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Management of Late Summer Planted Annual Forages for Grazing and the Impacts of Novel Sweet Bran Plus Products on Performance and Carcass Characteristics of Beef Finishing Steers

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MANAGEMENT OF LATE SUMMER PLANTED ANNUAL FORAGES FOR GRAZING AND THE IMPACTS OF NOVEL SWEET BRAN PLUS PRODUCTS ON PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF FINISHING STEERS

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MANAGEMENT OF LATE SUMMER PLANTED ANNUAL FORAGES FOR GRAZING AND THE IMPACTS OF NOVEL SWEET BRAN PLUS PRODUCTS ON PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF FINISHING STEERS

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Two separate grazing studies were conducted to evaluate: 1) the effects of rapeseed inclusion into late summer planted oats on the performance of growing steers during late fall and winter (Exp. 1) and 2) the effects of forage allocation on forage utilization and performance of steers grazing a late summer planted oat-rapeseed mix (Exp. 2). Variation in the corn wet milling process can result in negative effects on animal performance, nonetheless, there remains interest in further exploration and refinement of corn wet milling byproducts to achieve optimal byproduct compositions and cattle performance. Thus, another experiment was conducted to evaluate the effects of novel versions of Sweet Bran Plus on performance and carcass characteristics of beef finishing steers (Exp. 3). In Exp. 1, inclusion of rapeseed into late summer planted oats improved average daily gain for steers grazing during late fall and winter compared to steers grazing an oat monoculture. Rapeseed inclusion also resulted in a lower cost of gain because of greater average daily gain and a lower seed cost for rapeseed. In experiment 2, allocating forage twice weekly by strip grazing resulted in a greater gain per unit of land and a lower cost of gain than continuous grazing. Continuous grazing did result in greater average daily gain during the 71-day grazing season, but strip grazing offered more grazing days per hectare. Steers on treatment B

in Exp. 3 tended to have a greater dry matter intake, but no differences were observed among treatments for average daily gain or feed efficiency. Feeding treatment C resulted in decreased marbling score and yield grade. Grazing a late summer planted brassica-oat mix in late fall does improve performance compared to an oat monoculture and better forage utilization can be achieved by strip grazing a mix compared to continuous grazing. Novel Sweet Bran Plus versions A and B offer the best combination of steer performance and quality grade when fed in steam flaked corn-based finishing diets.

Keywords: annual forages, brassicas, wet corn gluten feed, corn byproducts, forage utilization

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INTRODUCTION

In the U.S., land use has changed over the last several decades as the population has grown and industries have changed. Cropland has declined 18% since 1949, while grazed forestland has declined over 50% (Bigelow, 2017). With the decrease in available land for agricultural use has come an increased adoption by farmers to incorporate cover crops, with the goal of reducing soil erosion and improving soil organic matter, among others. The wide use of cover crops has created potential for cattle producers to utilize them as a high-quality alternative forage source. Brassicas such as radishes or small cereal grains such as oats are two types of cool-season annual cover crops that are commonly planted in late summer after wheat harvest, corn silage harvest, or hybrid seed corn harvest (Drewnoski, 2015). Late summer planted cool-season annual forages are high in nutritive value and apt to yield well, making them a great alternative forage source for winter grazing. Furthermore, when paired as a mix, brassicas and small cereal grains offer greater digestibility and CP relative to a small cereal grain monoculture (Lenz et al., 2018). While previous work has explored the nutritive value and yield of oat-brassica mix, performance of cattle while grazing these forages and methods for increasing forage utilization of these forages in late fall and winter have not been studied.

The increased use of corn byproducts has brought improved cattle performance and economics to the feedlot industry and has contributed to

managing acidosis, particularly for wet corn gluten feed. Wet corn gluten feed is a byproduct of the corn wet milling process that, among other byproducts, is utilized in 97.1% of all feedlot finishing diets in the U.S. (Samuelson et al., 2016). Sweet Bran (Cargill, Inc.) is a branded wet corn gluten feed product. Sweet Bran is 60% DM and has 112% the feeding value of dry-rolled corn, making it a great energy and protein source for finishing rations (Klopfenstein et al., 2007). The wet milling process can be highly variable among plants, resulting in potential for variation in the composition of byproducts. While some variation can be detrimental to animal performance, there remains interest in further exploration and refinement of corn wet milling byproducts to generate optimal byproduct compositions and subsequent cattle performance.

YIELD AND NUTRITIVE VALUE OF ANNUAL COOL-SEASON FORAGES

Cool-season forages have been commonly used in row-crop production as a cover crop for the preservation of soil health, yet grazing late-summer planted forages in late fall and winter is not widely adopted. In general, grazing a cool-season forage in the fall and winter can provide adequate forage and nutrition to growing calves (Ulmer et al., 2016). Furthermore, grazing cool-season annual forages can minimize cost by extending the grazing season (McCartney et al., 2008). The type of cool-season forage grazed largely hinges on climate and region, as well as the preference of the producer. Grazing to achieve substantial

animal gain, increase forage utilization, or decrease the cost of gain are all things producers must consider when deciding what to plant.

Brassicas

Brassicas can add a valuable component to a cover crop mix to improve forage quality and nutrient composition (Lenz et al., 2018). Common brassicas utilized for grazing in Nebraska include rapeseed, turnips, radishes, and collards, and are best suited for planting after wheat or corn silage harvest (Drewnoski, 2015). Although dry matter (DM) yield declines due to factors such as weather events and trampling, the nutritive value of brassicas only declines slightly with plant maturity. Lenz et al. (2018) reported a 5 and 10 percentage-unit decline in IVOMD of brassicas and oats, respectively, from December to January when planted as a mixture. No significant changes in the quality of oats or brassicas were observed prior to December in the 2-year experiment, and CP content remained relatively constant from November to January. A 10-year study in Wyoming reported 7% unit declines in CP content of turnips and radishes from October to January; however, only one year reported sampling beyond November (Koch et al., 2002). Another experiment showed crude protein content in early October 70 days after planting was 20-22% and declined to 12-15% at 120 days after planting, suggesting declines due to winter kill and changes in concentration of plant nitrogen due to grazing (Reid et al., 1994). Others have reported declines in CP content between September and early November and have attributed the change to an increase in plant maturity during

active growth (Dillard et al., 2020). Nonetheless, overall CP content of brassicas remains high despite slight declines during active growth in the fall, and little change can be expected once dormancy begins.

Nutritive value of brassicas is consistent among the limited amount of available research. Much of the literature compares brassica monocultures to traditional grass pastures, or to mixtures of brassicas and cereal grains like oats. Table 1.1 provides a summary of the DM yield and nutritive value of several cultivars of brassicas from multiple studies. An experiment conducted in Colorado measured the nutritive value of 9 different cultivars of brassicas over 2 late-summer planting dates, and 2 different harvest dates (Villalobos & Brummer, 2015). They reported a range of 18.6-25.5% CP for the 9 cultivars of brassicas, with rapeseed being the greatest when planted in mid-August. Similar values (18-24.7%) for CP content were reported when brassicas were planted in mid-August with a cereal grain-clover mix (Farney et al., 2017). This is similar to observations reported by Lenz et al., (2018) that radishes and turnips had greater CP content than oats (24, 20, and 10% CP, respectively) in both years of a two-year study. Although digestibility among brassicas did not differ in each month, brassicas were more digestible than oats (Lenz et al., 2018). Turnips and radishes ranged from 86 to 88% IVOMD, while oats IVOMD was 69%. They did note that digestibility declined for both oats and brassicas which was primarily due to winter temperatures as all but one sample were taken after the first hard freeze. These values for digestibility of brassicas are similar to the

range of 85.5 to 92.9% IVTD reported by Villalobos & Brummer, (2015), although the process for measuring IVTD has some notable differences compared to IVOMD. McCormick et al., (2006) observed low NDF and high CP content of brassicas in fall grazing systems compared to cereal grains. Since NDF is a measure of structural carbohydrates such as cell wall content, lower values are desirable (Rasby et al., 2008). In this case, brassicas may offer greater digestibility by being lower in NDF than the cereal grain forages they may or may not be planted with. However, NDF is still needed for cattle grazing brassicas due to the high energy content and acidosis potential—making small cereal grains, which are greater in NDF, a great complement to brassicas when planted together in a mix.

Barry, (2013) observed similar CP content between perennial ryegrass pastures and several brassicas which is similar to a previous study showing CP to be between 15.4 and 17.4% for both hybrid turnip and perennial ryegrass (Lindsay et al., 2007). Brassicas are also generally higher in ME and apparent DM digestibility than perennial ryegrass (Barry, 2013). Another experiment done with sheep in New Zealand reported higher ME of turnips than perennial ryegrass-clover pastures, although ME did decrease over time (Lindsay et al., 2007).

Subtle differences exist among brassica cultivars and can be attributed to factors such as planting date, but brassica monocultures are well suited for high yields and nutritive value. While brassicas are similar in nutritive value to

ryegrass, they are superior in nutritive value to most other grasses that are commonly grazed in the U.S. Nonetheless, a more reasonable comparison can be made in comparing brassicas to late summer planted cool-season annuals such as oats or rye. In this case, brassicas likely increase digestibility and provide CP content of greater than 18% on a DM basis, thus, making them a great option for cover crop mixes.

Brassicas may offer some nutritive advantages over other cool-season annual forages, but it is important to note that they do contain secondary plant metabolites (Sun et al., 2012) such as glucosinolates (Tripathi & Mishra, 2007), S-methyl cysteine sulfoxide (Barry et al., 1982), and nitrates (Brunsvig et al., 2017). These secondary compounds could potentially cause anemia, iodine deficiency, depress DM intake, or suppress animal growth but the full quantifiable effect is not known (Belesky et al., 2007). High sulfur concentrations of 0.69% to 1.04% (Lenz et al., 2018) are considered above the maximum tolerable sulfur level of 0.5% in forages (NASEM, 2016) and can result in polioencephalomalacia (PEM) (McKenzie et al., 2009). Illnesses such as PEM can hinder animal performance and even lead to death if not treated. A wide range of factors may influence the intake of brassicas, but nothing has directly pointed to secondary plant compounds as the cause. It has also been suggested that brassicas reduce methane emissions/unit DM intake and

digestible OM and may be a more suitable forage if CH_4 mitigation is desired when grazing (Dillard et al., 2017; Sun et al., 2012).

A common intention of using late summer planted cool-season forages for grazing is to extend the grazing season and offer cows or stocker calves a quality forage. Four grazing experiments over a five year period reported yields of 3,375 to 5,942 kg DM/ha in the late fall and early winter for brassicas, similar to reports of 1,500 to 5,000 kg DM/ha by Simon et al., (2014) and Griffin et al., (1984). Other work evaluating growth potential of 9 cultivars of brassicas reported yields of 2,499 to 9,482 kg DM/ha, with variability in yield being due to planting date and harvest date (Villalobos & Brummer, 2015).

Time of planting has a significant effect on DM yield of brassicas, with earlier planting dates resulting in almost double the yield in some cases (Table 1.1). Geographic region, soil characteristics, and growing degree days are also contributing factors to yield (Belesky et al., 2007). Similar yields have been reported in Pennsylvania and Colorado (Dillard et al., 2020; Villalobos and Brumer, 2015). However, these yields are less than the yields of similar brassicas planted on similar late-summer dates in Nebraska and Colorado (Lenz et al., 2018; Villalobos & Brummer, 2015). Although the effects of planting date, harvest date, and region were demonstrated in the previous studies, an interaction of cultivar by planting date was also observed. Earlier planting dates resulted in higher overall DM yields. Villalobos & Brummer, (2015) observed higher yields in rape when planted early, but a larger reduction in DM yield

(65%) between the early and late planting date compared to turnips (46% reduction). This is consistent with previous studies that have shown that rape has a longer day length requirement; and thus, turnips and radishes tend to be better suited for growth when planting is delayed until late August (Jung et al., 1986; Jung & Shaffer, 1995). Previous work demonstrated a cultivar by soil temperature interaction in which cultivars differed in the percent germinated at all temperatures except 2°C and 50°C on day 4, suggesting that soil temperature should also be considered when deciding which cultivar to plant (Wilson et al., 1992). Differences among brassicas have been observed in yield, but there has been little fluctuation in nutritive value reported (Belesky et al., 2007) when comparisons have been made. That said, planting date and soil temperature, which may be dictated by geographic region, are the most important variables to consider when planting brassicas.

Overall, brassicas offer similar CP (18-25%) but are more digestible than other cool-season annual forages, having true digestibility of greater than 85%. Yield potential of brassicas is 2,500 to 7,000 kg DM/ha on average and makes them suitable for monocultures in terms of yield. However, the low NDF and high digestibility of brassicas does create a disadvantage if planted as a monoculture because of the acidosis potential and high sulfur concentration of the forage; thus, planting brassicas with a greater NDF plant such as a small cereal grain can negate the low fiber content of the brassicas and the lower digestibility of the cereal grain. Like all forages, factors such as planting date and soil temperature are important to consider when deciding which brassica to

plant and whether to plant it with another cool-season annual. Nitrate toxicity is a concern if brassicas are grazed prematurely, but like CP and digestibility, most changes in the plant occur prior to dormancy. Nonetheless, grazing must be managed as nitrate can accumulate even in cold temperatures and remain high in the stalks of plants once dormancy has begun. With proper management, brassicas can provide a forage source that is high in nutritive value for growing cattle well into winter.

Cereal grains

Cereal grains are common cool-season annual forages that are utilized for cover crop grazing in Nebraska. High volumes of hybrid seed corn and corn silage harvest in Eastern and Central Nebraska make growing cereal grains a viable option for maintenance of ground cover and extension of the grazing season when planted in late-summer after the aforementioned crops. These cool-season forages also can follow wheat and high moisture corn harvest in some instances. Common cereal grains utilized in Nebraska for grazing include oats, rye, triticale, and wheat (Drewnoski, 2015). While cost is a major consideration for the producer, cereal grains can be utilized as a forage source by grazing, haying, and stockpiling. The nutritive benefits of cereal grains provide producers with a quality alternative grazing source for backgrounding calves or grazing cows in the late fall and winter.

Like brassicas, differences in yield among cereal grains have been observed. A 2-year experiment in Wisconsin evaluated differences in yield among different cultivars of wheat, oats, and triticale (Coblentz & Walgenbach, 2010a).

All cultivars were planted in early to mid-August and harvested on the same days. Oats were the greatest yielding of the 3 cereal grains evaluated, with yields of 1,366 kg DM/ha in mid-September and 6,275 kg DM/ha in late October, while wheat yielded the least. A study in Nebraska reported much lower yield for oats in late October (Brinton et al., 2019). However, a later planting date was utilized, and the oats followed termination of corn silage or high moisture corn harvest; hence, the difference in respective yields of 2,475 and 1,020 kg DM/ha. A summary of yield from this and other studies is shown in Table 1.2. Planting date, harvest date, weather, region, and preceding crops are all factors that determine yield outcomes of late summer planted cereal grains, as illustrated by the previously mentioned studies. Bergen et al., (1991) reported that DM yield was 29-36% greater for oats and barley harvested at dough stage than milk stage. Lower DM yield of fall oats compared to spring oats has also been attributed to maturity, since there are less growing days in the fall (Contreras-Govea & Albrecht, 2006). Overall, maturity is the main driver of yield, but is influenced by many factors like those previously mentioned. When given the opportunity, late summer planted cereal grains have great yield potential before the first hard freeze and are suitable for monocultures or mixes.

Grazing days per acre or animal is a valuable representation of yield and a good indicator of the grazing potential among different cereal grains. An experiment done by Rivera et al., (2017) evaluated the effects of incorporating oats into annual ryegrass. They observed that pastures planted with oats had greater grazing days (128 d) than pastures with only annual ryegrass (94 d) and

concluded that incorporating small grains could extend the winter grazing period. Another experiment also observed greater grazing days for cool-season forage mixtures that contained cereal rye, and that those mixtures also allowed for greater stocking densities in winter without sacrificing gain (Bagley et al., 1988). Yield potential of cereal grains used in a cool-season fall cover crop system provides an opportunity to support a greater number of calves and extend the fall/winter grazing period.

Cereal grains, like other cool-season forages, generally decline in CP content as the stem elongates and the plant matures while a simultaneous increase in yield occurs—up to the first freeze (Bergen et al., 1991; Farney et al., 2017; Lundy et al., 2018). An experiment conducted in Iowa observed that CP declined from 31.2 to 22.2% in a mix of oats and brassicas when grazed by cows from October to December. However, the mix only declined from 24.3 to 22.2% CP between November and December, which is similar to the findings of Farney et al., (2017) in which minimal change in CP was observed during the same time period.

Late summer planted cereal grains have been shown to be relatively high in digestibility with in vitro true digestibility ranging from 86.5% to 91.2% in late summer planted oats, wheat, and triticale (Coblentz & Walgenbach, 2010b). An explanation for greater digestibility of fall grown cereal grains may be due to the reduction of the lignin to digestible forage ratio. Cooler weather in the fall likely stunts the development of tillers and results in less lignin content as the plant

matures, thus, leading to a greater digestibility (Coblentz & Walgenbach, 2010b).

Digestibility of cereal grains has been shown to decline slightly as maturation progresses. A two year experiment evaluated the forage quality of oats planted with radishes and turnips from November through January (Lenz et al., 2018). They reported a decline in IVOMD within each species from December to January with a 10- and 5%-unit decline for oats and brassicas, respectively. However, oats remained high in digestibility (67% IVOMD) even in January. They also noted no change in digestibility from November to December, which is in agreement with Coblentz & Walgenbach, (2010a) who reported no change in digestibility of several cereal grains between September and late October. This suggests that slight decline in digestibility of late summer planted cool-season cereal grains is possible after frost kill, but no declines in digestibility should be expected prior to the first hard freeze.

Reports regarding trends in TDN and NDF differ. An increase in NDF and TDN (15.7 to 23.3% and 69.5 to 77.8%, respectively) was observed in a fall oat-brassica mix from October to December (Lundy et al., 2018). On the contrary, an experiment conducted in Kansas observed no changes in TDN and NDF of a cereal grain-brassica mix during all stages of maturity at approximately the same time frame (Farney et al., 2017). An increase in NDF would be expected as the plant matures and accumulates more cell wall components as it enters the

secondary growth stage. Thus, it is unlikely that the TDN would increase by almost 10% from October to December as described by Lundy et al., (2018).

A year effect for IVOMD was observed in a previously mentioned experiment, with oats having less IVOMD in year two (69%) than in year one (80%) (Lenz et al., 2018). Lower values for IVTD in year two of a two year study for all 9 cereal grain cultivars were also reported by Coblentz & Walgenbach, (2010a). This suggests that factors like date of planting and the year largely affect the actual digestibility of cereal grains, as well as the digestibility trends associated with them. The general trends in nutritive value observed for cereal grains throughout the growing and grazing season can be expected, but the nutritive values and rates at which the plant changes will vary from year to year.

As previously described, nitrate toxicity is a concern in late summer planted cereal grains just as it is in brassicas. However, management strategies like adapting cattle and preventing overgrazing will decrease the risk for nitrate toxicity. Nonetheless, quality is undoubtedly sufficient for cattle performance and to meet the protein and energy requirements for maintenance and gain of growing beef cattle (NASEM, 2016). Furthermore, cereal grains have yield potential of 2,000 kg DM/ha, are roughly 20% CP and are relatively high in digestibility. They provide a dual benefit of a cover crop for maintaining soil integrity and an alternative grazing source in the fall and early winter. Numerous factors affecting yield and quality of cereal grains must be understood, but utilization of cereal grains can extend the late fall and winter grazing periods

and produce quality forage for ample gain in growing cattle (Bertrand & Dunavin, 1973; Burris et al., 1979).

Nitrates in brassicas and cereal grains

While glucosinolates and S-methyl cysteine sulfoxide are important to consider, nitrates remain the biggest concern for cattle grazing cool-season annual forages. Nitrate accumulation in plants can occur for many reasons. Application of nitrogen fertilizer may lead to an inability of the plant's assimilation rate to keep pace with the rate of uptake (Kemp, 1982). This is important because late summer planted annual forages often follow hybrid seed corn harvest or corn silage harvest in Nebraska, both of which require high amounts of nitrogen fertilization that results in residual nitrogen. Fall and spring cool-season annual forages are the most susceptible to nitrate accumulation because they correspond with shorter day lengths and cooler temperatures, both of which can result in greater nitrate accumulation (Bolan & Kemp, 2003). Additionally, the growing window for annual forages can be short and lead to premature grazing. This is important because nitrate accumulation tends to occur during the early vegetative stages of active growth (Bolan & Kemp, 2003; Crawford et al., 1961). Other factors such as drought or shortage of light may slow growth of the plant and lead to eventual nitrate accumulation, most of which occurs in the stems of plants closest to the ground. If intake of nitrate-rich forage is relatively high, nitrate-reducing microbes will reduce nitrate into nitrite in the rumen (Kemp, 1982). The conversion of nitrite to ammonium by ruminal microbes is considered a rate limiting step. Nitrite buildup in the rumen leads to

an eventually inability for microbes to synthesize ammonium from nitrite, leading to a spilling of nitrite across the rumen wall. Nitrite binds hemoglobin in the blood which is oxidized to methemoglobin. This results in chocolate blood and an inability for red blood cells to carry oxygen, resulting in suffocation and death.

While nitrates are a concern when grazing in the fall or spring, it is important to note that the degree of maturity, nitrogen content of the soil, and weather need to be evaluated to assess the risk of grazing. For fall grazing, nitrate accumulation occurs during early growth and is ceased when the plant enters dormancy; however, if the plants experienced stress such as frost or low temperatures during the growing period, nitrate content can be high and will remain in the stems of plants once dormancy is entered. Thus, the threat of nitrate toxicity when grazing late summer planted cool-season annual forages must not be ignored but with proper grazing management nitrate toxicity can be mitigated.

FACTORS THAT INFLUENCE ANIMAL PERFORMANCE AND FORAGE UTILIZATION WHEN GRAZING COOL-SEASON FORAGES

While nutritive value of forage plays an important role in influencing animal performance and forage utilization, there are other factors that must be considered when grazing late summer planted cool-season forages in the fall and winter. For example, how densely a field of cover crops is stocked will influence parameters of utilization like trampling, selection, and disappearance. Likewise, stocking density may also affect dry matter intake and ADG, both parameters of

animal performance. Other factors to consider as influencers of forage utilization and animal performance include diet selectivity, adaptation to novel forages, and methods of forage allocation.

Forage Allocation

Perhaps the least understood area of cool-season forages for grazing is how to best allocate forage to provide optimal utilization and gain. Gaps in communication between producers and researchers continue to fuel the debate as to if a defined practice for grazing can be attained. Producers/managers tend to establish grazing systems by trial and error and use what "works" while researchers base their conclusions on replicated research of treatments (Kothmann, 2009). Likely a combination of the two is needed to apply scientific research to the resources and options that are available and unique to each agricultural operation. Grazing methodology is a very important piece of forage allocation and includes continuous, strip, swath, and rotational grazing. Also of importance is the timing and frequency of forage allocation in non-continuous grazing systems.

Continuous grazing has been defined as a method that allows for maximum selection by an animal which may increase gain initially due to the animal selecting the high quality forages while rotational grazing is defined as rotating animals through 3 or more paddocks during the grazing season and utilizing higher stocking densities (Kothmann, 2009). Strip grazing has been described as allocating a new grazing area at one day intervals or less, but opinion varies widely. A study that collected 3 years of harvest data across the Midwest

reported that strip grazing yielded the most DM available and consumed, with a 31% loss of forage when compared to continuous and rotational grazing having losses of 60-70% and 43%, respectively (Larsen, 1959). Similarly, recent forage losses have been reported as high as 70% when cows were given access to a large area of stockpiled cool-season annual forages (Boyles et al., 1998-2007). The same authors also reported losses for strip grazing as low as 30% when given a 3-day supply. An experiment in which cows were continuously stocked or strip-grazed on corn residue yielded varying differences in BW gain, suggesting that animal gain and forage loss will undoubtedly be weather dependent (Russell et al., 1993).

Strip grazing stockpiled forage is a simple way to adjust forage allowance. Not only is it important to determine the amount of forage and area to allocate, but also the frequency at which forage is allocated. Two experiments conducted by Dalley et al., (2001) aimed to determine whether allowing herbage in smaller amounts more frequently than once per day would increase forage intake and milk production. In the first experiment, cows were offered either 40 or 65 kg DM/hd in one amount or in six smaller amounts to equal either 40 or 65 kg DM/hd. A second experiment utilized the same treatments (1 or 6 feedings/d), except forage was offered at different times of the day compared to the first experiment and the cows were offered 52 kg DM/hd daily. There was a slight increase in herbage intake in experiment one due to increased allowance, but no significant differences were observed in grazing time, milk production, or milk composition. Moreover, differences were not observed among treatments in

either experiment for BCS and only a slight difference was observed in weight lost per day in experiment 1. Interestingly, a different response was observed (Abrahamse et al., 2008) in an experiment that looked to compare daily forage allocation to allocation of forage every four days. Two groups of 10 dairy cows each were allocated to a fresh 0.125 ha plot of perennial ryegrass every day after morning milking or to a 0.5 ha plot every 4 days. Milk yield and fat-protein corrected milk were greater in 1D than in 4D. They attributed this to a change in grazing behavior that likely resulted in increased DMI. The previously mentioned studies suggest that there may be a slight benefit to allocating forage more frequently than every 4 days, but not more than once per day. In addition to using a small number of cows and having few replicates, these studies also primarily evaluated parameters of milk performance. The small amount of research done has evaluated perennial grass pastures and dairy cow performance, therefore, the question regarding frequency of allocation in late fall and winter cover crop grazing scenarios still lies unanswered and conclusions drawn from those studies are not interchangeable with late summer planted annual forages. A recent report stated that strip grazing on a 3-day frequency yielded over 40% more grazing days per acre than allocating stockpiled forage every 14 days in late fall and early winter cover crop grazing (Boyles et al., 1998-2007). While this is good information, the window of 3 days to 14 days is broad and needs to be further explored. Factors that influence disappearance of cover crops during winter grazing like trampling and

precipitation pose a need to address frequency of allocation and how that influences both forage utilization and performance of beef cattle.

Stocking rate and density

Animal performance and forage utilization can also be influenced by stocking rate (number of animals per unit of land over time) and stocking density (number of animals per unit of land at any given point of time).

Judson (2010) evaluated the effects of stocking lambs at a rate to achieve daily allowances of 1, 1.5, 2, or 3.5 kg DM/hd daily of rape with respective stocking rates being 93, 55, 51, and 38 lambs/ha. Liveweight gain increased from 59 g/d at an allowance of 1 kg DM/hd daily to 316 g/d at an allowance of 3.5 kg DM/hd daily. However, they noted that there was likely little effect on gain when allowance exceeded 2.5 kg DM/hd daily, but they couldn't prove this since they had no data points between 2 and 3.5 kg DM/hd daily. Gain per hectare was low (5.5 kg/ha/d) at an allowance of 1, which they attributed to low liveweight gains despite there being a high stocking rate. Contrarily, gain per hectare at an allowance of 3.5 kg DM/hd daily was also relatively low because although liveweight gain of the lambs was high, the stocking rate was low. As expected, an inverse relationship was observed between post-grazing crop mass and forage utilization, with forage utilization decreasing linearly as allowance increased. It is surprising that gain per hectare was low in the high stocking rate group since forage utilization was high (100%). Though the low liveweight gains of the lambs may have contributed to the low gain per hectare, others suggest that a linear increase in gain per hectare is observed when stocking rate

is increased until a point in which the amount of forage consumed equals the amount of forage available (Petersen et al., 1965). Thus, there are two extremes that point to two outcomes. First, forage utilization is best achieved at higher stocking rates, or in this case, higher stocking densities as well. Second, increased stocking rate that leads to a subsequent increase in stocking density like in a strip or rotational grazing system decreases animal gain when a certain point is exceeded (Bryant et al., 1970; Petersen et al., 1965; Smart et al., 2010). Considering whether the goal is to achieve high animal gain or optimal forage utilization is important in determining how to stock animals and allocate forage. There is likely a point at which forage utilization can be optimized without sacrificing animal gain, but this is a gap in the literature that needs to be addressed.

A study in South Dakota evaluated the effects of stocking rate on performance, selection, and digestibility among heifers grazing a mix of late summer planted annual ryegrass, radish, and purple top turnip (Brunsvig et al., 2016). Heifers were stocked to target utilization rates of 45, 55, and 65% by randomly assigning 3, 4, or 5 heifers to paddocks and continuously stocked for 48 days. Similar to previous observations, reductions in stocking rate increased intermediate and overall ADG. Reductions in stocking rate also reduced estimates of DM and OM digestibility from diet samples, which may suggest that selectivity increased with the reduced stocking rate and thus the heifers were selecting the ryegrass over the novel and more digestible brassicas. This is in agreement with the subsequent experiment by Brunsvig et al., (2017) in which

DM and OM digestibility increased in response to greater stocking density. This may be due to a forced and more rapid adaptation to the high energy brassicas. Brunsvig et al., (2017) also showed linear decreases in BW gain at greater stocking densities from d 1 to 22; however, no differences in BW gain were observed from d 22 to 48 of grazing.

Overall, increasing stocking rate or density both yield a decrease in animal gain, although that's not to say that animal gain is poor, just reduced. When grazing late summer planted cover crop mixes that contain brassicas, diet digestibility is likely increased as stocking density increases due to a more rapid adaptation to brassicas. Since cattle often select familiar plants and initially avoid novel species (Catanese et al., 2012; Provenza et al., 1991; Shaw et al., 2006), the conclusion can be made that increasing the stocking density caused animals to adapt to the brassicas quickly. The higher digestibility of brassicas thus increases diet digestibility. Forage utilization also increases in tandem with stocking density in rotational grazing systems but the impact in cool-season annual fall and winter strip grazing systems is unexplored.

Diet selectivity

An important piece of grazing late summer planted cover crops that contain brassicas is adaptation to the plant and selectivity. Feed "nephobia" has been described as the introduction of novel feeds or forages that can lead to reduced intake and even animal performance in grazing ruminants (Bowman & Sowell, 1997). In the Midwest, brassicas are usually a novel forage for grazing cattle

that are primarily used to grasses like brome, ryegrass, and oats. This poses a challenge to help animals adapt to cover crop mixes that may contain brassicas.

Several studies have examined an animal's ability to learn aversion of certain plants due to previous experiences or selection of plants that are nutritionally satisfying. One experiment observed that when sheep ingested non-lethal poison with a previously liked shrub, they would completely avoid it and exhibit a cautious selectivity (take fewer bites) when introduced to a new shrub (Burritt & Provenza, 1990). A similar concept examined how exposure of sheep to monotonous, diverse, or diverse with tannins diets affected intake later in life (Catanese et al., 2012). Initially, no differences in ADG, G:F or DMI were observed. However, the sheep exposed to diverse diets had greater ADG than monotonous sheep after initial exposure. Thus, an experience with a toxic plant may negatively impact selectivity of grazing animals while an experience with a diverse diet may positively impact selectivity (Bermúdez-Rattoni, 2004; Provenza et al., 1991).

Jung et al., (1989) reported that esophageal samples of sheep grazing smooth bromegrass were greater in CP and lower in NDF than clipped green and non-green forage samples. Furthermore, diet IVDMD was greater than the clipped non-green fractions of bromegrass through all 7 periods and greater than clipped green forage fractions in periods 3-7. Upon overcoming the novelty of a species such as brassica, animals exhibit conditioned selection for nutritionally

satisfying plants, which aligns with the concept discussed by Provenza et al., (1991).

The idea that greater stocking density or intensified grazing can decrease selectivity and increase adaptation to novel species as previously mentioned (Brunsvig et al., 2017) has been studied in sheep. Shaw et al., (2006) stocked sheep at high densities in a strip grazing system in which sheep were moved either daily or every 3 days. The novel species sagebrush was part of a diverse diet that the sheep were grazing. Biomass clippings revealed that selectivity for sagebrush increased over time, again suggesting that the high stock density in a non-continuous system helped sheep to adapt rapidly to the novel forage.

Strip grazing and rotational grazing are effective for reducing forage loss and increasing forage utilization by means of higher stocking densities despite the varying reports in frequency of allocation. High stocking densities and rates are sufficient for optimal forage utilization but may result in lower animal gain. Increased stocking densities are also beneficial for adaptation to novel forages when grazing a mix and may help to increase diet digestibility in that instance.

INFLUENCE OF BRASSICA INCLUSION IN LATE SUMMER PLANTED COVER CROP SYSTEMS ON ANIMAL PERFORMANCE

Quality Concerns

The high digestibility and CP of brassicas as previously described creates an opportunity for increased animal performance if managed correctly (Drewnoski et al., 2018). However, management is key as brassicas planted alone can have

negative effects on animal performance, hence why they are usually planted in tandem with cereal grains.

Though the attractiveness of high digestibility and CP of brassicas is important, they contain low concentrations of NDF. Reports of NDF have been similarly low, ranging from 14% to 35% in several different species of brassicas (Lenz et al., 2018; Westwood, 2012). A Colorado experiment also reported NDF concentrations of 19% to 25.9% in a two-year experiment that evaluated nine different cultivars of brassicas (Villalobos & Brummer, 2015). They also noted that there was an effect of cultivar and planting date for aNDF, which is expected since NDF increases with maturity. Brassicas have been likened to a concentrate in two separate sheep digestion studies in which digestible DMI increased as the proportion of brassica increased in the diet; however, these studies also showed that brassicas can even have negative associative effects on structural carbohydrates (Cassida et al., 1994; Lambert et al., 1987). The low NDF, coupled with high content of readily digested carbohydrates puts cattle at risk for subacute ruminal acidosis and bloat when grazing brassicas, especially during the first few weeks of exposure (Arnold, 2014; Westwood, 2012).

Low NDF and acidosis potential of brassicas warrants a need for an alternative fiber source. Seeding brassicas with a cereal gain ensures fiber intake but also serves to increase diet digestibility, making it an ideal grazing mix when the brassica is included at 70% or less of the diet dry matter (Arnold, 2014).

Furthermore, brassicas are relatively low cost which is another added benefit of including them as a mix.

Performance

Little is known about the added animal performance that brassicas may bring when included in a late summer planted cover crop mix. Furthermore, there is a lack of understanding of how a brassica might influence carcass characteristics, particularly in steers. Reid et al., (1994) reported higher dressing percentages in both ewes and lambs grazing Forage Star turnip and Tyfon cabbage during late fall compared to a stockpiled grass-clover control, with dressing percentages being 46.2%, 46.5%, and 42.8%, respectively. The higher dressing percentages coincided with higher ADG for the sheep grazing brassicas, but they did not mention carcass weights. A similar study by Rule et al., (1991) evaluated lambs grazing August-planted sugar beet tops, cabbage, and turnip and reported no differences in dressing percentage, yield grade or quality grade. However, they did report greater ADG and carcass weights of 54.5 to 56.8 lbs for lambs grazing brassicas compared to 49.4 lbs for lambs grazing sugar beet tops. Similarly, Campbell et al., (2011) noted greater liveweight gains and hot carcass weights in lambs grazing brassicas than lambs grazing pasture.

The subtle differences among dressing percent and carcass weight in the previous studies are likely due to differences in the controls. Greater gains were reported in all 3 studies and carcass weight and/or dressing percentage were improved in all cases. That said, it is possible that brassicas may have some

positive influences on carcass traits and animal performance when planted as a monoculture. However, whether those effects hold true when brassicas are planted with cereal grains in late summer is not known and needs to be studied.

PROCESSING METHOD AND FEEDING VALUE OF SWEET BRAN

With the increase of corn milling for ethanol production over the last several decades has come a concurrent increase in the knowledge of corn milling by-products. According to a survey conducted in 2015, by-products from both wet milling and dry milling are utilized in 97.1% of feedlot finishing diets and many cow/calf operations across the U.S (Samuelson et al., 2016). Corn gluten feed is the main by-product from the wet milling process that is used in cattle feeding, and is mostly utilized as wet corn gluten feed (NASEM, 2016). Sweet Bran is a branded wet corn gluten feed product that is produced by Cargill and has been shown to increase dry matter intake and promote rumen health by mitigating acidosis (Stock et al., 2000). Not only does Sweet Bran yield performance results and promote rumen health, but it also yields an increase in economic return as Sweet Bran is added to the diet (Erickson et al., 2007).

Processing method

The primary goal of the wet milling process is to isolate the starch of corn grain from the kernel to be sold as-is or to make high fructose corn sweeteners, dextrose, and ethanol (Stock et al., 2000). Contrary to dry milling, only #1 or #2 grade yellow corn is used in the wet milling process since most of the end products are produced for human food consumption (Stock et al., 2000). The process begins with a series of screenings to remove foreign material, fines, and

broken kernels before being steeped in a dilute solution of sulfurous acid for 40-48 hours (Blanchard, 1992). The steeping process serves to soften the kernel and improve separation of the kernel components. Water then enters the milling process during the last phase of steeping and runs opposite the flow of corn to undergo several separations and screenings in which it accumulates solubles. Lactic acid-producing bacteria then help to ferment the soluble carbohydrates that are collected by the water to further kernel softening (Klopfenstein et al., 2007). Upon completion of steeping, light steepwater remains (4-8% solids) and can be concentrated to form heavy steepwater (35-40% solids). This is performed by multiple-effect evaporators and can also be achieved by membrane filtration if the plant is limited in evaporator capacity (Rausch & Belyea, 2006). The kernels are then ground through a system of hydrocyclones, pressed, and dried to then be separated into bran (fiber), starch, and germ. The germ is removed by a system of hydrocyclones, pressed, and dried. The germ undergoes oil extraction and the corn germ meal that remains can be added back as a component of wet corn gluten feed (Stock et al., 2000). The fiber fraction of the kernel is removed via screens and is combined with distiller solubles and steep liquor to form corn gluten feed, which accounts for 22-24% of the initial corn solids entering the wet mill (Rausch & Belyea, 2006). The remaining solids are separated into starch and protein by a centrifuge. The protein is then concentrated with gluten thickener and dried to form corn gluten meal (Rausch & Belyea, 2006). The remaining slurry is composed mostly of starch and may be

fermented into ethanol by utilizing a portion of the steep water (steep liquor) to promote growth of ethanol-producing yeast cells (Klopfenstein et al., 2007).

Wet corn gluten feed may be dried and pelleted or sold wet (40-60% DM). Composition of wet corn gluten feed varies because the bran cannot absorb all of the steep that is produced; thus, some plants will dry the bran so that it can absorb more steep (Stock et al., 2000). Quantity of bran, steep liquor, cracked corn, solubles, and germ meal in corn gluten feed varies among plants.

Feeding value

Sweet Bran is a branded wet corn gluten feed that has several benefits in addition to rumen health, one of which is its feeding value. Typical dry matter of wet corn gluten feed varies from 40-45% DM, but Sweet Bran is greater (60% DM) due to drying of the bran (Klopfenstein et al., 2007; NASEM, 2016; Stock et al., 2000). The CP content of Sweet Bran as a percent of dry matter is typically 23% while NDF is 37% (Stock et al., 2000). According to NASEM, (2016), the NDF of Sweet Bran is 27% on average instead of 37%. Nonetheless, Sweet Bran is still lower in NDF and higher in CP than other wet corn gluten feed (39% NDF and 20% CP) which is likely due to a greater proportion of steep compared to bran in the product. Sweet Bran is also a source of rumen degradable protein (70-80% of CP) and is high in TDN (89% of DM; NASEM, 2016).

The feeding value of Sweet Bran is slightly greater than other wet corn gluten feed products, again likely due to the greater amount of steep in Sweet Bran. Research at the University of Nebraska reported that the feeding value of

Sweet Bran is 112% that of dry-rolled corn (Bremer et al., 2008). This is relatively higher than the feeding value of other wet corn gluten feed products which vary from 100-109% the value of DRC when fed at 20-60% of the diet DM (Klopfenstein et al., 2007). Thus, improvements in performance are seen by feeding as much as 40% Sweet Bran (DM basis) in the diet according to Bremer et al., (2008), who reported linear increases in DMI, ADG, and feed efficiency in their meta-analysis as inclusion of Sweet Bran in the diet increased. Others have reported increases in DMI, ADG, and F:G when Sweet Bran was included alone or in combination with other byproducts, as well as an increase in HCW compared to traditional DRC or HMC diets (Buckner et al., 2007; Spore et al., 2019; Spowart et al., 2020). To quantify these improvements in performance, a review by Klopfenstein et al., (2007) noted that F:G decreased from 5.96 to 5.74 when Sweet Bran replaced corn and was included at 0% and 40% of the diet DM, respectively. Average daily gains were also increased from 3.67 with 0% Sweet Bran to 4.17 with 40% Sweet Bran (DM basis). Other studies from the University of Nebraska reported that when averaged across CGF levels typically fed in feedlots (20-60%, DM basis), Sweet Bran increased ADG 11.4%, increased DMI 5.4%, and improved F:G 5.1% (Stock et al., 2000). Interactions of Sweet Bran and corn processing types have been reported, with improvements of feed conversion and feed efficiency relative to dry-rolled corn

when Sweet Bran was included in up to 32% of the diet (DM basis) with steam flaked corn (Scott et al., 2003).

A recent experiment was conducted at Kansas State University to evaluate 4 increasing levels of NEg, in which Sweet Bran was included at 40% of the diet (DM basis) (Spore et al., 2019). Dry rolled corn replaced prairie hay and alfalfa to increase NEg. Average ruminal pH decreased linearly from 6.11 at 0.99 Mcal NEg/kg DM to 5.66 at 1.32 Mcal NEg/kg DM which is expected due to the increase of rapidly fermentable carbohydrates caused by the increase in dietary energy. Time spent below a pH of 5.5 also increased as NEg increased. The decrease in pH was likely due to the increased inclusion of dry-rolled corn in the diet. Though pH dropped and more time was spent below a pH of 5.5, no adverse effects were observed. They attributed this to the inclusion of Sweet Bran, which helped to control ruminal acidosis. This is consistent with a study by Spowart et al., (2020) in which a corn control diet with no byproducts exhibited the lowest pH from 0800 to 1800 hours after feeding compared to the diets with Sweet Bran alone or in combination with other byproducts. Another study observed a tendency for a linear increase in DMI when Sweet Bran replaced steam flaked corn in up to 35% of the diet DM (Macken et al., 2004). Others have also attributed increases in dry matter intake in cattle fed Sweet

Bran to its ability to reduce acidosis (Bremer et al., 2008; Klopfenstein et al., 2007).

CONCLUSION

Based on the literature cited in this review, it is clear that late summer planted annual forages are suitable for grazing as an alternative forage source and provide forage nutritive value capable of meeting or exceeding the nutrient requirements for gain of stocker calves or the high nutrient needs of lactating beef cows during grazing. The understanding of risks associated with these forages has grown over the years as more producers continue to incorporate cool-season forages into their grazing and cropping systems; however, these risks can be mitigated with proper grazing management. Annual forages planted in late summer are suitable for high yield and digestibility and prove capable of returning high calf gain when grazed. Insight must be gained as to how forage allocation of late summer planted cool-season annual forages impacts forage utilization and animal performance. Moreover, benefits of forage allocation have been demonstrated in other grazing systems, but frequency of allocation still needs to be determined. Increasing stocking density in a winter strip grazing system of annual cool-season forages may help to understand diet selectivity and forage utilization just as it has with other grazing crops and systems. Brassicas are known for their high digestibility and crude protein and have improved nutritive value when planted with cereal grains. However, the impact of brassicas on beef cattle performance needs further exploration since most of the previous work done has been on sheep and has not directly compared a brassica-

small cereal grain mix to a small cereal grain monoculture. Variability in the corn wet milling process and composition of its products has been documented and will continue to change. While the feeding value of wet corn gluten feed is high, it is important to understand how evolving components of wet corn gluten feed will alter feeding value and to what extent. The objectives for this thesis include:

1. Evaluate the effects of forage allocation on forage utilization and performance of steers grazing a late summer planted oat and rapeseed mix.
2. Determine the impact of brassica inclusion in a late summer planted oat pasture on grazing steer performance.
3. Evaluate the effects of novel versions of Sweet Bran Plus™ on finishing steer performance and carcass traits.

Table 1.1. Summary of effect of harvest date, planting date, region, and year on yield and quality of various brassica cultivars

Experiment (author, year, exp. #)	Cultivar	Planting date	U.S. State	Harvest date, DAP	DM yield, kg/ha	CP, % DM	Digestibility, % DM[b]
Reid 1994 2	Forage star turnip	July 28	WV	90	5,942		
Reid 1994 3	Forage star turnip	July 31	WV	90	3,375		
Reid 1994 3	Chinese Tyfon cabbage	July 31	WV	90	4,772		
Villalobos 2015	Appin turnip	July 16/Aug 2	CO	Oct 10/Oct 16	7073	19.2	90.3[1]
Villalobos 2015	Appin turnip	Aug 14/Aug 18	CO	Nov 13	3363	20.4	90[1]
Villalobos 2015	Barkant turnip	July 16/Aug 2	CO	Oct 10/Oct 16	7129	18.6	61.2[1]
Villalobos 2015	Barkant turnip	Aug 14/Aug 18	CO	Nov 13	3688	19.3	90.7[1]
Villalobos 2015	Purple Top turnip	July 16/Aug 2	CO	Oct 10/Oct 16	5492	20.6	91.6[1]
Villalobos 2015	Purple Top turnip	Aug 14/Aug 18	CO	Nov 13	3463	20.9	89.9[1]
Villalobos 2015	Pasja hybrid	July 16/Aug 2	CO	Oct 10/Oct 16	7723	22.5	91.3[1]
Villalobos 2015	Pasja hyrbid	Aug 14/Aug 18	CO	Nov 13	2870	21.3	92[1]
Villalobos 2015	Bonar rape	July 16/Aug 2	CO	Oct 10/Oct 16	7835	21.4	90.5[1]
Villalobos 2015	Bonar rape	Aug 14/Aug 18	CO	Nov 13	2499	25.5	92.9[1]
Villalobos 2015	Barnapoli rape	July 16/Aug 2	CO	Oct 10/Oct 16	9482	22	87.5[1]
Villalobos 2015	Barnapoli rape	Aug 14/Aug 18	CO	Nov 13	3441	22.5	90.7[1]
Villalobos 2015	Winfred rape	July 16/Aug 2	CO	Oct 10/Oct 16	8418	21.7	89.3[1]
Villalobos 2015	Winfred rape	Aug 14/Aug 18	CO	Nov 13	3183	22.2	91.9[1]
Villalobos 2015	Groundhog radish	July 16/Aug 2	CO	Oct 10/Oct 16	6153	21.4	91.1[1]
Villalobos 2015	Groundhog radish	Aug 14/Aug 18	CO	Nov 13	2578	20.5	85.5[1]
Villalobos 2015	Major Plus Swede	July 16/Aug 2	CO	Oct 10/Oct 16	5784	19.9	88.7[1]
Villalobos 2015	Major Plus Swede	Aug 14/Aug 18	CO	Nov 13	1430	22.3	90.6[1]
Dillard 2017	Rapeseed		PA	70	1484	26.2[a]	
Dillard 2017	Turnip		PA	70	1023	26.2[a]	
Lenz 2018	Radish	Aug 25	NE	100[d]		24	86[3]
Lenz 2018	Turnip	Aug 25	NE	100[d]		20	88[3]
Dillard 2020	Rape	Mid-Aug	PA	35[e]	861	25.4	70.2[2]
Dillard 2020	Turnip	Mid-Aug	PA	35[e]	753	24.2	66.5[2]

[a]Combined average CP for rapeseed and turnip

[b]Measures of digestibility represented as: [1]IVTD using ANKOM Daisy incubator (ANKOM, 2017), [2]summative equation for TDN (Weiss et al., 1992), [3]IVOMD using Tilley and Terry method (Tilley & Terry, 1963)

[d]Average of 58-142 DAP

[e]Harvest began 35 DAP and occurred in subsequent 2-week intervals

Table 1.2. Summary of effect of planting date, harvest date, year, and location on yield and quality of various cereal grains

Study (author, year)	Cultivar	Planting date	U.S. State	Harvest date		DM yield, kg/ha		CP, % DM		Digestibility, % DM[d]	
				Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Coblentz 2010	Wheat[a]	Early August	WI	9/15	9/19	262	572	31.5	34.3	68.2[1]	66.9[1]
Coblentz 2010	Wheat[a]	Early August	WI	10/6	10/10	1184	2394	22.5	29.2	69.3[1]	64.1[11]
Coblentz 2010	Wheat[a]	Early August	WI	10/30	11/7	1589	3203	18.5	23	72.3[1]	65.8[1]
Coblentz 2010	Oat[b]	Early August	WI	9/15	9/19	479	1366	32	32.8	68.5[1]	66.9[1]
Coblentz 2010	Oat[b]	Early August	WI	10/6	10/10	2104	4561	18.3	20.5	67.6[1]	61.5[1]
Coblentz 2010	Oat[b]	Early August	WI	10/30	11/7	3246	6275	14.9	15.3	71.2[1]	61.5[1]
Coblentz 2010	Triticale[c]	Early August	WI	9/15	9/19	468	711	31.2	30.3	68.2[1]	69.6[1]
Coblentz 2010	Triticale[c]	Early August	WI	10/6	10/10	1730	2964	20.5	27.2	67.6[1]	64.5[1]
Coblentz 2010	Triticale[c]	Early August	WI	10/30	11/7	2286	4250	17.5	20.7	68.2[1]	66.8[1]
Brinton 2019	Oat	Sept. 1	NE	Late Oct.		2475		18			
Brinton 2019	Oat	Sept. 15	NE	Late Oct.		1020		22.7			
Lenz 2018	Oat	Aug. 25	NE		10/22, 12/10, 1/14				10	80[2]	69[2]
Ulmer 2016	Oat	Aug 15	NE		Early Dec.				14.3		

[a]Average of Hopewell and Kaskaskia wheat cultivars

[b]Average of Ogle, Drumlin, Vista, and ForagePlus oat cultivars

[c]Trical 2700 triticale cultivar

[d]Measures of digestibility represented as: [1]Summative equation for TDN using ADL option (Weiss et al., 1992), [2]IVOMD using Tilley and Terry method (Tilley & Terry, 1963)

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CHAPTER II. The impact of brassica inclusion on performance of steers grazing a late-summer planted oat monoculture or an oat-rapeseed mix

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ABSTRACT

There is little understanding as to whether inclusion of a brassica into late summer planted oats impacts gain of grazing steers. In a 3-year experiment, an oat (*Avena sativa* L) monoculture (OAT) was planted at a rate of 112 kg/ha and a mixture (MIX) of oats (*Avena sativa* L) and rapeseed (Brassica *napus*) was planted at a rate of 56 kg/ha and 3.4 kg/ha, respectively, in late summer following corn silage harvest or alfalfa termination in south central Nebraska. Spring born crossbred steers (n=600) were assigned to treatments using body weights taken prior to day 0 with 30 steers per rep for a total of 10 reps. Steers were then weighed, sorted, and began grazing on d 1 (initial BW = 262 kg, SD = 26 kg). Steers began grazing in early November each year and grazed until forage appeared to be limiting in one replicate, with approximately 7.6 cm of growth remaining, upon which grazing ceased for all steers. For forage biomass, a quadratic trend ($P = 0.02$) was observed for treatment across date in each year. Initial and final biomass were not different among treatment in any of the three years. Initial biomass was high in all years, with MIX and OAT yielding 3,022 to 4,251 kg DM/ha and 2,863 to 4,221 kg DM/ha, respectively. No differences ($P = 0.92$) were observed for forage disappearance, with an average of 12.8 kg/hd disappearing daily. Quadratic ($P < 0.01$) trends were curvilinear and observed for OAT and both species in the MIX for all measures of forage quality. Rapeseed was greater ($P \leq 0.05$) in digestible organic matter (DOM) within multiple dates in years 1 and 2 and within all dates in year 3, with a mean DOM of 63% and 70% for oats and rapeseed, respectively. Rapeseed was greater ($P \leq 0.05$) in crude protein than oats across dates in years 1 and 3, with an initial CP of 23%. Oats were also high in CP

and ranged from 16% to 19% initially. No treatment × year interaction ($P = 0.82$) was observed for ADG. Steers grazing MIX had a greater ($P < 0.01$) ADG than OAT, with gains of 0.95 and 0.88 kg, respectively. A lower seed cost for rapeseed contributed to a significantly lower ($P < 0.01$) cost of gain for MIX by $0.21/kg. Inclusion of rapeseed into late summer planted oats improves calf gain and lowers the cost of gain for growing steers grazing in late fall and winter.

Keywords: Annual forage, Brassicas, cattle, grazing, oats

INTRODUCTION

Cover crops planted in late summer can offer dual benefit for soil conservation and grazing potential. Cover crops have been shown to improve water infiltration rate and the microbial community of the soil. Limited data available has also suggested that grazing cover crops does not reduce soil health benefits of cover crops (Drewnoski et al., 2018). Thus, planting cover crops in late-summer can add value by extending the grazing season and minimize costs associated with stored feeds (McCartney et al., 2008). Brassicas and oats are two cool-season annual forages that can be used in a late summer planted cover crop system. Winter-sensitive annuals such as oats alone or in combination with brassicas such as radishes or rapeseed are commonly planted after spring wheat, corn silage harvest, or hybrid seed corn harvest in Nebraska (Drewnoski, 2015).

Late-summer planted, winter-sensitive cool-season species, such as oats, have shown to accumulate greater biomass in the fall when planted in late summer than winter hardy cool-season species. Monocultures of winter-sensitive, cool-season annuals are apt to yield well in the fall, with forage yields of small cereal grain monocultures ranging

from 1,020 to 6,225 kg DM/ha (Brinton et al., 2019; Coblentz & Walgenbach, 2010). Likewise, forage yields of brassica monocultures ranged from 1,430 to 9,482 kg DM/ha (Reid et al., 1994; Villalobos & Brummer, 2015). Furthermore, small grains and brassicas are both high in digestibility and CP, with digestibility declining slightly over winter and CP remaining largely constant (Lenz et al., 2018). Fall grazing oat monocultures in Nebraska following corn silage harvest resulted in average daily gain of 1.07 kg for 222 kg growing calves (Brinton et al., 2019). Another study reported an average daily gain of 0.72 kg for growing steers grazing an oat-brassica mix (Cox-O'Neill et al., 2017). The greater digestibility (85 to 93 % IVOMD) and CP (22%), coupled with lower fiber of brassicas, likens them more to a concentrate than a roughage. Thus, we would expect the energy content of the diet to increase (Lenz et al., 2018). While winter cereal grains are greater in fiber than brassicas, they tend to be lower in digestibility (69 % IVOMD) and CP (10-14%) (Lenz et al., 2018; Ulmer et al., 2016). However, direct comparisons of grazed oat monocultures to oat-brassica mixtures have not been made.

The differing characteristics of oats and brassicas suggests that they may possess desirable qualities for calf gain when planted as a mix. Therefore, including a brassica such as rapeseed into a late fall and winter grazing system may improve calf gain compared to grazing oats alone. Thus, the objective of this experiment was to evaluate the effects of rapeseed inclusion on growing calf performance when planted in late-summer and grazed in late fall and winter.

MATERIALS AND METHODS

Experimental Design and Procedures

A 3-year experiment was conducted at the U.S. Meat Animal Research Center near Clay Center, NE in which an oats (Avena *sativa*) monoculture (OAT) or oats and rapeseed (Brassica *napus*) mix (MIX) was planted at rates of 112 kg/ha or 56 and 3.4 kg/ha, respectively. Seeding was done using a no-till drill with 20.3 cm spacing and two replicates of each treatment were planted per pivot. Water and nitrogen (N) were applied via pivot to facilitate forage growth The nitrogen application rate was solely dependent on the preceding crop and was not determined by a soil composition test (Table 2.1).

Prior to the start of the experiment, all steers were fed a common grower ration. Spring born cross-bred steers (n = 120, 240 and 240 in years 1, 2 and 3, respectively) were stratified by BW and breed type and assigned to treatment and replicate (30 steers per 12.1 ha) with weights taken prior to d 1. On d 1, steers were weighed (initial BW: 265 kg, SD = 2 kg; 289 kg, SD = 5 kg; 234 kg, SD = 4 kg in years 1, 2 and 3, respectively), sorted and began grazing. A summary of the start and end dates and the grazing days for each year is provided in Table 2.1. Grazing continued until forage appeared to be limiting in one quarter, with approximately 7.6 centimeters of growth remaining. On the last day of grazing, steers were gathered early in the morning at the first signs of light and transported approximately 6 km to the nearby feedlot to be immediately weighed. Steers were then placed back onto the grower ration used prior to the start of the experiment and were fed for 8 days before being weighed again. These weights were compared to weights taken on the last day of grazing for variation. No significant variation was detected between weights and thus weights taken on the last day of grazing were used to determine ending body weight.

During grazing, water and mineral supplement were provided ad libitum to each group of steers, with tanks and feeders being equidistant from the center of each pivot. Wind breaks were also constructed for each group of steers.

Forage measures

Initial biomass was sampled on October 1, November 1, and October 30 in years 1, 2, and 3, respectively (Table 2.1), by clipping 4 random areas (0.91 × 0.61 m) within each quarter to ground level. Biomass samples were taken approximately every 30 d throughout the grazing season. Prior to drying, rapeseed and oats were hand-separated to determine proportions. Forage samples were bagged and dried for 48 to 72 h in a 60°C forced-air oven to determine biomass. At each of the 4 biomass sampling times, samples were also randomly clipped to ground level from each quarter for nutrient analysis and bagged separately according to species type. Samples were transported in a cooler with ice to the lab.

Lab Analysis

Clipped quality samples were dried for 48 to 72 h in a 60°C forced air oven and then ground through a 1-mm screen using a Wiley Mill (Thomas Scientific, Swedesboro, NJ). Because forage samples were obtained after the first frost, it was determined that drying via a forced air oven would not negatively impact the non-structural carbohydrate content of the forage. Dried samples were analyzed for dry matter (DM;105°C), organic matter (OM), crude protein (CP), in vitro organic matter digestibility (IVOMD), and total ethanol soluble carbohydrates (TESC).

Dry matter was determined by placing samples in a forced air oven for 12-24 h at 105°C. Subsequent OM was determined by placing the samples in a muffle furnace for 6 h at 600°C (AOAC, 1999). Methods described by Tilley & Terry, (1963) were used to determine IVOMD with 48 h incubation. Methods were modified by adding urea to the McDougall's buffer (McDougall, 1948) at a rate of 1 g urea/L buffer solution, to ensure adequate N was available for microbes in the rumen fluid (Weiss, 1994). Blanks were included in the in vitro run to adjust for any feed particles that might have come from the inoculum. Following incubation the Whatman 541 filter paper (22 µm pore size) plus samples was placed in crucibles and heated in a muffle furnace for 6-h at 600°C (AOAC, 1999). Two runs were conducted in years 1 and 2 and two runs were conducted in year 3 and five hay standards with known in vivo (total tract) digestibility (51-60% range) were used to adjust IVOMD values. These adjustment values resulted in an average of 3.5 percentage units added to IVOMD runs 1 through 4. Digestible organic matter (DOM) was calculated using the equation $OM \times IVOMD = DOM$ to better represent the potential energy availability in the forage. Total ethanol soluble carbohydrates and CP were determined by Dairyland Laboratories (Arcadia, WI) for each sample. The colorimetric method was used to determine TESC content by reacting phenol and sulfuric acid to generate a stable color in conjunction with paper partition chromatography (DuBois et al., 1956; Hall, 2000). Crude protein was determined using the Combustion Method (AOAC, 2006). Analysis for TESC was conducted in years 1 and 3.

Economics

A partial budget analysis was conducted to evaluate the establishment costs of the oat monoculture and oat/rapeseed mix (Table 2.2). Included in the budget were seed cost at a 3-year average of $0.44/kg for oats and $3.57/kg for rapeseed, as well as the cost of fertilizer (nitrogen) and application. Cost of irrigation per hectare was calculated using the amount of water applied (Table 2.1) with rates from the 2017 and 2020 Nebraska Crop Budgets and converted to hectare-mm (Klein et al., 2019; Klein et al., 2016). Costs associated with building the perimeter were accounted for at $2.02/ha. Steers were assumed to drink 20 L/hd of water daily (NASEM, 2016). One water tank (2650 Liters) was used per quarter. Thus, it was estimated that water tanks would need to be filled every 4.5 days or approximately twice weekly. It was estimated to require 2 hours for each fill for a total of 4 hours per week and charged $20/hr (McClure & Jansen, 2020). Health checks were incorporated into the cost of hauling water.

A sensitivity analysis was conducted to determine how sensitive the cost of gain for water was to the amount of water applied (Table 3.3). Water application amounts used for the analysis were assumed to be what would be needed to achieve the same amount of forage yield as that observed in this study. The range of water application in the analysis was based off averages of applied water in this study and previous late summer planted grazing experiments. The range of the cost of water application per ha-mm was determined using the 2017 and 2020 Nebraska Crop Budgets (Klein et al., 2016; Klein et al., 2019).

Statistical Analysis

Steer performance, forage quality, biomass, and forage disappearance were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.). Forage quality and biomass were analyzed by treatment as a repeated measure with a random residual statement with rep within pivot as the subject. The model contained treatment, year, and interaction as fixed effects, with sampling date being a covariate. The beginning of the Julian year was set to October 1st, so that equal comparisons could be made across years. Forage quality and biomass were also analyzed by species (oats and rapeseed) as a repeated measure with rep in a random residual statement. The model contained species, year, and interaction as fixed effects, with sampling date being a covariate. Steer performance, forage disappearance, and cost of gain were analyzed with treatment, year, and their interactions included as fixed effects in the model. Pivot was included as a random effect. Interactions not significant were removed from the model. Treatment means were separated using the pdiff statement when the F-test was significant. Treatment differences were considered significant when $P \leq 0.05$ with tendencies between $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Forage Production

A treatment × year interaction ($P = 0.02$) was observed for forage biomass. A quadratic trend ($P = 0.02$) was observed for each treatment across date in each year (Figure 2.1). Initial biomass was not different ($P = 0.91$) among treatment in any of the three years. Initial biomass was high in each year, with yields of 3,671 kg/ha, 5,037 kg/ha and 4,385 kg/ha (DM basis) in years 1, 2, and 3, respectively. Although there are no

previous reports of forage yield for an oat and rapeseed mix, pre-grazed yields in the current study were consistent with yields of monocultures reported by others. Brinton et al., (2019) and Coblentz & Walgenbach, (2010) reported yields of 1,020 to 6,275 kg/ha for late-summer planted small grain monocultures. Major differences in forage yield were attributed to planting date, weather, and harvest date. Similarly, differences in forage yield of brassica monocultures were attributed to region, weather, and planting date effects (Dillard et al., 2020; Villalobos & Brummer, 2015).

No treatment differences ($P = 0.40$) for biomass were observed within date in year one as OAT and MIX decreased at a similar rate. A significant difference ($P < 0.01$) between OAT and MIX was observed on Julian date 60 in year 2, but there was no difference ($P = 0.50$) on date 115 due to OAT decreasing at an increasing rate. Similar to year one, no treatment differences were observed within date in year 3.

No differences ($P = 0.92$) were observed between MIX and OAT for forage disappearance, at approximately 12 kg of DM/hd daily (Table 2.3). There were no differences ($P = 0.14$) in forage disappearance among years. The disappearance rate equated to 4.8% of BW, suggesting that significant trampling losses occurred as it is unlikely that cattle consumed more than 50 to 60% of what disappeared. A study conducted by Larsen, (1959) collected 3 years of harvest data from across the Midwest to evaluate grazing efficiency and DM loss for dairy cows grazing perennial grasses. They reported reduction in biomass when strip grazing or continuous grazing of 31% and 60 to 70%, respectively. Though not completely equivalent to grazing stockpiled forages, the

values for continuous grazing were similar to the loss that was occurred in the current study—most of which is attributed to weather events and trampling.

Comparisons of the species comprising MIX were also made and were designated as Oats, MIX and Rapeseed, MIX in Figure 2.1. Biomass differences ($P < 0.01$) between oats and rapeseed of MIX were observed within each date in years 1, 2, and 3. In year 1, oats biomass increased at a decreasing rate before decreasing at an increasing rate approximately halfway through the grazing season, while rapeseed declined steadily. Both oats and rapeseed decreased at similar rates in year 2. This might suggest that steers selected rapeseed initially and then increased their intake of oats as the rapeseed availability decreased. Animals select forages based on the novelty and the nutritional satisfaction of the forage (Bowman & Sowell, 1997; Provenza et al., 1991). Thus, steers may have preferentially selected rapeseed in year 1 due to its higher quality. In year 3, oats decreased at an increasing rate initially before decreasing at a decreasing rate while rapeseed decreased slightly over the grazing season. The first hard freeze (≤ 0 °C) occurred on November 19, October 27, and October 23 in years 1, 2, and 3 respectively (Figure 2.2). Unlike years 2 and 3, the first hard freeze in year 1 did not occur until 19 days after the start of grazing, which may have driven additional accumulation of forage biomass. Year 2 exhibited the least accumulated rainfall (2.4 cm) but had a colder average temperature (-0.8 °C) than years 1 and 2. Overall, each year differed in the disappearance of oats and rapeseed and these differences point toward the variability in forage quality profiles of plants, weather, and animal selectivity.

Forage Quality

Organic Matter and Crude Protein

Oats and rapeseed comprising MIX were analyzed separately due to concerns with potential preferential selection by the steers; thus, comparisons between forage quality and biomass could be made to better understand differences in animal performance.

The oats from both treatments ranged from 85-91% OM in years 1 and 2, while rapeseed from MIX ranged from 75-90% (Figure 2.3). Organic matter (OM) for both oats and rapeseed increased slightly from October to December in year 1, before rapeseed decreased at an increasing rate after December. This resulted in differences ($P \leq 0.05$) in OM between oats and rapeseed within Julian dates 96 and 113. A similar trend was observed in year 2. The differences in OM between oats and rapeseed near the end of the grazing season in years 1 and 2 was likely due to reduced rapeseed biomass availability. Thus, stems, along with potential soil contamination in the samples, might explain the decreased OM of rapeseed. Oats and rapeseed remained relatively constant in year 3, with no significant differences for OM observed within dates. This coincides with the greater amount of rapeseed biomass (456 kg DM/ha) available at the end of the grazing season in year 3, whereas less than 50 kg DM/ha of rapeseed was left in the first two years.

For crude protein (CP), a quadratic trend ($P < 0.01$) was observed for OAT and both species of MIX (Figure 2.3). The oats from both treatments were not different ($P \geq 0.12$) in initial or final CP in years 1 and 3, with a mean initial CP content of 19%.

However, oats in MIX tended to be greater ($P \leq 0.09$) in CP content than OAT by 17% on average across all Julian dates in year 2. Rapeseed was greater ($P \leq 0.05$) in initial CP than oats in all years, with a mean initial CP content of 22%. Differences ($P \leq 0.05$) were observed within all dates for rapeseed to be greater in CP than oats in years 1 and 2. In year 3, rapeseed was greater ($P = 0.03$) and tended to be greater ($P = 0.06$) in CP than the oat monoculture on Julian dates 61 and 113, respectively. In years 1 and 2, rapeseed CP content decreased from October to December but increased during the second half of the grazing season, with final values of 23.7% and 23.8% CP, respectively. A large decline in TESC content of rapeseed late in the grazing season in year 1 suggests that the CP increased simply due to a greater proportion of nitrogen compared to sugar. Overall, oats and rapeseed declined slightly over the grazing season in year 3 but remained of high value even in January. The decrease in CP content of rapeseed between October and December is in agreement with others that reported declines in the CP content of late summer planted brassicas from 70-120 days after planting, of which they attributed to winter kill (Koch et al., 2002; Reid et al., 1994). Lenz et al., (2018) observed little change in the CP content of oats and brassicas from November to January in a 2-year experiment, though CP did increase 5% units from December to January in year one, suggesting that year and weather are major factors in the change of CP content. Late-summer planted annual forages such as wheat and rye can scavenge up to 206 kg of nitrate-nitrogen per hectare, which is stored in the stem of the plant (Delgado et al., 2007). If the steers selected the tops of the plant first, then the crude protein may have increased due to the larger proportion of nitrogen remaining in the lower part of the plant. It is also possible

that a decrease in the sugar content (TESC) led to an increased concentration of nitrogen, and thus crude protein.

Digestibility and TESC

Digestible organic matter was determined for OAT and the oats and rapeseed that composed MIX and graphed (Figure 2.4). Quadratic ($P < 0.01$) trends were observed for OAT and both species of MIX. In year 1, the oats in MIX had greater ($P < 0.01$) DOM within Julian dates 74 and 110 than the oat monoculture, but otherwise digestibility of the oats from both treatments did not differ ($P \geq 0.11$) within date in all years with a mean DOM of 63%. Rapeseed was often greater ($P \leq 0.05$) in DOM than the oat monoculture within Julian date and year, with rapeseed having 71% DOM compared to oats (63%). This is in agreement with recent work that showed turnips and radishes to be 17-19% units greater in IVOMD than oats (Lenz et al., 2018). Others have also reported greater ME content of brassicas compared to perennial ryegrass (Barry, 2013; Lindsay et al., 2007). In addition to the higher digestibility of brassicas, the differences in DOM between the oats and rapeseed of MIX seem to be explained partly by the biomass disappearance in respective years. For example, as the proportion of oats declined, the digestibility of rapeseed decreased to a lesser extent as observed in year 3. Ruminants will exhibit diet selection when given the opportunity and they have been shown to select forage that is higher in crude protein and digestibility, and lower in fiber (Coleman & Barth, 1973; Fontenot & Blaser, 1965; Meyer et al., 1957; Pieper et al., 1959). This can be largely attributed to ruminants selecting the tops of plants first, as demonstrated by steers that selected the ends of leaves and stems of orchardgrass (Alder & Minson, 1963).

In the current study, greater selection of oats initially may have resulted in a decline of the digestibility of available oats as the most nutritious parts were selected first, while rapeseed maintained its digestibility until it was selected by the steers. Overall, the species of both treatments declined in digestibility after December, which is similar to previous work (Lenz et al., 2018). Nonetheless, DOM was still considerably high at the end of the grazing season, with the oats of both treatments ranging from 54-64% DOM and rapeseed ranging from 51-72% DOM. The large range in digestibility at the end of grazing is due to a combination of factors including weather, biomass availability, and selectivity by the steers. Years 1 and 2 concluded with little to no rapeseed biomass available at the end of the grazing season, which resulted in lower DOM values for rapeseed compared to year 3, in which almost 500 kg DM/ha remained. The same could be said for oats as biomass at the end of grazing influenced digestibility, largely due to differences in the parts of the oat plants that were available (i.e., stem vs. leaf). It has been shown that stems are lower in CP and digestibility due to higher proportions of fiber in orchardgrass (Bourquin & Fahey, 1994), which explains the relationship between biomass, selectivity, and digestibility. Weather events such as snow can lead to increased trampling and slight declines in digestibility throughout the grazing season. This may explain why oats and rapeseed were the lowest in DOM in year 1 since the grazing season was almost 30 days longer.

Total ethanol soluble carbohydrate (TESC) content was measured in years 1 and 3, with a quadratic ($P < 0.01$) trend being observed in the plant species of both treatments (Figure 2.4). The pattern of TESC closely resembled the digestibility pattern for each

year. In year 1, both species in MIX increased during the first half of the grazing season before decreasing at an increasing rate, while the oat monoculture remained steady initially before decreasing during the second half of the grazing season. Rapeseed decreased gradually over time in year 3 while both species of oats decreased drastically during the first half of the grazing season before leveling out. In year 1, no differences were observed between the oats and rapeseed of MIX, with initial TESC contents of 12.2 and 10.1%, respectively. A significant difference ($P < 0.01$) was observed for the oats of MIX to be 11% units greater in TESC content than the oat monoculture within Julian date 74 in year 1, although numerical differences were present within dates 18, 45, and 110. Since rapeseed was higher in sugar content to begin with, it might be that steers selected rapeseed initially, leading to minimal change in the TESC content of the oats. Rapeseed was greater ($P < 0.01$) in TESC content than the oats from both treatments within Julian dates in year 3, but no differences ($P \geq 0.19$) were observed between the oats in MIX and the oat monoculture. The TESC content of forage is an indicator of sugar content, which is highly and rapidly digested in ruminants. Increases in the TESC content suggest that the plants continued to photosynthesize and accumulate soluble carbohydrates after the first frost (Figure 2.2), before losing much of the soluble carbohydrates upon encountering weather events in December. This is likely as the first frost did not occur until November 19 in year 1, whereas the first frost occurred on October 23 in year 3. Similar occurrences were observed in an experiment that evaluated the change in late-summer planted oats and brassicas over the winter, although oats had greater TESC content than radish and turnip leaves (Lenz et al., 2018).

Cattle performance

For ADG, no treatment × year interaction ($P = 0.82$) was observed. Average daily gain (ADG) was greater ($P < 0.01$) for MIX than OAT, with MIX steers gaining 0.07 kg/d greater than OAT, although both would be considered moderate to high gains for grazing steers (Table 2.4). Cost of gain decreased significantly ($P < 0.01$) for MIX steers, being $0.21 lower per kilogram of gain. The lower cost of gain is due to not only a greater gain for MIX, but also to a lower seed cost as a result of planting rapeseed.

It is worth noting that beef systems such as feedlots may have an opportunity to decrease the cost of gain by applying manure as fertilizer. Furthermore, runoff control structures (RCS) such as retention ponds could supply water for irrigation of late summer planted cover crops, but costs associated with application such as electricity or fuel would still need to be accounted for. In the current study, a significant portion of the cost of gain was due to irrigation, thus a sensitivity analysis was conducted to determine the contribution of irrigation to the cost of gain (Table 2.3). The cost of gain due to irrigation doubled for both treatments when applying 41.2 ha-mm compared to 20.6 ha-mm. At a cost of $1.82/ha-mm, the cost of gain associated with irrigation increased by $0.12/kg for MIX and $0.13/kg for OAT when the amount of water applied was increased by increments of 10.3 ha-mm. This trend suggests that the overall cost of gain when grazing late-summer planted cool season annual forages is highly sensitive to irrigation. Thus, there is a risk for an increased cost of gain associated with irrigation that could be elevated in times of drought or in drier regions. Solutions such as utilizing water from

runoff control structures could be implemented to reduce the cost of irrigation, but the water level of the soil and weather trends should still be evaluated.

A year effect (*P* = 0.04) was observed for ADG, with gains of 1.0, 0.84, and 0.91 kg being observed in years 1, 2, and 3, respectively. This range is similar to a summary of experiments conducted in Eastern Nebraska in which the ADG of steers grazing late summer planted oats with or without brassicas ranged from 0.60 to 1.10 kg (Drewnoski et al., 2018). An Iowa State study evaluating the performance of cow-calf pairs in a dry lot versus grazing an oat-brassica mix reported an ADG of 1.04 kg for the suckling calves grazing cover crops, although milk likely contributed to gain since the initial BW of the calves was only 73 kg (Lundy et al., 2018). Others have reported improved gain in sheep grazing brassicas during late fall, but the controls were either a grass-clover mix or sugar beet tops, which closely resemble brassicas (Reid et al., 1994; Rule et al., 1991).

CONCLUSIONS

Including a brassica such as rapeseed at 3.4 kg/ha with 56 kg/ha of oat planted in late summer produced forage yield in November that did not differ from an oat monoculture planted at 112 kg/ha. Though timing of planting and sampling influences yield and forage quality, weather remains the largest contributor to variability in forage production and grazed forage losses. Precipitation largely dictates the rate at which plant biomass disappears and leads to a higher proportion of forage loss due to trampling, as evidenced in year 2. The higher digestibility and lower seed cost of rapeseed contributed to a higher quality cover crop when planted with oats in late summer. As a result, greater ADG and a decreased cost of gain were observed for steers grazing MIX, suggesting that

inclusion of rapeseed into late summer planted oats can be a viable option for economically improving calf gain.

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Table 2.1. Summary of water and fertilizer application rates, grazing duration, and preceding crops for pivots utilized in years 1, 2, and 3 of an experiment in which steers grazed an oat monoculture or an oat-rapeseed mix in late fall and winter

Item	Pivot IDs	# quarters/pivot	Preceding crop	N applied, kg/ha	Water applied, ha-mm	Start of grazing	End of grazing	Grazing days	Date of first freeze
Year 1	33A	4	Alfalfa		39.4	Nov. 1st	Feb. 7th	99	Nov. 19th
Year 2	23C, 24D	8	Corn silage			Nov. 13th	Jan. 23rd	71	Oct. 27th
23C				17.5	26.8				
24D				35.2	26.8				
Year 3	32B, 34A	8	Corn silage			Nov. 9th	Jan. 19th	71	Oct. 23rd
32B					45.4				
34A				29.5	48.6				

Table 2.2. Three-year average of input costs used in cost of gain calculation for steers grazing an oat monoculture (OAT) or an oat-rapeseed mix (MIX) over an 80-d grazing period in late fall and winter

Estimated Costs	OAT	MIX
$/ha		
Seed cost[a]	$50.24	$36.65
Seeding cost	$34.31	$34.31
Fertilizer[b] & application	$16.80	$16.80
Irrigation[c]	$82.52	$82.52
Water & health checks	$22.24	$22.24
Fence	$12.36	$12.36
Total	$196.23	$182.64

[a]OAT seeded at a rate of 112 kg/ha; MIX seeded at a rate of 56 kg/ha and 3.4 kg/ha for oats and rapeseed, respectively
[b]Average of 26.3 and 29.5 kg/ha of nitrogen applied in years 2 and 3, respectively
[c]39.4, 26.8, and 47.0 ha-mm applied years 1, 2, and 3, respectively

Table 2.3. Sensitivity analysis for the contribution of irrigation cost to the cost of gain ($/kg) based on water applied for steers grazing a late summer planted oat monoculture (OAT) or an oat-rapeseed mix (MIX) during late fall and winter

		Water applied, ha-mm[1]		
Treatment	$/ha-mm[2]	20.6	30.9	41.2
MIX	1.82	$ 0.24	$ 0.36	$ 0.48
OAT		$ 0.26	$ 0.39	$ 0.52
MIX	1.92	$ 0.26	$ 0.38	$ 0.51
OAT		$ 0.28	$ 0.42	$ 0.56
MIX	2.02	$ 0.27	$ 0.41	$ 0.54
OAT		$ 0.29	$ 0.44	$ 0.59

[1]Values represent the contribution of irrigation to cost of gain

[2]The range of the cost of water application was derived from the 2017 and 2020 Nebraska Crop Budgets (Klein et al., 2016 & 2019)

Table 2.4. Performance and forage disappearance for steers grazing a late summer planted oat monoculture (OAT) or an oat-rapeseed mix (MIX) over an 80-d grazing period in late fall and winter

Item	OAT	MIX	SEM	*P*-value
Initial BW, kg	263	262	1.49	0.60
Ending BW, kg	334	339	1.84	0.08
ADG, kg	0.876[a]	0.954[b]	0.024	<0.01
Cost of gain, $/kg	1.42[a]	1.21[b]	0.091	<0.01
Disappearance, kg/hd/d	12.8	12.9	5.70	0.92

[a,b]Means with different superscripts differ ($P \leq 0.05$)

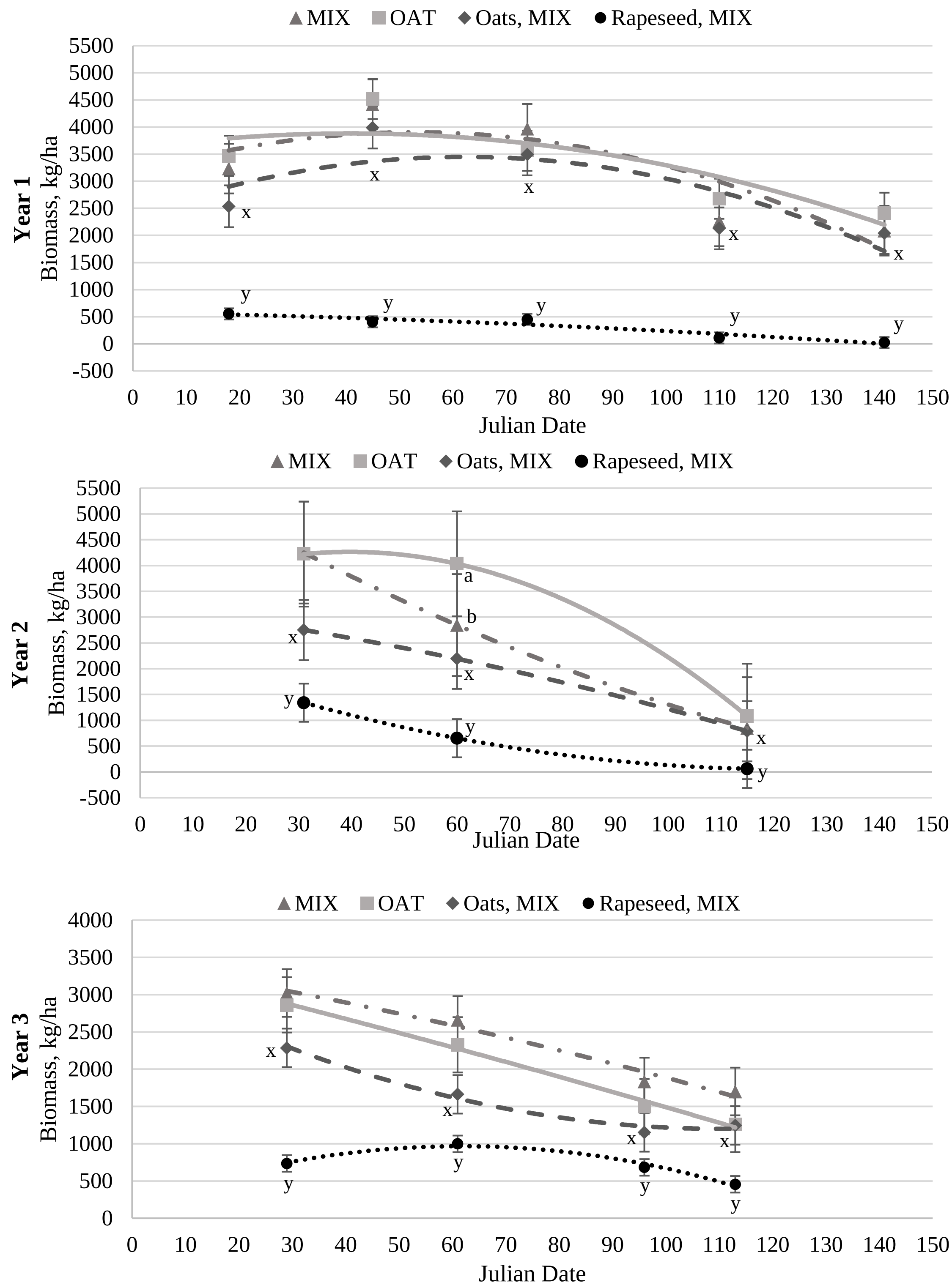

Figure 2.1. Biomass over time for OAT and MIX treatments and the individual species of MIX in years 1, 2, and 3. October 1st marked the first day of the Julian year so that equal comparisons could be made. Lines with different letters differ ($P \leq 0.05$).

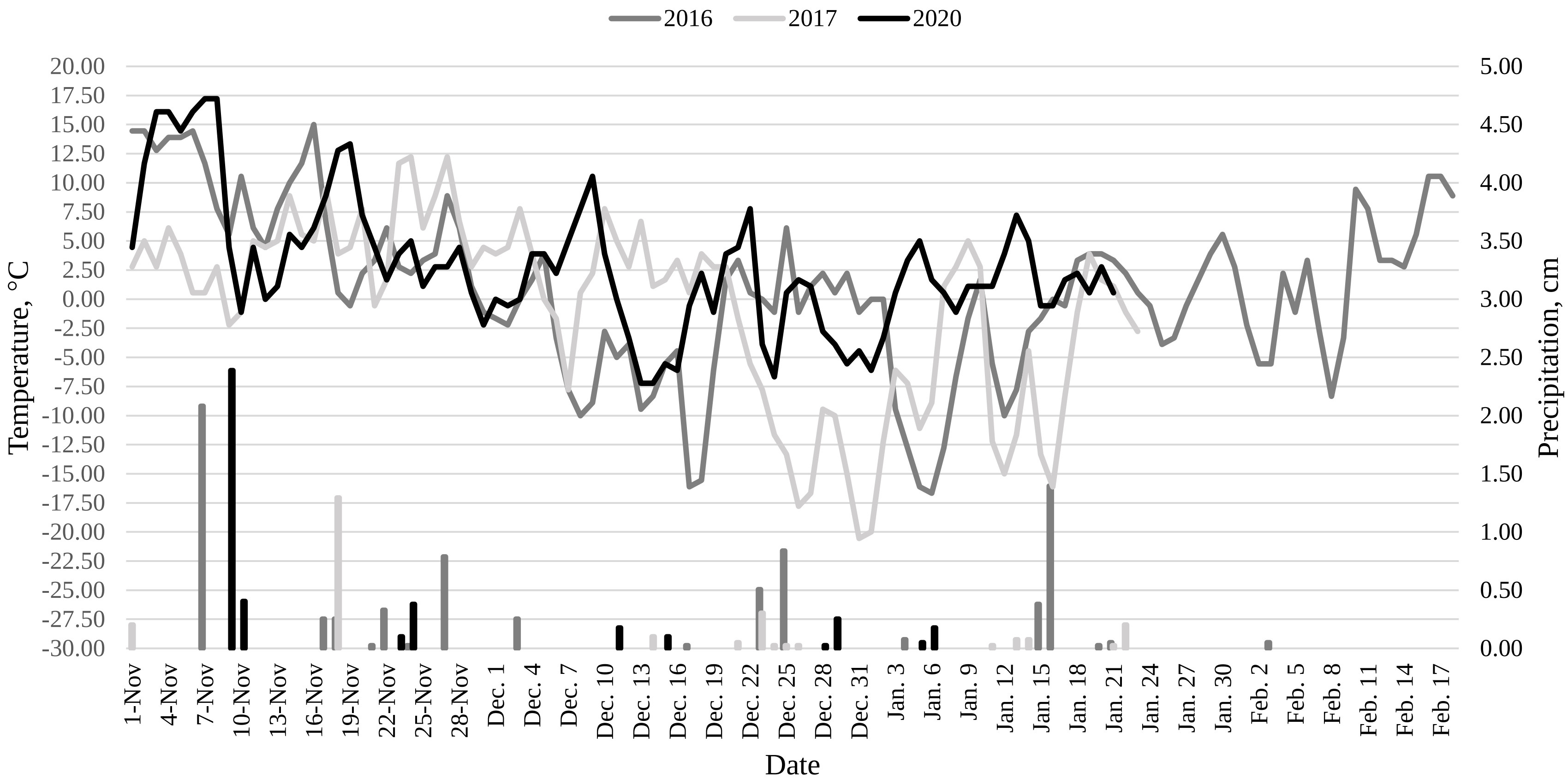

Figure 2.2. Daily average temperature and precipitation for each year throughout the grazing period. November 1st marked the earliest first day of grazing among the three years.

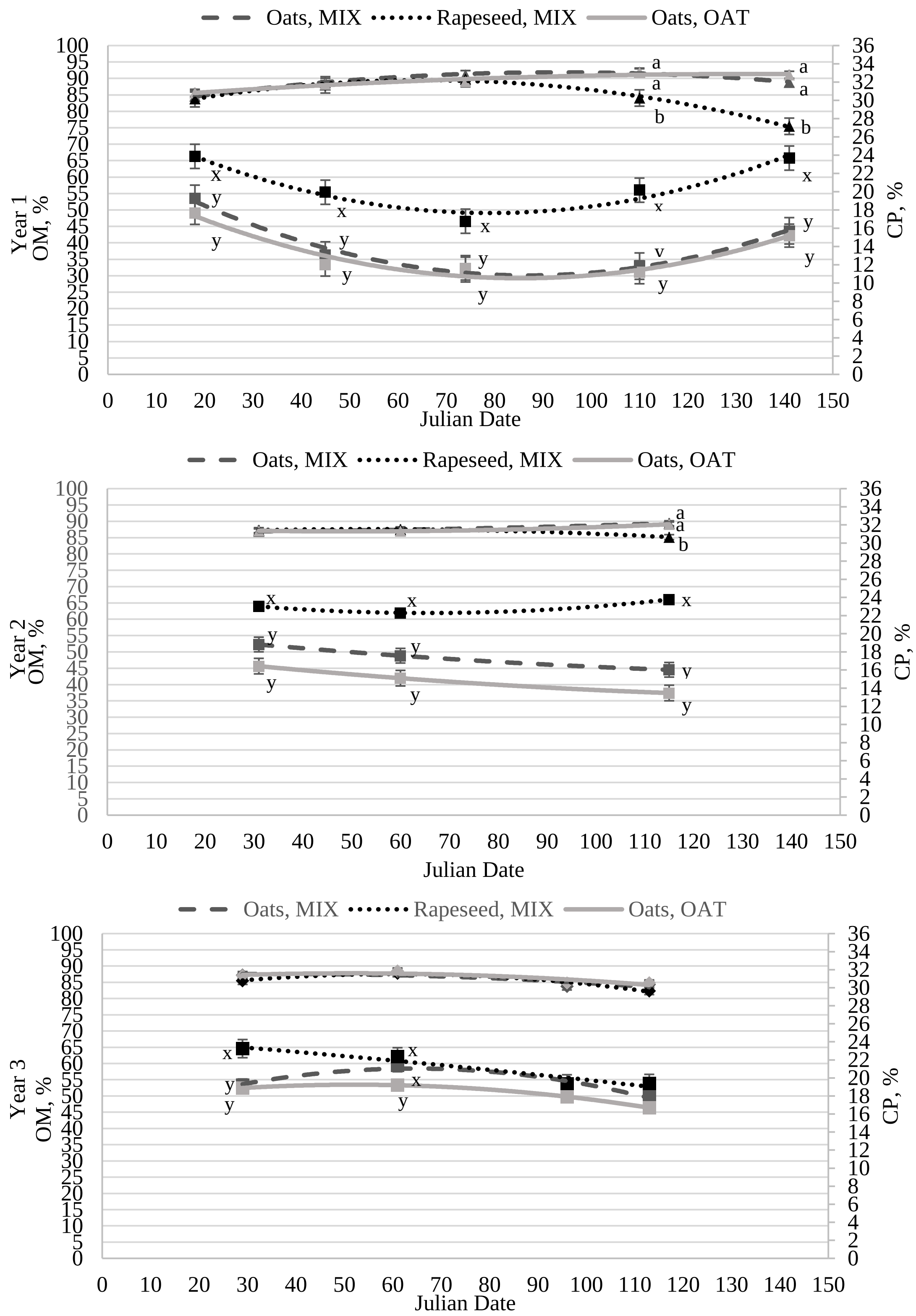

Figure 2.3. Organic matter and crude protein as a percentage of DM across dates within years 1, 2, and 3. October 1st marked the start of the Julian year so that equal comparisons could be made. Lines with different letters (a,b = OM; x,y = CP) differ ($P \leq 0.05$). Triangle markers represent OM and square markers represent CP.

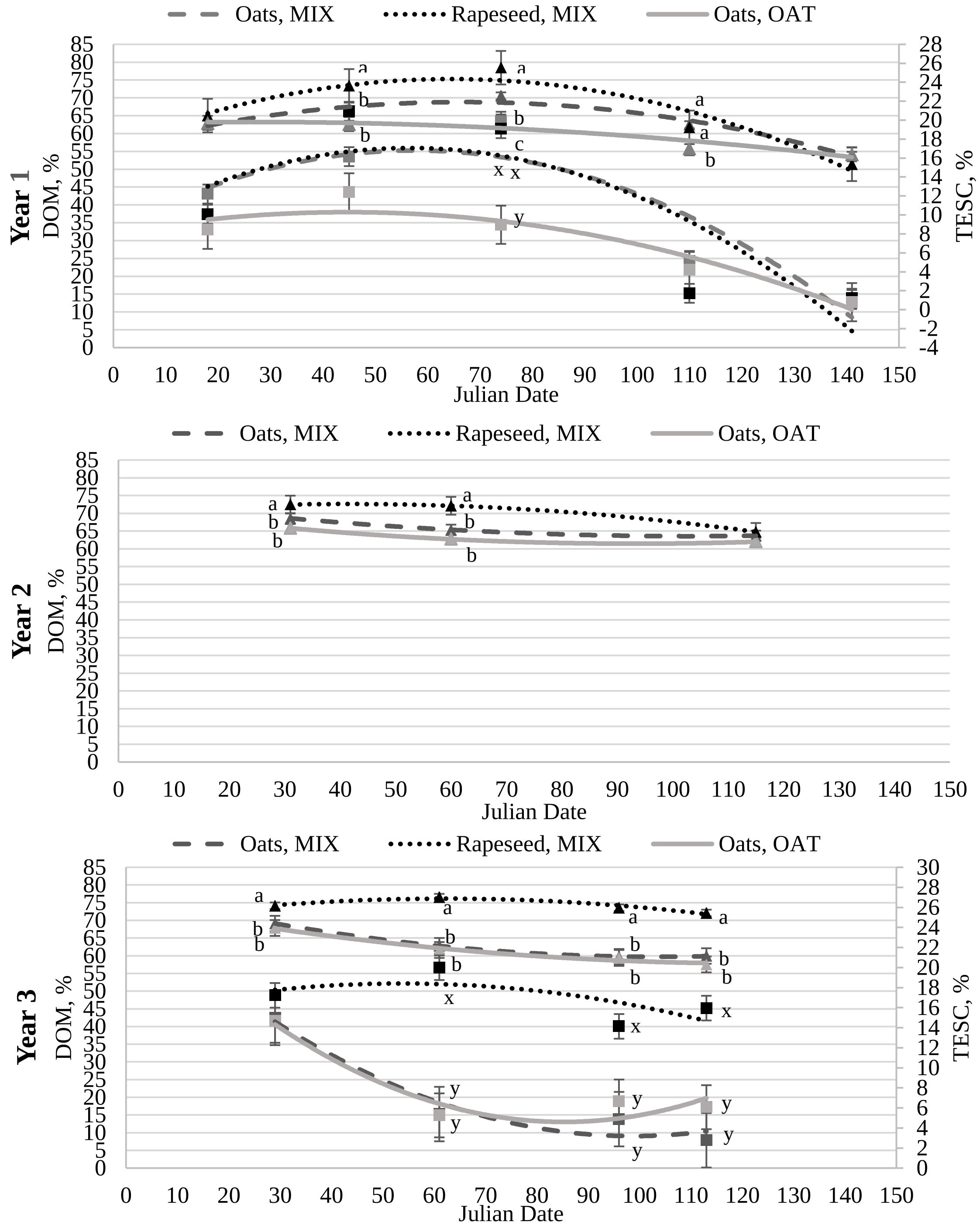

Figure 2.4. Digestible organic matter (DOM) and total ethanol soluble carbohydrates (TESC) as a percentage of DM of the oat monoculture (Oats, OAT) and the oats and rapeseed of the mix (Oats, MIX and Rapeseed, MIX, respectively). October 1st marked the start of the Julian year so that equal comparisons could be made. Lines with different letters (a,b = DOM; x,y = TESC) differ ($P \leq 0.05$). Triangle markers represent DOM and squares represent TESC.

CHAPTER III. The Effects of Forage Allocation on Forage Utilization and Performance of Beef Steers Grazing A Late-Summer Planted Oat-Rapeseed Mix

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ABSTRACT

Grazing management of late-summer planted, cool-season annual forages to improve forage utilization and performance of grazing steers is not well documented. A mixture of oats (*Avena sativa* L) and rapeseed (Brassica *napus*) was planted at a rate of 56 kg/ha and 3.4 kg/ha, respectively, in early August in east central Nebraska. Crossbred steers (n = 84; initial BW = 238 kg; SD = 17 kg) were stratified by BW and randomly assigned to either a continuously stocked (CONT) or a strip grazing (STRIP) treatment. Steers were stocked to attain a rate of approximately 2 steers/ha for a total of 14 steers per paddock (6.3 ha) with 6 paddocks total. Steers began grazing on November 12 and grazed until February 3. Initial forage biomass did not differ ($P = 0.91$), with CONT and STRIP yielding 4,852 and 4,914 kg/ha (DM basis), respectively. Initial digestible organic matter (DOM) was high for both treatments (73%) and did not differ by treatment on d 0. However, differences ($P \leq 0.05$) were observed on d 22, 42, and 71 as CONT declined to a greater extent than STRIP. Initial crude protein (CP) for CONT and STRIP did not differ (9.8% and 10.8%, respectively) and remained constant for STRIP, whereas CONT declined throughout the grazing season, leading to a difference ($P = 0.02$) on d 71. The difference is likely due to CONT steers selecting rapeseed which led to a lesser amount of rapeseed available over time and a subsequent decrease in the overall CP of available forage. Rapeseed had greater ($P < 0.01$) DOM and CP than oats throughout the grazing season. Strip grazing offered 126 more ($P = 0.03$) head days/ha than continuous grazing, suggesting an improvement in forage utilization. Ending body weight and ADG were greater ($P < 0.01$) for CONT, with CONT steers gaining 0.90 kg/d while STRIP steers gained 0.76 kg/d. However, gain per hectare was greater ($P = 0.02$) for STRIP, with gains

of 160 and 266 kg/ha for CONT and STRIP, respectively. A tendency (*P* = 0.09) was observed for cost of gain to be $0.27/kg lower for STRIP steers and, likely due to increased forage utilization as evidenced by a greater gain per hectare. Allocating late summer planted cover crops twice weekly to growing steers grazing during late fall and winter improves forage utilization and lowers cost of gain.

Keywords: Forage allocation, Brassicas, Oats, Annual forages, Cattle

INTRODUCTION

Grazing late summer planted cover crops during the fall and winter is not a new concept to producers in Nebraska. Cool-season annual forages that are planted in late summer yield a conservation benefit by improving soil organic matter and reducing erosion, while grazing these forages can help to offset establishment costs and yield calf gain (Drewnoski et al., 2018). Small cereal grains such as oats and brassicas such as turnips are two types of cool-season annual forages that can be utilized as cover crops and for grazing purposes when planted in late summer after corn silage harvest, spring wheat harvest, etc. (McCormick et al., 2006).

Planting a small cereal grain and a brassica in a mix offers a great combination of high yield and digestibility. A 2-year Nebraska study reported yields of 3,756 to 5,144 kg DM/ha for a mix of oats, turnips, and radishes (Cox-O'Neill et al., 2017). Moreover, these species are known to be highly digestible (69% and 88% IVOMD for oats and brassicas, respectively), with only slight declines in digestibility and CP remaining constant throughout winter (Lenz et al., 2018). Average daily gain of calves grazing an oat-

brassica mix has been high (0.72 kg) in previous work (Cox-O'Neill et al., 2017), thus high calf gain coupled with the low seeding cost of rapeseed may provide an opportunity to decrease cost of gain when grazing an oat-brassica mix compared to a monoculture.

While much is known of the yield and quality of late summer planted annual forages, there are more gaps in the literature regarding forage utilization. Strip grazing is one method of forage allocation and has been described as a method in which animals are confined to an area of grazing land to be grazed in a short amount of time, with the area of the strip varying in size (Allen et al., 2011). A study in which harvest data was collected for 3 years across the Midwest revealed losses of 31% to 70% for dairy cows grazing perennial grasses, with strip grazing having the least loss and continuous grazing having the most (Larsen, 1959). Similarly, Boyles et al., (1998) noted that losses were as high as 70% when cows were given access to a large area of stockpiled cool-season annual forages, with only 30% loss occurring when the cows were given a 3-day supply via strip grazing. Studies have also evaluated the effect of forage allowance on forage utilization. An experiment in New Zealand allocated forage rape to sheep at different daily allowances by adjusting stocking rate and found that more allowance resulted in a decrease in forage utilization but an increase in animal gain (Judson, 2010), similar to findings of Brunsvig et al., (2017) that reported increases in ADG of heifers grazing late summer planted annual forages when stocking density was decreased. Increases in animal gain in the previously mentioned studies were attributed to a decrease in stocking density, which likely allowed increased diet selectivity by the animals. Previous work has also shown that allocating forage as frequent as once a day but not less frequently than every

14 days has increased forage utilization due to a decrease in forage loss (Abrahamse et al., 2008; Boyles et al., 1998-2007). However, the bulk of the aforementioned studies were conducted on summer perennial pasture or annual spring cropping systems and is disparate from grazing stockpiled cool-season annuals in late fall and winter in which weather is a major factor and exhibits different effects compared to spring and summer. Furthermore, there remains a large gap in the understanding of forage allocation, particularly in fall and winter grazing of late summer planted forages. Therefore, the objective of this study was to evaluate the effects of forage allocation on forage utilization and animal performance of steers grazing a late summer planted oat-rapeseed mix.

MATERIALS AND METHODS

All procedures used in these experiments were reviewed and approved by the University of Nebraska – Lincoln Institutional Animal Care and Use Committee.

Experimental Design and Procedures

An irrigated field near Mead, NE was planted into Jerry oats (Avena *sativa*) and Trophy rapeseed (Brassica *napus*) on August 12, 2020 at rates of 56 kg/ha and 3.4 kg/ha, respectively. Seeding was done with a no-till drill, using a 20.3 cm spacing. A herbicide was applied prior to planting for control of weeds. Nitrogen was applied post-emergence in a solid application at a rate of 42 kg N/ha and the field was watered via center pivot with 16.5 ha-mm of water. The field was separated into 6 paddocks (6.3 ha) by a single-strand electric wire fence. Treatments, continuous grazing (CONT) and strip grazing

(STRIP), were arranged in a completely randomized block design, with paddock being the experimental unit. Treatments were randomly assigned within each of 3 blocks (2 blocks of irrigated paddocks and 1 block in which paddocks included dryland corners).

Steers were limit-fed (2% of BW) a diet consisting of 50% Sweet Bran® (Cargill Wet Milling, Blair, NE), and 50% alfalfa hay (DM basis) for 5 d to equalize gut fill before weighing (Watson et al., 2013). Steers were weighed 2 consecutive days (d 0 and 1) using a hydraulic squeeze chute with load cells mounted on the chute (Silencer, Moly Manufacturing Inc., Lorraine, KS: scale readability ± 0.90 kg) to establish initial BW. Steers were implanted with 36 mg of zeranol (Ralgro, Merck Animal Health, De Soto, KS) during the initial weighing (d 1) process. Steers (n=84; initial BW 238 kg; SD=17) were stratified by BW and randomly assigned to treatment and replicate on d -1.

Paddocks were stocked to achieve a stocking rate of approximately 2 steers per hectare for a total of 14 steers per paddock. Seven of the 14 steers from each paddock were randomly assigned as testers and used for gain comparison of treatments, since forage was expected to become limiting in CONT paddocks before STRIP paddocks. Grazing began on November 12, 2020 and the cattle grazed until the average available forage height was limiting (5.1 cm) in the continuous paddocks. Continuous grazing steers utilized 0.45 ha/hd throughout the grazing season while STRIP steers used 0.25 ha/hd. Steers were limit fed (2% BW) for 7 days after grazing ceased and then weighed on 3 consecutive days to mimic the same weighing procedures used for initial BW (Watson et al., 2013).

A mineral supplement containing calcium, salt, zinc, manganese, copper, cobalt, iodine, and selenium was provided ad-libitum to steers in each paddock during grazing in above-ground mineral feeders and water was hauled daily. STRIP calves were allocated a new strip on Monday and Thursday mornings of every week by moving a one-strand electric wire through the paddock. No back-wire was used so that steers had access to all previously grazed strips.

Forage measurements

Initial biomass was sampled on October 29, 2020 to determine forage production by clipping random areas (0.91 × 0.61 m) within each paddock to ground level. To account for the proportion of dryland area in the block with dryland corners, 3 random samples were taken in the irrigated portion and 2 samples were taken in the dryland portion of the paddocks. Four random samples were taken in each paddock of the other two blocks. Biomass samples were taken again on December 3 and December 23, 2020 and on January 21, 2021. The same sampling procedures used in initial biomass were also used in CONT paddocks for the other 3 sampling dates. Four samples were taken at random in STRIP paddocks for initial biomass. For the remaining sampling dates in STRIP paddocks, four samples were taken, except 2 of the clippings were taken in the non-grazed area of the paddock to serve as pre-graze samples and the other 2 clippings were taken in the grazed portion to serve as post-graze samples. Markers were used to identify where clippings were taken in each STRIP paddock so that pre- and post-graze measurements were taken in the same strips. Prior to taking measurements for post-grazing biomass, steers from an adjacent field grazed in the experimental paddocks

resulting in an inability to measure final biomass. Prior to drying, rapeseed and oats were hand-separated to determine proportions. Forage samples were bagged and dried for 48 to 72 hours in a 60°C forced air oven to determine biomass.

Disappearance for CONT and STRIP was calculated using the period of December 3, 2020 to January 21,2021 but STRIP disappearance was calculated using the average of two periods within that time frame (December 3 to December 23 and December 23 to January 21). Daily disappearance per hd for each paddock was calculated as follows: $Disappearance, \frac{kg}{hd} = \frac{initial \times hectares}{\# \ hd} - \frac{final \times hectares}{\# \ hd}$. The result of the previous equation was multiplied by the number of days steers grazed their allocated areas. Therefore, CONT steers had access to their whole paddock and grazed for 49 days between December 3 and January 21 while STRIP steers only had access to one strip at a time for 2 to 4 days in each strip.

At each of the 4 biomass sampling times, samples were also collected for nutrient analysis. Samples were collected at random within CONT paddocks and at random within the entire non-grazed portion of STRIP paddocks by clipping to ground level and bagged separately according to species type. Samples were transported in a cooler with ice to the lab for analysis.

Lab Analysis

Clipped quality samples were dried for 48 to 72 h in a 60°C forced air oven and then ground to pass a 1-mm screen using a Wiley Mill (Thomas Scientific, Swedesboro,

NJ). Dried samples were analyzed for dry matter (DM;105°C), organic matter (OM), crude protein (CP), and in vitro organic matter digestibility (IVOMD).

Dry matter was determined by placing the ground samples in a forced air oven for 12-24 h at 105°C. Subsequent organic matter (OM) was determined by placing the samples in a muffle furnace for 6 h at 600°C (AOAC, 1999). Crude protein (CP) analysis was conducted using the combustion method (AOAC, 2006) by Ward Laboratories (Ward Laboratories, Inc., Kearney, NE). Methods described by Tilley & Terry, (1963) were used to determine in vitro organic matter digestibility (IVOMD) with 48 h incubation. Methods were modified by adding urea to the McDougall’s buffer (McDougall, 1948) at a rate of 1 g urea/L buffer solution, to ensure adequate N was available for microbes in the rumen fluid (Weiss, 1994). Blanks were included in the in vitro run to adjust for any feed particles that might have come from the inoculum. After incubation, the Whatman 541 filter paper (22 µm pore size) plus samples was placed in crucibles and heated in a muffle furnace for 6-h at 600°C (AOAC, 1999). Two runs were conducted and five hay standards with known in vivo (total tract) digestibility (51-60% range) were used to adjust IVOMD values. These adjustment values resulted in 6.5 and 6.6 percentage units added to IVOMD runs 1 and 2, respectively. Forage digestibility was expressed using digestible organic matter (DOM) and calculated as: $DOM = OM \times IVOMD$.

Economics

A partial budget analysis was conducted to evaluate the establishment costs of the forage mix (Table 3.1). Costs included in the budget were seed and seeding cost, as well

as the cost of fertilizer and application. Herbicide and application costs were also included. These costs were the actual costs charged by the producer who planted, fertilized, and sprayed the field. Cost of irrigation per hectare was calculated using the metered amount of water applied and rates from the 2020 Nebraska Crop Budgets and converted to hectare-millimeters (Klein et al., 2019). Costs associated with building the perimeter electric fence were accounted for at $2.02/ha and based off previous calculations made for fencing costs associated with pivot quarters. Labor involved with moving electric fence twice weekly in the STRIP paddocks was calculated by multiplying the total weekly time (1 hour) to move fence for each paddock by a common rate of $20/hr (McClure & Jansen, 2020). That amount was multiplied by the number of weeks grazed and divided by the number of hectares grazed for a cost of $69.29/ha. Steers were assumed to drink 20 L/hd of water daily (NASEM, 2016). Three water tanks (2650 Liters) were used and shared by adjacent paddocks. Thus, it was estimated that water tanks would need to be filled every 4.5 days or approximately twice weekly. It was estimated to require 2 hours for each fill for a total of 4 hours per week and charged $20/hr (McClure & Jansen, 2020). Health checks were incorporated into the cost of hauling water.

A sensitivity analysis was conducted to determine how sensitive the cost of gain for irrigation was to the amount of water applied (Table 3.2). Water application amounts used for the analysis were assumed to be what would be needed to achieve the same amount of forage yield as that observed in this study. The range of water application in the analysis was based off averages of applied water in several previous late summer

planted grazing experiments. The range of the cost of water application per ha-mm was determined using the 2017 and 2020 Nebraska Crop Budgets (Klein et al., 2016; Klein et al., 2019).

Statistical Analysis

Steer performance, cost of gain, forage quality, biomass, and forage disappearance were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.). Forage quality was analyzed as a repeated measure with paddock within rep included in a random residual statement and paddock within rep as the subject. The model contained treatment, sampling date as a covariate, and interactions as fixed effects. Forage disappearance was averaged across three periods for each paddock for statistical analysis. Thus, steer performance, biomass and forage disappearance were analyzed with treatment and block included as fixed effects in the model. Treatment means were separated using the pdiff statement when the F-test was significant. Treatment differences were considered significant when $P \leq 0.05$ with tendencies between $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Forage Production and Quality

No differences ($P = 0.91$) were observed for initial biomass (Table 3.3). Rapeseed comprised 25.5% of the total initial biomass available with no treatment differences ($P = 0.25$). These yields were similar for other oat or brassica monocultures, although none reported yield for an oat-rapeseed mix (Coblentz & Walgenbach, 2010; Villalobos &

Brummer, 2015). Though not significantly different (*P* = 0.14), treatments were numerically different with disappearances rates of 28.7 and 20.3 kg/ha daily observed for CONT and STRIP, respectively (Table 3.3). This disappearance rate for CONT would equate to an intake of 6 to 9% of body weight, suggesting a large amount of the forage disappeared due to trampling and weather. A possible increase in forage utilization among STRIP was evidenced by 345 hd days/ha compared to 185 hd days/ha in the CONT treatment. An older study measured biomass of actively growing alfalfa-perennial grass mixtures grazed by dairy cows to calculate forage disappearance and averaged values over three years concluded that strip grazing resulted in the most forage utilization, as evidenced by 31% forage loss when strip grazing compared to losses of 60-70% when continuous grazing (Larsen, 1959). Similarly, the observed difference in forage disappearance in the current study equates to a 29% decrease in disappearance when strip grazing compared to continuous grazing. Though there are no reports of forage disappearance, Boyles et al., (1998) reported that strip grazing on a 3-day frequency compared to a 14-day frequency increased grazing days by 40%. In the current study, a 46% increase in the number of grazing days was observed for a 3-to-4-day allocation vs. continuous grazing. Increased precipitation led to a greater need for available forage in STRIP late in the grazing season. The average allocation size over the grazing season was 0.013 ha/hd and the minimum and maximum were 0.004 and 0.032 ha/hd, respectively. Standing forage in the non-grazed strips accumulated more snow than the available forage in the CONT paddocks; thus, STRIP steers required increased forage allocation when heavy snowfall occurred. Figure 3.1 demonstrates the relationship

between temperature, precipitation, and forage allocation. Periods of greater forage allocation between November and early January were due to precipitation events in which the temperature was above 0 °C, which likely led to more trampling loss. However, although more days in which the temperature was below freezing were observed between January and February, there was a demand for increased forage allocation due to the precipitation events being primarily snow. Nonetheless, cattle have been reported to graze through over 45 cm of snow if adequate forage is available underneath and improved forage utilization can still be achieved by strip grazing even if weather persists (Boyles et al., 1998-2007; Decker, 1988). Still, the duration of temperature above or below freezing and the amount of precipitation remain factors that influence allocation and consequently, length of the grazing season.

Forage nutritive value was compared by species over time. There were minor differences in OM content, with rapeseed having lower OM ($P \leq 0.05$) than oats on d 0 and 71 (Figure 3.2). However, mean OM content of oats and rapeseed was 91% and 89%, respectively. Rapeseed had greater ($P < 0.01$) CP content than oats and ranged from 14-17% CP throughout the grazing season, whereas oats ranged from 7-9% CP. The DOM of rapeseed was greater ($P < 0.01$) than oats throughout the grazing season (Figure 3.3).

Interestingly, CP values for rapeseed in the current study were much lower than in other studies, which have ranged from 18-26% CP for several different brassicas (Dillard et al., 2020; Lenz et al., 2018; Villalobos & Brummer, 2015). Likewise, the CP values for oats in the current study were also lower than the range of 14-23% that has been reported by others (Brinton et al., 2019; Coblentz & Walgenbach, 2010; Lenz et al., 2018).

Changes in CP content are especially present during active growth, with decreases being observed as days after planting increases, with planting date largely dictating maturity (Coblentz & Walgenbach, 2010; Lenz et al., 2018). Lower values for CP in the current study are likely due to a combination of factors including a later harvest date that corresponded to a greater degree of plant maturity.

Treatments were also compared for forage nutritive value. There were minor differences, with CONT having lower ($P \leq 0.05$) OM than STRIP on d 22 and 42, with mean OM of 90% and 91%, respectively (Figure 3.2). Differences in OM were small and likely due to soil contamination when sampling, particularly as more precipitation events occurred (Figure 3.1) and likely due to trampling by the steers. No differences ($P = 0.41$) were observed for initial CP, with CONT and STRIP being 9.8 and 10.8% CP, respectively. Crude protein content for STRIP stayed constant throughout grazing while CP content for CONT declined to 7.4% on d 71, in which it was significantly ($P = 0.02$) lower than STRIP. The initial DOM for CONT (72.3%) did not differ ($P = 0.58$) from STRIP (73.7%). Significant differences ($P < 0.05$) were observed for DOM within all sampling days after d 0, as digestibility declined more from October to January for CONT than STRIP (14%- and 7%-unit declines). This is expected since sampling for STRIP was conducted in the non-grazed portion of the paddock. This likely represented weathering effects, while sampling in the CONT paddocks represented weathering and selectivity since steers were allowed to graze the entire paddock.

As noted by Provenza et al., (1991), animals exhibit conditioned selection for nutritionally satisfying plants once the novelty of the plant is overcome. Thus, CONT

steers likely selected rapeseed first since it is higher in energy which led to a greater decline in the digestibility of available forage as rapeseed was removed by CONT calves. Nonetheless, the changes were slight and the forage DOM for both treatments remained above 56% into late January which is still considered relatively high. An experiment conducted by Lenz et al., (2018) evaluated the forage quality of an oat-brassica mix planted in late summer that was grazed continuously by growing steers. They reported that initial IVOMD was high and declined by 10% and 5% for oats and brassicas, respectively, with brassicas having greater digestibility throughout the grazing season. This was similar to the higher DOM observed in rapeseed in the current study.

Steer Performance

Initial body weight for both treatments was 238 kg ($P = 0.54$) with ending body weight being greater ($P \leq 0.01$) for CONT (Table 3.4). Steers that grazed continuously also had greater ($P \leq 0.01$) ADG than STRIP steers by 0.14 kg. This is supported by previous work that suggested increases in animal performance with a reduction in stocking density to a certain point, although grazing began in October which may suggest plants were still growing (Brunsvig et al., 2016; Bryant et al., 1970). Continuous grazing also tends to increase diet selectivity, resulting in a subsequent increase in diet quality and digestibility. This has led to increased animal performance, especially during grazing periods of less than 50 days (Brunsvig et al., 2017).

However, in the current study, differences ($P \leq 0.01$) were observed for gain per hectare, with STRIP calves gaining 36% more kg/ha. This was likely due to greater forage utilization by STRIP steers which overcame their lower gains to result in a greater

gain per hectare. The average allocation in new strips for STRIP steers was 15 kg/hd daily while CONT steers had access to 66 kg/hd daily, based on initial forage yield. This explains the greater forage utilization and is similar to results observed by Judson, (2010), in which sheep that were given a lower allowance of DM/hd had greater utilization than sheep with higher forage allowance. In the current study, STRIP calves may have had decreased diet selectivity which resulted in lower preferential selection of oats or rapeseed. A study by Shaw et al., (2006) showed a similar response in which sheep that grazed at higher stocking densities consumed more sagebrush over time in addition to the higher quality forages they had access to than sheep grazing at low stock densities which resulted in an overall decrease in selectivity.

Ultimately, greater forage utilization in this study resulted in a tendency ($P = 0.09$) for the cost of gain to be lower for STRIP (\$1.24/kg) than CONT (\$1.51/kg). This was in spite of the increased labor costs associated with moving fence twice per week. This equates to a cost of \$0.20/hd daily or \$0.27/kg of weight gained. Though this cost seems relatively high, the increase in gain per hectare still resulted in a lower cost of gain for STRIP. The lowest cost per hectare at which strip grazing would have resulted in a tendency ($P \leq 0.10$) for a lower cost of gain compared to continuous grazing was \$235.59/ha for CONT and \$304.87/ha for STRIP, both of which are approximately \$15/ha less than the cost per hectare used in this study. That said, the extent to which the cost of gain is lowered when strip grazing will vary and is heavily influenced by the cost per hectare. Factors such as terrain of the field, scale of fence, etc. could positively or

negatively impact the cost of gain for strip grazing a late summer planted cool-season annual forage and needs further exploration.

A sensitivity analysis was conducted to determine the cost of gain attributed to water based on theoretical amounts of water that could be applied to achieve the same amount of forage growth as that observed in this study (Table 3.2). The cost of gain attributed to irrigation doubled for both treatments when applying 41.2 ha-mm compared to 20.6 ha-mm. For the experiment, 16.5 ha-mm was applied, which is on the low end of the sensitivity analysis. That said, the total cost of gain for steers grazing a late summer planted oat-rapeseed mix is highly sensitive to the amount of water applied and could be drastically increased in times such as drought, when more water is needed to facilitate plant growth. However, using water from runoff control structures such as those in feedlots to irrigate may be an alternative to mitigate risk, especially in a dry year.

CONCLUSIONS

Allocating forage twice weekly to steers grazing late-summer planted oats and rapeseed resulted in a 29.3% decrease in forage disappearance compared to continuous grazing. Strip grazing also resulted in 126 more head days per hectare than continuous grazing, suggesting that allocating forage twice weekly does improve forage utilization when grazing late-summer planted cover crops during the fall and winter. Continuous grazing is apt to produce more gain per animal if grazing for less than 90 days due to the opportunity for diet selectivity; however, strip grazing does achieve more calf gain per hectare than continuous grazing and lowers the cost of gain, even with the additional

labor. Greater forage utilization and moderate to high calf gain can be achieved by strip grazing when allocating a high-quality forage such as an oat-rapeseed mix.

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Table 3.1. Partial budget used in cost of gain calculation for steers grazing a late summer planted oat-rapeseed mix continuously (CONT) or by strip grazing (STRIP) from November to early February

Estimated Costs	CONT	STRIP
$/ha		
Seed cost[a]	$26.69	$26.69
Seeding cost	$29.65	$29.65
Fertilizer[b]	$37.07	$37.07
Fertilizer application	$21.62	$21.62
Irrigation[c]	$37.11	$37.11
Herbicide	$46.38	$46.38
Herbicide application	$17.30	$17.30
Fence	$12.36	$12.36
Water & health checks	$22.24	$22.24
Labor[1]	-	$69.29
$/ha	$250.42	$319.71

[a]Oats and rapeseed planted at rates of 56 kg/ha and 3.4 kg/ha, respectively
[b]Nitrogen applied at a rate of 42 kg/ha of actual N
[c]Total water applied = 16.5 ha-mm
[1]Calculation factors: $20/hr, fence moved twice weekly, 30 minutes for each fence move = 1 hr/week, 11.86 weeks grazed

Table 3.2. Sensitivity analysis for the contribution of irrigation cost to the cost of gain ($/kg) based on water applied for steers either continuous grazing (CONT) or strip grazing (STRIP) a late summer planted oat-rapeseed mix from November to February

		Water applied, ha-mm[1]		
Treatment	$/ha-mm[2]	20.6	30.9	41.2
CONT	1.82	$0.25	$ 0.38	$ 0.50
STRIP		$0.16	$ 0.24	$ 0.32
CONT	1.92	$0.27	$ 0.40	$ 0.53
STRIP		$0.17	$ 0.26	$ 0.34
CONT	2.02	$0.28	$ 0.42	$ 0.56
STRIP		$0.18	$ 0.27	$ 0.36

[1]Values represent the contribution of irrigation to cost of gain
[2]The range of the cost of water application was derived from the 2017 and 2020 Nebraska Crop Budgets (Klein et al., 2016 & 2019)

Table 3.3. Initial forage yield, rapeseed proportion, and forage disappearance for an oat-rapeseed mix planted in late-summer and grazed from early November to early February

Item	CONT[3]	STRIP[3]	SEM	*P*-value
Biomass, kg/ha	4852	4914	337	0.91
Rapeseed proportion, %[1]	21.4	29.5	3.53	0.25
Disappearance, kg/ha	28.7	20.3	2.53	0.14
Head days/ha	185	345	20.76	0.03
Hectares grazed, %[2]	100	54.6	0.036	-

[1]% rapeseed = proportion of rapeseed in the total forage available prior to the start of grazing

[2]% hectares grazed = the total percentage of the allotted 6.3 hectares per paddock that was grazed over the 83-day grazing period

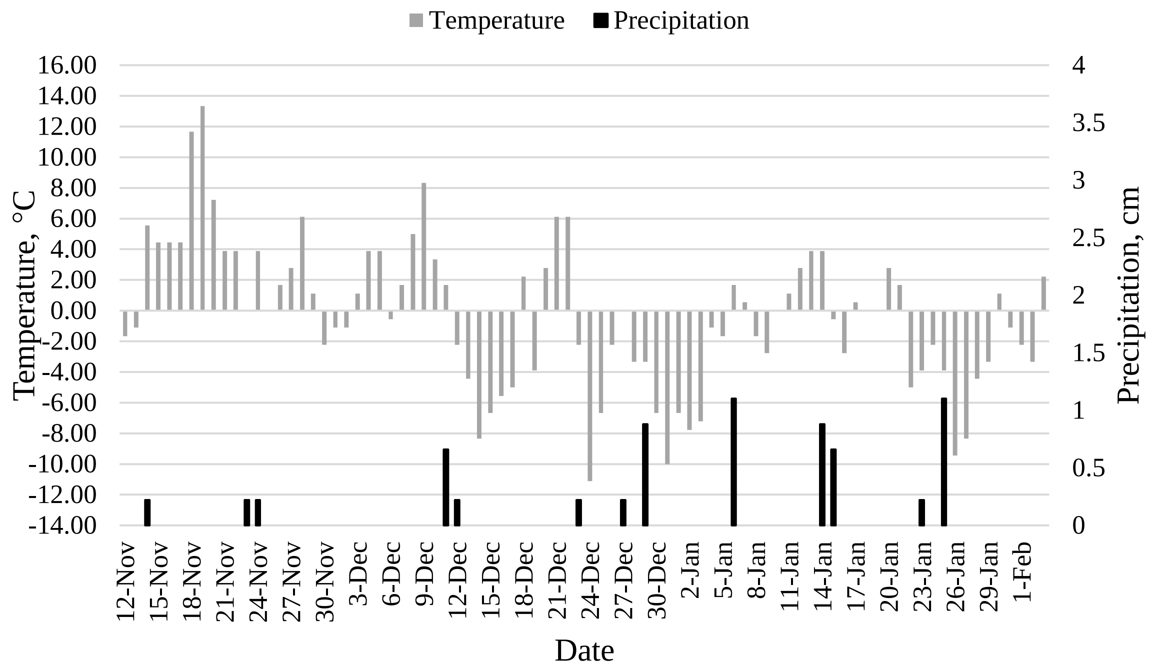
[3]CONT = continuous grazing with steers stocked at a rate of 2 steers per hectare, STRIP = strip grazing with access given to new strips twice weekly

Table 3.4. Performance of steers grazing a late summer planted oat-rapeseed mix either continuously (CONT) or by strip grazing (STRIP) over an 83-day grazing period during the late fall and winter

Item	CONT[1]	STRIP[1]	SE	*P*-value
Initial BW, kg	238	238	0.288	0.54
Ending BW, kg	312[a]	300[b]	1.24	0.01
ADG, kg	0.9[a]	0.76[b]	0.012	0.01
Gain, kg/ha	166[a]	260[b]	10.4	0.02
Cost of gain, $/kg	1.51	1.24	0.062	0.09

[a,b]Means with different superscripts differ ($P \leq 0.05$)

[1]CONT = steers were stocked at a rate of 2 steers per hectare, STRIP = Steers were allocated forage twice weekly



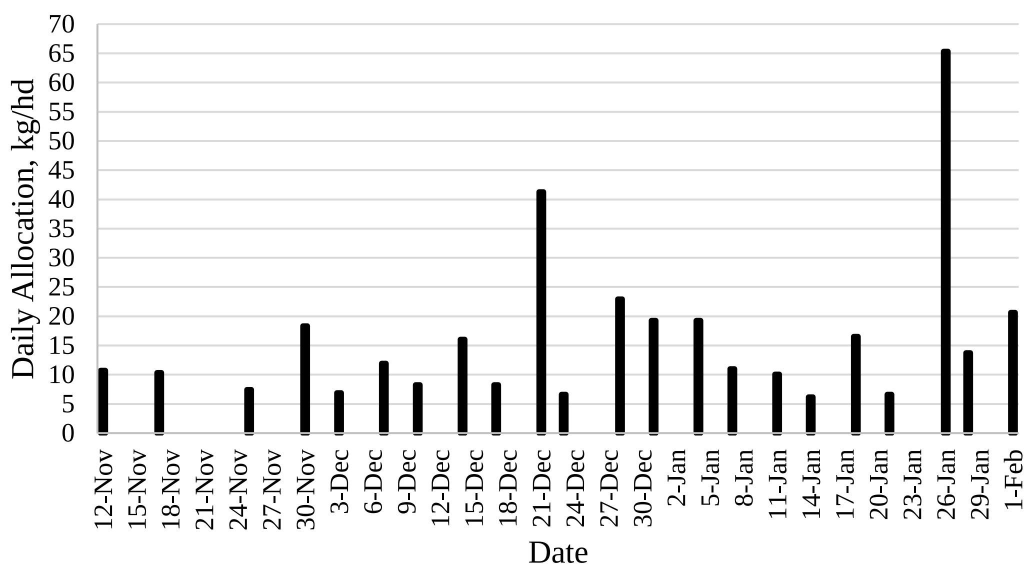


Figure 3.1. Daily precipitation and average temperature (top) and corresponding daily forage allocation per head (bottom) over the grazing season from November 12, 2020 to February 3, 2021. Allocation was determined using the average biomass over the grazing season in strip grazing paddocks (STRIP) multiplied by the area for each strip and divided by the days steers were allowed to graze in the corresponding strips. Back-grazing was not accounted for.

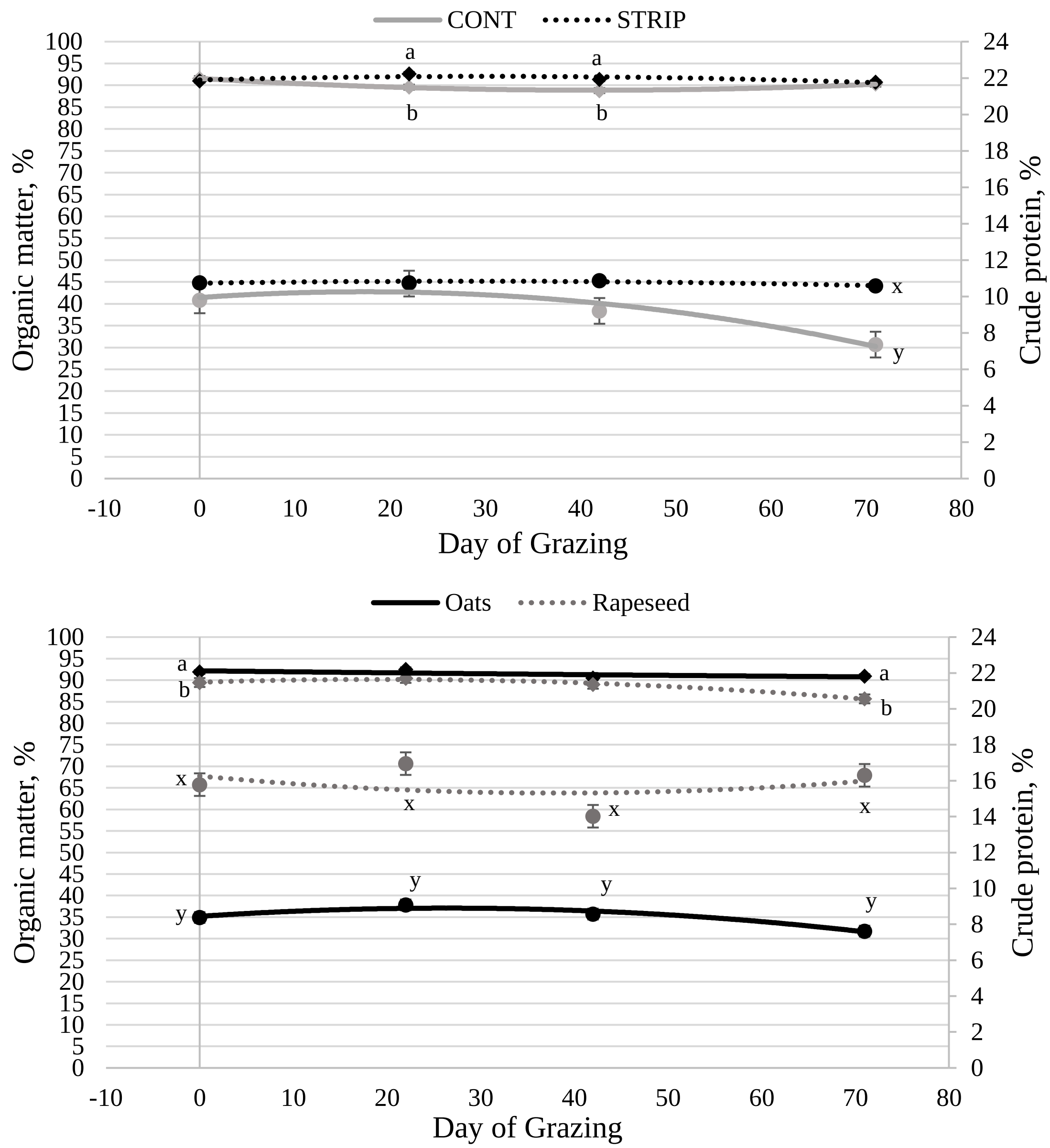


Figure 3.2. Organic matter and crude protein content of oats (Avena *sativa*) and rapeseed (Brassica *napus*) by treatment (top) and by species (bottom) across grazing season, with November 12th marking the first day of grazing. Diamond markers represent OM and circle markers represent CP. Lines with different letters differ (*P* < 0.05) within day.

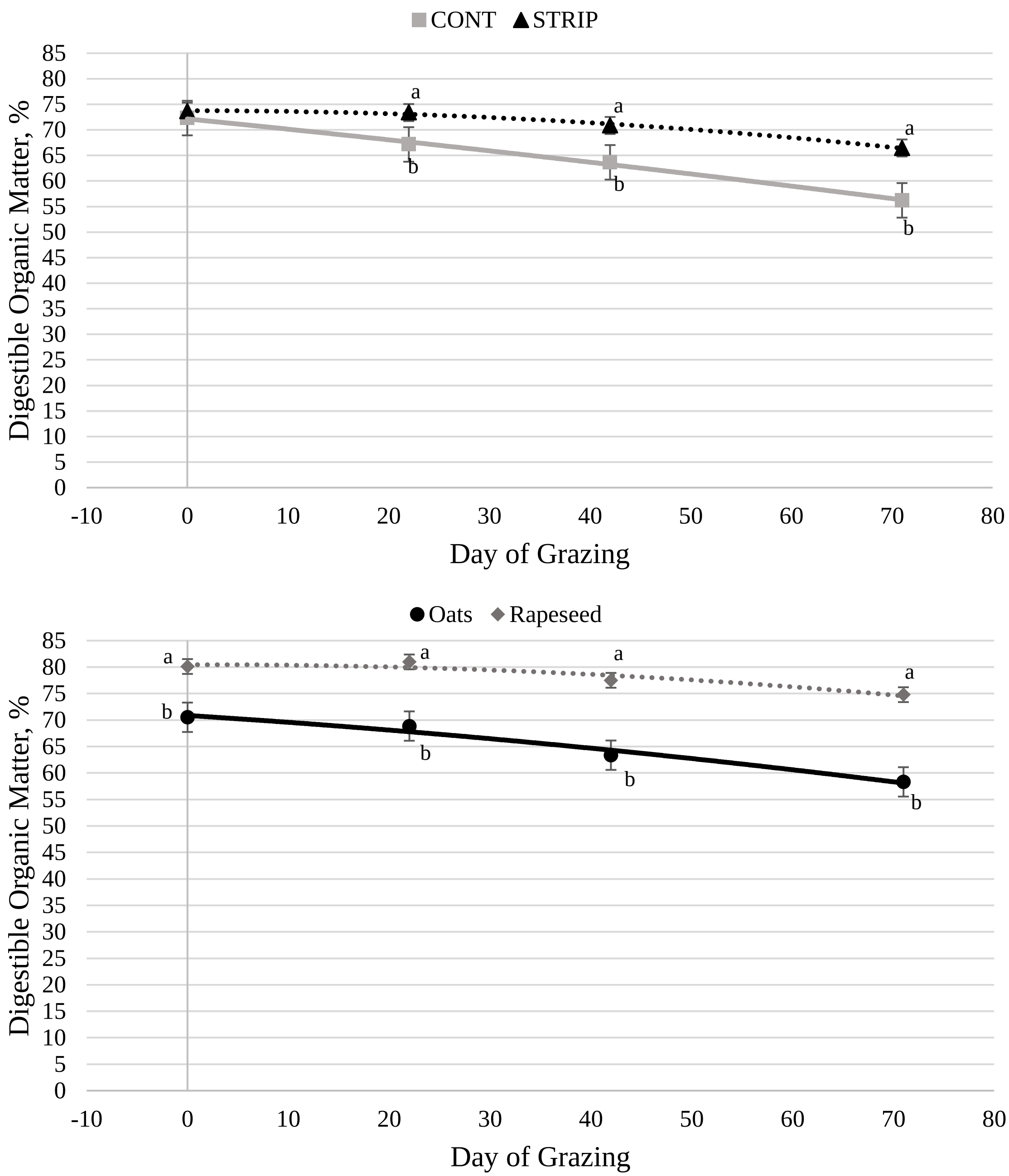


Figure 3.3. Total digestible organic matter content of oats (Avena *sativa*) and rapeseed (Brassica *napus*) by treatment (top) and by species (bottom) across grazing season, with November 12th marking the first day of grazing. Points with different letters differ ($P <$ 0.05) within day.

CHAPTER IV. Evaluation of Novel Versions of Sweet Bran® Plus and Their Impact on the Performance and Carcass Characteristics of Beef Finishing Steers

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ABSTRACT

An experiment was conducted at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE to evaluate the effects of novel versions of wet corn gluten feed (Sweet Bran® Plus, Cargill Wet Milling, Blair, NE) on performance and carcass characteristics when fed to beef finishing steers. Crossbred yearling steers (n = 600; initial BW = 349 kg; SD = 22 kg) were utilized in a completely randomized block design and assigned to treatment diets. The treatment diets to be evaluated consisted of three versions of wet corn gluten feed included in SFC based diets and were described as A, B, and C and were included at 20, 24, and 29% of dietary DM, respectively, due to differences in Sweet Bran Plus formulations. Treatments did not differ ($P \geq 0.26$) in carcass adjusted final BW, ADG, or G:F. Treatment B tended ($P = 0.06$) to increase DMI by 2%. No differences ($P \geq 0.12$) were observed for hot carcass weight, LM area, or fat thickness. Treatment A and B tended to be greater ($P = 0.07$) in marbling than treatment C by 3%. A significant difference ($P = 0.03$) was observed for Treatment C to decrease calculated YG by 5%. No treatment differences ($P = 0.55$) were observed for liver abscesses. Overall, only slight differences were observed between treatments, but treatment A and B resulted in the greatest performance without compromising quality grade.

Keywords: wet corn gluten feed, Sweet Bran, byproducts, finishing

INTRODUCTION

Since corn milling plants have now become widely dispersed and the accessibility of byproducts has been increased, 97.1% of cattle finishing rations in the U.S. now

contain one or more corn byproducts (Samuelson et al., 2016). In fact, distillers grains, gluten feed, and other cereal grain byproducts commonly comprise about 10-40% of diet DM in feedlots, with some feedlots including byproducts in up to 70% of the diet DM (Drouillard, 2018). With the adoption and continued use of these byproducts has come an increased understanding of the benefit of feeding byproducts. Not only do byproducts contain 112% to 140% the feeding value of dry rolled corn, but they also provide potential to increase animal performance and some may reduce acidosis (Stock et al., 2000). One particular byproduct is Sweet Bran, a byproduct of the corn wet milling process that has been branded by Cargill. Sweet Bran has 112% the feeding value of dry rolled corn and has been shown to improve F:G and increase average daily gain and dry matter intake (Bremer et al., 2008; Klopfenstein et al., 2007). Sweet Bran is unique in that it is has a higher dry matter (60%) than other wet corn gluten feeds (40-45%) yet has a greater feeding value (112%) as a percentage of dry-rolled corn. While the uniqueness of Sweet Bran compared to other wet corn gluten feed products remains apparent, there are many variables in the wet milling process that can alter the components of byproducts. Quantity of bran, steep liquor, cracked corn, solubles, and germ meal in corn gluten feed varies among plants. While differences in nutrient content and dry matter of byproducts among corn milling plants have been shown (Buckner et al., 2011), there remains much to be discovered as to how intentional alterations of corn processing can optimally improve byproducts and subsequent animal performance. Therefore, the objectives of this experiment were to 1) evaluate the effects of two novel versions of Sweet Bran Plus on performance and carcass traits of beef finishing steers and 2)

determine the impacts of corn wet milling alterations on the nutrient content of Sweet Bran Plus.

MATERIALS AND METHODS

All procedures used in these experiments were reviewed and approved by the University of Nebraska – Lincoln Institutional Animal Care and Use Committee (IACUC).

Experimental Design and Procedures

Crossbred yearling steers (n = 600; initial BW = 349 kg; SD = 22 kg) were utilized in a completely randomized block design at the University of Nebraska-Lincoln Eastern Nebraska Research and Extension Center near Mead, NE. Receiving and processing of calves into the feedlot included vaccination for protection against infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI3) virus, bovine viral diarrhea (BVD) virus (types I and II), bovine respiratory syncytial virus (BRSV), *Manheimia haemolytica* and *Pasteurella multocida* (Vista Once, Merck Animal Health, DeSoto, KS); Clostridium chauvoei, septicum, novyi, sordellii, perfringens Types C & D plus Haemophilus somnus (Ultrabac 7/Somubac, Zoetis Inc., Florham Park, NJ); a 10 percent fenbendazole oral suspension for the control of lung worms, stomach worms, and intestinal worms (SafeGuard Dewormer, Merck Animal Health); and one percent doramectin injectable for treatment and prevention of gastrointestinal and external parasite control (Dectomax, Zoetis Inc., Florham Park, NJ). Cattle were revaccinated 14-28 d following receiving and were administered an 18% tildipirosin injection (Zuprevo,

Merck Animal Health, De Soto, KS) for the control of bovine respiratory disease and a 9.6% oral amprolium solution (Corid, Huvepharma, Peachtree City, GA) for the control and prevention of coccidiosis; a 10 percent fenbendazole oral suspension for the control of lung worms, stomach worms, and intestinal worms (SafeGuard Dewormer, Merck Animal Health); a vaccine for protection against infectious bovine rhinotracheitis (IBR) virus, parainfluenza-3 (PI3) virus, bovine viral diarrhea (BVD) virus (types I and II), bovine respiratory syncytial virus (BRSV) (Vista 5, Merck Animal Health, De Soto, KS); and a vaccine for protection against Haemophilus somnus (Somubac, Zoetis Inc., Florham Park, NJ). Steers grazed cornstalks for approximately 60 days prior to being limit-fed (2% of BW) a diet consisting of 50% Sweet Bran® (Cargill Wet Milling, Blair, NE), and 50% alfalfa hay (DM basis) for 5 d before weighing to equalize gut fill (Watson et al., 2013). Steers were weighed 2 consecutive days (d 0 and 1) using a hydraulic squeeze chute with load cells mounted on the chute (Silencer, Moly Manufacturing Inc., Lorraine, KS: scale readability ± 0.90 kg) to establish initial BW. Each steer was implanted with 80 mg of trenbolone acetate and 16 mg of estradiol (Revalor-IS, Merck Animal Health, De Soto, KS). Steers were blocked by d 0 BW (light, mid, or heavy), stratified within BW within blocks, and assigned randomly to pen within block. Dietary treatments were blinded in that they differed by version and inclusion of Sweet Bran Plus and were thus identified as A, B, and C.

A total of 30 pens were randomly assigned to one of three dietary treatments with 10 replications per treatment and 20 steers per pen. Sweet Bran Plus® (Cargill Milling, Blair, NE) was supplied with the supplements and was fed with the primary components

as calcium, urea for rumen degradable protein, trace mineral premix, and vitamin ADE premix. Supplement was targeted to provide 33 mg/kg of monensin (Rumensin, Elanco Animal Health) and 9.8 mg/kg of tylosin (Tylan, Elanco Animal Health). Diets were formulated to provided similar amounts of calcium and thus appropriate Ca:P ratios. Steers were reimplanted on d 60 and 61 with 200 mg of trenbolone acetate and 20 mg of estradiol (Revalor-200; Merck Animal Health, De Soto, KS). Ractopamine hydrochloride (Optaflexx, Elanco Animal Health) was fed to target an intake of 300 mg/hd during the last 28 and 42 days of the finishing period for the heavy/mid blocks and the light block, respectively.

Feed bunks were assessed at approximately 0600 h and managed for trace (≤ 0.2 kg/steer) amounts of feed remaining in the bunk each morning at time of feeding. Feed was delivered in two feedings each morning at approximately 0700 h and 1030 h with a truck mounted mixer (Roto-Mix model 414, RotoMix, Dodge City, KS; scale readability ± 0.91 kg). Steers were adapted to finishing diets over a 20-d period. In step 1, steers were fed 100 % RAMP™ for 10 d beginning on March 26, 2021, to mimic a receiving period. RAMP was fed with supplement and targeted 33 mg/kg of monensin (Rumensin, Elanco Animal Health) and 9.8 mg/kg of tylosin (Tylan, Elancon Animal Health). Step 2 through 4 diets were delivered using a two-ration system, with RAMP being delivered in the first feeding and the finishing ration being delivered in the second feeding. However, due to digestive upsets, RAMP was included as an ingredient and mixed with the finishing diet beginning on d 5 of the second step with 50% of the totally mixed ration (TMR) delivered in the first feeding and 50% of the TMR delivered in the second

feeding. Sweet Bran Plus, SFC, and MDGS replaced RAMP in all 3 treatment adaptation diets during the adaptation period before reaching respective inclusions for the final treatment diets as seen in Table 4.1. Step 2 consisted of 75% RAMP and 25% of the finishing diet which was composed of 4% corn stalks, 2.5% MDGS, and 0.75% fat and was fed for 8 d. Step 3 diets were fed for 6 d and contained 6.5% corn stalks, 5% MDGS, and 1.5% fat with 50% of the diet being RAMP and 50% of the diet being finisher. Step 4 diets were fed for 6 d with 75% being finishing diet that contained 7.5% corn stalks, 7.5% MDGS, and 2.25% corn oil while the second ration contained 25% RAMP. Steam flaked corn was processed at and purchased from a nearby feedlot. Diet ingredient samples were collected weekly and diet samples were collected monthly and dried in a 60°C forced-air oven for 48 h to determine dry matter (DM) of the samples (AOAC International, 1997; Method 930.15). Composited ingredient samples and monthly diet samples were sent to a commercial laboratory (Ward Laboratories Inc., Kearney, NE) and analyzed for crude protein (CP;AOAC, 2006), neutral detergent fiber (NDF;ANKOM, 2017b), acid detergent fiber (ADF;ANKOM, 2017a), ether extract (AOAC International, 2006; Method 2003.6), Ca, P, S (Mills, 1996) and total starch (AOAC, 2000) content.

Cattle were shipped according to projections made utilizing pen weights from d 111 and ADG to target a final BW of 680 kg. Steers were fed for 159 (heavy and mid blocks) and 173 d (light block) and were harvested at a commercial abattoir (Greater Omaha Packing, Omaha, NE). Hot carcass weight and liver score were recorded on the day of harvest. Final body weight was calculated by dividing the hot carcass weight by a

common dressing percent (63%) to attain carcass adjusted final body weight. Marbling score, 12th rib fat thickness, and LM area were recorded following a 48-h carcass chill.

Statistical Analysis

Performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with pen as the experimental unit. The model contained block and treatment as fixed effects and the interaction. Dead and chronic steers (9 hd) were removed from the analysis. Five steers died from bloat (1 in A, 1 in B, and 3 in C) and one steer in C died from strangulation in the fence. One steer in B died from emphysema and another steer in C died from heart failure due to interstitial pneumonia. One steer in A was removed from experiment due to sepsis. Treatment differences were considered significant when $P \leq 0.05$ with tendencies between $P > 0.05$ and $P \leq 0.10$. Treatment comparisons were made using pairwise comparisons when the F-test statistic was significant.

RESULTS AND DISCUSSION

Except for DMI ($P = 0.02$), there were no treatment × block interactions ($P \geq 0.14$) for any measure of steer performance or carcass characteristics. No differences ($P = 0.34$) were observed for carcass adjusted FBW, with a treatment mean of 720 kg (Table 4.2). A tendency ($P = 0.06$) was observed for B to have greater DMI than A and C, but no difference ($P = 0.29$) was observed for ADG. Treatments did not differ ($P = 0.26$) for G:F, with the overall mean being 0.179. Feed efficiency and DMI values in the current study are similar to those observed in other work that has evaluated either the inclusion of

Sweet Bran from 0-40% of diet DM or the inclusion of Sweet Bran into SFC based diets (Bremer et al., 2008; Buckner et al., 2007; Scott et al., 2003). Average daily gain in the current study was higher than the range of 1.72 to 2.03 kg reported by the previously mentioned authors.

No difference (P = 0.34) among treatments was observed for HCW or LM area (P = 0.22; Table 4.2). Fatness did not differ (P = 0.12) among treatments, although a numerical difference was observed for C to be less fat (1.95 cm) than A and B (2.03 and 2.04 cm, respectively). Treatment C also tended (P = 0.07) to have a lower marbling score. A significant difference (P = 0.03) was observed for calculated YG, with C being 5% lower than A and B. No significant differences ($P \geq 0.29$) were observed for USDA quality grade distribution, with an overall mean of 80.6% of steers grading choice and 17.1% of steers grading prime. Values for fat thickness, LM area, and marbling were greater than those reported by Block et al., (2005) and a summary of studies that evaluated Sweet Bran inclusion (Bremer et al., 2008), resulting in higher subsequent yield grades in the current study. Liver scores did not differ (P = 0.55) among treatments. The relatively high rate of liver abscesses is likely due to increased occurrences of digestive upsets such as bloat during the adaptation period.

CONCLUSIONS

Minimal differences were observed for both steer performance and carcass characteristics. All treatments resulted in relatively high gain, efficiency, and DMI which contributed to greater final body weights and thus higher quality grades and yield grades. Though only statistically different for yield grade and marbling, Bran C resulted in the

poorest performance as those steers numerically gained less and had poorer quality grades than steers on treatment A and B. Though any of the bran products could achieve adequate performance when replacing SFC in the diet, the data suggests that A and B are best suited to return optimal animal performance without sacrificing quality grade.

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Table 4.1. Composition of dietary treatments as a percent of diet DM for different versions of Sweet Bran Plus fed to finishing steers

	Treatment		
Item	A	B	C
Ingredient, % DM[1]			
Sweet Bran Plus	20.00	23.92	29.15
SFC	60.00	56.08	50.85
MDGS	10.00	10.00	10.00
Corn stalks	7.00	7.00	7.00
Fat[2]	3.00	3.00	3.00
Chemical composition, %[3]			
CP	13.82	13.80	13.77
ADF	10.78	10.85	10.61
NDF	22.43	22.95	22.84
Fat	5.72	5.68	5.63
Starch	44.77	44.14	44.03
Ca	0.60	0.54	0.65
P	0.35	0.35	0.35
K	0.50	0.49	0.49
S	0.16	0.16	0.17

[1]SFC = steam flaked corn; MDGS = modified distillers grains plus solubles
[2]Fat included in diet as corn oil
[3]Based on ingredient compositions multiplied by the ingredient inclusion in the diet

Table 4.2. Steer performance and carcass characteristics during the finishing period for steers fed different versions of Sweet Bran Plus

	Treatment				
Item	A	B	C	SEM	*P*-value
Initial BW, kg	362	362	362	0.30	0.76
Carcass Adj. Final BW, kg[1]	721	721	717	2.52	0.34
DMI, kg/d	12.2	12.4	12.2	0.050	0.06
ADG, kg[1]	2.20	2.20	2.17	0.015	0.29
G:F[1]	0.180	0.178	0.178	0.0010	0.26
Carcass Traits					
HCW, kg	454	454	452	1.57	0.34
LM area, cm^2	97.6	97.0	98.3	0.581	0.22
12^{th}-rib fat, cm	2.03	2.04	1.95	0.035	0.12
Marbling[2]	591	589	570	7.15	0.07
Calculated YG[3]	4.0^a	4.0^a	3.8^b	0.050	0.03
Liver abscesses, %	27.6	33.6	31.0	4.22	0.55

[a,b]Means with different superscripts differ ($P \leq 0.05$)
[1]Calculated from HCW using a common dressing percentage of 63.
[2]Marbling score: 500 = Modest00.
[3]Yield Grade Calculation: 2.50 + (6.35 x 12th rib fat thickness, cm) + (0.2 x 2.5 [KPH]) + (0.0017 x HCW, kg) - (2.06 x LM area, cm2) from USDA (1997).

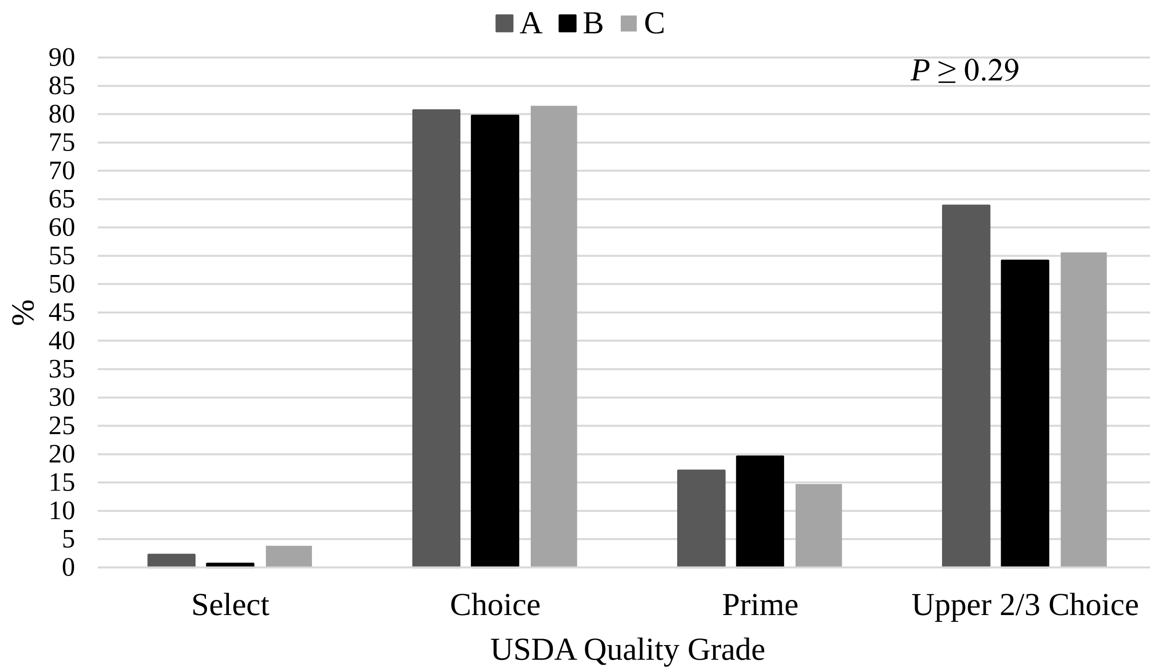

Figure 4.1. Quality grade distribution for finishing steers fed steam flaked corn-based diets differing in version and inclusion of Sweet Bran Plus for 166 days. Upper 2/3 choice represents the percentage of choice cattle that graded in the upper two thirds.