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Evaluation of Cattle Management for Systems with Limited Perennial Pasture

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EVALUATION OF CATTLE MANAGEMENT FOR SYSTEMS WITH LIMITED PERENNIAL PASTURE

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Due to the conversion of perennial pasture and hay land to cropland in the western corn belt region, alternative methods of cow/calf management are being used to decrease reliance on perennial forages. These include grazing corn residue and feeding cow/calf pairs in confinement. Previous research has shown that limit-feeding a diet of low-quality forage and energy-dense co-products to cows in confinement is cost effective. However, this strategy may limit the intake of the young calf and thus their performance. A study was conducted to evaluate the impacts of two alternative calf management strategies when pairs are in confinement, early weaning or creep feeding. The results suggest that providing a separate creep diet containing higher quality forage to the calf is a cost-effective option as opposed to keeping cows and calves as pairs providing the limit fed diet containing low quality forage, or weaning calves early and feeding the cow and calf separately. Winter grazing of corn residue is a common practice, whereas grazing into spring is rare due to concerns about soil compaction and negative effects on subsequent crop yield. A study was conducted to evaluate the impacts of spring grazing and stocking density when targeting a grazing rate of consumption of 50% of the leaf and husk. The results suggest that grazing in the spring when the soil is thawed and wet results in negligible compaction. Increased stocking density in the spring when grazing corn

residue does increase surface roughness and soil penetration resistance, but these effects were minimal. In fact, subsequent soybean yield was increased in a high yielding irrigated field due to grazing at both a normal and high stocking density in the spring. Combining confinement of cows with grazing residue may be a solution to maintain cow herds without utilizing perennial forages.

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CHAPTER I. REVIEW OF THE LITERATURE

Introduction

In the western corn belt region, perennial pasture and hay land has been converted to cropland, reducing not only the availability of perennial forages, but also increasing the costs of land and pasture rental rates (Preedy et al., 2018). In order to maintain cow herd size, alternative methods of management are being used, which decrease reliance on perennial forages. While grazing of corn residue in the winter can decrease the need for hay (Redfearn et al., 2019), an alternative to grazing perennial grasses during the spring, summer, and fall is needed. One option that is being utilized is feeding cows in confinement. Previous research has shown that when limit feeding by-products and crop residues to cows in confinement, producers can maintain body condition score (BCS) and lower feed costs (Jenkins et al., 2015). However, this has led to questions regarding management options to economically improve the performance of calves in these confinement cow-calf systems where the dam is being limit-fed a diet containing low-quality forage. This review will provide a summary of the research related to managing cows and their calves in confinement and explore management options for young calf management in these systems. Combining confinement during the summer months while fields are growing a cash crop and turning cows out in the fall to graze corn residue through the early spring can be a system to allow producers to maintain or even grow their cow herd with limited or no use of perennial forages. While fall and winter grazing of corn residue is common, grazing later into the spring is not typical due to concerns about soil compaction and potential negative effects on the

following crop yield. Thus, this review will investigate what is known about the impacts of grazing corn residue in both the winter and spring on the soil and the succeeding yield.

Limit-feeding in Confinement

The most expensive component of cow/calf operations is feed (Braungardt et al., 2010; Shike et al., 2009). Therefore, a natural question when feeding cows in confinement is how to meet their nutritional needs cost-effectively. Braungardt et al. (2010) had several experiments looking at diets containing varying degrees of alfalfa mixed hay, corn coproducts, and corn residue bales to evaluate lactating beef cow/calf performance during spring calving, from January to March, in addition to feed costs. In the first experiment, lactating beef cows were fed one of four diets: 1) 6.5 kg/d DDGs with free-choice corn residue bales, 2) 4.4 kg/d corn bran with 2.2 kg/d DDGs and free-choice corn residue bales, 3) 5.1 kg/d corn bran with 1.5 kg/d high-protein distillers dried grains and free-choice corn residue bales, or 4) free choice alfalfa hay. The coproduct supplements in treatments 1 through 3 were fed to all have similar caloric value and meet requirements necessary for cow maintenance and lactation. Diet treatments 2 and 3 were isonitrogenous and made to meet protein requirements. This was not the case for treatments 1 and 4 as protein was above requirements.

In the second experiment, cows were also fed one of four diets: 1) free-choice corn residue bales with 6.5 kg of DDGs, 2) 6.4 kg of ground corn residue bales, with 6.5 kg of DDGs, 3) 4.5 kg of ground corn residue bales, with 7.5 kg of DDGs, or 4) free-choice alfalfa hay. Again, the coproduct supplements in treatments 2 and 3 were fed to have similar caloric value and meet the requirements necessary for cow maintenance and lactation. None of the diets were isonitrogenous; however, protein requirements were

fully met. They observed that feeding cows free-choice alfalfa hay resulted in decreased bodyweight compared to cows that consumed corn coproducts and residue in both experiments. Regardless of diet, calf performance was not affected, as there were no differences in calf average daily gain (ADG). Price data was averaged over three years to evaluate feed costs, and hay was more expensive in both experiments compared to the corn residue and coproduct diets. Ultimately, cow body weight was increased, with no detrimental effect to milk production, conception rate, or calf performance when pairs were fed corn coproducts and corn residue bales as opposed to an alfalfa hay diet. In addition, feed costs were decreased when pairs were fed corn coproducts and corn residue bales. There were greater feed costs in the first experiment ($1.72-$1.94) when corn residue bales were provided ad libitum in the diets compared to the second experiment ($1.45-$1.48) when corn residue was limit-fed. Suggesting that feed costs can be further reduced if cows are limit-fed.

Jenkins et al., (2015) limit-fed different ratios of by-products and crop residues in comparison to alfalfa hay to gestating beef cows in three experiments. In experiment 1, cow BCS was not different at the beginning and end of the experiment when cows were fed 8.3 kg of dry matter (DM) of WDGs and wheat straw (30:70) compared to 9.1 kg DM of alfalfa hay. Experiment 2 evaluated three diets: 1) 8.5 kg DM/hd/d WDGs with wheat straw (30:70), 2) 8.5 kg DM/hd/d WDGs with sugar beet pulp, and wheat straw (20:20:60), and 3) 7.8 kg DM/hd/d ground alfalfa hay. The amount fed was targeted to achieve an intake of 11 Mcal/d to meet cow energy needs. However, it was observed that feeding alfalfa hay resulted in cows gaining less body weight and body condition than the diets containing WDGs. In the third experiment, 8.5 kg DM/hd/d

WDGs, sugar beet pulp, and wheat straw (20:20:60), was compared to 7.0 kg DM/hd/d WDGs, sugar beet pulp, and wheat straw (20:45:35) and there was no difference with cow body weight and BCS. These studies show that producers can utilize a variety of feedstuffs to create a diet that will meet needs and that limit feeding a more nutrient dense diet based on available byproducts and crop residues can be a cost-effective option.

Despite the opportunity to lower feed costs when limit-feeding pairs, it is not without challenges. Producers may potentially be limiting calf intake in the process, and as a result calf growth. When the amount of the diet fed is increased to account for calf intake, the cow maybe eating some or all of the calf's portion, as cows often consume the diet in a short period of time (2 to 3 hours).

Not only could calf growth be restricted due to limited access (quantity), but diet ingredients (quality) could play a role as well. Low-quality forage (high NDF content) acts as a filler limiting the amount of diet the calf can consume. The gastrointestinal tract fill causes a physical limitation to intake, which can be predicted by NDF content, in fact, "cell wall concentration of forage diets is the best single chemical predictor of intake" (Waldo, 1986). In these confinement systems where cows are limit fed a low-quality forage-based diet, weaning the calf so that a lower NDF diet can be fed or providing a separate diet to the calves in a creep area are two options that could be used to increase gain of calves.

Management of the Young Calf

In the United States, beef cattle are commonly weaned at 6 to 8 months of age (180 to 240 days; Warner et al., 2015). According to Amaral-Phillips et al., (2006), calves will begin exploring solid feed after just 14 days, with their intakes increasing after 21-28

days. Rasby and McGee (2011), noted that calves born in the spring begin consuming forage at 45 days of age. Even though calves are traditionally weaned around 7 months, they have a functioning rumen well before that, at approximately 3 months of age (90 days) (Linn et al, 2021). The timing of weaning has traditionally been based on the body condition of the cow and the quality/quantity of pasture available. In a traditional pasture-based system, weaning early has often been used in drought situations as it can reduce the energy needs of the cow in addition to helping reduce grazing pressure by removing the calf.

Preddy et al., (2018) evaluated the effects of weaning time on beef cow and calf performance in both a dry lot and pasture environment. Focusing on the dry lot treatments, calves were either weaned early at 153 days of age (DOA) and fed for 56 days in confinement separated from the cow, with the cow being limit-fed, or calves remained with their dam and creep fed until weaning at a more conventional time of 209 DOA. The early-weaned calves were provided a diet consisting of 21.9% sorghum silage, 63.4% dry rolled sorghum grain, 6.1% WDGs, 5.1% SBM, and 3.4% supplement fed on a DM basis. This diet was fed in order to target 2.2 lbs of ADG with target dry matter intake (DMI) of 2.5% of calf BW. Bunks were observed every morning and slick-bunk management was utilized. If all feed was consumed by calves, delivery was increased by 102% for the next day. The calves that remained as pairs were fed the same diet as the early-weaned calves, targeting intakes of 2% of initial BW. To allow for intake of the calf, creep panels were utilized so they alone had access to the weaning diet and not their dam. Creep fed calves had greater body weight and ADG than early-weaned calves.

Early weaning of calves being managed in a confinement cow/calf system was evaluated in a two-year study at two different locations in Nebraska (Warner et al., 2015). Calves were weaned early at approximately 90 days of age and compared to calves that remained with their dam until weaning at 203 days of age. The goal of the study compared feed utilization of pairs vs. feeding the cow and calf separately to determine if it is more efficient to feed a lactating cow a diet to produce milk which in turn feeds the calf, or perhaps to feed a cow at maintenance and provide the calf a separate diet where the feed can be used directly. Thus, a common diet was fed to the pairs and early weaned cows and calves. In year 1, the diet consisted of 56.5% MDGs in Mead, or 58% WDGs in Scottsbluff, 40% corn stalks in Mead, or 40% wheat straw in Scottsbluff with supplement fed at 3.5% and 2% for Mead and Scottsbluff, respectively. In year 2, the diet consisted of 40% corn silage at both locations, 36.5% MDGs in Mead, or 38% WDGs in Scottsbluff, 20% corn stalks in Mead, or 20% wheat straw in Scottsbluff with supplement fed at 3.5% and 2% for Mead and Scottsbluff respectively. The diets at Mead had approximately 47% NDF and 17.5% CP and the Scottsbluff diets had approximately 53% NDF and 17% CP. The early weaned cows were limit fed 6.9 kg per head per day (DM basis) with the goal of meeting maintenance requirements, whereas the early weaned calves had ad libitum access to feed and consumed 4.0 kg per head per day. Conventionally weaned cow-calf pairs were program-fed each day to target the same consumption as the early weaned treatment. Thus, the pairs were limit fed 10.9 kg/d. The BCS of cows was not impacted by weaning age. In Scottsbluff, the EW calves had greater gains than conventionally weaned calves. However, at Mead, the conventionally weaned calves had greater gains than EW calves. Thus, it was concluded that there was

no difference in performance and thus feed efficiency between cow/calf pairs and early weaned cows and calves when fed a diet that contained roughly 50% NDF. The type of diet, specifically the level of NDF in the diet, may impact young calf intake and thus calf performance. The question that remains, is if the early weaned performance and economics improves if calves were fed a diet containing higher quality forage.

Wiseman et al., (2019) compared early weaning (130 DOA) to creep feeding calves until 226 DOA. The same diet was fed to both cows and calves and on a DM basis consisted of 33.3% chopped bermudagrass hay, 32.3% DDGs, 24.1% rolled corn, 2.6% soybean meal, 2.1% limestone, and 5.1% of a liquid supplement for both years of the study in the dry lot. This diet was approximately 38% NDF and 17.7% CP. Cows gained condition throughout the experiment, with scores of 4.7 and 5.15 at the start and end of the trial, respectively. Calves in both treatments were fed ad-libitum. Though both treatments of calves had continuous access to feed, feed intake was greater for EW calves compared to the creep fed calves, likely because the creep calves were also nursing their dam. This agrees with the earlier findings of milk consumption affecting the intake of forage. Tedeschi and Fox (2009) found a relationship between consumption of milk and forage for nursing calves, observing that the intake of forage was dependent on the amount of milk being consumed. At 60 days of age, calves consumed less forage when dams had greater milk production than calves of dams with decreased milk levels at the same body weight.

The energy intake for creep calves was 1,031 and 649 Mcal ME for the diet and milk respectively whereas for EW calves, the intake of the diet was 1,231 Mcal ME. The diet plus milk resulted in greater ADG for creeped calves (1.32 kg) than the early weaned

calves (1.01 kg). Thus, creep feeding calves does improve gains over early weaning. However, a comparison of limit feeding pairs a low cost, high NDF ration to early weaning or creep feeding calves and providing a lower NDF diet has not been made.

Corn Residue Grazing

Corn residue is an effective way to integrate crop and livestock production, and can be incorporated into a producer's system to alleviate forage shortcomings. This can be done by either grazing or baling and feeding the residue to cows. Regardless of the method, it is an under-utilized forage resource. Only about 15% of the corn residue acres in the central U.S. are grazed. Although, the utilization rate in Nebraska is much greater, at around 50% of the acres with corn residue being grazed.

Grazing results in consumption of corn kernels from any missed ears left in the field, in addition to husks and leaves. These are the more digestible portions of the plant. The stalk and cob are not consumed if husk and leaf availability is not limiting (Fernandez-Rivera and Klopfenstein, 1989). It is usually suggested to target a removal rate of 50% of the husk and leaf which is about 15% of the total residue in the field (Gardine et al., 2016). Grazing is more advantageous, as it leaves more residue on the ground to protect the soil from wind and water erosion than baling. Baling removes more residue leaving the soil exposed to the elements (Rakkar et al., 2019). Grazing also results in minimal nutrient removal from the field. In fact, in some cases, there is a net import of nutrients such as phosphorus due to providing cattle supplements while grazing. Along with the environmental benefits of grazing corn residue, the value that gets added to the crop sector can be great. When the utilization data for the states of Nebraska, South Dakota, Kansas, and North Dakota were multiplied by the rental rate,

the value that was added to the crop sector was estimated to be greater than 95 million dollars. Thus, corn residue grazing is a significant source of income for farmers and can be a low-cost feed source for cattle producers (Redfearn et al., 2019) to utilize when perennial pastures are unavailable.

Even though the value of grazing corn residue is great, crop consultants and farmers have concerns. The reasons of highest importance for crop consultants to not recommend grazing were the beliefs that: 1) grazing has a negative impact on farming practices and the succeeding yield and 2) cattle producers "would not pay for the worth of corn residue" (Cox et al., 2017). The top reasons for farmers to not allow grazing of residue include: 1) concerns about soil compaction (47%), 2) lack of resources such as water and fencing (49%), and 3) deficiency of livestock (23%). A large majority of farmers are specialized and don't have cattle. In these situations, a relationship with a cattle producer and leasing agreements may have to be developed. Another major drawback to grazing is the need for water access, as hauling water for the cattle can be expensive. Ultimately, there seem to be environmental apprehensions, where farmers may worry about compaction and the potential negative impacts on crop growth and yield.

Impacts of Grazing Corn Residue

Past research at the University of Nebraska-Lincoln (UNL) has involved several studies looking at compaction with grazing corn residue. While the studies have not found significant issues with compaction due to grazing of residue, the majority of this

research focused on fall and winter grazing when the ground is more likely to be frozen (Drewnoski et al., 2016; Rakkar et al., 2017; Stalker et al., 2015; Ulmer et al., 2019).

Rakkar et al., (2019) conducted a 3-year study in the Central Great Plains looking at soil compaction when corn residue was either grazed or baled in the fall. There were 6 farms included in the study undergoing varying crop rotations and irrigation practices, but most managed with conservation tillage methods. Each farm had three treatments- control, baled, and grazed. Grazing periods varied from 14 to 91 days among the six farm sites and stocking density also varied among each farm location from 0.9 to 21.0 animals per hectare. Impacts on the soil were minuscule and did not seem to stem from grazing or baling. Bulk density was increased in the spring at one of the farms compared to the control treatment. Residue cover ranged from 56 to 94% in grazed paddocks, with an average of 72%. The no grazed control paddocks averaged 85% residue cover. In regards to yield, there were no differences in either corn or soybean yield among the three treatments.

A five-year study by Stalker et al., (2015) was done in Nebraska to evaluate stocking rate and its impact on the removal of residue and crop yield, in a field undergoing no-till management and continuous corn. There were four different treatments- a nongrazed control, grazing cattle at 2.5 AUM/hectare, grazing cattle at 5.0 AUM/hectare, and baling. The recommended stocking rate for the field was 3.75 AUM/ha, so grazing treatments were below and above the suggested rate. The grazing period was from late November to early February. After grazing, the treatment below the recommended stocking rate resulted in a reduction of 57% for the husk and 42% for the

leaf. The higher stocking rate resulted in 82% reduced husk and 47% reduced leaf. There was no effect on corn yield across any treatment over the course of the 5 years. Therefore, removal of residue from a field undergoing no till, continuous management is at no risk of negative impacts on yields. It was determined that as long as appropriate stocking rates are applied, corn yield is not negatively impacted.

Clark et al., (2004) conducted a study in southwestern Iowa, in a field undergoing a corn-soybean rotation, to address farmers' concerns about compaction and surface roughness. There were six paddocks allocated for treatments, with one being a nongrazed control and the remaining five paddocks being grazed in four-week intervals. Paddocks were grazed with 3.7 cows per hectare in October through February with the study being repeated over three years. When soil surface roughness was evaluated, roughness was increased in the grazing treatments compared to the nongrazed control treatment. In two of the three years of the study, the final grazing period in February showed increased surface roughness compared to the nongrazed control and the other grazing periods. When taking all grazing periods into consideration over the course of the three-year study, 4 of the 15 grazing periods had more roughness than the nongrazed control. They did see a reduction in soybean yield in one occurrence out of the 15 grazing periods over the three years. The reduction in yield could be due to increased surface roughness and greater variation in seed placement, which may impact emergence and thus yield.

Currently, many producers that do graze corn residue avoid grazing in the spring to minimize the risk of soil compaction as this risk is increased when the soil is thawed and wet. However, there are few studies which have actually evaluated if grazing in the spring will result in compaction. The soil property impacts of corn residue grazing in the

spring was evaluated in a 16-year grazing study (Rakaar et al., 2017). There were three treatments: 1) fall/winter grazing, 2) spring grazing and 3) a nongrazed control. Cattle in the fall/winter treatment grazed for a 90-day period from November to January. There were 3 calves per hectare with a target residue utilization rate of 15%. For spring grazing, cattle grazed for a period of 70 days, from February to Mid-April. There were 7.4 calves per hectare with a target utilization rate of 16 to 22%. Bulk density was not affected by grazing in the fall, nor was it affected by grazing in the spring when a heavier stocking density was applied. The companion paper evaluating crop yields, observed that soybean yields were slightly increased with fall and spring grazing compared to the control (Drewnoski et al., 2016). Therefore, it was concluded that producers could graze corn residue in the fall or the spring with either no impact on corn and soybean yields or potentially see a positive impact.

Conclusion

A combination of crop residues and by-products can be limit fed to cows in confinement to create a nutrient dense diet which can maintain cow body condition and body weight in a cost-effective manner. Nonetheless, these limit-fed, low quality forage-based diets, may not result in optimal calf performance. Weaning calves early with the provision of a low NDF diet or feeding calves a separate diet in a creep area can be strategies to increase gain. Previous studies suggest that providing feed in a creep area does allow calves to gain more than early weaning. However, a comparison between limit feeding a low-cost, high NDF diet to cow/calf pairs versus feeding a lower NDF diet to early weaned or creep fed calves needs to be assessed to determine which strategy will result in the greatest economic returns.

Most data have evaluated fall/winter grazing of residue when the ground is frozen and the soil is at lower risk for compaction. There is limited knowledge on grazing in the spring when the soil warms and is typically wet. There are also no comparisons of the effects of stocking density. Therefore, these factors need to be evaluated to determine their impact on the soil and succeeding yields as spring grazing would be a low-cost option to maintain cows.

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CHAPTER II. MANAGEMENT OF THE YOUNG CALF WHEN DAMS ARE LIMIT-FED IN CONFINEMENT

Abstract

Limit-feeding lactating beef cows in confinement can lower feed costs. However, this can result in nursing calves having limited time to access feed. This two-year study was designed to evaluate management options to economically improve young calf performance in these limit-fed confinement systems. Each year, cow-calf pairs (n=54 per year) were blocked into three groups by calf age (104 ± 15 DOA), resulting in three age blocks (DOA 85, 106, 122). Age blocks were then stratified within block by source of the dam and calf gender and assigned randomly to pen (n = 9). Pens within age block were then assigned randomly to 1 of 3 treatments. The three calf management treatments were: 1) kept with dam with access to cow diet only (PAIRS) 2) early-weaned (EW) and fed a diet or 3) kept with dam with access to the same diet as EW in a creep area (CREEP). The cow diet was 55% wet distillers grains (WDGS) and 43% straw. This diet was fed to meet dry cow requirements (7.7 kg DM/d) for EW, lactation requirements (10.9 kg DM/d) in CREEP, and lactation requirements plus allow for some calf intake (14.8 kg DM/d) in PAIRS. The calf diet consisted of 51% alfalfa hay, 25% WDGS, and 22% corn. Calves in the EW had greater ($P < 0.01$) intake of the calf diet (4.97 kg DM/d) than CREEP (3.89 kg DM/d) from 104 to 204 DOA. Calf ADG differed ($P < 0.01$) among treatments from 104 to 204 DOA in year 1, with CREEP (1.29 kg/d) being greater ($P < 0.02$) than EW (1.01 kg/d) and both being greater ($P \leq 0.02$) than PAIRS (0.74 kg/d). In year 2, CREEP (1.11 kg/d) was greater ($P < 0.01$) than PAIRS (0.78 kg/d) and EW (0.72 kg/d), which did not differ ($P = 0.42$). At ~204 DOA, PAIRS

and CREEP were weaned, and all calves were fed a growing diet. During the growing phase (223 to 311 DOA) there was a tendency for a treatment by year (*P* < 0.08) for both intake and ADG. The PAIRS and EW calves had greater (*P* < 0.05) intakes than CREEP in year 1, but there were no differences (*P* ≥ 0.31) among treatments in year 2. In year 1, ADG of CREEP was lower (*P* ≤ 0.02) than PAIRS and EW which did not differ (*P* = 0.62). However, in year 2, there were no differences (*P* ≥ 0.47) among treatments. When calf value and total feed costs were considered, CREEP resulted in the most return over feed costs at weaning (204 DOA) and if retaining ownership through a growing period (311 DOA), the returns remained greatest for CREEP. Thus, the CREEP treatment appears to be the best strategy for managing cow/calf pairs in confinement when the cows are being limit fed.

Introduction

Feeding cows in confinement is a management strategy for beef cow/calf producers when pasture resources are limited. Over the past decade, more grassland has been converted to cropland in the Midwest, decreasing the availability of pasture and increasing pasture rental rates. Feeding in confinement can allow producers to maintain a cow herd with limited or no pasture.

Previous research has evaluated limit feeding cows a protein/energy dense diet using lower-quality forage and co-products and have found that this strategy can lower feed costs in confinement (Braungardt et al., 2010; Jenkins et al., 2015). However, there may be consequences for the calf as limit-feeding results in the diet being consumed by the cows fairly rapidly, often within a few hours. Even if the amount

of the diet is increased to account for the potential feed intake of the nursing calf, intake may be limited due to the cow consuming the additional feed. This may potentially limit calf growth.

Warner et al., (2015) conducted a 2-year study at two locations, in Mead and Scottsbluff, Nebraska, to evaluate early weaning (EW) calves of limit-fed cows managed in confinement. Calves were either early weaned at 91 DOA or remained with their dam until 203 DOA. Cows and calves were fed the same diet which varied slightly across location and year, but all diets were relatively high NDF (47-54% NDF). The EW cows were fed to meet their maintenance requirements and EW calves were fed ad libitum. The cow/calf pairs that were not early-weaned (PAIRS) were fed the equivalent of what the EW cows and calves consumed. The PAIRS had greater ADG than EW calves at the Mead location; however, the EW calves had greater gains than the PAIRS calves at the Scottsbluff location. Thus, there was no clear advantage to early weaning over having calves remain with their dam. However, due to the base of the diet being low-quality forage, resulting in the diet being high NDF, intake of the early-weaned calves may have been limited by gut fill; therefore, use of a diet with higher quality forage needs to be evaluated.

Wiseman et al., (2019) compared early weaning (130 DOA) to creep feeding calves (226 DOA) when managed in confinement. The same diet was fed to cows and calves and contained 38% NDF. It consisted of 33.3% chopped bermudagrass hay, 32.3% DDGs, 24.1% rolled corn, 2.6% soybean meal, 2.1% limestone, and 5.1% of a liquid supplement (DM basis). Cows were fed to maintain their BCS while calves in both treatments were fed ad libitum. Feed intake was greater for EW calves compared to the

creep fed calves. However, because they were still nursing the dam, creep calves had more energy intake, resulting in greater ADG than the early-weaned calves. The creep cows and calves together consumed more feed energy intake than that of the early-weaned cows and calves. Despite the increased intake of the creep cows and calves, the improved performance of the calves offsets the costs of maintaining the lactating cows.

Thus, there appears to be no clear advantage for early weaning over feeding as cow calf pairs, when using a high NDF diet. When feeding a moderate NDF diet, there appears to be a performance advantage for creep feeding to weaning calves early cow/calf pairs are managed in confinement compared. However, feeding different diets to the cows and calves has not been explored. Limit-feeding cows diets that are based on low-quality forages and byproducts tend to be lower cost in the Midwest, but using a diet that contains moderate-quality forage for calves may allow their intakes to increase and potentially improve their growth. Rather than keeping nursing calves with their dam with access to the cow's limit-fed a high NDF diet until ~204 DOA (PAIRS), potential management options to improve calf performance when lactating cows are being limit-fed in confinement are to wean the calves early at ~104 DOA with calves offered a calf diet containing moderate quality forage plus concentrates ad-libitum (EW) or provide the nursing calves the calf diet in a creep area to which the cows do not have access, until ~204 DOA (CREEP).

The objectives of this study were to evaluate 1) how the performance of PAIRS, EW, and CREEP compare and 2) which of these management options is more economically favorable. It was hypothesized that creep feeding calves would be the best

management option to economically improve calf performance as opposed to limit-feeding cow-calf pairs or weaning calves early.

Materials and Methods

Site Description and Experimental Design

This was a 2-year study conducted at the Panhandle Research and Extension Center in Scottsbluff, Nebraska. Each year, 54 cow/calf pairs were utilized, with cows having an average weight of 547 kg ± 65.54 kg and calves being blocked by age (104 ± 15 DOA), resulting in 3 age blocks (DOA 85,106,122). Age blocks were then stratified within block by source of the dam and sex of the calf. Finally, each group was assigned randomly to pens (n = 9) and each pen within age block assigned to 1 of 3 treatments. The three treatments were 1) kept with the dam with access to a limit-fed cow diet containing distillers grains and straw (PAIRS) until calves were an average age of 204 DOA, 2) early-weaned (EW) when calves were an average age of 104 DOA, with calves receiving a calf diet containing alfalfa hay, distillers grains, and corn, or 3) kept with the dam with access to the calf diet in a creep area (CREEP) until calves were an average age of 204 DOA. The weaning age of calves was averaged across both years of the study and across all three age blocks (DOA 85,106,122).

Calves were born in early to mid-August in both years of the study, with the calving season ending in October. In December, the treatments began when calves averaged ~104 DOA (Figure 2.1). The EW calves were weaned at this time whereas the calves in the PAIRS and CREEP treatments remained with their dam until March, when they were weaned at an average of ~204 DOA, which will be referred to as normal weaning. In the first year, the early to normal weaning period began on December 17,

2019 and ended on March 23, 2020 totaling a 98-day period. The growing period began on April 15, 2020 and ended on July 9, 2020, for a total of 86 days in the period. In the second year, the early to normal weaning period began on December 19, 2020 and concluded on March 29, 2021 (101-day period), with the growing period beginning on April 15, 2021 and concluding on July 13, 2021 (90-day period). Between these phases, was a short period averaging 19 days, which was the weaning period for the PAIRS and CREEP calves. At this point, all calves were fed the EW and CREEP calves had access to since December.

The cow diet (Table 2.1) was approximately 55% wet distillers grain (WDGs) and 43% straw, with mineral making up the remainder of the ration. In the PAIRS treatment, the cows were fed the diet targeting an intake of 10 kg/hd/d to meet lactating requirements with approximately 2 kg extra provided to account for calf intake. The EW cows were fed to target an intake of 8 kg/hd/d to meet dry requirements and finally CREEP cows were fed to meet lactation requirements, targeting an intake of 10 kg/hd/d.

The calf diet (Table 2.2) during the early to normal weaning period from December to March was 50% alfalfa hay in addition to 25% WDGs and 22% corn plus a mineral and vitamin premix. This diet was also fed during the weaning period for PAIRS and CREEP in March and April before the growing phase began. Both the EW and CREEP calves had access to this diet ad-libitum using slick bunk management. There were 2 pens provided for each treatment, so that there was the same area allotted across all treatments. Each pen had 6.1 meters of bunk space, but for the PAIRS, both the cows and calves had access to both pens, resulting in 12.2 meters of bunk space. Each pair averaged 1.11 meters of bunk space. For the EW treatment, cows and calves

were separated each into one pen. Lastly, for the CREEP treatment, cows had access to only one pen and calves had access to both pens. The calf diet was offered to the CREEP calves in the pen that only the calves could access. After the early to normal weaning period concluded in late March, all three calf treatments were fed the calf diet until mid-April, when calves were then placed on a growing diet (Table 2.3) to begin their growing phase from April to July (223 to 311 DOA). The growing diet varied from the first year to the second year due to limited availability of distillers grains in year 1.

Performance measurement

At the beginning and end of the early to normal weaning period and the growing period, calves were weighed prior to feeding over two consecutive days. Cow body condition score (BCS) was measured on a scale of 1 to 9 at the start of the trial in December and at the end of the normal weaning period in March.

Economics

Returns above feed costs were evaluated by calculating the calf values and subtracting the cost of the diets for each study year that would have occurred when using prices from each of the previous 6 years (2013-2018). Nebraska feed prices for 2013-2018 were obtained from USDA-ERS Feed Grains Database Yearbook Tables. Feed costs did not account for machinery or labor and thus any of the extra mixing costs of mixing a separate calf diet for the EW and CREEP treatments during the early to normal weaning period. Similarly, the calf market value at the beginning and end of each phase for each year was calculated using data from LMIC using the Weighted Average Summary for Nebraska Combined Auctions. The PAIRS were considered the baseline and both EW and CREEP were evaluated by taking the difference from return in the PAIRS treatment for each of the phases.

Statistical analysis

All performance data for the calf, cow intakes, and economic data were analyzed using the MIXED procedure of SAS as a randomized complete block design. Pen was considered experimental unit. The fixed effects included in the model were treatment, year, and calf age. Significance was declared at $P \leq 0.05$, with a tendency for significance declared at $P \leq 0.10$.

Results and Discussion

Performance

Cows. As designed, cow diet intakes were the greatest ($P < 0.01$) for PAIRS (12.1 kg/hd/d) followed by CREEP (10.3 kg/hd/d), and least ($P < 0.01$) for the EW cows (8.1 kg/hd/d). Cows were being program-fed, targeting to meet their dry (EW), or lactating requirements (PAIRS, CREEP) with PAIRS being fed an extra 1.8 kg/d for the calf. However, it should be noted that the cows in PAIRS may have consumed a proportion of that which was allocated to the calf. Body condition score of cows from December to March, shifted to the right (Figure 2.2), with cows gaining condition. This suggests that the amount of feed allocated to the EW cows was more than required to maintain body condition.

Calves. At the start of the early to normal weaning period, there was no treatment by year interaction ($P = 0.58$), year ($P = 0.98$) or treatment ($P = 0.82$) effect for the initial BW of the calves in December.

There was a treatment by year interaction ($P < 0.03$) for ADG during this early to normal weaning period. In year 1, CREEP gained the most (1.29 kg) having greater ($P < 0.01$) ADG than both EW and PAIRS, with EW (1.01 kg) being greater ($P < 0.01$) than PAIRS (0.74 kg). In year 2, CREEP (1.11 kg) calves still had the greatest ($P < 0.01$)

ADG, but ADG of EW (0.72 kg) and PAIRS (0.78 kg) did not differ (*P* = 0.42) from each other.

As a result of differences in ADG, the BW at the end of the early to normal weaning period in March when calves were about 204 DOA, had a significant treatment by year interaction (*P* < 0.05). In the first year, CREEP calves tended to be greater (*P* = 0.08) than EW calves, and both were greater ($P \leq 0.02$) than PAIRS. In year two, the BW of CREEP calves was greater ($P \leq 0.02$) than both PAIRS and EW which did not differ (*P* = 0.20).

There was no treatment by year interaction (*P* = 0.36) for intake of the calf diet offered to CREEP and EW from December to March. There was a treatment effect (*P* < 0.01) with the EW calves (4.95 kg/hd/d) having greater (*P* < 0.01) intakes than CREEP calves (3.89 kg/hd/d) in both years of the study. The EW calves may potentially have greater intakes than the CREEP calves because they are solely eating their own calf diet, whereas the CREEP calves may be eating some of the cow's diet as they were observed at the bunks next to the dam at the time of feeding. The CREEP calves were also consuming milk which may have also reduced feed intake (Tedeschi and Fox, 2009). Wiseman et al., (2019) also observed greater intakes for EW calves than that of CREEP calves.

In the current study, there was also a tendency for a year effect (*P* = 0.09) with both CREEP and EW eating less in year 2 than in year 1. The EW calves in year 2 had much lower (-0.29 kg/d) gain than in year 1 while CREEP had a slight decline (-0.18 kg/d) and ADG of PAIRS (+0.04 kg/d) did not differ. The lower intake in year 2 may partially explain the lower gains of EW and CREEP in year 2. The difference

in gain response between EW and CREEP may be due to weather (Figures 2.3 and 2.4) influences. On average, in year 2, temperatures were colder (-0.94 °C) and precipitation was higher (0.85 mm) than that of year 1 (0.40 °C and 0.34 mm) (AerisWeather, n.d.). Therefore, cold stress could very well play a role in the early to normal weaning period in year 2. Early-weaned calves were not able to use their dam as windbreak unlike the other two treatments. It appears that when there is cold stress, keeping cows and calves as pairs may offer a buffering effect. Suggesting that in times when cold stress in more likely, there is more risk of lower performance for EW than PAIRS or CREEP. The current study cannot definitively say there is a benefit to managing an early weaned calf or keeping as pairs, but CREEP calves had the best performance in both years of the study for the early to normal weaning period.

Once the early to normal weaning period concluded in March, PAIRS and CREEP were weaned. Thus, PAIRS and CREEP calves underwent weaning stress at this time, whereas EW calves went through this in December. At the time of PAIRS and CREEP weaning, all calves were fed the calf diet for approximately three weeks. There was not a significant treatment by year interaction ($P = 0.88$) or treatment ($P = 0.74$) effect for ADG during this relatively short period of time with all calves gaining about 1.0 kg/d. There was a significant treatment by year ($P < 0.01$) interaction for intakes. However, within year, EW (6.5 kg/d) had the greatest ($P < 0.01$) intakes and CREEP (5.4 kg/d) had greater ($P \leq 0.03$) intakes than PAIRS (4.4 kg/d). Early-weaned calves may have had the greatest intakes due to the fact that they did not undergo weaning stress at this time, plus, they were already familiar with the diet. The CREEP calves were also familiar with the diet, but they had weaning stress, and lastly,

PAIRS may have had the least intake because they had both weaning stress and an unfamiliar diet at this time.

All calves (~223 DOA) were then fed a growing diet from April to July (~89 days). There was a treatment by year interaction ($P < 0.05$) for calf BW at the start of the growing period due to differences in gain during the early to normal weaning period. In year 1, CREEP calves tended to have greater ($P < 0.06$) weights than EW and both having greater ($P \leq 0.02$) BW than PAIRS. In year 2, CREEP calves had greater ($P < 0.01$) weights than both EW and PAIRS, with no difference ($P = 0.25$) between EW and PAIRS.

For ADG during the growing period, there was a tendency for a treatment by year interaction ($P = 0.08$). In year 1, ADG of CREEP was lower ($P \leq 0.02$) than PAIRS and EW which did not differ ($P = 0.62$). However, in year 2, there were no differences ($P \geq 0.47$) among treatments.

Thus, there was a significant treatment by year interaction ($P < 0.02$) for calf BW at the end of the growing period in July. In year 1, the end BW of CREEP and EW calves did not differ ($P = 0.16$) but were greater ($P < 0.01$) than PAIRS. In year 2, CREEP calves had greater ($P < 0.01$) end BW than both EW and PAIRS, which did not differ ($P = 0.33$).

Intakes followed the same pattern as ADG during the growing period with a tendency ($P = 0.08$) for a treatment by year interaction. The PAIRS and EW calves had greater ($P < 0.05$) intakes than CREEP in year 1, but there were no differences ($P \geq 0.31$) among treatments in year 2. All of the calves ate more in the second year of the study than in the first year. This interaction may be a result of potential compensation for lower

gains due to the unfavorable weather during the previous period (early to normal weaning) in the second year of the study.

Economic evaluation

Early to Normal Weaning Period (December to March)

In December, there were no differences in initial calf BW and thus no differences in calf value ($P \geq 0.44$) with an initial value of $697 (Table 2.6). In March, there was a significant ($P < 0.01$) treatment by year interaction. In year 1, there was a tendency ($P < 0.06$) for CREEP calves to have greater value than EW, with both CREEP and EW being greater ($P < 0.01$) than PAIRS. In year 2, CREEP was greater ($P < 0.02$) than EW and PAIRS ($P < 0.01$), with PAIRS tending to be greater ($P = 0.07$) than EW.

During the early to normal weaning period, there was no treatment by year interaction ($P = 0.43$), but there was a significant treatment ($P < 0.01$) effect for feed cost with CREEP ($40) having the greatest ($P < 0.01$) costs, EW ($25) being intermediate, and PAIRS ($0) having the least ($P < 0.01$) feed costs. This is because CREEP includes both the greater intake of the lactating cow and calf intake, where the calf had ad-libitum access to a higher cost diet with higher quality forage. The EW treatment would have had lower cow diet costs as the dry cows were fed less cow diet and this compensated for the greater intake and cost of the calf diet fed which was fed to the EW calves. The PAIRS were receiving only the limit-fed, lower cost cow diet.

There was a tendency for a significant ($P = 0.09$) treatment by year interaction for returns above feed cost during the early to normal weaning period. However, in both years, return during this period was greater for CREEP than EW and PAIRS with a significant treatment effect ($P < 0.01$). The CREEP calves ($117) had greater ($P < 0.01$) returns above feed costs than EW ($24) and PAIRS ($0) with no difference ($P = 0.70$)

between EW and PAIRS. Therefore, CREEP would be the best option if producers are going to sell at ~204 DOA.

Growing Period (March to July). There was no treatment by year interaction (P = 0.11) for calf value at the end of the growing period in July. There was a significant treatment (P < 0.01) effect with CREEP ($1,452) having the greatest (P < 0.01) value, EW ($1,348) being intermediate, and PAIRS ($1,331) having the least (P < 0.01) value.

There was a tendency for a treatment by year interaction (P = 0.06) and effect of treatment (P = 0.06) on feed costs during the growing period. There was also a tendency for a significant treatment-by-year interaction (P = 0.06) for returns during the growing period, but there was no treatment (P = 0.30) effect. In the first year of the growing period, PAIRS had greater returns (P < 0.05) than EW and CREEP, with no difference (P = 0.75) between EW and CREEP. In the second year of the growing period, there was no difference among treatments (P = 0.17). Having a growing period allows some compensation for the EW and PAIRS treatments, so if producers do not have a way to creep, adding a growing phase maybe beneficial.

However, when looking at the system in its entirety, there was no significant treatment by year interaction (P = 0.77) for feed costs. There was a significant treatment (P < 0.01) effect, with no difference (P = 0.23) in feed costs between CREEP ($41) and EW ($34), but both having greater (P < 0.01) feed costs than PAIRS ($0).

There was no treatment by year interaction (P = 0.16), but there was a treatment effect (P < 0.01) for returns above feed costs. The CREEP ($72) calves had

greater ($P < 0.01$) returns than both EW ($-5) and PAIRS ($0) with no difference ($P = 0.73$) between them.

Conclusion

If producers are to sell at weaning, the most cost-effective system was CREEP, as it was more economical than PAIRS and EW at the end of the early to normal weaning period. If producers are to retain ownership, CREEP still has the greatest returns above feed costs.

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Table 2.1 Cow diet ingredients and diet composition for two years of a study evaluating the management of the young calf when dams are limit-fed in confinement. Three treatments were applied 1) Kept with the dam with access to cow diet only (PAIRS) until 204 days of age (DOA), 2) Early-weaned (EW) at 104 DOA, and 3) Kept with the dam with access to calf diet (CREEP) until 204 DOA.

Ingredient (% DM)	**Year 1**	**Year 2**
Wet Distillers Grains[1], %	55.4	55.4
Straw, %	43.4	43.5
Mineral[2], %	1.2	1.1
Diet Composition		
Crude Protein, %	20.3	16.4
Acid Detergent Fiber, %	35.7	33.3
Neutral Detergent Fiber, %	58.6	51.2
Fat, %	5.5	3.9
Total Digestible Nutrients, %	74.5	76.6

[1] Total digestible nutrients used for wet distillers grains was 104%.
[2] Vitamin/mineral premix consisted of 15.5-17.5% Ca, 3% P, 16-18% NaCl, 1.3% Mg, 0.9% K, 2500 ppm Cu, 22 ppm Se, 7500 ppm Zn, 3000 ppm Mn, 250,000 IU Vitamin A, 11,000 IU Vitamin D_3, and 225 IU Vitamin E.

Table 2.2 Calf diet ingredients and diet composition for two years of a study evaluating the management of the young calf when dams are limit-fed in confinement. Three treatments were applied 1) Kept with the dam with access to cow diet only (PAIRS) until 204 days of age (DOA), 2) Early-weaned (EW) at 104 DOA, and 3) Kept with the dam with access to calf diet (CREEP) until 204 DOA.

Ingredient (% DM)	**Year 1**	**Year 2**
Alfalfa Hay, %	51.0	51.3
Wet Distillers Grains[1], %	25.2	25.3
Corn, %	22.0	22.1
Mineral[2], %	1.8	1.3
Diet Composition		
Crude Protein, %	18.3	16.1
Acid Detergent Fiber, %	27.1	25.5
Neutral Detergent Fiber, %	39.0	36.7
Fat, %	2.4	2.6
Total Digestible Nutrients, %	73.6	70.8

[1] Total digestible nutrients used for wet distillers grains was 104%.
[2] Vitamin/mineral premix consisted of 15.5-17.5% Ca, 3% P, 16-18% NaCl, 1.3% Mg, 0.9% K, 2500 ppm Cu, 22 ppm Se, 7500 ppm Zn, 3000 ppm Mn, 250,000 IU Vitamin A, 11,000 IU Vitamin D_3, and 225 IU Vitamin E.

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Table 2.3 Growing calf diet ingredients and composition fed post-weaning from April (223 DOA) to July (311 DOA) for a two-year study evaluating the management of the young calf when dams are limit-fed in confinement.

Ingredient (% DM)	**Year 1**	**Year 2**
Corn, %	40	34
Corn Silage, %	18	25
Wet Distillers Grains[1], %	-	25
Soybean Meal, %	18	-
Alfalfa Hay, %	18	10
Mineral[2], %	6	6
Total, %	100	100
Diet Composition		
Crude Protein, %	15.8	13
Acid Detergent Fiber, %	15.7	16
Neutral Detergent Fiber, %	24.5	26.9
Fat, %	0.4	3.6
Total Digestible Nutrients, %	71.1	74.6

[1] Total digestible nutrients used for wet distillers grains was 104%.

[2] Vitamin/mineral premix consisted of 15.5-17.5% Ca, 3% P, 16-18% NaCl, 1.3% Mg, 0.9% K, 2500 ppm Cu, 22 ppm Se, 7500 ppm Zn, 3000 ppm Mn, 250,000 IU Vitamin A, 11,000 IU Vitamin D_3, and 225 IU Vitamin E.

Table 2.4 Intake of cows (547 kg ± 65.54 kg) from December and March across two years of a study evaluating the management of the young calf when dams are limit-fed in confinement. Three treatments (trt) were applied 1) Kept with the dam with access to diet only (PAIRS) until 204 days of age (DOA), 2) Early-weaned (EW) at 104 DOA, and 3) Kept with the dam with access to calf diet (CREEP) until 204 DOA.

	Treatments				P-Values		
Item	PAIRS	EW	CREEP	SEM	Trt	Year	Trt*Year
Intake, kg/hd/d	12.10a	8.10c	10.34b	0.099	<0.01	<0.01	0.53

[1] Means with common letters within the row indicate no significant differences among treatments.

Table 2.5 Performance of calves from December (104 DOA) to March (204 DOA) when kept with the dam and only allowed access to the cow ration (PAIRS), early-weaned (EW) at 104 DOA, or kept with the dam but given access to the calf ration in a separate area (CREEP). Calves in the PAIRS and CREEP were then weaned at 204 DOA. All calves were fed the calf ration until April (223 DOA) at which point they were transitioned to a growing ration through July (311 DOA)

	Year 1 Treatments			**Year 2 Treatments**				**P-Values**		
Item	PAIRS	EW	CREEP	PAIRS	EW	CREEP	SEM	Trt	Year	Trt*Year
104 to 204 DOA (Early Weaning to Weaning of PAIRS and CREEP)										
Dec Wt., kg	112	119	116	118	107	122	6.25	0.82	0.98	0.58
Mar Wt., kg	184b	218a	242a	197b	180b	234a	8.81	<0.01	0.15	0.05
ADG, kg	0.74c	1.01b	1.29a	0.78c	0.72c	1.11b	0.053	<0.01	<0.01	0.03
Intake[1], kg DM/d	NA	5.04	4.12	NA	4.89	3.66	0.110	<0.01	0.09	0.36
204 to 223 DOA (Weaning of PAIRS and CREEP)										
Intake, kg DM/d	4.58d	6.44a	4.99c	4.21e	6.57a	5.86b	0.148	<0.01	0.07	<0.01
ADG, kg	1.17	1.23	1.10	0.83	1.00	0.93	0.259	0.74	0.10	0.88
223 to 311 DOA (Growing period)										
Apr Wt., kg	210b	243a	268a	210b	196b	249a	8.18	<0.01	<0.01	0.05
July Wt., kg	313c	343b	356a	326b	317c	367a	6.42	<0.01	0.94	0.02
ADG, kg	1.20	1.16	0.97	1.29	1.34	1.32	0.042	0.18	<0.01	0.08
Intake, kg/hd/d	6.67	6.66	6.09	7.53	7.69	7.82	0.151	0.57	<0.01	0.08

[1] Intake of calf ration. Calves in PAIRS were not offered any calf ration and only had access to the cow ration which was limit fed.

[2] Means with common letters within the row indicate no significant differences among treatments.

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Table 2.6 Calf value data from the preweaning period in December (104 DOA) to March (204 DOA) and then to the growing period from April (223 DOA) to July (311 DOA) in both years of a study evaluating the management of a calf when dams are limit-fed in confinement. Three treatments (trt) were applied 1) Kept with the dam with access to cow diet only (PAIRS) until 204 days of age (DOA), 2) Early-weaned (EW) at 104 DOA, and 3) Kept with the dam with access to calf diet (CREEP) until 204 DOA.

	Year 1 Treatments			**Year 2 Treatments**				**P-Values**		
Item	PAIRS	EW	CREEP	PAIRS	EW	CREEP	SEM	Trt	Year	Trt*Year
Dec Calf Value, $	682	723	704	716	652	710	28.5	0.89	0.76	0.44
Mar Calf Value, $	868bc	1000ab	1084a	929b	848c	1045a	28.3	<0.01	0.09	0.01
July Calf Value, $	1328	1375	1430	1333	1321	1473	16.8	<0.01	0.92	0.11

Table 2.7 Feed costs and returns above feed costs in a study evaluating the management of the young calf when dams are limit-fed in confinement for three periods. The first period was the early to normal weaning period from December (104 DOA) to March (204 DOA), followed by the growing phase from March to July (311 DOA), and finally a total phase, from the beginning of the trial in December until July. Three treatments (trt) were applied 1) Kept with the dam with access to cow diet only (PAIRS) until 204 days of age (DOA), 2) Early-weaned (EW) at 104 DOA, and 3) Kept with the dam with access to calf diet (CREEP) until 204 DOA. The PAIRS treatment was considered the baseline, with the EW and CREEP treatments being evaluated by taking the difference from the outcome of the PAIRS.

	Year 1 Treatments			**Year 2 Treatments**				**P-Values**		
Item	PAIRS	EW	CREEP	PAIRS	EW	CREEP	SEM	Trt	Year	Trt*Year
December to March										
Feed Costs	0	24.73	45.08	0	24.84	34.94	3.04	<0.01	0.37	0.43
Returns	0	65.62	147.86	0	-41.85	87.08	14.6	<0.01	0.01	0.09
March to July										
Feed Costs	0	7.73	-8.05	0	10.21	10.23	2.46	0.06	0.04	0.06
Returns	0	-92.16	-105.18	0	58.41	13.38	19.4	0.30	<0.01	0.06
Total										
Feed Costs	0	32.45	37.03	0	35.06	45.18	3.99	<0.01	0.46	0.77
Returns	0	-26.53	42.68	0	16.56	100.98	9.85	<0.01	0.02	0.16

[1] Feed costs do not account for the mixing of a second calf diet, they account for the two diets allocated to the cow and the calf. The cow diet was approximately 55.5% WDGs and 43.5% straw plus 1% mineral at $140/ton. The calf diet consisted of roughly 51% alfalfa hay, 25% WDGs, and 22% corn plus 1-2% mineral at $159/ton. Costs were determined by taking feed costs and averaging them across 6 years.

[2] Means with common letters within the row indicate no significant differences among treatments.

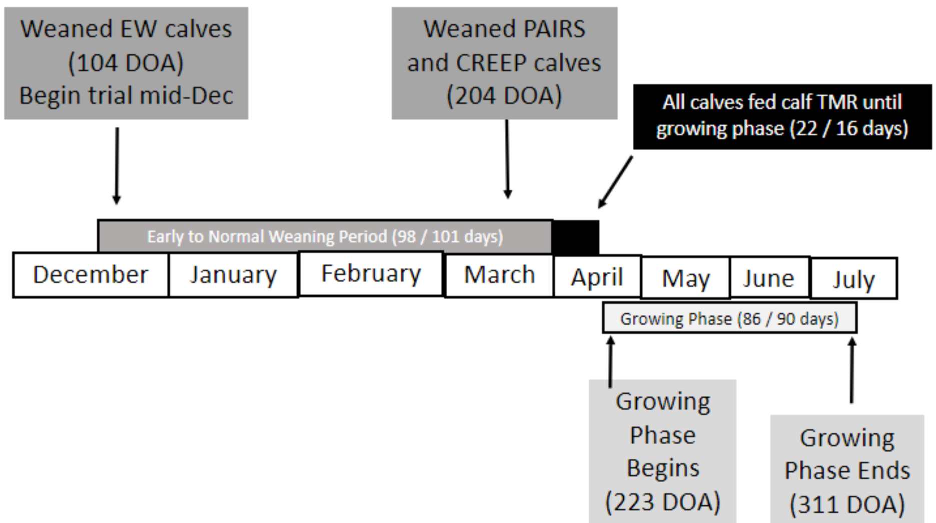

Figure 2.1 Timeline of the study specifying the early to normal weaning period, transition period, and growing period, including the calves' day of age (DOA) at the time and how long the period was. The number before the '/' represents the length of the period in year 1 whereas the number after represents the length of the period in year 2. Calves were born in August with the trial beginning in December. Early weaned (EW) calves weaned at ~104 DOA. In March, the other two treatments were weaned (PAIRS and CREEP) at ~204 DOA. In April, the 90-day growing phase began at ~223 DOA and concluded in July when calves were ~311 DOA.

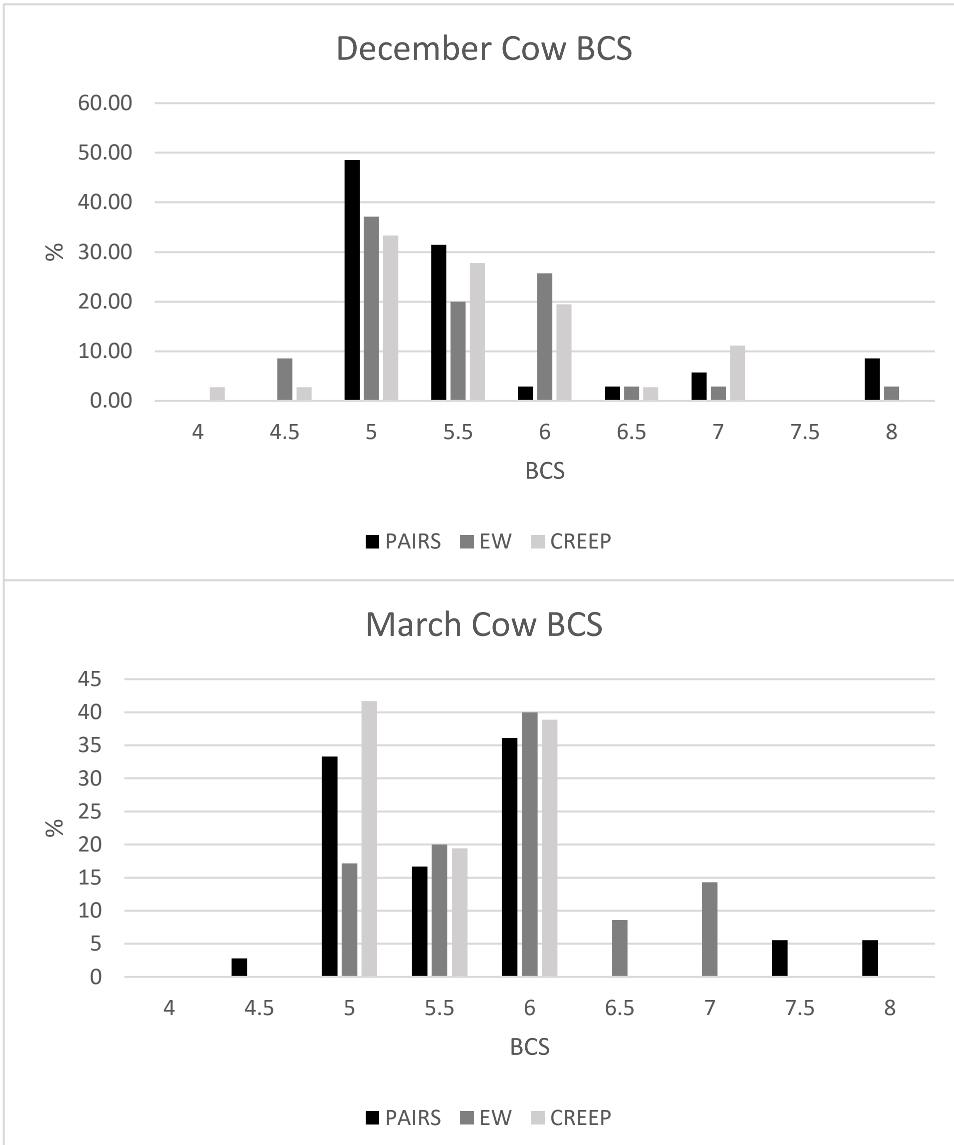

Figure 2.2. Body condition score of cows on a scale of 1 to 9 at the beginning and end of the early to normal weaning period in December and March, shown as a percentage of cows classified under whichever score.

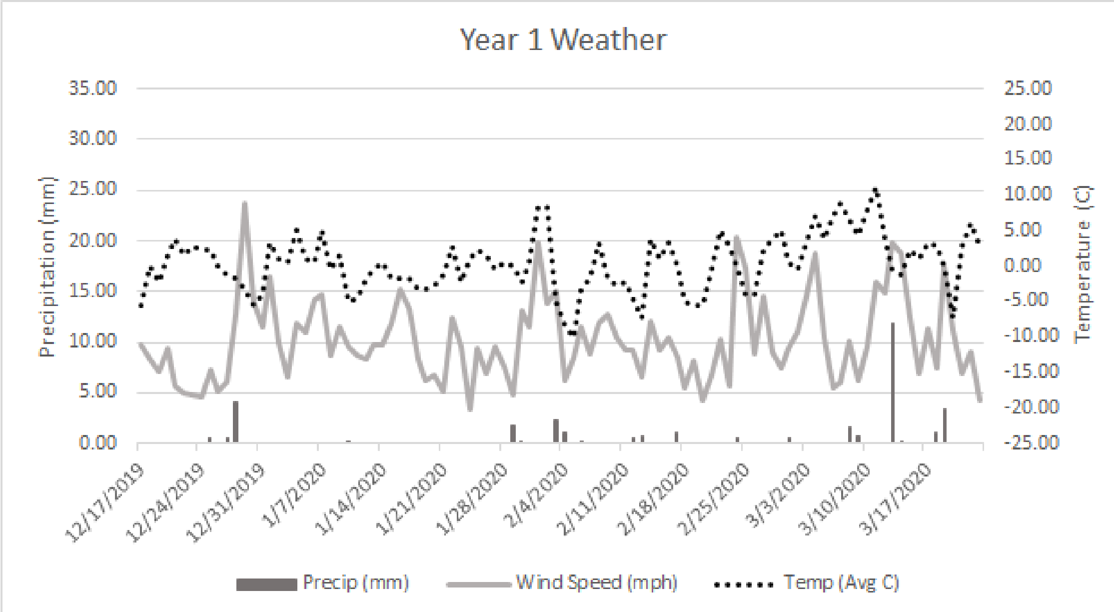

Figure 2.3 Precipitation, temperature, and wind speed during the early (104 DOA) to normal (204 DOA) weaning period (December to March) for year 1 of a study evaluating the management of the young calf when dams are limit-fed in confinement.

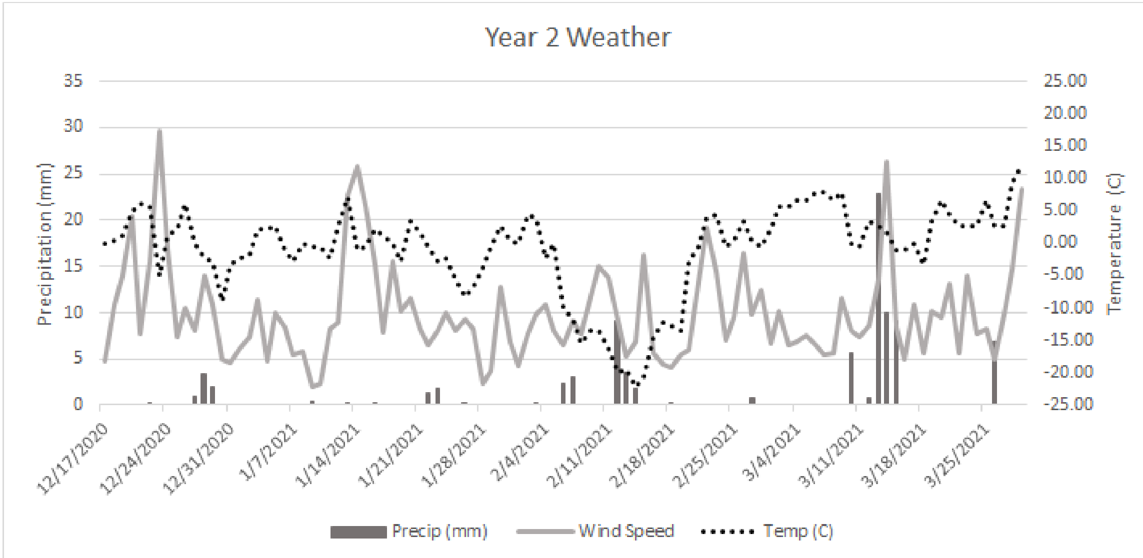

Figure 2.4 Precipitation, temperature, and wind speed during the early (104 DOA) to normal (204 DOA) weaning period (December to March) for year 2 of a study evaluating the management of the young calf when dams are limit-fed in confinement.

CHAPTER III. IMPACTS OF STOCKING DENSITY ON SOIL PHYSICAL PROPERTIES AND SUBSEQUENT SOYBEAN YIELD WHEN CATTLE ARE GRAZING CORN RESIDUE IN THE SPRING

Abstract

The effects of spring corn residue grazing and stocking density on soil physical properties and crop yields, were evaluated in an experiment with three treatments: no grazing (NG), normal stocking density (NSD), and high stocking density (HSD). The study was conducted over two years with four replicates per treatment each year. Calves (277 ± 4.4 kg) were stocked at 7.5 calves/ha for NSD with target grazing of 45 days starting in mid-February, and 22.5 calves/ha for HSD with target grazing of 15 days in mid-March, such that head days per hectare were equal. Target consumption was 3.64 kg per 25.5 kg of corn grain. Bulk density, penetration resistance, and surface roughness were measured pre-and post-planting, with soybeans planted 15 and 9 days after the pre-planting sampling in years 1 and 2 respectively. Post-planting samples were taken 13 and 20 days after planting in years 1 and 2 respectively. At 0-5 and 5-10 cm depths, bulk density and penetration resistance were greater ($P < 0.01$) for NSD than NG. There was no difference in bulk density ($P \geq 0.45$) between grazed treatments. At 0-5 cm, penetration resistance was not different ($P = 0.29$) between grazed treatments. For 5-10 cm, penetration resistance was greater ($P = 0.02$) for HSD compared to NSD. Surface roughness was greater ($P < 0.01$) for NSD than NG, and greater ($P < 0.01$) for HSD than NSD. There was no difference ($P \geq 0.34$) in soybean emergence among treatments. Soybean yield was greater ($P < 0.01$) for NSD compared to NG and tended to be greater ($P < 0.06$) for HSD compared to NSD. The results indicate that spring grazing may cause minor compaction, without reducing subsequent soybean yield.

Introduction

Corn residue grazing is an effective way to integrate crop and livestock production, but it is an under-utilized forage resource. A survey of 19 states in the U.S. determined that only 12% of corn residue is utilized (Schmer et al., 2017). When the utilization data for North Dakota, South Dakota, Nebraska, and Kansas were multiplied by the grazing rental rate, the value that was added to the crop sector was greater than 95 million dollars (Redfearn et al., 2019). Thus, corn residue grazing has potential to be a significant source of income for farmers and can be a low-cost feed source for cattle producers. The grazing of residue by cattle includes grazing kernels from any missed ears remaining in the field, in addition to husks and leaves. These are the more digestible portions of the plant. The stalk and cob are usually left in the field (Fernandez-Rivera and Klopfenstein, 1989). Grazing is more advantageous than baling, as it typically results in more residue on the ground to protect the soil from wind and water erosion than baling (Rakkar et al., 2019). Grazing also results in minimal nutrient removal from the field and can import nutrients, such as phosphorus, into the soil from the provision of supplement while cattle are grazing. Not only are there benefits to the soil, but seed emergence may improve as well. Studies have shown that the removal of residue could promote emergence (Rakkar et al., 2019) and may furthermore improve yield in some instances (Drewnoski et al., 2016).

Despite the environmental and economic advantages of grazing corn residue, not all farmers are comfortable with residue grazing due to concerns about compaction. In a survey of Nebraska farmers, of those who chose not to graze residue, 47% thought soil compaction was a major issue (Cox et al., 2017). Farmers may be uneasy about the risk of compaction and the potential negative impacts on soil physical properties, even though

previous studies have shown little impact on soil physical properties under normal grazing conditions during the winter months (Drewnoski et al., 2016; Rakkar et al., 2017; Stalker et al., 2015; Ulmer et al., 2019). However, there is minimal research looking at impact on the soil when cattle graze corn residue in the spring. Spring grazing was done by Clark et al., (2004) and the risk is greater for compaction and surface roughness when the soil is wet with above freezing temperatures, so grazing in the spring is quite different from winter grazing in that regard, with more wet conditions from the thawed ground. There is potential to cause compaction and negatively affect subsequent yield. We hypothesized that stocking at a higher density in the spring will negatively impact soil physical properties by increasing penetration resistance and impeding root growth thus negatively affecting subsequent soybean yield. Thus, the objective of this study was to evaluate the effects of stocking density of growing steers grazing corn residue in the spring, on soil physical properties and subsequent soybean yield, when the soil was thawed and wet.

Materials and Methods

Site Description and Experimental Design

A corn residue grazing experiment was conducted from 2018 to 2020 on 65-ha of cropland at the Eastern Nebraska Research and Extension Center of the University of Nebraska-Lincoln located near Mead, Nebraska (41.18°N; -96.45°W) to evaluate the effect of stocking density on soil physical properties and its influence on soybean emergence and yield. The soil was Tomek silt loam (43.3%), Yutan silty clay loam (32.9%), Filbert silt loam (22.4%), and Fillmore silt loam (1.5%); with a 0 to 6 percent slope (Web Soil Survey, n.d.). The experiment was a complete block design with three treatments: (i) no grazing (NG) (negative control), (ii) normal stocking density

(NSD) (positive control), and (iii) high stocking density (HSD). Previous grazing treatment (Drewnoski et al., 2016; Rakkar et al., 2017) applied to the land was used as a blocking factor. Within the four replicates, there were three previous treatments that had been applied for the previous decade: no grazing, fall grazing, or spring grazing of corn residue. The no graze treatment was maintained on the same area as it had been previously, so that nongrazed areas were preserved across experiments. The NSD and HSD were blocked by previous spring or fall grazing across replicates. The average amount of grazing days, according to surveyed states of Nebraska, Iowa, South Dakota, and Kansas, is 40 days, which was utilized when determining grazing days for the normal density treatment (Schmer et al., 2017). The corn yield in this field was ~14.61 Mg/ha and target grazing rate was based on the estimate of 7.27 kg of leaf and husk being produced per 25.5 kg of corn grain, and a target grazing rate of 50% of leaf and husk, which is 15% of the residue in the field (Gardine et al., 2016). The daily intake was assumed to be 5 kg of corn residue per steer plus the 2.45 kg DM· $steer^{-1} \cdot d^{-1}$ of dry distillers grain supplement provided.

The study utilized 128 calves each year (277 kg; SD ± 4.4 kg) that were stratified by BW and assigned to either NSD (7.5 calves/ hectare) with a target grazing period of 45 days or HSD (22.5 calves/ hectare) with a target grazing period of 15 days such that the number of head days per hectare were equal. Each grazed treatment paddock contained 1.08 ha which resulted in eight calves grazing in each NSD paddock and 24 calves grazing in each HSD paddock. Calves grazed within an irrigated, no-till, corn-soybean production system in eastern Nebraska, with NSD beginning to graze in mid-February and the HSD beginning to graze in early March (Figure 3.1). The objective of

the HSD was to create a worst-case scenario in order to evaluate the effects on the soil; thus, HSD was put on their paddocks once a moisture event occurred. Until then, the HSD cattle grazed corn residue in an adjoining field at normal stocking rate.

Calves were turned out onto NSD treatment on February 13, 2019 in year 1 and February 15, 2020 in year 2. The HSD calves began on treatments March 15, 2019 in year 1 and March 6, 2020 in year 2. Calves in NSD treatments were pulled off paddocks on March 27, 2019 in year 1 and March 31, 2020 in year 2. The HSD calves were pulled off treatments March 25, 2019 in year 1 and March 21, 2020 in year 2. Weather data (AerisWeather, n.d.) includes the temperature and precipitation for both years of the study during the grazing period (Figure 3.2).

Soil measurements were taken 21- and 50-days post removal of NSD calves in both years and 23 and 52 days and 31 and 60-days post removal of HSD calves in years 1 and 2, respectively. Soybean planting occurred on May 2, 2019, and April 29, 2020, and crop emergence was evaluated 30 days post-planting. The planter was set to seed 59,514 seeds per ha and planter down pressure was adjusted with changes in surface roughness.

The width of each paddock consisted of thirty-two, 76 cm corn/soybean rows, with all the data being collected within the center 16 rows to avoid edge effects. Soil samples were taken at three locations, within four randomly selected rows that did not receive equipment traffic, resulting in 12 sample sites per paddock.

Field and Laboratory Measurements

Soil compaction.

Bulk density and soil penetration resistance were evaluated within rows that did not receive equipment trafficked to avoid potential compaction from equipment masking treatment effects. Both measurements were evaluated at a depth from zero to five

centimeters and from five to ten centimeters. Penetration resistance was measured with a penetrometer (Eijkelkamp Co., Giesbeek, the Netherlands; Lowery and Morrison, 2002). A cone index of 2 cm^2 was utilized and measurements were converted from Newtons to megapascals (MPa) dividing by the cone area specified above. Intact bulk density cores with diameter of 4.83 cm by 5 cm long were taken at each depth. Soil cores were placed in the oven at 60°F to determine gravimetric water content and dry soil weight.

Surface roughness.

A 6.1-meter-long chain was utilized to measure surface roughness with 12 measuring sites per paddock. As the chain follows the contours of the ground, it will ultimately decrease in length with increased surface roughness (Clark et al., 2004). The length that the chain covered on the ground was measured, and this difference in measured length from actual length was then divided by the actual length of the chain and multiplied by 100 in order to express the percent change in chain length. Therefore, a larger number is an indicator of more surface roughness.

Residue cover.

Residue cover was measured only in year 2 of the study, pre-planting, on April 21, 2020. Three 30.5 m measuring tapes were laid along the ground diagonally in a zig-zag pattern across rows in each paddock. At every 0.3-meter mark, it was recorded whether the measuring tape was touching residue or bare ground, resulting in a total of 300 measurements per treatment paddock.

Soybean emergence.

Emergence was measured in 4 rows of each treatment paddock, with 3 sites per row, resulting in 12 sample sites per paddock. A 5.3-meter pole was used to count the number of seedlings within that length.

Soybean yield.

Yield was measured from the center 16 rows in each paddock to avoid edge effects. The grain was harvested using an 8-row combine and soybeans were weighed in a grain cart with load cells. Yield was adjusted to 13% moisture.

Statistical analysis

Evaluated as a randomized, complete, block design, the model included treatment, year, and block within year. Two orthogonal contrasts were developed: 1) to compare the no graze treatment to normal stocking density, and 2) normal to high stocking density. Significance was declared at $P \leq 0.05$, with a tendency for significance declared at $P \leq 0.10$.

Results and Discussion

Soil cover.

The amount of residue cover at the end of grazing differed ($P < 0.01$) among treatments, with NG having greater ($P < 0.01$) cover than NSD and NSD having greater ($P < 0.01$) residue cover than HSD (Table 3.1). The differences in cover could easily be visually observed (Figure 3.3). The decreased residue cover in the high stocking density treatment is thought to be primarily due to increased trampling losses as the intake between NSD and HSD cattle would be expected to be similar. Shelton et al. (1997) evaluated the percentage of residue cover as cattle were grazing for two months in the fall after harvest. Shelton et al. (1997) then used this data to predict residue cover reduction due to grazing (CR = GRF x AN x AW x D / GA / k where CR = residue cover reduction due to grazing; %; GRF = grazing reduction factor; AN = number of animals; AW = average weight of the animal, kg; D = grazing period length, days; GA = corn residue area grazed, ha; k = 1000, conversion to animal units). They predicted that the grazing reduction factor ranges from 0.28 to 0.49 %/ha/day^{-1}/1000 kg animal unit^{-}

^{1}. Based on this equation, Shelton et al. (1997) would have predicted a 26 to 45% residue cover reduction due to grazing for the current study. This is far from the actual residue cover reduction, which was a 50% reduction from the non-grazed to NSD treatment, and a 70% reduction from the non-grazed to the HSD treatment. The current study's reduction in cover in HSD was well above that which would have been predicted by Shelton et al. (1997) which could be explained by the time at which grazing occurred. Shelton et al. (1997) had cattle grazing in November thru January when the ground was likely to be frozen. In the current study HSD grazed in March, when the ground was less likely to be frozen and more likely to be wet.

Rakkar et al., (2019) evaluated the impacts of grazing corn residue at six farms in Nebraska. The no grazed paddocks had an average of 85% residue cover, which is similar to the current study (88%) and the observed residue cover averaged 72% in the grazed paddocks. This (13%) reduction in cover was slightly less than the predicted range (22-39% residue cover reduction) by Shelton et al. (1997). Like Shelton et al. (1997), all farm sites in Rakkar et al., (2019) were grazed during the fall/winter months when the ground is more likely to be frozen. Therefore, the current study most likely saw higher residue removal due to the conditions during grazing as the ground was thawed and wet suggesting that season may have a lot of influence on how much residue is trampled. In the current study, HSD had greater residue cover reduction and had more head days on thawed wet ground, which may explain why residue the reduction falls well outside the range of what was previously predicted.

Across both years, surface roughness at the end of grazing (Table 3.1) differed ($P < 0.01$) among treatments with NG having less ($P < 0.01$) surface roughness than NSD

and NSD having less ($P < 0.01$) surface roughness than HSD. Again, suggesting increased trampling in HSD. Even though both groups of cattle were grazing during periods with above freezing temperatures, the HSD groups spent almost all of their grazing time under wet conditions. The ground was thawed 39 and 87% of the grazing period for NSD during years 1 and 2 respectively, with 36 and 29 mm of precipitation falling during this time. For HSD, 100 and 87.5% of the grazing period had thawed ground in years 1 and 2 respectively, with the total amount of precipitation during this period being 13 and 25 mm for each year, respectively. Although there was less total precipitation when HSD was grazing, when considered as precipitation per grazing day, it was greater for HSD. Both the above freezing temperatures and soil moisture contribute to the increased roughness. Others have shown that environmental factors like precipitation and temperature play a critical role in the extent of surface roughness that may occur when grazing corn residue. Soil surface roughness was evaluated in Clark et al., (2004), and like the current study, the roughness was increased in the grazed treatments compared to the nongrazed control treatment. In two of the three years of the study, the final grazing period in February showed increased surface roughness. Approximately 75% of this last period had above freezing soil temperatures.

Compaction parameters.

Bulk density and penetration resistance (Table 3.2) were measured at two depths, 0-5 cm and 5-10 cm, and two timepoints, before and after planting. At both timepoints and depths, NG had less ($P < 0.01$) bulk density compared to NSD suggesting that NG had more pore space between soil particles than NSD. No difference ($P \geq 0.45$) between the grazed treatments (NSD and HSD) were observed for bulk density. Thus, indicating that grazing seemed to result in minor compaction, but stocking density did

not impact bulk density. For both timepoints, penetration resistance at the shallow depth followed the same pattern as bulk density. No graze had less ($P < 0.01$) penetration resistance at 0-5 cm than NSD at both timepoints but there was no difference ($P = 0.29$) among the grazed treatments. At 5-10 cm, NG again had less ($P < 0.01$) penetration resistance than NSD at both timepoints. However, at 5-10 cm, NSD and HSD differ pre-planting, with NSD having less ($P = 0.02$) penetration resistance than HSD. At post-planting, there was a tendency for NSD ($P < 0.08$) to be less than HSD. While bulk density and penetration resistance were increased by grazing, it is important to understand that these changes were very minor and likely of little biological significance. A penetration resistance value greater than 2 MPa in this soil type could result in restricted root growth. A bulk density value of 1.65 g/cm³ or more could also indicate that root growth could be restricted. Thus, it is unlikely that the increase in penetration resistance and bulk density would be considered detrimental as penetration resistance values were ≤ 1.76 MPa and bulk density values were ≤ 1.27 g/cm³ across all treatments at both depths and timepoints. This was a short-term study and compaction was not an issue, but even in a long-term spring corn residue grazing study by Rakkar et al., (2017) there were no major compaction effects due to grazing. Penetration resistance values were ≤ 1.5 MPa and bulk density values were ≤ 1.55 g/cm³ for spring grazing.

The moisture content (Table 3.2) at the shallow depth was greater ($P < 0.01$) for NG than NSD at both timepoints. At pre-planting, moisture content of NSD was greater ($P < 0.01$) than HSD at 0-5 cm. However, there was no difference ($P < 0.20$) between grazed treatments at 0-5 cm post-planting. There was also no difference ($P \geq 0.78$) between the grazed treatments at 5-10 cm depths at either time point. With

less residue cover, there appeared to be more evaporative loss, resulting in dryer soil, especially within the HSD treatment. However, the field in this study was irrigated, which means evaporative effects may not be as impactful as a non-irrigated field, especially in areas with limited rainfall. It is important to note that penetration resistance was not adjusted for moisture content of the soil and the wetter the soil, the easier it is to penetrate. Differences in moisture content may explain why more change was seen with penetration resistance compared to bulk density and why bulk density is usually considered a better estimate of true compaction.

Soybean emergence and yield.

There were no differences (P > 0.34) in emergence among treatments. Similarly, Ulmer et al., (2019) also found there to be no difference in soybean plant populations between grazed treatments and no grazed control treatments when grazing in the winter (November through February) in Nebraska.

Unlike emergence, yield differed (P < 0.01) among treatments in the current study (Table 3.3). Soybean yield was less (P < 0.01) for NG (4,902 kg/ha) than NSD (5,084 kg/ha) and tended to be less for (P = 0.06) NSD compared to HSD (5,202 kg/ha). The greater yields in the grazing treatments may be due to warmer soil temperatures, because of less residue cover, or potentially increased microbial activity in the soil which may speed up nutrient cycling. Ultimately, cattle are consuming nutrients while grazing, but also returning nutrients to the soil through manure. Rakkar et al., (2017) found that grazing residue increases the microbial population in the soil and in the companion paper, Drewnoski et al., (2016) reported a positive effect on soybean yield when grazing corn residue. It is important to note that in both the current study and that of Drewnoski et al., (2016), the corn was high yielding (~209-211

Mg ha^{-1}) meaning there would be high amounts of residue present. Also, in both of these studies, a distillers supplement was provided, which would result in some importing of both nitrogen and phosphorus. Other studies have observed no impact on yield under fall/winter grazing situations (Stalker et al., 2015; Ulmer et al., 2019).

However, Clark et al. (2004) grazed five 0.81 ha paddocks moving to a new paddock every 4 weeks from October to February over a 3-year period. In one period of year 3, they observed increased penetration resistance, surface roughness, and decreased soybean yield, but only in the no-tillage system. In this period the soil was wet from precipitation, and the temperatures were above freezing. The decrease in yield may have been due to poorer seed placement. Without adjustments to planting speed and down pressure, increased surface roughness may result in greater variation in seed placement, which may impact emergence. In the current study, planting down pressure and speed was adjusted in order to achieve good seed placement across treatments. It was not clear if adjustments in down pressure or planting speed due to surface roughness were made in the Clark et al., (2004).

Conclusions

This study attempted to evaluate a worst-case scenario, as cattle were deliberately grazed when the soil was thawed and wet. However, grazing seems to cause only minor compaction without reducing subsequent soybean yields. When stocking to have cattle consume 50% of the leaf and husk (15% of the total corn residue), in the spring, increased stocking density impacts soil physical properties, increases residue cover loss, but may improve subsequent yield in high yielding irrigated fields.

Acknowledgements
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Table 3.1 Percentage of residue cover and surface roughness present after corn residue was not grazed (NG), grazed in the spring at a normal stocking density (NSD) with 7.5 calves/hectare for 45 days or at a high stocking density (HSD) with 22.5 calves/hectare for 15 days.

	NG	NSD	HSD	SEM	NG vs NSD	NSD vs HSD
Residue cover[1], %	87.9	37.7	17.7	2.8	<0.01	<0.01
Surface roughness[2], %	1.6	9.5	14.9	0.78	<0.01	<0.01

[1]Residue cover only measured in year 2, at 21-days and 31-days post removal of NSD and HSD calves respectively.
[2]Surface roughness was measured using a 6.1-meter-long chain which decreased in length with increased surface roughness. It is expressed as the percent change in chain length.

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Table 3.2 Soil parameters measured[1] after corn residue was either not grazed (NG), grazed in early spring at a normal stocking density (NSD) with 3 steers/acre for 45 days or at a high stocking density (HSD) with 9 calves/acre for 15 days.

Item	NG	NSD	HSD	SEM	*P*-value	
					NG vs NSD	NSD vs HSD
Bulk density, g/cm³						
Pre-plant						
0-5 cm	0.85	1.02	0.99	0.041	<0.01	0.45
5-10 cm	1.16	1.25	1.25	0.028	<0.01	0.92
Post-plant						
0-5 cm	0.88	1.01	1.02	0.036	<0.01	0.80
5-10 cm	1.18	1.27	1.27	0.016	<0.01	0.86
Penetration resistance, MPa						
Pre-plant						
0-5 cm	0.50	1.53	1.64	0.12	<0.01	0.29
5-10 cm	0.71	1.36	1.58	0.07	<0.01	0.02
Post-plant						
0-5 cm	0.52	1.67	1.76	0.11	<0.01	0.37
5-10 cm	0.73	1.45	1.64	0.12	<0.01	0.08
Moisture content, %						
Pre-plant						
0-5 cm	23.8	19.7	17.1	0.89	<0.01	<0.01
5-10 cm	23.0	22.2	22.0	0.59	0.35	0.81
Post-plant						
0-5 cm	25.2	19.5	18.0	0.86	<0.01	0.20
5-10 cm	24.1	22.0	21.9	0.37	<0.01	0.78

[1] Steers were removed from treatments at the end of March. Pre-plant soil samples were taken approximately 21- and 27-days post removal of NSD and HSD calves. Post-plant soil samples were taken 50 and 56 days post removal of NSD and HSD calves. Samples were taken in rows in which no equipment had traveled.

Table 3.3 Soybean emergence and grain yield (87% DM) when planted after corn residue was either not grazed (NG), grazed in early spring prior to soybean planting[1] at a normal stocking density (NSD) with 7.5 calves/hectare for 45 days or at a high stocking density (HSD) with 22.5 calves/hectare for 15 days.

	NG	NSD	HSD	SEM	NG vs NSD	NSD vs HSD
Emergence[2], plants/ha	252,709	265,129	269,889	8,700	0.34	0.70
Soybean yield, kg/ha	4,902	5,084	5,202	41.0	<0.01	0.06

[1] Cattle were pulled off treatments at the end of March and soybeans were planted approximately 30 days later.

[2]Emergence counts were taken 30 days post-planting.

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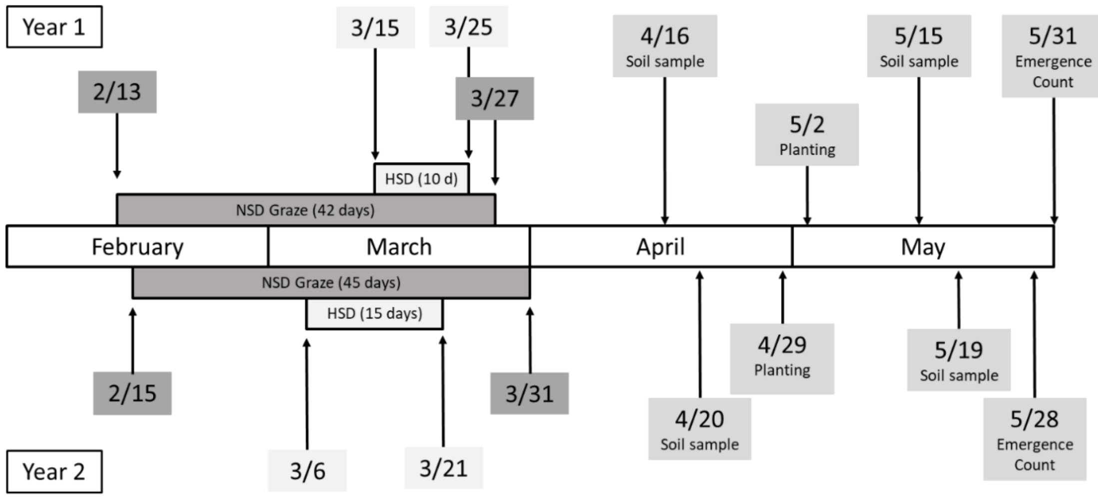

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Figure 3.1 Timeline of study comparing impacts of grazing corn residue using normal stocking density (NSD) with 7.5 calves/hectare for ~43 days or at a high stocking density (HSD) with 22.5 calves/hectare for ~12 days on soil physical properties. Grazing and sampling dates for year 1 are presented at the top and year 2 is presented at the bottom.

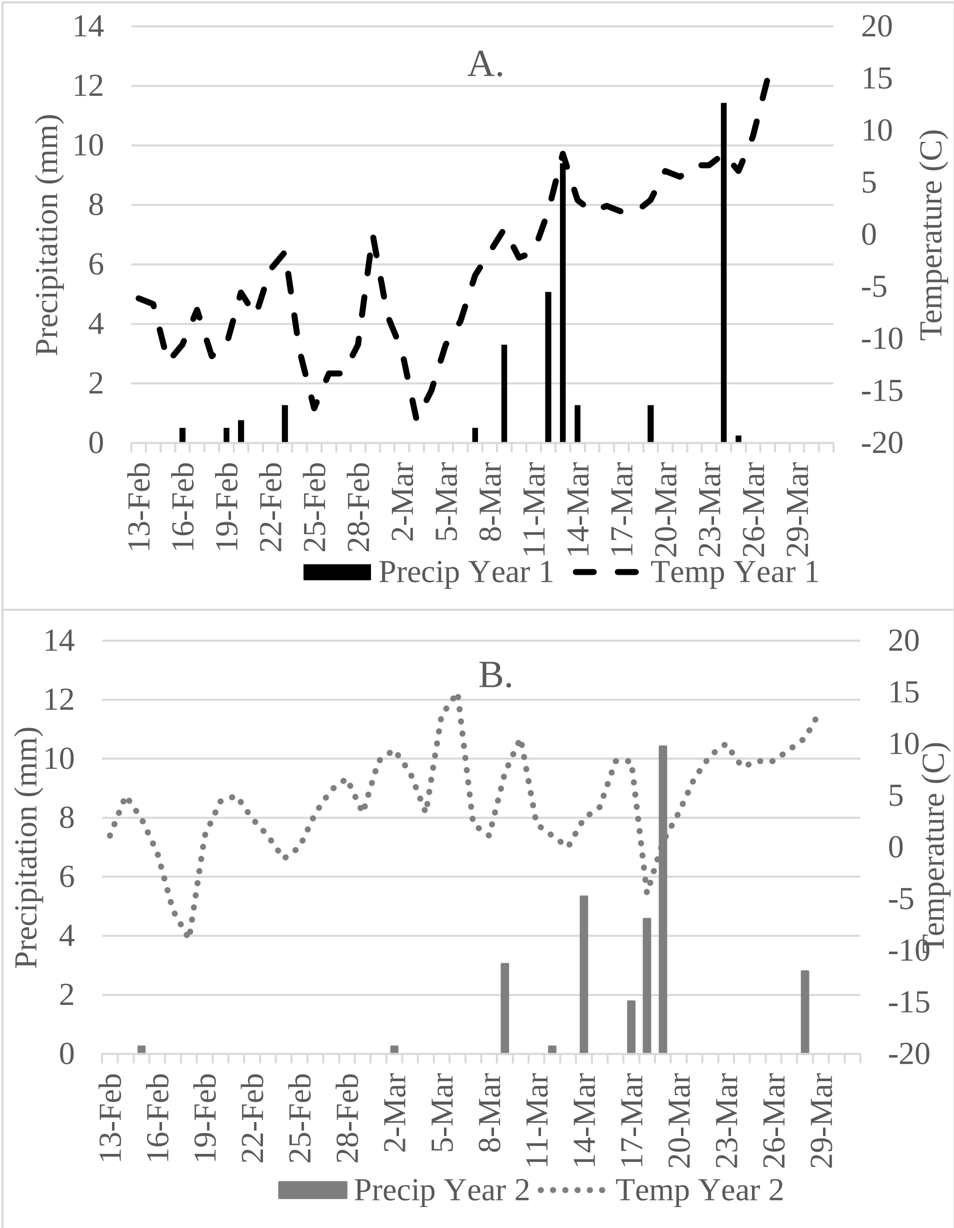

Figure 3.2 Weather data for year 1 (A) and year 2 (B) of the study. The NSD cattle grazed from February 13, 2019 to March 27, 2019 in year 1 with total precipitation of 35.56mm and 39% of the grazing period above freezing. In year 2, NSD cattle grazed from February 15, 2020 to March 31, 2020 with total precipitation of 28.70mm and 87% of the grazing period had above freezing temperatures. The HSD cattle grazed from March 15, 2019 to March 25, 2019 in year 1 with a total of 12.95mm in precipitation and 100% of the grazing period containing above freezing temperatures. Finally, in year 2, HSD cattle grazed from March 6, 2020 to March 21, 2020 with 25.40 mm of precipitation and 87.5% of the grazing period with above freezing temperatures.

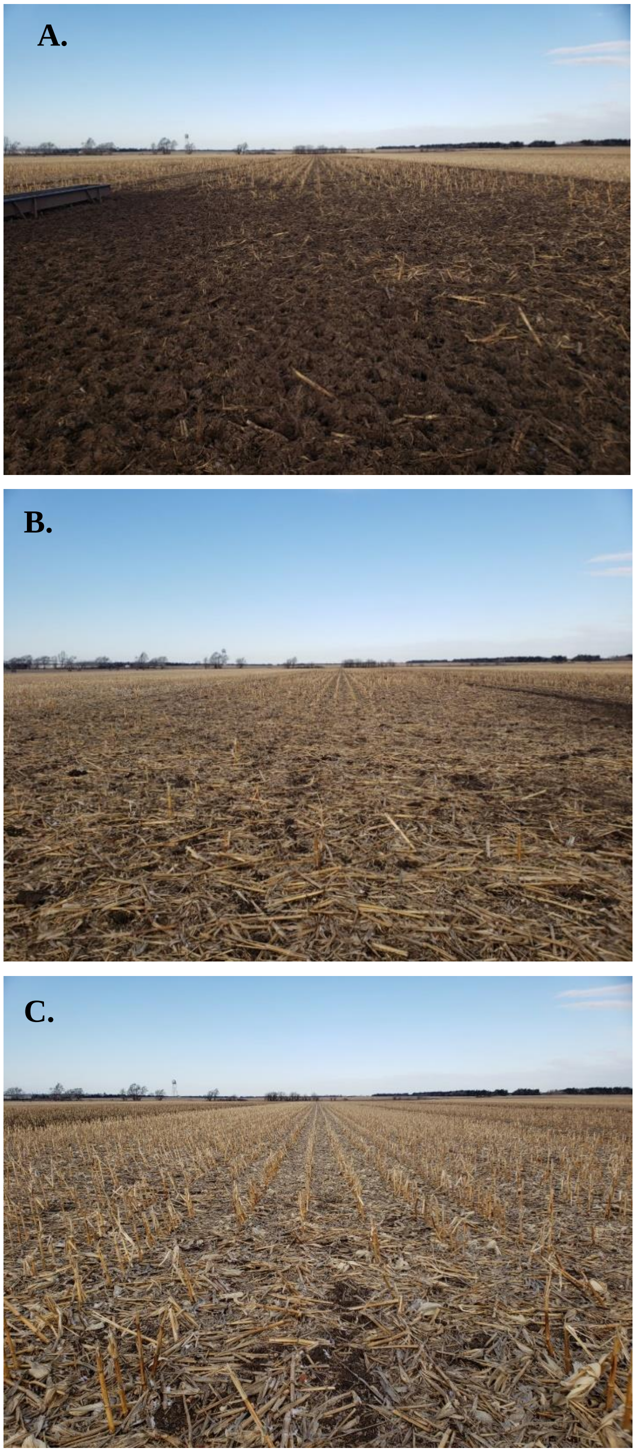

Figure 3.3. Residue cover images post-grazing in all three treatments- high stocking density (A), normal stocking density (B), and no graze (C).