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Small Grain Cereal Cover Crops for Late Fall or Early Spring Grazing

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By

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Beef cattle operations are confronted with early spring and late fall forage deficiencies. Producers in integrated crop and livestock systems can fill forage gaps using cover crops as a forage source in between cash crops.

A five-year study evaluating forage production, growing calf performance and economics of grazing an oats cover crop planted after corn silage (CS) and high moisture corn (HMC) corn harvests was conducted. The economic analysis accounted for costs of establishing and grazing the oats and the value of calf gain to determine fall grazing system profitability. Steers had greater average daily gain grazing oats after CS harvest than steers grazing oats plus corn residue after HMC harvest. Based on this study, grazing oats after HMC is not an economically viable option as it resulted in profit or near breakeven for three out of five years with an average profit of less than $1 per steer. The oats after CS fall-grazing system proved to be profitable four of five years with the average profit of approximately $100 per steer and thus could be a viable option for producers. Within system, weather proved to have a strong influence on system profitability as it impacted oats biomass production, oats utilization and trampling losses, animal performance, and length of grazing, which impacted timing of calves entering the cattle market.

The amount of heat units available in the fall after soybean harvest are not enough to accumulate grazeable fall biomass. Winter hardy species such as cereal rye, winter

wheat, and winter triticale are options for fall planting that have potential to provide early spring grazing. A study investigated the grazing potential of these three species in Eastern Nebraska was conducted. The timing of the start of grazing and nutritive value of forage as measured by growing steer gain were evaluated. When grazing in early spring there were no differences in carrying capacity or growing steer gains when grazing cereal rye, winter wheat, or winter triticale. Cereal rye did result in the ability to start grazing earlier.

Cover crops can produce high quality fall, winter, and/or spring forage and possible economic profit.

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Table of Contents

List of Tables

CHAPTER I: Review of the Literature

INTRODUCTION

Farming operations have historically been diversified with multiple crops and livestock classes being present in a single operation; however, within the last century, agriculture has become more specialized with the development of commercial fertilizer and advancements in technology (Clark, 2004, Hilimire, 2011). Producers have become more focused on specific crops or livestock production. While this has led to increased food supply and decreased food prices, prolonged specialization agriculture can have negative environmental impacts such as soil erosion, water pollution, decreased biodiversity, and pest increase (Hilimire, 2011). Little product diversity increases production risk and decreases economic stability (Clark, 2004). Specialized operations may also endure extra expenses due to the nature of their operation (Clark, 2004, Kumar et al, 2019). Confined cattle operations, for example, will require stored feeds, feed delivery, and manure management while a continuous cash crop operation will require fertilizer and possibly suffer losses from soil erosion. While no farming practice is perfect, specialized agriculture may not be sustainable long-term and result in under or overutilized resources, such as farm ground, leading to system health and sustainability issues. Specialized agriculture can be amended by re-diversifying farming systems. Re-diversification may include alternating cash crop species, adding cover crops, introducing livestock, or any combination of these.

COVER CROPS

Several cash crops, such as corn and soybeans, occupy farm ground for only a portion of the year resulting in field vacancy for the remainder. In some instances, cash crop residue after harvest, such as corn residue, provide ground cover and livestock grazing opportunity while some cash crop harvests, such as corn silage and soybeans, do not. Bare ground in these cases can result in increased soil erosion, increased weed pressure, and underutilized farm ground. Also, growing degree days, which are an accumulation of heat units each day, are left unutilized after cash crop harvest in the late summer/fall and before cash crop planting in the spring. Cover crops established before or after cash crops have the ability to utilize these growing degree days and can provide soil cover, reduce erosion, sequester nutrients, and contribute to soil health.

The time window around cash crop production highly influences cover crop species selection and use. In the North Central United States corn and soybeans are the primary cash crops planted. Corn is typically planted in late April through mid-May with harvests occurring in September for corn silage, late September for high moisture corn, and late September though late October when harvested for grain after drying down (USDA, 2010). Soybeans are typically planted in May and are commonly harvested sometime in late September through late October depending on the soybean variety maturity type (USDA, 2010). Due to the later harvest, the cover crop windows for traditional dry corn or soybean cash crops usually involves fall planting of winter hardy species with most of the growth occurring in the spring before the planting of the next crop. These winter hardy cover crops require termination before cash crop establishment. The earlier harvest of corn silage, early maturity soybean, and high moisture corn harvest in late summer/early fall may or may not provide a viable window for cover crop establishment and growth of winter sensitive species.

Cover Crop Characteristics

Cover crop selection varies with operation based on personal goals and time windows available for cover crop growth. Goals may include erosion control, nutrient/pollutant uptake, nutrient supply, forage production, or any combination of these (Ramírez-García et al, 2015).

Ramírez-García et al (2015) evaluated the potential of several cultivars of five cover crop species to these meet the goals listed above and found that small grain grasses (barley, rye, triticale) performed best to provide ground cover and erosion reduction, capture soil nutrients and pollutants, and produce adequate quantities of quality forage. The vetch best provided nutrient supplementation to the soil. The most commonly planted cover crops based on a nationwide SARE survey were cereal rye, radish, oats, rapeseed, winter wheat and turnip (SARE/CTIC/ASTA, 2019).

Utilizing cover crops as a forage source may provide economic incentive to establish cover crops by offsetting economic costs and generating additional revenue. Despite the fact that using cover crops for forage reduces the amount of residue left on the soil surface, forage cover crops can still protect soil from erosion and maintain soil properties if sufficient surface cover is left (Blanco-Canqui et al, 2013).

Winter Hardy Small Grain Grasses

Winter hardy small grains planted in the fall are capable of overwintering and resuming production in the spring without replanting. Fall establishment of cover crops allows for earlier spring growth and utilization of forage compared to spring planted cover crops. Planting cover crops in spring commonly takes place after fall planted cover crops have already begun to grow and would be viable for grazing. Thus fall planted cover crops better fit the time window before cash crop planting than spring planting.

Winter hardy small grain grasses include cereal rye, winter wheat, winter triticale, and winter barley. It is worth noting that winter barley is not winter hardy in far northern regions such as the North Central United States and areas northward. Seed prices for cereal rye, winter triticale, and wheat are $0.57, $0.75, $0.53/kg, respectively (Millbourn Seeds, Millbourn, NE, Stock Seed Farms, Murdock, NE). Cereal rye is the most commonly planted winter hardy small grain (SARE/CTIC/ASTA, 2019). Cereal rye is the most winter hardy small grain species and experiences less winter kill than winter wheat (Daniels et al, 2001). When compared to winter triticale, winter wheat, and winter barley, cereal rye matures and offers grazing forage sooner (Edmisten et al, 1998, Maloney et al, 1999, Baron et al 1999) which may be an important factor for producers wishing to utilize cover crops forage before spring cash crop planting. Winter triticale is a hybrid of cereal rye and winter wheat but has been found to favor the maturation rate of winter wheat which is slower than that of cereal rye (Baron et al, 1999). Previous research found cereal rye to outyield winter triticale and winter wheat in vegetative stages with its earlier spring growth when harvested at the same maturity stage (Maloney et al, 1999) and when harvested on the same calendar day (Brown and Almodares, 1976), although species relationship to greatest forage yield appeared to blur with increasing maturity and vary among species variety. Edmisten et al (1998) reported vegetative yield (Zadok's stage 14) for cereal rye, winter wheat, and winter barley to have three year average yields of 1100, 1430, and 1530 kg DM/ha, respectively. Cereal rye out yielded winter wheat and winter barley in one year but had lesser yield in two.

Thelen and Leep (2002) evaluated the yield and quality potential of fall-planted cereal rye and winter wheat for spring harvest. Wheeler cereal rye and Harus winter wheat varieties were used. The two year study took place near East Lansing, MI. Forages were planted in late September (Yr 1) or mid-October (Yr 2) and received 52 kg N/ha. Cereal rye was harvested in late April or early May (early boot stage) averaging 3,810 kg DM/ha of yield. Winter wheat (boot stage) was harvested around mid-May yielding 5,828 DM/ha on average. While cereal rye, reached harvest stage approximately two weeks before wheat, it produced less forage biomass. When harvested in boot stage, these forages proved to be high quality. Rye in early boot had 48.6% neutral detergent fiber (NDF), 26.8% acid detergent fiber (ADF), and 19.4% crude protein (CP). Wheat in boot stage had 59.1% NDF, 30.6% ADF, and 16.2% CP. A later harvest date resulted in yield increase and decreased forage quality. Wheat in the early head stage had 59.8% NDF, 31.6% ADF, and 14.0% CP.

The potential of cereal rye, winter triticale, and winter wheat for fall and spring forage when planted in late summer were evaluated in a three year study near Stratford, WI (Coblentz et al, 2020a). Forages were planted in early/mid-August and received 56 kg N/ha in the first two years. In year three, forages received a (20-10-20 N-P-K) fertilizer at 112 kg/ha. All forages were harvested near four fall harvest target dates (October 15, November 1, November 15, and December 1) in order to determine impact on spring yields. Average fall yields across harvest dates were 1513, 1308, and 1425 kg DM/ ha for cereal rye, winter triticale, and winter wheat, respectively. Yields varied across the three year trial, but no species consistently produced the greatest fall biomass. Forage stands were then harvested uniformly at the late boot stage in spring. Spring yields did not differ among species with 2747, 3569, and 4661 kg DM/ha being produced by cereal rye, winter triticale, and winter wheat, respectively. Wheat had the greatest total yield (fall plus spring biomass) in all three years. Nutritive value of forages harvested in the fall had some statistical differences among species but these differences numerically small and likely not biologically relevant. Average CP values were 18.5, 18.4, and 19.5% for cereal rye, winter triticale, and winter wheat, respectively. The average fall total digestible nutrients (TDN) values were 67.0, 68.3, and 68.4% for cereal rye, winter triticale, and winter wheat, respectively.

The impact of fall planting date on spring yields of winter hardy small grains were evaluated during a two year study in Lacombe, AB, Canada (Baron et al, 1999). Seeding dates were August 15th, September 1st, and September 15th both years. Forages received 50 kg N/ha in the fall and an additional 25 kg N/ha in the spring. First harvest dates occurred among each species upon reaching a 5.08 cm height at which forage supported a weighted disc, with a second harvest following one week later to measure regrowth. Earlier planting in the fall resulted in forages reaching target heights earlier in the spring. Cereal rye reached target height 1 to 2 weeks before either winter triticale or winter wheat. Winter triticale and winter wheat were similar in their timing. There was a correlation between seeding date and yield at first harvest with earlier planting dates resulting in greater forage yield. Across the three seeding and two harvest dates there was no clear difference in yield among cereal rye, winter triticale, and winter wheat although in some instances cereal rye had a tendency to have greater yield. Cereal rye averaged 1603 and 2757 kg DM/ha for first and second harvests, respectively. Average yields for winter triticale were 1423 and 2051 kg DM/ha for first and second harvests, respectively. Winter wheat averaged 1300 and 2343 kg DM/ha for first and second harvests, respectively.

Mullenix et al (2014) conducted a 3-year grazing experiment in Headland, Alabama to evaluate the performance of cattle (initial BW 322 kg) continuously grazing winter triticale (Trical 2700) and winter wheat pasture (SS8641). Forages were planted in early fall and stocked with yearling steers (1.7 steers/ha) in late fall or early winter upon the forage reaching 1,000 to 1,200 kg DM/ha. Pastures were continuously stocked to maintain forage biomass of 1,500 to 2,000 kg DM/ha, using additional put-and-take steers when necessary, until forages could no longer support adequate animal performance. Cattle were weighed every 28 days. The average daily gain (ADG) of the steers did not differ between triticale and wheat cattle 1.23 and 1.36, respectively. However, stocking rates on wheat pastures were 25% greater than triticale in order to maintain forage biomass. Therefore, wheat forage offered more grazing days and gain per hectare.

Daniels et al (2001) evaluated the potential of small grain grasses for fall and winter grazing options in stocker cattle operations in Arkansas. Eight forage treatments were used: winter wheat (Delta King 9207 soft red winter wheat), cereal rye (Elbon), oats (Bob Oat), annual ryegrass (Marshall ryegrass), winter wheat plus cereal rye mixture, winter wheat plus ryegrass mixture, cereal rye plus ryegrass mixture, and winter wheat plus cereal rye plus ryegrass mixture. Forages were seeded in September receiving fertilizer as recommended by soil analysis. Growing steers (initial BW 181 kg) were stocked targeting a stocking density of 272 kg BW/ha in late October. Grazing was continuous through late March with the exception of December 20 to January 24 in which pastures were covered in ice and cattle were fed common diets of hay and corn. Performance did not differ prior to the ice storm with ADG ranging from 1.1 kg/d (ryegrass) to 1.3 kg/d (winter wheat, cereal rye, and ryegrass mixture). Gains also did not differ during hay and corn diets. Oats winter killed in the ice storm and those steers were removed from grazing. About 50% of winter wheat suffered from winter kill but grazing continued. Ryegrass pastures experienced growth delay due to cold temperatures. Cereal rye and mixtures containing cereal rye had little winter kill producing greater gains than treatments without cereal rye. Steer performance ranged from 0.83 kg/d (cereal rye plus winter wheat) to 0.85 kg/d in ADG (cereal rye) in cereal rye forages while other treatments produced 0.62 kg/d (ryegrass) to 0.68 kg/d (winter wheat) for ADG. Although forage yields were not reported, cereal rye and mixtures containing cereal rye were not as negatively impacted by cold temperatures as the other forages and likely offered greater forage quantities. This likely explains the increased gains of cattle grazing cereal rye and forage mixtures containing cereal rye.

Brassicas

Radish, rapeseed and turnips are all brassicas that are commonly used as forage sources. Brassicas have been reported as a frequently planted cover crop type with radish being the most common species (SARE/CTIC/ASTA, 2019, Drewnoski et al, 2015). These cool season species grow well in the fall and spring seasons but are susceptible to winter kill. Brassica seed prices are $3.86/kg, $2.65/kg, and $3.86/kg for radish, rape, and turnips, respectively when purchased in batches of 22.7 kg or more (Stock Seed Farms, Murdock, NE). Stock Seed Farms Recommended seeding rates are 5.6 kg/ha to 13.4 kg/ha for radish, 2.8 kg/ha to 5.6 kg/ha for rapeseed, and 4.5 kg/ha to 6.7 kg/ha for turnips (Stock Seed Farms, Murdock, NE).

Villalobos and Brummer (2015) examined the nutritive value and yield of nine brassica cultivars to determine grazing potential. Research took place near Fort Collins, CO for two years. Brassica cultivars included three turnips (Purple Top, Barkant, Appin), three rapeseed (Winfred, Barnapoli, Bonar), Groundhog radish, Major Plus swede, and Pasja Hybrid. Forages were planted twice each year (early planting and late planting) on July 16 and August 14 (Yr 1) or August 2 and August 18 (Yr 2). Harvests occurred in mid-October and mid-November. Earlier planting dates and later harvest dates increased yields. Yields from early planted brassicas were almost double (5492 to 9482 kg DM/ha) those of the late planted (1430 to 1603 kg DM/ha). Rape tended to produce higher yields than other cultivars with early planting; however late planted forages differed little across cultivar. Nutrient content of all brassicas surpassed the needs of all beef cattle classes with low fiber (19 to 25.2%), high CP (18.6 to 25.5%), and high in-vitro true digestibility (85.5 to 92.9%). It is common to dilute the high nutritive content of brassicas in cover crop mixtures to increase dietary fiber and avoid digestive upset.

Reid et al (1994) evaluated brassica cultivars over four years to determine brassica grazing potential and sheep performance. Research took place in Morgantown, WV with brassicas being seeded in mid-July. Forages included turnips (Green Globe, Forage Star), kales (Premier, Maris Kestrel), stockpiled tall fescue (Kentucky 31), and stockpiled orchard grass, red clover mixtures. Sheep (25 to 40 kg) grazed forages from 6 to 10 weeks starting in late October. Sheep performance varied greatly for brassica treatments (ADG 17 to 359 g) but tended to be greater than either stockpiled tall fescue (-47 to -1 g) or stockpiled orchard grass and red clover mix (131 to 264 g).

Winter Sensitive Small Grain Grasses

Winter sensitive small grain grasses include oats, spring triticale, spring wheat, and spring barley. Based on a nationwide survey of farmers, oats are planted as a cover crop more than other winter sensitive small grain grasses (SARE/CTIC/ASTA, 2019). Seed prices for oats, spring barley, and spring wheat are $0.84, $0.66, and $0.75/kg, respectively (Millbourn Seeds, Millbourn, NE). Winter sensitive species winter kill and must be planted and utilized in the fall or planted and utilized in the spring. Cover crop termination is not necessary when winter sensitive species are planted in the late summer as they will winter kill. Maloney et al (1999) found that winter sensitive small grain grasses produce more fall biomass than winter hardy small grain grasses. Research by Maloney et al (1999) found oats and spring barley to produce similar fall yields while outperforming winter wheat. However, Cobletz et al (2020b) found spring barley to produce more fall biomass than oats and spring wheat which did not differ from one another.

Coblentz et al (2020b) evaluated varieties of early and late maturing cultivars of later summer-planted and fall-harvested spring barley, spring wheat, and oats. Early and late cultivars of each species were Newport and Hays spring barley, Select and Iguacu spring wheat, and Ogle and ForagePlus oats. The trial took place for two years near Stratford, WI. Varieties were planted in early/mid-August, received nitrogen fertilizer, and were harvested on the same dates in mostly fully headed and boot maturity stages. Both spring barley cultivars (early and late maturity) had significantly greater fall biomass than all other species cultivars in year one without differing from one another; however, early maturing spring barley had greater yield than late maturing spring barley in year two. No differences were found among spring wheat and oats cultivars in year one and year two. In year two, late maturing spring barley yield did not differ from spring wheat or oats. Cultivar maturity only impacted yield once while forage nutritive values varied greatest by maturity type within species with late maturing varieties having slightly higher quality likely due to being less mature than the early maturing varieties. Differences in forage nutritive contents were fairly minor with all species having decent quality. Average yields across species were 957, 781, and 823 kg DM/ha for spring barley, winter wheat, and oats, respectively.

While spring barley may yield more than oats in some situations, oats may be more disease tolerant (Deen et al, 2019). Deen et al (2019) examined fall-planted, winter sensitive small grains of spring barley, oats (at two planting rates 80 and 120 kg ha^{-1}), and oats plus peas for fall forage sources in a two year study in Lora and Woodstock, ON, Canada. Nitrogen fertilizer was applied at 0 and 50 kg ha^{-1} to all forage types three weeks after planting. All forage stands were planted in mid/late August and harvested simultaneously two or three times from late October or early November beginning when oats forages reached the flag leaf stage. Total average forage yields within experimental trials across two years were 825, 2025, 2000, and 2025 kg DM/ha for barley, oats (80 kg ha^{-1}), oats (120 kg ha^{-1}), and oat plus pea mixtures, respectively. Barley was more susceptible to Septoria (*Septoria passerinii* Sacc) leaf spot than the other trial species and suffered reduced yields. Authors noted that at one test site where leaf spot wasn't an issue, spring barley yields were like those of oats and oats plus peas. Forage nutritive values between species did not differ greatly although some significant differences were found. Barley averaged 72.4% in neutral detergent fiber digestibility (NDFD), 14.2% CP and 74.1% TDN. Oats averaged 77.5% NDFD, 13.4% CP, and 77.8% TDN. Finally, oats plus peas averaged 80.6% NDFD, 16.4% CP, and 78.0% TDN.

Two years of research completed in Pasman, Buenos Aires, Argentina evaluated performance of growing cattle grazing March-planted oats forage with and without supplement in two separate experiments (Arelovich et al, 2003). Heifers (204 kg) grazed July through September (55 days) in the first experiment. Treatments included 1) oats grazing with no supplement, 2) oats grazing with ground corn supplement, 3) oats grazing plus ground corn and corn gluten meal supplement. Oats plus ground corn and corn gluten meal treatment resulted in the greatest ADG of 0.92 kg/d. Oats with no supplement and oats plus ground corn did not differ with 0.67/d and 0.76 kg/d. Oats yields were 1777, 1425, and 1209 kg DM/ha for July, August, and September, respectively. Average oats qualities were 9% CP, 64% NDF, and 27% ADF. In the second experiment, growing heifers (192 kg) continuously grazed oats for 140 days from May to October. Oats yields remained between 1600-1700 kg DM/ha from May to September and were 980 kg DM/ha in October. Three treatments were used in experiment two: 1) oats grazing with no supplement, 2) oats grazing with ground corn supplement, 3) oats grazing plus alfalfa hay. The ADG of heifers in oats with no supplement and oats plus alfalfa hay did not differ at 0.72 and 0.78 kg/d, respectively. Oats plus ground corn had the greatest ADG of the three treatments with 0.87 kg/d. Oats qualities averaged 10% CP, 46% NDF, and 22% ADF over the grazing period.

COVER CROP ECONOMICS

While cover crops can reduce soil erosion, sequester nutrients, improve soil structure, provide weed competition, and offer forage resources, individual produces may choose to forgo them due to time commitment, added management, and establishment costs associated with them. In order to evaluate cover crop economics, five areas of interest identified in a review by Bergtold et al (2017) will be discussed: "(i) direct production costs, (ii) indirect and opportunity costs, (iii) direct benefits, (iv) indirect benefits, (v) risk and crop insurance, (vi) policy incentives and (vii) economic examination of cover-crop adoption and usage".

Direct Production Costs

Costs directly related to cover crop usage include labor, materials (i.e. seed, fertilizer, herbicide), equipment operation (planting, fertilizer application, termination), and expenses of livestock grazing when applicable (i.e. yardage, transportation fencing) (Bergtold et al, 2017, Drewnoski et al, 2018). Almost half of producers nationwide reported paying an average of $27 to $49 per hectare for cover crop seed (2019 SARE/CTIC/ASTA). Seeding options vary (i.e. broadcast v.s. drilling) with operation and equipment availability. Broadcast application is reported to be cheaper than drilling (McClure and Jansen, 2020) although better germination rates are achieved by drilling and thus less seed is needed (Koehler-Cole et al, 2020). Fertilizer is not always necessary but is commonly applied to cover crop forages to boost yield. Fertilizer expense varies with fertilizer type, application process, and number of applications. Custom fertilizer application ranged from an average price of $16.45/ha for dry fertilizer broadcast to $39.92/ha for anhydrous ammonia application (knife with coulters) in a Nebraska survey (McClure and Jansen, 2020). Cover crop termination adds expense to prepare for cash crop planting when winter kill is not an option. Herbicide, tillage, and roller-crimping are popular termination methods with varying levels of expense.

Indirect and Opportunity Costs

Indirect and opportunity costs associated with cover crop establishment and grazing can be difficult to account for. These expenses may include time spent planning for cover crop and possible production losses due cover crop presence. Some producers cite fear of decreased cash crop yields due to cover crop use as a reason for not adopting cover crops (2019 SARE/CTIC/ASTA). For example, improved water infiltration by cover crops may speed up nutrient and chemical leaching beyond root zone (Lue et al, 2000). Increased amounts of plant residue from cover crops may slow soil warm up in the spring and delay the emergence of cash crops (Snapp et al, 2005). Cover crops may reduce soil moisture available to cash crops (Lesoing et al, 1997, Thelen and Leep, 2002). Results of the impacts of cover crops on cash crop yield have varied with decreased Thelen and Leep, 2002, non-impacted (Thelen and Leep, 2002, Blanco-Canqui et al, 2021, Blanco-Canqui et al, 2020), and increased crop yields after cover crop use (Blanco-Canqui et al, 2012). Impacts on cash crop yields and soil properties likely depend on precipitation, cover crop type, season of use, biomass return, tillage type, and duration of cover crop usage (Blanco-Canqui et al, 2012). Despite the fact that using cover crops for forage reduces the amount of residue left on the soil surface, forage cover crops can still protect soil from erosion and maintain soil properties if sufficient surface cover is left (Blanco-Canqui et al, 2013).

Thelen and Leep (2002) evaluated the impact of fall planting the small grain grasses of cereal rye and winter wheat for spring forage on subsequent cash crop yields (corn grain, corn silage, soybean). Forage harvest took place when cereal rye reached early boot, when winter wheat reached boot for early harvest, and when winter wheat reached early head for late harvest. Cereal rye was harvested in late April or early May about a week before early-harvested winter wheat. Early-harvested winter wheat was then harvested about a week before late-harvested wheat (early head stage). Cereal rye had no significant impact on corn grain, corn silage, or soybean yields although yields after rye were numerically decreased when compared to a no cover crop control. Winter wheat harvests (early and late) depressed corn grain and corn silage yields significantly and more so than cereal rye. However, no cover crop negatively impacted soybean yields. Later wheat harvest dates may have depleted soil moisture more so than the rye causing greater loss in cash crop harvest. Forage net values did not cover the worth of lost cash crop yields in the corn grain and corn silage treatments; however, income per hectare increased with cover crops that were relay-intercropped with soybeans.

A three year study near Firth, NE by Blanco-Canqui et al (2021) examined the impact of late-summer planted cover crops blends (varying mixtures including cereal rye, oats, mustard, radish, rapeseed, spring pea) on subsequent irrigated corn silage yield and soil properties. Three treatments were used: 1) no cover crop control, 2) non-harvested cover crop 3) harvested cover crop. Cover crop impacts on soil properties were mixed, but it was found that establishing cover crops was more beneficial than no cover crop. Corn silage yields were decreased after cover crop only one year out of three, possibly due to lack of moisture.

Sun hemp and late maturing soybean were used as summer cover crops in winter wheat and grain sorghum rotations in a long-term study conducted in Hesston, KS (Blanco-Canqui et a, 2012). Grain sorghum was planted in June and harvested in the fall with winter wheat being planted soon after. Winter wheat was harvested in June of the following year with cover crop mixtures being planted after winter wheat harvest. Grain sorghum would then be planted back in June of the following year. Sun hemp and late maturity soybeans as well as nitrogen application were found to improve cash crop yields. Cover crops benefits were more robust when cash crops received little to no nitrogen application as the cover crops were able to supplement nitrogen.

Research took place near North Platte, NE for three years to determine cover crop establishment and grazing impact on soil properties and cash crop yield (Blanco-Canqui et al, 2020). Three treatments were applied: 1) no cover crop control, 2) non-grazed cover crop, 3) grazed cover crop. Cereal rye was planted after corn silage harvest in mid/late-September. Each year 1.4 cow-calf pairs (680 and 68 kg) per hectare grazed forage in from March 15 through April 15 while 2.5 cow-calf pairs per hectare grazed from April 15 through May 15. In two out of three years, 1 yearling heifer (295 kg) per hectare grazed for approximately two winter months. Results show that planting and grazing the cereal rye cover crop had no impact on soil fertility and no impact on subsequent cash crop yields.

Utilizing cover crops as a forage source may provide economic incentive to establish cover crops by offsetting economic costs and generating additional revenue. Drewnoski et al (2018) reviewed the economics of fall and spring cover crop grazing trials. Seed and planting, nitrogen fertilizer and application, and fencing for livestock were considered without accounting for environmental benefits (i.e. reduced soil erosion, improved soil health) and impact on subsequent cash crop yields. It was found that grazing systems have the potential to offset the expenses of establishing and grazing cover crops in addition to possible profits.

Profit of livestock grazing systems is influenced by several factors such as weather and cattle market. Adverse weather, such as freezing temperatures and precipitation, can decrease cattle performance (Han, 1985). Cattle markets fluctuate with average rise and falls throughout the year (Birch and Brooks, 2015). Time of animal purchase and sale will influence value of gain. It is also important to consider price slide as animals gain weight.

Direct and Indirect Benefits

Direct and indirect benefits of cover crops may be difficult to quantify. Cover crops can directly benefit production systems by reducing weed populations (Blanco-Canqui et al, 2015, Werle et al, 2017) and thus reduce herbicide expenses. Soil erosion is decreased, and soil structure improved by cover crop use (Blanco-Canqui et al, 2015). Legumes have the unique ability to scavenge soil nitrogen making it available to subsequent crops, and cash crop yield increases have been reported after legume cover crops (Blanco-Canqui et a, 2012) although this is not the norm for most cover crop situations. Cover crops in general have been found to improve retention of soil nutrients (Blanco-Canqui et al, 2015) and release vital nutrients as they decompose possibly increasing cash crop yields over time (Bergtold et al, 2017). In these ways, cover crops directly, even if difficult to account for, benefit agriculture ground and save money on possible expenses.

Insurance and Policy Incentives

Producers who fear cover crop failure and resulting economic loss may procure insurance for financial protection (Bergtold et al, 2017). Although assistance would vary with location and situation, several conservation programs offer assistance to producers looking to adopt cover crops (Bergtold et al, 2017). Cover crops have the ability to decrease production risks as they increase system diversity and offer long term systems health benefits (Bergtold et al, 2017). Many factors influence the economic standing of cover crops, and they continue to be a focus in research.

CONCLUSION

Current literature suggests that specialized agriculture may leave agricultural resources under or over utilized and suffer negative impacts on system health, such as erosion, that may limit specialized agriculture's ability to be utilized over a long term; however, specialized agriculture systems can be aided or amended by re-diversifying farming systems. Re-diversification may include alternating cash crop species, adding cover crops, introducing livestock, or any combination of these. Cover crops have been found to benefit the environment, produce high quality forage, and possible economic incentive to utilize cover crops when used as livestock forage. Further research is needed to investigate growth patterns of cover crops and the factors influencing economics of cover crop grazing systems. Small cereal grain grasses (winter hardy and winter sensitive) are among the most frequently planted cover crops as they can be grown in the time windows unoccupied by corn and soybean cash crops. These cover crops have the potential to produce high quality fall, winter, and/or spring forage. Therefore, the objective of the research discussed in this thesis is to:

1) Determine performance of growing cattle grazing an oats cover crop planted after corn silage and an oats cover crop plus corn residue after high moisture corn harvest in Eastern Nebraska as well as the profitability of these fall grazing systems.

2) Directly compare cereal rye, winter wheat and winter triticale as a source of early spring grazing to provide an understanding of the relative timing that grazing can be initiated, the carrying capacity and nutritive value of forage when grown in Eastern Nebraska.

LITERATURE CITED

Arelovich, H. M., Arzadún, M. J., Laborde, H. E., & Vasquez, M. G. (2003). Performance of beef cattle grazing oats supplemented with energy, escape protein or high quality hay. *Animal Feed Science and Technology*, *105*(1-4), 29–42. https://doi.org/10.1016/s0377-8401(03)00045-2

Baron, V. S., Dick, A. C., Salmon, D. F., & McLeod, J. G. (1999). Fall seeding date and species effects on spring forage yield of winter cereals. *Journal of Production Agriculture*, *12*(1), 110–115. https://doi.org/10.2134/jpa1999.0110

Bergtold, J. S., Ramsey, S., Maddy, L., & Williams, J. R. (2017). A review of economic considerations for cover crops as a conservation practice. *Renewable Agriculture and Food Systems*, *34*(1), 62–76. https://doi.org/10.1017/s1742170517000278

Birch, J., & Brooks, K. (2015). Nebraska Historical Prices, Seasonal Price Patterns, and Futures Basis Beef Cattle, 2001– 2015. *University of Nebraska— Lincoln Extension*, 1–27.

Blanco-Canqui, H., Claassen, M. M., & Presley, D. R. (2012). Summer cover Crops fix Nitrogen, increase crop yield, and Improve Soil-Crop Relationships. *Agronomy Journal*, *104*(1), 137–147. https://doi.org/10.2134/agronj2011.0240

Blanco-Canqui, H., J.D. Holman, A.J. Schlegel, J. Tatarko, and T. Shaver. (2013). Replacing fallow with cover crops in a semiarid soil: Effects on soil properties. Soil Sci. Soc. Am. J. 77:1026-1034.

Blanco-Canqui, H., Shaver, T. M., Lindquist, J. L., Shapiro, C. A., Elmore, R. W., Francis, C. A., & Hergert, G. W. (2015). Cover crops and ecosystem Services: Insights from studies in Temperate Soils. *Agronomy Journal*, *107*(6), 2449–2474. https://doi.org/10.2134/agronj15.0086

Blanco-Canqui, H., Drewnoski, M. E., & Rice, D. G. (2021). Does harvesting cover Crops eliminate the benefits of Cover Crops? Insights after three years. *Soil Science Society of America Journal*, *85*(1), 146–157. https://doi.org/10.1002/saj2.20175

Blanco-Canqui, H., Drewnoski, M. E., MacDonald, J. C., Redfearn, D. D., Parsons, J., Lesoing, G. W., & Williams, T. (2020). Does cover crop grazing damage soils and reduce crop yields? *Agrosystems, Geosciences & Environment*, *3*(1). https://doi.org/10.1002/agg2.20102

Brown, A.A., Almodares, A. 1976. Quantity and Quality of Triticale Forage Compared to Other Small Grains. *Agron. J.* 68: 264-266.

Bulk grass Seed, cover Crops, Alfalfa seed & more. Millborn Seeds. (2021, April 14). https://www.millbornseeds.com/.

Buxton, D. R. (1996). Quality-related characteristics of forages as influenced by plant environment and agronomic factors. *Animal Feed Science and Technology, 59*(1-3), 37-49. doi:10.1016/0377-8401(95)00885-3

Buxton, D. R., & Redfearn, D. D. (1997). Plant Limitations to Fiber Digestion and Utilization. *The Journal of Nutrition, 127*(5). doi:10.1093/jn/127.5.814s

Buxton, D. R., Mertens, D. R., Moore, K. J., Boyd, L., & Oldfield, J. (1995). Forage Quality for Ruminants: Plant and Animal Considerations11This paper includes data presented by the senior author to the 28th Pacific Northwest Animal Nutrition Conference, Boise, ID, October 26–28, 1993. *The Professional Animal Scientist, 11*(3), 121-131. doi:10.15232/s1080-7446(15)32575-4

Clark, E. A. (2004). Benefits of Re-integrating livestock and forages in crop production systems. *Journal of Crop Improvement*, *12*(1-2), 405–436. https://doi.org/10.1300/j411v12n01_06

Coblentz, W. K., Akins, M. S., & Cavadini, J. S. (2020). Fall dry matter yield and nutritive value of winter rye, wheat, and triticale cultivars in Wisconsin. *Crop, Forage & Turfgrass Management*, *6*(1). https://doi.org/10.1002/cft2.20075

Coblentz, W. K., Akins, M. S., & Cavadini, J. S. (2020). Dry matter yield and nutritive value OF EARLY- or LATE-MATURING spring Wheat, spring barley, and oat cultivars planted in late summer. *Crop, Forage & Turfgrass Management*, *6*(1). https://doi.org/10.1002/cft2.20034

Cover crops. Stock Seed Farms. (n.d.). https://www.stockseed.com/Shop/cover-crops.

Daniels, L. B., Harrison, K. F., Hubbell, D. S., & Johson, Z. B. (2001). Small Grain Forage for Stocker Cattle Production. *Arkansas Animal Science Department Report*, 88–90.

Deen, W., Janovicek, K., Landry, E., & Lee, E. A. (2019). Annual cereal cover Crops following winter Wheat produce high quality Fall Forage. *Agronomy Journal*, *111*(4), 1634–1642. https://doi.org/10.2134/agronj2018.03.0221

Denman, C.B., Arnold, J. 1970. Seasonal forage production for small grain species in Oklahoma. Oklahoma Agric. Exp., 1-21 Stn. 680

Drewnoski, M., Muller, N., Randy Saner, Jasa, P., Gary Zoubek, Jenny Rees, Pekarek, K., Elmore, R., Redfearn, D., & Lesoing, G. (2015, December 23). *Report of cover* *crop survey of nebraska farmers*. CropWatch. https://cropwatch.unl.edu/report-cover-crop-survey-nebraska-farmers.

Drewnoski, M., Parsons, J., Blanco, H., Redfearn, D., Hales, K., & MacDonald, J. (2018). Forages and pastures Symposium: Cover crops in ivestock production: WHOLE-SYSTEM Approach. can cover Crops pull double DUTY: Conservation and profitable FORAGE production in the Midwestern United States? *Journal of Animal Science*, *96*(8), 3503–3512. https://doi.org/10.1093/jas/sky026

Edmisten, K. L., Green, J. T., Mueller, J. P., & Burns, J. C. (1998). Winter annual small GRAIN forage POTENTIAL. I. dry matter yield in relation to morphological characteristics of four small grain species at six growth stages. *Communications in Soil Science and Plant Analysis*, *29*(7-8), 867–879. https://doi.org/10.1080/00103629809369992

Hahn. (1985). Weather and Climate Impacts on Beef Cattle. *University of Nebraska - Lincoln University of Nebraska - Lincoln Digital Commons*.

Hilimire, K. (2011). Integrated crop/livestock agriculture in the United States: A review. *Journal of Sustainable Agriculture*, *35*(4), 376–393. https://doi.org/10.1080/10440046.2011.562042

Jung, H. (2012). Forage Digestibility: The Intersection of Cell Wall Lignification and Plant Tissue Anatomy. *Proc. 23rd Annual Florida Ruminant Nutrition Symposium, Gainesville, FL (2012)*, pp. 162-173

Koehler-Cole, K., Elmore, R. W., Blanco-Canqui, H., Francis, C. A., Shapiro, C. A., Proctor, C. A., Ruis, S. J., Heeren, D. M., Irmak, S., & Ferguson, R. B. (2020). Cover crop productivity and subsequent soybean yield in the western corn belt. *Agronomy Journal*, *112*(4), 2649–2663. https://doi.org/10.1002/agj2.20232

Kumar, S., Sieverding, H., Lai, L., Thandiwe, N., Wienhold, B., Redfearn, D., Archer, D., Ussiri, D., Faust, D., Landblom, D., Grings, E., Stone, J. J., Jacquet, J., Pokharel, K., Liebig, M., Schmer, M., Sexton, P., Mitchell, R., Smalley, S., … Jin, V. (2019). Facilitating Crop–Livestock Reintegration in the Northern Great Plains. *Agronomy Journal*, *111*(5), 2141–2156. https://doi.org/10.2134/agronj2018.07.0441

Lesoing, G., Klopfenstein, T., Williams, M., Mortensen, D., & Jordon, D. J. (1997). Cover Crops in Crop/Livestock Production Systems. *Nebraska Beef Cattle Reports*, 31–34.

Maloney, T. S., Oplinger, E. S., & Albrecht, K. A. (1999). Small grains for fall and spring forage. *Journal of Production Agriculture*, *12*(3), 488–494. https://doi.org/10.2134/jpa1999.0488

McClure, G. (n.d.). *Nebraska farm Custom RATES Report*. Center for Agricultural Profitability. https://cap.unl.edu/customrates.

Mekonnen, M. M., Neale, C. M., Ray, C., Erickson, G. E., & Hoekstra, A. Y. (2019). Water productivity in meat and milk production in the US from 1960 to 2016. *Environment International*, *132*, 105084. doi:10.1016/j.envint.2019.105084

Mullenix, M. K., Dillard, S. L., Lin, J. C., Gamble, B. E., & Muntifering, R. B. (2014). Evaluation of wheat AND TRITICALE forage for stocker production in the Gulf Coast region. *The Professional Animal Scientist*, *30*(3), 296–304. https://doi.org/10.15232/s1080-7446(15)30120-0

Newman, Y. C., Lambert, B., & Muir, J. P. (2006). Defining Forage Quality.

Ramírez-García, J., Carrillo, J. M., Ruiz, M., Alonso-Ayuso, M., & Quemada, M. (2015). Multicriteria decision analysis applied to cover crop species and cultivars selection. *Field Crops Research*, *175*, 106–115. https://doi.org/10.1016/j.fcr.2015.02.008

Reid, R. L., Puoli, J. R., Jung, G. A., Cox-Ganser, J. M., & McCoy, A. (1994). Evaluation of brassicas in grazing systems for sheep: I. quality of forage and animal performance. *Journal of Animal Science*, *72*(7), 1823–1831. https://doi.org/10.2527/1994.7271823x

Sustainable Agriculture Research and Education program, Conservation Technology Information Center, and American Seed Trade Association. (2020, August). *Annual Report 2019-2020*. SARE. https://www.sare.org/wp-content/uploads/2019-2020-National-Cover-Crop-Survey.pdf.

Thelen, K. D., & Leep, R. H. (2002). Integrating a Double-cropped winter Annual Forage into A corn-soybean rotation. *Crop Management*, *1*(1), 1–5. https://doi.org/10.1094/cm-2002-1218-01-rs

United States Department of Agriculture. (2010, October). *Field crops Usual planting and Harvesting Dates 10/29/2010*. https://www.nass.usda.gov/Publications/Todays_Reports/reports/fcdate10.pdf.

Villalobos, L. A., & Brummer, J. E. (2015). Forage brassicas stockpiled for FALL Grazing: Yield and nutritive value. *Crop, Forage & Turfgrass Management*, *1*(1), 1–6. https://doi.org/10.2134/cftm2015.0165

Werle, R., Burr, C., & Blanco-Canqui, H. (2017). Cereal Rye cover crop Suppresses winter Annual Weeds. *Canadian Journal of Plant Science*. https://doi.org/10.1139/cjps-2017-0267

CHAPTER II: Economics of Grazing Calves on Oats Planted after Corn Silage and High Moisture Corn Harvests in Eastern Nebraska[1]

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ABSTRACT

A five-year study (2015-2019) evaluated forage production, growing calf performance and economics of grazing an oats cover crop planted after corn silage (CS) and high-moisture corn (HMC) harvests. Growing steers (BW 220; SD ±11 kg) were stocked to oats biomass for CS (2470 kg DM/ha) and oats (784 kg DM/ha) plus corn residue (leaf and husk, 3388 kg DM/ha) for HMC. An economic analysis accounting for costs associated with establishing the oats and grazing was conducted to determine fall grazing system profitability. The grazing period ranged from 30 to 69 d. Steers had greater ($P < 0.01$) average daily gain grazing oats after CS harvest (0.90 kg) than steers grazing oats plus corn residue after HMC harvest (0.51 kg). In 4 out of 5 years, grazing oats after CS was profitable, with a mean of $100/steer and range of $-16.85 to $193.77. In 2018, heavy precipitation created muddy conditions for planting of CS and shortened the grazing season, resulting in grazing of oats in CS not being profitable. Grazing oats plus corn residue in HMC returned profit three out of five years with an average profit of only $0.72 and a range of $-52.23 to $28.79. Weather and cattle markets were drivers in system profitability. Grazing oats after CS appeared to be a profitable and thus viable option for grazing growing calves in the fall but grazing oats plus corn residue after HMC harvest appears to be less favorable due to lower oats yield, calf gains, and profit potential.

INTRODUCTION

Early corn silage harvest leaves behind bare ground which can increase erosion and weed pressure potential while high moisture corn harvest results in corn residue being left on the field. Corn silage (CS) and high moisture corn (HMC) harvest occur in mid-August through September. Temperatures after the harvest of CS and HMC may have the potential to allow for growth of cool season cover crops. Planting cover crops after cash crop harvest can provide several benefits including ground cover, weed suppression, reduced soil erosion, improved soil structure, and soil nutrition capture (Blanco-Canqui, et al, 2015). Cover crops can also provide forage for livestock during the traditional spring or fall gaps in forage production (Drewnoski, et al, 2018). Winter sensitive small cereal species, such as oats, produce more fall biomass than winter hardy species (Maloney, et al, 1999). Late summer planted oats have also been shown to produce high-quality fall forage (Lenz, et al, 2018). Additionally, oats do not over winter in the North Central Region of the US and thus do not require spring management.

The purpose of this study was to evaluate whether planting an oat cover crop after corn silage or high moisture corn harvest would result in sufficient quantity and quality of forage to cost effectively graze growing calves in the fall and winter.

MATERIALS AND METHODS

Animal care and management practices were approved the University of Nebraska Lincoln’s Institutional Animal Care and Use Committee.

A center-pivot irrigated corn field, located at the Eastern Nebraska Research Center (ENREC) near Mead, Nebraska, was utilized during this research. The 42-hectare field was managed in a corn and soybean rotation with the ground being split evenly between the two crops (21-hectares each) with the two halves switching crops each year. Corn and soybeans were planted with 76-cm row spacing using a no-till drill. Each year, the 21-hectares of corn was then evenly split between two corn harvest methods of CS or HMC (10.5 hectares each). Three post-harvest treatments were applied to both CS and HMC ground after corn harvests. The treatments include a no oats control, oats that were not grazed, and oats that were grazed creating a 2 x 3 factorial. These treatments were maintained over a five year period (2015-2019). The effects of these treatments on the soil parameters and cash crop yields are reported in Anderson, 2021. This paper will focus on the forage production, growing calf performance and economics of grazing the oats planted after corn harvest. Within each corn harvest method ~9 ha were designated to be grazed and this area was split into two, each area being grazed by a group of steers, resulting in two replicates (4.54 ha SD ± 0.45) per corn harvest method per year.

Forage

Horsepower oats were planted after CS harvest in late August or early September and after HMC harvest in mid-September at a rate of 108 kg/ha (Table 1). At or just before oats were planted 32% urea ammonium nitrate fertilizer was applied at 44.8 kg N/ha to the entire 21 ha corn field. In 2018, oats planted after CS experienced limited emergence due to wet conditions and were replanted at 108 kg/ha on the day that oats were planted on HMC ground. Each year, pre-graze oats biomass collections occurred in late October or early November. In each replicate, five randomly selected areas (0.91 x 0.57 m^2) were hand harvested at ground level. Samples were dried in a 60°C forced air oven until a constant weight was reached in order to determine dry matter (DM) yield. Starting in 2016, post-grazing oats biomass samples were collected after the grazing period ended using the same procedure as the pre-graze biomass. Post-graze samples were collected on March 15, 2016, December 15, 2016, March 2, 2018, March 27, 2019, and February 26, 2020 as weather conditions after cattle grazing allowed.

Oats quality samples were also collected in late-October or early November. Forage samples were cut at ground level from ~20 random locations within each replicate. These samples were freeze dried and ground through a 1 mm Cyclone Mill. A sub-sample was then dried for 24 hours in 100°C forced air oven to determine DM content and then burned in a 600°C muffle furnace for 6 hours to determine organic matter (OM). Neutral detergent fiber was determined using the method described by Van Soest (1991) and acid detergent fiber as described by Van Soest (1963). Each sample received 0.5 g of sodium sulfite for protein removal. Samples were analyzed using a TrueSpec micro analyzer (LECO Corp.) to determine crude protein (CP) content.

Corn plants were collected according to the method reported in Anderson, 2021 prior to harvest and used to determine pre-graze residue biomass. Starting in 2016, post-grazing residue biomass samples were collected from 5 (0.76 x 0.76 m) random locations per replicate at the same time as the post-grazing oat biomass. Residue samples were dried for 48 hours in a 60°C forced air oven to determine post-graze residue biomass.

Cattle

Growing steers (~220 kg) were stocked according to available initial forage biomass (Table 2.1). Cattle in the CS treatment were stocked using only pre-graze oats biomass. Cattle in the HMC treatment were stocked using pre-graze oats biomass plus corn residue biomass as the animals had access to both corn residue and the oats forage. Only 39% of the total corn residue was considered potentially grazeable, as this would have been the proportion of leaf and husk (Wilson et al, 2004). Before being turned out to graze, steers were limit fed a common diet of 50% Sweet Bran (Cargill Wet Milling; Blaire, NE) and alfalfa hay for 5 days before being weighed for 3 consecutive days in order to establish initial body weight (BW). Steers were implanted with 36 mg Zeranol (Ralgro, Merck Animal Health, Madison, NJ), stratified by body weight, and assigned to paddock. Randomly selected steers in each paddock were designated as testers and used to evaluate animal performance. Ten steers in 2015 and 2016, 5 steers in 2017 and 2018, and 6 steers in 2019 per paddock were designated as testers. Steers were turned out on their assigned pastures in early November and allowed to graze until oat biomass in the corn silage treatment or weather limited intake (Table 2.1). After the grazing season, steers were pulled from pastures and limit fed the same diet for 8 days and weighed during the last 3 days to determine ending BW (Watson, et al, 2013).

Economics

A partial budget was constructed for each replicate in each year in order to determine system profitability. No effect of grazing oats on cash crop yields were found when compared to the no cover crop control (Anderson, 2021); therefore, cash crop yields were not included in the economic analysis. Oats seed was obtained from Green Cover Seed (Bladen, NE) at a cost of \$0.48/kg (\$51.48 per hectare). Fertilizer prices were based on 45% N urea obtained from Index Mundi (Barrientos and Soria, 2017). Urea costs ranged from \$0.19 to \$0.28/kg and resulted in \$27.61, \$19.28, \$21.24, \$24.85, and \$24.36/ha in fertilizer expenses in years 1 through 5, respectively. Custom seed drilling (\$37.40/ha) and custom dry fertilizer application (\$15.40/ha) prices were based on a custom operator survey in Nebraska (Wilson and Jansen, 2016). Transportation costs of

$2.64 were charged per steer to account for hauling steers to and from the field. This expense was based on the most commonly charged rate of $2.48 per loaded km for 60 calves for 60 km reported also in Wilson and Jensen (2016). Fencing expense was charged a cost of $10.87 per hectare for a temporary, double-strand electric fence. The value of corn residue was charged at $37.50 per hectare to the HMC treatment. This was based on the most commonly reported corn residue rental rate reported by Cox-O'Neill et al, (2017). Cattle interest was charged at 5% annual interest on the initial steer price. The number of days steers were retained was considered when calculating total interest. Steers were valued prior to and after grazing using LMIC Weekly & Monthly Combined Nebraska Auction Cattle Prices (Livestock Marketing Center, Lakewood, Colorado). Initial steer market value, cost of cover crop establishment and the expenses associated with grazing cattle were then subtracted from the post grazing market value to determine return.

Statistical Analysis

These data were analyzed as a randomized block design. Treatment, replicate within year and year were analyzed as fixed effects using the MIXED procedure in SAS (SAS Institute, Inc., Cary, N.C.). The pdiff statement was used to separate treatment means when the F-test was significant. Differences were considered significant at $P \leq 0.05$ and tendencies at $P > 0.05$ and ≥ 0.10.

RESULTS AND DISCUSSION

Weather

Weather data can be found in Table 2.2. An ice storm occurred in 2016 causing cattle to be pulled from pastures prematurely.

Forage Yield and Quality

The year, treatment, and treatment by year interaction were significant ($P < 0.03$) for pre-and post-graze oats biomass (Table 2.3). However, within year oats pre-graze biomass in CS was always greater ($P < 0.01$) than in HMC, with a 5-yr mean of 2470 vs. 784 kg DM/ha for CS and HMC, respectively. Yield differences between the two treatments can likely be attributed to the increased number of growing degree days (GDD) received by the CS oats (953 GDD) compared to HMC oats (641 GDD; Table 2.1). Low emergence in 2018 resulted CS oats being replanted at the same time HMC oats planting; therefore, CS oats yields were more similar to HMC oats yields than in other years but was still greater ($P = 0.01$), likely due to the survival of some of the earlier planted oats. With the exception of CS in 2016, there was very little oats biomass left post grazing across all years in both treatments. The significant interaction was due to a 2016 ice storm causing cattle to be pulled from grazing prematurely leaving more post-graze biomass. The 2016 CS post graze biomass (1342 kg/ha) was significantly greater ($P < 0.01$) than all other post-graze oats biomass (174 kg/ha) which did not differ from one another ($P \geq 0.11$) with the exception of 2017 HMC (0 kg/ha) tending to be lower ($P = 0.08$) than 2018 CS (360 kg/ha). The HMC steers appeared to consume oats early in the grazing season and due to the lesser initial biomass, they would typically limit themselves only to corn residue later in the grazing season. Oats biomass was greater in the CS treatments to begin with and those cattle had not consumed oats to the same level as the HMC cattle before grazing ended in 2016.

Total pre-graze corn residue biomass did not differ ($P = 0.85$) among years with an average yield of 8,688 kg DM/ha (Table 2.3). However, there was a year effect ($P <$

0.01) for post-graze corn residue biomass. Corn residue biomass post grazing in 2016 was significantly less ($P < 0.01$) than corn residue biomass post-grazing in all other years. The post-graze corn residue biomass in 2017 (8,075 kg DM/ha) tended to be greater (P = 0.08) than 2018 (7,030 kg DM/ha) with both 2017 (P = 0.14) and 2018 (P = 0.61) not differing from 2019 (8,904 kg DM/ha).

The forage nutritive value of the oats pre-grazing is reported in Table 2.4. There was a significant year by treatment interaction ($P \leq 0.05$) for OM, CP, NDF, and IVOMD but not ADF (P = 0.17). A tendency (P = 0.08) for year by treatment interaction occurred for DOM. There were inconsistent differences in OM content between oats from CS and HMC with all differences within year being less than 1% unit. The OM content of CS oats was greater (P = 0.01) than HMC oats in 2016 and tended to be greater (P = 0.09) than HMC oats in 2019. However, the OM content of CS oats tended (P = 0.10) to be lower than HMC oats in 2015. There were no ($P \geq 0.43$) treatment differences for OM content of CS and HMC oats in 2017 and 2018.

For CP, the treatment by year interaction appears to be driven by 2018 in which the CS oats were replanted at the same time HMC resulting in CS oats not differing (P = 0.53) from HMC oats CP content. However, in all other years, oats planted after CS had lesser CP (18%) than HMC (22%).

For NDF content of the oats, there were no consistent differences between the oats planted after CS vs. HMC. The NDF content of oats planted after CS was greater (P < 0.01) than HMC in 2015 and tended to be greater (P = 0.06) than HMC in 2016. However, in 2018 the NDF of CS oats tended (P = 0.06) to be lesser than HMC oats. In 2017 and 2019, NDF content of oats did not differ ($P \geq 0.13$) between CS and HMC.

There was a significant treatment effect ($P < 0.01$) and year effect ($P < 0.01$) for ADF. Oats after CS had greater (23.4 %) ADF than oats following HMC (20.9 %). The ADF content of oats in 2015, 2016 and 2017 did not differ (23.9%; $P \geq 0.77$) but were greater ($P \leq 0.04$) than 2018 and 2019 which did not differ (19.6%; $P \geq 0.20$).

In 2015 and 2017, the IVOMD of CS oats were lesser ($P \leq 0.04$) than HMC oats, and tended to be lesser ($P = 0.09$) in 2016. However, in 2018 and 2019, IVOMD of CS and HMC did not differ ($P \geq 0.69$). The replanting in 2018 and lower CS yield in 2019 probably resulted in less mature CS oats plants compared to other years.

Similarly, when the OM content and the IVOMD are coupled to estimate the DOM content of the forage, DOM of CS oats in 2015 tended to be lesser ($P = 0.07$) and were lesser ($P \leq 0.05$) in 2016 and 2017 than HMC oats. While the DOM of CS oats and HMC oats did not differ ($P \geq 0.51$) in 2018 and 2019. Although there were minor differences in nutritive content of the oats between treatments, both digestibility and CP were quite good.

Calf Performance

As designed, there was no difference ($P = 0.84$) between treatments for initial steer BW (Table 2.5). There was a year by treatment interaction ($P \leq 0.04$) for ending BW, ADG, and animal grazing days. Ending BW of CS steers were greater ($P < 0.01$) than HMC steers in 2017 and 2019 and CS steers had a tendency ($P = 0.09$) for greater ending BW than HMC steers in 2015. Ending BW in the two shortest grazing years, 2016 and 2018 did not differ ($P \geq 0.20$) between CS and HMC. Within all years, the ADG of CS steers was greater ($P < 0.01$) than HMC steers, with means of 0.90 kg/d and 0.52 kg/d, respectively. The gains of the calves grazing on the oats in the CS treatment ranged from 0.59 to 1.52 kg/d. Given that there was minimal differences in nutritive value of the oats in the CS treatment the differences in gain appear to be mainly driven by weather. The greater performance for CS was in 2017 and may be due to it having the fewest days below freezing coupled with the least days with precipitation while grazing, followed by 2016 having the next fewest days with cold temps and precipitation (Table 2.2). These weather data suggesting that lowered gains for CS in 2015, 2018 and 2019 may have been due to increased energy needed to combat freezing temperatures with wet hair coats. The lower range for rate of gain for CS was similar to growing steers continuously grazing fall-planted rye in the spring in Iowa (0.69 kg/d) reported by Lundy et al, (2018). Mullenix et al, (2014) reported gain of fall/winter grazing yearling steers under set stocking management of fall-planted triticale, wheat, and ryegrass to be 1.23, 1.36, and 1.51 kg/d, respectively. These gains were more similar to the greater rate of gain achieved in the current trial.

Little to no information is available for growing cattle performance grazing corn residue and cover crops simultaneously. The calves in the HMC treatment appeared to be grazing almost solely on oats early in the grazing period and once oats became limited, they started grazing the corn residue more heavily. Year difference for ADG within HMC seem to be due to weather coupled with duration of grazing. The ADG of HMC steers in 2016 was significantly greater ($P \leq 0.05$) than in 2015, 2018, and 2019 and tended to be greater ($P = 0.06$) than 2017. The ADG of HMC in 2015, 2017 and 2018 did not differ from each other but 2019 was lesser ($P \leq 0.03$) than 2017 and 2018 and tended ($P = 0.08$) to be lesser than 2015. In 2016 the greater gains of the HMC steers was likely due to the milder weather coupled with the shorter grazing period allowing them to consume oats as a greater portion of their diet as the cattle were pulled early for ice storm conditions. The 2019 grazing period was the longest (69 d) and had the least amount of pre-graze oats biomass in HMC. When grazing seasons were prolonged such as 2019, HMC steers had lesser ADG than in years in with shorter grazing seasons. This is likely due to HMC calves eating all of their oats early in the grazing season, limiting themselves to corn residue in the latter part of the grazing period resulting in little gain during this period. Previous work has shown that calves grazing corn residue without supplementation lose 0.18 kg/d (Tibbets et al, 2016).

Due to difference in stocking rates among treatments within year, coupled with the length of grazing season achieved, there was variation among treatments in the number of animal grazing days. The higher stocking rate for CS compared to HMC, coupled with the longer grazing season in 2015, resulted in CS have the greatest (P < 0.01) number of head days per hectare. In 2016 and 2017, animal grazing days did not differ ($P \geq 0.51$) among treatments. The muddy conditions resulted in the need to replant the oats in the CS treatment in 2018, resulted in a lower stocking rate for CS, this coupled with a short grazing season lead CS in 2018 having the least ($P < 0.04$) amount of head days per hectare. In 2019, animal grazing days were greater ($P < 0.01$) for HMC than for CS due to the lower stocking rate used in CS as a result of a low oat yield. Overall, across all years animal grazing days per hectare did not differ ($P = 0.24$) among treatments, 113 vs 117 steer days per ha, for CS and HMC, respectively.

There was no treatment by year interaction ($P = 0.12$) for gain per hectare. There was a significant treatment effect ($P < 0.01$) with CS having greater gain per hectare than HMC, 110 vs. 51 kg/ha, respectively.

Economics

Economic analysis information is reported in Table 2.6. There was a year by treatment interaction ($P < 0.01$) for all costs except transportation and interest when evaluated on a per steer basis. This is mainly due to the majority of costs being on a land basis and there being differences in stocking rates between the two treatments among years. Total costs per steer were lower ($P \leq 0.02$) in CS treatments ($72.76) than HMC treatments ($80.02) in all years except 2018. In most years, CS treatments were able to support a similar number or more steers per hectare than HMC treatments. This coupled with the additional cost of the corn residue in HMC resulted in costs per steer being greater ($P < 0.01$) for HMC than CS. However, due to the poor initial oats establishment for CS in 2018, the stocking rate of CS was lower than HMC resulting in total costs to be greater ($P < 0.01$) for CS than HMC in that year.

Given that the HMC steers in 2019 did not gain weight, the COG was extremely high, resulting in a large error term and a tendency ($P = 0.06$) for a treatment by year interaction. The COG of HMC in 2019 was greater than all others which did not differ ($P \geq 0.99$). Across all years, the COG for HMC tended ($P = 0.08$) to be greater than CS, $421 vs. $2.20, respectively. When 2019 is removed from the model, there was no treatment by year interaction ($P = 0.54$) and the COG of HMC ($3.97) tended ($P = 0.10$; SEM ± $0.59) to be greater than CS ($2.22).

The value of gain (VOG) describes how market value of the steers ($/kg of BW) changed over the grazing period. There was a year by treatment interaction ($P < 0.01$) and again due to the fact that HMC cattle in 2019 lost weight, the value of gain was inflated for that treatment in that year, resulting in the VOG of the HMC steers in 2019 being greater ($P < 0.01$) than all others which did not differ ($P \geq 0.91$). However, when 2019 is removed from the model there is no treatment by year interaction ($P = 0.55$) and no treatment effect ($P = 0.51$), but there is a tendency ($P = 0.10$) for year effect with mean VOG of $4.40/kg. Value of gain in 2015, 2017, and 2018 did not differ ($P = 0.34$) from one another, and 2018 VOG was greater ($P = 0.03$) than 2016. Tendencies ($P = 0.07$) for both 2015 and 2017 to be greater than 2016 existed.

There was a significant year by treatment interaction ($P = 0.05$) for return per steer. Steers grazing oats after CS had a greater return ($100/steer) than steers grazing oats after HMC ($0.72/steer) except in 2018 in which the treatments did not differ ($P = 0.68$). In most years, steers grazing oats after CS experienced greater performance than cattle grazing oats after HMC which put them in standing for better profit. Grazing oats after CS proved to be profitable four out of five years, while grazing oats after HMC returned profit only three out of five years.

Profit per hectare had no ($P = 0.15$) year by treatment interaction but differed ($P = 0.01$) by treatment with CS ($247/ha) treatment resulting in greater profit than HMC ($47/ha).

CONCLUSION

Based on this study, grazing oats after HMC is not an economically viable option as it resulted in profit or near breakeven for three out of five years with an average profit of $0.72 per steer. The oats after CS fall-grazing system proved to be profitable four of five years with the average profit of approximately $100 per steer and thus could be a viable option for producers. Weather proved to have the strongest influence on system profitability as it impacted many factors within the system, including oats biomass production, oats utilization (potential trampling losses), animal performance, and length of grazing which impacted timing of entering the cattle market.

LITERATURE CITED

Anderson, L. K., Blanco-Canqui, H., Drewnoski, M. E., Calus, K. J., MacDonald, J. C., Brinton, M. K. M., Hansen, B. H., Ulmer, K. M., Carlson, Z. E., & Hilscher, F. H. (2021). Cover Crop Grazing Impacts on Soils and Crops under Irrigated No-Till Corn-Soybean. *Soil Science Society of America Journal*. (In review).

Blanco-Canqui, H., Shaver, T. M., Lindquist, J. L., Shapiro, C. A., Elmore, R. W., Francis, C. A., & Hergert, G. W. (2015). Cover crops and ecosystem Services: Insights from studies in Temperate Soils. *Agronomy Journal*, *107*(6), 2449–2474. https://doi.org/10.2134/agronj15.0086

Cox, J. L., K. E. Hales, K. M. Ulmer, R. J. Rasby, S. D. Shackleford, H. C. Freetly, and M. E. Drewnoski. 2017. The effects of backgrounding system on growing and finishing performance and carcass characteristics of beef steers. J. Anim. Sci. 95:5309-5319. doi:10.2527/jas2017.1934.

Cox-O'Neill, J.L., K.M. Ulmer, M. Rakkar, L. Franzen-Castle, H. Blanco-Canqui, M.E. Drewnoski, J.C. MacDonald, and R.J. Rasby. 2017. Perceptions of crop consultants and crop producers on grazing corn residue in Nebraska. J. Ext. 55(8):5RIB2.

Drewnoski, M., Parsons, J., Blanco, H., Redfearn, D., Hales, K., & MacDonald, J. (2018). Forages and Pastures Symposium: Cover Crops in Livestock Production: Whole-System Approach. Can Cover Crops Pull Double Duty: Conservation and Profitable Forage Production in the Midwestern United States? *Journal of Animal Science*, *96*(8), 3503–3512. https://doi.org/10.1093/jas/sky026

Lenz, M. E., Cox, J. L., Hales, K. E., Wilson, H. C., & Drewnoski, M. E. (2018). Late Summer Planted Oat-Brassica Forage Quality and Change during Winter. *Journal of Animal Science*, *96*(suppl_2), 219–220. https://doi.org/10.1093/jas/sky073.406

Lundy, E., Vittetoe, R., DeJong, J., Doran, B., Kassel, P., Loy, D., Sellers, J., & Witt, M. (2018). Wilson, R., & Jensen, J. (2016). 2016 Nebraska Farm Custom Rates Statewide Survey Summary. Univsersity of Nebraska-Lincoln Agricultural Economics. *Iowa State University-Farm Reports*.

Maloney, T. S., Oplinger, E. S., & Albrecht, K. A. (1999). Small Grains for Fall and Spring Forage. *Journal of Production Agriculture*, *12*(3), 488–494. https://doi.org/10.2134/jpa1999.0488

Mullenix, M. K., Dillard, S. L., Lin, J. C., Gamble, B. E., & Muntifering, R. B. (2014). Evaluation of wheat and triticale forage for stocker production in the Gulf Coast region. *The Professional Animal Scientist*, *30*(3), 296–304. https://doi.org/10.15232/s1080-7446(15)30120-0

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, Neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dariy Sci. 74:3583.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. 2. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

Watson, A. K., B. L. Nuttleman, T. J. Klopfenstein, L. W. Lomas, and G. E. Erickson. 2013. Impacts of Limit-Feeding Procedure on Variation and Accuracy of Cattle Weights. J. Anim. Sci. 91:5507-5517. doi:10.2527/jas.2013-6349.

Wilson, C. B., G. E. Erickson, T. J. Klopfenstein, R. J. Rasby, D. C. Adams, and I. G. Rush. 2004. A Review of Corn Stalk Grazing on Animal Performance and Crop Yield. Nebraska Beef Cattle Rep. MP80-A:13-15.

Wilson, R., & Jensen, J. (2016). 2016 Nebraska Farm Custom Rates Statewide Survey Summary. *Univsersity of Nebraska-Lincoln Agricultural Economics*

Table 2.1: Seeding and grazing information for when oats were planted after high moisture corn (HMC) or corn silage (CS) harvest and grazed in the fall/winter with growing steers.

	Year									
	2015		2016		2017		2018		2019	
	Treatment									
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS
Oats seeding date[1]	9/17/15	9/1/15	9/20/16	9/6/16	9/22/17	9/7/17	9/11/18	8/29/18	9/17/19	9/5/19
GDD[2] (base 0ºC)	673	1027	584	888	571	903	758	1040	618	906
Grazing start date[1]	11/4/15	11/4/15	11/2/16	11/2/16	11/1/17	11/1/17	11/15/18	11/15/18	11/15/19	11/15/19
Grazing end date[1]	1/3/16	1/3/16	12/15/16	12/15/16	12/9/17	12/9/17	12/14/18	12/14/18	1/23/20	1/23/20
Stocking rate, steer/ ha	3.2	4.0	3.2	3.1	2.3	2.2	2.6	1.6	1.4	1.9
Oats, kg/steer	180	795	186	821	331	1244	588	1230	143	1221
Corn leaf and husk[3], kg/steer	976	-	1090	-	1547	-	1226	-	1859	-

[1]Dates are formatted as month, date, and year (MM/DD/YY).

[2]Growing degree days (GDD) = [maximum temperature (°C) - minimum temperature (°C)) (when min. temp. <0, then = 0)] summed from date oats were seeded to date of pre-graze oat biomass samples.

[3] Numbers represent corn leaf and husk which was assumed to be 39% of the total corn residue present

Table 2.2: Weather conditions and number of grazing days of each year's grazing season.

	Year				
Item	2015	2016	2017	2018	2019
Number of grazing days	62	42	48	30	69
Percentage of grazing days at or below 0° C[1]	39	31	19	60	45
Percentage of grazing days with precipitation, %[2]	31	14	8	20	23
Precipitation total for grazing period, centimeters	16.3	3.0	0.5	4.8	10.9

[1]Percentage of total grazing days at or below freezing.

[2]Percentage of total grazing days in which precipitation was received.

Table 2.3: Forage biomass (kg DM/ha) taken before grazing (pre-graze) and after grazing (post-graze) activity of growing steers. Oats were planted after corn silage (CS) and high moisture harvests. Corn residue was measured in the HMC treatment.

	Year													
	2015		2016		2017		2018		2019					
	Treatment										SEM	*P*-value		
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS		trt*year	trt	year
Oat pre-graze biomass, kg DM/ha	587f	3202a	597f	2547b	746e	2691b	1716d	2188c	276g	1720cd	71.5	<0.01	<0.01	<0.01
Oat post-graze biomass, kg DM/ha	-	-	76b	1342a	0b	349b	109b	360b	41b	285b	111	0.03	<0.01	0.02
Corn residue pre-graze biomass, kg DM/ha	8155	-	8952	-	8937	-	8493	-	8904	-	613	-	-	0.85
Corn residue post-graze biomass, kg DM/ha	-	-	4095b	-	8075a	-	7030a	-	7271a	-	441	-	-	<0.01

Table 2.4. Forage nutritive value in late October of oats that was planted after corn silage (CS) or high moisture corn (HMC) harvest.

	Year										SEM	*P*-value		
	2015		2016		2017		2018		2019					
	Treatment													
Item[1]	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS		trt*year	trt	year
OM, % DM	84.4cd	83.8d	87.9b	89.1a	85.0c	85.0c	89.1a	88.9a	88.5ab	89.1a	0.235	**0.05**	0.29	**<0.01**
CP, % DM	23.2ab	18.0e	24.7a	19.2de	22.6bc	17.1ed	19.2de	18.6e	20.4cd	15.5f	0.667	**0.04**	**<0.01**	**<0.01**
NDF, % DM	37.5bc	43.7a	37.6bc	40.8ab	34.2de	36.6cd	35.4cde	32.3e	35.3cde	36.7cd	0.951	**0.02**	**0.02**	**<0.01**
ADF, % DM	22.1	25.6	22.2	25.7	22.0	25.4	19.5	19.5	18.6	20.8	0.685	0.17	**<0.01**	**<0.01**
IVOMD, %														
OM	81.7c	78.4d	82.8c	80.4cd	85.1b	78.5d	89.5a	89.4a	87.8ab	88.2a	0.856	**0.03**	**<0.01**	**<0.01**
DOM, % DM	60.8de	57.6e	66.4bc	63.0d	64.1cd	58.4e	71.2a	70.8a	69.1ab	70.9a	1.00	0.08	**<0.01**	**<0.01**

[1]OM, organic matter, CP, crude protein, NDF, neutral detergent fiber, ADF, acid detergent fiber, IVOMD, in-vitro dry matter digestibility, DOM, digestible organic matter.

Table 2.5: Performance of growing steers grazing oats plus corn residue after high moisture corn (HMC) and oats after corn silage (CS) in fall grazing systems.

	Year													
	2015		2016		2017		2018		2019					
	Treatment										SEM	*P*-value		
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS		trt*yr	trt	year
Initial BW, kg	213	212	228	228	209	210	231	230	221	221	0.758	0.82	0.84	**<0.01**
Ending BW, kg	233de	249cd	263bc	274ab	232d	285a	243d	248d	220e	269ab	5.47	**0.02**	**<0.01**	**0.02**
ADG[1], kg/d	0.33de	0.59cd	0.84bc	1.10b	0.46cd	1.52a	0.44d	0.59cd	-0.03e	0.70cd	0.113	**0.04**	**<0.01**	**<0.01**
Gain, kg/ha	65	150	113	144	47	161	36	29	-4	68	18.7	0.12	**<0.01**	**<0.01**
Animal grazing days[2], steer·d·ha^{-1}	180b	227a	120c	117c	97d	93d	72e	45f	115c	87d	3.96	**<0.01**	0.24	**<0.01**

[1]ADG, average daily gain.

[2]Number of days of grazing x number of steers per hectare.

Table 2.6: Economic analysis of two fall grazing systems: oats planted after corn silage harvest (CS) and oats planted after high moisture corn harvest (HMC).

	Year													
	2015		2016		2017		2018		2019					
	Treatment										SEM	*P*-value		
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS		trt*year	trt	year
Total costs[1], $/steer	64f	41h	63f	51g	88d	73e	76e	96c	109a	103b	1.15	**<0.01**	**<0.01**	**<0.01**
Cost of gain, $/kg	3.81	1.15	1.72	1.09	4.40	1.00	5.95	5.63	2090.76	2.14	304	0.06	0.08	0.06
Value of gain, $/kg	3.87b	5.62b	2.68b	2.29b	5.69b	3.80b	6.30b	4.96b	757.89a	5.41b	23.03	**<0.01**	**<0.01**	**<0.01**
Return per steer, $/kg	29c	152ab	27c	51bc	17c	194a	1c	-17c	-52c	148ab	23.2	**0.05**	**<0.01**	0.07

[1] Total costs included: urea fertilizer which varied by year ($19.28 to $27.61/ha), custom application of fertilizer ($15.40/ha), oats seed ($51.48/ha) plus drilling ($37.50), fencing at $10.87/ha for a temporary two-strand electric fence, hauling steers to and from the field at a cost of $2.48 per loaded km assuming 60 calves per load and 60 km, cattle interest at a 5% annual interest on the initial steer price over the number of days cattle were retained for both CS and HMC. Additionally, HMC was charged for corn residue valued at $37.50/ha.

CHAPTER III: Winter Hardy Small Cereal Cover Crops for Grazing in Eastern Nebraska[2]

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ABSTRACT

Cereal rye, winter wheat, and winter triticale are commonly planted cover crops in corn and soybean systems and have the potential to provide early spring grazing. A study was conducted to investigate the grazing potential of the three species in Eastern Nebraska, including the timing of the start of grazing and nutritive value of forage as measured by growing steer gain. A 7.3 hectare field was divided into 9, 0.81-hectare paddocks. Three paddocks (n = 3 replicates per treatment) were randomly assigned to each treatment: variety not stated cereal rye, Pronghorn winter wheat, or NT11406 triticale. Pastures were seeded in Mid-September following early maturity soybean harvest and received no fertilizer. Fifty-four steers (305 kg SD ± 5 kg) were stratified by weight and assigned to one of nine groups which were then assigned to a paddock. The paddocks were split in half. Steers were turned out when forage reached a 12.7 cm height and rotated to the other half once the occupied half reached 5 cm. Grazing began April 3 for rye pastures and April 9 for triticale and wheat pastures. Two groups of cattle grazing rye were pulled April 29 due to limited forage. All remaining cattle were pulled May 8 to allow for soybean planting. Throughout the grazing period pre and post-graze biomass did not differ ($P \geq 0.36$) among treatments. Average daily gain did not differ among treatments ($P = 0.88$) averaging 1.79, 1.86, 1.84 kg/day for rye, wheat and triticale, respectively. Likewise, gain per hectare did not differ ($P = 0.80$) among treatments with 378, 399, 394 kg/ha for rye, wheat, and triticale, respectively. Rye offered grazing a full week before triticale and wheat, but all three small grain cereal species resulted in desirable animal performance.

INTRODUCTION

Beef cow operations are often confronted with early spring and late fall forage deficiencies. Producers involved in integrated crop and livestock systems have the opportunity to fill these forage gaps using cover crops as a source of forage. Cash crop harvest, such as soybean, leaves minimal ground cover which may increase erosion potential and weed pressure while leaving unutilized growing degree days (heat units) available after cash crop harvest in late summer/early fall and before cash crop planting in the spring. Cover crops not only reduce soil erosion, sequester nutrients, improve soil structure, provide weed competition, and capture growing degree days, but they can also be a forage resource (Blanco-Canqui et al, 2015). Utilizing cover crops as a forage source may provide economic incentive to establish cover crops by offsetting economic costs and generating additional revenue. Despite the fact that using cover crops for forage reduces the amount of residue left on the soil surface, forage cover crops can still protect soil from erosion and maintain soil properties if sufficient surface cover is left (Blanco-Canqui et al, 2013).

Cereal rye is the most commonly planted cover crop in corn and soybean systems. Winter wheat and winter triticale are also sometime used (SARE/CTIC/ASTA, 2019). Cereal rye over-winters well and tends to offer grazing before other winter hardy small grains (Baron et al, 2013) although its fast maturation may pose quality risks in grazing situations. Both low stocking rates and delayed grazing initiation may allow cereal rye to mature beyond desirable, high quality stages. Winter triticale is a hybrid of cereal rye and winter wheat but has been found to favor the maturation rate of winter wheat (Baron et al, 2013). Previous research found rye to produce greater spring biomass than winter wheat or triticale (Denman and Arnold, 1970, Brown and Almodares 1976) although Edmisten and others (1998) reported vegetative yield (Zadok's stage 14) for cereal rye (Vitagraze) and winter wheat (Roy) to have a three-year average of 1100 and 1400 kg DM/ha, respectively. The average daily gain (ADG) of growing cattle (324 kg initial body weight) continuously grazing triticale and wheat pastures during winter through spring in Alabama did not differ and were 1.23 and 1.36 kg, respectively (Mullenix et al, 2014).

Cereal rye, winter wheat and winter triticale have the potential to produce forage that can be grazed in the early spring before perennial pastures are ready for grazing. However, they will differ in growth pattern (Maloney et al, 1999) and thus may differ in timing of when they are ready to graze in the spring. Therefore, the objective of this project is to investigate the grazing potential of three winter-hardy, small grain cover crop species, winter wheat, cereal rye, and winter triticale planted after a soybean crop, including the timing of the start of grazing and nutritive value of forage as measured by cattle gain in Eastern Nebraska. We expect that cereal rye will be ready to start grazing first but may mature more quickly and thus may have lower feed value (Maloney et al, 1999). Winter wheat is usually lowest cost in terms of seed but is also likely to have slower early spring growth and thus may delay the start of grazing but maintain nutritive value longer in the spring as it is slower to mature. Winter triticale is a hybrid of cereal rye and winter wheat and therefore maybe intermediate between the two in terms of start date and maturity. The goal is to be able to directly compare these forages options so that producers can make decisions about which species fit their needs.

MATERIALS AND METHODS

Animal care and management practices were approved the University of Nebraska Lincoln's Institutional Animal Care and Use Committee.

Field

A 7.3-ha field, located at the Eastern Nebraska Research Center (ENREC) of the University of Nebraska-Lincoln located near Mead, Nebraska, was utilized during this research. The land aforementioned was enrolled in dryland, continuous soybean cropping system. The soybeans used were a Group 1, short-season variety planted on May 15 with 76-cm row spacing. Three treatments, cereal rye, winter triticale, and winter wheat, were employed on the soybean ground after harvest, each having three replicates (n = 3). Cereal rye was seeded at approximately 99 kg/ha to target 84 kg of pure live seed (PLS) per ha using a variety-not-stated (VNS), costing $0.51 per kg. Winter triticale was seeded at approximately 121 kg/ha to target 112 kg PLS/ha using the NT11406 variety, costing $0.70 per kg. Pronghorn winter wheat was seeded at approximately 114 kg/ha to achieve 112 kg PLS/ha, costing $0.53 per kg. This study targeted the same number of seed to germinate per ha; therefore, cereal rye, having a smaller seed, received fewer kg/ha in seed.

Soybeans were harvested on September 10 with the small grain forages being planted using a no-till drill on September 15 with 17.8 cm row spacing. The small grain forages received no fertilizer, because it was assumed the soybean crop left behind enough nitrogen to satisfy them. The 7.3-ha were split into 0.81 ha paddocks (experimental units). The 0.81 ha paddocks were assigned randomly to treatment, planted to species and then divided into 2, 0.4 ha paddocks in order to allow rotational grazing between the two paddocks within the experimental unit. When each species reached a height of 12.7 cm, cattle were moved to a 0.4-ha and allowed to graze forage down to a height of 5 cm before being rotated to the other half. Grazing continued until forage biomass limited intake or until the scheduled pull date of May 10. Remaining forages were then terminated using herbicide in order to prepare for soybean planting.

Forage

Forage heights were collected using a disc-plate meter. Ten heights were randomly collected across each 0.4 ha and then averaged. Forage height was recorded when 50% of the leaves under the disc touched the plate. Paddock heights were used to determine the start of grazing and when to rotate among the two paddocks within the experimental unit.

Forage biomass samples were collected right before each grazing period began (before cattle entered) and immediately after the grazing period ended (after cattle left) in each 0.4-ha paddock. Three samples were collected randomly across each 0.4-ha paddock. Samples areas were 0.49 m^2 with forage being clipped to ground height. Pre-graze biomasses samples were used to determine the amount of forage available when grazing periods began. Post-graze biomasses were then collected to determine the forage amount remaining after a grazing period ended. Enclosures were placed in areas of average pre-graze biomass to account for forage growth during the grazing period. and one sample would be collected from the enclosure area at the end of each grazing period. Enclosures were moved with each rotation. Samples were dried in a 60° C forced air oven until a constant weight was reached in order to determine dry matter (DM) content. The cover crop samples were then used to calculate forage yield in kg/ha on a DM basis.

Forage disappearance was calculated by subtracting post-graze biomass from enclosure biomass divided by the number of grazing steers divided by the number of grazing days. Forage disappearance per steer per day is attributed to both cattle consumption and trampling. Rye, triticale, and wheat pre-graze biomass samples were also used to determine forage nutritive quality. After being dried in 60° C forced air oven, samples were ground through a 1-mm screen Cyclone Mill. Samples were dried for 24 hours to determine DM. Organic matter (OM) was then determined by burning samples at 600° C for 6 hours in a muffle furnace. Samples were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), and in-vitro dry matter digestibility (IVDMD) using methods described in Vogel et al (1999) utilizing the ANKOM A2000 Fiber Analyzer and Daisy^{II} Incubator (ANKOM Technology Corporation). Rumen fluid was collected from ruminally fistulated steers (*Bos taurus*) that were offered a diet containing 70% bromegrass hay and 30% concentrate which containing distillers grains, dry rolled corn, mineral supplement. Lastly, forage crude protein (CP) was determined using a TrueSpec micro analyzer (LECO Corp.).

Cattle

Fifty-two growing steers (305 kg SD ± 5 kg) were utilized during this study. Steers were limit fed in a feedlot for 8 days before and after taking part in the trial in order to equalize gut fill. Initial and ending weights were taken pre-feeding during the last three days of each limit feeding period (Watson, et al., 2013). While in the feedlot, steers received a diet of 50% Sweet Brand and 50% alfalfa hay at a 2% of body weight DM intake. It was estimated that cattle ADG was 1 lb/d during the limit feeding period and this gain was removed from the steer BW. Steers were stratified by weight and assigned randomly to experimental unit. Six steers were stocked per experimental unit for a stocking density of approximately 2,288 kg BW/ha. While grazing, steers had access to a high magnesium mineral at ad libitum intake. The mineral mix contained 59.25% salt, 10.5% calcium, 5% magnesium, 1080 ppm zinc, 1080 ppm manganese, 540 ppm copper, 10 ppm cobalt, 27 ppm iodine, and 5 ppm selenium.

Statistics

The data were analyzed a complexly randomized design using the MIXED procedure in SAS (SAS Institute, Inc., Cary, N.C.). Treatment was considered a fixed effect. Each treatment had 3 replicates (0.8-ha paddock) that served as the EU. All forage data were averaged across grazing event within EU before analysis. The pdiff statement was used to separate treatment means when the F-test was significant. Differences were considered significant at $P \leq 0.05$ and tendencies at $P > 0.05$ and ≥ 0.10.

RESULTS AND DISCUSSION

Forage Yield and Quality

There was no significant difference ($P \geq 0.35$; Table 3.1) among treatments for pre-graze or post-graze biomass. The mean pre-graze biomass was 1,432 kg DM/ ha and is similar to those previously reported for small cereals in the vegetative stage in other studies (Coblentz et al, 2018, Edmisten et al, 1998). However, unlike our study, previous studies have found cereal rye to out yield winter triticale and winter wheat in vegetative stages (Brown and Almodares, 1976, Maloney et al, 1999). It is important to note that the forages in these studies were not grazed and thus do not take into account any differences in regrowth potential.

Rye cattle began grazing on April 3, 2020 when the forage species reached a 12.7 cm height. Triticale and wheat cattle began grazing on April 9, 2020 when those species reached a 12.7 cm height. However, on April 29, 2020, cattle were pulled on 2/3 of the rye EU due to lack of forage. It is worth mentioning that two rye paddocks were assigned randomly to a lower portion of the field. Heavy rains in 2019 washed soybean residue into them and caused excess accumulation of soybean trash. This accumulation may have inhibited rye establishment in those two EUs. Therefore, cattle being pulled early on those two rye paddocks due to lack of forage may not be the result of differences in growth potential.

Average pre-graze and post-graze forage heights can be found in Table 3.1. A treatment effect ($P = 0.05$) was found in pre-graze forage heights. Triticale and wheat did not differ ($P = 0.76$) from one another with both being greater ($P \leq 0.04$) than rye. The shorter pre-graze height being rye was due to the two paddocks of rye in the low lying areas. There were no treatment effects ($P = 0.53$) for post-graze forage heights.

There were treatment effects ($P = 0.01$) for total number of rotations with rye having the greatest ($P < 0.01$) number of rotations compared to triticale and wheat, which did not differ ($P = 1.0$) from each other. There was a treatment effect ($P < 0.01$) for the average number of days per rotation with triticale and wheat not differing ($P = 1.00$) but both being greater ($P < 0.01$) than rye.

Cattle were allotted approximately 13 kg DM/steer/day of forage (Table 3.2). Forage disappearance (kg DM/steer/day, Table 2) measures the amount of forage biomass that disappeared each day due to livestock consumption and trampling. No significant difference was found (P = 0.14) among treatments in forage disappearance with a mean of 10.3 kg DM/steer.

The number of grazing days each species afforded did not differ among treatments (P = 1.00, Table 3.2) with a mean of 29 days. It is important to note that cattle were removed from wheat, triticale due to the need to plant soybeans and not due to limited forage availability.

Forage quality

Forage nutritive value data are found in Table 3.3. No differences (P = 0.98) were found among forages for IVDMD. Values forage IVDMD were quite high, averaging 92% across all species.

There were treatment differences ($P \leq 0.04$) for NDF, ADF and ADL. There was no difference (P = 0.23) in NDF content between wheat and triticale but wheat NDF was significantly greater (P = 0.01) than rye while triticale and rye did not differ (P = 0.19) from one another. Wheat tended (P = 0.08) to have greater ADF than triticale with both being significantly greater ($P \leq 0.02$) than rye ADF. There was no difference (P = 0.32) between wheat and triticale for ADL and were greater (P <0.01) than rye.

Forage CP had a tendency (P = 0.08) to differ by treatment with wheat tending (P = 0.08) to be greater than triticale. Wheat CP content was significantly greater (P = 0.04) than rye but triticale and rye did not differ (P = 0.80) from one another.

Although there were minor differences were present in the nutritive value of cereal rye, winter triticale, and winter wheat, digestibility and CP were quite good with all treatments being high in quality.

Calf Performance

Cattle performance data can be found in Table 3.4. As designed, there was no difference (*P* = 0.6) in initial cattle body weight (BW). Ending BW also did not differ (*P* = 0.97) among treatments with a mean of 355 kg. The average daily gain of steers did not differ (*P* = 0.76) among treatment with a mean 1.8 kg/steer/day. It is important to note that in the winter prior to the trial the steers had been gaining about 0.5 kg/day. Therefore, they may have been experiencing some compensatory growth during the grazing period. If 25% of their ADG is credited to compensatory gain, the ADG would still be 1.37 kg/steer/day which is still quite high for a forage-based diet. Total gain per steer did not differ (*P* = 0.78) among treatments averaging 53 kg. Total gains per hectare also did not differ (*P* = 0.80) among treatments with a mean of 391 kg/ha.

When 25% of ADG is attributed to compensatory gain, cattle performance is more similar to those reported in a three year Alabama winter grazing study. Mullenix et al (2014) stocked growing steers on fall planted ryegrass, triticale, and wheat to maintain forage biomass to 1500 to 2000 kg DM/ha from mid to late January to early May. Steer performance was 1.51, 1.23, and 1.36 kg in ADG for ryegrass, triticale, and wheat, respectively. The Mullenix et al (2014) study utilized fall planted cover crops for both winter and spring grazing while our study only focused on spring grazing. Warmer conditions in the southern United States affords more opportunities for winter forage production than in Nebraska. Rotational grazing with a set stocking density was used in our study to maintain biomass of approximately 1400 to 700 kg DM/ha while Mullenix et al, (2014) used varying stocking densities to maintain 1500 to 2000 kg DM/ha.

When evaluating seed cost, triticale had the most expensive seed without offering any additional benefits; therefore, it is unlikely to be the best option for planting when the goal is early season grazing in Nebraska. Rye seed was the lowest cost per kg and required fewer kg of seed to result in similar seeding rate on a pure live seed basis thus it was the lowest cost option. Additionally, rye offered the earliest grazing. However, due to the risk of feral rye that could contaminate small grain cash crops it may not be well suited to some regions. In these areas, wheat may be more appropriate, despite the slightly greater seed cost and potential for delayed onset of grazing.

CONCLUSION

When grazing in early spring there were no differences in carrying capacity or growing steer gains of cereal rye, winter wheat or triticale. Cereal rye did result in the ability to start grazing earlier.

LITERATURE CITED

Baron, V. S., Dick, A. C., Salmon, D. F., & McLeod, J. G. (1999). Fall seeding date and species effects on spring forage yield of winter cereals. *Journal of Production Agriculture*, *12*(1), 110–115. https://doi.org/10.2134/jpa1999.0110

Blanco-Canqui, H., J.D. Holman, A.J. Schlegel, J. Tatarko, and T. Shaver. 2013. Replacing fallow with cover crops in a semiarid soil: Effects on soil properties. Soil Sci. Soc. Am. J. 77:1026-1034.

Brown, A.A., Almodares, A. 1976. Quantity and Quality of Triticale Forage Compared to Other Small Grains. *Agron. J.* 68: 264-266.

Edmisten, K. L., Green, J. T., Mueller, J. P., & Burns, J. C. (1998). Winter annual small GRAIN forage POTENTIAL. I. dry matter yield in relation to morphological characteristics of four small grain species at six growth stages. *Communications in Soil Science and Plant Analysis*, *29*(7-8), 867–879. https://doi.org/10.1080/00103629809369992

Maloney, T. S., Oplinger, E. S., & Albrecht, K. A. (1999). Small grains for fall and spring forage. *Journal of Production Agriculture*, *12*(3), 488–494. https://doi.org/10.2134/jpa1999.0488

Mullenix, M. K., Dillard, S. L., Lin, J. C., Gamble, B. E., & Muntifering, R. B. (2014). Evaluation of wheat AND TRITICALE forage for stocker production in the Gulf Coast region. *The Professional Animal Scientist*, *30*(3), 296–304. https://doi.org/10.15232/s1080-7446(15)30120-0

Sustainable Agriculture Research and Education program, Conservation Technology Information Center, and American Seed Trade Association. (2020, August). *Annual Report 2019-2020*. SARE. https://www.sare.org/wp-content/uploads/2019-2020-National-Cover-Crop-Survey.pdf.

Vogel, K. P., Pedersen, J. F., Masterson, S. D., & Toy, J. J. (1999). Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. *Crop Science*, *39*(1), 276–279. https://doi.org/10.2135/cropsci1999.0011183x003900010042x

Watson, A. K., B. L. Nuttleman, T. J. Klopfenstein, L. W. Lomas, and G. E. Erickson. 2013. Impacts of limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91:5507-5517. doi:10.2527/jas.2013-6349.

Table 3.1: Average forage biomass (kg DM/ha) and heights of cereal rye, winter triticale, and winter wheat taken before grazing (pre-graze) and after grazing (post-graze) activity of growing steers. Forages were planted after group 1 soybean harvest.

	Treatment				
Item	Rye	Triticale	Wheat	SEM	*P-value*
Pre-Graze Biomass, kg DM/ha	1236	1641	1420	187.7	0.35
Post-Graze Biomass, kg DM/ha	831	723	589	148.2	0.52
Average Pre-Graze Height, cm	11.0b	14.5a	14.9a	0.822	**0.05**
Average Post-Graze Height, cm	6.1	6.8	7.1	0.598	0.53
Number of Rotations in Grazing Season[1]	5.3a	4.0b	4.0b	0.193	**0.01**
Average Number of Days per Rotation[2]	5.8b	7.8a	7.8a	0.116	**<0.01**

[1]Number of events in the grazing season that cattle were rotated from one 0.4 ha within 0.8 ha experimental unit (EU) to the other 0.4 ha half.

[2]Number of days cattle spent grazing 0.4 ha paddock within 0.8 ha EU before being rotated to the other 0.4 ha half.

Table 3.2: Spring pre-graze forage nutritive value of cereal rye, winter triticale, and winter wheat planted after fall soybean harvest.

	Treatment				
Item[1]	Rye	Triticale	Wheat	SEM	*P-value*
IVDMD, % DM	91.9	92.0	91.8	0.604	0.98
NDF, % DM	49.4b	51.8ab	54.2a	1.19	**0.04**
ADF, % DM	21.4b	23.4a	25.0a	0.556	**<0.01**
ADL, % DM	3.7b	5.8a	6.2a	0.275	**<0.01**
CP, % DM	18.2	18.3	19.6	0.436	0.08

[1]IVDMD, in-vitro dry matter digestibility, NDF, neutral detergent fiber, ADF, acid detergent fiber, ADL, acid detergent lignin, CP, crude protein.

Table 3.3: Forage allowance and disappearance, steer mineral consumption, and number of grazing days achieved per treatment.

	Treatment				
Item	Rye	Triticale	Wheat	SEM	*P-value*
Forage allowance, kg $steer^{-1}$ d^{-1}	14	14	12	1.42	0.66
Forage disappearance, kg $steer^{-1}$ d^{-1}	8	12	11	1.19	0.14
Mineral consumption, g $steer^{-1}$ d^{-1}	48	71	68	7.4	0.16
Grazing days	29	29	29	1.73	1.00

[1]Forage disappearance per steer per day attributed to livestock consumption and trampling

Table 3.4: Performance of growing steers grazing cereal rye, winter triticale, and winter wheat.

	Treatment				
Item	Rye	Triticale	Wheat	SEM	*P-value*
Initial BW, kg	304	303	303	0.509	0.60
Ending BW, kg	355	354	355	3.43	0.97
Average daily gain, kg	1.77	1.83	1.87	0.093	0.76
Total gain kg $steer^{-1}$	51	53	54	3.07	0.78
Gain per hectare, kg/ha	378	395	399	22.6	0.80

APPENDIX

Table 1A. Pre-grazing and post-grazing steer values ($/steer) and daily interest charge ($/steer/day) of two fall grazing systems: oats after corn silage harvest (CS), oats after high moisture corn harvest (HMC).

	Year									
	2015		2016		2017		2018		2019	
	Treatment									
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS
Initial steer value at purchase, $/steer	759	872	746	710	765	714	764	822	753	684
Interest charged per steer per day, $/steer	0.12	0.12	0.10	0.10	0.10	0.10	0.11	0.11	0.09	0.09
End value of steer, $/steer	849	1072	825	815	854	986	852	904	842	941

Table 2A: Cost ($/steer) of two fall grazing systems: oats after corn silage harvest (CS), oats after high moisture corn harvest (HMC).

	Year													
	2015		2016		2017		2018		2019					
	Treatment										SEM	*P*-value		
Item	HMC	CS	HMC	CS	HMC	CS	HMC	CS	HMC	CS		trt*year	trt	year
Corn Residue[1]	12.92c	-	13.17c	-	18.61b	-	15.58bc	-	22.67a	-	0.952	-	-	**<0.01**
Fertilizer[2]	14.82f	11.78g	12.18g	12.51g	18.19d	19.00d	16.72e	27.00b	24.04c	28.90a	0.320	**<0.01**	**<0.01**	**<0.01**
Seed plus drilling[3]	30.62f	24.35g	31.22f	32.06f	44.11d	46.10d	36.93e	59.61b	53.74c	64.61a	0.759	**<0.01**	**<0.01**	**<0.01**
Fencing[4]	3.34f	2.65g	3.40f	3.49f	4.81d	5.02d	4.03e	6.49b	5.85c	7.04a	0.083	**<0.01**	**<0.01**	**<0.01**
Transportation[5]	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	-	-	-	-
Interest[6]	7.42	7.41	4.08	4.08	4.68	4.70	3.37	3.38	6.47	6.46	0.005	0.08	0.55	**<0.01**

[1]Corn residue was valued at $37.50/ha

[2]Urea fertilizer ($19.28 to $27.61/ha) plus custom application ($15.40/ha) cost.

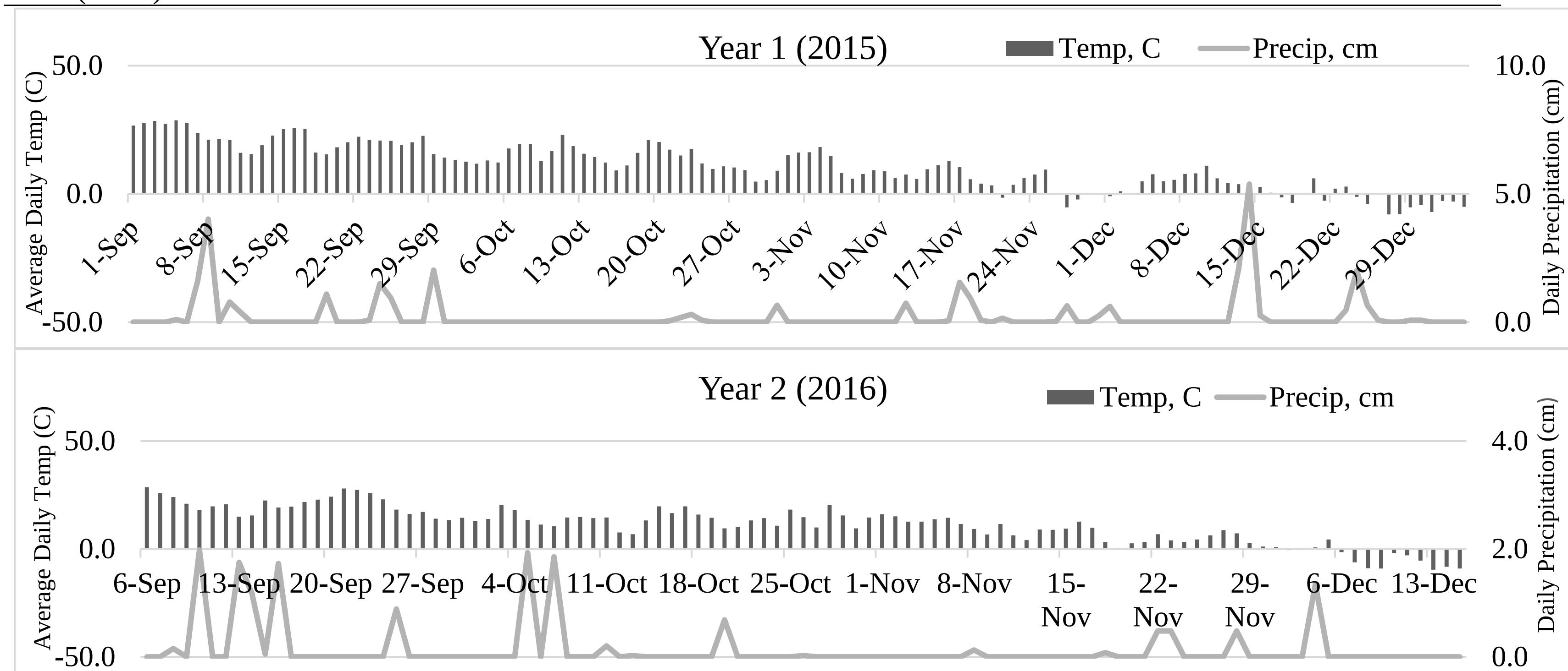
[3]Oats seed ($51.48/ha) plus drilling ($37.50) cost.

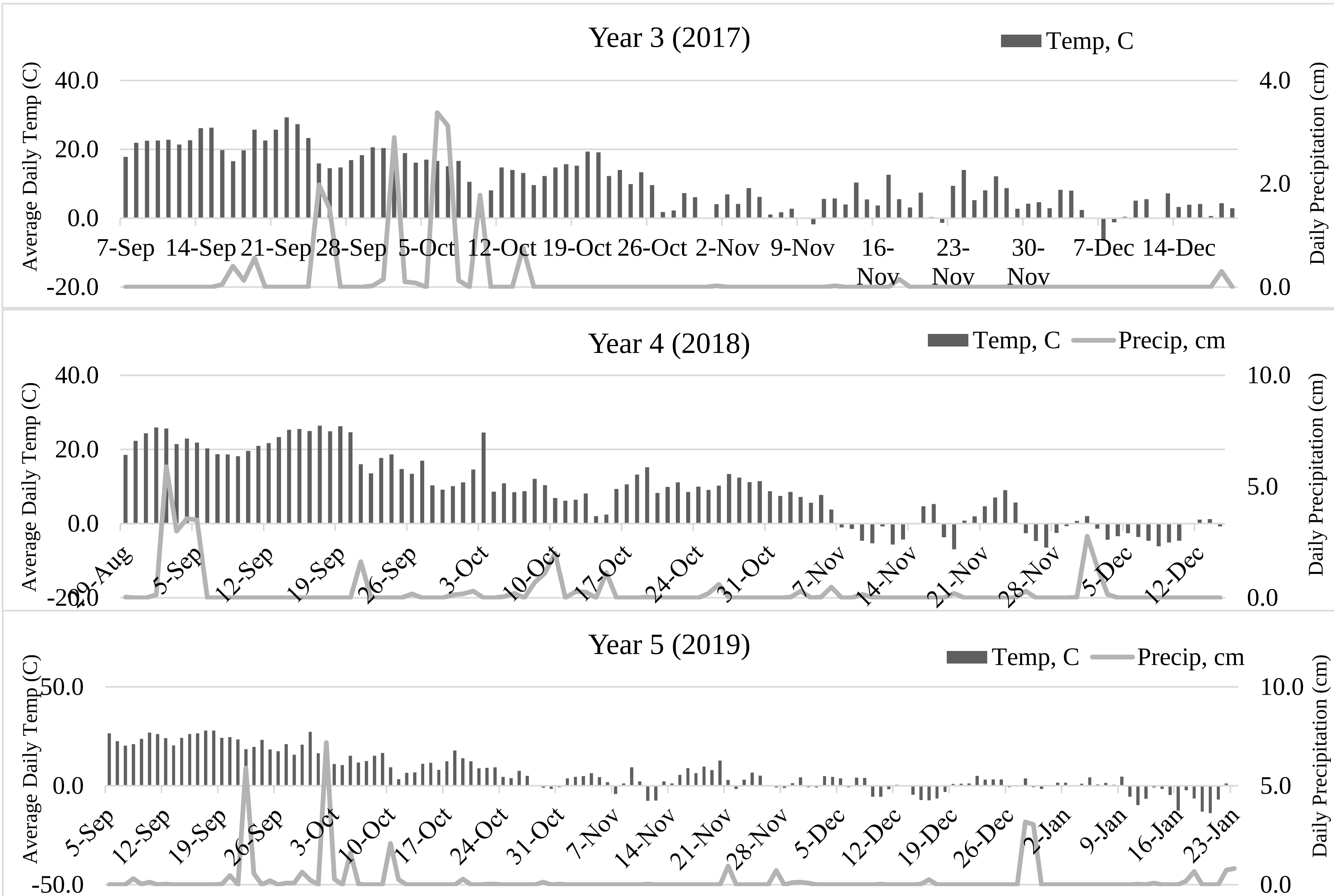
[4]Fencing was charged at $10.87/ha for a temporary two-strand electric fence.

[5]Hauling steers to and from the field at a cost of $2.48 per loaded km assuming 60 calves per load and 60 km

[6]Cattle interest was charged per head at a 5% annual interest on the initial steer price over the number of days cattle were retained

Table 3A: Average daily temperatures (temp, °C) and daily precipitation (cm) in Mead, Nebraska. Dates begin at the planting of oats after corn silage (CS) harvest and discontinue at the end of grazing periods in both CS and high moisture corn (HMC) treatments.




Year 3 (2017)
Temp, C
Average Daily Temp (C)
Daily Precipitation (cm)
40.0
20.0
0.0
-20.0
4.0
2.0
0.0
7-Sep
14-Sep
21-Sep
28-Sep
5-Oct
12-Oct
19-Oct
26-Oct
2-Nov
9-Nov
16-Nov
23-Nov
30-Nov
7-Dec
14-Dec
Year 4 (2018)
Temp, C
Precip, cm
Average Daily Temp (C)
Daily Precipitation (cm)
40.0
20.0
0.0
-20.0
10.0
5.0
0.0
29-Aug
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
Year 5 (2019)
Temp, C
Precip, cm
Average Daily Temp (C)
Daily Precipitation (cm)
50.0
0.0
-50.0
10.0
5.0
0.0
5-Sep
12-Sep
19-Sep
26-Sep
3-Oct
10-Oct
17-Oct
24-Oct
31-Oct
7-Nov
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2-Jan
9-Jan
16-Jan
23-Jan