SUPPLEMENTING DISTILLERS GRAINS IN A YEARLING SYSTEM AS A FORAGE REPLACEMENT TOOL WITH BUNK OR GROUND FEEDING, AND IMPACT OF WINTER SUPPLEMENTATION LEVEL ON FINISHING PERFORMANCE AND PROFIT

Kari L. Gillespie
University of Nebraska-Lincoln, karigillespie87@hotmail.com

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By

Kari L. Gillespie

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Kari L. Gillespie, M.S.

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Advisors: Terry J. Klopfenstein and L. Aaron Stalker

The benefit of adding weight to cattle prior to entering the finishing phase through a forage-based backgrounding system has become more important with increased corn price. Further, as competition for available forage increases, the value of replacing grazed forage with a supplement such as distillers grains, also increases.

A 2-year beef systems study evaluated optimal supplementation time of distillers grains and summer forage savings with distillers supplementation. High winter level supplementation of distillers grains increased winter ADG, decreased summer ADG, and increased final live weights and HCW compared to cattle supplemented at a low supplement level designed to only meet protein needs. Summer supplementation of distillers grains increased summer ADG, but decreased feed efficiency and in year 1, decreased finishing ADG. Gains through the forage-based system were similar when cattle were supplemented at a high winter level but not in the summer, compared to cattle supplemented at a low winter level and in the summer. There were no overweight carcasses with supplementation using spayed heifers. System profitability increased with high winter supplementation, and but was unaffected by summer supplementation.

Summer supplementation reduced grazed forage consumption 17-24% when fed at 0.6% BW daily.

Six systems studies using various winter supplements on corn residue at a high and low supplementation level were analyzed. Cattle backgrounded at a high supplementation level during the winter had a greater finishing ADG and produced 37 kg greater final BW, created more revenue, and were more profitable across four economic scenarios.

Finally, distillers grains as a summer supplementation and forage replacement tool was investigated with spayed yearling heifers. Supplemented heifers had greater ADG and ending BW. Animal performance was similar between bunk fed and ground fed heifers, with loss factor of MDGS when ground fed calculated at 5.6%. Forage savings was approximately 15-17% when distillers grains were fed at 0.6% BW daily.

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CHAPTER I

A Review of the Literature

I. Forage Systems

Forage-based systems

Cattle have a unique advantage in utilizing forage over other livestock. The ruminant's ability to utilize grain, however, is less efficient than non-ruminants. Therefore, the beef industry needs to develop production systems which exploit cattle's forage use advantage rather than being dependent upon grain feeding (Klopfenstein et al., 1987). Historically, cattle feeders prefer mid-weight (295 kg) calves that can be placed directly into the feedlot as a calf fed during the fall months (Klopfenstein et al., 2007a). This pricing incentive then creates a place for lightweight cattle to enter a forage-based system, which allows them to gain additional weight before feedyard entry.

In the last 15 years, corn prices have increased over 150% (USDA NASS, 2013). Rising grain prices have increased the incentive to add additional weight to cattle prior to finishing. Adding weight is logical on pasture when yearling cattle make their most economical gains (Lewis et al., 1989), and that response can be increased through supplementation during summer grazing (Rolfe et al., 2011) as well.

In evaluating forage-based systems with multiple phases, the system should be viewed as a whole because biological and economic interactions exist among various phases of the system (Lewis, 1990). In addition, it is crucial to use limit fed weights when evaluating treatments within forage-based systems so weights are not influenced by the variability in rumen fill at weighing (Watson et al., 2012b).

Backgrounding System

Backgrounding systems utilize readily available, grazed forages which contribute to the beef industry's cost competitiveness. In addition, it prepares cattle for feedlot entry by increasing age, weight, and potentially, quality of groups (Peel, 200). By backgrounding cattle, cattle inventory can be managed within and across years to provide a consistent cattle supply for feeding and provides an economic balance between the livestock, grain, and forage markets (Peel, 2000).

Weaned calves can be either directly placed in the feedlot at weaning to be finished (calf-fed), or backgrounded on a high forage diet. The backgrounding phase occurs through winter, after which point cattle may enter the feedlot in late spring (known as a summer, or short yearling), or graze through the summer before feedlot entry in the fall (known as a fall, or long yearling), according to (Adams et al., 2010; Griffin et al., (2007).

Calf-feds reach finish earlier and at a lighter carcass weight, which may decrease total pounds of carcass produced (Turgeon, 1984). These lighter carcass weights from calf-feds may consequently lower profitability as weight is a major economic driver in beef production (Feuz, 2002; Shain et al., 2005; Tatum et al., 2006). To avoid these potential discounts and because the cattle population is diverse in breed, size, body weight and type (Dolezal et al., 1993), cattle must be placed in the correct production system to maximize profit (Griffin et al., 2007). Typically smaller framed cattle best fit a yearling system as it allows them to grow skeletal frame and muscle without the concern of becoming too large and consequently receiving overweight discounts (Vieselmeyer, 1993) which may occur with larger framed cattle.

Backgrounding effectively increases beef production by increasing HCW (Jordon, 2000; Schoonmaker et al., 2002; Sainze and Vernazza Paganini, 2004). An eight-year meta-analysis by Griffin et al. (2007) comparing calf-fed and long yearlings determined that cattle developed in a long-yearling system gained an additional 0.3 kg per day during finishing, and had a 4.2 kg greater DMI to finish with a 38 kg greater BW. Despite calf-feds being more efficient, they required more days on feed to reach finish, so consequently consumed more total feed during the feedlot phase. When carcass characteristics were adjusted to a common rib fat thickness, long-yearlings required 62 fewer days on feed to produce a carcass 67 kg heavier than calf-feds.

Long yearlings tend to be leaner and have lower quality carcasses at harvest compared to calf-feds (Schoonmaker et al., 2002; Sainze and Vernazza Paganini, 2004) if initial body types are similar. This quality grade difference can be negated by sorting cattle into production systems (Griffin et al., 2007).

Backgrounding economics

The use of low-cost forages is integral to the backgrounding system's profitability. Griffin's (2007) economic analysis of calf-fed and yearling production systems noted that low cost inputs during the winter backgrounding phase was the key to the long-yearling system's lower breakevens and increased profitability compared with the calf-fed system. In his analysis, cattle developed as long-yearlings and retained through finishing were over $61 more profitable than calf-feds.

The faster gains and lower total feed intake during finishing also contributes to the long-yearling's economic efficiency. Lewis et al. (1990) noted that cattle grown in an extensive system consume 15% less corn during finishing than cattle grown in an

intensive system. In addition, the extensive system produces heavier cattle which dilute the initial calf purchase cost, thus lowering the break-even price. Lewis et al. (1990) concluded extensive systems produce more pounds of beef at a lower per unit cost than intensive systems

Compensatory gain

The compensatory gain concept is integral to the backgrounding system. During backgrounding, cattle are nutritionally restricted but then exhibit compensatory growth during subsequent periods of higher nutrient intake. The historical backgrounding philosophy has centered on lowering winter feed input costs and then capitalizing on compensatory gain during summer grazing (Downs et al., 1998), when yearling cattle can make their most cost efficient gains (Lewis et al., 1989).

Compensating animals have increased DMI, both in kg/d (Fox et al., 1972) and as a percentage of BW (Jordan et al., 2002). Predicting compensatory gain is challenging as it tends to be highly variable depending on severity and duration of restriction (Jordon et al., 2000). Systems studies at the University of Nebraska have reported compensatory gain values ranging from 18 to 100% (Jordan et al., 2000). Klopfenstein et al., (1999) suggested that partial season grazing and longer restriction periods may reduce compensatory gain while full season grazing typically provides 50 to 60% compensation. Following even a short restriction period, cattle have an increased DMI and gain, but efficiency is not affected (Klopfenstein et al., 1999).

Backgrounding supplementation level

A systems study by Lewis et al., (1989) compared a low, medium, and high rate of winter gain for yearling steers. As winter gain level increased, there was a subsequent linear decrease in gain over summer grazing. For each kilogram of additional daily winter gain, gain on summer grass decreased 0.45 kg. Because cumulative winter and summer gains were similar between treatments and there were no differences in finishing efficiency, authors attributed the high rate of winter gain treatment cattle's increased finishing ADG to increased intake and of little economic value. Lewis concluded that it was not beneficial to winter cattle above 0.27 kg of gain/day if cattle are to be maintained beyond the wintering phase. Conversely, Downs et al. (1998) observed steers on a high-winter gain treatment maintained nearly 80% of their weight advantage through finishing over steers from the low-winter gain treatment. He concluded that a winter gain rate greater than 0.32 kg of gain/day is justified as the higher winter gain treatment produced heavier steers which finished with fewer days on feed.

Cattle wintered at a high level in a forage-based system gained more during finishing (Lewis et al, 1989; Downs et al, 1998) and had heavier slaughter weights (Jordon et al., 2000; 2002). In a summary of compensatory gain research, Klopfenstein et al., (1999) reported that 69 kg of extra winter gain resulted in an additional 32 kg of final weight. Heavier slaughter weights tended to be negatively correlated to slaughter breakeven and positively correlated to profitability in Jordon et al. (2002), thus cattle from a high wintering level which produced heavier carcasses were more profitable.

There has been little carryover effect from backgrounding on DMI or feed efficiency observed. Hersom et al. (2004) varied stocking rates on winter wheat pasture to produce a high winter gain (1.31 kg) and low winter gain (0.54 kg) and then saw no differences in DMI or feed efficiency due to backgrounding. Pavan and Duckett (2008)

saw no difference in feedlot DMI or G:F due to backgrounding supplement type (corn grain or corn oil) on tall fescue pasture. However, Buttrey et al. (2012), supplemented dry rolled corn or DDG on wheat pasture and did not affect feedlot or carcass characteristics, but did see a change in G:F compared to no supplement.

II. Plant characteristics

Forage characteristics and quality

The plant consists of cell contents and the cell wall. The cell contents are the most readily and highly digested components of the plant and include organic acids, proteins, lipids, and carbohydrates (Barnes et al., 2003). The fibrous portion, or cell wall of the plant, contains the structural carbohydrates including cellulose, hemicellulose, and lignin. The fibrous portion is represented by neutral detergent fiber (NDF) content, which is the forage's total fiber content, and acid detergent fiber (ADF), which is an estimate of the cellulose and lignin in forage (Barnes et al., 2003). The ruminant animal is unique in their ability to use this fibrous material to meet their energy needs (Burns, 2008).

Forage quality is the physical and chemical characteristics of forage that make it nutritionally valuable for animal productivity (Barnes et al., 2003). Productivity is the effect of intake, digestion, and utilization efficiency of absorbed nutrients (Smith et al., 1972). Forage quality is highly variable and is plant species, plant maturity, climate, elevation, management, soil moisture, soil fertility, and weather all affect the forage quality factors which include digestibility, crude protein content, and palatability (Bohnert et al., 2011; Barnes et al., 2003).

Quality of a forage is greatest while the plant is young and in the vegetative growth stage. As the plant develops and matures, ADF and NDF content increase in concentration to provide additional structure while digestibility and crude protein values decline (Barnes et al., 2003). With maturity, the leaf : stem ratio declines (Burns, 2008), which contributes to mature forages being lower quality (Fontenot and Blaser, 1964).

Voluntary intake in a forage situation is regulated by gut fill. Cellulose and hemicellulose digestion rate limits intake (Burns, 2008), as forages of greater fibrous content require additional space in the rumen, which decreases forage intake (Oba and Allen, 1999). Thus, mature forages of lower digestibility cause lower intakes compared to grasses in the vegetative state (Oba and Allen, 1999).

Forages are classified as cool season (C3) or warm season (C4). Cool season plants generally have greater nutritional value than C4 plants due to having greater amounts of nonstructural carbohydrates and protein (Wilson et al., 1983). Consequently, rumen degradation of C3 plants is faster and more complete (Barnes et al., 2003). Additionally, intake and digestion of C3 forages is greater than that of C4 plants of similar CP, NDF, and ADF levels (Bohnert et al., 2011).

Warm season plants have a greater proportion of highly lignified, lower digestible tissues than C3 plants (Akin, 1989). The higher lignin concentration in C4 plants compared to C3 plants leads to slower rumen degradation. At similar growth stages, C4 plants have a lower protein concentration, lower leaf: stem ratio, and are composed of more structural tissue (Barnes et al., 2003). A study by Reid (1988), reported 22% of C4 grass samples had CP levels lower than 6%, compared to only six percent of C3 grass samples at that level.

Digestibility of a plant is the percentage of dry matter that is digested by the animal as it passes through the digestive tract (Barnes et al., 2003). Digestibility is inversely related to ADF (the least digestible plant parts), thus forages with low ADG concentrations are typically higher in energy.

The digestion rate is the proportion or the percentage of digestible material remaining in the rumen that is digested each hour (Barnes et al., 2003). Cell contents are digested at a higher rate than fibrous portion of the plant.

Voluntary intake is the amount an animal consumes when given an unrestricted supply. Animal species, sex, physiological status, and health impact voluntary intake in addition to forage digestibility components (Barnes et al., 2003). When intake increases, total energy and nutrient consumption also increase, while the proportion of energy used for maintenance needs declines (Barnes et al., 2003) thus excess energy is allocated to growth needs.

Intake of highly fibrous forages can be limited by the time to digest fiber, reduce particle size, and move undigested feed through the digestive tract. In instances of high fiber diets where fill effects restrict animals from increasing voluntary intake levels, the animal may not be able to physically consume enough forage to meet their nutrient requirements (Barnes et al., 2003). Variation in forage intake accounts for approximately 70% of the total variation in forage feeding value, with nutritive value of the plant making up the remaining 30% of forage feeding value variation (Barnes et al., 2003). Intake can be predicted by using the animal’s known body weight, and NDF percent of the forage.

Geisert et al. (2008a) analyzed diet samples from both a Sandhills and southwest Nebraska ranch and observed that diets collected in late spring and early summer were of higher nutritive quality than diets collected later in the summer. Digestibility values, as measured by in vitro organic matter digestibility (IVOMD), ranged from 66.8% in June to 56.5% in September (Gesiert et al., 2008a). In early summer, plants are highly digestible as the leaf to steam ratio is high, but as warm season plants mature and reproduce during July and August, digestibility declines. Crude protein content peaked in May at 14.1% and was lowest at the end of the growing season in September at 9.6% (Geisert et al., 2008a). Logically, NDF content increased over the growing season from 56.4% in June to 63.6% in September (Geisert et al., 2008a).

Precipitation, particularly during May and June, is correlated to total forage yield, with shortgrass prairie correlations of r = 0.675 (Smoliak, 1956) and r = 0.859 reported (Rauzi, 1964). Consequently, forage production is lower during drought, but plant maturity is delayed. Geisert et al. (2008b) observed that diet samples collected during a drought year and recovering drought year were higher in digestibility (59.1% and 55.4% IVOMD, respectively) than samples collected in a normal year (53.0% IVOMD). Geisert et al. (2008b) suggested that the decreased precipitation delayed plant maturity and therefore OMD was greater.

Protein in Forages

Crude protein is merely a reflection of the N content of a feedstuff and is the sum of degradable intake protein (DIP) and undegradable intake protein (UIP); (NRC, 1996). Degradable intake protein, also known as ruminally degradable protein (RDP) is the

fraction of the protein which is used as protein to meet the microbes' needs for growth and microbial crude protein (MCP) synthesis.

Undegradable intake protein, also referred to as ruminally undegradable protein (RUP), bypass protein, or escape protein, is protein which bypasses the rumen and is digested in the intestine to meet the ruminant's needs for maintenance, growth and lactation.

Protein within the plant cell contents is rapidly degraded within the rumen. This rapid degradation of forage proteins by rumen microbes results in the forage supplying relatively small quantities of UIP to the animal. Forage protein is commonly 10 to 40% RUP, as a percent of CP (NRC, 1996 and 2001), while grain sources and some protein supplements may exceed 50% RUP (NRC, 1996).

Forages vary in CP, RUP, and RUP digestibility depending on forage type, year, and time within year. Generally, forage CP values are greatest early in the growing season and decline as the forages mature. The amount of RUP as a percent of CP, however, is lowest early in the growing season and increases as the plants mature. A study by Buckner et al., (2013), showed that upland native range samples averaged 1.94% RUP as a percent of DM over the growing season but RUP digestibility declined throughout the growing season.

A study sampling Sandhills upland range pastures at the UNL Gudmundsen Sandhills Laboratory (GSL) once a month from May to September using two esophageally fistulated cows showed RUP digestibility values ranging from 41.8% in May to a low of 10.8% in September. In this study, RUP and IVDMD were closely related (r^2 = 0.90) and IVDMD values also declined over this time period from 68.9% to

51.4%. There were no changes in RUP content of the samples over the grazing season, with range samples averaging 1.94% RUP of DM (Buckner et al., 2013).

A similar study was completed sampling Sandhills range pastures with warm season grasses at the UNL Barta Brothers Ranch (BBR). Four esophageally fistulated cows were used to collect an early and late sample for each month from June through September. In contrast to the GSL work, RUP content increased over the growing season and no IVOMD differences were detected. There was a quadratic effect on RUP, % DM, increasing from 3.09 in early June to 5.04 in early June, declining to 3.84 in early August, and then increasing to 5.3 in early September. Percent digestibility of RUP, increased from 55.7% in early June to 58.9% in early July, and then declined to 42.5% in late September. Authors hypothesized that the differences between the GSL and BBR work may have been due to different grass species between locations or consumption of leadplant (Schroeder, 2007).

Because of the high RDP content and rapid protein degradation of forages in the rumen, cattle with high metabolizable protein requirements such as growing cattle respond positively to UIP supplementation. In eight experiments with yearling beef cattle grazing cool- and warm-season grasses over the summer, cattle gains increased with UIP supplementation in all studies (Klopfenstein et al., 2001), despite seemingly adequate DIP.

The benefit of supplying additional UIP to growing cattle in a forage situation is illustrated by Watson et al., 2012a. Nonsupplemented yearling steers on smooth bromegrass, averaging 15.8% CP, consumed sufficient forage to meet their CP requirement. However, the smooth bromegrass UIP content averaged 1.32% of DM,

which is less than the 1.64% of DM requirement (NRC, 1996), creating a 99 g/d MP deficiency. By supplementing steers with 2.45 kg/d DDGS, (65% UIP of the 32% CP, DM basis), CP and UIP levels were increased greater than the steers' requirements, which with the additional energy provided, produced an additional 0.26 kg/d gain.

Further, as forage digestible energy values decline, passage rate, microbial growth rate, and microbial growth conversion efficiency are reduced (Klopfenstein, 1996). This decline in microbial efficiency on low quality forage prompts a positive UIP response (Klopfenstein et al., 2001).

Estimating RUP or digestible RUP over time for different forage species remains a challenge as neither IVDMD nor CP are good indicators for doing so (Buckner et al., 2013). By measuring RUP content of feeds and RUP digestibility by analyzing neutral detergent insoluble nitrogen after incubation for 75% of total mean retention time, estimated from IVDMD plus a 10-hr passage lag (Haugen et al., 2006a; Haugen et al., 2006b), it is possible to estimate RUP and content and digestibility.

Corn Residue

Corn residue is a relatively inexpensive, abundant feed resource in Nebraska (Griffin et al., 2007). Corn residues are an economical alternative for beef cattle production systems in the Midwest, with grazing being the lowest-cost means of utilizing the resource (Klopfenstein et al., 1987).

Corn residue is higher quality and requires less protein supplementation than native winter range (Clanton et al., 1989), which can provide an extended grazing season and reduce feed costs, (Wilson et al., 2004). For 500 calves grazing corn stalks over 10

years, daily gains have averaged 0.51 kg/d on cornstalks, with a range from 0.22 kg/d to 0.74 kg/d (Klopfenstein et al., 1987). With supplemental protein, these gains can be further increased.

In a beef production systems economic analysis, wintering systems that utilized cornstalk grazing had a lower cost of gain and final break-even price than drylot systems which used predominately husklage and alfalfa hay (Lewis et al., 1990).

Despite its economic competitiveness, corn residue is low in protein and energy, thus supplementation is necessary if it is to be used for the growing calf. When weaned steer calves grazed nonirrigated corn residue and were supplemented with dried distillers grains (DDGS), calf gains increased with increasing levels of DDGS in a quadratic manner (Gustad et al., 2006). Authors suggested a practical feeding limit of 1.1% BW of DDGS, as there was little gain increase above that feeding level.

Quality of corn residue (CP, ADIN, RUP, IVDMD, IVOMD, and grain content) declines over time with grazing (Gutierrez-Ornelas and Klopfenstein, 1994) and is influenced by available residue, stocking rate, trampling, environmental factors, and cattle's experience grazing corn residue. During the first month of grazing, leftover corn provides relatively large amounts of energy, CP, and RUP, but as the grazing period continues, nutritive quality declines (Fernandez-Rivera and Klopfenstein, 1989). Stocking rate for grazing corn residue is generally recommended at 3.7 to 5.0 AUM/ha (animal units per hectare) (Clanton, 1989).

Because corn residue is only available after the plant has reached physiological maturity and the highest quality part of the crop (corn grain) has predominately been harvested, protein and energy are low. Residue TDN values average 54% to 55% but can

vary from 50% to 60% TDN (Wilson, 2004). Crude protein values range from 2.2% and 3.6% for the cob and husk, respectively, to 4.5% and 7.8% for the stem and leaf, respectively (Wilson et al., 2004).

Cattle graze the highest digestibility residue components first, thus residual corn grain is consumed first, followed by husks, and then leaves. The stems and cobs are low in palatability and digestibility and thus not typically consumed (Wilson et al., 2004).

Quality of corn residue grazed can be highly variable as the plant part grazed, genetics, maturity (harvest date) and plant growing conditions, are highly variable characteristics which impact overall quality (Klopfenstein et al., 1987). The proportion of grain to other plant parts is highly variable, which further increases corn residue quality variance (Clanton, 1989).

Crude protein is often a limiting nutrient when grazing corn residue, particularly for growing calves which require greater protein levels for growth (Fernandez-Rivera and Klopfenstein, 1989). To maximize calf gains, supplemental levels of rumen undegradable protein must be provided when grazing corn residue (Gutierrez-Ornelas and Klopfenstein, 1991, 1994). There may be additional benefit to providing calves with supplemental protein early in the grazing period rather than later due to their need to use the higher energy content of the diet at that time (Gutierrez-Ornelas et al, 1991). In addition, supplementation is necessary as corn residue may be low in Vitamin A and phosphorus (Clanton, 1989).

Sandhills forages

The Sandhills region is the largest sand-dune area in the Western Hemisphere (Bleed and Flowerday, 1989), consisting of the north central one-third of Nebraska at approximately 52,000 square kilometers (Seevers, 1975).

Valentine fine sands (mixed, mesic, and Typic Ustipsamments) occupy more than 90 percent of the Sandhills region (Mousel, 2011; Seevers, 1975), making the region ecologically sensitive and best fitted to grazing cattle rather than crop production. Nearly half of the state's range and pastureland lies in the Sandhills (Nebraska Department of Agriculture, 2012), providing a large forage source for the region's nearly 1.5 million head of beef cattle (Volesky, 2005). re

Warm and cool season grasses, sedges, and forbs are common on the mixed-grass prairie. Upland range vegetation in the Sandhills is predominately warm-season grasses (Bragg and Steuter, 1995), which provide 60% to 90% of upland range sites production (Volesky, 2005). Warm season grasses include prairie sandreed (Calamovilfa longifolia), little bluestem (Schizachrium scoparium), switchgrass (Panicum virgatum), sand dropseed (Sporobolus cryptandrus), blue grama (bouteloua gracilis), hairy grama (bouteloua hirsuta), sand bluestem (Andropogon halli), and western ragweed (Ambrosia psilostachys) (Gustad et al., 2008). Key Sandhills cool season grasses include needleandthread (stipa comata) and prairie junegrass (Koeleria macrantha) (Gustad, 2008). As cool-season plants' nutritional value begins to decline, warm season grass growth accelerates on upland areas at which point the grazing season is typically initiated (Volesky, 2005). Grazing typically begins around mid-May and continues through mid-October (Coady and Clark, 1993).

Grazing systems

Animal performance during grazing depends on both forage quality and quantity available (Holecheck, 2004). Stocking rate is the most important factor affecting both animal and pasture performance, in addition to the range site's plant community and range condition class (Anderson et al., 1997). Multiple grazing intensity studies have illustrated that average daily gains decline with increased stocking rate (Holecheck, 2004).

Numerous grazing systems have been designed to allow key plant species adequate resources to improve forage growth and production, thereby allowing livestock to more efficiently utilize available forage. This is commonly done by allowing key species to rest during the growing season, which will increase plant competitiveness or production. Grazing systems may include continuous grazing, simple deferred systems, rest-rotational systems, and intensive short duration systems (Briske et al., 2008).

Continuous grazing systems allow livestock to graze a single pasture through the entire grazing season. Grazing distribution is often uneven and harvest efficiency (forage consumed in relation to available forage) is typically low. Continuous grazing allows livestock to select the most palatable forage as they have unlimited access to the pasture. Consequently, individual livestock performance is typically high during the first half of the grazing season, when selection opportunities are greatest (Schacht et al., 2011), but plant vigor and reproductive potential may be hindered long term. In a study comparing continuous and rotational grazing of warm-season grasses at three stocking rates, continuous stocking produced the greatest declines in yearling steer ADG and stand basal cover, and caused greatest changes in botanical composition (Anderson et al., 1997).

Deferred rotational grazing systems involve rotating cattle through typically three to six pastures over the grazing season, and deferring grazing for at least one of the pastures until the end of the growing season. The deferment period allows dominant, warm-season tallgrasses to gain vigor and reproduction potential without grazing pressure (Schacht et al., 2011), thus this system is recommended in the Sandhills where 60% to 90% of upland range sites production are warm-season grasses (Volesky, 2005). Animal performance tends to decline during the last half of the grazing season as livestock are grazing mature, lower quality forages that haven’t yet been grazed.

Rest-rotational grazing systems focus on improving range condition by allowing one pasture in a three to six pasture rotation to rest each year. However, this increases the stocking rate in the remaining pastures, which coupled with grazing pastures late in the season for the first time (which by then are of low quality) can lead to low animal performance during the last half of the grazing season due to the available forage’s low quality (Shacht et al., 2011).

Short-duration grazing systems are intensively managed systems providing relatively short grazing periods and multiple grazing cycles per year. Theoretically, livestock performance per acre should be increased as they are allowed high quality forge over the entire grazing season (Schacht et al., 2011).

Potential stocking rates are calculated based upon range site, vegetative zone, and range condition. A sands site in vegetative zone II (representative of upland Sandhills range in the central Sandhills) would have a suggested stocking rate of 0.53 to 0.7 AUM’s/acre, for rangeland in good to excellent condition, respectively. A similar site in

zone III (eastern Sandhills) is recommended to be stocked at 0.68 to 0.9 AUM's/acre for good and excellent condition pastures, respectively (Stubbendieck and Reece, 1992).

Measuring forage intake and quality

Measuring cattle's DMI of forage is particularly challenging in range situations (Macoon et al., 2003), but is necessary in order to estimate nutrient consumption or animal performance. To estimate grazing cattle's intake, external or internal markers, ingestive behavior, herbage mass disappearance, prediction from forage characteristics, and animal performance can be used (Macoon et al., 2003). Through use of the beef NRC model (1996) and NE equations, forage intake can be calculated retrospectively. By using known values of animal performance, supplementation intake, and digestible energy densities for forage and supplement, it is possible to back-calculate for forage DMI (MacDonald et al., 2007).

Due to varied plant communities and rough rangeland, accurately characterizing the grazing animal's diet is a unique challenge (Holecheck et al., 1982). However, knowledge of range livestock selection habits is necessary for effective range management and even more so, to obtain an accurate assessment of the available forage's nutritional value. Obtaining a representative forage sample of ingested material selected by cattle is necessary to detect nutritional deficiencies in range situations and determine nutrient intake of grazing animals in research situations (Cook, 1964). Methods to estimate plant composition of the grazing animal's diet include diet observation or hand plucking, utilization techniques, fistula sampling, and fecal analysis (Cook, 1964; Holecheck, 1982).

Diet observation is a simple, economical, and relatively easy procedure to use. By observing forage species that cattle appear to be consuming and then clipping them for analysis, a good prediction of nutrient content is possible (Wilson et al., 2011). However, the observer's training, plant community's complexity, and phonological development of the individual plants can all influence the accuracy and precision of the direct observation procedure. In addition, diet observation is impractical in large pastures with rough terrain (Holecheck, 1982). Finally, cattle can typically select a higher quality diet for most nutrients than what clippings represent (Wilson et al., 2011).

Using utilization techniques to evaluate the grazing animal's diet is a quick process which provides information as to where and to what degree range is being used. This may be done through evaluating grazed and ungrazed plots, evaluating differences before and after grazing, using correlation and regression to measure utilization, and making general observations and comparisons with set standards. However, weathering, trampling, plant regrowth following grazing, and animals other than those of interest can skew results (Cook and Stoddart, 1953; Holecheck, 1982). Studies that have compared utilization techniques with fistula samples have produced inconsistent results (Holecheck et al., 1982).

Fecal analysis can be used to compare the diets of multiple animals and provide a potential method of identifying species selected. However its use in range cattle diets to determine forage quality is limited due to microbial fermentation. In addition, accurately identifying plant fragments is a challenge as some species are unidentifiable in the feces, fecal material is often aged before sample collection, and sample collection procedures influence results (Holecheck et al., 1982).

Fistulated cattle give the best representation of the actual diet cattle are selecting in a natural setting (Holecheck et al., 1982). The first reported use of the esophageal fistula in cattle was reported in 1939 and has been used extensively since then as it represents the best estimate of grazing animals' intake selection, and thus diet quality (Van Dyne and Torrell, 1964). Challenges with the esophageal fistula include salivary contamination, potentially incomplete recovery of selected forage, leaching of soluble organic components, and difficulty obtaining a representative sample in a large pasture (Holecheck, 1982; Musgrave, 2013; Acosta and Kothmann, 1978).

Ruminally fistulated cattle have been successfully used to predict forage selectivity of grazing cattle, but have been found to be less indicative of known diets compared to esophageal fistula samples. In addition, use of the rumen fistula is more laborious and subjects animals to abnormal physiological conditions (Holechek, 1982).

Regardless of fistula type, fistulated animals allow cattle to select a diet similar to what other cattle are consuming, an advantage over a researcher attempting to replicate the grazing animal's diet via clipping. In a study using three or four ruminally fistulated cows over two years, diet samples were collected every two to four weeks on native southwestern Idaho range from early spring through fall. While clipped and grazed samples were similar, cows generally selected a diet higher in CP and TDN than that from clipped samples (Wilson et al., 2011)

III. Supplementation and Distillers Grains

Distillers grains

With 24 ethanol plants utilizing over 40% of the state's corn crop, Nebraska ranks second in the nation in ethanol production (Nebraska Department of Agriculture, 2012). Consequently, distillers grains, a byproduct of the ethanol process, has provided a relatively readily available, high quality feedstuff for producers in recent years.

The two corn milling processes which produce corn co-products are wet milling and dry milling. From the wet milling process, corn gluten feed is produced from the corn bran with the addition of germ meal, screenings, and distillers solubles. The dry milling ethanol process utilizes cornstarch as a sugar source which is converted to ethanol and carbon dioxide through fermentation. Following starch conversion to ethanol using corn, approximately one-third of the dry matter remains as a feed product which includes distillers solubles and distillers grains. The wet distillers grains can then be partially dried to modified wet distillers grains plus solubles (MWDGS), 42-50% DM, or dried to dry distillers grains plus solubles (DDGS) (Stalker et al., 2010).

Because starch is removed during the milling process, co-products are an ideal supplement for a forage situation. Starch based supplements commonly interfere with fiber fermenting bacteria, but with the starch removal in corn co-products, this is no longer a concern (Stalker et al., 2010) as the energy from distillers grains is not starch, but highly digestible fiber, and fat. Because corn grain is approximately two-thirds starch which is removed during fermentation, all the remaining nutrients are concentrated three-fold. This makes corn milling co-products an excellent supplemental feed as they are high in protein, energy, and phosphorus. Average nutrient composition for WDGS was determined from 6 ethanol plants with 10 samples collected per day across 5 days, with sampling completed over 4 separate months. Nutrient composition was 31.0% crude protein, 11.9% fat, 0.84% phosphorus, and 0.77% sulfur (Buckner et al., 2011).

Distillers grains in forage situations

Distillers grains supplementation may be appropriate when forage quality is low, such as during the dormant season, when forage quantity is limiting such as during drought, or in a backgrounding situation. If fed at less than 15% of the diet dry matter, the distillers grains will be considered a protein supplement, and if fed at greater than 15% of the diet dry matter, it will be considered used for both protein and an energy source (Stalker et al., 2010).

Backgrounding situations often warrant supplementation as winter forage is dormant and low quality. The growing calf commonly requires supplemental protein, phosphorus, and additional energy. In certain situations, lightweight growing cattle may need additional undegradable intake protein (UIP) to meet their metabolizable protein (MP) requirements. Distillers grains are approximately 65% UIP as a percent of crude protein (National Research Council, 2000), thus forage-based diets that include DDGS as an energy source may be DIP deficient but have excess MP (Stalker, 2010).

Distillers grains as a forage replacement tool

Distillers grains have also been established as a forage replacement tool in addition to subsequently increasing animal performance. The forage replacement rate is defined as the unit reduction in forage intake per unit of supplement consumed by the animal (MacDonald et al., 2007). When yearling steers were fed increasing levels of DDGS on native Sandhill summer range, forage intakes linearly decreased and average daily gain (ADG) linearly increased. For each kg of DDGS fed, forage DMI declined by 1.66 kg (Morris, 2006). An economic analysis further supported supplementing DDGS to grazing cattle, as the increased selling weight and decreased forage costs lowered

breakeven price in scenarios with cattle sold directly off grass or retained through finishing.

In a summary of grazing trials supplementing distillers grains, the mean forage substitution rate at a moderate stocking rate was 0.22 kilograms of forage per kilogram of distillers grains supplemented, when calves were fed harvested forages. Grazing yearlings had a slightly greater reduction in grazed forage intake, approximately 0.27 to 0.32 kilograms per pound of distillers grains, versus the 0.23 kilograms for calves. In addition, yearling ADG increased by 0.13 kg/d for each kg of supplemented DDGS (Klopfenstein, 2007).

A five-year study summarizing backgrounding strategies for calves on smooth bromegrass further supports forage replacement work. Using forage intake estimates from NRC (1996) equations and known supplementation amounts, a retrospective analysis estimated that each kilogram of DDGS fed replaced approximately 0.79 kg of forage. When DDGS was fed at approximately 0.6% of bodyweight, high quality (65% TDN) forage intake was reduced by 18.6% and low quality (53% TDN) forage intake was reduced by 16.1% (Morris et al., 2005). It was concluded that the forage intake reduction by supplementing cattle with DDGS is a viable means of concurrently increasing stocking rate and animal performance (Watson, 2012).

MacDonald (2007) estimated that stocking rates can be increased 10 to 20% by supplementing cattle who would typically consume 2.0% of BW daily of forage, with daily DDG supplementation from 0.5 to 0.75% of BW. This is based on the estimate that DDG replaces grazed forage at approximately 50% of the amount supplemented for cattle receiving up to 7.5 g of DDG per kilogram of BW.

Summer supplementation of distillers grains

In a study evaluating daily DDGS supplementation at 0, 0.26, 0.51, 0.77, and 1.03% BW to yearling steers on Sandhills range, summer ADG increased linearly as DDGS level increased (Morris et al., 2006). Forage DMI decreased linearly with increasing supplementation level, reiterating that DDGS supplementation increases animal performance while replacing forage.

Rolfe et al. (2011) supplemented modified wet distillers grains with solubles to long yearling steers during summer grazing in a forage-based system. Supplemented steers had 0.30 kg greater ADG during the summer phase, and were more profitable than non-supplemented steers. Supplemented steers entered the feedlot 48 kg heavier than non-supplemented steers, had greater LM area, and required 24 less days on feed to reach similar fat thickness.

A meta-analysis of DDGS supplementation in forage situations by Griffin et al. (2012), showed that ADG and ending BW increased linearly with increasing DDGS supplementation levels. Supplemented cattle gained 37 kg more during grazing than non-supplemented cattle. This additional weight was maintained through finishing, with supplemented cattle having HCW 31 kg greater than non-supplemented cattle.

Gustad et al., (2008), supplemented lightweight, summer-born spayed yearling heifers (year 1) and spayed yearling heifers and yearling steers (year 2) with 2.3 kg/d (DM) DDGS. Cattle grazed upland, native Sandhills range, and paddocks were stocked at double the recommended stocking rate. Gustad et al. (2008) observed a 0.68 kg ADG response to DDGS supplementation.

Supplementation carryover effects and profitability impacts

During the finishing phase, summer supplemented cattle in Rolfe et al. (2011), required less DOF as a consequence of greater initial BW, but tended to gain less than non-supplemented cattle. However, feed efficiency and DMI were similar between supplemented and non-supplemented cattle. Similarly, Morris et al. (2006), supplemented yearlings steers with varying levels of DDGS on Sandhills range and observed no differences in feedlot ADG, DMI, or feed efficiency between supplemented and non-supplemented steers during the grazing period.

Greenquist et al., (2009) supplemented yearling steers with 2.3 kg (DM) of DDGS daily on smooth bromegrass and observed no difference in gain during finishing between supplemented and non-supplemented cattle, indicating no compensatory response from grazing that carried over into finishing. Supplemented steers maintained their performance advantage through finishing, resulting in 6.3% heavier carcasses.

In a review of four experiments, Klopfenstein et al., (2007) concluded that extra gain from grazing supplementation of distillers grains does not negatively impact finishing performance provided the grazing period is less than 150 days and the cattle are slaughtered at equal fat thickness. This is similar to the meta-analysis including some of the same data by Griffin et al., (2012), who concluded that with the exception of increased HCW for supplemented cattle, finishing and carcass characteristics are similar between supplemented and non-supplemented cattle.

Due to increased selling weight and lower forage costs, feeding distillers grains to cattle in grazing situations has been profitable. Morris et al., (2006) determined that if yearling cattle were sold directly off summer pasture, the highest supplementation level

evaluated (1.03% BW) would result in the lowest breakeven price. However, if cattle were retained through finishing, the mid supplementation level (0.51% of BW) would produce the lowest breakeven cost. Regardless of marketing method, distillers supplementation to grazing yearlings was profitable.

Rolfe et al. (2011) concluded that summer MDGS supplementation which consequently added additional weight prior to feedlot entry, resulted in decreased finishing inputs. Consequently, supplemented steers were more profitable than non-supplemented steers when sold on either a live weight or value-based marketing system basis.

Distillers Feeding Method

The efficacy of distillers grains supplementation in range situations is related to feeding method. Distillers grains dry matter content, type of ground the distillers grains are fed on, and cattle type supplemented all impact distillers grains loss when fed on the ground.

Compared to ground feeding WDGS on native Sandhills winter range to pregnant cows and steer calves, cattle performance was improved with bunk feeding. Bunk-fed cows lost less bodyweight and gained more condition than ground-fed cows. Steer calves fed WDGS in a bunk had greater ADG than ground fed calves, and a retrospective analysis determined that 13-20% of WDGS supplementation was lost when fed on the ground (Musgrave et al., 2010). When DDGS was fed on a subirrigated meadow, steer calves had greater ADG than calves supplemented on the ground, but ground feeding loss was greater than WDGS at 36-41% (Musgrave et al., 2012). A separate study that fed

DDGS to calves on tall-fescue pastures illustrated no performance differences between bunk and ground feeding (Sexten et al., 2011).

In comparing bunk and ground feeding economics of wet distillers grains on range, bunk feeding was estimated at $0.16/day and determined to be more profitable when calf sale value exceeded $0.81/lb (Musgrave et al., 2010). In the study using DDGS on meadow where the loss factor was greater, ground feeding was determined to be more profitable if a producer was targeting least cost. However, if overall profitability during supplementation was the objective, bunk feeding was more desirable. The cost of gain when DDGS was bunk fed was less than the steers' breakeven price, thus profitability was greater when bunk feeding steers (Musgrave et al., 2012).

IV. Cattle type

Spayed heifer

Heifers, compared to steers, are discounted by feedyards as they are slower gaining, less efficient, weigh less at finish, may exhibit estrus and upset other cattle, and have a greater risk of becoming injured or pregnant (Zinn et al., 2008, Ray, 1969, Dinusson et al., 1950, Cameron et al., 1977, Horstman et al., 1982). Spaying, or ovariectomizing, female cattle is the process of surgically removing the ovaries which eliminates the primary estrogen source and renders the cattle unable to exhibit estrus. Vaginal spaying of heifers effectively eliminates reproductive activity in beef cattle and maximizes their growth performance potential (Garber, 1990).

Early research indicated that spayed heifers were lower performing compared to intact heifers, but these studies involved heifers which were spayed using the flank

method and were not implanted (Sharman et al., 2011). The vaginal spaying method using the Kimberling-Rupp procedure (Rupp and Kimberling, 1982) is now widely preferred over the flank spaying method.

Because spaying removes the progesterone source and primary estrogen source, it is important to implant spayed heifers to maximize growth potential. In a Garber study (1990), spayed heifers had a daily gain response to implanting (Synovex-H) that was four times greater than intact heifers. Similarly, heifers that were spayed and implanted (Synovex-S) had a 17.6% greater rate of gain than spayed, non-implanted heifers (ZoBell et al., 1993). In a systems study, spayed heifers compared to intact heifers had no gain advantage during winter or summer grazing, but were more efficient during finishing and had a greater ADG (Sharman, 2011). Similar feedlot performance was observed between spayed, implanted heifers and intact, implanted heifers in a study by Adams et al. (1990).

Regarding carcass characteristics, marbling deposition was not affected by spaying (Sharman et al., 2011; Adams et al., 1990), but HCW and REA were greater in spayed heifers (Garber et al., 1990). Yield grades were slightly higher for spayed heifers, but there was a tendency for spayed heifers to have lower maturity scores as well in the systems work (Sharman et al., 2011).

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Chapter II. Distillers grains supplementation in a forage system with spayed heifers[1]

K. L. Gillespie*, T. J. Klopfenstein[2]*, B. L. Nuttelman*, C. J. Schneider*, J. D. Volesky†, J. C. MacDonald*, and G. E. Erickson*

*Department of Animal Science, University of Nebraska, Lincoln 68583; †Department of Agronomy & Horticulture, University of Nebraska, Lincoln 68583

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[2]Corresponding author: C220g Animal Science Building; Phone: 402-472-6443; Fax: 402-472-6362; E-mail: tklopfenstein1@unl.edu

ABSTRACT

A two-year beef systems study was conducted to determine the optimal time within a forage system to supplement distillers grains. A completely randomized design with a 2 x 2 factorial arrangement was used. Each year, 229 spayed heifers (BW = 215 ± 26 kg) grazed corn residue 144 d and bromegrass 32 d (WTR), native range 120 d (SMR), and were finished. Treatments were 0.91-kg DM wet distillers grains with solubles (WDGS) (LO) or 2.3-kg DM WDGS (HI) supplement on corn residue, and modified distillers grains with solubles (MDGS) fed at 0.6% BW daily (SUP) or no MDGS (NO SUP) during SMR. Previous research had shown a 17% forage savings from MDGS supplementation at 0.6% BW, and available SMR SUP animal unit months were 24% less than NO SUP. Forage residual height was measured to validate forage savings. Winter ADG was 0.31 kg greater ($P < 0.01$) for HI in year 1 and 0.18 kg greater ($P < 0.01$) in year 2. Summer SUP ADG was greater ($P < 0.01$) by 0.14 kg in year 1, and 0.08 kg in year 2. Gains throughout the entire forage-based system were greatest for HI, SUP, intermediate for HI, NO SUP and LO, SUP, and least for LO, NO SUP. There was no difference in residual forage height ($P = 0.50$), supporting a 17-24% forage savings hypothesis. There were no differences in DOF, DMI, or marbling. Final BW was 36 kg and 26 kg greater ($P < 0.03$), year 1 and 2, respectively, for HI than LO, and HCW was greater ($P < 0.03$) by 23 kg and 15 kg (year 1 and 2, respectively) for HI than LO. Summer SUP decreased finishing ADG by 0.20 kg ($P = 0.02$) in year 1 and decreased G:F ($P < 0.07$) both years, with no other finishing or carcass characteristics consistently affected. Across both years, profit was greater for HI than LO cattle ($P < 0.02$), but summer supplementation did not impact profit.

KEYWORDS: backgrounding, beef cattle, distillers, supplement, winter, summer

INTRODUCTION

In the last seven years, corn prices have increased nearly 250% (USDA NASS, 2013). Rising grain prices have increased the incentive to add additional weight to cattle prior to finishing, which may be done with a forage-based backgrounding system. Backgrounding systems utilize readily available, grazed forages to create yearlings for summer grazing, target different marketing windows, and create a year-round beef supply. In a yearling system, growing calves backgrounded on corn stalks through the winter are commonly supplemented to meet protein requirements (Fernandez-Rivera and Klopfenstein, 1989), but summer supplementation is a relatively recent development that has arisen as a result of readily available, competitively priced distillers grains (Griffin et al., 2012).

Distillers grains from the corn milling industry work well in forage-based systems as the starch source has been removed, thus there's little interference with fiber digestion (Stalker et al., 2010). Distillers grains are high in CP, energy, and phosphorus and have been shown to increase ADG and BW with increasing levels of supplementation (Griffin et al., 2012). In addition to increasing ADG, distillers grains have been demonstrated to reduce forage intake by 0.79 kg for each kg DGS fed (Watson et al., 2012). Cattle supplemented with DGS during the summer had increased summer ADG, greater final BW at finish, required fewer DOF, and were more profitable (Rolfe et al., 2011).

The objective of this experiment was to determine optimal winter and summer supplementation level and interaction of timing within a forage-based system using spayed yearling heifers. In addition, use of MDGS as a forage replacement tool when fed at 0.6% BW on Sandhills range would be investigated.

MATERIALS AND METHODS

All procedures and facilities utilized were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Each year of a two year study, 229 crossbred heifers (initial BW = 215 ± 26 kg) were used in a completely randomized design with a 2 × 2 factorial treatment design. Factors were winter supplement level and summer supplement level. At the beginning of the winter backgrounding phase, heifers were stratified by initial BW and assigned randomly to a winter supplementation level: 1) 0.91-kg DM wet distillers grains with solubles (WDGS) (**LO**); or 2) 2.3-kg DM WDGS (**HI**) and a summer supplementation level: 1) modified distillers grains with solubles (MDGS) fed at 0.6% BW daily (**SUP);** or 2) no MDGS supplementation (**NO SUP**). Heifers were serially slaughtered in an early and late group (1 pen early, 1 pen late) from each experimental unit to adjust carcass measurements to a common fat thickness. Thus, there were two replicates (feedlot pens) within year for each combination of winter and summer supplementation level treatment. Within year, 29-head groups (2 feedlot pens) were the experimental unit. Therefore, 16 feedlot pens resulted in 8 experimental units.

Winter

Each fall at receiving, calves were processed within 24-hours of arrival at the University of Nebraska Agricultural Research and Development Center (ARDC) feedlot near Mead, Nebraska. A BW was collected at initial receiving (assumed as a shrunk BW), and calves were vaccinated according to UNL health protocol. Calves were individually tagged with a panel tag, electronic identification tag, and metal clip tag.

In year 1, calves were vaccinated for prevention of *infectious bovine rhinotracheitis virus*, *bovine virus diarrhea*, *parainfluenza* (PI_3), and *bovine respiratory syncytial virus* (BoviShield Gold 5, Zoetis Inc., Kalamazoo, MI) and *Haemophilus somnus* (Ultrabac 7/Somubac, Zoetis Inc.). A parasiticide was injected (Dectomax, Zoetis, Inc.) and a parasiticide was orally administered (Safegaurd, Merck Animal Health, Summit NJ). Cattle were re-vaccinated approximately two weeks later with a second dose of viral, bacterial, and clostridial vaccines (BoviShield Gold 5, Ultrabac 7/Somubac) and dosed with Piliguard Pinkeye-1 (Merck Animal Health) to prevent against *Moraxella Bovis.*

In year 2, initial processing methods were similar but with the use of One Shot (*Pasteurella)* (Zoetis Inc., Kalamazoo, MI) and no Safeguard administration. Revaccination protocol used BoviShield Gold 5 and Vision 7/Somnus (Merck Animal Health), and a Piliguard (Merck Animal Health) vaccination for pinkeye protection.

In both years, heifers grazed cool season pastures as a common group following initial processing. Prior to revaccination, heifers were limit fed a diet of 50% alfalfa hay, 50% Sweet Bran (Cargill, Blair, NE) at 1.8% BW daily for 5 days to minimize differences in gut fill (Stock et al., 1983). Initial BW was collected over two days and the mean weight used as the initial weight for the winter phase and growing system. At this time (Dec. 12, 2010 in year 1, Nov. 22, 2011 in year 2), heifers were stratified by initial BW, assigned randomly to treatment, and sorted into winter treatment groups, HI or LO and winter phase of the system was initiated.

Heifers then grazed corn residue in winter treatment groups at the ARDC from late fall until early spring. The LO supplement level of 0.91 kg WDGS daily was

selected to meet protein requirements, whereas the HI level of 2.3 kg WDGS daily was designed to meet metabolizable protein requirements (NRC, 1996) and supply additional energy. In addition to MDGS, a daily supplement was provided at 0.11 kg per head, to provide 200 mg/heifer daily of monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

During cornstalk grazing, heifers in year 2 were poured with Phonectin (Teva Animal Health, St. Joseph, MO) in February.

At the conclusion of grazing corn residue, (April 20, 2011 in year 1, April 17, 2012 in year 2), heifers were dry-lotted 24 hours and then surgically spayed by a DVM using the Kimberling-Rupp procedure (Rupp and Kimmerling, 1982). Heifers were immediately turned onto bromegrass pasture where they grazed an average of 31 days, and winter supplementation treatment was discontinued. The winter phase (corn stalk grazing with winter supplement treatment and bromegrass grazing) averaged 175 days.

Summer

Upon removal from bromegrass pasture, heifers were limit fed five days, weighed two consecutive days (Stock et al., 1983), and the average weight was used as heifers' ending BW from the winter phase of the system, and beginning BW of summer phase. At this time, heifers were stratified by summer initial BW and assigned randomly to summer treatment.

Heifers were then processed for summer grazing and implanted with a Revalor-G implant (40 mg trenbolone acetate and 8 mg estradiol, Merck Animal Health) and were hot iron branded. At this time, heifers were given an insecticide pour-on (Saber, Merck Animal Health, Summit, NJ) in year 1 or Phonectin (Teva Animal Health, St. Joseph,

MO) in year 2. In year 2 heifers were given a Piliguard (Merck Animal Health) vaccination for pinkeye protection, and received a Python MAGNUM insecticide ear tag (Y●Tex Corporation, Cody, WY).

Heifers were sorted into summer treatment groups at this processing time. Treatments included supplemented at 0.6% BW daily (SUP) or no supplementation (NO SUP). Heifers were then transported by semi approximately 370 km to the UNL Barta Brother’s Ranch near Rose, NE, to native Sandhills range. A deferred rotational grazing system was used to allow dominant, warm-season grasses additional growing time without grazing pressure (Schacht et al., 2011). The first pasture of the rotation was grazed at 75% usage, the second pasture at 100% usage, and the third pasture at 125% usage. Order of pastures grazed was alternated between years by using the first grazed pasture for year 1 as the last grazed pasture in year 2. In year 1, grazing season was 120 days, however drought conditions limited forage production in year 2 and heifers were removed earlier than anticipated, for a total of 111 grazing days.

Pastures were stocked to test the forage savings hypothesis that when distillers grains is fed at 0.6% BW daily, 1 kg of distillers grains replaces approximately 0.79 kg of forage (Watson et al. 2012a). This was tested by stocking pastures with an equal number of cattle but due to the size of available pastures, supplemented cattle were provided 24% less animal unit months (AUMs). Pastures were stocked at 1.59 AUM/ha (0.64 AUM/ac) for unsupplemented cattle and 2.08 AUM/ha (0.84 AUM/ac) for supplemented cattle.

It was hypothesized that there would be similar amounts of residual forage between pastures grazed by supplemented and unsupplemented cattle at the end of each grazing rotation. Forage residual height measurements (Bureau of Land Management's

National Applied Resource Sciences Center, 1984) were taken at the conclusion of each grazing rotation to test this hypothesis.

To measure residual height, a transect across each pasture from two perimeter fences was visualized, and then forage residual height was measured every 10 steps. This was done by lowering a plastic disc onto the forage until approximately half of the tillers touched the disc, and a yardstick was used to measure forage height at that level. This process was completed twice in each pasture, with any sacrifice areas avoided. Residual height measurements in each pasture were averaged, within year.

Within year, distillers supplementation feeding amount was adjusted monthly based on an assumed ADG of 0.68 kg/d (Rolfe et al., 2011). A distillers grains sample was taken bi-weekly and analyzed for dry matter content, which was used to adjust feeding amounts on a DM basis. Three loads of distillers grains were procured throughout the summer with each load analyzed for nutrient analysis (Table 1). Distillers grains was stored in a modified bunker adjacent to the study location and covered with 4 mm agricultural plastic.

Nutrient analysis of distillers grains was conducted using the Van Soest et al. (1991) and Van Soest and Marcus (1964) methods to determine NDF content. Crude protein was calculated as N x 6.25 with nitrogen concentration determined by combustion method (AOAC, 1999) using a N combustion analyzer (Leco FP-523, St. Joseph, MO). Ether extract (fat) was analyzed according to the (AOAC, 1965) procedure.

Daily supplementation amounts for supplemented heifers was calculated at 0.6% BW, a level based on Morris et al. (2005, 2006) showing increased gains and complete consumption of DDGS when fed at 0.5% BW to yearling steers on native range. Daily supplementation levels were pro-rated over 6 days per week, and distillers grains was fed directly on the ground with a tractor and feed wagon. Supplement was fed in a new location of the pasture each day to promote uniform grazing distribution. Both treatment groups had continual access to trace mineralized salt and an oil rub for fly control. At the conclusion of the summer grazing phase, heifers were transported via semi back to the ARDC at Mead, NE.

Finishing

Following arrival at the ARDC, heifers were limit fed 8 days to minimize differences in gut fill (Stock et al., 1983; Watson et al., 2012b), and weighed for two consecutive days. Their average two-day weight was their ending BW for the summer phase and forage system, and beginning BW for the finishing phase. Heifers were re-implanted with Revalor-200 (200 mg trenbolone acetate, 20 mg estradiol, Merck Animal Health.

Because heifers would be serially slaughtered to allow carcass measurements to be adjusted to a common fat thickness, heifers were stratified by initial feedlot entry BW within treatment group, and then assigned randomly to an early or late slaughter group. The combination of an early and late slaughter group within a treatment served as the experimental unit, thus there were two feedlot pens (replicates) within year for each treatment. Pens were randomly assigned at this time.

In year 1, heifers were adapted to a common finishing diet by replacing alfalfa hay at 35%, 25%, 15%, 7.5%, and 0% with high moisture corn at 15%, 25%, 35%, 42.5%, and 50% of the diet DM for steps 1 through 5 of the ration. Wet corn gluten feed was held constant at 40% while supplement and wheat straw were both held constant at 5%. During adaptation, heifers were on step 1 for three days, step 2 for four days, step 3 for seven days, step 4 for seven days, and step 5 was the finishing ration. The final finishing diet included 50% high moisture corn, 40% wet corn gluten feed, 5% wheat straw, and 5% supplement.

In year 2, one replicate of each treatment was adapted to a finishing diet identical to year 1 (50% high moisture corn, 40% wet corn gluten feed, 5% wheat straw, and 5% supplement). The other replicate was adapted in the same manner as previously described, but using MDGS in place of the wet corn gluten feed at a level equal to its inclusion level in the finisher previously described. This resulted in a finisher ration that was 50% high moisture corn, 40% MDGS, 5% wheat straw, and 5% supplement.

Diets in both years were formulated to provide 30 g/ton monensin daily (Elanco Animal Health) and 90 mg/heifer tylosin daily (Tylan, Elanco Animal Health) assuming a 12.3 kg DMI; and to meet or exceed NRC (1996) metabolizable protein, Ca, P, and K requirements.

Initial BW at finishing phase entry differed between treatments, thus DOF among treatment groups were varied to produce carcasses with a similar 12th rib fat thickness. This was achieved through use of serial slaughter, with half of each treatment group's cattle slaughtered at an earlier date, and half slaughtered at a later date to produce

differences in 12th rib fat thickness. These differences then allowed carcass measurements to be adjusted to a common fat thickness for an equitable comparison.

In year 1, actual DOF for cattle in the early slaughter group were 90 or 111 d, 111 or 132 d, 111 or 132 d, and 132 or 153 d for HI, SUP; HI, NO SUP; LO, SUP; and LO, NO SUP treatments, respectively. Within treatment, the early and late slaughter group carcass measurements were regressed to a common fat thickness of 1.32 cm across all treatments. There were two replications of each treatment regression.

In year 2, only two slaughter dates were utilized, resulting in 113 DOF for cattle slaughtered in the early group and 134 DOF for cattle slaughtered in the late group. Fat thickness was virtually identical between slaughter dates (1.35 cm for early slaughtered cattle, 1.40 cm for late slaughtered cattle), so carcass measurements from the early and late slaughter groups were averaged within treatment, but no regression was used.

The lack of difference in fat thickness between the two groups in addition to low performance data suggests cattle had marginal gain during the final weeks of finishing. This may have been due in part to weather and pen conditions. Pens used in year 2 have been designed for environmental work with solid walls between pens, no mounds, and seemingly little drainage occurs which left pens in poor condition. Consequently, cattle would have allocated additional energy to maintenance requirements under these conditions.

Carcass Characteristics

All cattle were slaughtered at the same commercial abattoir (Greater Omaha Packing Co., Omaha, NE) across both years. Hot carcass weight and liver scores were collected at harvest. Final BW was calculated from HCW assuming a 63% common

dressing percentage. Following a 48-hour chill, carcass characteristics were measured using commercial instrument grading and 12^{th} rib fat thickness, LM area, and marbling scores were recorded. Yield grade was calculated as (USDA, 1996):

Calculated YG (CYG) = (2.5 + (5.51 x 12^{th} rib fat thickness, cm) – (0.70 x LM area, cm^2) + (0.2 x KPH) + (0.0084 x HCW, kg)), with KPH assumed to be a constant 2.5%.

Economic Analyses

For each phase of the economic analysis, economic assumptions were applied to the actual performance values and actual days in each production phase from year 1 and year 2.

Initial purchase price was calculated as the average price from the first and last week of November, 2011 and 2012, for 182-227 kg medium and large framed, number 1 feeder heifers from the Nebraska weekly feeder cattle summary, at $137.73/45.4 kg.

Distillers price was calculated using a $5.50/25.4 kg ($5.50/bu) corn price and pricing distillers equal to corn on a DM basis, resulting in a cost of $0.097/.454 kg distillers grains (DM) fed.

Winter Phase

Daily stalk grazing was charged at $0.31 per heifer and WDGS charged at $0.097/.454 kg fed (DM). Grazing costs were modified from Johnson (2013). Total winter cost was the sum of WDGS supplement cost and stalk grazing cost.

Summer Phase

Daily summer grazing costs were charged at $0.80 per head for non-supplemented heifers. Grazing costs were modified from Johnson (2013). Given supplemented heifers were provided 22% less acres due to MDGS supplementation and projected forage savings, daily grazing cost was reduced to $0.62 per head for supplemented heifers. Supplemented heifers were charged an additional $0.20 daily to account for additional labor, fuel, and equipment to provide distillers supplementation. Non-supplemented heifers during the summer phase were charged $0.10 daily in yardage costs. Total summer costs included MDGS supplementation cost (if applicable), yardage, and summer grazing cost.

Finishing Phase

Yardage during finishing was assumed to be $0.45 daily. Feedlot diet was charged at $0.115/.454 kg (DM) of DMI. Cattle were sold on a live weight basis using the USDA live heifer average price from the final week of January, 2012 and 2013, at $124.38/45.4 kg, when these cattle were actually marketed. Total finishing costs included finishing diet (DMI) cost and yardage during finishing.

Overall analyses

Profitability was calculated as total revenue (selling price multiplied by final live weight determined on carcass adjusted basis) minus total costs (initial purchase cost, wintering costs, summer costs, and finishing costs).

Statistical Analyses

Data were analyzed as a 2 × 2 factorial, with winter supplementation level, summer supplementation level, and the winter by summer supplementation interaction included as fixed effects in the statistical model. Due to numerous significant effects of

year or treatment interactions with year, data are presented by year. The combination of an early and late slaughter group within a treatment served as the experimental unit, thus there were two replicates within year for simple effects.

Performance and economic data were analyzed using the GLIMMIX Procedure of SAS (SAS Inst., Inc., Cary, NC). Effects of the treatment or the interaction were considered significant when $P < 0.10$ as detected by the Fischer test for performance data, or when $P < 0.05$ as detected by the Fischer test for economic data. When the F-test was significant, least squares means of treatments were separated using a t-test when $P < 0.10$ for performance data and $P < 0.05$ for economic data. When an interaction did not occur, main effects are discussed.

RESULTS AND DISCUSSION

Forage Savings

There was no difference ($P = 0.50$) in residual forage height between pastures grazed by supplemented and unsupplemented cattle during the summer (Table 2). Numerically, pastures grazed by unsupplemented cattle had 1.5 cm greater residual forage. Because pastures were stocked assuming a 24% forage savings rate by SUP to utilize available acres and considering Watson et al., (2012a), this numerical difference suggests forage savings may be less than the 24% pastures were stocked for.

A similar, but more intensive study was conducted during the same years approximately 260 km west (Gillespie et al., 2013). Gillespie et al. (2013) results affirmed the 17% forage savings hypothesis demonstrated in Watson et al. (2012a) through clipping quadrats in paddocks grazed by unsupplemented and supplemented

cattle. In Gillespie et al. (2013), however, spayed heifers supplemented on the ground at 0.6% BW/d numerically left 120 kg/ha more live material at the conclusion of the grazing season, which would indicate forage savings was greater than the assumed 17% for that study.

In consideration of the intensive results from Gillespie et al., 2013, and the current results, these data indicate forage savings when supplementing MDGS at 0.6% BW/d on a native Sandhills range situation results in a 17% to 24% forage savings.

Winter

By design, there was no difference in initial BW ($P > 0.24$) between LO and HI treatment groups in either year (Table 3). Supplementation at HI level increased ADG 0.31 kg ($P < 0.01$) in year 1, and 0.18 kg ($P < 0.01$) in year 2, compared to LO. The energy value of WDGS is 130% the energy value of corn (Nuttelman et al., 2009) in growing situations. Thus the additional energy available in DGS, in addition to metabolizable protein, has been attributed to increase gain in supplementation situations (MacDonald et al., 2007). Griffin et al. (2012) observed DDGS supplementation in a forage-based production system increases ADG and BW quadratically. Therefore, the additional ADG and 50 kg greater ($P < 0.01$) winter ending BW for HI in year 1 or 33 kg greater ($P < 0.01$) winter ending BW for HI than LO in year 2 is a response to the additional protein and energy provided with HI level, whereas the LO treatment was only designed to meet protein requirements.

Summer

In year 1, there was an interaction between treatment ($P = 0.02$) for summer initial BW (same as winter ending BW, Table 3) with HI cattle having greater initial BW than

LO, but HI, NO SUP also being greater than HI, SUP. Because summer treatment had not yet been applied, this interaction is due to treatment groups.

In year 1, there was a winter by summer interaction ($P = 0.07$) for summer ADG with LO, SUP having the greatest daily gain at 0.90 kg, followed by HI, SUP at 0.74 kg, LO, NO SUP at 0.65 kg, and HI, NO SUP gained 0.54 kg.

In year 2, no interactions were observed during the summer phase, but winter treatment and summer treatment were both significant ($P = 0.01$). Winter supplementation at the HI level reduced summer ADG ($P < 0.01$) by 0.08 kg/d and summer supplementation of MDGS increased ADG 0.20 kg ($P < 0.01$).

In both years, the greater summer gain by LO is a classic compensatory gain response, which is well documented and defined as the accelerated and/or more efficient growth that commonly follows a period of growth restriction (Bohman et al., 1955). This illustrates gain following a period of restriction (winter backgrounding) are greatest for cattle which had the greatest nutritional restriction, which in this study were LO calves which had been supplemented with WDGS during the winter to only meet their protein requirement. Thus LO had a greater prior nutritional restriction than HI calves and consequently had a larger compensatory grain response.

The increased summer gain with MDGS supplementation is supported by Rolfe et al. (2011), who reported steers supplemented with MDGS at 0.6% BW during summer grazing gained an additional 0.30 kg/d. Rolfe et al. (20011) attributed the observed response to additional RDP supplied to supplemented steers in excess of metabolizable protein requirements.

Increased gain due to summer supplementation is supported by a meta-analysis from Griffin et al. (2012), which concluded ADG and ending BW increase linearly with increasing DDGS supplement level. However, the additional gain from SUP (24 kg in year 1 or 18 kg in year 2) in this study is less than Griffin's conclusion of 37 additional kg for supplemented than non-supplemented cattle. In addition, a lower response was consistently observed across years in this dataset compared to Rolfe et al. (2011).

The Sandhills are dominated by warm-season grasses (Bragg and Steuter, 1995; Volesky, 2005) which are more highly lignified (Akin, 1989) and have lower leaf : stem ratios and protein concentrations than cool season plants at similar growth stages (Barnes et al., 2003). Of the pasture studies used in the Griffin et al. (2012) analysis, only three of the 13 studies were solely warm-season pastures. Consequently, gain response in the meta-analysis may have been related to grass type.

The lower gains in the current study may be partially due to using spayed heifers rather than steers as Rolfe et al. (2011) used. Heifers are slower gaining and less efficient than steers (Zinn et al., 2008). In addition, the 2012 growing season was hotter (Table 4, Figure 1) and drier (Table 5, Table 2) than average. Precipitation is related to total forage yield (Smoliak, 1964) and year 2 drought conditions limited forage production which prompted removal of heifers from summer pasture 10 days earlier than scheduled. This management decision illustrates the possibility that availability of forage may have been limited prior to that point and cattle may have been forced to consume a greater proportion of year-old, mature forage than normal. Mature plants have a lower leaf : stem ratio (Burns, 2008), thus forage quality is lower (Fontenot and Blaser, 1964) and performance may be hindered. Across all treatments, summer gains in year 2 averaged

0.19 kg less than year 1, illustrating potential differences in performance related to drought and forage availability.

Forage system

There were no winter by summer supplementation treatment interactions ($P >$ 0.12) when examining the entire forage-based growing system for ADG (Table 3). With HI supplementation, ADG increased ($P < 0.01$) 0.11 kg in both year 1 and year 2. With summer supplementation, ADG increased 0.09 kg in year 1 ($P < 0.01$) and ADG increased 0.06 kg in year 2 ($P < 0.01$).

In year 1, there was a winter by summer treatment interaction ($P = 0.02$) for system ending BW with HI, SUP having greatest ending BW at 400 kg, followed by HI, NO SUP at 382 kg, LO, SUP at 372 kg, and finally LO, SUP at 343 kg.

In year 2, HI winter supplementation increased system ending BW ($P < 0.01$) 23 kg, and SUP increased system ending BW ($P < 0.01$) 26 kg.

Finishing phase

In both years, there were no statistical differences in DOF across treatments (Table 6), which is in contrast to Rolfe et al. (2011) who observed summer supplemented steers entered the feedlot 48 kg heavier than non-supplemented steers, and required 24 fewer DOF to reach a similar 12th rib fat thickness. Similarly, Funston et al., (2007) observed yearling steers supplemented with *ad libitum* DDGS during summer grazing entered the feedlot phase 27 kg heavier than non-supplemented steers, and required 14 less DOF. In this study, initial feedlot BW difference between SUP and NO SUP (21 kg) was not as great as the difference observed by Rolfe et al. (2011) or Funston et al. (2007)

of 24 less DOF and 14 less DOF, respectively. Had cattle responded to summer supplementation in a manner similar to those studies, perhaps a difference in DOF would have been observed.

In year 1 and 2, DMI was similar (*P* > 0.23) across treatments which is similar to other supplementation studies. Jordan et al. (2000), Lewis et al. (1989), and Klopfenstein et al. (1999) all observed similar DMI values across varying winter treatment levels. Only Downs et al. (1998), observed increased DMI for cattle wintered at a high level and response was inconsistent among cattle summered on bromegrass or Sandhills range. No DMI difference regardless of summer treatment is similar to the Griffin et al. (2012) meta-analysis which reported generally summer supplementation does not impact finishing characteristics.

Feedlot ADG was not impacted (*P* > 0.78) by winter supplement level in either year. This is in contrast to a six study summary (Gillespie et al., 2013) using a similar systems approach. In Gillespie et al. (2013), cattle supplemented at a high winter level and then summered without supplementation, tended to gain more (0.09 kg) during finishing than cattle in the same system backgrounded at a low supplement level. Data from this study using HI, NO SUP and LO, NO SUP cattle was included in that analysis, so the lack of difference observed here suggests the inclusion of SUP cattle in these data diluted the effect seen in Gillespie et al. (2013).

Feedlot ADG declined 0.21 kg with summer MDGS supplementation (*P* = 0.02) in year 1 and is similar to a tendency seen in Rolfe et al. (2011). Lower feedlot gains from SUP is likely due to compensatory gain observed in the non-supplemented heifers as they moved from grass to an energy dense finishing ration. It would seem that feedlot

compensatory gain may be irrelevant here if final BW was greater for SUP than NO SUP regardless of feedlot gain, however that was not the case. There were no differences in feedlot ADG observed in year 2.

Feed efficiency was not impacted by winter treatment ($P > 0.14$) but decreased ($P < 0.07$) 0.01 kg with summer supplementation in year 1 and year 2. In contrast, Rolfe et al. (2011) did not observe any efficiency differences during finishing.

In year 1, there was a winter by summer treatment interaction ($P = 0.08$) for final BW with HI, NO SUP finishing 21 kg heavier than HI, SUP, which was followed by LO, SUP and LO, NO SUP which were similar. In year 2, HI winter supplementation increased ($P = 0.03$) final BW 26 kg and summer supplementation increased ($P = 0.10$) final BW 16 kg.

Greater final BW for winter or summer supplemented cattle is supported by Gillespie et al. (2013) and Griffin et al. (2012). Gillespie et al. (2013) reported 37 additional kg final BW from high winter supplement level. Griffin et al. (2012) reported cattle supplemented with DDGS on pasture maintained 84% of their summer weight advantage for 31 additional kg.

Carcass characteristics

In year 1, consistent with final BW data, there was a winter by summer treatment interaction for HCW with HI, NO SUP producing the heaviest carcasses, followed by HI, SUP 14 kg less, and then LO, SUP and LO, NO SUP were similar. Similar to year 2 final BW data, HCW in year 2 was increased ($P = 0.03$) with HI by 15 kg and decreased ($P = 0.10$) 10 kg with SUP.

In year 1, winter and summer treatments interacted (*P* = 0.03) to produce the largest LM area in HI, NO SUP and LO, SUP, followed by HI, SUP and LO, NO SUP. Year 2 data were clearer, with HI cattle having 3.5 cm^2 larger (*P* = 0.01) LM area than LO cattle, and no summer effect. This increased muscle development for HI may be related to the tendency for greater feedlot ADG and greater final BW observed in high level supplemented cattle in Gillespie et al. (2013).

Treatments had no effect on marbling scores (*P* > 0.49), similar to Rolfe et al. (2011) and consistent with Griffin et al. (2012) who noted no consistent effects of DDGS supplementation on marbling after the finishing phase.

There was a treatment interaction for CYG in year 1, with LO, SUP and HI, NO being most desirable, followed by LO, NO and HI, SUP. There were no CYG differences in year 2.

Finally, there were no overweight carcasses (greater than 453 kg) across treatments in either year. In contrast, yearling steers supplemented during the summer in Rolfe et al. (2011) entered the feedlot 48 kg heavier and consequently produced 7.8% overweight carcasses. Spayed yearling heifers can be successfully adapted to a supplementation system which will add additional weight without the concern of reaching carcass discounts as observed with yearling steers.

System profitability

Winter Backgrounding. There were no winter by summer treatment interactions or summer effects during the winter phase, as summer treatment had not yet been applied (Table 7). Corn residue cost, including yardage to deliver WDGS supplement, was

consistent across treatments at $42.78 per head (year 1) or $46.19 per head (year 2). Supplementation costs, and consequently total wintering costs were greater (P < 0.01) for HI than LO by $40.12 in year 1, and $43.31 in year 2. Total winter backgrounding costs averaged $69.52 (year 1) or $75.07 (year 2) per head for LO cattle, and $109.64 (year 1) or $113.38 (year 2) per head for HI cattle.

Summer grazing. There were no winter by summer treatment interactions during summer grazing. Grazing cost was greater (P < 0.01) for SUP at $102.40 (year 1) or $95.20 (year 2), compared to NO SUP at $79.87 (year 1) or $74.26 (year 2). These differences reflect that supplemented cattle were provided 22% fewer acres. For SUP cattle, supplementation cost was $52.34 (year 1) or $49.93 (year 2) greater ($P$ < 0.01) and yardage costs $12.80 (year 1) or $11.90 (year 2) greater ($P$ < 0.01). Total summer grazing costs averaged $157.81 for SUP compared to $115.20 for NO SUP in year 1 (P < 0.01), and $147.99 for SUP and $107.10 for NO SUP in year 2 (P < 0.01).

Finishing phase. There were no winter by summer treatment interactions affecting finishing costs in either year. In year 1, finishing diet cost tended (P = 0.06) to be $21.54 greater for NO SUP cattle, there were no differences in yardage cost, and overall finishing cost tended (P = 0.07) to be $22.95 greater for NO SUP cattle, with no differences observed from winter treatment. Numerically, NO SUP cattle had a greater DMI and DOF, which created these tendencies for differences in finishing cost.

In year 2, there were no winter or summer treatment effects on diet cost, yardage, or total finishing cost. There were minimal performance differences in year 2 across treatments, consequently there were minimal finishing cost differences.

Overall profitability. In year 1, initial cost was similar ($P > 0.55$) as initial weights were also similar by design. Total costs tended ($P = 0.07$) to be $32.52 greater for HI, due to additional winter supplementation costs. Summer supplementation numerically increased total costs $15.43 due to MDGS cost and additional summer yardage cost, but was not statistically significant ($P = 0.62$). Revenue was $98.62 greater ($P < 0.01$) for HI than LO cattle, due to the additional 36 kg of saleable weight. There was a winter by summer treatment interaction ($P = 0.05$) on overall profitability with HI, NO SUP most profitable at $359.29 per head, followed by HI, SUP at $303.32, LO, NO SUP at $271.73 and LO, SUP at $258.69.

In year 2, initial cost was similar ($P > 0.08$) by design. Total costs were not impacted by winter treatment ($P = 0.23$) but were $47.23 numerically greater ($P = 0.31$) with summer supplementation due to MDGS and additional yardage cost. Similar to year 1, revenue was greater ($P = 0.03$) by $69.59 for HI, but summer supplementation increased ($P = 0.10$) revenue $42.99 as well. Similar to year 1 as well, profit was greater for HI than LO ($P = 0.02$) by $37.71, and NO SUP ($P = 0.15$) was more profitable than SUP by $4.25. Profit differences between year 1 and year 2 are due to lower year 2 performance, and consequently lower revenue.

Across both years, these data parallel with Gillespie et al. (2013) which illustrated cattle supplemented at a high winter level had greater final BW and were more profitable. The Gillespie et al. (2013) economic analysis included this current dataset and four other similar studies. In the Gillespie et al. (2013) economic analysis, corn was priced at $5.50/bu and distillers grains at 105% corn price which resulted in high winter level supplemented cattle being $56.32 more profitable than cattle supplemented at a low winter level.

Summer supplementation was profitable in Rolfe et al. (2011), but had minimal impact in the current study. Corn price was lower in the Rolfe et al. (2011) analyses and distillers grains cost was set at 75% the price of corn whereas in the current analysis, corn and distillers grains costs were equal. Thus the current distillers grains price coupled with the additional summer yardage costs to supplement cattle make summer supplementation economically unreasonable, given this dataset's performance.

CONCLUSIONS

Spayed heifer calves supplemented at a high winter level to meet metabolizable protein and energy needs (2.3 kg WDGS daily) compared to a low winter level (0.91 kg WDGS daily) to only meet metabolizable protein needs, gained an additional 0.31 kg/d (year 1) and 0.18 kg/d (year 2) during winter backgrounding. Summer gain was 0.14 kg/d (year 1) and 0.08 kg/d (year 2) lower for HI than LO heifers, but final live weight was 36 kg greater (year 1) and 26 kg greater (year 2), resulting in greater HCW as well.

Summer supplementation of MDGS at 0.6% of BW daily on the ground increased summer gains 0.23 kg/d (year 1) and 0.20 kg/d (year 2). During finishing, SUP cattle gained less and were less efficient. The summer supplementation benefit results from forage savings, which was affirmed to be approximately 17-24%.

Gains throughout the entire forage-based system were greatest for HI, SUP cattle, intermediate for HI, NO SUP and LO, SUP cattle, and least for LO, NO SUP cattle. There were no overweight carcasses in this system using spayed yearling heifers. Finally, across both years profit was greatest with high winter level supplementation, but not impacted by summer supplementation.

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Table 1. Nutrient analysis of modified distillers grains with solubles

Nutrient	**DM, %**
CP	31.9
Ether extract	8.9%
NDF	31.4%

Table 2. Season average forage residual height

Item	Residual height, cm	SEM	*P*-value
NO SUP[1]	16.30	1.47	0.50
SUP[2]	14.83		

[1] NO SUP = Pastures grazed by non-supplemented cattle
[2] SUP = Pastures grazed by supplemented cattle

Table 3. Winter, summer, and system performance of yearling spayed heifers supplemented distillers grains in a forage-based system

	LO[1]		HI[2]			*P* –value[3]		
Item	NO SUP[4]	SUP[5]	NO SUP[4]	SUP[5]	SEM	Winter	Summer	W x S
Winter								
Initial BW, kg – Year 1	206	205	206	205	2	0.96	-	-
Initial BW, kg – Year 2	225	225	221	227	2	0.24	-	-
ADG, kg – Year 1	0.32[b]	0.31[b]	0.64[a]	0.60[a]	0.01	<0.01	-	-
ADG, kg – Year 2	0.44[b]	0.44[b]	0.63[a]	0.60[a]	0.01	<0.01	-	-
Ending BW, kg[6] – Year 1	260[c]	258[c]	313[a]	305[b]	0.8	<0.01	<0.01	0.02
Ending BW, kg[6] – Year 2	305[b]	306[b]	337[a]	341[a]	2.0	<0.01	0.25	0.48
Summer								
ADG, kg – Year 1	0.65[c]	0.90[a]	0.54[d]	0.74[b]	0.01	<0.01	<0.01	0.07
ADG, kg – Year 2	0.46[c]	0.66[a]	0.38[d]	0.58[b]	0.02	0.01	<0.01	1.0
Growing System								
ADG, kg – Year 1	0.47[c]	0.57[b]	0.59[b]	0.66[a]	0.01	<0.01	<0.01	0.12
ADG, kg – Year 2	0.46[c]	0.54[b]	0.59[b]	0.62[a]	0.01	<0.01	<0.01	0.55
Ending BW, kg[7] - Year 1	343[d]	372[c]	382[b]	400[a]	1.3	<0.01	<0.01	0.02
Ending BW, kg[7] - Year 2	360[c]	385[b]	382[b]	409[a]	0.93	<0.01	<0.01	0.18

[1]LO = supplemented at 0.91 kg. WDGS daily during winter backgrounding phase on corn residue

[2]HI = supplemented at 2.3 kg. WDGS daily during winter backgrounding phase on corn residue

[3]*P*-Value: Winter = effect of winter supplementation treatment across year 1 and 2; Summer = effect of summer supplementation treatment across year 1 and 2; W x S = effect of winter x summer treatment interaction across year 1 and 2

[4]NO SUP = not supplemented during summer grazing

[5]SUP = supplemented at 0.6% BW daily with MDGS during summer grazing period

[6]Winter ending BW = Summer phase initial BW

[7]Growing System ending BW = Summer ending BW

[a,b,c,d] = Within a row (year), values lacking common superscripts differ when year or year x treatment interaction was significant at $P \leq 0.10$

Table 4. Monthly temperature at BBR[1] during years of study, °C

Month	Average 12 year temperature	Average 2011 temperature	Average 2012 temperature
January	-4	-8	-1
February	-3	-5	-3
March	3	1	10
April	9	8	11
May	14	13	16
June	20	19	23
July	24	25	27
August	22	23	22
September	17	16	17
October	9	11	8
November	2	3	2
December	-4	-2	-3

[1] BBR = Barta Brothers Ranch, Rose, NE

Table 5. Average precipitation, in cm, at BBR, during study years growing season

Month	**30-year average cumulative**	**2011**	**2012**
Oct-Mar	5.08	4.77	5.7
Apr	7.78	6.82	9.76
May	10.92	10.54	11.15
Jun	14.85	16.45	11.62
Jul	17.32	18.97	11.92
Aug	19.48	22.51	13.74
Sept	21.38	23.33	14.23

[1] BBR = Barta Brothers Ranch, Rose, NE

Table 6. Finishing performance and carcass characteristics of yearling spayed heifers supplemented distillers grains in a forage-based system

	LO[1]		HI[2]			*P* –value[3]		
Item	NO SUP[4]	SUP[5]	NO SUP[4]	SUP[5]	SEM	Winter	Summer	W x S
Days on feed – Yr 1	125	126	126	120	3	0.53	0.45	0.39
Days on feed – Yr 2	124	124	124	124	0	1.0	1.0	1.0
Final BW, kg – Yr 1	557[c]	565[c]	607[a]	586[b]	6	<0.01	0.31	0.08
Final BW, kg – Yr 2	541[b]	555[b]	565[a]	582[a]	7	0.03	0.10	0.85
DMI, kg – Yr 1	12.7	12.3	12.5	12.3	0.3	0.96	0.23	0.57
DMI, kg – Yr 2	13.0	12.6	12.5	12.8	0.7	0.79	0.92	0.66
ADG, kg – Yr 1	1.72[a, b]	1.54[b]	1.80[a]	1.57[b]	0.05	0.34	0.02	0.66
ADG, kg – Yr 2	1.47	1.39	1.49	1.41	0.06	0.78	0.28	0.96
G:F, kg/kg – Yr 1	0.140[a,b]	0.128[c]	0.144[a]	0.132[c]	0.001	0.14	<0.01	0.93
G:F, kg/kg – Yr 2	0.113[a]	0.110[b]	0.119[a]	0.111[b]	0.002	0.25	0.07	0.34
HCW, kg – Yr 1	351[c]	356[c]	383[a]	369[b]	4	<0.01	0.33	0.08
HCW, kg – Yr 2	341[c]	350[b,c]	355[a,b]	366[a]	5	0.03	0.10	0.84
LM area, cm.^{2} – Yr 1	81[b]	86[a,b]	90[a]	83[b]	0.1	0.21	0.82	0.03
LM area, cm.^{2} – Yr 2	81[b]	81[b]	84[a]	85[a]	0.1	0.01	0.76	0.44
Marbling score[6] – Yr 1	629	618	603	627	23	0.73	0.79	0.49
Marbling score[6] – Yr 2	585	582	582	586	13	0.97	0.97	0.77
Calculated YG[7] – Yr 1	3.22[a]	2.99[b]	3.06[a,b]	3.26[a]	0.08	0.51	0.85	0.05
Calculated YG[7] - Yr 2	3.14	3.25	3.22	3.25	0.13	0.79	0.61	0.76
HCW > 453 kg – Yr 1	0	0	0	0	-	-	-	-
HCW > 453 kg – Yr 2	0	0	0	0	-	-	-	-

[1]LO = supplemented at 0.91 kg. WDGS daily during winter backgrounding phase on corn residue

[2]HI = supplemented at 2.3 kg. WDGS daily during winter backgrounding phase on corn residue

[3]*P*-Value: Winter = effect of winter supplementation treatment over two years; Summer = effect of summer supplementation treatment over two years; W x S = effect of winter x summer treatment interaction across year 1 and year 2.

[4]NO SUP = not supplemented during summer grazing

[5]SUP = supplemented at 0.6% BW daily with MDGS during summer grazing period

[6]Marbling: Small^{00} = 500, Small^{50} = 550, Modest^{00} = 600

[7]Calculated YG = (2.5 + (5.51 x 12th rib fat thickness) – (0.70 x LM area) + (0.2 x KPH) + (0.0084 x HCW))

[a,b,c] = Within a row (year), values lacking common superscripts differ when year or year x treatment interaction was significant at $P \leq 0.10$

Table 7. Profitability of yearling spayed heifers supplemented distillers grains in a forage-based system, Year 1

	LO[1]		HI[2]			*P* –value[3]		
Item	SUP[4]	NO SUP[5]	SUP	NO SUP	SEM	Winter	Summer	W x S
Winter backgrounding phase								
WDGS cost, $	26.74[b]	26.74[b]	66.86[a]	66.86[a]	6.62	<0.01	–[6]	–[6]
Stalk cost, $	42.78	42.78	42.78	42.78	0	–[6]	–[6]	–[6]
Total cost, $	69.52[b]	69.52[b]	109.64[a]	109.64[a]	0	<0.01	–[6]	–[6]
Summer grazing phase								
Grazing cost, $	79.87[b]	102.40[a]	79.87[b]	102.40[a]	0	–[6]	<0.01	–[6]
MDGS cost, $	52.34[a]	0[b]	52.34[a]	0[a]	0	1.0	<0.01	–[6]
Yardage, $	25.60[a]	12.80[b]	25.60[a]	12.80[b]	0	–[6]	<0.01	–[6]
Total cost, $	157.81[a]	115.20[b]	157.81[a]	115.20[b]	0	1.0	<0.01	1.0
Finishing cost								
Diet cost, $	383.04[a,b]	389.08[a,b]	360.73[b]	397.76[a]	8.13	0.45	0.06	0.13
Yardage, $	56.28	56.23	53.69	56.56	1.68	0.54	0.45	0.43
Total cost, $	439.32[a,b]	445.31[a,b]	414.42[b]	454.32[a]	8.52	0.44	0.07	0.14
Profitability								
Initial cost, $	621.15	624.86	620.97	625.72	6.45	0.96	0.55	0.94
Total cost, $	1,287.80	1,254.89	1,302.84	1,304.88	13.15	0.07	0.62	0.25
Revenue, $	1,546.49[b,c]	1526.62[c]	1606.16[a,b]	1664.17[a]	17.97	<0.01	0.32	0.08
Profit, $	258.69[c]	271.73[c]	303.32[b]	359.29[a]	7.63	<0.01	0.19	0.05

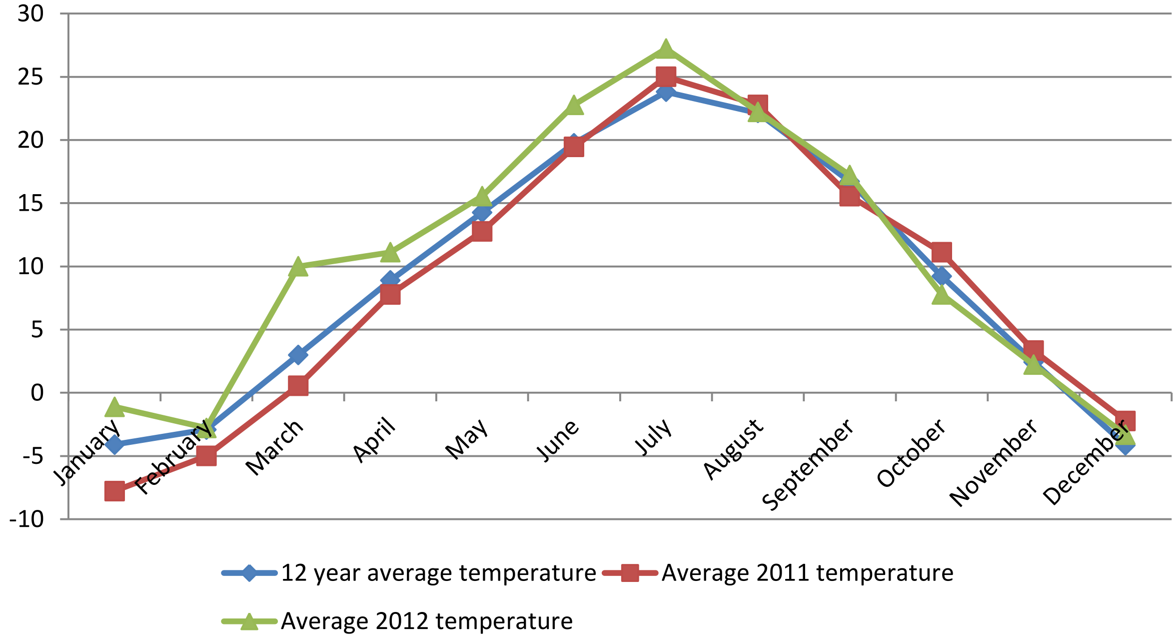
[1]LO = supplemented at 0.91 kg. WDGS daily during winter backgrounding phase on corn residue
[2]HI = supplemented at 2.3 kg. WDGS daily during winter backgrounding phase on corn residue
[3]*P*-Value: Winter = effect of winter supplementation treatment; Summer = effect of summer supplementation treatment; W x S = effect of treatment interaction.
[4]SUP = supplemented at 0.6% BW daily with MDGS during summer grazing period
[5]NO SUP = not supplemented during summer grazing
[6]Did not vary within treatment combination
[abc]Within a row, means with unlike superscripts differ ($P < 0.05$)

Table 8. Profitability of yearling spayed heifers supplemented distillers grains in a forage-based system, Year 2

	LO[1]		HI[2]			*P* –value[3]		
Item	SUP[4]	NO SUP[5]	SUP	NO SUP	SEM	Winter	Summer	W x S
Winter backgrounding Phase								
WDGS cost, $	28.88[b]	28.88[b]	72.19[b]	72.19[b]	6.62	<0.01	–[6]	–[6]
Stalk cost, $	46.19	46.19	46.19	46.19	0	–[6]	–[6]	–[6]
Total cost, $	75.07[b]	75.07[b]	118.38[a]	118.38[a]	0	<0.01	–[6]	–[6]
Summer grazing phase								
Grazing cost, $	74.26[b]	95.20[a]	74.26[b]	95.20[a]	0	–[6]	<0.01	–[6]
MDGS cost, $	49.93[a]	0[b]	49.93[a]	0[b]	0	1.0	<0.01	1.0
Yardage, $	23.80[a]	11.90[b]	23.80[a]	11.90[b]	0	–[6]	<0.01	–[6]
Total cost, $	147.99[a]	107.10[b]	147.99[a]	107.10[b]	0	–[6]	<0.01	–[6]
Finishing phase								
Diet cost, $	396.00[a]	409.25[a]	400.40[a]	391.88[a]	23.10	0.79	0.92	0.66
Yardage, $	55.80	55.80	55.80	55.80	0	–[6]	–[6]	–[6]
Total cost, $	451.80[a]	465.05[a]	456.20[a]	447.68[a]	23.10	0.79	0.92	0.66
Profitability								
Initial cost, $	683.42	683.32	687.09	669.77	3.79	0.26	0.08	0.09
Total cost, $	1,358.28	1,330.54	1,409.66	1,342.93	22.54	0.23	0.31	0.44
Revenue, $	1,519.85[a,b]	1,481.17[b]	1,593.75[a]	1,546.45[a,b]	20.33	0.03	0.10	0.84
Profit, $	161.57[b]	150.63[b]	184.09[a,b]	203.52[a]	9.34	0.02	0.15	0.18

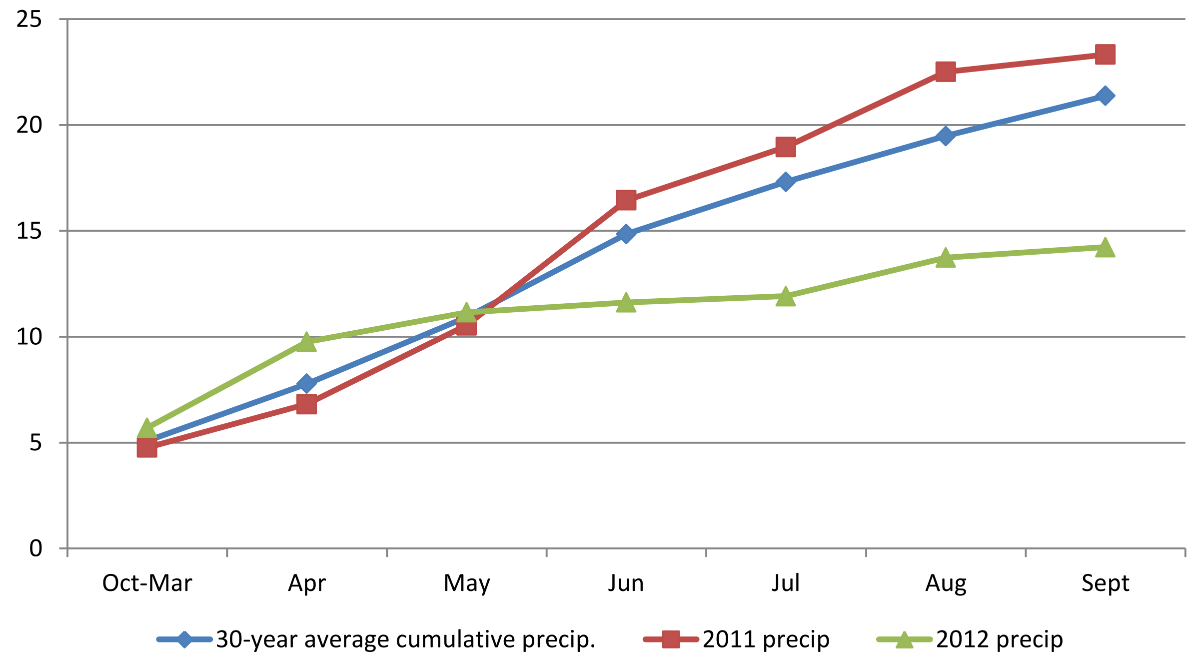
[1]LO = supplemented at 0.91 kg. WDGS daily during winter backgrounding phase on corn residue
[2]HI = supplemented at 2.3 kg. WDGS daily during winter backgrounding phase on corn residue
[3]*P*-Value: Winter = effect of winter supplementation treatment; Summer = effect of summer supplementation treatment; W x S = effect of treatment interaction.
[4]SUP = supplemented at 0.6% BW daily with MDGS during summer grazing period
[5]NO SUP = not supplemented during summer grazing
[6]Did not vary within treatment combination
[abc]Within a row, means with unlike superscripts differ ($P < 0.05$)

Figure 1. Monthly mean temperature and long-term mean temperature, in °C, at BBR during years of study



[1]BBR = Barta Brothers Ranch, Rose, NE

Figure 2. Monthly mean precipitation and long-term mean precipitation, in cm, at BBR[1] during years of study



[1] BBR = Barta Brothers Ranch, Rose, NE

Chapter III. Effect of winter supplementation level on yearling system profitability

K. L. Gillespie, T. J. Klopfenstein[2]*, J. C. MacDonald, B. L. Nuttelman*,

C. J. Schneider*

*Department of Animal Science, University of Nebraska, Lincoln 68583; University of Nebraska, Lincoln 68583

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[2]Corresponding author: C220g Animal Science Building; Phone: 402-472-6443; Fax: 402-472-6362; E-mail: tklopfenstein1@unl.edu

ABSTRACT

Winter supplementation level economics in a forage-based calf backgrounding system was analyzed by combining six experiments. In each study, British breed calves were backgrounded on corn residue with high (HI) or low (LO) winter supplementation level treatments, grazed through the summer, and finished. Within study, cattle were assigned randomly to treatment and had identical implant procedures and finishing diets. Feedlot performance values were adjusted to an equal fat thickness and current economic assumptions applied. Data were analyzed as a complete block design with winter supplementation level a fixed effect and study included as a random effect. During winter backgrounding, HI gained 0.38 kg/d ($P < 0.01$) more than LO. Summer compensatory gain occurred for LO cattle, gaining 0.15 kg/d more ($P = 0.02$) than HI during the summer grazing period. There were no differences in DOF, G:F, or DMI ($P > 0.51$) during finishing, but HI had 0.09 kg greater ADG ($P = 0.05$) and 37 kg greater final BW ($P < 0.01$). This secondary compensatory gain in a three phase forage system illustrates the importance of backgrounding nutrition, evaluating systems, and carryover effects. Four economic scenarios were applied to the dataset in a sensitivity analysis. Assumptions were 227 kg British breed calves backgrounded on corn residue with modified distillers grains (MDGS) supplemented at 0.91 or 2.27 kg/head/day, summered on grass, and finished. Corn price, distillers grains price relative to corn, and grazing costs varied upon scenario. Across all scenarios, HI averaged $54.87 additional profit compared to LO. Corn price/25.4 kg would have to exceed $11.70/25.4 kg, regardless of scenario, for HI and LO profit to be equal. Calves backgrounded at HI level maintained their performance advantage through finishing and were more profitable across multiple economic scenarios.

KEYWORDS: Beef cattle, carryover, supplement, backgrounding, winter supplement level

INTRODUCTION

With nearly 75% of the U.S. calf crop spring-born (USDA-NASS, 2013), placing a consistent supply of feeder cattle in feedlots to produce a year round beef supply is a challenge. That challenge is partially remedied with backgrounding systems which capitalize on the ruminant's ability to use readily available, grazed forages. Cattle are nutritionally restricted to varying degrees which can create yearlings for summer grazing, target different marketing windows, and create a year-round beef supply.

Wintering programs are typically associated with high feed costs and thus decades of research have focused on the effects of low nutritional inputs during the winter period as a means to lower costs (Drouillard and Kuhl, 1999) but then attain increased summer grazing gains (compensatory growth), during a period of higher nutrient intake (Downs et al., 1998). However, this philosophy may not have considered the benefits of a high supplementation level when cattle are retained through finishing, or when ethanol byproducts are available as a supplement. When ethanol byproducts are readily available and competitively priced (Griffin et al., 2012); it may be profitable to supplement growing cattle at a higher level than previously believed.

In the last seven years, corn prices have increased nearly 250% (USDA NASS, 2013). Thus previous economic analyses may no longer be relevant and increasing gain prior to feedlot entry through backgrounding may be of even greater value than previously realized. The objective of this study was to compare a high and low winter

supplementation level in a forage-based backgrounding system regarding animal performance and profitability through finishing, and supplementation level profitability sensitivity relating to corn price and distillers grains price relationship to corn.

MATERIALS AND METHODS

All procedures and facilities utilized were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Six studies, completed from 1987 through 2013, examined a high (HI) and low (LO) winter supplementation level within a forage-based backgrounding system, and subsequent feedlot performance. Four studies utilized long yearling steers, and two studies used spayed heifers. Cattle were purchased as weaned calves in the fall, backgrounded on corn residue with varying supplementation levels, grazed through the summer, and then finished.

In each study, animals were assigned randomly to treatment and initial and system phase weights were an average of two consecutive day's weights (Stock et al., 1983) to minimize differences in fill and obtain accurate gains within phases (Watson et al., 2012). Final BW was calculated from hot carcass weights adjusted to a 62% dressing percentage on steer studies and to a 63% dressing percentage on the spayed heifer studies. Within studies, treatment groups had identical implant procedures and finishing diets.

When cattle of varying types or treatments are compared, it is necessary to do so at an equal fat thickness (Tedeschi et al., 2004). Knowing that carcass gain is constant (MacDonald et al., 2007) and long-yearlings fatten in a linear matter (May et al., 1992) throughout finishing, treatments within studies were adjusted to an equal fat thickness. A

daily fattening rate was determined and then by using this calculated fattening rate, days on feed were adjusted to determine the number of days it would take a treatment group within study to reach an equal fat thickness. Performance measurements were then adjusted based on the number of days to reach an equal fat thickness, a manner similar to Griffin et al. (2007).

In Lewis et al. (1989), each year for two years, 60 British breed yearling steers (initial BW = 237 kg) were wintered 106 days on crop residues beginning in early January. Different levels of supplemental protein and alfalfa hay were fed to achieve a high (0.49 kg) or low (0.28 kg) daily gain. Cattle then grazed cool-season followed by warm-season pastures 116 days until mid-August, and then were finished 113 days.

In Downs et al. (1998), 80 British-breed steers (initial BW = 226 kg), were fed to achieve winter gain levels of approximately 0.32 kg/day or 0.77 kg/day. Steers grazed corn residue, and were then fed bromegrass hay and corn gluten feed, during the 163-day winter period. Steers then grazed eastern Nebraska bromegrass or Sandhills range 124 days from May 6 until September 6, and then entered the feedlot phase.

The third study utilized a design similar to Downs et al. (1998) with steers fed 163 days with 16 head per treatment. Steers then grazed Sandhills range or bromegrass pasture 124 days and were finished (Klopfenstein et al., 1999).

Jordon et al. (2000) used 108 crossbred steers (initial BW = 243 kg) which were wintered on cornstalks from Dec. 4 through Feb. 19 during phase I of winter backgrounding. In phase I, high level supplemented steers were fed 2.27 kg/head/day (DM basis) of wet corn gluten feed and low level supplemented steers were

supplemented with 0.64 kg/head/day (DM basis) of wet corn gluten feed. In phase II of winter backgrounding, steers were drylotted from Feb. 20 through April 28 with both treatments fed ad-libitum ammoniated wheat straw and HI steers also fed 2.27 kg/head/day (DM basis) of wet corn gluten feed. Steers then grazed bromegrass 45 d, native warm season pastures 82 d, and then bromegrass regrowth 26 d. Steers were then finished in a feedlot phase.

Gillespie et al. (2013), used 118 heifer calves (initial BW = 207 kg) which grazed corn residue 138 days and were supplemented with 0.91 kg (LO) or 2.27 kg (HI) wet distillers grains with solubles (WDGS) on a DM basis. Following the winter phase, spayed yearling heifers grazed smooth bromegrass 29 days, grazed native Sandhills range 128 days, and were then fed a common finishing diet for 126 d.

The final study (Gillespie et al., 2013) used 110 heifer calves (initial BW = 223 kg) which grazed corn residue 149 days and were supplemented with 0.91 kg (LO) or 2.27 kg (HI) wet distillers grains with solubles (WDGS) on a DM basis. Following the winter phase, spayed yearling heifers grazed smooth bromegrass 33 days, grazed native Sandhills range 119 days, and were then fed a common finishing diet for 124 d.

Performance values from each of the six studies (Table 1) were adjusted to an equal fat thickness within study as previously described to adjust DOF, ADG, and G:F, and an economic sensitivity analysis was applied to the two backgrounding gain levels to compare supplementation level profitability using four scenarios. Economic scenarios included 1) corn priced at \$5.50/25.4 kg (\$5.50/bu) with distillers grains priced at 85% corn price, **\$5.50 and 85%**; 2) corn priced at \$5.50/25.4 kg (\$5.50/bu) with distillers

grains priced at 105% corn price, **$5.50 and 105%**; 3) corn priced at $7.50/25.4 kg ($7.50/bu) with distillers grains priced at 85% corn price, **$7.50 and 85%,** 4) corn priced at $7.50/25.4 kg ($7.50/bu) with distillers grains priced at 105% corn price, **$7.50 and 105%.**

Initial feeder calf cost and live cattle price was held constant across the four analyses. Initial purchase price, $174.95 per 45.4 kg, was derived from the average November, 2011 price for 182-227 kg medium and large framed, number 1 feeder steers from the Nebraska weekly feeder cattle summary. Cattle were assumed to be sold on a live weight basis using the USDA live steer, 65-80% choice grade, average price for January, 2013, at $125.53 per 45.4 kg, at which date these November, 2011 purchased cattle would actually be sold.

Depending on scenario, stalk grazing, summer grazing, and feedlot diet costs varied. For $5.50/bu corn scenario, stalk grazing cost was $0.31/d per head, summer grazing cost was $0.80/d per head, and feedlot diet cost was $0.115/.454 kg of diet DM. At $7.50/bu corn scenario, stalk grazing cost was $0.35/d per head, summer grazing cost was $0.90/d per head, and feedlot diet cost was $0.156/.454 kg of diet DM. Stalk grazing costs were assumed to include equipment and labor costs to deliver MDGS supplement. Grazing costs were modified from Johnson (2013).

Across scenarios, modified distillers grains (MDGS) was the winter supplement fed at 0.91 kg/head daily for the low supplementation level and 2.27 kg/head daily for the high supplementation level, on a DM basis. Distillers supplement was charged at $0.097,

$0.12, $0.132, and $0.164/.454 kg DM for $5.50 and 85%, $5.50 and 105%, $7.50 and 85%, and $7.50 and 105% scenarios, respectively.

Feedlot yardage was held constant at $0.45 daily per head. Total finishing costs included finishing diet and yardage during finishing.

Profitability was calculated as the total revenue at finish less initial calf purchase, winter backgrounding costs, summer grazing costs, and finishing costs.

Given profitability results, corn price/bu was then adjusted to determine the point at which HI and LO had equal profit within each of the four scenarios. All economic assumptions were held constant for each scenario, with only corn price varied (which consequently varied MDGS supplement price as well).

Statistical analyses

Data were analyzed using the GLIMMIX Procedure of SAS (SAS Inst., Inc., Cary, NC). Performance data and profitability comparisons were analyzed as a complete block design with treatment within study serving as the experimental unit. Winter supplementation level (HI or LO) was a fixed effect, and study was included as a random effect to overcome differences across years. Effects of the treatment were considered significant when $P < 0.05$ as detected by the Fischer test.

RESULTS AND DISCUSSION

Cattle performance

By design, there was no difference in initial BW. Calves supplemented at HI level gained 0.64 kg/d, compared to 0.26 kg/d for cattle at the LO level ($P < 0.01$) during

winter backgrounding. Because supplements varied among the six studies used in this analysis, it is difficult to directly identify the reason for the increased response. However, growing calves require greater protein levels for growth, particularly when grazing corn residue where CP is often a limiting nutrient (Fernandez-Rivera and Klopfenstein, 1989) so it is logical to assume that the additional gain for HI cattle is a response to additional protein supplied, or energy provided above their maintenance requirement.

Summer grazing (132 days) (Table 2) were identical between treatments (P = 1.0). Cattle supplemented at the LO winter level gained 0.15 kg/d (P = 0.02) more during the summer phase, (0.63 kg/d for LO compared to 0.48 kg/d for HI). The greater summer gain by LO is a classic compensatory gain response, which is well documented and defined as the accelerated and/or more efficient growth that commonly follows a period of growth restriction (Bohman et al., 1955). Compensatory gain values often range from 18% to 100% (Jordan et al., 2000), and cattle in this dataset compensated for 39% of HI's gain value. While compensatory gain has been the basis for backgrounding systems, it's important to realize that restricted cattle's compensation does not typically reach 100%. Unless restricted cattle gain at a level greater than their non-compensating counterparts while in the feedlot, they will finish with a lower final BW regardless of their compensatory gain.

Finishing DOF were similar (P = 0.51) between treatments (Table 2), but numerically LO cattle required an additional 4 days to reach a common fat endpoint as they entered the feedlot phase at a lighter BW and gained less as well. Downs et al.

(1998), observed that cattle backgrounded at a high winter gain (0.76 kg) compared to a low gain (0.32 kg) and then summered on Sandhills range required 28 less DOF.

Total DMI and feed efficiency were similar across treatments, and consistent in each of the six studies used in the analyses. These results agree with Hersom et al. (2004) who varied stocking rates on winter wheat pasture to produce a high winter gain (1.31 kg) and low winter gain (0.54 kg) and then saw no differences in DMI or feed efficiency due to backgrounding. Pavan and Duckett (2008) saw no difference in feedlot DMI or G:F due to backgrounding supplement type (corn grain or corn oil) on tall fescue pasture. Additionally, Buttrey et al. (2012), supplemented dry rolled corn or DDG on wheat pasture and did not affect feedlot or carcass characteristics, with the exception of G:F compared to no supplement.

Interestingly, gain during finishing was greater ($P = 0.05$) by 0.09 kg/d for HI cattle. The compensatory gain response has been well established, but has typically been examined in only two phases, nutrient restriction followed by increased nutrient availability. This three phase system including nutrient restriction (corn residue with LO vs HI), increased nutrient availability (summer grazing), and finally a high concentrate diet (finishing) shows the opportunity for secondary compensatory gain with gain from HI greater during the winter, lower in the summer, and greater during finishing relative to LO.

The increase in daily gain for HI coupled with their maintained weight advantage from the winter phase, resulted in 37 kg greater final weight ($P < 0.01$) for HI cattle at 596 kg, compared to 559 kg for LO cattle. Increased final BW from a higher winter

supplementation level has been previously observed, but its importance has been inconsistently appreciated. Lewis et al. (1989) attributed the tendency for increased feedlot gain to greater DMI and of little economic value, concluding that wintering cattle above 0.27 kg gain was not beneficial. However, Downs et al. (1998) also observed a final BW advantage to cattle from a high winter gain, but instead concluded that a higher winter gain was justified as it produced heavier steers with less DOF.

In this analysis, each additional 1 kg of winter gain from HI, produced 0.65 extra kg of final weight. This response exceeds that of Klopfenstein et al. (1999), who reported an added 0.46 kilograms of final BW for every kilogram of additional winter gain.

Economic Analyses

Across all scenarios (Table 3), stalk grazing costs were similar between HI and LO. Additional MDGS supplement for HI resulted in significantly greater ($P < 0.01$) MDGS cost and total winter cost for HI, ranging from a $42 difference between HI and LO for $5.50 and 85% to a $71 difference for $7.50 and 105%, with $5.50 and 105% and $7.50 and 85% intermediate.

In each scenario, summer grazing cost was similar ($P = 1.0$) for HI and LO at $110.00 for $5.50/bu corn scenario, or $123.75 for $7.50/bu corn scenario. The lack of DMI and diet cost differences in this study coupled with similar yardage costs produced similar total finishing costs ($P > 0.73$) between HI and LO at $420.66 (LO) and $414.26 (HI) with $5.50/bu corn, or $552.42 (LO) and $544.34 (HI) with $7.50/bu corn.

Across all studies, initial calf cost was similar between treatments ($P = 0.36$), winter costs were greater for HI than LO ($P < 0.01$), summer costs were similar ($P = 1.0$),

and finishing costs were similar (*P* > 0.73). Total costs tended to be greater for HI than LO when distillers grains were priced at 85% corn price, and total cost was significantly greater for HI than LO when distillers grains were priced at 105% corn price.

Due to the additional WDGS input for HI during the winter phase, but similar summer and finishing costs, it is logical HI would have a greater production cost. The difference in total cost between HI and LO is more pronounced when distillers grains are priced higher (105%) than lower (85%) relative to corn.

Despite additional costs for HI, the additional 37 kg of weight from HI produced an added $100.84 revenue (*P* < 0.01) compared to LO cattle.

Overall, profitability was $68.18 greater for HI (*P* < 0.01) compared to LO at $5.50 and 85% (Table 4), $58.28 greater for HI (*P* = 0.01) at $5.50 and 105% (Table 5), $54.57 greater for HI (*P* = 0.02) at $7.50 and 105% (Table 6), and $41.12 greater for HI (*P* = 0.04) at $7.50 and 105% (Table 7). At both the low corn price and the low distillers price, there was a greater profit response with high winter supplementation level than was observed with the high corn price and high distillers price. Because revenue was constant among studies, the greater winter cost due to supplement price is responsible for the various responses in profit difference across studies.

Clearly the greater final weight and consequently greater revenue from HI offset greater supplementation costs, regardless of scenario (Table 8). This is in agreement with Jordan et al. (2002) who concluded heavier HCW (and presumably final BW) was negatively correlated to slaughter (or presumably live) breakeven, and positively correlated to profit. Because weight is a major economic driver in beef production (Shain

et al., 2005; Tatum et al., 2006), the greater final weight from HI was the key to the profit difference.

Given these results, corn price/25.4 kg was then adjusted to determine the point at which HI and LO had equal profit within each of the four scenarios. That breakpoint was $14.50, $11.70, $14.65, and $11.90/25.4 kg, at $5.50 and 85%, $5.50 and 105%, $7.50 and 85%, and $7.50 and 105%, respectively (Table 9). Due to this breakpoint occurring at a lower corn price/bu when distillers grains were priced at 105% versus 85% corn value, we can conclude that as distillers grains price increases, the point at which HI supplementation no longer has a profit advantage decreases.

Logically, if corn price were to hit these breakpoint levels, then stalk grazing, summer grazing, and feedlot diet costs would also increase, impacting this breakpoint as well. Further, cattle may be fed to a greater final BW if corn price rose to these breakpoint levels, which would increase revenue. However, this illustrates that corn price/25.4 kg would have to dramatically increase before increased winter gains from supplementation level would no longer be profitable.

CONCLUSIONS

Cattle developed on a higher nutrition plane during the winter backgrounding phase had a 0.09 kg/d greater ADG during finishing. The performance advantage of HI cattle was maintained through the system, resulting in an additional 37 kg of final BW.

Total profitability across these four scenarios resulted in an average $54.86 additional profit when backgrounding cattle at a 2.3 kg/head/day MDGS supplement level, compared to a 0.9 kg/head/day supplementation level. Regardless of corn price or

distillers grains price relative to corn, HI was more profitable than LO. When economic assumptions were held constant, corn price/bu would have to exceed at least $11.70/25.4 kg, regardless of scenario, for HI supplementation to no longer have a profit advantage compared to LO.

IMPLICATIONS

These data illustrate that the historical backgrounding philosophy of minimizing winter feed costs does not account for additional performance from increased winter inputs, and the optimum level of winter gain in a forage-based system should be elucidated. In addition, a secondary compensatory gain response is possible for cattle in a three phase system, and high winter level supplementation is more profitable than low winter supplementation.

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Table 1. Backgrounding and finishing average performance across six systems studies comparing winter supplement level

	LO	HI	SEM	*P* – value
Winter backgrounding phase				
Initial BW, kg	227	226	0.54	0.36
ADG, kg	0.26[a]	0.64[b]	0.04	<0.01
Summer grazing phase				
ADG, kg	0.63[a]	0.48[b]	0.03	0.02
Compensation, %	35[1]			
Finishing phase				
DOF	114	110	3.72	0.51
ADG, kg	1.82[a]	1.90[b]	0.02	0.05
Total DMI, kg	1,459	1,440	43.1	0.77
Gain : feed, kg	0.146	0.147		0.63
Final BW, kg	559[a]	596[b]	4.38	<0.01

[ab]Means with different superscripts differ ($P < 0.05$).
LO = cattle supplemented during the winter phase for a low daily gain
HI = cattle supplemented during the winter phase for a high daily gain
[1]Percent compensation, calculated as difference in total kg of summer gain divided by difference in total kg of winter gain.

Table 2. Days in production phase within entire system

	LO[1]	**HI**[2]	**SEM**	***P* – value**
Backgrounding days	144	144	0	1.0
Summer grazing days	138	138	0	1.0
Finishing DOF	114	110	3.72	0.51

[1]LO = cattle supplemented during the winter phase for a low daily gain
[2]HI = cattle supplemented during the winter phase for a high daily gain

Table 3. Economic assumptions using $5.50/25.4 kg or $7.50/25.4 kg corn and distillers grains priced at 85% or 105% value of corn

Scenario[1]	Purchase price, $/45.4 kg	Stalk grazing, $/day	Summer grazing, $/day	Feedlot diet, $/.454 kg	Feedlot yardage, $/day	MDGS[2], $/45.4 kg	Sale price, $/45.4 kg
$5.50 and 85%	174.95	0.31	0.80	0.115	0.45	0.097	$125.53
$5.50 and 105%	174.95	0.31	0.80	0.115	0.45	0.12	$125.53
$7.50 and 85%	174.95	0.35	0.90	0.156	0.45	0.132	$125.53
$7.50 and 105%	174.95	0.35	0.90	0.156	0.45	0.164	$125.53

[1] Scenario corn price ($/bu) and distillers grains price percentage relative to corn price
[2]MDGS assumed to be fed at 0.91 kg/head daily for LOW cattle and 2.27 kg/head daily for HI cattle

Table 4. Profitability of High and Low winter supplementation levels at $5.50/25.4 kg corn and distillers grains priced at 85% value of corn

	LO[1]	**HI**[2]	**SEM**	***P* – value**[3]
Winter backgrounding phase, $/hd				
Stalk grazing cost	44.69	44.69	0	1.0
MDGS cost	27.99	69.97	2.73	<0.01
Summer grazing phase, $/hd				
Grazing cost	110.00	110.00	0	1.0
Finishing phase, $/hd				
Diet cost	369.55	364.84	15.44	0.77
Yardage	51.11	49.43	1.67	0.51
Profitability, $/hd				
Initial cost	$873.87	$870.96	2.1	0.36
Winter cost	72.69	114.66	1.18	<0.01
Summer cost	110.00	110.00	0	1.0
Finishing cost	420.66	414.26	12.49	0.73
Revenue	1545.90	1646.74	12.10	<0.01
Total cost	1477.22	1509.9	11.71	0.11
Profit	68.68	136.86	9.78	<0.01
Profit difference		$68.18		

[1]LO = cattle supplemented during the winter phase for a low daily gain
[2]HI = cattle supplemented during the winter phase for a high daily gain
[3]Means with $P < 0.05$ differ

Table 5. Profitability of High and Low winter supplementation levels at $5.50/25.4 kg corn and distillers grains priced at 105% value of corn

	LO[1]	HI[2]	SEM	*P* – value[3]
Winter backgrounding phase, $/hd				
Stalk grazing cost	44.69	44.69	0	1.0
MDGS cost	34.57	86.44	2.19	<0.01
Summer grazing phase, $/hd				
Grazing cost	110.00	110.00	0	1.0
Finishing phase, $/hd				
Diet cost	369.55	364.84	10.91	0.77
Yardage	51.11	49.43	1.67	0.51
Profitability, $/hd				
Initial cost	873.87	870.96	1.62	0.36
Winter cost	79.26	131.13	2.19	<0.01
Summer cost	110.00	110.00	0	1.0
Finishing cost	420.66	414.26	12.49	0.73
Revenue	1545.90	1646.74	12.10	<0.01
Total cost	1483.81	1526.35	11.44	0.05
Profit	62.11	120.39	9.45	0.01
Profit difference		58.28		

[1]LO = cattle supplemented during the winter phase for a low daily gain
[2]HI = cattle supplemented during the winter phase for a high daily gain
[3]Means with $P < 0.05$ differ

Table 6. Profitability of High and Low winter supplementation levels at $7.50/25.4 kg corn and distillers grains priced at 85% value of corn

	LO[1]	HI[2]	SEM	*P* – value[3]
Winter backgrounding phase, $/hd				
Stalk grazing cost	50.46	50.46	0	1.0
MDGS cost	38.17	95.42	2.42	<0.01
Summer grazing phase, $/hd				
Grazing cost	123.75	123.75	0	1.0
Finishing phase, $/hd				
Diet cost	501.31	494.91	14.81	0.77
Yardage	51.11	49.43	1.67	0.51
Profitability, $/hd				
Initial cost	$873.87	$870.96	2.06	0.36
Winter cost	88.62	145.88	2.42	<0.01
Summer cost	123.75	123.75	0	1.0
Finishing cost	552.42	544.34	16.38	0.74
Revenue	1545.90	1646.74	12.10	<0.01
Total cost	1638.67	1684.92	14.81	0.07
Profit	-92.76	-38.19	11.55	0.02
Profit difference		54.57		

[1]LO = cattle supplemented during the winter phase for a low daily gain
[2]HI = cattle supplemented during the winter phase for a high daily gain
[3]Means with $P < 0.05$ differ

Table 7. Profitability of High and Low winter supplementation levels at $7.50/25.4 kg corn and distillers grains priced at 105% value of corn

	LO[1]	HI[2]	SEM	*P* – value[3]
Winter backgrounding phase, $/hd				
Stalk grazing cost	50.46	50.46	0	1.0
MDGS cost	47.15	117.87	2.99	<0.01
Summer grazing phase, $/hd				
Grazing cost	123.75	123.75	0	1.0
Finishing phase, $/hd				
Diet cost	501.31	494.91	14.81	0.77
Yardage	51.11	49.43	1.67	0.51
Profitability, $/hd				
Initial cost	873.87	870.96	2.06	0.36
Winter cost	97.61	168.33	2.99	<0.01
Summer cost	123.75	123.75	0	1.0
Finishing cost	552.42	544.34	16.38	0.74
Revenue	1545.90	1646.74	12.10	<0.01
Total cost	1647.65	1707.37	14.78	0.04
Profit	-101.75	-60.63	11.06	0.05
Profit difference		41.12		

[1]LO = cattle supplemented during the winter phase for a low daily gain
[2]HI = cattle supplemented during the winter phase for a high daily gain
[3]Means with $P < 0.05$ differ

Table 8. Profitability of High and Low winter supplementation across economic scenarios

Scenario[1]	LO	HI	SEM	Profit difference	*P* - Value
$5.50/25.4 kg corn, 85%	$68.68	$136.86	9.78	$68.18	<0.01
$5.50/25.4 kg corn, 105%	$62.11	$120.39	9.45	$58.28	0.01
$7.50/25.4 kg corn, 85%	$-92.76	$-38.19	11.55	$54.57	0.02
$7.50/25.4 kg corn, 105%	$-101.75	$-60.63	11.06	$38.42	0.05

[1]Scenario from which economic assumptions were used, 85% = MDGS priced at 85% corn price, 105% = MDGS priced at 105% corn price

LO = cattle supplemented during the winter phase for a low daily gain

HI = cattle supplemented during the winter phase for a high daily gain

Profit difference = Profit advantage of supplementing at a high winter level over low winter level

Table 9. Corn price at which high and low winter supplementation levels result in equal profit

Scenario Assumptions[1]			
Corn price/25.4 kg	Distillers price relative to corn	Table[2]	Corn Price/25.4 kg[3]
$5.50	85%	5	$14.50
$5.50	105%	6	$11.70
$7.50	85%	7	$14.65
$7.50	105%	8	$11.90

[1]Scenario from which economic assumptions were used
[2]Table number listing complete economic assumptions
[3]Corn price/25.4 kg = The corn price/25.4 kg at which point there would be no profit difference between cattle supplemented at a low or high supplementation level

Chapter IV. Replacement of Grazed Forage and Animal Performance when Distillers Grains are fed in a Bunk or on the Ground

K. L. Gillespie*, L. A. Stalker‡, T. J. Klopfenstein*, J. D. Volesky†, J. A. Musgrave*, B. L. Nuttelman*, C. J. Schneider*,

*Department of Animal Science, University of Nebraska, Lincoln 68583; †Department of Agronomy & Horticulture, University of Nebraska, Lincoln 68583, ‡University of Nebraska, West Central Research and Extension Center, North Platte 69101

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[2]Corresponding author: 402 W. State Farm Road; E-mail: astalker3@unl.edu

ABSTRACT

A two year completely randomized grazing experiment estimating forage savings and ground feeding efficiency when supplementing spayed yearling heifers with modified distillers grains (MDGS) on native range was completed. Heifers (n=24, BW = 282 ± 26 kg) grazed Sandhills range 120 d beginning approximately May 21. Treatments were no supplementation (CON), ground-fed MDGS at 0.6% BW (GRD), or bunk fed MDGS at 0.6% BW (BNK). There were four heifers per replication with two replications per treatment. Each treatment group rotated through six one-hectare paddocks. Rotation length was longer for grazing cycle two due to forage growth stage. A 17% forage savings from MDGS supplementation at 0.6% BW was assumed based on smooth bromegrass research, thus supplemented groups grazed their paddocks 17% longer than CON each rotation. In cycle two, all early, middle, and late rotationally grazed paddocks were hand-clipped to determine residual forage. Diet samples were collected via esophageally fistulated cows at mid-point of the grazing period to estimate forage quality over the grazing season. Supplemented cattle gained more per day ($P < 0.01$) and had greater final BW ($P < 0.01$) than CON. There was no difference in ADG ($P = 0.28$) or ending BW ($P = 0.91$) between GRD and BNK. Daily gains were 0.43, 1.03, and 1.09 kg/d for CON, GRD and BNK respectively, with final BW's of 325, 368, and 373 kg, respectively. A retrospective analysis determined 5.6% of offered MDGS was lost when ground fed. Residual forage indicated control cattle consumed similar forage to supplemented cattle ($P = 0.31$), indicating forage savings when supplementing MDGS at 0.6% BW was approximately 17%. Supplementing MDGS at 0.6% BW can be fed to decrease forage consumption and increase summer grazing gains. Supplementation of

distillers grains to spayed yearling heifers increased ADG and ending BW and decreased forage consumption, with no statistical difference between BNK and GRD.

KEYWORDS: Beef cattle, supplement, bunk

INTRODUCTION

Distillers grains fits well into forage situations as it is a highly fermentable fiber source which does not hinder forage digestion, and also supplies undegradable intake protein (UIP) to meet metabolizable protein deficiencies common in grazing situations (MacDonald et al., 2004).

Distillers grains supplementation increases ADG of growing cattle while reducing forage intake in a forage-based system *(*Morris et al., 2005). Forage intake was reduced 0.23 kg for each .45 kg of distillers grains fed, as summarized from six distillers grains supplementation studies (Klopfenstein et al., 2007). Distillers grains loss when ground-fed appears to be affected by distillers grain form, animal type, and grazing situation. Wet distillers grains with solubles (WDGS) fed to yearling steers on Sandhills winter range resulted in a 13-20% loss (Musgrave et al., 2010), while dried distillers grains with solubles (DDGS) fed to calves on a subirrigated meadow resulted in a 36-41% loss (Musgrave et al., 2012). Thus, this study's objectives were to determine forage replacement rate and performance of spayed yearling heifers when supplemented with MDGS at 0.6% BW in a native Sandhills range situation, and calculate MDGS loss that resulted from ground feeding.

MATERIALS AND METHODS

All procedures and facilities utilized were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Each year of a two year study, 24 spayed yearling heifers were stratified by initial BW (282 ± 26 kg) and assigned randomly to treatment in a completely randomized design. Treatments were no supplementation (control), MDGS supplementation fed at 0.6% of BW daily in a bunk, and MDGS supplementation fed at 0.6% of BW daily on the ground. Ground-fed heifers were fed at a different location within their paddock each day. There were two replications per treatment, with four heifers per replication per year. Treatments were assigned randomly and blocked by location to minimize differences in plant species and topography.

Heifers grazed upland Sandhills summer range 120 days at the Gudmundsen Sandhills Laboratory (11 km northeast of Whitman, Nebraska (lat 42°04′N, long 101°26′W, elevation = 1075 m), beginning May 18, 2011, in year 1 and May 23, 2012 in year 2. At the conclusion of summer grazing, heifers were transported to the ARDC, limit fed five days at 1.8% BW (DM) to minimize differences in gut fill (Watson et al., 2012), and weighed on the last two days of the limit feeding period. Final BW was the mean of consecutive day BW measurements (Stock et al., 1983).

Within year, distillers supplementation feeding amount was adjusted monthly based on an assumed ADG of 0.68 kg/d (Rolfe et al., 2011). Samples of MDGS were collected every 15 d to calculate DM and used to adjust feeding amount to 0.6% BW on a

DM basis. A composite of the MDGS samples was analyzed for nutrient composition (Table 1).

Each replication rotated through six, 1-hectare paddocks twice throughout the grazing season. Paddocks were stocked at 1.98 AUM/ha (0.8 AUM/acre). Grazing days per paddock were increased during the second grazing cycle to account for additional forage growth. Pastures were stocked to test the forage savings hypothesis that each kilogram of distillers grains replaces approximately 0.79 kg of forage (Watson et al. 2012). This was accomplished by causing supplemented cattle to graze each of their paddocks 17% longer than control cattle, and was done by moving control cattle either one or 2.5 days earlier than supplemented cattle during a six- and 14-day grazing cycle, respectively. This was done by moving control cattle from their grazing paddock to a paddock of similar forage species composition that was not part of the 6 paddock rotation, at the conclusion of their grazing days. There, control cattle were managed separately until rotating into their next paddock on the same day that supplemented cattle rotated. It was hypothesized there would be similar amounts of residual forage between pastures grazed by supplemented and control cattle at the end of each grazing rotation. Residual forage was clipped to test this hypothesis.

Diet quality estimates (Table 2, 3) were obtained using esophageally fistulated cows at the mid-point of each grazing rotation during the first, third, and fifth rotations of both grazing cycles. Three esophageally fistulated cows were fasted overnight, had collection bags attached and then allowed approximately 20 minutes to sample the selected paddock. One paddock grazed by bunk-fed, ground-fed, and control heifers were sampled each collection period.

In year 1, extrusa samples were collected using screen bottom bags and then following collection, total sample was hand mixed, and a representative sample was placed in a sealable, plastic bag to be freeze dried. In year 2, extrusa samples were collected using solid bottom bags and following collection period, all sample contents were placed in a sealable, plastic bag and then transported from the field to the lab where the entire sample was weighed. Sample was then placed in a food grade style colander, and liquid portion of the sample was collected. The liquid and remaining fibrous components of the sample were then weighed, and a sample of the fibrous component was used for a dry matter analysis. The remaining fibrous component of the sample was then freeze dried, and a representative sample of the liquid component was frozen for further laboratory analysis. Following freeze drying, samples were ground through a Wiley mill (Thomas Scientific, Swedesboro, NJ) fitted with a 1-mm screen for further laboratory analysis.

Extrusa samples were analyzed for CP, NDF, and IVDMD. *In vitro* dry matter digestibility (year 1) and *in vitro* organic matter digestibility (year 2) was determined through two separate *in vitro* runs using the Tilley and Terry method (1963) modified by the addition of 1 g/L of urea to the McDougall's buffer solution (Weiss, 1994). Five forage standards of varying qualities with known *in vivo* DM digestibilities were included in both IVDMD runs. Regression equations were generated for each run by regressing the IVDMD values of the standards on their known digestibilities to then correct all the IVDMD to *in vivo* values, as described by Stalker et al. (2013). The Van Soest et al. (1991) and Van Soest and Marcus (1964) methods were used to determine NDF content. Crude protein was calculated as N x 6.25 with nitrogen concentration determined by

combustion method (AOAC, 1999) using a N combustion analyzer (Leco FP-523, St. Joseph, MO).

In year 2, CP, NDF, and IVOMD analyses were calculated to account for solid and liquid proportion of sample. The nutrient evaluated (CP, NDF, IVOMD) from both the liquid and solid component of the sample was multiplied by its respective percentage liquid or percentage solid proportion, and then summed.

To test forage savings hypothesis, 10 quadrats (1 m^2) were hand clipped at ground level in each paddock at the conclusion of grazing each paddock during the first, third, and fifth grazing periods of the second grazing cycle (early July, early August, late August, respectively). Forage was sorted by live grass, standing dead, litter, forbs, and shrubs. Samples were dried in a forced-air oven for 48 hours at 60°C and weighed. Total live material was calculated as live grass, forbs, and shrubs. Standing dead represented previous year's growth, and litter represented any material on the ground grown in years prior to previous growing season. Residual forage per acre was then calculated to verify forage replacement and evaluate the equal grazing pressure hypothesis between treatments (Table 4).

The 1996 NRC model was used to estimate range forage intake based on known cattle performance (Table 5) and supplement offered, in a manner similar to that described by MacDonald, et al. (2007). The model also was used to retrospectively calculate the MDGS intake difference between bunk and ground-fed treatments.

Data were analyzed using the GLIMMIX Procedure of SAS (SAS Inst., Inc., Cary, NC). Animal was the experimental unit, treatment was considered a fixed effect,

and year was a random effect. Effects of treatment were considered significant when $P < 0.05$ as detected by the Fischer test. When the F-test was significant, least squares means of treatments were separated using a t-test when $P < 0.05$.

RESULTS AND DISCUSSION

During the grazing season, paddocks averaged 10% CP, 66% NDF, and 61% IVDMD during year 1 (Table 2). In year 2, paddocks averaged 7.5% CP, 69.4% NDF, and 65.1% IVOMD (Table 3). Across years, there was a general forage quality decline throughout the grazing season, as CP and IVDMD or IVOMD decreased, and there was a general increase in NDF as forages matured.

Digestibility values were numerically greater in year 2, which is similar to Geisert et al. (2008b) who reported diet samples collected during drought were higher digestibility than during a normal year. Geisert et al. (2008b) attributed greater digestibility values under drought to decreased precipitation delaying plant maturity. Geisert et al. (2008b) reported IVOMD values of 59.1% and 55.4% for a drought and post-drought year, respectively. Given the observation of Giesert et al. (2008b) and the low CP values for year 2, it is puzzling why IVOMD values in the current dataset exceed 60%.

Diet sampling methodology in the current study was different from Geisert et al. (2008a; 2008b). Musgrave et al. (2013), demonstrated that squeezing diet samples, as was done in Giesert et al. (2008b), significantly skews forage nutrient composition, particularly NDF and IVDMD. In addition, Musgrave et al. (2013) noted saliva contamination from fistulated animal increased ash content of diet sample. Given the

Musgrave et al. (2013) dataset, it is reasonable that forage quality results in the current study would differ somewhat from that observed by Giesert et al. (2008b) given different methodologies used.

In addition, year 1 digestibility values in this dataset are expressed on a DM basis, but on an OM basis in year 2. Therefore, it is logical that year 2 values would be somewhat higher simply by virtue of expressing digestibility on an OM basis. However, IVOMD values from year 2 seem surprisingly high, perhaps new lab correction procedures are inflating diet sample quality values. Also taking into consideration the year 2 drought and therefore the potential that cattle were consuming year-old forage, these values presented are higher than expected.

Further, NDF values were numerically higher in year 2 than year 1, indicating that forage selected in year 2 had a greater proportion of highly lignified, lower digestible tissues than in year 1. These NDF values and CP values of forage quality are similar to what Geisert et al. (2008) observed in September and October, but IVOMD values are similar to what Geisert et al. (2008) observed in May, thus the lack of consistent relationship between forage quality parameters is puzzling.

By design, heifer initial BW was similar across treatments ($P = 0.82$). Supplemented cattle gained more (1.06 vs. 0.43 kg/d; $P < 0.05$) and had greater ending BW (417 vs. 337 kg; $P < 0.05$) than CON (Table 5).

This 0.63 kg ADG response to MDGS is greater than the 0.30 kg ADG increase Rolfe et al. (2011) observed for yearling steers ground supplemented with MDGS on Sandhills range. The current response is also greater by 0.14 kg or 0.09 kg than Gillespie

et al. (2013) observed with spayed yearling heifers and conditions similar to Rolfe et al. (2011). Furthermore, Watson et al. (2012) observed a 0.27 kg ADG increase for yearling steers bunk supplemented DDGS on bromegrass, at the same level, also less than the current response.

However, the current response is remarkably similar to that of Gustad et al., (2008), who observed a 0.68 kg ADG response when lightweight, summer-born, spayed yearling heifers and yearling steers were supplemented with 2.3 kg/d (DM) DDGS on paddocks stocked at double the recommended stocking rate. Gustad et al. (2008) research was conducted at the same study location as the current study, thus response may be impacted by inherent location differences, small paddock size, or the similarity of using lightweight cattle.

These data show a 0.35 kg ADG increase for each kg of MDGS supplemented. This response is greater than that seen in other studies for each kg DGS fed, Klopfenstein et al. (2007) reported a 0.13 kg/d increase in ADG, Watson et al. (2012) reported 0.11 kg/d ADG increase, and Morris et al. (2005) reported 0.20 kg/d increase. Klopfenstein et al. (2007) did not report DGS type fed (wet, modified, or dry), whereas Watson et al. (2012) and Morris et al. (2005) both used DDGS. While drying DGS does decrease its energy value in finishing rations (Bremer et al., 2011; Nuttelman et al., 2013), there was no performance difference when DDGS and WDGS were used in a growing study (Ahern et al., 2011), so it does not seem likely that drying differences among distillers supplement would account for the greater response between these studies.

Forage quality analysis of diet samples over the grazing season averaged 9.7% CP in year 1, and 7.5% in year 2, which is lower than the 15.4% CP in the Watson et al. (2012) bromegrass pastures. It has been demonstrated that cool season plants, such as bromegrass, are higher in CP (Wilson et al., 1983) than warm season plants, which dominate the Sandhills (Bragg and Stueter, 1995). In Watson et al. (2012), yearlings consumed enough forage to meet their CP requirement, but had a 99 g/d MP deficiency. Thus the DDGS response was concluded to be a result of the DDGS high RUP content (65% of DM) meeting steers' UIP needs. Forage supplies low amounts of RUP, and because forage in this study was even lower CP than that of Watson et al. (2012), it is likely that the MDGS was meeting a MP deficiency and response was even more pronounced than Watson et al. (2012) observed.

Because gain response to MDGS was greater during drought (year 2; Table 5), these data suggest that with DGS supplementation, animal performance can be maintained comparable to a non-drought year.

Heifers supplemented on the ground (Table 5) gained 0.06 kg/d less than those fed in bunks, a difference that was not statistically significant ($P = 0.16$). The similar performance between bunk-fed and ground-fed calves is similar to Sexten et al. (2011), who observed no performance advantage to bunk-feeding calves DDGS on tall-fescue pasture, compared to ground-feeding.

In contrast, bunk feeding increased gain with both yearling steers fed WDGS on native Sandhills winter range (Musgrave et al., 2010) and steer calves fed DDGS on subirrigated meadow (Musgrave et al., 2012). However, ground-feeding loss was

calculated to be 13-20% with the yearling steers ground-fed WDGS (Musgrave et al., 2010), and 36-41% with the steer calves ground-fed DDGS (Musgrave et al., 2012). In the current study, a retrospective analysis estimated 5.6% of offered MDGS was lost when ground-fed, by using the 0.06 kg/d difference in performance from bunk and ground-fed heifers. Thus, the greater efficiency of picking up distillers grains in this study resulted in no performance difference between bunk-fed and ground-fed heifers.

Differences in distillers grains form (wet or dry) and ground type used impacted ground feeding efficiency in Musgrave's work, as DDGS on subirrigated meadow resulted in greater loss (36-41%) than WDGS on native, upland range (13-20%). This was attributed to the small grain particle size of DDGS being difficult for cattle to consume among the dense plant growth of a meadow.

Thus, if a higher moisture type of distillers grains coupled with a native, upland range is more desirable for ground-feeding efficiency, it's logical that the loss reported in this study would be similar to the 13-20% loss in Musgrave et al. (2010). The greater efficiency in this study, though, may be due to yearlings' familiarity with distillers grains. Prior to the summer supplementation study, heifers had been backgrounded on corn residue with daily WDGS supplement, so may have already experienced the learning behavior of consuming distillers grains in comparison to the newly weaned calves in Musgrave et al. (2010). In addition, weights in the current study were limit-fed weights, whereas Musgrave's were not, thus performance differences (and consequently ground feeding-loss) may have been inflated given Watson et al., (2012b). Watson et al. (2012b) concluded limit-fed weights are less variable and more accurate than weights taken from cattle not limit-fed.

Through use of the NRC model using known animal weights and ADG, forage intake of CON and BNK was estimated. By using the MDGS intake of BNK with the forage DMI difference of CON and BNK cattle, it was calculated that in year 1, 1 kg MDGS replaced 0.63 kg forage. This is a 15.6% forage replacement rate and is similar to Watson et al. (2012) who reported yearling steers grazing bromegrass replaced 0.79 kg of forage per kilogram of DDGS supplement. MacDonald et al. (2007) estimated forage intake using a chromic oxide marker and found 0.50 kg forage replaced for each kilogram of DDGS supplement.

In year 2, forage growing conditions were under severe drought (Tables 6 and 7, Figures 1 and 2) which resulted in CON gaining 0.20 kg less in year 2 than year 1 (Table 5). Due to poor CON gains, it would have been inappropriate to use a similar NE adjuster with the NRC to estimate forage intake. Thus, forage savings was instead estimated from residual forage clip data in year 2.

If average animal performance values across the two years are used, 1 kg of MDGS supplement fed replaced approximately 0.53 kg of forage intake. This equates to a 12.9% forage replacement rate and is less than what Watson et al. (2012) and MacDonald et al. (2007) observed. This lower forage replacement value is likely due to differences in forage replacement from year 1 to year 2 and can be attributed to differences in forage availability related to drought.

There was no difference ($P = 0.31$) in residual forage among paddocks grazed by different treatment groups (Table 3). This lack of difference illustrates similar grazing pressure by supplemented and unsupplemented heifers, as grazing days had been adjusted

assuming a 17% forage savings when supplementing MDGS at 0.6% BW to yearlings in a range situation.

IMPLICATIONS

Supplementing MDGS to spayed yearling heifers at 0.6% BW daily increased summer grazing gains and final BW. There was no performance advantage to bunk feeding over ground feeding. Forage replacement was affirmed to be approximately 17% based on residual forage.

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Table 1. Nutrient analysis of modified distillers grains with solubles

Nutrient	DM, %
CP	31.41%
Ether extract	12.25%
NDF	24.95%

Table 2. Forage quality over time[1] Year 1

Sample dates	5/20-21	6/1-2	6/13-14	6/23-24	7/21-22	8/18-19
CP%	10.6	10.3	11.1	8.8	8.4	8.7
NDF%	64.9	64.6	55.8	69.1	70.6	70.8
IVDMD%	65.5	64.8	64.5	66.9	56.0	50.5

[1]Sequence of grazing paddocks over summer, from May 20 through August 19, 2011

Table 3. Forage quality over time[1] Year 2

Sample dates	5/25-26	6/6-7	6/18-19	6/28-29	7/26-27	8/23-24
CP%	9.5	9.0	7.4	6.4	6.4	6.3
NDF%	68.9%	69.6%	68.2%	72.8%	71.7%	65.4%
IVOMD%	66.9	66.4	66.2	65.4	64.0	61.6

[1]Sequence of grazing paddocks over summer, from May 25 through August 24, 2012

Table 4. Residual forage post-grazing (kg/ha) [1] (Year 1 and 2)

	Treatment[2]				
	Control	Bunk-fed	Ground-fed	SEM	*P*-value
Total live[3]	827	1032	947	473	0.31
Standing dead	630.25	595.94	641.65	105	0.89
Litter	1359	1192	1285	338	0.64

Means with different superscripts differ (*P*-value < 0.01)

[1]Average post-grazing values from six paddocks per treatment over three clipping dates (early July, late July, late August)

[2]Paddocks grazed by control cattle, bunk-fed cattle, or ground-fed cattle

[3]Total live represents live grass, forbs, and shrubs

Table 5. Performance response of heifers to distillers grains

	Treatment				
	Control[1]	Ground-fed[2]	Bunk-fed[3]	SEM	*P*-value
Initial BW (kg)	283	283	281	1.5	0.82
ADG (kg) Year 1	0.53[a]	1.08[b]	1.14 [b]	0.03	<0.01
ADG (kg) Year 2	0.33[a]	0.99[b]	1.05[b]	0.04	<0.01
ADG (kg) Year 1 & 2	0.43[a]	1.03[b]	1.09[b]	0.07	<0.01
Ending BW (kg)	337[a]	414[b]	419[b]	3.5	<0.01

[1] Control = Cattle grazed with no MDGS supplement
[2] Ground-fed = Cattle supplemented with MDGS daily at 0.6% BW, fed on the ground
[3] Bunk-fed = Cattle supplemented with MDGS daily at 0.6% BW, fed in a bunk
[ab]Means with different superscripts differ ($P < 0.05$).

Table 6. Monthly mean temperature and long-term mean temperature (°C) at GSL[1] during years of study

Month	25 year mean temperature	2011 mean temperature	2012 mean temperature
January	-4	-6	-2
February	-2	-5	-3
March	3	2	8
April	8	7	9
May	13	11	13
June	18	18	22
July	22	24	24
August	21	22	21
September	15	14	15
October	8	9	6
November	1	2	2
December	-3	-2	-3
Average	**8**	**8**	**9**

[1] GSL = Gudmundsen Sandhills Laboratory

Table 7. Monthly total precipitation and long-term mean precipitation (cm) at GSL during years of study

Month	25 year mean precipitation	2011 mean precipitation	2012 mean precipitation
January	0.86	0.80	0.20
February	0.98	0.52	1.98
March	1.77	1.00	1.02
April	5.25	2.16	4.93
May	7.35	4.20	2.41
June	8.94	6.55	1.30
July	7.76	6.61	1.14
August	5.37	3.58	0.76
September	4.26	1.20	0.91
October	2.99	1.44	0.43
November	1.35	0.41	0.89
December	0.47	0.04	0.61
Total	**47.3**	**28.5**	**16.6**

[1] GSL = Gudmundsen Sandhills Laboratory

Figure 1. Monthly mean temperature and long-term mean temperature (°C) at GSL during years of study

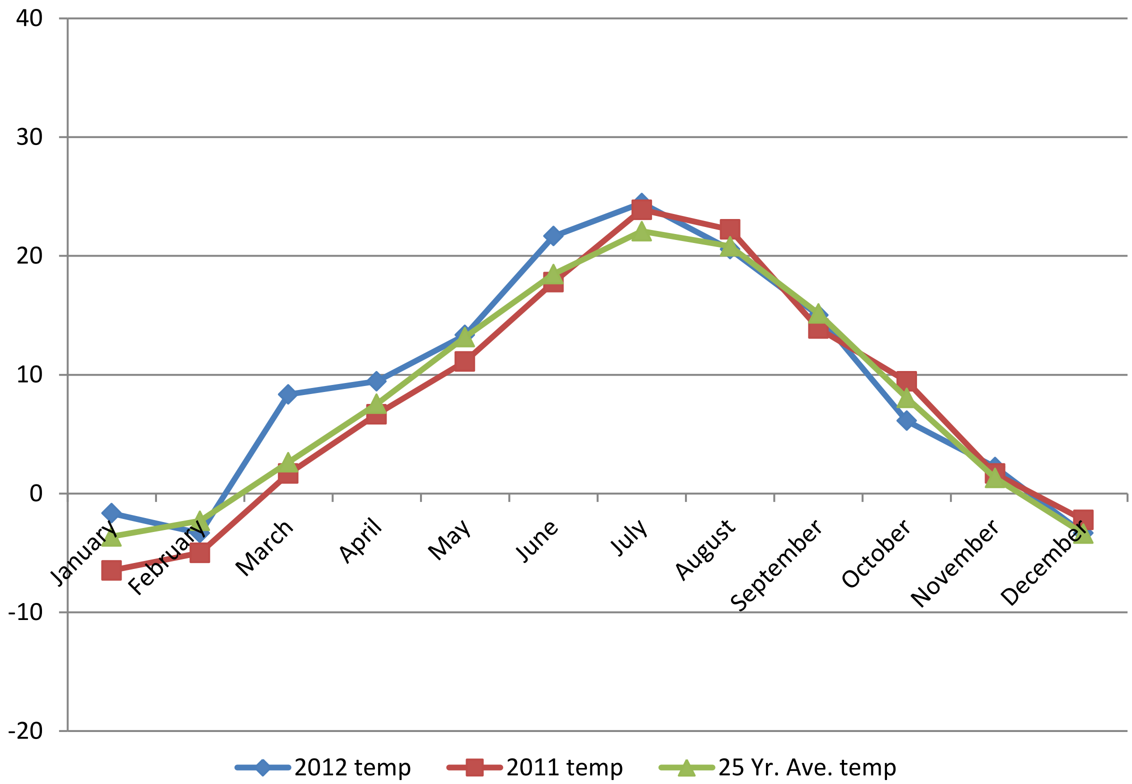
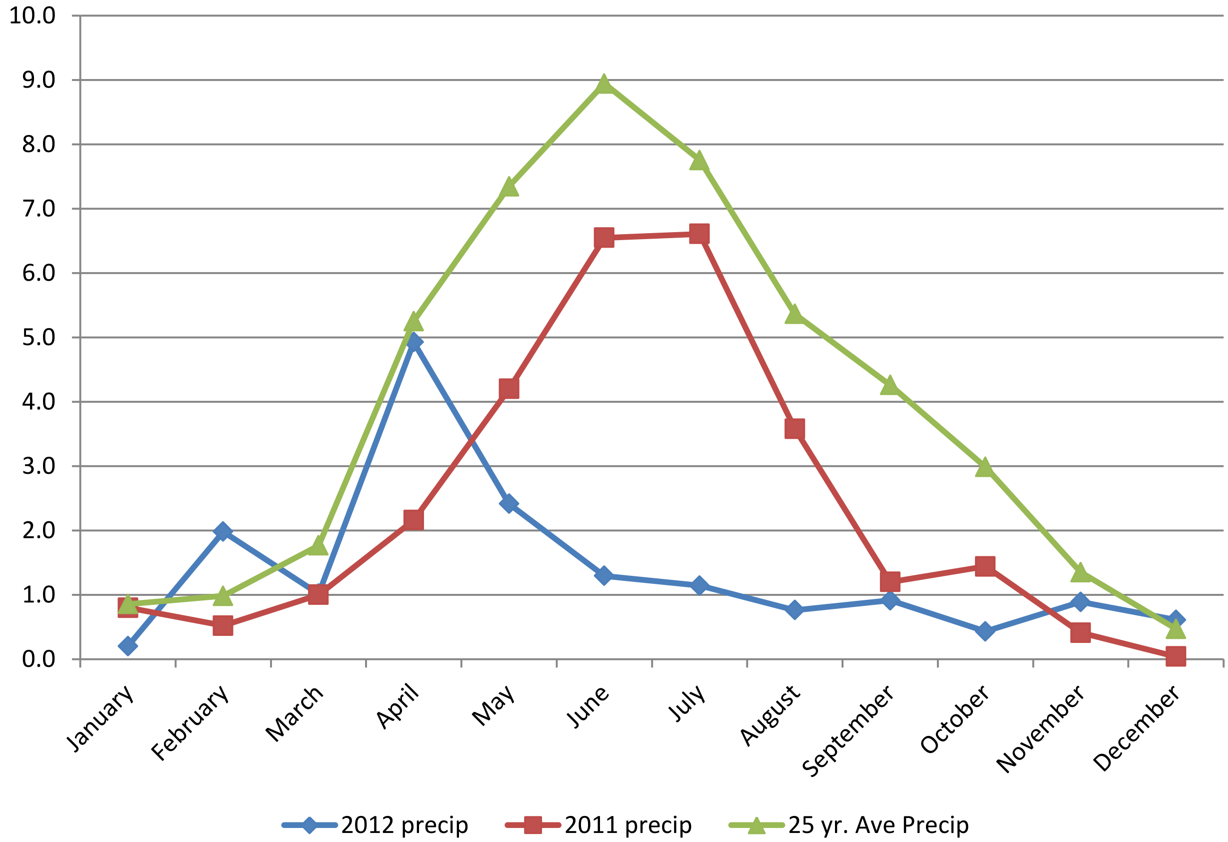


Figure 2. Monthly mean precipitation and long-term mean precipitation (cm) at GSL during years of study



[1] GSL = Gudmundsen Sandhills Laboratory