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EFFECTS OF STOCKING RATE ON FORAGE NUTRIENT COMPOSITION OF NEBRASKA SANDHILLS UPLAND RANGE WHEN GRAZED IN EARLY SUMMER AND THE EFFECTS OF GRAZING ON NEBRASKA SANDHILLS MEADOW FORAGE NUTRIENT COMPOSTION

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SANDHILLS MEADOW FORAGE NUTRIENT COMPOSTION

by

Jared Vern Judy

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The objectives of this research were to 1) evaluate the effects of stocking rate on forage nutrient quality 2) quantify the relative proportions of current vs. previous year growth being consumed in early summer upland range pastures and 3) determine how grazing effects forage nutrient quality in subirrigated meadows in the Nebraska Sandhills. Experiment 1 was a two year study conducted on the experimental upland range paddocks at Gudmundsen Sandhills Laboratory. Twelve 2-hectare paddocks were assigned one of three treatments stocked at 0 (control), 0.57 (light), and 0.85 (heavy) AUM/ha. Ten 0.25 m^2 quadrats were clipped per paddock during the study. Diet quality was determined using esophageally fistulated cows.

Experiment 2 was conducted at a commercial ranch near Lakeside, NE. Esophageally fistulated cows sampled pastures either grazed or non-grazed

throughout the grazing season starting on June 14 and ending late August in a two year study. Samples were analyzed for IVOMD, CP and NDF content.

Stocked upland range paddock diet samples had decreased CP, IVOMD, and greater NDF content compared with control paddocks for diet samples. Diet samples were lower in quality compared with current year growth but greater in quality compared with previous year growth indicating cattle consumed previous year growth as part of the diet. Forage accumulation increased linearly in control paddocks but did not change in stocked paddocks. Grazed samples had lower CP content than non-grazed pastures early in the grazing season and unaffected later in the season. Neutral detergent fiber was greater in grazed compared with non-grazed pastures early in the grazing season. Diet IVOMD was most affected by grazing as season progressed. These studies indicate grazing and stocking rate effect diet quality in subirrigated meadows and upland range. Producers need to rotate cattle frequently in early summer to ensure high quality intake.

Key words: diet quality, grazing, stocking rate

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Introduction

The Nebraska Sandhills provide an excellent forage resource for cattle production. The Sandhills contain about 5.16 million hectares of rangeland and are primarily dominated by native grass species comprised of both warm and cool season grasses (Adams et al., 1998). The Nebraska Sandhills contain upland range and subirrigated or wetland meadows. Recommended stocking rates for upland range ranges from 0.99 to 2.22 AUM/ha for Western to Eastern Sandhills (Stubbendieck and Reece, 1992) depending on range site, range condition and precipitation. The subirrigated meadows range from 3.9 to 4.9 AUM/ha (Volesky et al., 2004).

Upland range is dominated by warm season grasses, in consequence, diet quality increases during April and May reaching a peak between late May and early June, and then decreases for the remainder of the year (Lardy et al., 2004). Due to the unique nature of the meadows having a large portion of cool season grasses, there is a rapid increase in forage quality with CP reaching a peak in April, NDF reaching its lowest point in April and IVOMD reaching a peak between May and June. During the warmer summer months, the quality of the forage decreases until the temperature cools and the cool season species can regrow during late summer to early fall periods (Lardy et al., 1997).

Cattle numbers are continually fluctuating due to markets and weather, however, Nebraska currently has three counties ranked in the top ten for cattle numbers in the United States. Those counties are located in the Nebraska Sandhills and are Cherry (166,000 cows), Custer (100,000 cows) and Holt

(99,000 cows). These strong numbers in cattle are attributed to the natural resources that are available in the State (Nebraska Beef Council, 2013). Forage growth in these counties provide an excellent forage resource for grazing cattle.

Literature Review

Methods for determining diet nutrient composition

A major tool for producers to optimize their resources is knowing the quality of the forage. Knowing the quality of the forage is necessary for matching the requirements of the animal to the available nutrients. Determining the quality of the nutrients that the animal actually consumes is more complicated than simply clipping a grass sample and sending it to a lab. Methods that have been devised include: direct observation, clipping, stomach analysis, fecal analysis, and fistula techniques (Holechek et al., 1982b). Each technique has positive and negative attributes which must be taken into consideration when choosing a method that best fits.

Direct Observation

Direct observation may be the simplest and least expensive method when it comes to tools needed for sampling. However, Cook (1964) emphasized that direct observation or hand plucking is best utilized on lightly grazed pastures due to the ability to observe plant material being consumed. With heavy stocking, use of a cage to protect certain areas would be needed so a representative sample could be collected. A potential problem with using a cage is knowing what is actually being consumed during different growing periods. It is quick and relatively inexpensive, however, a well trained eye and especially a well-trained plant identifier is crucial for accurate sampling (Holechek et al., 1982a).

Estimating the diet being consumed can become very difficult depending on the range type as well as season of sampling. Free et al. (1971) stated that early season growth becomes more challenging to distinguish between species compared with sampling when the plants have matured and distinguishing characteristics become more evident. Cattle are also able to strip leaves and fruit from certain plants (Cook, 1964) which could prove difficult for a person to determine.

Stomach Analysis

Determining the quality of the forage being consumed via stomach analysis would allow the animal to selectively consume diets without performing a surgical operation prior to diet collection. However, stomach analysis may require the sacrifice of the animal and hence would only be applicable to animals with large populations unless one was able to tranquilize the animal and use a trocar to remove the sample (Holechek et al., 1982a). While this may give a general idea of what the animal has consumed it does have potential problems besides the possible sacrifice of the animal and could be potentially expensive. Rice (1970) suggested that the stomach analysis may favor less digestible forage due to passage rate. Alternative methods for livestock have proven more effective for determining diet quality which results in this method being less utilized. This method would be best suited for wild animals.

Fecal Analysis

In the early 80's, fecal analysis became more popular as a resource for evaluating quality of cattle diets. Fecal analysis was a way to determine diet quality without potentially altering the animal's grazing behavior as the animal can move about freely (Mcinnis et al., 1983). Hence the major advantage of utilizing fecal analysis is that it

allows the animal to behave naturally and move about freely, which would help avoid any error that could be caused by human intervention. Two methods of fecal analysis include the nutritional balance analyzer (NUTBAL) and microhistological techniques. NUTBAL technique predicts CP and digestible organic matter using equations developed from samples that have been analyzed by near infrared spectroscopy (NIRS; Cook, 1999). With microhistological analysis, fecal samples are ground, soaked in a dilute solution of sodium hydroxide, then particles are identified using a microscope (Vavra and Holechek, 1980). However, because some plants are digested differently, lab analysis may become tedious and difficult and an extensive collection of reference plants is needed (Holechek et al., 1982a). McInnis et al. (1983) reported that fecal samples had greater percent of grasses in the sample compared with esophageal diets and stomach content samples which could be caused by differences in digestibility of the different species of plants. Rice (1970) suggested that due to mixing, regurgitation and different rates of digestion, fecal analysis can misrepresent the true quality of the diet compared with other collection methods.

Clipping

Clipping quadrats is also a relatively inexpensive method for determining quality of the available forage (Holechek et al., 1982b). Clipped samples are free from salivary contamination which can occur with other methods of sampling. If the number of quadrats is small, clipping may be quicker than other methods, however, it can have a significant time requirement if sampling large number of quadrats. If sampling occurs during the dormant season, then clipping samples may be an effective measure of available nutrients because they more closely match the value of the actual cattle diets

(Wallace et al., 1972). Jefferies and Rice (1969) also showed in drier years clipped sample protein content may be comparable to the actual diets of the animal which could be caused by decreased animal selectivity.

Lesperance et al., (1960b) conducted four studies comparing fistulated cattle with clipped samples under a protective cage. No agreement was found between fistula samples and clipped samples harvested on the same day. Rao et al., (1973) sampled monthly during the growing season (May, June, July, August, September and October) and reported increased protein and ash and decreased crude fiber when using esophageally fistulated steers compared with hand clipped samples. Clipping quadrats to predict diet quality does have a higher potential for committing error such as misrepresenting actual diet and hence, should be used with caution when used to estimate diet nutrient composition (Edlefsen et al., 1960; Lesperance et al., 1960b; Kiesling et al., 1969; Rao et al., 1973; Kirch et al., 2007; Hughes et al., 2010).

Fistula technique

Edlefsen et al. (1960) reported that grazing animals select their diet from a variety of plant species. Due to cattle selectivity, allowing the cattle to sample the plant species they prefer would help eliminate the aspect of human bias in diet sampling. Two different fistula techniques are common for collecting diet samples for grazing animals which are esophageal and ruminal.

Ruminally fistulated cattle are commonly used to collect diet samples. However, this technique has its limitations when being used on range conditions. The rumen has to be emptied prior to sampling and cleaned thoroughly and thus is more time consuming and labor intensive then other methods (Holechek et al., 1982). Due to the evacuation of

the rumen the animal could be less selective (Van Dyne and Torell, 1964) due to grazing haphazardly. Multiple sampling during a single day or even a week have shown to decrease digestibility in the animal and subsequently may have an impact on grazing performance (Lesperance and Bohman, 1964). Holechek et al., (1982b) reported the advantages of using the rumen versus the esophageal fistulated include ease of establishment and maintenance, and less care while sampling while the disadvantages include increased time required to empty and wash rumen and then replace contents after collection.

Van Dyne and Torell (1964) reported the use of esophageal fistulas as early as the 1800's by Claude Bernard and Pavlov, however, the procedure became popular in ruminant animal research in the 1960's to early 1970's. Development of the fistula technique has evolved so the procedure is safe and essentially harmless to the animal. A review of the development of surgical techniques was done by Van Dyne and Torell (1974) who reported success rates over 90%. Even though it is difficult to quantitatively evaluate differences in fistulated compared with non-fistulated steers, successfully fistulated animals graze normally (Arnold et al., 1964). Animal longevity was once believed to be an issue, however, with progressing research and better surgical techniques, it is not now an issue with longevity being greater than 6 years for cattle and 4 years for sheep (Langlands, 1969; Grings et al., 1995).

Potential problems with using esophageally fistulated cattle were reported by Holechek et al. (1982b) include: contamination due to saliva, rumen contamination, incomplete recovery, and collecting a representative sample on large pastures. Other possibilities for variation could be due to animal differences such as: breed differences,

age, diet and sex (Langlands, 1969; Hodgson and Jamieson, 1981; Miller and Gaud,

1989; Griggs et al., 1995; Hollingsworth-Jenkins et al., 1995; Mohammad et al., 1996).

In a study to determine the effects of evacuating the rumen while diet sampling,

Olson (1991) compared three different collection techniques: esophageal collection with

a full rumen, esophageal collection after rumen evacuation and lastly rumen collection

after the rumen evacuation. Olson hypothesized that selectivity would not be altered by

rumen evacuation, and that each collection technique would be the same relative to the

feed offered. Esophageal masticate samples were equal in N as the hay offered, however,

rumen masticate samples had greater N ($P = 0.04$). If caution is taken, Olson concluded

that both collection techniques are satisfactory in determining the diet. Utilizing

esophageal vs. rumen fistulas should be determined based on the grazing situation and

not basing the decision on cattle selectivity due to technique. Diet sampling very large

pastures with ruminally fistulated cattle compared with esophageally fistulated cattle that

diet sample for about 20 min. may be one situation that the rumen fistula could be better.

Ruminally fistulated cattle require less maintenance once the fistula is established, if

cattle are not observed frequently, ruminally fistulated cattle may be more practical.

Other situations include age of the animal and potential use in metabolism trials as is

done at the University of Nebraska-Lincoln.

Salivary contamination/Sample preparation

Salivary contamination is one of the most widely known problems with using

fistulated cattle. Nitrogen levels in saliva have been highly disputed with some

investigators claiming it has an effect on the N level sampled compared with the N level

offered (Lesperance and Bohman, 1964; Blackstone et al., 1965; and Marshall et al.,

1967) whereas others dispute it has no effect (Bath et al., 1956; Lesperance et al., 1960a; Shumway et al., 1963). Galt and Theurer (1976) reported N content of saliva from range samples contain from 0.003 to 0.018% and hay samples from 0.007 to 0.27% which did not significantly alter N content from the fistulated diet samples. Holechek et al. (1982b) concluded that cattle consuming a diet similar in protein content as the pastures being sampled would minimize N contamination. Bath et al. (1956) and Wallace et al. (1972) reported increased ash content of the sample due to salivary contamination without significantly affecting any other constituents.

Dry matter of bovine saliva is approximately 1.02% (Bailey and Balch, 1961). Ash content of bovine saliva has been reported between 0.85% (Lesperance et al., 1960a) to 0.89% (Bailey and Balch, 1961). Nitrogen contamination in saliva ranges from 0.007% to 0.027% when alfalfa hay is consumed and 0.003% to 0.018% when grazing summer range (Galt and Theurer, 1976). Slightly lower values were reported by Bailey and Bach (1961) with steers being fed alfalfa having N levels of 0.003% to 0.007%. Cook (1964) reported salivary N for cattle grazing mountain range in the summer at 0.04%. Nitrogen values where not significantly altered for samples collected from esophageally fistulated cattle (Bath et al., 1956; Galt et al., 1976; and Lesperance et al., 1960a). Significant increases in P content were shown in fistulated samples (Lesperance et al., 1960a; Langlands, 1966; Little, 1972; Scales et al., 1974; Mayland and Lesperance, 1977). Due to greater P content in fistulated samples from salivary contamination, it is not recommended to use fistulated samples to evaluate dietary P concentrations. The major contributor to salivary contamination is primarily caused by minerals which decrease the amount of organic components in the sample on a DM basis but remain relatively

unchanged when expressed on an OM basis (Wallace et al., 1972). Cattle fed grass hay had greater moisture added than those fed fresh grass indicating that saliva secretion may change between diets (Blackstone et al., 1965). Hence, when collecting diets using fistulated cattle, results must be presented on an OM basis (Van Dyne and Torell, 1964).

Due to salivary contamination while sampling with fistulated cattle, preparation technique can influence chemical components of diet samples (Hoehne et al., 1967). A study was performed that tested two preparation technique methods for masticate samples (Musgrave et al., 2012). Vegetative fresh grass (high quality) and grass hay (low quality) samples were collected throughout 6 trials using either esophageally fistulated cows equipped with screen bottom bags or rumen fistulated steers which had rumen contents evacuated prior to collection. Once samples were obtained, samples were divided into squeezed and un-squeezed samples. Squeezed samples were squeezed until saliva no longer drained. Un-squeezed samples were left unaltered by squeezing. High quality vegetative fresh grass samples which were squeezed, had lower CP, ash, and higher NDF compared with un-squeezed samples. Low quality grass hay samples showed no difference in quality between squeezed and un-squeezed samples. Previous work done by Hoehne et al. (1967) also found greater ash content in un-squeezed samples compared with squeezed samples. When working with fistulated cattle, squeezing saliva from the masticate sample is inappropriate and should not be done especially in high quality forage. However, correcting for greater ash content and presenting on an OM basis is necessary.

Traditionally, screen bottom bags have been used while collecting diet samples (Edlefsen et al., 1960, and Barth and Kazzal, 1971). These bags allow for drainage of

saliva leading to reduced drying time. However, recent research has shown nutrient loss caused by squeezing saliva from samples (Musgrave et al., 2012). Nutrients such as cell solubles may leach from the forage when combined with the saliva and possibly become lost when drained and affect the quality of the sample (Holechek et al., 1982b). Using solid bottom bags to collect the forage and saliva portion may represent the diet more accurately. Musgrave et al. (2015) used fresh vegetative grass, grass hay, fresh vegetative alfalfa and alfalfa hay to determine the influence of bag type on nutrient composition. Bag type did not affect IVOMD (67.3% vs. 67.6% for solid vs screen, respectively; $P >$ 0.10), ash with the exception of fresh alfalfa (14.5% vs. 20.8%; for screen vs. solid, respectively; $P = 0.02$), and NDF except for fresh alfalfa (47.4% vs. 53.1%; for screen vs. solid, respectively; $P = 0.03$). Alfalfa CP was not affected by bag type ($P > 0.10$), however, grass CP was affected by bag type (11.5% vs. 11.1%; for screen vs. solid, respectively; $P = 0.02$). Minimal nutrient composition differences were shown indicating that screen bottom bags may be an appropriate method for collecting masticate samples on an OM basis.

Rumen Contamination

Contamination due to regurgitation could also significantly impact the diet sample collected via esophageal fistulae. Methods devised to avoid rumen contamination have included fasting the animal and adjusting time of feeding. Arnold et al. (1964) suggested that fasted animals graze more vigorously which reduces the chance for contamination from rumen contents. Regurgitation is more common in cattle grazing the hot part of the day on summer range where grazing would primarily occur in the morning or late evening. On winter and cool summer range, contamination does not seem to be as

relevant (Van Dyne and Torell, 1964). Holechek et al. (1982a) found the problem to be related to time since eating and if animals were withheld from feed for a few hours before collections then regurgitation could be avoided.

Incomplete recovery and representative samples

Blackstone et al. (1965) showed recovery was related to the opening of the esophageal fistula, smaller openings consistently yielded lower amounts of sample whereas sheep with larger fistula yielded larger amounts of sample. One primary problem with smaller openings is the opening may become plugged (Holechek et al., 1982b). Esophageal openings tend to decrease in size as time without the esophageal plug increases (Blackstone et al., 1965). Musgrave et al., (2014) found recovery to be influenced by forage type in cattle (70.5% vs. 52.8% for fresh vs. hay, respectively; $P = 0.01$). Recovery was determined by taking the initial dry matter weight of the sample offered and subtracting the weight of the dry matter recovered from the esophageal opening. Total recovery has been shown to be between 53% and 73% with the botanical composition of the diet being unchanged (Grimes and Watkins, 1965). However, Cook (1964) reported an average recovery of 97% with minimal variation. Even though diet nutrient composition from the esophageal fistulae sample was unchanged from the recovery errors, another method to reduce possible error would be to have adequate cattle numbers for sampling.

Holechek et al., (1983) found that 4 esophageally fistulated animals are needed to identify diet nutritive quality. However, as few as 3 animals per treatment would allow for a 10% level of significance and an 85% confidence interval. With an increased

number of cattle, more precise measurements would be able to be taken (Obioha et al.

1970).

Animal Effects

Possible sources of variation in diet selection may include age, sex, diet prior to

collections, and breed of the animal (Langlands, 1969; Ferrell et al., 1979; Hodgson and

Jamieson, 1981; Walker et al., 1981; Miller and Gaud, 1990; Grings et al., 1995;

Hollingsworth-Jenkins et al., 1995; and Muhammad et al., 1996). A two year study was

conducted to determine differences in diet quality between steers older than 2 years and

suckling calves in June, July, September, October and November. Results indicated that

suckling calves consumed a diet 21% greater in CP ($P < 0.01$) and 5% lower in NDF ($P <$

0.06) than mature steers in June and July diet samplings. No differences were shown in

diet quality in September, October or November, indicating that differences in diet

quality occur only when forage quality permits selectivity (Grings et al., 1995).

Hollingsworth-Jenkins et al. (1995) showed a tendency for greater CP in calf diets versus

cow diets, and no difference was shown in IVOMD. Hodgson and Jamieson, (1981)

showed calf diets higher in digestibility than mature cows (lactating and non-lactating).

Greater N content was found in young animal diets compared to mature animals

(Langlands, 1969; Walker et al., 1981). Difference in diet quality between young and

mature animals is believed to be due to a decreased muzzle size. A decreased muzzle

increases the capability of the younger animal to select higher quality plant parts

especially when the plant matures (Giessert, 2007).

Sex of the animal may change the animal's selectivity. Ferrell et al. (1979) found

greater CP in ram vs. ewe diets ($P < 0.01$) which was attributed to different maintenance

energy requirements which lead to different DMI and selectivity. However, Langland, (1969) observed no difference between sex and strain for sheep selectivity. Mohammad et al. (1996) found no difference between 2 year old steer and mature cow diets. These studies indicate that gender of the animal does not impact diet selectivity.

A three year trial was conducted to determine plant consumption between Santa Gertrudis and Hereford cattle on range. There were no reported differences between breeds for the quantity of plants consumed (Herbal and Nelson, 1966). Walker et al., (1981) compared Hereford, Angus × Herford, and Charolais × Hereford cattle diets and found relatively small differences in diet quality between breeds. Langland (1969) found mixed results when comparing different sheep breeds. Some pastures had greater dietary N content for one breed whereas some pastures showed no difference.

Diet consumed prior to diet collection of fistulated cattle has the potential to alter the diet selectivity caused by N recycling and urea in the saliva. Musgrave et al. (2012) studied the effects of maintaining fistulated cattle on high (vegetative subirrigated meadow) or low (meadow hay) CP diets pre-collection. Crude protein content of masticate samples was not affected ($P = 0.49$) by pre-collection diets. Blood samples tended to be greater in serum urea nitrogen for cattle on high CP diet (27.6 vs. 23.5 ml/dl; high vs. low, respectively; $P = 0.08$). In this particular study the difference did not influence overall total N content of the diet, however, further investigation is needed.

Diet Selectivity and Grazing Behavior

Grazing Behavior

Cattle make thousands of decisions everyday which result in the acquisition of nutrients which lead to growth, lactation, reproduction and the evasion from lethal

species of plants (Launchbaugh and Dougherty, 2007). Coleman and Sollenberger,

(2007) found that grazing animal's behavior is influenced by thirst, maintenance of

homeothermy, energy balance or hunger (usually the driving force whether the animal

will graze or not), time of day (predator avoidance or nighttime as an orientation

influence), rumination, rest, social cues and sleep. Grazing animals are born with physical

abilities and behavioral predispositions affecting foraging decisions (Launchbaugh and

Dougherty, 2007). Hodgson and Jamieson, (1981) compared foraging behavior of

weaned calves with lactating and non-lactating cows for 2 years. In year one, calves were

experienced grazers which were able to adapt to a changing sward, whereas younger

weaned calves used in year 2 had less experience and had more difficulty adapting to a

changing sward. As growth occurs, selectivity becomes refined due to personal

experience by positive (high digestibility) or negative digestive feedback (high levels of

tannins), modeling diet from what their mother is eating, and from interactions with other

members in the herd (Launchbaugh and Dougherty, 2007).

Selectivity

Diet selectivity has been researched extensively throughout the last 60 years with

differing livestock grazing management techniques and environmental conditions (Weir

and Torell, 1959; Reppert, 1960; Cable et al., 1966; Langlands, 1966; Bredon et al.,

1967; Bedell, 1968; Langlands, 1969; Barth and Kazzal, 1971; Rao et al., 1973; Vavra et

al., 1977; Taylor et al., 1980; Kirch et al., 2007). Grazing animals face two opposing

problems while selecting diets: they must obtain maximal quality while obtaining

adequate quantity (Senft et al., 1985). Obtaining representative samples is a difficult task

even in monocultures because animals prefer to graze regrowth vs. mature forage due to

greater quality (Coleman and Sollenberger, 2007). A tradeoff occurs between the regrowth because the greater quality usually means lower quantity so that animal's graze the non-grazed areas with lower quality and greater quantity. Fisher et al. (1991) found that animals have an increased selection for leaf and live material and discriminate against previous year growth. The increased selectivity for leaf and live material causes a discrepancy between clipped versus a diet selected by an animal itself. Hence, clipped samples are not representative of the diet consumed by grazing animals (Edlefsen et al., 1960; Lesperance et al., 1960b; Kiesling et al., 1969; Rao et al., 1973; Kirch et al., 2007; Hughes et al., 2010). In an experiment comparing clipped samples and esophageal diet samples, Weir and Torell (1959) found little difference in protein content for esophageal versus clipped samples when grazing had previously occurred. However, clipped samples had lower protein content versus esophageal samples when no previous grazing had occurred.

Jeffries and Rice, (1969) conducted a two year experiment determining the nutritive value of clipped and grazed forage samples. They found comparable protein values in dry years however, years with abundant moisture, clipped samples had lower nutritional quality. With the abundance of moisture, more forbs were produced and consumed while in a vegetative stage resulting in greater protein and IVDMD levels than clipped samples. In more recent years, Coleman and Sollenberger, (2007) found in dry years or years were grazing had already occurred, cattle would be forced to eat less desirable species resulting in lowered selectivity which is in agreement with work done previously (Weir and Torell, 1959, and Jeffries and Rice, 1969).

In an experiment to determine selectivity and dietary quality, Kirch et al. (2007) compared smooth bromegrass (*Bomus inermis Leyss*), switchgrass (*Panicum virgatum L.*) and big bluestem (*Andropogon gerardii Vitman)* at varying stages of development via clipped samples and rumen fistulated cattle. CP content increased 3 to 4% for switchgrass and big bluestem and 8% for smooth bromegrass ($P < 0.05$) for rumen masticate samples compared with clipped samples. Dietary IVDMD was greater for switchgrass and big bluestem in the elongation and reproductive stages and smooth bromegrass was improved in the vegetative and reproductive stages for rumen masticate samples compared with clipped samples indicated cattle selectivity. Dietary NDF was 7 to 13% lower in smooth bromegrass diet samples compared to clipped samples whereas switchgrass and big bluestem were not different. In a similar study comparing forage sampling method to determine value of Bahiagrass (*Paspalum Notatum Flugge*), masticate samples had greater IVOMD, CP ($P \leq 0.001$) and lower ADF ($P < 0.001$) concentration than hand plucked samples (Hughes et al., 2010). It has consistently been demonstrated that fistulated diets have greater CP content than clipped samples (Bredon et al., 1967; Galt et al., 1969; Rao et al., 1973; Hughes et al., 2010).

When comparing clipped samples vs. fistulated cattle it is not evident if the clipped samples were separated into current year and previous year growth. This could impact the estimated nutritional value of the clipped forage. When adequate current year growth is available cattle are able to be more selective. Comparing diet samples to current year growth via clipping samples may give a better representation of actual cattle diets, however, more research is needed to compare the differences.

Factors Affecting Diet Quality and Nutritive Quality of Forage

The composition of forage is highly influenced by many factors such as soil type,

climate, plant variety, extent of insect infestation, and presence of diseases (Blaser,

1964). However, quality of the forage is affected by factors such as level of

maturity/stage of development, plant part (leaf vs. stem), plant species (cool season vs.

warm season), and environmental effects (moisture, and temperature). Management

decisions such as level of grazing (E.G. stocking rate or grazing pressure) can also have

an impact on the quality of diet (Lyons et al., 1996). Understanding these effects and

managing accordingly are crucial for proper grazing systems.

Plant Maturity/Development Stage

Maturation of the plant has the greatest impact on forage quality (Buxton and

Fales, 1994). Blaser (1964) reported physiological and morphological stage of

development of grasses and legumes is the primary factor determining nutritive quality.

Rangelands plants go through a cycle in forage quality throughout the year which affects

nutritive quality (Kamstra et al., 1968; Wallace et al., 1972; Kamstra, 1973; Cogswell and

Kamstra, 1976; Powell et al., 1982; White, 1983; McCollum et al., 1985; McCollum and

Galyean, 1985; Hakkila et al., 1987; Adams et al., 1994; Lardy et al., 1997; Johnson et

al., 1998). For example, as the plant progresses from the vegetative to reproductive

stage, it has increased levels of lignin and cellulose which results from a decrease in leaf-

to-stem ratio and fewer cell solubles (Blaser, 1964; Burns, 2008). Minson et al. (1960)

reported a rapid decline in digestibility occurring after forage species reproductive

structures appear. A decrease in the leaf-to-stem ratio affects overall forage quality due to

greater levels of cell solubles (proteins, and sugars) and less structural carbohydrates

(hemicellulose, cellulose, and lignin) found in leaves vs. the stem in mature plants (Lyons et al., 1996). As the plant matures and the leaf-to-stem ratio decreases, there is increased ADF, NDF, and lignin and decreased CP (Roa et al., 1973; Streeter et al., 1974; Cogswell and Kamstra, 1976; McCollum et al., 1985; Hakkila et al., 1987; Lardy et al., 1997; Johnson et al., 1998; Cline et al., 2009) and decreased IVOMD (Cogswell and Kamstra, 1976; McCollum et al., 1985; Schacht et al., 2010).

Utilizing clipped samples to determine seasonal changes in quality of range grasses, Kamstra (1973) compared two cool season and two warm season grass species from mid-June through late September and found as the plant matured, CP and IVDMD decreased in value. Similar results were observed by White (1983) who found an average decrease of 4 percentage units in CP and an 8 percentage unit reduction in DMD when comparing the vegetative tillers vs. reproductive tillers for both western wheatgrass (*Agrophyron smithii)* and green needlegrass (*stipa viridula*).

Rao et al. (1973) determined seasonal changes in nutritive value in bluestem pastures utilizing both esophageally fistulated cattle and hand plucked samples. Results showed an increase in IVOMD from June to July then declined until October. Crude protein was greatest in June and decreased in quality until October. Neutral Detergent Fiber increased from June to July and then decreased through September after which, an increase was observed in October.

Cline et al., (2009) utilized four ruminally cannulated steers grazing native range in western North Dakota to determine seasonal changes in forage quality and showed a linear decrease in N from June through November (1.95% to 1.15%, respectively) and a linear increase in NDF (72.4% to 85.1%, respectively). Similar results were observed in

the high plains in eastern Wyoming where there was an average decrease in CP of 0.03-0.23 percentage points per day and IVDMD of 0.06-0.90 percentage points per day from June through November (Hart et al., 1983). Numerical values varied among some trials however. Similar seasonal changes in diet quality were found throughout the literature (Wallace et al., 1972; Streeter et al., 1974; McCollum and Galyean, 1985; McCollum et al., 1985; Kirby and Parman, 1986). Results indicate a reduction in diet quality occurring with increasing plant maturity similar to the seasonal change shown for plant quality. As season progressed and plants matured, cattle selected a diet to maximize quality (Hakkila et al., 1987).

In the Nebraska Sandhills, seasonal changes in diet quality composition on both subirrigated meadows and upland range pastures were observed (Lardy et al., 1997). Using esophageally fistulated cows, samples were collected over two different one year periods. This meadow is dominated by cool season plant species with a small mixture of legumes. It showed a rapid increase in CP and IVOMD during March and April with a decline during June and July when the plant goes dormant and then increases in August due to regrowth when the temperature begins to decrease. Regrowth of the cool season plant species is dependent on soil moisture levels. If adequate moisture is available and the temperature is optimum, then the regrowth will occur. If not, the quality of the plant species available will continue to decline until it reaches the dormant season. During the dormant season, CP and IVOMD remain relatively constant from November to March. Upland range are typically dominated by warm season grass species with a relatively small mixture of cool season grass species. As such, diet quality during the dormant season showed little change from November through March. An increase in CP and

IVOMD was shown from April to June and then declined through September. Meadow CP and IVOMD were greater during the growing season compared with upland range possibly due to the cool season grasses containing more mesophyll cells which are greater in quality.

Mixed grass prairies or ranges such as those in the Sandhills provide a diet of greater quality for a more sustained period of time compared to prairie dominated by a monoculture by providing two peaks in CP and IVOMD, one in late April to early May (cool season species) and one in mid-June to Mid-July (warm season species) and potentially a third peak in late August to early September (cool season species) dependent on soil moisture.

Plant Species/Environmental Factors

Plant nutritive quality is partially dependent on plant species (cool vs. warm season). Most cool season plant species (C_3) in northern latitude areas thrive in late spring to early summer and again in the fall with temperatures around 20° C (Nelson and Moser, 1994). Warm season plant species (C_4) have adapted to warmer temperatures with an optimum between 30 to 35° C and are more efficient with water utilization than C_3 plants. Forage quality reaches its maximum during the summer but unlike C_3 species, only one peak is observed. This adaption to warmer temperatures and greater water efficiency by C_4 plants has resulted in a decreased number of mesophyll cells than C_3 plants, and an increase in vascular bundles. Vascular bundles are high in lignin and mesophyll cells are high in protein which results in decreased forage quality in C_4 vs. C_3 plants (Wilson et al., 1983). Mixed grass prairies that have both C_3 and C_4 plants maintain a greater quality diet throughout the growing season verses C_3 or C_4

communities alone. Knowing the quality available leads to better capabilities to matching the animal's requirements to available forage nutrients and potentially extending the grazing season.

Some plant species decline in quality at different rates than others. Hart et al. (1983) found CP concentration of western wheatgrass, blue grama (*Bouteloua gracilis*), and sedges (*Carex*) declined in quality at a more rapid rate than needleandthread (*Stipa Comata*), and scarlet glibemallow (*Spahaeralcea coccinea*). Sedges were of similar quality as western wheatgrass and blue grama during the spring, however, CP decreased more rapidly and the fibrous portion increased at a slower rate compared with the grasses. Understanding that plant species present in pastures have inherent differences and that each range is different can help producers make key management decisions such as when to calve and wean.

Environmental factors have the potential to affect the plant's stage of growth and in essence the quality of the range. Two of the main factors generally included are temperature and moisture. Of these environmental factors, temperature usually has the greatest impact on forage quality (Buxton and Fales, 1994). High temperature has generally shown decreased digestibility (Wilson et al., 1976). In a three year controlled environment study determining the effects of temperature on forage dry matter production with both florigraze (*Arachis glabrata*) a C_3 legume and bahiagrass (*Paspalum notatum*) a C_4 grass, Newman et al. (2001) showed an average increase of about 16% in dry matter production with an increase of 4.5° C in temperature across both plant species. An increased production results in an increase in cell wall constituents. This increase in cell wall constituents decreases the digestibility of both the leaves and

stem due to higher indigestible fraction of the cell wall. (Akin et al., 1987). The decrease in quality is a result of an increase in stem components decreasing the leaf-to-stem ratio.

Ivory et al. (1974) studied the temperature effects on IVDMD of leaf and stem in two tropical grass species (Buffel and Kikuyu). Grasses were grown in a controlled environment with four different temperatures (15, 25, 30, and 35°C). Lower temperatures resulted in greater IVDMD for both leaf and stem compared with higher temperatures. Increased temperatures lead to increased growth rates. Increased growth rates resulted in decreased digestibility. The decreased digestibility possibly resulted from a decreased leaf-to-stem ratio. Duru and Ducrocq (2000) studied the effect of temperature on tiller growth and found that higher temperatures accelerate the rate of change in tiller characteristics which helps explain the decrease in digestibility shown by Ivory et al. (1974). High temperatures have also been found to decrease the rate of photosynthesis, leaf area, shoot and grain mass, and reduced the efficiency of water use (Shah and Paulsen, 2003).

Timing of precipitation is a crucial component for plant growth. If large amounts of the seasonal precipitation occur after the plants have matured, the plant would benefit very little in the current season. Increased precipitation can result in increased forage production (Snaydon, 1972; Perry, 1976) and lack of precipitation can result in decreased forage production (Hazell, 1965; Shiflet and Dietz, 1974) but effects on quality are variable depending on plant species (Wilson, 1983; Halim et al., 1989). With 20 years of data, Smoliak (1956) showed a correlation of $r = 0.859$ between May-June precipitation and forage production, this implies that about 86% of the variation in forage production can be explained by differences in May-June precipitation. Pre-season precipitation was

not correlated with forage production. Rauzi (1964) found a correlation of r = 0.675 for precipitation on shortgrass prairie during the same time period. Dahl (1963) showed an estimate of total forage production by August could be predicted by soil moisture in mid-April and climatic factors such as prior year's precipitation seem to cancel by mid-season. However, previous precipitation for two years prior can give an estimate of potential production.

Wilson (1983) studied the effects of water stress on in vitro dry matter digestibility and chemical composition of three tropical grasses (green panic, buffel and spear grass) and one tropical legume (Siratro). Dry matter digestibility was of equal or greater quality for dry treatments compared with wet treatment plots. Grasses in the dry treatment were slower in development of stem tissue compared with wet treatments early in the spring which resulted in greater DMD for dry treatment stem compared with wet treatment stem. Applying water stress after elongation did not affect grass DMD on either treatment. Dry conditions tend to slow the growth of stem which results in a delay in maturation and a greater leaf-to-stem ratio. In contrast to the grasses, the water stressed legume had lower digestibility compared with the non-water stressed legume. In contrast, Halim et al. (1989) found a linear decrease in maturity of alfalfa with increasing water stress, which, resulted in a 9% increase in IVDMD and 11% increase in CP. Legumes seem to be most affected by water stress compared with grasses. Shah and Paulsen, (2003) reported drought and high temperatures usually occur concurrently. Drought increased water use efficiency, however there was a reduction in photosynthesis, soluble sugar content in the kernel, viable leaf area and shoot and grain mass.

Kirby and Parman, (1986) studied seasonal change in cattle diets in the mixed grass prairie in North Dakota. Year one of the study had 55% of average rainfall and year two exceeded average rainfall. Variation in plant species was present in diet samples between years with grasses and forbs being limited in the drought year. Diet quality differed between the two seasons with year one being lower in CP and IVOMD. Difference in CP and IVOMD contributed to cattle being forced to consume more mature forage due to lack of available high quality forage and not necessarily the change in plant quality due to lack of moisture.

Grazing

Cattle grazing has the potential to impact forage quality. Jones and Jones (1997) reported grazing intensity has the greatest impact on management decisions due to effects on forage production, animal gain, and profitability of the operation. Kamstra et al. (1968) studied the maturity of western wheatgrass found that leaf blades removed from heavily grazed pastures had greater digestibility in vitro vs. lightly grazed pastures. This was attributed to the possibility of a delayed emergence or shorter height for the plant essentially keeping the plant in more of a vegetative stage.

Anti-quality factors such as tannins, lignin, or alkaloids can impact the extent to which grazing will occur due to metabolic feedback or simply taste (Coleman and Sollenberger, 2007). With higher stocking rates cattle may be forced to consume less desirable forage such as those that contain anti-quality factors.

Stocking Rate/Grazing Intensity

Stocking rate may be one of the most important decisions a manager has to make. Stocking rate has an impact on animal performance, forage production, and possibly has

an effect on diet quality. It is well-documented that with increased stocking rate or grazing pressure, there is a decline in animal performance (Petersen et al., 1965; Jones and Sandland, 1974; and Hart, 1978). In a 16 year study at the High Plains Grasslands Research Station near Cheyenne, Wyoming, the effect of stocking rates on steer gains were evaluated (Derner, 2009). Stocking rates consisted of heavy (5.5 acres per steer) and moderate stocking rate (7.5 acres per steer). In heavily stocked pastures, ADG was reduced by 10-16% compared with moderate stocked pastures. Holechek et al. (1999) found reduced calf crops and ADG for heavily stocked pastures compared with moderate. However, heavy stocked pastures had higher per acre gains than moderate stocking which may not be consistent over a 20-30 year period. Smart et al. (2010) evaluated the effects of grazing pressure on ADG and found ADG decreased linearly with increasing grazing pressure.

Forage production may also be affected by stocking rate. Cullan et al. (1999) compared both grazing method (continuous vs. rotational) and stocking rate (51.5 AUD/ha vs. 89.9 AUD/ha). No difference was observed when comparing grazing method however, as stocking rate increased, standing crop decreased for all components of the major herbage species. Volesky et al. (2004) investigated stocking rate effects on the Nebraska Sandhills subirrigated meadow. Stocking rates were 148, 296, and 444 AUD/ha^{-1}. Standing crop disappearance increased linearly (1,920, 2,700, and 3,090 kg ha^{-1}, respectively) with increasing stocking rate (148, 296, and 444 AUD/ha^{-1}, respectively).

Rauzi, (1964) studied the effects of moderate and light stocking rates on forage production on native upland range in Eastern Wyoming. Moderately grazed pastures produced nearly three times more mid-grass than lightly grazed pastures, however, no

difference was shown for production in short grass or warm-season grass species between stocking rates. Derner, (2009) found no difference in vegetation production for heavily stocked pastures compared with moderate stocked pastures. However, Holechek et al. (1999) in an extensive review of the literature, found heavily stocked pastures had a 23% reduction in forage production compared with moderately stocked pastures and a 36% reduction compared with lightly stocked pastures. When comparing stocking rate effects over time, heavily stocked pastures resulted in a 20% decline in forage production whereas moderate showed no change and light showed an 8% increase. Stocking rates may affect production differently depending on range site and plant species.

Even though forage production and animal gain have been extensively researched, little is known on how grazing and stocking rates affect the quality of the diet. Ralphs et al. (1986) investigated the effects of increased grazing pressure on diet quality of esophageally fistulated sheep and cattle and found a negative relationship between grazing pressure and diet quality of cool season species. This study conducted on the salt desert ranges in Utah determined the effects of grazing intensity on diet quality from late October through early March on pure stands and mixed stands of forage. In pure stands, lignin increased with increasing grazing intensity while protein, digestibility of cellulose and gross energy decreased. Mixed stand pastures showed an increase in protein at times which was attributed to a change in plant preference but results were inconclusive. This study used fecal collection to determine diet quality rather than using fistulated cattle. Results may not accurately represent differences between grazing pressure (Pieper et al., 1959).

Previous research in the Nebraska Sandhills studied the effect of stocking rate from 2003 to 2005 (Geisert, 2007). Stocking rates consisted of high (the recommended stocking rate of 1.2 AUM/ha or higher), moderate stocking rate (between 0.1 AUM/ha to 1.1 AUM/ha), and non-grazed. The non-grazed pastures remained non-grazed throughout the study. Variation in moderately stocked pastures stocking rate was caused by set sampling days while cattle rotation varied. Diet samples were taken every three weeks (9 times) during the growing season (April through September) and monthly (6 times) during the dormant season (October through March) to equal 15 total samplings. Increased stocking rate, decreased OMD and DMD of diet samples ($P < 0.02$). In the final year of the study, average CP content was lower compared with normal stocking rate pastures, however, this did not occur in 2003 and 2004 possibly due to below average rainfall for 2003 and 2004 and average precipitation for 2005.

The biggest gap in diet quality work occurs early in the growing season when the early diet samples have been compromised by squeezing. Impacts of grazing mature forage (Geisert, 2007) and dormant forage (Pieper et al., 1959) have been well characterized but there is a need to investigate how stocking rate affects diet quality in early summer pastures when the plants are rapidly growing and changing.

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Chapter II

Effects of stocking rate on forage nutrient composition of Nebraska Sandhills upland range when grazed in early summer

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ABSTRACT: Twelve Nebraska Sandhills upland range paddocks were utilized in a two year study to determine effects of stocking rate on grazed forage nutrient composition in early summer. Stocking rates consisted of control, light, and heavy stocked at 0, 0.57, and 0.85 animal unit months per hectare respectively. Three esophageally fistulated cows per paddock collected diet samples on May 14 (d 0), May 21 (d 7), May 28 (d 14), and June 4 (d 21) in 2013 and 2014. Ten quadrats per paddock were clipped and separated into current year growth or previous year growth on each diet sampling date. Diet and clipped samples were analyzed for CP, NDF, and IVDMD and adjusted to an in vivo OM basis (IVOMD). Diet samples had significant treatment x date interactions ($P < 0.01$) for CP, NDF, and IVOMD. However, treatment and date did not interact ($P > 0.05$) for clipped samples. Diets collected in control paddocks had greater IVOMD, CP and lower NDF compared with light and heavy stocking rate paddocks on d 7, 14, and 21 ($P < 0.05$). Diet samples collected from light stocking rate paddocks did not differ ($P > 0.05$) in IVOMD, CP, or NDF compared with heavy stocked pastures. Previous year growth IVOMD, CP, and NDF were not affected ($P > 0.05$) by treatment. Current year growth IVOMD and CP were not affected ($P > 0.05$) by treatment, however, control paddock CP was lower ($P = 0.02$) compared with light and heavy on d 21. Current year growth NDF did not differ (P

= 0.23) among stocking rates on d 0, however, control paddock had lower ($P = 0.02$)

NDF compared with light and heavy on d 7, 14, and 21. In stocked pastures, diet samples

had greater ($P < 0.01$) IVOMD and CP and lower NDF compared with current and

previous year growth across all dates except IVOMD on d 0 where diet and current year

growth did not differ ($P = 0.34$). Generally, in stocked and control paddocks, current year

growth had greater ($P < 0.01$) IVOMD and CP compared with previous year growth but

did not differ ($P > 0.05$) in NDF. Control paddocks had greater ($P < 0.01$) forage

accumulation compared with stocked paddocks on d 7, 14, and 21, however, light and

heavy stocked paddocks did not differ ($P > 0.05$). Stocking rate affects forage quality and

forage accumulation and therefore diet quality in early summer as cattle are forced to

consume previous growth.

Key words: diet quality, forage accumulation, sampling method, Sandhills upland range,

stocking rate,

Introduction

Upland range in the Nebraska Sandhills is an excellent resource for grazing cattle.

Native upland range is dominated by warm-season grass species. Forage quality increases

during the spring reaching a peak in early June and then steadily declines in quality

throughout the remainder of the growing season (Lardy et al., 2004). Lardy et al. (2004)

reported changes in forage nutrient composition throughout the year, but effects of

stocking rate on Sandhills upland range were not addressed. Cattle select higher quality

forage as stocking rate decreases (Heitschmidt and Taylor, 1991), Thus with higher

stocking rates, cattle nutrient intake declines. Kirch et al. (2007) reported that cattle are

known to be selective grazers and will select a higher quality diet compared with hand

clipped samples or available forage, especially as maturation of the plant occurs. Early in the grazing season, high quality forage may be sparse due to the nature of forage growth with lower amounts of production in the spring. The majority of growth occurs with warmer temperatures during summer months, resulting in cattle consuming lower quality forage (Ralphs et al., 1986), resulting in less cattle selectivity. Therefore, the objectives of this research were to determine the effects of stocking rate on forage nutrient quality in early summer pasture and to quantify the relative proportions of current year verses previous year growth being consumed by cattle in the Nebraska Sandhills.

Materials and Methods

Animals, Pastures and Stocking Rates

With the approval of the University of Nebraska, Institutional Animal Care and Use Committee, esophageally fistulated cows were utilized to determine effects of stocking rate on diet quality of cattle grazing native upland pastures. Native rangeland in the Nebraska Sandhills is composed of choppy sands soil and dominated by the following grass species: little bluestem (*Schizachyrium scoprium*), prairie sandreed (*Calamovilfa longifolia*), sand bluestem (*Andropogon gerardii* var. *paucipilus* Fern.), switchgrass (*Panicum viergatum* L.), sand lovegrass (*Eragrostis trichodes*), indiangrass (*Sorghastrum nutans*), and blue grama (*Bouteloua gracilis*) with major forbs and shrubs including western ragweed (*Ambrosia psilostachya*) and leadplant (*Amorpah canescens*) (Lardy et al., 2004) as well as prairie rose (*Rosa arkansana*). Twelve, 2-ha upland range paddocks at the Gudmundsen Sandhills Laboratory near Whitman, NE (lat 42°04′ N, long 101°26′ W, elevation = 1,075 m) were used each year in this two year study. The study started on May 14 when the cattle were introduced into the paddocks after initial diet samples were

taken and cattle were removed 21-days later on June 4. Paddocks were assigned randomly with a treatment each year. Treatments consisted of three stocking rates which were stocked at 0 (control), 0.57 (light) and 0.85 (heavy) animal unit months per hectare (AUM/ha) with March calving primiparous heifers (366 kg ± 50) with suckling calves. Animal unit month was defined as the approximate amount of forage a 454 kg cow with calf will eat in one month (Redfearn and Bidwell, 2003). Calf weight was excluded from AUM calculation as animal unit was defined as cow with suckling calf and calves were less than 3 months of age. A stocking rate of 1.2 AUM/ha (Stubbendieck and Reece, 1992) is commonly allotted for the entire grazing season (May through October), so early in the growing season, before the majority of the growth has occurred, a stocking rate of 0.85 AUM/ha was considered heavy. Cattle were assigned randomly to each treatment replication to achieve desired stocking rates based on BW. Each stocked paddock was continuously grazed during the trial and all paddocks were sampled at 7-day intervals during the 21-day trial in 2013 & 2014.

Three esophageally fistulated cows were used to sample each paddock on each date to determine diet quality. Esophageally fistulated cows were used for diet sampling and not used in the continuous grazing of the experimental paddocks. Prior to each diet sample collection, cows were withheld from feed, but not water, for 12 h. At 0700 hours, esophageally fistulated cattle were transported to paddocks where diets samples were collected. Cows were fitted with solid bottom collection bags after removal of the esophageal plug and introduced to the paddock, then allowed to graze for about 20 min. After collection, fistulated cows were removed from the paddocks, fitted with esophageal plugs and then transported to a separate upland range pasture.

Ten 0.25 m^2 quadrats per paddock were clipped at ground level on four sampling dates. Sampling dates corresponded with diet sampling dates with initial clipping taking place on d 0 then on d 7, 14, and 21. Clipped samples were separated into previous year growth and current year growth. To obtain sampling points, each paddock was divided into eight sectors and randomly allocated one GPS sampling point for each sector. Then two sectors were randomly selected to contain an additional sampling point making a total of 10 sampling points per paddock per time point. On subsequent sampling dates, quadrats adjacent to original GPS coordinate sampling points were sampled. Once samples had been clipped, they were immediately taken to the lab and dried in a forced air oven at 60°C for 48h.

Lab analysis

Immediately after collection, diet samples were separated into fibrous and liquid fractions, then a representative aliquot from the fibrous and liquid fractions were combined together physically, maintaining the same proportions of fibrous and liquid fractions as the original sample. Combined samples were then frozen and stored at -20º C, then lyophilized. Both diet and clipped samples were ground to pass a 1-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) and analyzed for nitrogen concentration using a Leco, FP 2000 combustion nitrogen analyzer (Leco Corp, St. Joseph, MO) then converted to CP by multiplying by 6.25 and adjusted to an OM basis by dividing by the % OM. Organic matter was found using the equation 100 - % ash = % OM. Ash weight was determined by placing the dry sample in a combustion chamber at 600°C for six hours. Percent ash was determined by taking the ashed sample weight divided by the dry sample weight then multiplying by 100 to get ash %. Neutral detergent

fiber content of diet and clipped samples was determined using the Van Soest et al. (1991) method then adjusted to an OM basis. Diet and clipped samples, were analyzed for IVDMD using the Tilley and Terry (1963) method with the modification of adding 1 g of urea to the buffer and ashing the residue to determine OM digestibility and adjusted to an in vivo (IVOMD) value using standard mean adjustment reported by Ahern (2014).

Statistical analysis

Diet sample, clipped sample, and forage accumulation data were analyzed by repeated measures analysis using the PROC GLIMMIX procedure in SAS (SAS Inst., Inc., Cary, NC). Paddock was used as the experimental unit. The model statement contained treatment, date, and their interaction as fixed effects with year and treatment nested within paddock as random effects. Various covariance structures were tested and evaluated for quality of fit based on the Akaike criterion with the lowest value. A first order autoregressive covariance structure was the best fit for the diet samples comparison and compound symmetry was best fit for the clipped sample comparison. Orthogonal contrasts were used to determine if effects were linear, quadratic or cubic over sampling time. Significance level was set at 0.05 probability level. Nutrient quality differences among diet samples, current year growth and previous year growth clipped samples were compared with an F-test using the PROC GLIMMIX procedure of SAS (SAS Inst., Inc., Cary, NC). The model statement included method and treatment with paddock and year being random variables. Lsmeans was used to determine differences among method types (diet sample vs. previous year growth vs. current year growth). Significance level was set at the 0.05 probability level.

Results and Discussions

Diet Samples

Diet samples had significant treatment x date interactions ($P < 0.01$) for IVOMD,

CP, and NDF. For IVOMD, control stocking rate paddocks increased quadratically ($P <$

0.01, Table 1) while lightly stocked paddocks showed a cubic effect ($P < 0.01$) and

heavily stocked paddocks decreased quadratically ($P < 0.01$). Diet CP increased

quadratically ($P < 0.01$) for control paddocks, whereas, light and heavy stocked pastures

showed a cubic effect ($P < 0.01$). Neutral detergent fiber decreased linearly ($P < 0.01$) for

control paddocks, while light stocked paddocks increased quadratically ($P < 0.01$) and

heavy stocked paddocks showed a cubic tendency ($P = 0.08$).

Control stocking rate paddocks reached peak quality in late May for both IVOMD

(74.3%) and CP (17.6%) and then decreased in quality. Similarly, Lardy et al., (2004)

found a peak in diet quality with a CP level of 13.8% and an IVOMD level of 67.6% in

non-grazed pastures in late May to early June in the Nebraska Sandhills. Geisert (2007)

found levels of 12.0% CP and 65.8% IVOMD. These values are lower compared with the

current study which may be caused by inherent year to year variation or collection

method. Screen bottom bags and squeezing saliva from the esophageal sample were

methods used by both Lardy et al., (2004) and Geisert (2007) whereas, in the present

study solid bottom bags were used and no squeezing occurred.

No differences ($P = 0.60$, Table 2) in IVOMD occurred among treatments on d 0,

however, control paddocks had greater IVOMD ($P < 0.01$) compared with light and

heavy stocked paddocks on d 7, 14, and 21. Light compared with heavy stocked

paddocks did not differ ($P > 0.05$) in IVOMD on any collection day. Geisert (2007),

reported decreasing IVOMD with increasing stocking rates ($P < 0.02$) where high grazing was lower compared with non-grazed pastures, and the medium stocking rate was not different from non-stocked or highly grazed pastures. McCollum III et al., (1994) found no change in IVOMD between high and low stocking rates which is in agreement with the current study.

On collection d 0, CP did not differ ($P = 0.41$) among stocking rates, however, control paddocks had greater CP ($P < 0.01$) compared with light and heavy stocked pastures for collection d 7, 14, and 21. Light compared with heavy stocked pastures did not differ ($P > 0.05$) in CP content on any collection day. Lower CP was reported by Geisert (2007) in heavily stocked pastures compared with medium and non-stocked pastures during the third year of the study and no difference shown for years one and two believed to be caused by drought situations in 2003 and 2004. McCollum III et al., (1994) reported depressed dietary CP in heavily grazed pastures compared to lighter grazed pastures in a longer study season (152 d vs. 21 d for McCollum III et al., (1994) vs. this current study, respectively). Unlike McCollum III et al., (1994), the current study showed lighter stocked pastures had lower CP compared with control paddocks but did not differ compared with heavily stocked paddocks.

Control paddock NDF tended ($P = 0.06$) to be lower than heavy stocked pastures on d 0, however, no differences were shown for control compared with light stocked paddocks ($P = 0.16$) and light compared with heavy stocked paddocks ($P = 0.62$). On d 7, 14, and 21, the concentration of NDF in diets collected in control paddocks was lower ($P = 0.01$) than light and heavy stocked paddocks.

When cattle were introduced into the paddock they were able to select a diet greater in quality. As the season progressed, cattle in the stocked paddocks consumed a diet lower in quality than the control paddocks indicating that previous year growth was being consumed. The decrease in diet quality early in the season is similar to results found by Ralphs et al., (1986) who reported decreased diet quality with stocked pastures with cool season growth during September and October in western Texas. Ralphs et al., (1986) reported that vegetative cool season grasses were initially consumed in the diet but declined in the season as stocking rate increased resulting in cattle eating dormant warm-season grasses, which lowered diet quality for higher stocked pastures.

Clipped samples

No differences ($P > 0.05$, Table 3) in the CP concentration of previous year biomass of clipped samples occurred among treatments for any collection day, although CP decreased linearly ($P = 0.03$) in heavy stocked paddocks. Current year growth did not differ by ($P > 0.05$, Table 4) day regardless of treatment and did not change over time for IVOMD, and NDF. A linear decrease in CP was shown for all stocking rates ($P = 0.01$). Neutral detergent fiber showed no change over time for any stocking rate ($P > 0.05$) except for the heavy which increased linearly ($P = 0.01$).

Previous year growth was not different ($P > 0.05$, Table 5) in CP, NDF, and IVOMD concentrations among treatments which would be expected with the plant being in a dormant stage. Current year growth did not differ among treatments for IVOMD ($P > 0.05$, Table 6). However, CP was lower ($P = 0.02$) in control paddocks compared with grazed paddocks on d 21. The greater CP content in the stocked pastures could have resulted from delayed maturation caused by grazing. Neutral detergent fiber was lower (P

< 0.02) for control pastures than light and heavy stocked paddocks on d 7, 14, and 21 with the exception of d 14 where the heavy stocked paddock was not different than control.

As the grazing season progressed, the decline in forage quality for the current year growth samples could be explained by increasing plant maturity. Wallace et al., (1982) found decreased CP and increased fiber and lignin with advancing plant maturity for non-grazed pastures. In the current research the change in diet quality for control pastures could be explained by maturing forage. The control pasture had lower CP than the stocked pastures which could be explained by a slight delay in plant maturity for the stocked pastures. Kamstra et al. (1968) studied the maturity of western wheatgrass and found that leaf blades removed from heavily grazed pastures had greater digestibility in vitro vs. lightly grazed pastures. This was attributed to the possibility of a delayed emergence or shorter height for the plant essentially keeping the plant in more of a vegetative stage. However, the NDF data does not agree with that statement. Control paddocks had lower NDF. This could be explained by diet selectivity and possibly by cattle consuming the more digestible plant parts in the stocked paddocks leaving less digestible plant parts (Lyons et al., 1996) which were clipped for analysis.

Diet versus Clipped Samples

In stocked paddocks, diet and current year growth samples were greater ($P < 0.01$, Table 7) in IVOMD and CP than previous year growth. On d 0 diet and current year growth did not differ in IVOMD ($P > 0.05$) however, on d 7, 14, and 21, current year growth was greater ($P < 0.01$) than diet samples indicating consumption of previous year growth. Current year growth was greater in CP ($P < 0.01$) compared with diet samples

on all sampling days. Diet sample NDF was lower ($P < 0.01$) compared with current and previous year growth samples. Current and previous year growth samples did not differ in NDF ($P > 0.05$). As the time in the pastures increased, current year growth may have become more difficult to consume resulting in declined diet quality available in stocked pastures.

In control paddocks, diet and current year growth were greater ($P < 0.01$, Table 8) in IVOMD and CP compared with previous year growth. Diet samples were lower ($P < 0.01$) in IVOMD on d 0, higher on d 14 and did not differ ($P > 0.05$) on d 7 and 21 compared with current year growth. Crude protein was greater ($P < 0.01$) in diet and current year growth compared with previous year growth. Initially, on d 0 diet CP was lower ($P < 0.01$) compared with current year growth with no difference shown on d 7 and 14. However, on d 21, diet samples had greater CP than current year growth ($P < 0.01$). Diet samples had lower NDF ($P < 0.01$) compared with previous year growth. Diet samples had lower NDF ($P < 0.01$) compared with current year growth on d 0, 14 and 21, however, on d 7 they did not differ ($P < 0.01$) between method types. Current year growth had lower NDF ($P < 0.01$) compared with previous year growth on d 0 and 7 with no difference ($P > 0.05$) being shown on d 14 and 21. Results indicate that cattle are selective when forage availability allows selection. Hand clipped samples are not representative of the diet.

Weir and Torell (1959) observed diet samples were higher in CP than clipped samples. Neutral detergent fiber was greater ($P < 0.01$) in clipped samples versus diet samples which was also observed by Weir and Torell. It is unclear whether Weir and Torell (1959) separated the clipped sample into current year growth and previous year

growth for the comparison. The current experiment is one of the only research to separate

current year growth and previous year growth clipped samples and compare it against

diet samples.

Forage accumulation

Current year growth increased linearly ($P = 0.01$, Table 9) for all treatments from

d 0 through d 21. Forage accumulation in control paddocks on d 21 (June 4) was 439

kg/ha which was slightly lower than those values reported by Volesky et al., (2005) who

reported 472 kg/ha for current year herbage growth for late May. Previous year growth in

stocked paddocks decreased linearly ($P = 0.02$) from d 0 to d 21. Current year growth

accumulation was affected by treatment. On d 0, treatments did not differ ($P > 0.05$,

Table 10), however, control paddocks on d 7, 14, and 21 had greater ($P < 0.01$) forage

accumulation than stocked paddocks. Forage accumulation in light and heavy stocked

paddocks did not differ ($P > 0.05$) for any sampling day. Similarly, Gillen et al., (1998)

reported decreased standing crop with stocked pastures, however, they reported a decline

in standing crop with increasing stocking rate whereas this study only found a difference

between control paddocks and stocked paddocks. The difference could be a result of the

duration of this study only being 21 days. If the study was prolonged, differences

between stocking rates may have become more evident, however, cattle were consuming

previous year growth as part of the diet. Using a simple algebraic equation ($63.7 = .707x$

$+ .474(100-x)$) for IVOMD on d 21 about 70% of the animals diet is current year growth

and 30% previous year growth. Comparing the percentage of current year growth being

consumed using the clipping samples, about 62% of the diet was predicted to be current

year growth and 38% was previous year growth. Results indicate that cattle are consuming a large portion of previous year growth as part of their diet.

Other factors to consider in this study were timing of precipitation and growing-degree days. In 2013 and 2014, yearly totals for precipitation were slightly above the long term average (Table 11). However, cumulative precipitation from the previous October to the start of the trial were below average for both 2013 and 2014. Hazell (1965) reported a decline in forage production with lower amounts of precipitation. Cumulative growing-degree days were also lower in 2013 and 2014 than the long-term average (Figure 1). Therefore, decreased precipitation and fewer growing-degree days early in the growing season could have delayed growth resulting in less forage availability during this study.

Implications

Stocking pastures at 0.57 AUM/ha and 0.85 AUM/ha resulted in lower diet quality in early summer. Forage accumulation was likewise decreased by stocking rate. In stocked paddocks, diet samples had lower concentrations of IVOMD and CP compared with current year growth clipped samples but greater in quality than previous year growth. Diet samples in control paddocks were higher in CP at the end of the study and lower in NDF compared with current year and previous year growth samples. Producers can expect lower diet quality after grazing has occurred early in the grazing season due to consumption of previous year growth. Rapid rotation, supplementation, or delayed grazing start date may be required to help account for the loss in quality.

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Table 1. Nutrient content of diet samples collected from esophageally fistulated cows comparing collection dates by stocking rate.

Item	Day				SEM[1]	P-value	Linear	Quadratic	Cubic
	0	7	14	21					
IVOMD, %									
Control[2]	70.2[b]	73.5[a]	74.3[a]	71.5[b]	1.05	< 0.01	0.39	< 0.01	0.64
Light[3]	71.1[a]	65.0[bc]	65.5[b]	63.6[c]	1.05	< 0.01	< 0.01	< 0.01	< 0.01
Heavy[4]	71.0[a]	65.8[b]	63.8[c]	63.6[c]	1.05	< 0.01	< 0.01	< 0.01	0.64
CP, %									
Control[2]	15.4[b]	17.0[a]	17.6[a]	16.9[a]	0.68	< 0.01	< 0.01	< 0.01	0.22
Light[3]	14.6[a]	11.1[b]	12.6[c]	13.0[c]	0.61	< 0.01	0.08	< 0.01	< 0.01
Heavy[4]	14.2[a]	10.1[c]	11.1[bc]	12.0[b]	0.83	< 0.01	0.05	< 0.01	< 0.01
NDF, %									
Control[2]	59.4[a]	61.7[a]	54.1[b]	50.0[b]	2.83	< 0.01	< 0.01	0.11	0.13
Light[3]	66.0[ab]	68.0[a]	68.2[ab]	63.0[b]	2.85	< 0.01	0.33	< 0.01	0.22
Heavy[4]	68.4	71.0	67.7	72.2	2.81	0.11	0.15	0.51	0.08

[1] Standard error of the least squares mean
[2] Non-stocked paddock (0 AUM/ha)
[3] Light stocking rate paddock (0.57 AUM/ha)
[4] Heavy stocking rate paddock (0.85 AUM/ha)
[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 2. Nutrient Content of diet samples collected from esophageally fistulated cows comparing stocking rate on each date.

Item	Control[2]	Light[3]	Heavy[4]	SEM[4]	P-value
IVOMD, %					
d 0	70.2	71.1	71.0	1.81	0.60
d 7	73.5[a]	65.0[b]	65.8[b]	1.68	< 0.01
d 14	74.3[a]	65.5[b]	63.8[b]	1.74	< 0.01
d 21	71.5[a]	63.6[b]	63.6[b]	1.88	< 0.01
CP, %					
d 0	15.4	14.6	14.2	1.51	0.41
d 7	17.0[a]	11.1[b]	10.1[b]	1.41	< 0.01
d 14	17.6[a]	12.6[b]	11.1[b]	1.42	< 0.01
d 21	16.9[a]	13.0[b]	12.0[b]	1.38	< 0.01
NDF, %					
d 0	59.4	66.0	68.4	4.74	0.06
d 7	61.7[b]	68.0[a]	71.0[a]	4.61	0.01
d 14	54.1[b]	68.2[a]	67.7[a]	4.80	0.01
d 21	50.0[b]	63.0[a]	72.2[a]	5.01	0.01

[1] Non-stocked paddock (0 AUM/ha)

[2] Light stocking rate paddock (0.57 AUM/ha)

[3] Heavy stocking rate paddock (0.85 AUM/ha)

[4] Standard error of the least squares mean

[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 3. Nutrient content of previous year growth clipped samples comparing collection dates by stocking rate.

Item	Day 0	7	14	21	SEM[1]	*P*-Value	Linear	Quadratic	Cubic
IVOMD, %									
Control[2]	46.7	47.3	45.4	46.8	1.6	0.44	0.19	0.77	0.11
Light[3]	47.0	48.9	47.5	48.8	1.6	0.43	0.10	0.67	0.43
Heavy[4]	49.3	48.2	46.9	46.5	1.6	0.43	0.08	0.85	0.84
CP, %									
Control[2]	6.0	5.5	5.4	5.2	0.42	0.08	0.04	0.53	0.62
Light[3]	6.0	5.4	5.3	5.4	0.42	0.15	0.20	0.32	0.77
Heavy[4]	6.3[a]	6.3[a]	5.5[ab]	5.2[b]	0.42	0.01	0.03	0.64	0.40
NDF, %									
Control[2]	80.9	80.2	81.8	81.8	2.52	0.31	0.49	0.81	0.53
Light[3]	81.3	80.2	82.3	80.3	2.52	0.31	0.97	0.66	0.23
Heavy[4]	79.8	80.5	84.1	81.9	2.52	0.31	0.36	0.54	0.43

[1] Standard error of the least squares mean
[2] Non-stocked paddock (0 AUM/ha)
[3] Light stocking rate paddock (0.57 AUM/ha)
[4] Heavy stocking rate paddock (0.85 AUM/ha)
[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 4. Nutrient content of clipped sample current year growth comparing collection dates by stocking rate.

Item	Day 0	7	14	21	SEM[1]	*P*-value	Linear	Quadratic	Cubic
IVOMD, %									
Control[2]	71.1^{ab}	73.2^{a}	67.6^{b}	69.1^{ab}	2.51	0.04	0.15	0.87	0.08
Light[3]	70.9	72.1	70.6	71.2	2.51	0.55	0.95	0.86	0.62
Heavy[4]	72.1	71.8	70.1	70.7	2.51	0.44	0.36	0.77	0.58
CP, %									
Control[2]	18.3^{a}	16.8^{b}	15.6^{b}	13.7^{c}	0.66	< 0.01	< 0.01	0.46	0.46
Light[3]	18.4^{a}	17.4^{a}	15.8^{b}	15.7^{b}	0.66	< 0.01	0.01	0.60	0.48
Heavy[4]	18.5^{a}	16.8^{b}	16.0^{bc}	15.4^{c}	0.66	< 0.01	< 0.01	0.17	0.61
NDF, %									
Control[2]	74.3	69.8	72.7	71.5	3.09	0.39	0.66	0.54	0.37
Light[3]	78.9	80.1	84.7	81.2	3.09	0.39	0.30	0.34	0.31
Heavy[4]	75.3	79.2	74.5	80.2	3.09	0.39	0.01	0.17	0.41

[1] Standard error of the least squares mean
[2] Non-stocked paddock (0 AUM/ha)
[3] Light stocking rate paddock (0.57 AUM/ha)
[4] Heavy stocking rate paddock (0.85 AUM/ha)
[abc] Means within rows lacking common superscript differ (*P* < 0.05)

Table 5. Nutrient content of previous year growth clipped samples comparing stocking rates on each date.

Item	Control[2]	Light[3]	Heavy[4]	SEM[4]	*P*-value
IVOMD, %					
d 0	46.7	47.0	49.3	1.59	0.21
d 7	47.3	48.9	48.2	1.59	0.21
d 14	45.4	47.5	46.9	1.59	0.21
d 21	46.8	48.8	46.5	1.59	0.21
CP, %					
d 0	6.0	6.0	6.3	0.40	0.12
d 7	5.5[b]	5.4[b]	6.3[a]	0.40	0.03
d 14	5.4	5.3	5.5	0.40	0.12
d 21	5.2	5.4	5.2	0.40	0.12
NDF, %					
d 0	80.9	81.3	79.8	2.48	0.93
d 7	80.2	80.2	80.5	2.48	0.93
d 14	81.8	82.3	84.1	2.48	0.93
d 21	81.8	80.3	81.9	2.48	0.93

[1] Non-stocked paddock (0 AUM/ha)

[2] Light stocking rate paddock (0.57 AUM/ha)

[3] Heavy stocking rate paddock (0.85 AUM/ha)

[4] Standard error of the least squares mean

[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 6. Nutrient composition of current year growth clipped samples comparing stocking rate on each date.

Item	Control[2]	Light[3]	Heavy[4]	SEM[4]	*P*-value
IVOMD, %					
d 0	71.1	70.9	72.1	2.45	0.63
d 7	73.2	72.1	71.8	2.45	0.63
d 14	67.6	70.6	70.1	2.45	0.63
d 21	69.1	71.2	70.7	2.45	0.63
CP, %					
d 0	18.3	18.4	18.5	0.63	0.81
d 7	16.8	17.4	16.8	0.63	0.29
d 14	15.6	15.8	16.0	0.63	0.52
d 21	13.7[b]	15.7[a]	15.4[a]	0.63	0.02
NDF, %					
d 0	74.3	78.9	75.3	3.69	0.23
d 7	69.8[b]	80.1[a]	79.2[a]	3.69	0.02
d 14	72.7[b]	84.7[a]	79.5[ab]	3.69	0.02
d 21	71.5[b]	81.2[a]	80.2[a]	3.69	0.02

[1] Non-stocked paddock (0 AUM/ha)

[2] Light stocking rate paddock (0.57 AUM/ha)

[3] Heavy stocking rate paddock (0.85 AUM/ha)

[4] Standard error of the least squares mean

[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 7. Nutrient content of stocked treatments for esophageal diet sample versus current and previous year growth clipped samples.

Item	Diet[1]	Current year growth[2]	Previous year growth[3]	SEM[4]	*P*-value
IVOMD, %					
d 0	70.3[a]	71.3[a]	48.0[b]	1.32	< 0.01
d 7	65.9[b]	72.0[a]	48.6[c]	2.09	< 0.01
d 14	65.2[b]	70.3[a]	47.1[c]	1.89	< 0.01
d 21	63.7[b]	70.7[a]	47.4[c]	1.65	< 0.01
CP, %					
d 0	13.7[b]	18.3[a]	6.0[c]	0.76	< 0.01
d 7	9.4[b]	17.1[a]	5.9[c]	0.78	< 0.01
d 14	11.4[b]	15.9[a]	5.4[c]	1.07	< 0.01
d 21	11.8[b]	15.6[a]	5.3[c]	1.11	< 0.01
NDF, %					
d 0	66.7[a]	77.1[b]	80.5[b]	2.64	< 0.01
d 7	74.0[a]	79.6[b]	80.3[b]	3.43	< 0.01
d 14	69.6[a]	81.9[b]	83.4[b]	4.05	< 0.01
d 21	71.2[a]	80.7[b]	81.1[b]	3.37	< 0.01

[1] Diet collection with esophageally fistulated cattle
[2] Clipped sample current year forage growth
[3] Clipped sample previous year forage growth
[4] Standard error of the least squares mean
[abc] Differences in letter among rows signifies significant differences between methods (*P* < 0.05)

Table 8. Nutrient content of control treatment paddock samples for esophageal diet sample versus current and previous year growth clipped samples.

Item	Diet[1]	Current year growth[2]	Previous year growth[3]	SEM[4]	*P*-value
IVOMD, %					
d 0	68.4[b]	71.1[a]	46.7[c]	1.27	< 0.01
d 7	72.0[a]	73.1[a]	47.3[b]	1.77	< 0.01
d 14	72.5[a]	67.2[b]	45.1[c]	1.25	< 0.01
d 21	69.2[a]	69.1[a]	46.8[b]	2.47	< 0.01
CP, %					
d 0	13.8[b]	18.2[a]	6.0[c]	0.80	< 0.01
d 7	16.0[a]	16.9[a]	5.6[b]	1.82	< 0.01
d 14	16.7[a]	15.4[a]	5.3[b]	1.69	< 0.01
d 21	16.1[a]	13.6[b]	5.2[c]	0.67	< 0.01
NDF, %					
d 0	59.0[a]	74.7[b]	80.9[c]	5.15	< 0.01
d 7	66.4[a]	70.2[a]	80.2[b]	3.39	< 0.01
d 14	57.9[a]	74.0[b]	82.8[b]	5.89	< 0.01
d 21	47.8[a]	73.0[b]	82.9[b]	7.54	< 0.01

[1] Diet collection with esophageally fistulated cattle

[2] Clipped sample current year forage growth

[3] Clipped sample previous year forage growth

[4] Standard error of the least squares mean

[abc] Differences in letter among rows signifies significant differences between methods ($P < 0.05$)

Table 9. Sandhills upland range current year forage accumulation and previous year growth stocking rate by date.

Item	Day 0	7	14	21	SEM[1]	*P*-value	Linear	Quadratic	Cubic
Current year forage accumulation, kg/ha									
Control[2]	127.9[c]	201.2[b]	403.2[a]	439.1[a]	31.24	< 0.01	< 0.01	0.57	0.05
Light[3]	93.7[b]	95.6[ab]	133.8[ab]	155.4[a]	31.24	0.05	< 0.01	0.41	0.32
Heavy[4]	120.2	149.0	166.4	172.3	31.24	0.10	0.01	0.44	0.99
Previous year growth, kg/ha									
Control[2]	965.6[a]	781.6[a]	1038.3[a]	729.9[b]	134.09	< 0.01	0.37	0.58	0.05
Light[3]	862.3[a]	543.2[b]	676.1[ab]	429.7[b]	134.09	< 0.01	< 0.01	0.69	0.05
Heavy[4]	802.5	720.0	634.0	563.5	134.09	0.08	0.02	0.94	0.96

[1] Standard error of the least squares mean

[2] Non-stocked paddock (0 AUM/ha)

[3] Light stocking rate paddock (0.57 AUM/ha)

[4] Heavy stocking rate paddock (0.85 AUM/ha)

[abc] Differences in letter among rows signifies significant differences between treatment (*P* < 0.05)

Table 10. Sandhills upland range current year forage accumulation and previous year growth treatment by date.

Item	Control[2]	Light[3]	Heavy[4]	SEM[4]	P-value
Current year forage accumulation, kg/ha					
d 0	127.9	93.7	120.2	43.48	0.43
d 7	201.2[a]	95.6[b]	149.0[ab]	43.48	< 0.01
d 14	403.2[a]	133.8[b]	166.4[b]	43.48	< 0.01
d 21	439.1[a]	155.4[b]	172.3[b]	43.48	< 0.01
Previous year growth, kg/ha					
d 0	965.6	862.3	802.5	173.84	0.35
d 7	781.6	543.2	720.0	173.84	0.17
d 14	1038.3[a]	676.1[b]	634.0[b]	173.84	0.02
d 21	729.9	429.7	563.5	173.84	0.09

[1] Non-stocked paddock (0 AUM/ha)

[2] Light stocking rate paddock (0.57 AUM/ha)

[3] Heavy stocking rate paddock (0.85 AUM/ha)

[4] Standard error of the least squares mean

[abc] Means within rows lacking common superscript differ ($P < 0.05$)

Table 11. Monthly and yearly precipitation for Gudmundsen Sandhills Laboratory. Precipitation total for the current year begins October 1st of the previous year.

Month	Average	Year		
		2011-2012*	2012-2013	2013-2014
Oct. - Mar.	8.5(3.3)	8.0(3.2)	7.2(2.8)	8.0(3.2)
April	5.3(2.1)	4.9(1.9)	5.1(2.0)	2.3(0.9)
May	7.3(2.9)	2.4(1.0)	10.3(4.1)	9.1(3.6)
June	8.9(3.5)	1.3(0.5)	7.8(3.1)	19.5(7.7)
July	7.7(3.1)	1.1(0.5)	6.2(2.4)	1.5(0.6)
August	5.4(2.1)	0.8(0.3)	7.5(3.0)	8.8(3.5)
September	4.3(1.7)	0.9(0.4)	8.0(3.2)	4.8(1.9)
Year Total	**47.4(18.7)**	**19.5(7.7)**	**52.1(20.5)**	**54.1(21.3)**

* Precipitation is presented in cm(in)
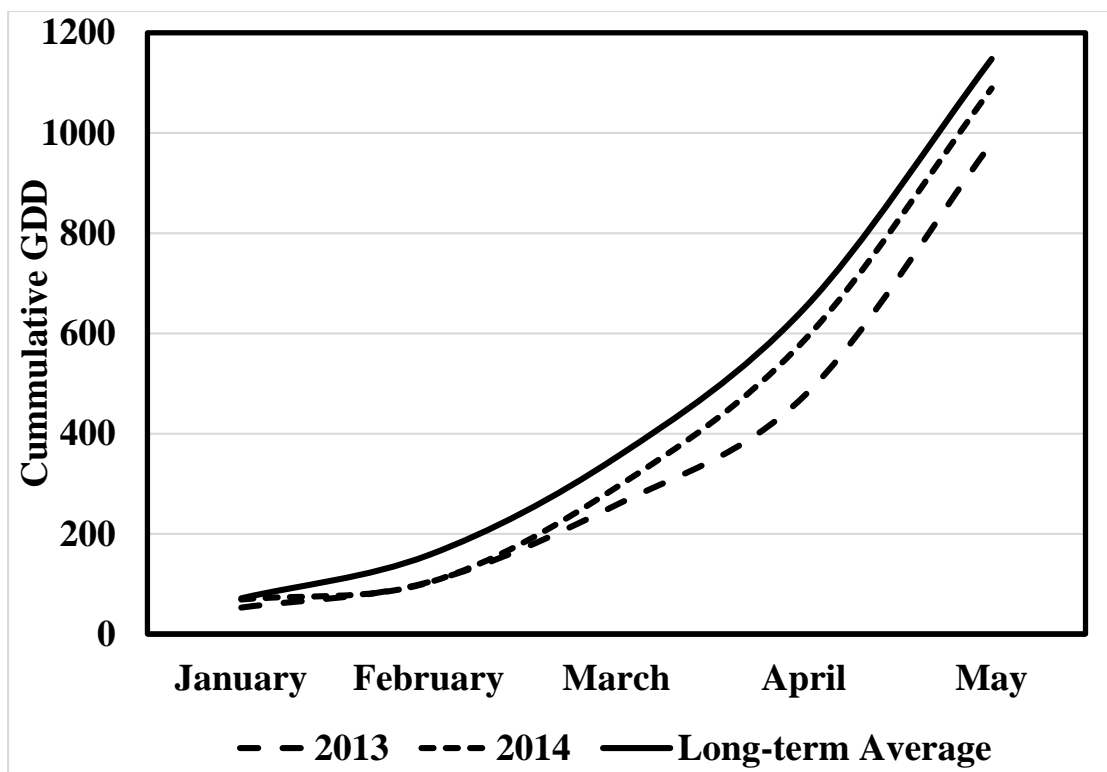
Figure 1. Long-term average, 2013, and 2014 cumulative growing-degree days (GDD$_{40}$) through the end of May at the Gudmundsen Sandhills Laboratory

Chapter III

Grazing Effects on Nebraska Sandhills Meadow Diet Nutrient Composition

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ABSTRACT: Thirty-six Nebraska Sandhills subirrigated meadow pastures (90 ha ± 43 ha) on a commercial ranch were utilized to measure the effects of grazing on forage nutrient composition. Pastures were sampled before and after grazing. Three esophageally fistulated cows per pasture were utilized for sample collection on thirteen dates in 2013 and seventeen dates in 2014 spanning from early June through late August. Grazing pressure ranged from 2.38 to 20.75 animal units per 1000kg of available forage. Samples were analyzed for CP, NDF, and IVDMD and adjusted to an in vivo basis (IVOMD). There were significant quadratic day by treatment interactions ($P < 0.01$) for IVOMD and NDF and day by treatment ($P < 0.01$) interactions for IVOMD, NDF, and CP. Non-grazed masticate samples decreased quadratically ($P < 0.01$) throughout the study for IVOMD. Non-grazed masticate samples tended to have greater IVOMD compared with grazed masticate samples on d 0 ($P = 0.06$), d 5 ($P = 0.07$) and d 10 ($P = 0.11$). Non-grazed masticate samples had greater ($P < 0.01$) IVOMD on d 35 through d 70. Crude protein decreased quadratically for grazed and non-grazed masticate samples ($P < 0.01$). Non-grazed pastures were greater in CP on d 0 through d 35 compared with grazed pastures ($P < 0.01$). Crude protein did not differ ($P > 0.016$) between grazed and non-grazed masticate samples on d 35 through d 70. Non-grazed and grazed masticate

samples increased quadratically ($P < 0.01$) in NDF throughout the study. Non-grazed masticate samples did not differ ($P > 0.05$) from grazed pastures on d 0, or d 50-60 in NDF content, however, non-grazed masticate samples had lower NDF on d 5 through d 45 and d 65 through d 70 ($P < 0.01$). These data suggest grazing an impact on forage quality both early, when the majority of growth occurs, and late in the grazing season when regrowth of cool season grasses occurs.

 Key words: forage quality, grazing effects, Sandhills meadows

Introduction

Subirrigated meadows in the Nebraska Sandhills are an excellent resource for grazing cattle. The Nebraska Sandhills are about 5.16 million ha, of which about 10% are subirrigated meadows (Volesky et al., 2004). Most are dominated by cool-season grass species which have greater growth during early spring. Historically, the meadows have been harvested and had the hay fed to cattle during the dormant season (Coady and Clark, 1993). However, Adams et al., (1994) reported extending the grazing season into May on the meadows helped improve economic returns. This lead to producers using cattle to harvest the forage from the meadows as opposed to mechanical harvesting. Understanding diet quality is crucial for these operations to meet animal requirements.

As temperatures increase by mid-summer, forage quality decreases (Lardy et al., 2004). Previous research has shown the changes in forage nutrient composition throughout the year, but it is unclear exactly how grazing affects the nutrient composition of Sandhills subirrigated meadows. According to Heitschmidt et al. (1991) stocking rate has an impact on the quantity of forage consumed and possibly quality. However, even though stocking rate may have an impact on forage quality, maturity is still one of the

primary factors affecting forage quality. The decrease in forage quality occurs because of decreasing digestibility and protein content with increasing maturation (Cogswell & Kamstra 1976). Baleseng, (2006) reported a linear decrease in IVOMD and a quadratic decrease in CP for monoculture smooth bromegrass (Bromus inermis Leyss) pastures un-grazed at the beginning of a grazing period compared with grazed pastures in Eastern Nebraska. Mixed grass prairie such as subirrigated meadow may react differently than monoculture pastures due to quality differences in grass species (Wallace et al., 1972). Therefore, the objective of this research was to determine the difference in forage quality between grazed pastures and non-grazed pastures in the Nebraska Sandhills subirrigated meadows.

Materials and Methods

Under approval of the University of Nebraska, Institutional Animal Care and Use Committee, esophageally fistulated cows were utilized to determine the effects of grazing on forage quality in the Nebraska Sandhills subirrigated meadows. A total of thirty-six subirrigated meadow pastures (90 ha ± 43 ha) in the Nebraska Sandhills were used. The pastures used in the study were located at a commercial ranch located near Lakeside, NE (lat 42°14′ N, long 102°25′ W, elevation ~ 1,180m). The meadow was divided into multiple pastures to allow for management intensive rotational grazing. Two adjacent pastures were sampled on one of thirteen dates in 2013 and one of seventeen dates in 2014. Dates sampled were: June 17, June 26, July 2, July 11, July 15, July 18, July 22, July 26, July 31, August 7, August 12, or August 22, for both 2013 and 2014. Due to cattle rotation, four additional dates were sampled in 2014: June 14, June 20, June 23, and June 30. August 12 and August 22 pastures had been grazed early in the growing

season but had been allowed a recovery of at least 60 d prior to grazing of the regrowth.

Dates were adjusted to Julian day with d 0 being the initial sampling day (June 14). Of

the two adjacent pastures sampled each date, one pasture was non-grazed while the other

pasture had been grazed previously for about 3 days. On each sampling date the non-

grazed pasture was sampled prior to cattle being rotated into the pasture and the grazed

pasture was sampled after cattle were rotated to the non-grazed pasture, where sampling

had just occurred. Grazing pressure ranged 2.38 to 20.75 animal units per 1000 kg of

available forage.

Three esophageally fistulated cows were used to sample each pasture on each

sampling day to determine forage quality. Prior to each masticate sample collection, cows

were withheld from feed, but not water, for 12 h then transported to pastures where

masticate samples were to be collected at 0700 hours. Cows were fitted with solid bottom

bags after removal of the esophageal plug and introduced to the pasture then allowed to

graze for about 20 min.

Forage accumulation prediction/calibration

Forage accumulation was determined using the pasture plate method developed

by Rayburn, (1997) which measures standing crop height and uses a quadrat to measure

forage accumulation. The pasture plate is made from 5.59 cm acrylic plastic sheet cut in a

457.2-cm square with a 38.1 cm hole in the middle. The pasture plate is gently placed on

top of the forage, then a yardstick was used to measure forage height in the hole in the

middle. Forage growth beneath the pasture plate is clipped to calibrate the pasture plate.

One hundred quadrat samples clipped in late Jun through late Sep on subirrigated

meadows at the commercial ranch near Lakeside, NE were immediately taken to the lab

and dried in a forced air oven at 60°C for 48h. The corresponding height and weight were matched to build a regression equation. The resulting regression equation was y = 624.53x – 519.65 (R^2 = 0.5864, Figure 1.) were x is forage height and y is predicted forage accumulation.

Laboratory analysis

Immediately after collection, masticate samples were separated into fibrous and liquid fractions, then a representative aliquot from the fibrous and liquid fractions were combined together maintaining the same proportions of fibrous and liquid fractions as the original sample. Combined samples were then frozen and stored at -20º C, then lyophilized. Lyophilized samples were ground to pass a 1-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) and analyzed for nitrogen using a Leco, FP 2000 combustion nitrogen analyzer (Leco Corp, St. Joseph, MO) then converted to CP by multiplying by 6.25 and adjusted to an OM basis by dividing by the % OM. Organic matter was found using the equation 100 - % ash = % OM. Ash weight was determined by placing the dry sample in a combustion chamber at 600°C for six hours. Percent ash was determined by taking the ashed sample weight divided by the dry sample weight then multiplying by 100 to get ash %. Neutral detergent fiber content was determined using the Van Soest et al. (1991) method, and IVDMD using the Tilley and Terry (1963) method with the modification of adding 1 g of urea to the buffer and ashing the residue to calculate organic matter digestibility and adjusting to an in vivo (IVOMD) value using the standard mean adjustment used by Ahern (2014).

Statistical analysis

Data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst.,

Inc., Cary, NC). Experimental unit was pasture. Regression was used to determine best fit for the model to predict IVOMD, CP, and NDF. Fixed effects included treatment and year, with Julian day used as a covariate and random variables included pasture and cow. Initial model included treatment, day, year, grazing pressure, treatment × day, year × day, quadratic day, quadratic grazing pressure, treatment × grazing pressure, treatment × quadratic day, treatment × quadratic grazing pressure, and treatment × grazing pressure × day interactions. Insignificant terms ($P > 0.05$) were dropped from the model. Final model for IVOMD included: treatment, year, day, day × treatment interaction, quadratic day, and quadratic day × treatment interaction. Final model for CP included: treatment, year, day, day × treatment, and quadratic day. Final model for NDF included: treatment, year, day, day × treatment, quadratic day, and quadratic day × treatment. Significance was reported at a probability level of less than 0.05.

Results and Discussion

Significant quadratic day × treatment ($P < 0.01$) and day × treatment ($P < 0.01$) interactions occurred for IVOMD. Initially, there was a tendency for non-grazed masticate samples to be greater in IVOMD compared with grazed masticate samples on d 0 ($P = 0.06$), d 5 ($P = 0.07$), and d 10 ($P = 0.11$, Figure 2.). Day 15 through 25 did not differ in IVOMD ($P > 0.05$). However, non-grazed masticate samples had greater ($P < 0.01$) IVOMD content on d 35 through the end of the study on d 70. Baleseng, (2006) reported that IVOMD decreased linearly when comparing non-grazed masticate samples, mid-grazed masticate samples and grazed masticate samples. In the current study, mid-point masticate samples were not taken, however, the effects of grazing are evident. As cattle graze, they consume the higher quality forage, after which they consume a diet

lower in quality.

Non-grazed masticate samples initially had an IVOMD value of about 75% then decreased quadratically ($P < 0.01$) reaching the convex at about 65% in mid-July or d 35 then increases by d 70 to about 69%. Similarly, Lardy et al., (2004) reported IVOMD values for June at 70.8% then decreased for July (66.0%) and August (64.4%) and then increased in October (67.7%). The values given by Lardy et al., (2004) were lower than the current study, however, even though the values in the current study were within the standard deviation given. Lardy et al., (2004) also reported an increase occurring later in the season compared with the current study. This difference could be explained by year to year variation in climatic factors such as moisture and temperature or the difference that the samples were squeezed to remove saliva and collected using screen bottom bags (Lardy et al., 2004). The increase in IVOMD in August is due to plant regrowth typical of the bimodal growth pattern of cool season grasses when temperature begins to decrease at the end of summer. Grazed masticate samples were at the apex at the beginning of the experiment at about 70.0% then decreased throughout the study.

A significant day × treatment interaction ($P < 0.01$) and quadratic day effect ($P < 0.01$) occurred for CP. Grazed and non-grazed masticate sample CP content decreased quadratically ($P < 0.01$) with advancing grazing season. Grazed masticate samples were lower in CP ($P < 0.01$, Figure 3) compared with non-grazed masticate samples from the beginning of the grazing season to about d 35 of the grazing season (Figure 3.). From d 40 through the end of the study (d 70), grazed and non-grazed masticate samples did not differ in CP ($P > 0.05$). Baleseng (2006) reported grazed smooth bromegrass masticate samples had lower CP content than non-grazed smooth bromegrass masticate samples

which is in agreement with the current study. Earlier in the grazing season CP is most affected. Cattle are able to select a diet greater in CP early in grazing season but later in the grazing season CP content of the diet is less affected by grazing.

Initially in non-grazed pastures, CP content of the masticate samples was about 20%. As the season progressed, plants matured, resulting in decreased CP content. Toward the end of the grazing season when regrowth occurred, masticate samples were once again high in CP content. Similarly, Lardy et al., (2004) showed a diet CP content of 17.3% for June which then decreased in July to 12.4% and increased to 17.2% in August. Lardy et al., (2004) reported that the August samples were regrowth which would be greater in quality than plants that have matured. Sub-irrigated meadows are dominated by cool season grasses which increase rapidly in quality early in the growing season and decline in quality as the plant matures and the temperature increases in mid-summer. As the temperature begins to decline in late-summer, cool season grasses are able to regrow causing an increase in diet quality.

A significant quadratic day $\times$ treatment interaction ($P < 0.01$) occurred for NDF. Both grazed and non-grazed masticate samples increased quadratically ($P < 0.01$) throughout the study. The slopes of each line for grazed and non-grazed were not equal which is explained by the quadratic day $\times$ treatment interaction. Grazed masticate samples were not different ($P > 0.05$, Figure 4.) compared with non-grazed masticate samples on d 0. Grazed masticate samples were greater in NDF ($P < 0.01$) compared with non-grazed masticate samples on sampling d 5 through 45. From d 50 to 60 grazed did not differ ($P > 0.05$) compared with non-grazed masticate samples.

In non-grazed masticate samples, NDF increased initially reaching an apex on

about d 35 at about 62% after which it declined the remainder of the study. The increase agrees with previous research indicating that plants are maturing. The decline is due to plant regrowth which would have less structural components. Lardy et al., (2004) also reported an increase in NDF from June (68.6%) to July (72.0%) after which it decreased to 63.2% in August. This timeline agrees with the current study, however, the values were lower in the current study compared with those observed previously.

Early in the growing season when cattle are first introduced into a pasture they consume the highest quality forage available. When the highest quality forage is consumed, cattle consume lower quality forage which creates a change in diet quality over time independent of change in nutrient content of the forage. Ralphs et al., (1986) reported that vegetative cool season grasses were initially consumed in the diet but declined in the season as stocking rate increased resulting in cattle eating dormant warm-season grasses, which lowered diet quality for higher stocked pastures. The lower quality forage could result from consuming more stem or consuming growth from the previous year. A decrease in cattle selectivity would occur because the preferred feed would be already consumed.

In 2013 and 2014, precipitation was lower than average for October through April (Table 1). However, by early June in both years, precipitation was either average or above average for the remainder of the season. With the precipitation accumulated at this time combined with increasing temperatures, plant growth increases resulting in greater plant maturity but lower quality. With precipitation occurring in the summer, soil moisture levels could have been more favorable for regrowth to occur which is why an increase in masticate sample quality possibly occurred late in the summer in this study.

With greater grazing pressure, new growth may become less available more rapidly which would expedite the consumption of less desirable material such as mature forage with increased structural components or previous year's growth that was still available. This would account for the decline in CP that was observed earlier in the growing season. As the growing season progresses ample forage becomes available and grazing pressure may not have as great an impact on diet quality so averaging the values of the pastures before grazing and after grazing may be practical. Later in the growing season, as regrowth of the cool season grass species occurs and higher quality diet may become more available, once again grazing pressure may impact the duration that the new growth is available and cattle are once again forced to be less selective and eat mature forage or old growth which would account for the decline in IVOMD.

It is likely stocking rate plays a role in differences in nutrient content between grazed and non-grazed masticate samples (Judy et al., 2015). In this study, cattle were rotated to new pastures relatively quickly resulting in light stocking rates and low grazing pressures. If the same study were to be conducted under suggested or heavy stocking rate conditions, larger differences in nutrient content of grazed compared with non-grazed masticate samples would be expected.

Implications

These data suggest grazing has the most impact on CP early in the grazing season, IVOMD mid to late in the grazing season and NDF for the majority of the grazing season. The majority of grass growth occurs early in the grazing season when CP is most affected by grazing, and late in the grazing season when regrowth of cool season grasses occurs at which time IVOMD is most affected by grazing. Therefore, grazing impacts

diet quality during summer grazing and producers need to take into consideration these effects while planning cattle management practices. Frequent rotation as occurred in these pastures may avoid the potential for cattle not meeting requirements in years with lower forage quality. Furthermore, grazing pressure effects need to be investigated further across a wide range of levels to determine effects of diet composition.

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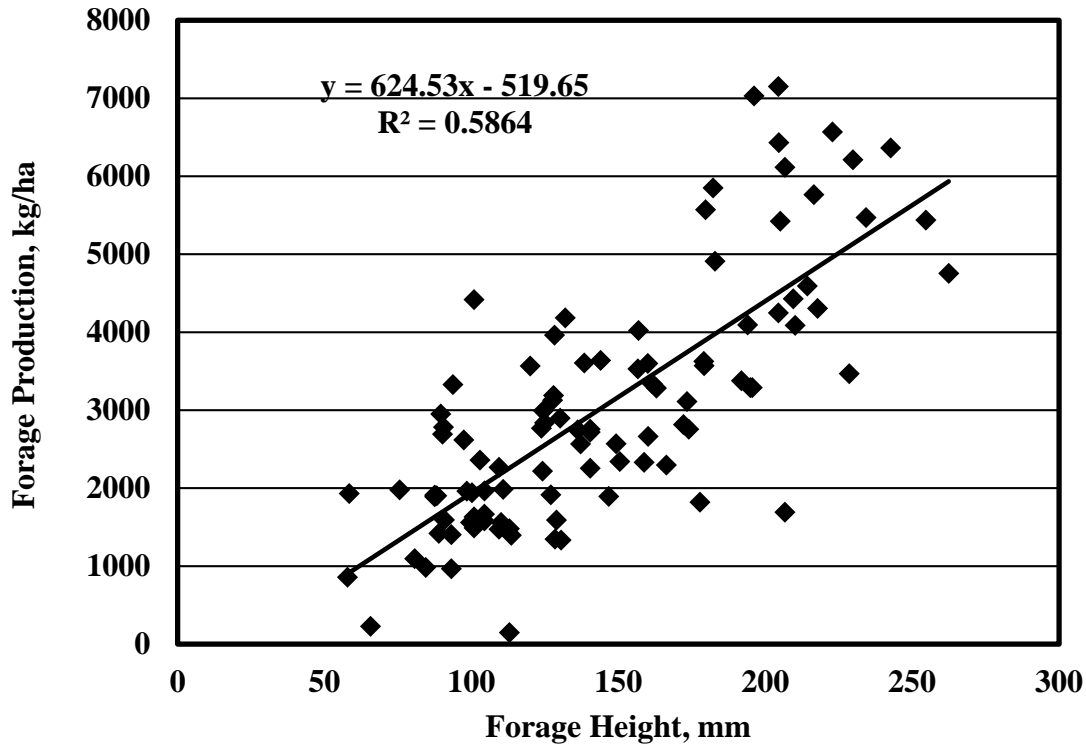
Figure 1: Regression analysis of forage accumulation determined by clipping quadrats in the Nebraska Sandhills subirrigated meadows determined using the pasture plate method.
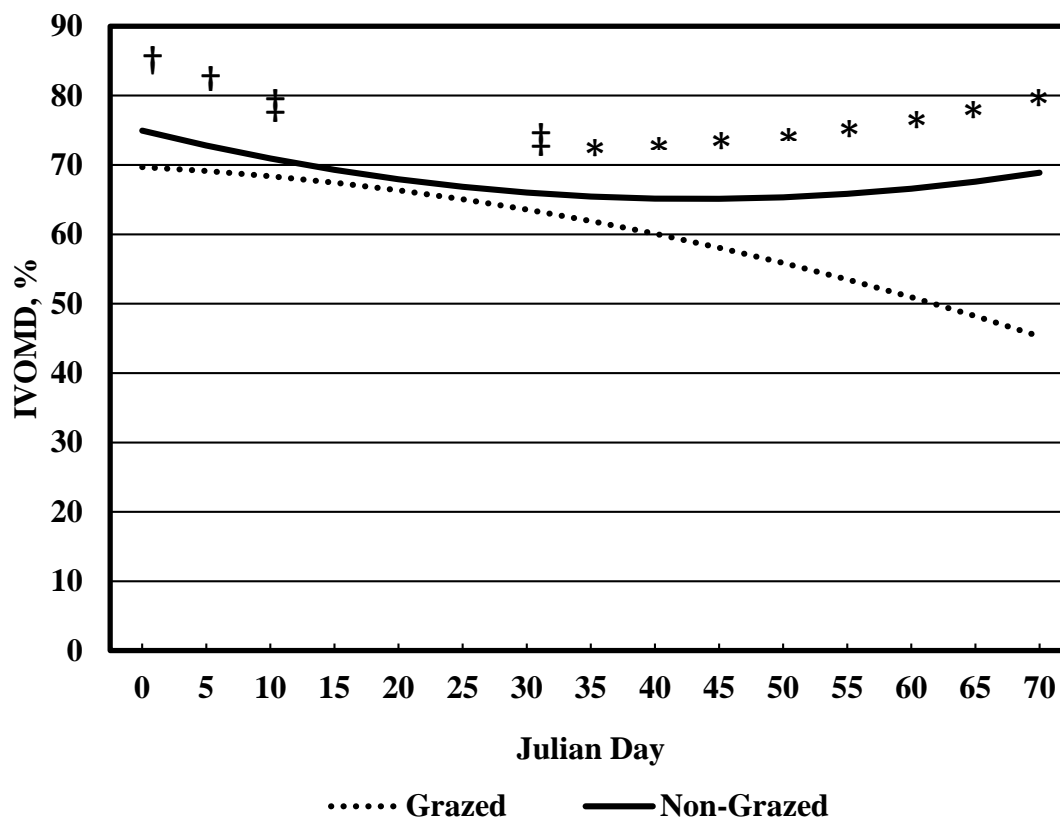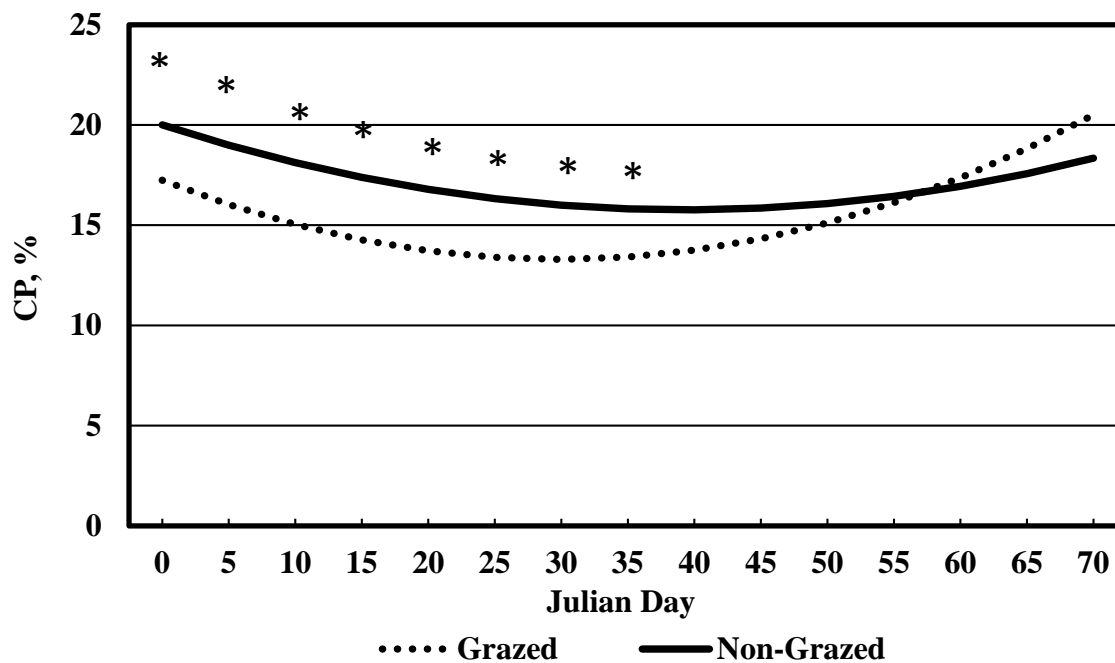
Figure 2: Predicted IVOMD for grazed and non-grazed for subirrigated meadows in the Nebraska Sandhills from mid-June through mid-August. * signifies a significant difference with a *P* < 0.05, † signifies a trend with a *P* ≤ 0.10, and ‡ signifies a trend with a *P* ≤ 0.15. Prediction equations: Grazed IVOMD = 69.7016 − 0.09595*Julian day − 0.00361*Julian day², Non-grazed IVOMD = 74.9571 − 0.4559*Julian day + .005272*Julian day².
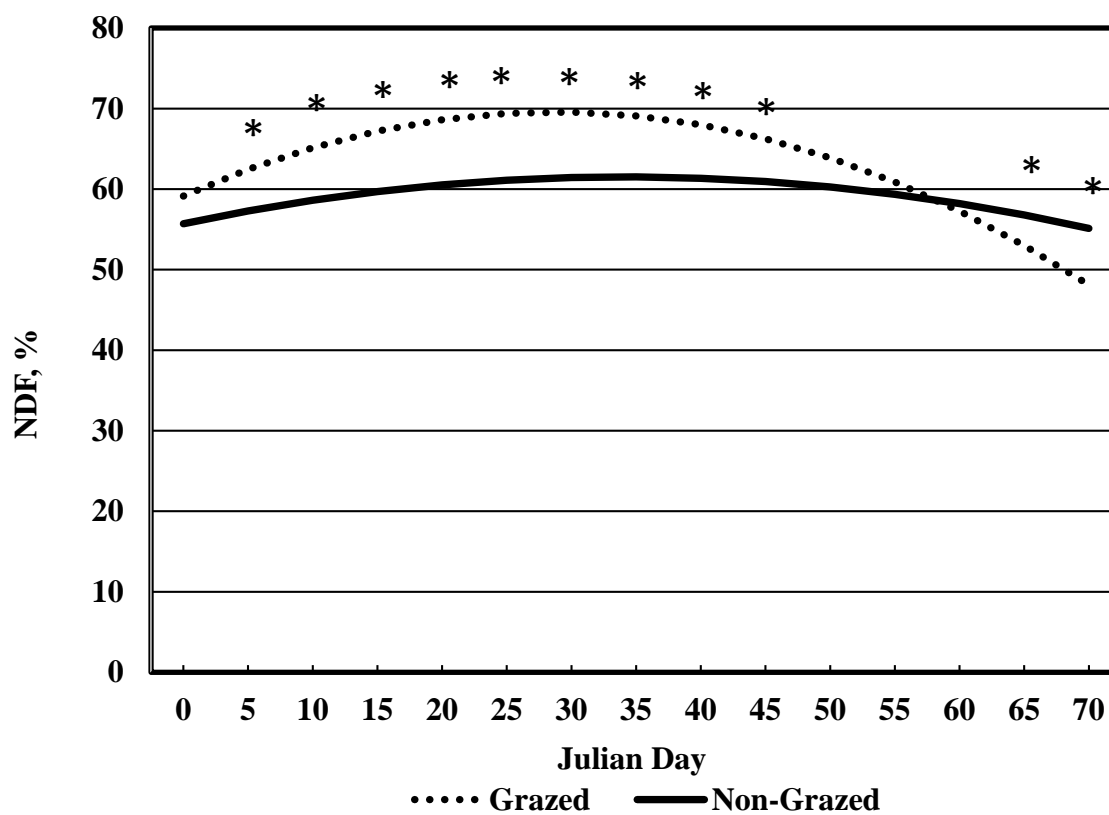
Figure 3: Predicted CP content for grazed and non-grazed for subirrigated meadows in the Nebraska Sandhills from mid-June through mid-August. * signifies a significant difference with a *P* < 0.05. Prediction equations: Grazed CP = 17.2441 - 0.2654*Julian day + .004456*Julian day^2, Non-grazed CP = 20.0014 – 0.2156*Julian day + 0.002742*Julian day^2.

Figure 4: Predicted NDF content for grazed and non-grazed for subirrigated meadows in the Nebraska Sandhills from mid-June through mid-August. * signifies a significant difference with a *P* < 0.05. Prediction equations: Grazed NDF = 59.1406 + 0.7265*Julian day – 0.01263*Julian day^2, Non-grazed NDF = 55.7073 + 0.3403*Julian day - .00498*Julian day^2.

Table 1: Monthly and yearly precipitation for Gudmundsen Sandhills Laboratory. Precipitation total for the current year begins Oct. 1st of the previous year.

Month	Average	Year		
		2011-2012*	2012-2013	2013-2014
Oct. - Mar.	8.5(3.3)	8.0(3.2)	7.2(2.8)	8.0(3.2)
April	5.3(2.1)	4.9(1.9)	5.1(2.0)	2.3(0.9)
May	7.3(2.9)	2.4(1.0)	10.3(4.1)	9.1(3.6)
June	8.9(3.5)	1.3(0.5)	7.8(3.1)	19.5(7.7)
July	7.7(3.1)	1.1(0.5)	6.2(2.4)	1.5(0.6)
August	5.4(2.1)	0.8(0.3)	7.5(3.0)	8.8(3.5)
September	4.3(1.7)	0.9(0.4)	8.0(3.2)	4.8(1.9)
Total	**47.4(18.7)**	**19.5(7.7)**	**52.1(20.5)**	**54.1(21.3)**

* Precipitation is presented in cm(in)

Appendix: Meadow forage variation in nutrient quality and grazing effects

Year to year variation in forage nutrient quality is shown in figures 1 through 3 for three pastures sampled in the Nebraska Sandhills on the same date each year. In 2012, the Sandhills experienced a severe drought and forage nutrient quality was lower than 2014 where there was ample moisture. In 2013, the Sandhills were starting the recovery process from the drought in 2012 which could explain the lower values that occurred in 2013 compared with 2014. Growing degree days may also have impacted forage growth as cumulative growing degree days were below average (Figure 4). Temperature and moisture are key variables that effect the year to year variation observed on any rangeland.

In 2012, crude protein was greater in non-grazed masticate samples ($P < 0.05$, Table 1) compared with grazed masticate samples in June and late July sampling. In early June, IVDMD was greater ($P = 0.03$) in non-grazed compared with grazed masticate samples and tended to be greater ($P = 0.09$) in late June and early July. Neutral detergent fiber tended to be lower ($P < 0.11$) in grazed compared with non-grazed masticate samples in June and early July. Grazing affected masticate quality in June pastures. Further investigation was warranted later in the season when regrowth would occur to determine the grazing effects late in the season. Drought in the region could have led to forage available in parts of the meadow that would have been difficult to reach during a normal precipitation year which possibly could account for no difference being detected in July pastures. Plant maturity could also have increased which possibly could have decreased cattle selectivity.
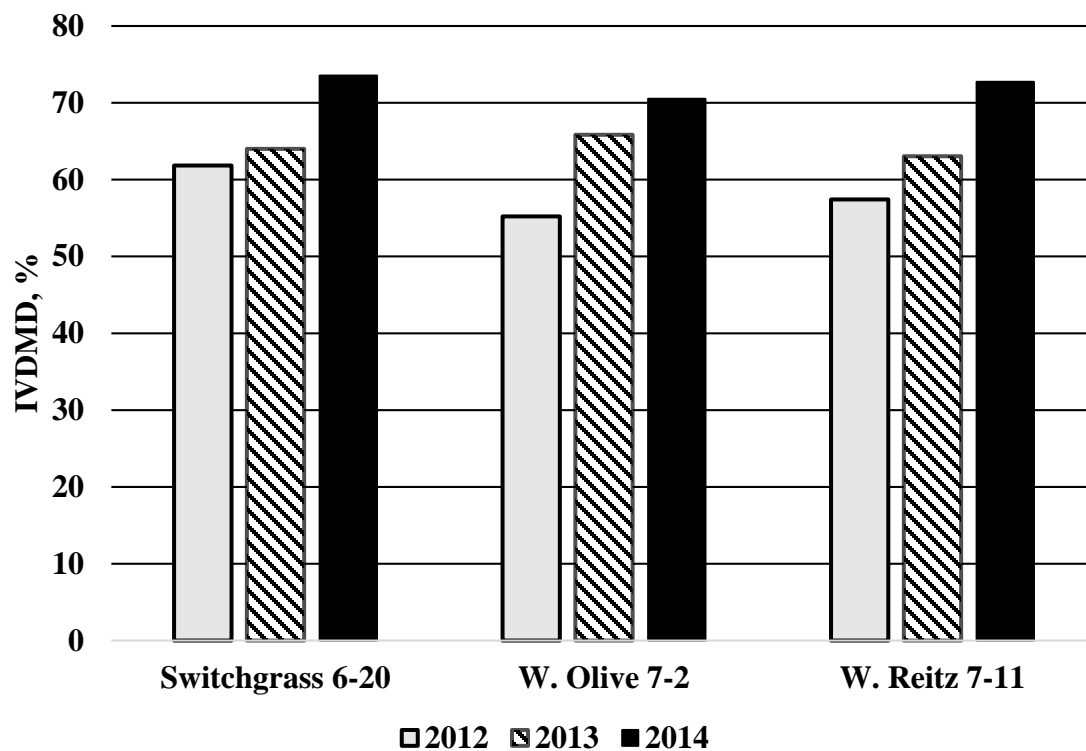
Figure 1. Variation among years for IVDMD in non-grazed for subirrigated meadows in the Nebraska Sandhills. Pasture was sampled on the same day each year.
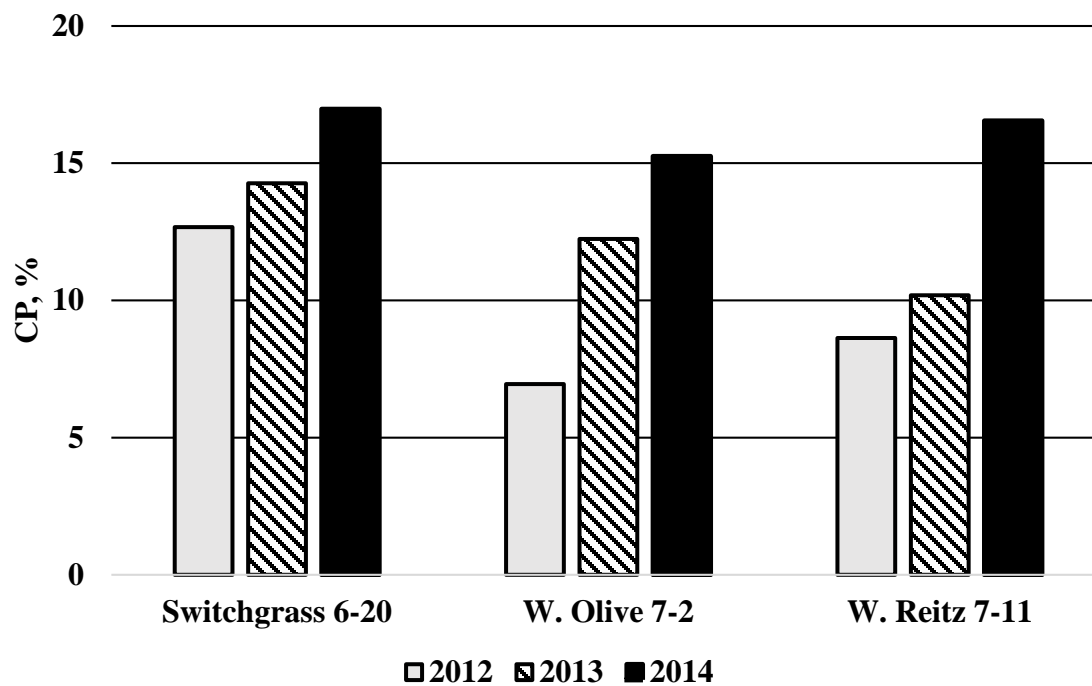
Figure 2. Variation among years for CP in non-grazed for subirrigated meadows in the Nebraska Sandhills. Pasture was sampled on the same day each year.
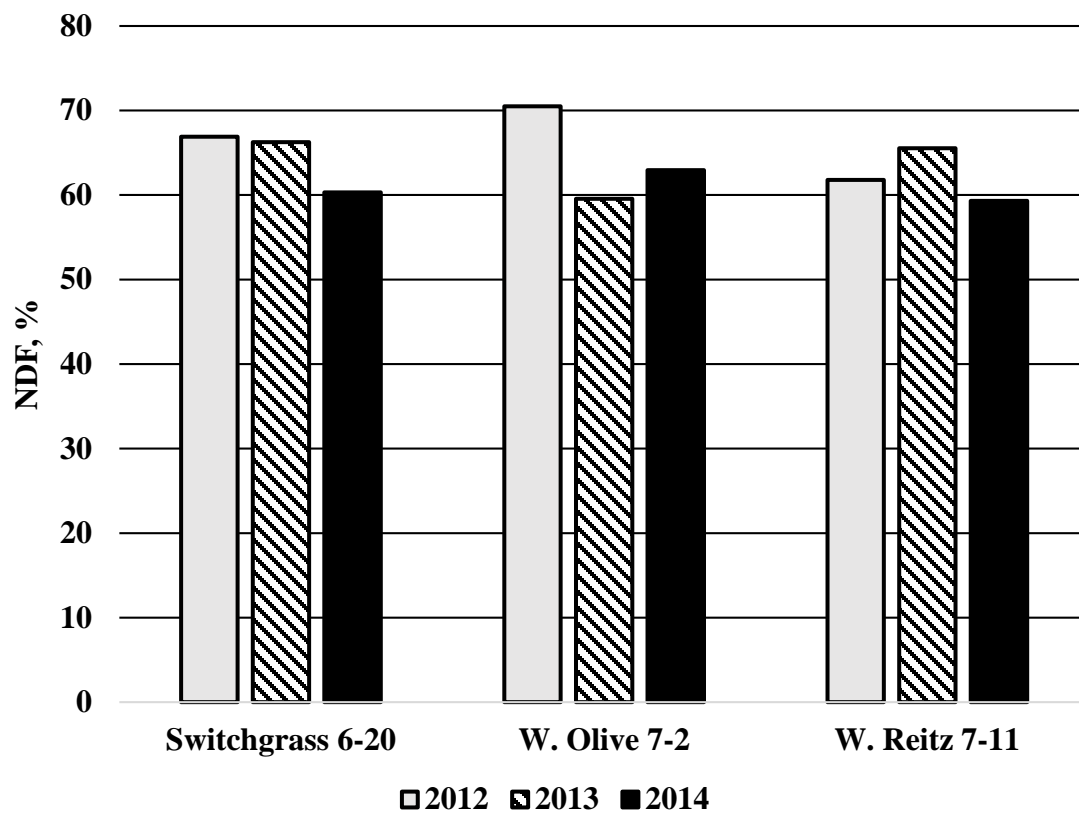
Figure 3. Variation among years for NDF in non-grazed for subirrigated meadows in the Nebraska Sandhills. Pasture was sampled on the same day each year.
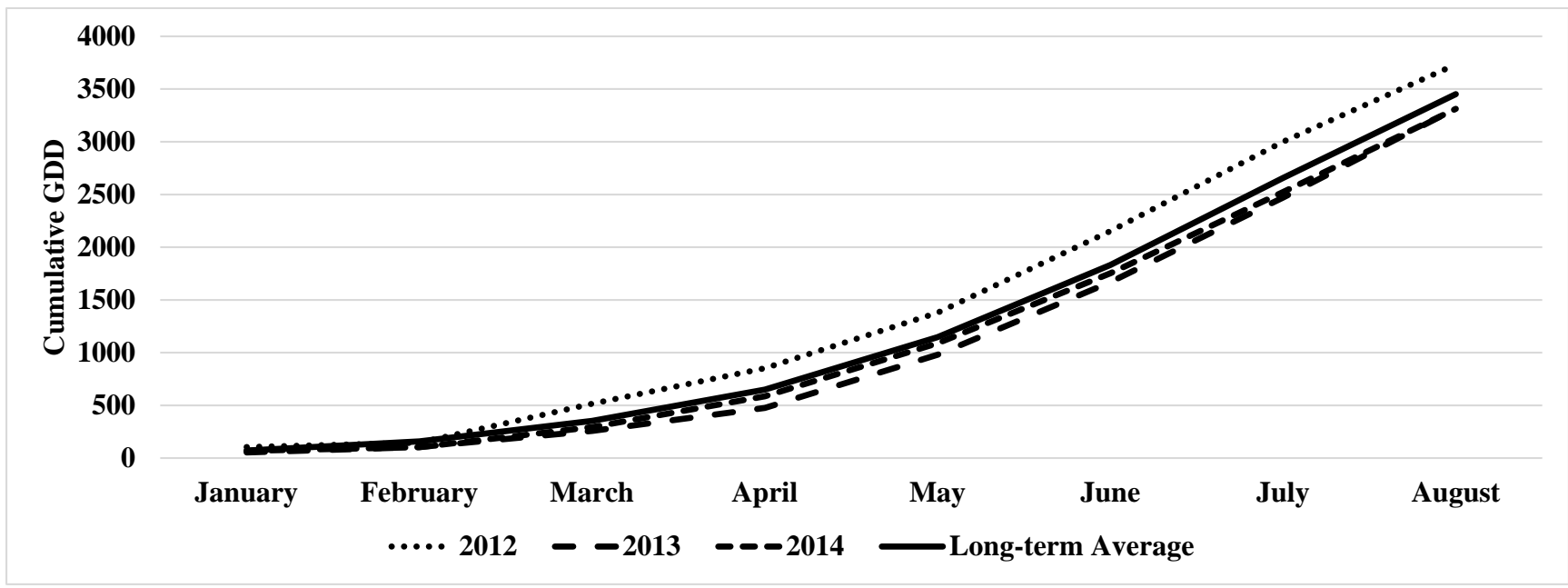
Figure 4. Long-term average, 2012, 2013, and 2014 cumulative growing-degree days (GDD_{40}) through the end of August at the Gudmundsen Sandhills Laboratory

Table 1. Crude protein, NDF and IVDMD values of masticate samples collected from Sandhills subirrigated meadow during the summer of 2012

Item	Non-Grazed[1]	Grazed[2]	SE[4]	P-value
Early June[3]				
CP, %	12.0	7.1	0.3	< 0.001
NDF, %	66.8	75.7	4.8	0.07
IVDMD, %	66.7	58.1	2.3	0.03
Late June[3]				
CP, %	9.8	7.2	0.3	0.03
NDF, %	70.4	78.7	2.5	0.11
IVDMD, %	63.5	57.0	1.4	0.09
Early July[3]				
CP, %	8.7	8.3	0.2	0.30
NDF, %	61.8	67.8	1.3	0.08
IVDMD, %	58.2	54.1	1.4	0.09
Late July[3]				
CP, %	10.0	8.0	0.5	0.05
NDF, %	66.1	63.0	3.5	0.56
IVDMD, %	54.6	54.0	1.4	0.78

[1] Pastures sampled prior to grazing

[2] Pastures sampled after grazing

[3] Date pasture was sampled using esophageally fistulated cows

[4] Standard error of the simple effect mean