for the cow is important during this period because of its effect on subsequent reproductive performance (Pond et al., 2005). Gestation involves the time during which a fetus is growing and developing within the cow. Nutrient requirements are influenced by expected calf birth weight and stage of gestation (Pond et al., 2005). After a calf is born, nutrient requirements rise dramatically to meet the demand of milk production and this is known as lactation (Pond et al., 2005). The nutrients requirements necessary for a cow to function is known as maintenance. Maintenance requirements generally increase with body size (National Research Council, 2000; Pond et al., 2005).

Attempts to extend the grazing season often occur during late fall and early winter months in the northern Great Plains. During this time of year, a large majority of beef cows are in mid-gestation. While nutrient requirements are low, body condition and other performance

measures are able to use a greater portion of the available energy. Providing high quality forage for livestock in mid-gestation may reduce the amount of feedstuff or supplementation needed to return the animal to their next pre-calving condition (National Research Council, 2000; Pond et al., 2005). Additional supplementation may be necessary if feedstuff is unable to meet nutrient demands of the animal. Adams et al. (1996) concluded that crude protein (**CP**) content of forages is typically limited during late fall and early winter months. Numerous supplements are available in a variety of forms though none are best suited for all situations (DelCurto et al., 2000).

Cool Season Annual Forages

Yield and nutritive values of forages used for late season grazing are important for livestock producers to consider. Simulated grazing plot trials were used to assess the potential of cool season annual forages on Black Chernozemic and Gray-Wooded Luvisolic soils in central Alberta (Berkenkamp and Meeres, 1988). Dry matter (**DM**) production of oat (*Avena sativa*) on Black Chernozemic soil yielded 3,350 kilogram (**kg**)/hectare (**ha**), which was 50% more than DM production of barley (*Hordeum vulgare*) (Berkenkamp and Meeres, 1988). Oat was the most productive crop on Gray-Wooded Luvisolic soil (2110 kg/ha) and possessed a greater tolerance to moderate acidity (Walton, 1975; Berkenkamp and Meeres, 1987; Kibite et al., 2002). Robertson (1980) and May et al. (2007) studied forage yields of oat and barley under grazed and single cut conditions, respectively. Production of barley was equivalent to or greater than oat yields (Robertson, 1980; May et al., 2007). The equal or superior levels of barley to forage yield of oat was supported by research performed in sub-humid regions of Minnesota, but inconsistent when compared with other locations throughout the northern Great Plains (Carr et al., 2004).

Literature suggested that wheat (*Triticum aestivum*) possessed greater drought resistance than barley or oat and was recommended for use as forage (Anonymous, 1940). Analysis of wheat at 6 locations in Alberta yielded an average protein content of 581 kg/ha (Berkenkamp and Meres, 1987). Yields that have been considerably reduced because of limited moisture conditions were not recommended for grazing (Walton, 1975; Berkenkamp and Meres, 1987). Berkenkamp and Meres (1988) performed a simulated grazing study and found that spring rye (*Secale cereal*) yielded less than oat in areas where Grey Wooded Luvisolic soil was dominant but was more adapted to acidic soils. Forage yields of triticale (*Triticosecale*), a hybrid between wheat and rye, was also studied by Berkenkamp and Meres (1987, 1988). Information on rye and triticale grown in the northern Great Plains is limited and more research is needed to evaluate whether or not these cereal crops have a role in grazing systems (Berkenkamp and Meres, 1987, 1988).

Hansen et al. (2013) studied the suitability of cover crops for late season grazing. Lentil (*Lens culinaris*), cowpea (*Vigna unguiculata*), oat and forage radish (*Raphanus sativus*) were grown as a monoculture in central and southeastern South Dakota. Data indicated that yields increased as the growing season progressed but forage quality tended to decrease (Hansen et al., 2013). In central South Dakota, radish had the highest protein content [194 to 313 grams (g)/kg]; whereas, oat had the lowest protein content (63 to 108 g/kg) in southeastern South Dakota (Hansen et al., 2013). Limited levels of protein may require supplementation to meet nutrient requirements of beef cattle. Provided that establishment persisted, Hansen et al. (2013) concluded that all crops produced adequate amounts of forage and were suitable for late season grazing except cowpea.

Effect of seeding date on forage yield and nutritive values of cool season cereals in Saskatchewan revealed a decrease in DM yield with later seeding dates (May et al, 2007; Foster and Malhi, 2013). Foster and Malhi (2013) concluded that DM yield was further influenced by rainfall distribution throughout the growing season. Though planting date had no consistent effect on nutritive value, protein content of forages tended to be greater for cereals that were seeded early and possessed the lowest number of days to harvest (May et al., 2007; Foster and Malhi, 2013). Information regarding the forage quality of cool season cereal crops used in actual animal grazing trials is limited. An assessment of cropping system type and its effect on subsequent crop performance would also help unveil the potential of cool season annual forages.

Environmental conditions during late fall and early winter months in the northern Great Plains are a concern for both crop and livestock producers. It was determined by Klink et al. (2014) that a change in growing season conditions is expected to effect the production of cool season crops. To determine whether observed changes have an impact on crops, differences of growing season temperature and precipitation and of annual yield data of Robust spring barley and Gopher oats were analyzed from 1980 to 2012 (Klink et al., 2014). The results indicated that observed climate changes have contributed to a decrease in barley and oat yields throughout the region of study. On the contrary, recent releases of plant cultivars have helped to compensate for poor growing season conditions (Klink et al., 2014).

Livestock producers should be aware of the strengths or limitations of cool season forages to meet nutrient demands. Several studies in Saskatchewan yielded 3,800 to 6,000 kg/ha DM of oat which provided 100 to 150 steer days of grazing/ha and extended the season by a minimum of 40 days (d) (Beacom, 1991). Calves grazing oat and annual ryegrass (*Lolium multiflorum*) and oat and fall rye (*Secale cereale*) or oat and winter triticale pastures in Ontario

experienced 157 and 75 kg/ha of gain over 28 d, respectively (Johnston, 2000). Research has also demonstrated that Italian ryegrass (*Lolium multiflorum*) could be heavily grazed after establishment in the early summer and the re-growth could again be grazed in the fall (McCartney, 2000, 2003; McCartney et al., 2008a). Weaned calf gains were documented as high as 718 kg/ha and average daily gain (ADG) was 0.68 to 1.13 kg/d from late August to mid-November (McCartney, 2000, 2003). McCartney et al. (2008a) documented that backgrounding calves on Italian ryegrass was more economical than backgrounding in a drylot setting. Actual grazing trials that study the potential of annual forages to extend the grazing season and also consider livestock performance are limited. Future research is needed to develop an understanding of how animal performance might be affected.

Yield and nutritive value of cool season annual forages to meet nutrient demands of livestock during the late fall and early winter months are readily available. Actual animal grazing trials are needed to develop a more thorough understanding of cool season forages and their effect on livestock performance and subsequent crop performance. An assessment of various soil parameters would further unveil the potential of cool season forages to extend grazing. The limited number of grazing trials inhibits our understanding of the economics associated with annual forage grazing systems. Economic considerations are important and will likely help determine the future role of annual crops as a means of extending the grazing season to reduce production costs.

Warm Season Annual Forages

Several small plot research trials in the northern Great Plains have evaluated the value of sorghum (*Sorghum bicolor*), sudangrass (*Sorghum bicolor*) and sorghum sudangrass hybrids. Wedin (1970) and McKinlay and Wheeler (1998) found that when sorghum sudangrass was

sampled at the vegetative state it possessed CP concentrations of 184 and 170 g/kg DM, respectively. Undersander et al. (2000) found that sudangrass could provide abundant grazing with yields of 6,720 to 13,440 kg/ha DM during mid- to late-summer when perennial cool season species became dormant. Poor and inconsistent emergence of sorghum sudangrass in southeastern Saskatchewan resulted in inconsistent yields (0.2 to 13 tons (T)/ha) (May et al., 2007). Analysis of yield and nutritive values suggested that the quality of sorghum sudangrass can be variable and may require protein supplementation. Though adequate yield and high quality forage is important, systems that produce variable amounts of forage can still be useful. Livestock that possess low nutrient requirements may be better suited to land that has variable production but adequate nutritive values. When animals have high nutrient requirements, more forage is needed to maintain body condition.

The review of literature that considers yield and nutritive value of millet includes different types of annual grasses. Plot trials with pearl millet (*Pennisetum glaucum*) and Japanese millet (*Echinochloa esculenta*) were performed in eastern Canada and yielded 12,000 and 6,000 kg/ha, respectively (Banks and Stewart, 1998). Pearl millet possessed higher CP concentrations of 180 g/kg DM than Japanese millet or sudangrass (Banks and Stewart, 1998). Levels of 690 g/kg total digestible nutrients was also achieved by pearl millet. May et al. (2007) reported that Crown proso millet (*Panicum miliaceum*) had an average yield of 6.15 T/ha DM which could be maximized with higher growing degree days and moderate rainfall. Golden German foxtail millet (*Setaria italica*) yielded more consistently but maximized yield as both growing degree days and rainfall increased (6.35 T/ha) (May et al., 2007). McCaughey et al. (2002) reported that DM yields of Golden German foxtail millet ranged from 7,270 to 8,860 kg/ha over 4 years. The study performed by May et al. (2007) reported CP concentrations of 93

to 97 g/kg DM for Crown proso millet and Golden German foxtail millet. The concentrations were sufficient to meet nutrient requirements for cattle during winter grazing in Saskatchewan.

The opportunity to include late season cover crops in northern cropping systems has been improved with the use of brassica species. Forage rape (*Brassica napus*), turnip (*Brassica rapa*) and forage radish provided an average of 4,350 and 5,690 kg/ha DM during September, October and November (Kunelius and Sanderson, 1989, 1990). Dry matter yields of brassica crops increased as growing season progressed (Kunelius and Sanderson, 1989, 1990; Wiedenhoft and Barton, 1994; Narasimhalu et al., 2000), but CP concentration decreased (Kunelius and Sanderson, 1989, 1990; Narasimhalu et al., 2000). The decreased levels of CP for brassica species ranged from 130 to 195 g/kg DM and were adequate for cows in mid-gestation (Wiedenhoft and Barton, 1994; Narashimhalu et al., 2000).

Livestock producers should be aware of the strengths or limitations of warm season forages to meet nutrient demands. The suitability of annual forage crops to provide grazing for livestock was studied in Saskatchewan (Holt, 1993). The average steer grazing days per hectare were 225, 198 and 173 for fall rye, sorghum sudangrass, and proso and foxtail millet, respectively (Holt, 1993). Dry matter yields of Golden German foxtail millet provided weaned calves with 188 to 385 grazing d/ha over a period of 4 years (McCaughey et al., 2002). Holt (1993) reported that the mean ADG was 1 kg/d and was greater than performance of steers grazing perennial pastures in the same area. Elsewhere in Saskatchewan, newly weaned calves averaged 1.06 kg/d over a 26 d period on swathed Golden German foxtail millet (Lardner, 2004). Lardner et al. (2008) backgrounded weaned calves on swathed millet and found the cost per kilogram of weight gain was \$1.90 for calves grazing millet, while calves on swathed barley cost \$1.39/kg, and calves in a drylot setting cost \$2.57/kg. The majority of research has been done on

swath grazed crops and a need persists for actual animal grazing trials of standing forages. An assessment of cropping system type and its effect on subsequent crop performance would also help unveil the potential of warm season annual forages for grazing.

Effect of seeding date on forage yield and nutritive values is an important consideration for livestock producers. Dry matter yield of foxtail millet was affected by seeding date (Foster and Malhi, 2013; Hansen et al., 2013), but nutritive value of millet and cowpea were not inhibited (May et al., 2007; Foster and Malhi, 2013; Hansen et al., 2013). The highest level of protein was attained when foxtail millet was seeded at the latest date but with the fewest days to harvest (Foster and Malhi, 2013; Hansen et al., 2013). May et al. (2007) recommended a later seeding date to inhibit weed emergence prior to seeding. Despite the decline of forage quality as the growing season progressed, research suggested that warm season cereals were able to meet nutrient requirements of beef cattle during late fall and early winter months. More data is needed to determine the adaptability of warm season crops in the northern Great Plains.

A review of yield and nutritive value of warm season annual forages to meet nutrient demands of livestock during the extended grazing season complements the review of cool season annual forages. Several annual crops show promise for use but actual animal grazing trials are needed to develop an understanding of the role of annual forages. Though these crops have high yield and nutritive potential, assessment of soil health and the cost of grazing has not been adequately researched.

Annual Forage Mixtures

Field based evidence of yield and nutritive values of cool and warm season annual forages in monocrop production systems are fairly strong, but research is more limited when considering mixed species crops. Seminar abstracts from the Ontario Central Experimental Farm

indicated that there was no advantage to seeding annual crops in mixtures unless it was for the purpose of palatability (Anonymous, 1950). However, recent studies indicated that a major advantage of mixtures is the ability to accumulate DM later in the growing season which allowed for an extended grazing period (Carr et al., 1998, 2004; McCartney et al., 2004).

A study performed by Jedel and Salmon (1995) evaluated forage yield and quality of spring cereal monocrops and binary mixtures. Spring cereal monocrops included triticale and barley and binary mixtures involved winter triticale or winter rye. Two simulated regimes included: 1) a soft-dough cut for silage, followed by fall clipping and 2) annual pasture with up to 5 clippings during the growing season. The mixed annual pasture system produced 4,850 kg/ha DM; whereas, the silage and pasture forage yield was 8,325 kg/ha DM (Jedel and Salmon, 1995). The spring monocrop yields averaged 8,710 kg/ha DM which were 31% less than the mixtures under simulated grazing (Jedel and Salmon, 1995). Throughout the growing season (May to August), Jedel and Salmon (1995) observed a decline in Alberta monocrop yields while yields from mixtures increased until mid-summer before experiencing decline. At the end of the growing season, mixtures possessed greater levels of CP than spring cereal monocrops, but similar levels of nutritional quality was experienced when treatments were clipped early (Jedel and Salmon, 1995).

Conversely, Poland et al. (2003) experienced a reduction of winter and spring cereal DM yields in North Dakota when compared with spring cereal monocrop production. It appears that leaf rust and other pathogens inhibited the production of winter triticale and wheat, thereby preventing an extension of fall grazing (Poland et al., 2003). Though infection occurred, seeding of spring barley, oat or triticale with winter rye, triticale or wheat produced approximately 3,360 kg/ha DM by mid-July (Poland et al., 2003).

A mixture of 5 cover crop species consisting of lentil, cowpea, foxtail millet, oats and forage radish were planted after a winter wheat harvest in central and southeastern South Dakota (Hansen et al., 2013). The focus of this study was to develop an understanding of the suitability of these crops as late season forages. Data was collected at the beginning of each month from October to December. On the second sample date of the first year, DM yield of the cover crop was greater than 4,000 kg/ha (Hansen et al., 2013). Though forage quality tended to decrease after each harvest date, the mixture was a viable forage option through the late fall months with a potential need for protein supplementation when feeding beef cattle.

The presence of legumes in annual forage mixtures is also an important aspect. Walton (1975) determined that the presence of a non-cereal in a mixture reduced yield but the presence of peas in a mixture with oats led to an increase of CP. Carr et al. (2004) found that mixtures with peas resulted in an increase of forage and nitrogen yield. It was further demonstrated that in unfertilized areas with low soil nitrogen, intercropping barley or oat with pea improved forage yield and quality (Carr et al., 2004).

The result of research that focused on forage crop mixtures and production was variable but yield data appears adequate to meet the nutritive demands of beef cattle. Similar to cool and warm season annual forages, actual animal grazing trials are needed to assess the role of annual forage mixtures in grazing systems. Research involving soil health parameters and economic analysis is also needed.

Annual Forages and Soil Health

The need to reduce production costs and greater awareness of the role of soil health has prompted researchers to consider alternative production systems. The integration of crop and livestock should be thoroughly explored due to climate variation, plant species availability and

economic uncertainty in crop and livestock markets. The potential of forages should consider the suitability of crops for livestock performance and contributions to soil health. An advantage of cover crops is they can provide physical, chemical and biological improvements to the soil (Fageria et al., 2005).

Two brassica cover crop species (forage radish and rape) and rye were studied by Chen and Weil (2010) to analyze the effect of root structure on porosity of Maryland soils. Soil penetration by forage radish roots was least affected by compaction while penetration by rye roots was most inhibited (Chen and Weil, 2010). Rivenesshield and Bassuk (2007) demonstrated the ability of organic amendments like sphagnum peat and food waste compost to decrease bulk density (**Db**) and increase soil porosity.

Franzluebbers and Stuedemann (2008a, 2008b) studied conventional and no-till cropping systems which included summer grain followed by a winter cover crop and winter grain followed by a summer cover crop in Georgia. It was reported that total organic carbon at depths of 0 to 10 centimeters (**cm**) was greater in the no-till system at the end of 3 years. Furthermore, cover crop grazing appeared to have little influence on soil carbon and nitrogen fractions at 0 to 10 cm (Franzluebbers and Stuedemann, 2008a). Soil Db was reduced within 30 cm after 1 season of conventional tillage, but reduction only occurred within 12 cm as management continued. The conventional tillage system resulted in degraded aggregate stability but grazing had little effect on the stability of aggregates in either cropping system (Franzluebbers and Stuedemann, 2008b). Introduction of cattle to consume cover crop forages did not cause substantial damage to the soil (Franzluebbers and Stuedemann, 2008a, 2008b).

Integrated crop and livestock production systems are typically developed in an effort to efficiently utilize resources and improve the long-term productivity of a landscape. Schuman et

al. (1991) evaluated the effects of livestock grazing on carbon and nitrogen balances of native mixed-grass rangeland in Wyoming. Results indicated that 12 years of grazing at heavy stocking rates did not change the amount of carbon and nitrogen but distribution was altered (Schuman et al., 1991). An increase in masses near the root zone suggested a greater opportunity for plants to cycle nutrients and provide quality forage.

Adequate levels of soil nitrogen are important for crop production (Karlen et al., 1997). A study performed by Staver and Brinsfield (1998) evaluated the usefulness of cereal grain winter cover crops following no-till corn (*Zea mays*) production to sequester nitrogen in the mid-Atlantic Coastal Plain. Rye cover crops reduced nitrate leaching by approximately 80% in the field and 60% in the field-scale watershed (Staver and Brinsfield, 1998). Forage radish, oilseed radish (*Raphanus sativus*), rape and rye were evaluated for nitrogen retention following corn/soybean (*Glycine max*) production in the mid-Atlantic Coastal Plain (Dean and Weil, 2009). All cover crop applications decreased nitrogen losses and uptake by brassica species was as effective as rye (Dean and Weil, 2009). Researchers suggested both cereal grain cover crops and brassica species were effective at sequestering nitrogen (Staver and Brinsfield, 1998; Dean and Weil, 2009).

The amendments of carbon and nitrogen through soil organic matter can improve soil quality and could be positively reflected by crop yields (Karlen et al., 1997). A 15 year study compared the balances of carbon and nitrogen on 3 different corn/soybean production systems (Drinkwater et al., 1998). One system was conventional while the others depended on legumes for nitrogen fixation. One of the legume dependent systems was simulated as a beef operation and received cattle manure as a primary source of nitrogen. The other system received nitrogen from legumes through incorporation of biomass prior to planting of the cash crop (Drinkwater et

al., 1998). It was concluded that net primary productivity and nitrogen balances do not account for observed changes in soil carbon and nitrogen. Furthermore, producers should diversify cropping sequences and implement low carbon to nitrogen organic residue to maintain soil fertility (Drinkwater et al., 1998).

Animal Health Concerns

Cool Season Annual Forages

During late fall and early winter months, the majority of beef cows are in mid-gestation. With the intent to extend the grazing season, producers should be aware of potential health concerns. The presence of nitrates is common in all plants, but an excessive amount may be dangerous to livestock. Stressful conditions like drought, which cause an abrupt decrease in plant growth, may contribute to plant nitrate accumulation (Bradley et al., 1940; Osweiler et al., 1985; Radostits et al., 2000). Upon consumption, nitrates are converted to nitrites which are absorbed into the blood and reduce the ability of blood to carry oxygen (Radostits et al., 2000). Bradley et al. (1940) reported that nitrate concentrations of plant material greater than 0.5% were considered harmful. A wide variation in the response to nitrate intake occurs because of differences in environment, diet and feeding practices (Thomas, 1970). Since variation exists, producers should take precaution and test suspected forages. High nitrate forages can be gradually introduced into a ration but attentiveness is important to reduce livestock poisoning (Adams et al., 1992).

Another health concern for beef cows is acute bovine emphysema which is caused by exposure to pneumotoxins from protein rich forages. Also known as fog fever, this respiratory disease can arise when livestock are moved from dry grazing areas to lush pastures (Radostits et al., 2000). There is little that can be done for affected livestock, but measures of prevention can

be implemented. Ideally, pastures should be used before they become overly lush and protein-rich. If this is not possible, then forages should be slowly introduced to the animal (Carlson and Breeze, 1983). An additional concern associated with lush pastures is diarrhea. Lush pastures often contain forages that possess high levels of protein and low fiber content. The high moisture content coupled with low levels of fiber can lead to a quick rate of passage through the digestive tract (Radostits et al., 2000). Feeding adequate amounts of hay or straw has been shown to increase the amount of fiber and, thereby, slow the rate of passage (Radostits et al., 2000).

A form of indigestion marked by excessive accumulation of gas in the rumen is known as bloat (Majak et al., 2003). Type of forage, weather, time of day, mineral nutrition, animal characteristics and rumen conditions all influence the likelihood of animals bloating. Feeding consistent and steady diets and controlling access to high bloat-potential plants can help reduce or eliminate problems (Majak et al., 2003).

Warm Season Annual Forages

Grazing of warm season annual forages present some of the same health concerns as cool season annual forages. Nitrate poisoning can occur when plants accumulate excessive amounts of nitrates (Radostits et al., 2000). The same precautions taken when grazing cool season annual forages should be implemented when grazing warm season annual forages.

Specific to sorghum, sudangrass or sorghum-sudangrass hybrids, producers should be aware of prussic acid poisoning. Varying amounts of cyanogenic glycoside can accumulate in the rumen, be converted to prussic acid and absorbed into the blood (Radostits et al., 2000). Once in the blood system, respiratory issues can occur and death may result. Accumulation of cyanogenic glycoside is likely to occur when plants endure stress, but will break down 1 to 2

weeks after stressful conditions are eliminated (Radostits et al., 2000). Sorghum, sudangrass and sorghum-sudangrass hybrids contain varying levels of prussic acid can be further influenced by management practices (McCartney et al., 2009). Young plants have a higher cyanogenetic glycoside potential than mature crops. McKinlay and Wheeler (1998) suggest that grazing of sorghum, sudangrass and sorghum-sudangrass hybrids should occur at heights greater than 55, 45, and 55 cm, respectively. If a killing frost should occur, plants should not be grazed for 7 to 10 d. A hard frost causes damage to many cells and elevated amounts of prussic acid can be released (McKinlay and Wheeler, 1998; Radostits et al., 2000).

If not properly managed, brassica forages can cause a number of health problems to beef cows in mid-gestation. The main areas of concern are bloat, diarrhea, atypical pneumonia, nitrate poisoning, hemolytic anemia, hypothyroidism and polioencephalomalacia (Radostits et al., 2000). Though a number of concerns may arise, 2 management practices generally alleviate health concerns. Practices include: 1) avoid abrupt changes from dry to lush pastures and 2) supplementation of hay or straw should occur if brassica crops constitute more than 75% of the animal's diet (Radostits et al., 2000).

Research Challenges

Research regarding yield and quality content of annual forages in the northern Great Plains has been summarized for possible use in grazing systems. From the above discussion, several studies of annual forage crops show promise for extending the grazing season. However, in this region few actual animal grazing trials have been performed. Other important aspects of research should include the effect of annual forages on livestock performance, soil health and economics. A need persists for improved information so that appropriate management decisions can be made by livestock producers.

The main objective of this study was to evaluate the potential of annual forages in south central North Dakota to extend the grazing season for beef cattle producers. With regard to single- and dual-crop production systems, the annual forages were evaluated for their impact on herbage production, livestock performance, soil health and cost effectiveness. It is hopeful that an improved understanding of annual forages to extend the grazing season will lead to improved management systems.

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CHAPTER 2. ANNUAL FORAGES IN SINGLE- AND DUAL-CROP SYSTEMS FOR LATE SEASON GRAZING IN SOUTH CENTRAL NORTH DAKOTA

Abstract

Annual forages planted in late summer can provide an early winter grazing option to complement rangeland. The selection of species within a mixture offers producers the opportunity to minimize production costs and tailor soil benefits. During 2012 through 2014, this study tested 3 grazing treatments on 2 cropping systems. Angus crossbred beef heifers in mid-gestation were assigned to treatments from mid-October to late November or early December. Single-crop (annual cocktail forage crop) and dual-crop (annual cash crop/annual cocktail forage crop) systems were subjected to the following grazing treatments: 1) full use, 2) 50 percent degree of disappearance and 3) no use. A traditional drylot feeding treatment served as the control. Herbage production, livestock performance, economic efficiency and soil health were monitored. The costs associated with the cocktail seed mixture ranged from \$37.56 to \$44.50/hectare among the 3 years. Average daily gain was highest in the drylot, which was also the only treatment with a positive return per head per day for all years. Returns of the full use grazing of annual cocktail forages were positive 2 of the 3 years and losses were limited compared to other grazing treatments. Grazing cover crops provided either neutral or positive soil health characteristics compared to no use.

Keywords: cattle performance, feed costs, forages (annual), grazing (late-season), soil health

Introduction

Livestock producers are often challenged by the costs of production and other economic uncertainties. The United States Department of Agriculture (2012) reported that the highest cost

experienced by livestock producers was purchased feed (United States Department of Agriculture-National Agricultural Statistics Service, 2014). Though it is unlikely to alter market prices, strategies can be implemented to reduce the cost of production (Adams et al., 1996; Walker, 2010).

Research has demonstrated that an extended grazing season has the ability to reduce feed costs, thereby lowering production costs (D'Souza et al., 1990; Adams et al., 1994; McCartney et al., 2009). Information regarding monoculture crops has been readily available but the exploration of mixed species in a cropping system has been limited. Studies suggest that a major advantage of forage mixtures is the ability to accumulate DM late into the growing season which allows for an extended grazing period (Carr et al., 1998, 2004; McCartney et al., 2004). Selection of an appropriate cocktail mixture can also result in an increase of forage and nitrogen yield while serving as a cover crop (Jedel and Salmon, 1995; Carr et al., 2004; Hansen et al., 2013).

The perceived benefits of cover crops are closely tied with soil health. Delgado et al. (2007) provided a detailed review of advances in cover crops achieved during the previous decade. Research suggests that cover crops reduce sediment transport, increase nutrient use efficiencies and limit nitrate-nitrogen leaching (Delgado et al., 2007). The development of cropping systems that conserve soil and water quality are a crucial aspect of maintaining forage quality and yields.

Though information exists on the benefits of cover crops, their use in cropping systems has been limited. As producers continue to be challenged by the elevated costs of animal production systems, a need persists to evaluate the economics of using annual forages to extend the grazing season. The objective of this study was to determine the effects of an annual

cocktail forage crop on herbage production, livestock performance, economic efficiency and soil health as affected by 3 grazing strategies. The potential of annual forages was evaluated in both single- and dual-crop production systems. It was hypothesized that herbage production would meet the nutrient requirements of beef cattle during the extended grazing period. Furthermore, incorporation of cover crop species as part of the annual cocktail forage crop would yield positive soil health characteristics. In years when moisture was not a limiting factor, cropping systems and grazing treatments would prove cost effective to varying degrees.

Materials and Methods

Study Area and Crop System Design

Prior to initiation of the study, all animal care and handling procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. This study was conducted in south central North Dakota, located near Central Grasslands Research Extension Center (latitude 46°45'N, longitude 99°28'W). The land was located in both Stutsman and Kidder counties, bound by the Missouri River basin on the west and the James River basin to the east. Soil within the study site consisted of Barnes-Svea loams (1 to 6% slopes), Barnes-Sioux sandy loams (3 to 9% slopes) and Sioux-Arvilla sandy loams (1 to 9% slopes; United States Department of Agriculture-Natural Resources Conservation Service, 2011).

Annual temperature variations range from mean monthly temperatures of -12.0°C in January to 21.0°C in July, with a mean annual temperature of 5°C (North Dakota Agricultural Weather Network, 2015). This area receives an average of 46.8 cm of annual precipitation (North Dakota Agricultural Weather Network, 2015), with the majority being received during the typical 110 to 135 d growing season (McNab and Avers, 1994; North Dakota Agricultural Weather Network, 2015).

The study design was a randomized split-plot design with 3 replicates. Each plot was approximately 4 ha and the site consisted of 9 plots. One half of each plot was dedicated for the annual cocktail forage crop (single-crop system) while the other half (dual-crop system) was planted to the annual cash crop followed by the annual cocktail forage crop. The cropping systems were subjected to the following grazing treatments: 1) full use, 2) 50 percent degree of disappearance and 3) no use. Grazing was the between effect and cropping system was the within effect. Cattle fed in a traditional drylot served as the control.

Forage Establishment

A no-till drill (John Deere, Model 750; Des Moines, IA) was used to establish cropping systems. The annual cash crop seeded in mid-May of 2012, 2013 and 2014 consisted of barley, oats and field peas (*Pisum sativum*), and barley, respectively. In 2012 and 2014, barley was seeded at a rate of 73 and 81 kg/ha. In 2013, oats and peas were seeded at a rate of 56 kg/ha for each species.

The annual cocktail forage crop, seeded as a single-crop, was planted in mid-July during 2012 through 2014. The annual cocktail forage crop seeded in the dual-crop system was planted in late July or early August after the cash crop was harvested during all years of the study. Seeding rates were 17, 12, 5, 2, 1 and 0.5 kg/ha for oats, field peas, sorghum-sudangrass, sunflower (*Helianthus annuus*), radish and turnip, respectively. In 2014, due to the unavailability of seed, sorghum-sudangrass was replaced by foxtail millet seeded at a rate of 5 kg/ha. Information regarding fertilizer and herbicide application can be found in Appendix A (Tables A1, A2 and A3).

Animal Grazing and Drylot Management

Mid-gestation, Angus crossbred beef heifers (18 to 20 months of age) were assigned to treatments from mid-October to late November or early December. Seventy-eight [434 ± 3 kg initial body weight (**BW**)], 83 ($402 \text{ kg} \pm 3 \text{ kg}$ initial BW) and 68 heifers (461 ± 3 kg initial BW) were used during 2012, 2013 and 2014, respectively. Carrying capacity for grazing treatments was determined based on predicted peak biomass production. The peak biomass production was measured by clipping six 0.25-m² frames per experimental split plot during the first week of October which was approximately 10 d prior to cattle turn out. Clippings were oven-dried at 50°C for 48 hours (**hr**) and samples were weighed. Harvest efficiency, which was used in calculating carrying capacity, was estimated at 80 and 50% for full use and 50% degree of disappearance, respectively (Neville et al., 2008; Sedivec et al., 2011). Stocking rate was determined by dividing available forage by estimated dry matter intake (**DMI**) per day, and then dividing by the projected grazing period which was 60 d. The DMI per day was estimated at 13 kg/d in 2012, 2013 and 2014. The estimated DMI per day is greater than the recommended nutrient requirements for a beef heifer weighing 454 kg, as described by the National Research Council (2000), because of elevated forage palatability (Sedivec et al., 2011).

Electric poly-wire fence and step-in posts were utilized as portable cross fences within each plot throughout the duration of the grazing study. Each plot was divided into 6 allotments and each allotment had a scheduled grazing period of 9 to 10 d. Water was distributed to tanks in each plot on a daily basis and a propane heater was used to provide continued access. The allotment closest to the water tank was used first and the cross fence moved further away from the water tank, which allowed for continued access to water and previously grazed allotments.

Animals in the drylot were given ad libitum access to water. Purina Wind and Rain mineral (Purina, Shoreview, MN) was also made available to all heifers.

Although the grazing study was based on 60 d, actual grazing occurred from October 22 to November 23, 2012 (32 d); October 22 to November 21, 2013 (30 d); and October 24 to December 1, 2014 (39 d). Beef heifers assigned to the drylot were managed to reflect the extended grazing period during each year. Diet composition for cattle in the drylot are available in Appendix B (Table B1). Livestock performance was determined using the mean from a 2 d BW and body condition score (**BCS**) both prior to turn out and after removal from the study. A visual scoring system described by Wagner et al. (1988) was utilized to determine BCS.

Economics

An economic analysis was conducted for all treatments. Input costs and grazing costs were calculated in dollars per hectare and dollars per head per day, respectively (Appendix A; Tables A1, A2 and A3). The land rental rate was assessed with the cash crop which appropriately reduced the cost of the annual forage crop. Average non-irrigated cropland cash rent values for Kidder County, North Dakota were used each year (National Agricultural Statistics Service, 2012; North Dakota Trust Lands, 2013, 2014). Actual costs for seed, fertilizer and herbicide were used. If fertilizer was spread, the costs were included with the cost of no-till seeding. Additionally, 2010 and 2013 North Dakota average custom rates for no-till seeding, combining and herbicide application were used to represent input costs for all years of the study (National Agricultural Statistics Service, 2010; North Dakota State University, 2013). Return per head per day and net return per hectare were calculated in dollars per head per day and dollars per hectare, respectively. Net return per hectare included the returns of both the cropping system and livestock performance.

Input costs and diet costs for the drylot were calculated in dollars per kilogram and dollars per head per day, respectively (Appendix B; Table B1). Actual cost of feed and an estimation of yardage and delivery were used to represent input costs for all years of the study. Yardage and delivery is greater than the estimated service fee, as described by Wagner et al. (2014), to account for regional rates. Return per head per day was calculated in dollars per head per day.

Soil

Samples were collected in both the single- and dual-crop system to characterize physical and chemical properties of the soil. To reduce variation associated with soil texture, slope or drainage class, sampling occurred within the Barnes-Sioux and Sioux-Arvilla sandy loam soil series. Sub-samples were collected within close proximity of each other and sample sites remained the same throughout the duration of the study. Prior to conducting the appropriate sampling technique, above ground residue was gently removed at each sampling site. Analysis of soil physical properties included Db, saturated hydraulic conductivity (K_{sat}) and soil aggregate stability. Analysis of soil chemical properties included soil nutrients and pH. Soil samples were collected in early June of each year, except for soil aggregate stability samples which were collected in mid-August. Three sub-samples per split plot were collected for K_{sat} . Six sub-samples per split plot were collected for all other measurements.

Soil Db was sampled using a 5.4 cm diameter sampler at 0 to 3 and 5 to 8 cm depths. Soil samples were then dried at 105°C for a 24 hr period. In calculating Db, the weight of the oven dried soil (**ODS**) was divided by the volume of the ring that enclosed the sample.

Saturated hydraulic conductivity was determined by utilizing a single-ring infiltrometer to test the rate of water infiltration. Before implementation of the infiltration test, a soil sample

was collected to a depth of 5 cm adjacent to the infiltrometer in order to later determine soil moisture content at the time of sampling. An amount of 1500 milliliters of water was poured into each infiltrometer ring and water infiltration was measured every 5 minutes (**min**). At the conclusion of the test, a 5 cm depth of soil was removed from within the infiltrometer ring for comparison of the soil moisture content after water infiltration was completed.

The before and after field soil-water content samples were weighed wet and then dried at 105°C for 24 hr to collect the ODS weight. The gravimetric water content was determined for both the before and after field moisture content measurements by subtracting the ODS weight from the wet soil weight and then dividing that value by the ODS weight. Both water content values were used in the subsequent calculation of K_{sat} and wetting front suction, plus documentation of the level of water in the single-ring infiltrometer at each 5 min increment. A computational Excel worksheet, which involved an equation derived from Asleson et al. (2009), was established to determine K_{sat} and wetting front suction (Equation 1; Appendix C; Table C1).

$$i(t) = \frac{\pi}{3}(\theta_1 - \theta_0)\{2[R(t)]^3 + 3[R(t)]^2L_{max} - L_{max}^3 - 4r_0^3\} \quad (\text{Equation 1})$$

$i(t)$ = infiltration over time

$R(t)$ = radius to wetting front

L_{max} = depth of infiltrometer insertion

Soil aggregate stability samples were collected to a depth of 15 cm with a tiling spade. The whole soil stability index (**WSSI**) developed by Nichols and Toro (2011) was implemented to quantify aggregate stability. This method combines both dry- and wet-sieved aggregates and utilizes a given quality constant that reflects the value of each aggregate size class as a soil quality indicator (Nichols and Toro, 2011). Soil samples were air dried for approximately 3 days until a constant moisture level was reached. Soil was then dry-sieved into 5 size classes: 8.0 to 4.75, 4.75 to 2.0, 2.0 to 1.0, 1.0 to 0.25 and 0.25 to 0.053 millimeters (**mm**). The > 8.0 and <

0.053 mm size soil fractions were retained for the calculation of WSSI. After dry-sieving, aggregates were treated with 10 min of capillary rewetting. This was followed by 5 min of mechanical wet-sieving by the apparatus used in the Kemper and Rosenau (1986) methodology. Soil remaining after wet-sieving was subjected to bath of 0.5% sodium hexametaphosphate coupled with shaking in order to disrupt aggregation. Soil particles were then washed through the appropriate sieve while being dispersed with the aid of water and a plastic policeman. This process left only the coarse fraction of the soil sample remaining on the sieve. The amount of water-stable aggregates from each sample was then calculated by subtracting the coarse fraction from the total amount of sample remaining after wet-sieving. Equation 2, 3 and 4 were used to calculate proportion of dry-sieved aggregates by size class (Nichols and Toro, 2011).

$$P_{ai} = \frac{\{W_A - [(W_c/W_o) \times W_A]\}}{W_T} \quad (\text{Equation 2})$$

P_{ai} = proportion of dry-sieved aggregates by size class
 W_A = weight of the total amount of soil in the selected weight class after dry-sieving
 W_c = weight of the coarse fraction remaining after dispersion
 W_o = weight of the sample prior to wet-sieving
 W_T = weight of the total amount of soil that was initially dry-sieved

$$WSA_i = [(W_a - W_c) \div W_o] \times 100 \quad (\text{Equation 3})$$

WSA_i = water-stable aggregation
 W_a = weight of sample left on sieve after wet-sieving
 W_c = weight of coarse fraction remaining after dispersion
 W_o = weight of initial sample

$$WSSI = \left\{ \sum_i^n [(I) \times (P_{ai}) \times ((WSA_i) \div 100)] \right\} \div n \quad (\text{Equation 4})$$

$WSSI$ = whole soil stability index
 n = number of aggregate size classes
 I = number of aggregate size classes subtracted by an increment of 1 every time you descend from the largest size class to the smallest

When identifying soil aggregate stability properties, both mean weight diameter (**MWD**) and geometric mean diameter (**GMD**) indices are commonly used. Data collected to determine WSSI was used to calculate MWD and GMD values (Kemper and Rosenau, 1986).

Soil was sampled to a depth of 60 cm using a 17.8 mm diameter soil probe for soil chemical analysis. Soil nitrate (**NO₃-N**) concentrations and pH levels were determined at 15 cm increments. Soil phosphorus (**P**), potassium (**K**), sulphur (**S**), zinc (**Zn**), copper (**Cu**) and chloride (**Cl**) concentrations and electrical conductivity (**EC**) were determined at the 0 to 15 cm soil depth. Nutrient and chemical analyses were performed by the North Dakota State University Soil Testing Laboratory (Waldron Hall, Fargo, ND).

Prior to nutrient analysis, soil was dried at 50°C for a 24 hr period, ground and passed through a 2 mm sieve. Soil NO₃-N concentration was determined with the colorimetric Olsen sodium-bicarbonate method (Olsen et al., 1954) with ascorbic acid reduction (Watanabe and Olsen, 1965) using a DU-64 spectrophotometer (Beckman Instruments, Fullerton, CA). Soil pH and soil EC (Appendix C; Table C2) were determined with a 1:1 soil to deionized water suspension. Concentration of soil P and K was determined through extraction with ammonium acetate, shaking and centrifugation followed by the mercury (II) thiocyanate method developed by Adriano and Doner (1982) using an Autoanalyzer II (Technicon Industrial Systems, Tarrytown, NY). Sulphur concentration (Appendix C; Table C2) was determined by adding 500 parts per million (**ppm**) P as monobasic calcium phosphate to the soil sample (Nathan and Gelderman, 2012). Concentration of Zn, Cu and Cl (Appendix C; Table C2) were extracted with diethylenetriaminopentaacetic acid, shaken, filtered and analyzed by an atomic emissions spectrophotometer (Nathan and Gelderman, 2012). Organic carbon was determined by combustion with a carbon-nitrogen analyzer (CN-2000, Leco Corporation, St. Joseph, MI;

DeSutter et al., 2005). Inorganic carbon was analyzed by the addition of hydrochloric acid and water, resulting in removal of inorganic carbon (Sparks, 1996).

Statistics

Herbage production, initial and final BW, ADG, initial and final BCS, Db, NO₃-N, P and K were measured in 2012, 2013 and 2014. Aggregate stability, MWD and GMD were measured in 2012 and 2014. Total carbon (TC) was measured in 2011 and 2014. Biomass clippings for 2012, 2013 and 2014 were averaged in order to account for some of the variation among subsamples. Data was transformed to help satisfy the distributional assumptions of the statistical methods prior to analysis (McCune and Grace, 2002; Quinn and Keough, 2002). A log transformation was applied to herbage production and NO₃-N, a fourth root transformation was applied to P and K, and the arcsine square root transformation was applied to TC. Statistical analyses were conducted in SAS version 9.4 (SAS Institute Inc. Cary, NC). Least square means estimates were calculated for statistically significant main effects and multiple comparisons used the Tukey-Kramer adjustment.

Herbage Production. Above ground biomass was analyzed using a split-plot design with repeated measures. Grazing and year were treated as the between effects and crop system was the within effect. The first-order autoregressive covariance structure was specified. This is appropriate because the observations collected during recent sampling sessions are expected to be more highly correlated than are observations collected at longer time intervals (Littell et al., 2006).

Livestock Performance. Initial and final BW, ADG and initial and final BCS were analyzed using a randomized design with grazing and year treated as main effects.

Soil Health. Bulk density was analyzed using a split-plot design with repeated measures. Grazing and year were treated as the between effects and cropping system was the within effect. The first-order autoregressive covariance structure was specified.

Aggregate stability, GMD and MWD were analyzed using a completely randomized design with a 2-way factorial. Year, grazing treatment and interactions were treated as main effects. Each plot was treated as a split plot and analyzed separately. A general linear model with multivariate analysis of variance (MANOVA) was implemented to analyze numerical differences ($P \leq 0.05$) regarding WSSI. This model was used to compare the single- and dual-crop system.

Nitrate, P and K were analyzed using a split-plot design with repeated measures. Grazing and year are the between effects and cropping system is the within effect. The first-order autoregressive covariance structure was specified. Total carbon was analyzed using a split-plot design with time as a 2-way factorial. Grazing treatment was treated as the between effect and cropping system was the within effect.

Results and Discussion

Climate

Average annual precipitation for Streeter, North Dakota was 46.8 cm, with the majority being received during the typical 110 to 135 d growing season (Table 2.1; McNab and Avers, 1994; North Dakota Agricultural Weather Network, 2015). Variability of mean seasonal precipitation was minor in relation to the 30 year average, with the exception of June, July and August of 2013 (North Dakota Agricultural Weather Network, 2015). Mean monthly temperature variations during the growing season for the 30 year average ranged from 6.0°C in

April to 14.0°C in September, with a mean annual daily temperature of 5°C (Table 2.2; North Dakota Agricultural Weather Network, 2015).

Table 2.1. Average monthly precipitation levels¹ (cm) by month and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014 growing seasons

Year	Month					
	April	May	June	July	August	September
2012	6.8	5.6	6.1	6.2	10.8	0.6
2013	3.1	12.2	2.5	1.4	0.61	10.2
2014	5.3	2.5	13.1	3.6	10.6	3.7
30 year average	2.7	6.2	8.7	8.1	5.9	5.2

¹ Data obtained from the North Dakota Agricultural Weather Network, 2015

Table 2.2. Average monthly temperature¹ (°C) by month and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2012	-7	-6	6	7	13	19	23	19	14	5	-2	-10
2013	-12	9	-10	-1	12	17	21	21	17	5	-3	-15
2014	-13	-16	-5	3	12	17	19	19	14	8	-7	-8
30 year average	-12	-9	-3	6	12	17	21	20	14	7	-2	-10

¹ Data obtained from the North Dakota Agricultural Weather Network, 2015

Herbage Production

During all years of the study, annual herbage production was not different ($P > 0.05$) between grazing treatments (Table 2.3). Annual herbage production was different ($P \leq 0.01$) between the cropping systems with the single-crop producing greater amounts of forage compared to the dual-crop system in all 3 years. This loss in herbage production of the dual-crop system appeared to be a function of water availability and competition with volunteer crop regrowth. Herbage production of the cover crop suffered when moisture was limited during the time of seeding. This was demonstrated by the dual-crop in 2013 when precipitation was below average during June, July and August. The additional stress resulted in poor seed germination and limited growth of cover crops.

Table 2.3. Average production (kg/ha) of single-crop (SC) and dual-crop (DC) systems by grazing treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Grazing treatment					
	Full use		50% degree of disappearance		No use	
	SC	DC	SC	DC	SC	DC
2012	2,521 ^a	1,658 ^b	2,456 ^a	1,367 ^b	3,145 ^a	1,039 ^b
2013	2,462 ^a	281 ^b	2,776 ^a	176 ^b	2,962 ^a	170 ^b
2014	1,890 ^a	829 ^b	2,003 ^a	712 ^b	2,503 ^a	747 ^b

^{a,b} Means of cropping system within grazing treatment and row followed by same letter are not different at $P > 0.05$

Sedivec et al. (2011) also studied the potential of utilizing annual forages in single- and dual-crop systems for late fall and early winter grazing at the Central Grasslands Research Extension Center near Streeter, North Dakota. During 2 consecutive years, when a burn down treatment was implemented to reduce re-growth of the first crop and weed invasions, production of the second forage crop within the dual-crop system was reduced by 60 and 21% compared to the single-crop system in years 1 and 2, respectively. It appeared that soil moisture was a critical aspect when trying to achieve a productive second crop in a dual-crop system (Sedivec et al., 2011).

Livestock Performance

Average daily gain was higher ($P \leq 0.05$) in the drylot treatment compared to the full use grazing treatment for all 3 years (Table 2.4). In 2013, ADG was higher ($P \leq 0.05$) for the drylot compared to 50 percent degree of disappearance grazing treatment; however, there was no difference between drylot and 50 percent degree of disappearance grazing treatment ($P > 0.05$) in 2012 and 2014. Average daily gain of cattle in the drylot suggests the more involved control of feed rations might account for elevated levels of ADG when compared to grazing systems. An evaluation of swathed oat/pea and triticale crop residue and swathed corn along with swathed western wheatgrass (*Pascopyrum smithii*) and cows fed in a drylot displayed limited variation of

beef cow performance (Karn et al., 2005). However, Funston and Larson (2011) observed that bred heifers developed in a drylot during the winter grazing period gained more than bred heifers grazing a combination of corn residue and winter range during the same period. Average daily gain of cows fed in cropping systems or drylot settings produce variable results (Karn et al., 2005; Funston and Larson, 2011). Perhaps issues of wind protection and differences in forage quality and energy expenditure, which were not accounted for during this study, also influenced the performance of livestock.

Table 2.4. Stock density, initial and final body weight (BW), average daily gain (ADG) and initial and final body condition score (BCS) of beef heifers by treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Item	Treatment		
		Full use	50% degree of disappearance	Drylot
2012	Stock density	36	15	37
	Initial BW, kg	435 ^a	433 ^a	435 ^a
	Final BW, kg	464 ^a	468 ^a	477 ^a
	ADG, kg	0.92 ^a	1.1 ^{ab}	1.3 ^b
	Initial BCS	5.4 ^a	5.3 ^a	5.2 ^a
	Final BCS	5.4 ^a	5.6 ^a	5.6 ^a
2013	Stock density	26	14	43
	Initial BW, kg	402 ^a	402 ^a	402 ^a
	Final BW, kg	411 ^a	419 ^a	441 ^b
	ADG, kg	0.34 ^a	0.58 ^a	1.29 ^b
	Initial BCS	5.3 ^a	5.3 ^a	5.2 ^a
	Final BCS	5.5 ^a	5.6 ^a	5.7 ^a
2014	Stock density	20	11	37
	Initial BW, kg	460 ^a	461 ^a	461 ^a
	Final BW, kg	469 ^a	475 ^a	479 ^a
	ADG, kg	0.23 ^a	0.38 ^{ab}	0.47 ^b
	Initial BCS	5.2 ^a	5.3 ^a	5.3 ^a
	Final BCS	5.3 ^a	5.6 ^a	5.5 ^a

^{a,b} Means within row followed by same letter are not different at $P > 0.05$

Variation in BCS of livestock has several implications that can be used for management decisions. Initial and final BCS, measured by treatment and year, were not different ($P > 0.05$;

Table 2.4) during all 3 years of the study. Kunkle et al. (1993) and Adams et al. (1994) determined that it is likely for BCS to vary 1 to 2 scores on a herd of beef cattle throughout the year. Research that considers the relationship of body condition to maintenance and productivity is readily available, though research that relates body condition to the type of winter grazing systems and grazing intensity is lacking. Body condition or change in body condition is a valuable indicator in evaluating nutritional status. Although livestock with a higher BCS tend to have higher weight, body weight alone is not a good estimate of body condition (Kunkle et al., 1993). All treatments showed neutral or increased final BCS during the 3 years of this study, which suggests that herbage production of the annual cocktail forage crop was adequate for maintenance of mid-gestation heifers.

Economics

The only negative return (return per head per day) to the crop system or grazing treatment in 2012 was experienced in the single-crop of the 50 percent degree of disappearance grazing treatment (Table 2.5). In 2013 and 2014 all treatments resulted in negative returns except for the drylot treatment. Positive returns of drylot management during the 3 years of this study suggest that producers could expect variable, but consistent, return per head per day. Returns of the full use grazing treatment were not positive in 2013 and 2014, but losses were limited when compared to other grazing treatments. The dual-crop of the full use grazing treatment resulted in limited losses when compared to the single-crop in 2012 and 2014. The 50 percent degree of disappearance and no use grazing treatments were not cost effective during all years of the study, with the exception of the dual-crop of the 50 percent degree of disappearance grazing treatment in 2012. When moisture and herbage production was adequate and when commodity prices were strong, the full use grazing treatment had potential to be cost effective. The calculated return

values indicated that the dual-crop generally had greater potential to be cost effective, especially when commodity prices were high. It is important to understand that adequate moisture will not always result in cost effective systems. Other factors like commodity prices, price of land, cost of fuel and market returns influence cost effectiveness.

Net return per hectare which considers the returns from both the cropping system and livestock performance displayed similar trends (Table 2.5). The only negative net return in 2012 was experienced in the single-crop system of the 50 percent degree of disappearance grazing treatment. In 2013, all treatments displayed negative net returns except the full use grazing treatment of the single-crop. In 2014, all grazing treatments resulted in negative net returns. The losses of the full use grazing treatment were limited when compared to other grazing treatments during all 3 years.

Table 2.5. Return per head per day¹ (\$/hd per d) and net return per hectare¹ (\$/ha) of single-crop (SC) and dual-crop (DC) systems by treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Item	Treatment						Drylot
		Full use		50% degree of disappearance		No use		
		SC	DC	SC	DC	SC	DC	
2012	\$/hd per d	0.75	1.78	(1.14)	0.87	-	-	1.70
	\$/ha	85.15	194.60	(57.20)	83.59	(218.32)	(9.48)	-
2013	\$/hd per d	(0.76)	(4.33)	(1.56)	(14.50)	-	-	1.91
	\$/ha	90.30	(69.60)	(100.40)	(77.05)	(230.82)	(87.13)	-
2014	\$/hd per d	(1.48)	(0.58)	(2.76)	(2.24)	-	-	1.15
	\$/ha	(133.29)	(146.40)	(138.54)	(161.06)	(242.75)	(197.05)	-

¹ Values in parenthesis indicate negative returns

Though research is limited regarding the economics of integrated crop and livestock production systems, Munson et al. (1999) concluded that the costs of grazing windrowed millet during the winter months was significantly less than the cost of baling and feeding millet in a drylot. Karn et al. (2005) reported that grazing windrowed annual forages as opposed to feeding

cows in a drylot could reduce winter feeding cost provided that climatic conditions were not a limiting factor. Net return per hectare was influenced by the same factors that effected cropping system returns but also included factors of livestock performance and market returns. Though economic uncertainties can be challenging strategies can be implemented to reduce production costs.

Soil Health

Grazing treatments did not affect Db ($P > 0.05$) at the 0 to 3 or 5 to 8 cm depth compared to no use during all 3 years (Table 2.6). Level of compaction at the indicated depths was not affected ($P > 0.05$) from 2012 to 2014 although a trend of decreasing measurements was observed. A study performed on Alberta pastures found Db was significantly greater up to a 10 cm depth in short duration grazing than continuous grazed and ungrazed pastures due to trampling (Donkor et al., 2002). It was determined that variation in the amount of organic residue at the soil surface, and stocking rate and density may have reduced compaction by trampling on soil. In a study evaluating the impact of reduced tillage and no-tillage systems on soil pore distribution under animal grazing, cattle trampling had a more pronounced effect under reduced tillage (Iglesias et al., 2014). As suggested by Mapfumo et al. (1999), differences in soil properties such as texture, organic matter, water content and other environmental conditions could also contribute to the variation of Db in our study and others.

In 2013, the dual-crop had lower ($P \leq 0.05$) levels of Db than the single-crop although this was not observed in 2012 or 2014. It has been suggested that organic residues at the soil surface, or within the soil, can limit increases in Db (Gupta et al., 1987; Soane, 1990; Blanco-Canqui and Lal, 2009). Perhaps the increased levels of organic residue in the dual-crop system

helped reduce the impacts of grazing in 2013. Gupta et al. (1987) concluded that residue addition to soils, at realistic levels, can only have limited beneficial impact on soil compaction.

Table 2.6. Bulk density (Db; g/cm³) of single-crop (SC) and dual-crop (DC) systems by grazing treatment, depth and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year ¹	Depth, cm	Grazing treatment					
		Full use		50% degree of disappearance		No use	
		SC	DC	SC	DC	SC	DC
2012	0-3	1.30	1.34	1.41	1.35	1.24	1.32
	5-8	1.39	1.32	1.44	1.47	1.28	1.34
2013	0-3	1.16 ^a	1.12 ^b	1.28 ^a	1.15 ^b	1.19 ^a	1.06 ^b
	5-8	1.36 ^x	1.22 ^y	1.40 ^x	1.34 ^y	1.28 ^x	1.20 ^y
2014	0-3	1.02	1.07	1.18	1.16	1.09	1.06
	5-8	1.26	1.23	1.42	1.43	1.36	1.34

¹ There was no difference ($P > 0.05$) between SC and DC systems for any grazing treatment in 2012 and 2014

^{a,b} Means of cropping system within grazing treatment and row followed by the same letter are not different at $P > 0.05$

^{x,y} Means of cropping system within grazing treatment and row followed by the same letter are not different at $P > 0.05$

Aggregate stability was similar across all grazing treatments in 2012; however, by 2014 measurements increased ($P = 0.02$) in the full use and 50 percent degree of disappearance grazing treatments (Table 2.7). Aggregate stability of the no use grazing treatment showed no change ($P > 0.05$) from 2012 to 2014. Geometric mean diameter and MWD were not affected by year or treatment ($P > 0.05$). Franzluebbers and Stuedemann (2008) determined that the stability of aggregates was unaffected by grazing in both conventional and no-tillage systems. Barto et al. (2010) observed that agricultural practices such as grazing and fertilization can increase aggregate stability. It was further concluded that abiotic factors can be more important for determining aggregate stability than biotic factors (Barto et al., 2010). Though the aim of aggregate stability analysis is to give a reliable description of the behavior of soils under the

effect of water, wind and management, it can be difficult to quantify and interpret (Amezqueta, 1999).

Table 2.7. Aggregate stability measured by the whole soil stability index (WSSI), geometric mean diameter (GMD) and mean weight diameter (MWD) by grazing treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 and 2014

Year	Item	Grazing treatment		
		Full use	50% degree of disappearance	No use
2012	WSSI	0.14 ^{ax}	0.16 ^{ax}	0.16 ^{ax}
	MWD, mm	1.92	2.17	1.89
	GMD, mm	1.21	1.71	1.27
2014	WSSI	0.33 ^{ay}	0.24 ^{by}	0.15 ^{cx}
	MWD, mm	2.69	1.49	1.72
	GMD, mm	1.35	1.49	1.20

^{a,b,c} Means within row followed by same letter are not different at $P > 0.05$

^{x,y} Means within column followed by same letter are not different at $P > 0.05$

Concentration of NO₃-N at all sample depths indicated that a crop system and year effect occurred, but no grazing treatment effect (Table 2.8). The single-crop system consistently had greater amounts ($P \leq 0.05$) of NO₃-N than the dual-crop system at all sample depths. Nitrate concentration indicated a crop x year interaction ($P \leq 0.05$) at depths of 0 to 15 cm. Studies suggest that cover crops have the ability to scavenge residual soil NO₃-N left from previous crops and reduce losses during the following crop (Delgado, 1998; Delgado et al., 2001). Crop residue is an important aspect of cover crops and can contribute significant quantities of nutrients for herbage production.

Soil phosphorus concentration showed a year effect ($P \leq 0.05$), but no treatment or crop effect and no interactions ($P > 0.05$; Table 2.9). Potassium concentration, measured by treatment, crop, year and interactions, was not different ($P > 0.05$) during all 3 years (Table 2.9). Though grazing treatments did not affect concentration of K, the full use grazing treatment resulted in greater amounts ($P = 0.0848$) than the 50% degree of disappearance grazing

treatment. With the exception of K, our findings are similar to others where they showed grazing under well managed systems had little effect on short-term soil nutrient distribution (Mathews et al., 1994; Lavado et al., 1996; Mapfumo et al., 2000).

Table 2.8. Average soil nitrate (NO₃-N) concentration (ppm) of single-crop (SC) and dual-crop (DC) systems by grazing treatment, depth and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Depth, cm	Grazing treatment					
		Full use		50% degree of disappearance		No use	
		SC	DC	SC	DC	SC	DC
2012	0-15	19 ^a	12 ^b	13 ^a	9 ^b	12 ^a	16 ^b
	15-30	17 ^a	11 ^b	12 ^a	9 ^b	10 ^a	14 ^b
	30-45	13 ^a	10 ^b	13 ^a	9 ^b	10 ^a	6 ^b
	45-60	9 ^a	6 ^b	9 ^a	6 ^b	8 ^a	7 ^b
2013	0-15	60 ^a	28 ^b	48 ^a	16 ^b	63 ^a	18 ^b
	15-30	46 ^a	18 ^b	23 ^a	12 ^b	31 ^a	18 ^b
	30-45	30 ^a	12 ^b	14 ^a	8 ^b	13 ^a	12 ^a
	45-60	36 ^a	12 ^b	19 ^a	7 ^a	10 ^a	8 ^b
2014	0-15	16 ^a	14 ^b	9 ^a	10 ^a	12 ^a	8 ^b
	15-30	12 ^a	9 ^b	13 ^a	9 ^b	12 ^a	6 ^b
	30-45	7 ^a	7 ^a	8 ^a	5 ^b	7 ^a	4 ^b
	45-60	6 ^a	7 ^a	7 ^a	4 ^b	5 ^a	4 ^b

^{a,b} Means of cropping system within grazing treatment and row followed by same letter are not different at $P > 0.05$

Total carbon showed a year x crop interaction ($P \leq 0.05$), but no grazing treatment, crop or year effect and no other interactions ($P > 0.05$; Table 2.9). A 12 year study performed on 2 dryland cropping systems in North Dakota concluded that conversion from crop-fallow to more intensive cropping systems utilizing no-tillage are needed to increase carbon in croplands of the northern Great Plains (Halvorson et al., 2002).

Table 2.9. Average soil phosphorus (P), potassium (K), and total carbon (TC) concentration at 0 to 15 cm by grazing treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Grazing treatment		
	Full use	50% degree of disappearance	No use
	P, ppm		
2012	20 ^a	4 ^a	12 ^a
2013	23 ^b	13 ^b	19 ^b
2014	20 ^a	11 ^b	23 ^b
	K ¹ , ppm		
2012	309	135	207
2013	314	236	220
2014	586	180	203
	TC ² , %		
2011	2.6	2.4	2.7
2014	2.7	2.4	2.3

¹ Concentration measured by treatment, crop, year and interactions are not different at $P > 0.05$

² Concentration measured by treatment, crop and year are not different at $P > 0.05$

^{a,b} Means within column followed by same letter are not different at $P > 0.05$

Implications

Grazing treatments did not have an effect on herbage production of the cropping system, but production of the single- and dual-crop system were different. The reduced production of the dual-crop may be attributed to limited moisture conditions which also has an effect on time of seeding and volunteer crop regrowth and weeds. Inhibited herbage production is likely to be reflected in the cost efficiency of grazing systems. Returns of the full use grazing treatment were not consistently positive, but losses were limited when compared to other grazing treatments. The drylot provide variable, but consistent returns during all 3 years of the study. Cattle ADG was highest in the drylot, though all systems provided neutral or increased BCS and ADG. If considering a graze versus no-graze scenario, this study has demonstrated that soil health tested in this study was not impacted by grazing the cropping system.

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**APPENDIX A. COSTS AND RETURNS BY GRAZING TREATMENT AND CROPPING
SYSTEM (2012 TO 2014) AT CENTRAL GRASSLANDS RESEARCH EXTENSION**

CENTER NEAR STREETER, ND

Table A1. Costs and returns of single-crop (SC) and dual-crop (DC) systems by grazing treatment at Central Grasslands Research Extension Center near Streeter, ND during 2012

Item	Grazing treatment					
	Full use		50% degree of disappearance		No use	
	SC	DC	SC	DC	SC	DC
Input costs, \$/ha						
Cash crop seed ¹	-	17.67	-	17.67	-	17.67
No-till seeding ²	-	36.99	-	36.99	-	36.99
Fertilizer ^{1,3}	-	52.39	-	52.39	-	52.39
Combining ²	-	63.80	-	63.80	-	63.80
Herbicide ^{1,4}	16.38	10.50	16.38	10.50	16.38	10.50
Herbicide application ²	12.36	12.36	12.36	12.36	12.36	12.36
Land rent ⁵	108.97	108.97	108.97	108.97	108.97	108.97
Annual forage mix seed ¹	38.40	38.40	38.40	38.40	38.40	38.40
No-till seeding ²	29.48	29.48	29.48	29.48	29.48	29.48
Returns, \$/ha						
Cash crop	-	360.78	-	360.78	-	360.78
Annual forage costs, \$/ha	205.59	67.88	205.59	67.88	205.59	67.88
Stock density/ha	3.34	2.38	1.49	0.91	-	-
Grazing costs, \$/hd per d	1.92	0.89	4.35	2.34	-	-

¹ Actual cost

² ND custom rate values (National Agricultural Statistics Service, 2010)

³ April application of 90 kg/ha urea nitrogen

⁴ Single-crop: 1 to 2 qt/ha glyphosate; Dual-crop: 2 qt/ha glyphosate

⁵ Non-irrigated cropland average rental rates for Kidder County, ND (National Agricultural Statistics Service, 2012)

Table A2. Costs and returns of single-crop (SC) and dual-crop (DC) systems by grazing treatment at Central Grasslands Research Extension Center near Streeter, ND during 2013

Item	Grazing treatment					
	Full use		50% degree of disappearance		No use	
	SC	DC	SC	DC	SC	DC
Input costs, \$/ha						
Cash crop seed ¹	-	79.38	-	79.38	-	79.38
No-till seeding ²	-	37.21	-	37.21	-	37.21
Fertilizer ¹	-	-	-	-	-	-
Combining ²	-	73.24	-	73.24	-	73.24
Herbicide ^{1,3}	16.38	10.50	16.38	10.50	16.38	10.50
Herbicide application ²	15.69	15.69	15.69	15.69	15.69	15.69
Land rent ⁴	116.64	116.64	116.64	116.64	116.64	116.64
Annual forage mix seed ¹	44.50	44.50	44.50	44.50	44.50	44.50
No-till seeding ²	37.21	37.21	37.21	37.21	37.21	37.21
Returns, \$/ha						
Cash crop	-	327.42	-	327.42	-	327.42
Annual forage costs, \$/ha	230.43	81.72	230.43	81.72	230.43	81.72
Stock density/ha	4.0	0.46	2.15	0.16	-	-
Grazing costs, \$/hd per d	1.94	5.51	3.58	16.53	-	-

¹ Actual cost

² ND custom rate values (North Dakota State University, 2013)

³ Single-crop: 1 to 2 qt/ha glyphosate; Dual-crop: 2 qt/ha glyphosate

⁴ Non-irrigated cropland average rental rates for Kidder County, ND (North Dakota Trust Lands, 2013)

Table A3. Costs and returns of single-crop (SC) and dual-crop (DC) systems by grazing treatment at Central Grasslands Research Extension Center near Streeter, ND during 2014

Item	Grazing treatment					
	Full use		50% degree of disappearance		No use	
	SC	DC	SC	DC	SC	DC
Input costs, \$/ha						
Cash crop seed ¹	-	17.79	-	17.79	-	17.79
No-till seeding ²	-	40.20	-	40.20	-	40.20
Fertilizer ^{1,3}	-	54.36	-	54.36	-	54.36
Combining ²	-	73.24	-	73.24	-	73.24
Herbicide ^{1,4}	20.41	29.01	20.41	29.01	20.41	29.01
Herbicide application ²	15.69	15.69	15.69	15.69	15.69	15.69
Land rent ⁵	131.46	131.46	131.46	131.46	131.46	131.46
Annual forage mix seed ¹	37.56	37.56	37.56	37.56	37.56	37.56
No-till seeding ²	37.21	37.21	37.21	37.21	37.21	37.21
Returns, \$/ha						
Cash crop	-	239.82	-	239.82	-	239.82
Annual forage costs, \$/ha	242.33	74.78	242.33	74.78	242.33	74.78
Stock density/ha	2.31	1.07	1.29	.44	-	-
Grazing costs, \$/hd per d	2.69	1.79	4.83	4.31	-	-

¹ Actual cost

² ND custom rate values (North Dakota State University, 2013)

³ April application of 112 kg/ha urea nitrogen

⁴ Single-crop: 4.57 qt/ha Weld; Dual-crop: .66 qt/ha glyphosate, 1.63 oz/ha Sharpen

⁵ Non-irrigated cropland average rental rates for Kidder County, ND (North Dakota Trust Lands, 2014)

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**APPENDIX B. COSTS AND RETURNS FOR DRYLOT MANAGEMENT (2012 TO
2014) AT CENTRAL GRASSLANDS RESEARCH EXTENSION CENTER NEAR
STREETER, ND**

Table B1. Costs and returns for drylot management by year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Item	Year and diet composition (%)					
	2012	%	2013	%	2014	%
DM costs¹, \$/kg						
Barley	0.33	7	-	-	-	-
Corn	0.37	7	-	-	-	-
Oats	-	-	0.26	30	-	-
Distillers	-	-	-	-	0.11	14
Hay	0.11	27	0.84	27	0.07	41
Winter wheat haylage	0.13	27	-	-	-	-
Corn silage	0.11	32	0.04	43	0.11	45
Yardage and delivery, \$/hd per d²	0.40	-	0.40	-	.040	-
Feeding costs, \$/hd per d	2.13	-	2.63	-	1.47	-
Returns, \$/hd per d	1.70	-	1.91	-	1.15	-

¹ Actual cost

² Service fee (Wagner et al., 2014)

Literature Cited

Wagner, J. J., S. L. Archibeque, and D. M. Feuz. 2014. The modern feedlot for finishing cattle.

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**APPENDIX C. ADDITIONAL SOIL PARAMETERS (2012 TO 2014) BY GRAZING
TREATMENT AT CENTRAL GRASSLANDS RESEARCH EXTENSION CENTER
NEAR STREETER, ND**

Table C1. Soil saturated hydraulic conductivity (K_{sat}) and soil wetting front suction by grazing treatment at Central Grassland Research Extension Center near Streeter, ND during June and August of 2014

Year	Month	Grazing treatment		
		Full use	50% degree of disappearance	No use
K_{sat} , cm/min				
2014	June	0.68 ^a	0.54 ^a	0.84 ^a
	August	1.33 ^b	0.84 ^b	1.62 ^b
Wetting front suction, cm				
2014	June	4.80 ^a	1.56 ^b	4.25 ^a
	August	4.96 ^a	2.51 ^b	4.58 ^a

Note. Statistical analysis conducted in SAS 9.4 (SAS Institute Inc. Cary, NC). Analyzed using a completely randomized design with 2-way factorial. Year, grazing treatment and interactions were main effects.

^{a,b} Means within column by row with same letters are not different at $P > 0.05$

Table C2. Soil pH, electrical conductivity (EC), sulphur (S), zinc (Zn), copper (Cu) and chloride (Cl) concentration¹ by grazing treatment and year at Central Grasslands Research Extension Center near Streeter, ND during 2012 to 2014

Year	Grazing treatment	pH	EC ²	S ³	Zn ³	Cu ³	Cl ³
2012	Full use	6.33	0.27	4.73	2.22	0.86	1.63
	50% degree of disappearance	6.62	1.08	2.58	0.68	0.51	1.31
	No use	6.63	0.74	4.44	1.71	0.61	1.04
2013	Full use	5.68	-	11.96	2.13	0.70	3.67
	50% degree of disappearance	6.68	-	12.96	1.65	0.47	4.21
	No use	6.40	-	7.89	1.78	0.58	4.64
2014	Full use	6.32	0.21	6.39	1.93	0.69	3.37
	50% degree of disappearance	7.05	0.13	4.73	1.23	0.54	4.66
	No use	6.75	0.14	3.24	1.38	1.55	3.03

¹ Samples were collected from 0 to 15 cm

² Unit is mmhos/cm

³ Unit is ppm