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Managing Corn Residue and Double Cropped Forages in Crop and Livestock Systems

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MANAGING CORN RESIDUE AND DOUBLE CROPPED FORAGES IN CROP AND LIVESTOCK SYSTEMS

By

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Integrating crop and livestock systems leads to opportunities to utilize land resources; however, crop producers focus on grain yields and ground cover, while livestock producers see opportunity to graze corn residue or annual forages. After wheat harvest or corn silage harvest, above ground forage production for brassica mixes and oats is greater than forage oats or oat production after high moisture corn harvest. Grazing steers on forage crops after grain harvest provides moderate gains. While annual forages provide good quality forages, corn residue grazing and utilization is still a cost-effective feedstuff for cattle producers. In the short term, grain yields do not differ for treatments that were baled, grazed, or not baled or grazed. Residue ground cover after grazing is greater than after baling. An alternative way to utilize the baled corn residue is treating corn residue with CaO; however, the energy value needs to be improved, so addition of components such as distillers solubles or crude glycerin could apply. Treating corn residue with CaO and utilizing distillers solubles, crude glycerin, and treated corn residue as a replacement for distillers grains in a brome hay diet reduced steer ADG. Combining protein, solubles and glycerin components with treated corn stover does not provide the same performance response as modified distillers grains plus solubles.

Finding ways to integrate livestock and crop production is a way to become better stewards of the resources available.

Keywords: annual forages, brassicas, by-products, corn residue, treated stover

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Lastly, to the farmers that work day-in and day-out to put food on our tables. Farmers are the people to whom I owe this thesis. Without their help, where and what would we be doing today?

DEDICATION

“I have been crucified with Christ and I no longer live, but Christ lives in me.

The life I now live in the body, I live by faith in the Son of God,

who loved me and gave himself for me.”

~ Galatians 2:20, Holy Bible, NIV version

“Each of you should use whatever gift you have received to serve others, as

faithful stewards of God’s grace in its various forms.”

~ 1 Peter 4:10, Holy Bible, NIV version

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CHAPTER I. Review of Literature

Introduction

Cattle producers benefit from feed resources that can be utilized without harvesting. Feed costs average $0.91 / cow per day during the winter and provide producers with a management challenge (Larson et al., 2009). According to the Nebraska Corn Board in 2015, corn yields averaged 10,613 kilograms per hectare in 2015 and 34.7 million kilograms are produced in the state (2016). Nationally, the amount of corn produced in 2015 averaged 346 million kilograms and yields hovered at 10,550 kilograms per hectare (Nebraska Corn Board, 2016). These yields indicate the value of corn at the time, and the enormity of a by-product resource of corn grain production. Perlack and Turhollow (2003) state that according to resources in 2000, the availability of corn stover and wheat straw averaged 136 million metric dry tons with 28 million corn hectares harvested each year.

Methods such as baling or grazing corn residue allow for the removal of a portion of the corn residue, while also leaving some residue as organic matter for the soil. If the residue is removed from the field by baling, it can be transported to a location where chemical treatment can be used to improve the digestibility of less digestible parts when fed to cattle. Calcium oxide (CaO) treatment improves the digestibility of residue and may provide an alternative to other feedstuffs. However, removing residue may increase erosion potential if the ground is bare. Cover crops may provide a possible solution to this issue and may increase the total amount of forage mass produced per acre. For example, after harvesting wheat grain in July or corn in September, the ground may be somewhat bare, so an opportunity exists to remove the residue or plant a cover crop for protection or utilize it as a grazing opportunity for growing calves.

Effect of Baling or Grazing on Subsequent Crop Yield on Varying Soil Types

Harvest index and timing of harvest

The harvest index is the amount of grain yielded in proportion to the amount of residue biomass above the ground (leaf, stalk, husk and cob; Prince et al., 2001). The harvest index reaches its peak at black layer, which is known as the physiological maturity of the corn kernel (Daynard and Duncan, 1969). Johnson et al. (2006) summarized historic records of the harvest index and noted that in 1940, the harvest index was 0.35; by 2000, the harvest index averaged 0.53. Several factors influence the enhancement or reduction of the harvest index, for example, fertilization or genetic enhancement. Johnson et al. (2006) observed a 30 - 50% corn yield increase in the harvest index due to N and P additions through chemical fertilizers. Sixty percent of that improvement is also due to genetic engineering. The improvements in abiotic and biotic stress tolerance in high density populations attributes to the yield increases (Johnson et al., 2006).

In 1989, Crookston and Kurle assumed a harvest index of 0.47 for corn, based on a 6-year study. Prince et al. (2001) reported that experiments have indices ranging from 0.50 to 0.58, depending on stress and weather conditions. The generally recognized index in corn industry seems to be about 0.53. In 2012, Wortman et al. recorded that the harvest index for all organic and conventional corn treatments was 0.52, or 52% grain, making this the most recent harvest index estimate.

For soybeans, the harvest index is approximately 0.42 (Prince et al., 2001). There is a 20-30% bias on soybean harvest index due to leaf loss before harvest, therefore, the timing of biomass harvest becomes critical (Johnson et al., 2006). With nitrogen fertilization now possible and the ability to estimate nutrients needed by soil tests, the potential to increase the harvest index improved from the 1980's (Prince et al., 2001).

Sampling errors in the field can occur and elevate the harvest index estimate. As the plant matures leaves senesce and fall off the plant, therefore, becoming a loss and that material is not calculated into the harvest index (Prince et al., 2001). As the plant moves from physiological maturity to grain harvest, the concentration of nutrients in the portion of the plant above the ear changes by at least 17% in N and twice as much in Ca (Johnson et al., 2010). Depending on the harvest date, the nutrient concentration in the plant will have changed due to the plant drying down over time (Johnson et al., 2010).

A number of factors affect crop yields. For example, in no-till environments, weed control can be a big challenge that can inhibit yield (Wortman et al., 2012). Alternatively, Johnson et al. (2006) writes that the cultivar and the environment affect the harvest index. Jaeger et al. (2006) summarized that corn hybrids have different ratios of corn grain to residue, and these potential differences pertain to plant efficiency and overall differences in the amount of residue produced. Prince et al. (2001) suggests that the harvest index should not vary more than 10 percentage units, even with different climatic condition and management resources. DeLoughery and Crookston (1979) argued that the harvest index and grain yield are positively correlated in stress conditions. Prince et al. (2001) agreed that changes in yield and biomass occur when stress conditions are present, however, the harvest index does not necessarily change as the grain and plant yields both undergo stress (Prince et al., 2001). DeLoughery and Crookston (1979) suggested that there are two considerations that must be accounted for when determining harvest index. As plants mature, the harvest index decreases. In addition, the harvest index is affected by the planting density, as the planting density increases the harvest index decreases.

The hybrid variety and harvest date can also influence the harvest index estimate. In 2011, Musgrave et al. evaluated grain and residue yields from 12 different corn hybrids. Two locations, South Platte River near Paxton and Scottsbluff, declared a harvest index range from 0.49 to 0.58 with averages of 0.55 and 0.58, respectively by location. These numbers agreed with Prince et al. (2001) that the harvest index should not vary more than 10 percentage units.

Irrigated corn harvested at three different dates in York, Nebraska showed that as you move closer to grain harvest the percentage of grain increased (Burken et al., 2013b). This is due to the increase in grain weight as sugar is stored in the grain; however, once physiological maturity is reached at grain harvest, the shrinking of the cells in the corn grain occurs, as well as, the leaves are senescing due to translocation of nutrients and the plant drying down (Daynard and Duncan, 1969). Burken et al. (2013b) wrote that starting at 28 days prior to grain harvest, the percentage of grain is 51% and continues to increase to 62% at black layer. The effect of plant population on the harvest index is less influential it seems, the grain percentage changed 1 unit from 28,000 to 38,000 plants per acre. Both population density and timing of harvest averaged a 0.55 harvest index (Burken et al., 2013c).

Congruent with a study done by Burken in 2012, 18 days prior to black layer, the corn harvest index was 0.40, but 4 days prior rose to 0.64. After black layer, the harvest index dropped to 0.37 indicating that once black layer is reached, the degradation of the sugars in the kernel occurs, therefore, the quality of the corn decreases (Burken, 2014).

McGee et al. (2012) harvested corn on Oct. 2 and determined there to be 33.67 lbs. plant DM for every bushel of grain. However, McGee et al. (2012) noted that their digestible residue yields, 13.40 lbs of plant DM (leaf, leaf sheath, shank and husk) per bushel of corn grain, are lower than research conducted on that field the last 15-20 years. Therefore, they suggested that the increasing corn yields due to hybrid differences may have caused the decline in leaf and husk per bushel. Over the past 60 years, research leads one to believe that the harvest index estimate has increased due to the improvement in corn genetics and development of hybrids, as well as, changes in the time of harvest.

Silage harvest

Corn silage is a major feed source for finishing cattle. The whole plant can be utilized in the silage to feed to cattle (Burken et al., 2013). The maximum corn grain yield is said to be reached at 35% DM (Shinners and Binversie, 2007). Wiersma et al. (1993) discussed literature pertaining to silage DM content where the ideal DM content is between 30-40%, thus acceptable silage quality.

Corn silage quality is affected by the time of harvest in relation to plant maturity. Cummins (1970) reported that as the plant matures, the leaf content decreases and nutrients may be relocated or weather conditions cause changes in the leaves. First harvest of silage is typically at the late milk stage and as the harvest date moves closer to mature grain stage, there is an increase in DM content. However, the dent stage seems to be where the greatest grain percentage is noted. Leaves are actively photosynthesizing carbohydrates to be stored by the plant in the ear, but once the leaves start to senesce, the carbohydrate storage in the ears is reduced (Cummins, 1970). Leaves become brittle with age and start to senesce as the nutrients are translocated (Shinners and Binversie, 2007).

The greatest yield and grain harvest in terms of dry tons is reached when the ear reaches the dough or dent stage as the most amount of carbohydrate storage has occurred and plant growth has ceased (Cummins, 1970). Pordesimo et al. (2004) agrees that the stover DM yield increases 2 weeks prior to physiological maturity. Row et al. (2016) reported that silage grain percentages increased as the plant matured, up to 59.4%, 3 weeks after black layer. The grain yield showed a linear increase until black layer, and then showed a decrease as time proceeded from black layer. The week prior to and following black layer had the most dramatic increase and decrease in grain yield, respectively.

An experiment conducted by Wiersma et al. (1993) illustrated that silage DM tons ranged from 9.2 metric tons DM / hectare to 17.7 metric tons DM / hectare in 1990. At black layer, DM yields are the greatest, 32.6 metric tons / hectare, for silage (Filya, 2004). Silage DM yield in the Row et al. (2016) study reached 28.2 metric tons DM per hectare at black layer, and at half milkline, it was 23 metric tons DM per hectare. They also concluded that the higher the cutting height of the plant, the greater the grain percentage for silage (Row et al., 2016). Silage quality and quantity vary based on factors, such as harvest date and cutting height; therefore, the producer’s end goal is what determines the quantity harvested or the quality of corn silage desired.

Crop residue removal concerns

With higher prices received for corn in the previous decade, there was an increase in hectares planted to corn, and therefore, an increase in corn residue on the field. The continual question still remains in regards to what is the best solution for utilization of the corn residue and how the removal of corn residue will affect the following year's yield if there is more corn residue available. Gutierrez-Ornelas and Klopfenstein (1991) suggested that weathering may cause the most damage to the corn residue due to cell soluble leaching and soil contamination from trampling of the residue. Wilhelm et al. (1986) commented that residue plays key roles in soil protection, soil temperature control, mulching and providing plants with nutrients. In this study, it was concluded that as more residue was removed from the soil, grain yields decreased by 0.10 Mg / ha and subsequent residue yields decreased by 0.30 Mg / ha with each Mg of residue was removed.

Crookston and Kurle (1989) found no effect on corn or soybean yield by removing the corn residue in Minnesota. Irrigated fields produce as much as two times the amount of residue as the non-irrigated fields (Gutierrez-Ornelas and Klopfenstein, 1991). Van Donk et al. (2012) found that yield differences were not evident on subsequent grain yields following the removal of corn residue by grazing, baling or leaving residue on fully irrigated fields in the two year study. Stalker et al. (2015) completed a 5-year study in Brule, NE that looked at the cattle performance on residue, but treatments applied were two grazings (light and heavy stocked), no removal and removal of residue by baling, and they found no effect on subsequent yields with any of the treatments.

Kenney et al. (2015) had irrigated and rainfed sites around the state of Nebraska and during the 3-year study, they found variations in grain yields due to stover removal. However, by the third year, there were no significant changes in grain yield. Therefore, it is variable from year to year based on the location, weather and management type. Kenney et al. (2015) concluded that results suggested that the yields did not change or increased slightly due to residue removal leaving the connotation that residue removal would not lead to decreased yields.

Blanco-Canqui et al. (2006) indicated that removing excessive amounts of residue can negatively impact crop production on certain soil types in the short term. Sloping areas where residue is removed are more prone to decreased crop yields (Blanco et al., 2006). Perlack and Turhollow (2003) articulated that the benefits of leaving stover on the soil is dependent on tillage type, crop rotation, slope of the land, and soil properties. Areas with high yields of residue may benefit from the removal of residue as emergence of the following crop may be delayed or uneven (Blanco et al., 2006). Irrigated corn fields tend to have higher yields, therefore, more corn residue covering the field. Therefore, finding a way to best utilize this abundant resource becomes key.

Removal by baling

Optimal residue removal ensures emergence of the following crop, but leaves adequate cover for the soil component. Residue management can be influenced by cutting height. Hoskinson et al. (2007) implied that removal of stalks too close to the soil surface can increase erosion by wind or water, provide less coverage of the soil surface and decrease soil carbon stores. However, the closer the cut to the ground when harvesting the residue, the greater the stover yield (Hoskinson et al., 2007). The weight of stover bales is dependent on corn grain yields an baling efficiency, but baling corn stover into 1.5 meter by 1.8 meter bales amounts to about 576 kg dry material per bale (Perlack and Turhollow, 2003).

A three year study by van Donk et al. (2012) indicated that about 4.48 metric tons residue per hectare was removed by baling in 2008 and 2010, with 2009 having less removed due to hail damage affecting corn productivity. As expected, the amount of cover on the baled treatments was the lowest as compared to grazing or no residue removal. The amount of water lost from runoff in the top 1.8 meter equaled 10.9 cm. Van Donk et al. (2012) concluded that yield differences did not change between the treatments applied (grazing, baling and no removal), and hypothesized that a difference may be observed over a longer period of time as effects on soil quality would not be noticed for several years. Additionally, irrigated fields tend to have less variability due to water stress across treatments (van Donk et al., 2012). Stalker et al. (2015) found that baling did not affect subsequent yields on a no-till, continuous corn field.

Removal by grazing

Mechanical removal costs the producer time and money, so the other side of the debate is utilizing a biological resource, such as cattle. According to previous 1990's research listed by Tracy and Zhang (2008), grazing cattle on croplands has a negative effect on corn yields. Drewnoski et al. (2016) grazed cattle on cornstalks in the fall and spring on fields in a corn-soybean rotation. Their results concluded that there was no effect of grazing on subsequent corn yields, and soybean yields actually increased with the grazing of corn residue. It was also observed by McGee et al. (2013) that heavily grazing cattle on corn residue (about 23.4% removal) and lightly grazing cattle on corn residue (about 12.6% removal) had no negative impact on yields over a three year period (McGee et al., 2013).

On continuous corn treatments, Tracy and Zhang (2008) found that grazing cattle in winter on residues had no negative effect on the subsequent crop yield, but grazing may have been a factor in the increase in corn yield while reducing winter feeding costs. Clark et al. (2004) indicated that grazing cattle on residues when the temperature is below freezing minimizes negative effects on soil compaction and roughness of the surface. Furthermore, they concluded that grazing residue changed subsequent soybean yields minimally, but the added value of grazing livestock at an economical cost may be of significance (Clark et al., 2004). Conclusive with other researchers, Sulc and Franzluebbers (2014) wrote a review of managing integrated cropping systems and explained that the most detrimental part of grazing residue is to the soil surface. However, managing the time of grazing can prevent the destruction of soil properties and the effect on grain yields (Sulc and Franzluebbers, 2014).

Soil properties and fertility

Having adequate soil organic matter (SOM) allows the retention of N and water in the system (Wortman et al., 2012). Soil organic matter is dominated by the amount of aggregate formation, thereby management strategies that disrupt this phenomenon reduce the productivity and stability of the soil (Hammerbeck, 2012).

Removal of residue can cause a deficit in the soil nutrients making the following year’s crop fertility requirements greater. Seemingly, there is often more nutrients exported from the system than inputted due to crop removal (Wortman et al., 2012). Removing the corn residue has negative impacts on the physical and chemical properties of the soil. The more residue removed, the greater the impact on soil properties (Hammerbeck, 2012). However, applying manure to the system increased nutrients such as organic matter carbon, Ca, K, P, Zn and Mg (Wortman et al., 2012).

Kenney et al. (2015) indicates that soil temperature fluctuations and water erosion increase with stover removal, thereby affecting soil properties. Rain fed locations were more variable than the irrigated sites as residue was removed; however, the irrigated sites had an increased level of residue which seems to depress the soil changes in comparison to the rain fed. The soil contains many nutrients that are necessary for plant growth and development, so the removal of these nutrients without replacing them can be costly.

Nutrient removal

As corn residue is removed from the crop field, nutrients are effectively removed as well. However, grazing cattle on residue does return some nutrients back to the field. Magdoff (1978) reported that liquid manure applications have a positive effect on soil fertility, and depending on the manure N level, provide N for plant growth. Having cattle graze corn ground means that some nutrients will be re-applied to the soil. Depending on the soil type, the soil concentration of N, P, Ca and Zn nutrients after continuous stover harvest by grazing may not change (Johnson et al., 2010).

Wortman et al. (2012) noted that in corn-based systems, the amount of K removed from the soil by the crop equaled 76-79 kg per hectare. In terms of P, removed by the crop, the amounts average 70-73 kg per hectare. Nitrogen removed from harvesting corn stover ranged from 34-42 kg per hectare, depending on the height of the cut (Hoskinson et al., 2007). Cutting height becomes important when removing residue as it affects the amount of nutrients removed from the soil. The removal of solely grain rather than residue leaves more nutrients in the field (Johnson et al., 2010). Normal cutting height of 75 cm from the soil surface removed 27.5 kg / ha of Ca, while low cut of 10 cm from soil surface removed 24.7 kg / ha Ca in the stover (Hoskinson et al., 2007). Phosphorus and K removal by stover averaged 3.9 kg / ha and 34 kg / ha, respectively. Zinc removal was 25 and 46 g/ha, respective to cutting height low and normal (Hoskinson et al., 2007).

The removal of residue will also affect the amount and type of fertilizer needed to replace the nutrients removed. The removal of nutrients from the soil comes with a price, so the economics behind whether or not to remove stover becomes an opportunity cost and decision (Johnson et al., 2010). The estimates of nutrient cost for stover removal vary. Perlack and Turhollow (2003) summarized several authors indicating that the range in price of stover collection is from $43.10 – 51.60 per dry ton depending on the assumptions. Farmers should be compensated about $10 per dry ton for nutrients removed. Delivery cost is based on the availability of corn residue as well as the corn yield and amount of stover removed from fields (Perlack and Turhollow, 2003).

Corn residue is an abundant resource, and there are many opportunities for utilization of this resource. Baling, grazing, or leaving the residue on the surface present several issues and opportunities to harvest the by-product of the corn grain industry, in addition to the corn grain itself.

Calcium Oxide Treated Corn Stover and Distillers Grains

Grazing corn residue and supplementing with distillers grains with solubles

Wilson et al. (2004) suggested that 39% of the corn residue is husk and leaf, the most palatable pieces of the corn plant. Calves select for the grain first, followed by the husk and leaf (Gutierrez-Ornelas and Klopfenstein, 1991). The digestibility of corn residue ranges from 50-60% (Wilson et al., 2004). Protein is a necessary component that is often limiting in corn residue diets; protein supplementation is necessary when grain levels in the field decrease as the protein content in the fibrous parts is not enough for a growing calf (Gutierrez-Ornelas and Klopfenstein, 1991). Fernandez Rivera and Klopfenstein (1989) reported that the nutrient first limiting in growing calves on cornstalks is protein. The longer calves are out on a cornstalk field, the greater the decrease in nutritive value of the forage due to the least digestible parts being left to graze. Starch content decreased as calves grazed and NDF content increased. Protein available to the animal decreased from 11 to 6%, depending on the corn management type, as time continued on that same field (Fernandez-Rivera and Klopfenstein, 1989).

Klopfenstein (1996) concluded that distillers grains with solubles (DGS) have a lower starch and higher fiber content than corn, making them a likely choice for calf diets as they reduce the risk of acidosis and provide necessary nutrients. The removal of starch from the corn during the fermentation and distillation processes causes the available nutrients to be three times as concentrated (Klopfenstein, 1996). The supplementation of dried distillers grains with solubles (DDGS) to calves on cornstalks increased ADG and stocking rate due to decreased forage intake (Gustad et al., 2006; Jones et al., 2014; Jones et al., 2015). Using this concept, corn residues that are baled and fed in growing or finishing diets at the feedlot require protein. Therefore, coupling corn residue and distillers grains into a product may make transport, handling and feeding easier and cost-effective.

Feeding value of DGS

Historically, distillers grains were used as a protein source rather than an energy source, but with the cost effectiveness and quantity of the by-product when corn prices were high, the opportunity to replace corn with the distillers by-product arose. Dried distillers grains with solubles offers 130% the value of corn in energy (Klopfenstein, 1996). If distillers were wet and fed at 40% of the diet, they would provide from 132 to 174% the energy value of dry rolled corn in finishing diets (Klopfenstein, 1996; Bremer et al., 2011). Feeding a low-quality forage with wet distillers grains with solubles (WDGS) worked well in feedlot systems as diet conditioning and palatability improved (Klopfenstein et al., 2008). Distillers grains plus solubles (DGS) fed to growing cattle have 136% energy of corn (Ahern et al., 2016). Loy et al. (2003) reported that adding dried DGS to a hay diet improved gain and efficiency when compared to corn.

The production of distillers grains by-products is dependent on the processing. Ahern et al. (2016) notes that distillers grains (wet or dry) will have a greater energy value than corn in forage diets. Wet and dry distillers grains plus solubles have equal energy values averaging 136.5% the value of dry rolled corn in growing or forage based diets (Ahern et al., 2016). The process of wet and dry milling of corn for ethanol production, and thereby, the production of distillers grains is outlined by Erickson et al. in a manual devised in conjunction with the Nebraska Corn Board for producers (2005). Distiller’s grains by-products have become a huge asset for the cattle feeding business due to the cost-effectiveness and availability from ethanol production of the by-products compared to corn (Stock et al., 2000).

CaO treatment- method to utilizing cornstalks

At the time of harvest, corn stalks have high concentrations of cell wall and lignin, making the stalks less digestible, about 50% (Klopfenstein, 1978). Klopfenstein summarized various chemical treatments that were used to solubilize hemicellulose and increase the rate and extent of digestion of the residue. When corn prices are high, it is cost effective to utilize chemical treatments to change the nutritive value of the corn residue. Klopfenstein (1978) utilized sodium hydroxide as it provided the greatest improvement and had favorable binding qualities, but Oji et al. (1977) argued that calcium oxide (CaO) reduced treatment costs, especially if the process is done on farm. Kaar and Holtzapple (2000) concluded that treating corn residues with calcium hydroxide provides a nine-fold increase in the B-glucosidase or cellulase enzyme's ability to hydrolyze bonds compared to corn stover that was not treated. Sixty percent of the cellulose is enzymatically converted to monosaccharides providing the potential for greater digestibility by a calf (Kaar and Holtzapple, 2000).

The amount of CaO used to treat the residue becomes an important component. The addition of 1.2% CaO to a DGS diet allowed for an increase in ruminal pH by as much as 1.82 units at one time point in the study but did not improve fiber disappearance in situ (Schroeder et al., 2014). Duckworth et al. (2014) fed a finishing diet consisting of 20% corn stover, both 5% CaO treated and untreated, with modified distillers grains with solubles (MDGS) and found that the CaO treated residue increased digestibility, but the overall improvement in growth performance did not occur (Duckworth et al., 2014). Shreck et al. (2015b) showed that an increase in forage digestibility results from chemically treating corn stover with calcium oxide at 5%. Shreck et al. (2015a) fed a

CaO treated corn stover product in combination with distillers grains, and it provided a competitive advantage for feedlot producers in terms of performance and cost if corn price was high. Nunez et al. (2014) added varying levels of CaO to a 60% DDGS diet and found that increasing the level of CaO improved fiber digestibility and stabilized rumen pH, as well as, increased VFA production and improved ADG. Authors cautioned that levels greater than 1.6% inclusion of CaO in diet DM tend to reduce DMI and palatability, most likely due to chalky texture, resulting in no improvement in ADG (Nunez et al., 2014). Peterson et al. (2015) conducted two experiments evaluating CaO treated corn residue and saw increased performance (ending BW, ADG, and feed conversion) with the use of 5% CaO treated corn residue in growing diets. In addition, Peterson et al. (2015) evaluated feeding treated corn residue in growing diets, and they concluded that both pelleting and chemical treatment with CaO caused an increase in performance, DMI and ADG, but feed efficiency improved with only CaO treatment.

Duckworth et al. (2014) and Russell et al. (2011) agreed that CaO treated stover silage provides moderate gains and feed efficiency with Russell et al. (2011) declaring a 83.2% DM digestibility of the silage. These studies were performed with feedlot cattle, not with growing cattle, so research with treated stover on growing calves is needed.

Feeding DGS and CaO treated stover

Feeding CaO treated stover with DGS provides a good combination in cattle diets. The binding qualities that chemically treating stover produced back in 1978 by Klopfenstein led to research that dealt with putting the residue and DGS into a combination pellet for ease of handling. Sewell et al. (2009) fed a pellet consisting of 75% residue and 25% DDGS compared to a dry rolled corn finishing diet. They found that it was plausible to feed the combination as it increased DMI and maintained acceptable performance, although at that combination level did not outperform dry rolled corn (Sewell et al., 2009). Gramkow et al. (2016) fed 40% MDGS with pelleted treated corn stover and DDG, a replacement for 20% of the corn, to finishing steers and found no loss of performance. They recommended a diet with up to 10% of the corn replaced with 20% MDGS and a pellet containing treated corn stover and DDG would not negatively impact performance.

Shreck et al. (2015a) evaluated feeding a diet to growing calves with 10, 25, and 40% dry rolled corn replaced with 2:1 or 3:1 MDGS and additional treatments with 3:1 ratios of MDGS and wheat straw or corn stover. They found that feeding up to 20% corn residue and at the minimum 25% of corn in a calf diet, performance might be optimized for growing calves fed a combination of corn residue and modified distillers grains with solubles. Peterson et al. (2014) fed a pelleted corn residue consisting of 35% corn residue and a blend of by-products with minerals to receiving calves. They found that the calves gained over 1.35 kg / day with a G:F of 0.114, making feeding received calves the pelleted residue a possibility when cost effective.

Gramkow et al. (2016) fed a diet consisting of untreated corn stover and MDGS compared to a complete pelleted feed composed of CaO treated corn stover dry distillers grains (DDG) and supplement in a growing diet. The results show that the complete pelleted feed pair fed with MDGS provided similar performance, except that greater DMI and ADG were observed in the pelleted feed (Gramkow et al., 2016). The utilization of pelleting to feed treated corn stover in the diet was compared to unpelleted treated corn stover in a study done by Carlson et al. (2016a). The pelleted treated corn stover product was composed of 18.75% solubles, 12.5% treated corn stover and 18.75% high protein dried distillers grains plus solubles. The study showed no differences in performance, except that the pelleted treated corn stover product had a lower DMI (P = 0.03). However, replacing distillers grains with treated corn stover and the addition of components such as isolated bran (fiber), high protein dried distillers grains with solubles (DDGS, protein), and solubles did not provide the same performance as distillers grains (Carlson et al., 2016a). Several combinations of DGS and CaO treated stover show that the combination is a good one; however, the energy density of the CaO treated stover needs to be improved.

Isolating components and feeding value resulting of DGS

It is known that the ethanol industry removed oil from the DGS because the nutrient was more valuable than DGS, and in the same way, removing the fiber in cellulosic ethanol has become popular. The goal of distillers work in the last decade is to determine the value of each component individually in order to evaluate the change in DGS value if one component is removed. Conroy et al. (2016) found that when nutrients in MDGS were isolated, the protein factor, in this case 20% corn gluten meal, provided similar feed conversions with a feeding value of 134% the value of corn. It was further suggested that the amino acid carbon backbone may be the determining factor of the MDGS feeding value when cattle are fed diets high in forage.

A study by Oglesbee et al. (2016) evaluated the various nutrient components of WDGS that made up its feeding value and found that the composite diet of fat (whole fat germ), protein (corn gluten meal), fiber (corn bran and solvent extracted germ meal) and solubles provided an equal feeding value to that of WDGS. A 2-8% increase in the feeding value was noticed as the addition of whole fat germ to the diet caused DMI to decrease and G:F to improve. Another study looked at the feeding value of WDGS with differing protein concentrations, and it was determined that a large proportion of the feeding value of WDGS is due to the protein content (Carlson et al., 2016b). Bremer et al. (2014) noticed that higher fat content in normal 12% MDGS caused lower DMI as compared to de-oiled 7.2% fat MDGS. Removing oil from MDGS (7.2% fat resulting) did not change cattle performance when fed a forage-based diet (Bremer et al., 2014).

Adding glycerin

Fat is often added to a diet to increase the energy density of the diet (Fluharty and Loerch, 1997). Some of fat in DGS is protected in the rumen from biohydrogenation, so there is greater unsaturated fat in the small intestine (Klopfenstein et al., 2008). Zinn and Jorquera (2007) reported that the feeding value of fat can vary based on the type and source, fatty acid concentration, and method and level of supplementation. The digestion of fiber can become limited as fat is added to the diet. Biohydrogenation allows for unsaturated fats that are toxic to the rumen to be converted to saturated fats that can be absorbed and utilized by the animal (Zinn and Jorquera, 2007).

Fluharty and Loerch (1997) said that past research showed that additions of fat to a corn diet showed no improvements in performance. Therefore, they conducted a study where they fed newly received feedlot calves a diet with 4% animal-vegetable blend and found that the calves improved ADG and feed efficiency in the second week of the trial. There was a shift in VFA profile to more propionate with the addition of animal-vegetable fat (Fluharty and Loerch, 1997). Vander Pol et al. (2009) concluded that substituting fat in equal quantities of corn oil or fat from distillers grains in high moisture corn or dry rolled corn diets did not provide the same animal performance, but if tallow is compared to fat from DDGS, then similar animal performance resulted in finishing diets. They believe the WDGS provides lower acetate to propionate levels, more fat was digested and more unsaturated fats went into the small intestine (Vander Pol et al., 2009).

Gunn et al. (2010) commented that glycerin becomes a good, cheap alternative of fat as the biodiesel industry continues to expand. Gunn et al. (2010) conducted a study where 1, 5, 10, 15, and 20% dietary crude glycerin was added to a starch-based diet. They found that supplementing up to 15% crude glycerin in the diet improved performance of the wethers. Feeding 20% crude glycerin caused a decrease in G: F and ADG (Gunn et al., 2010). Hales et al. (2013) suggested that a change in performance is observed depending on the source that glycerol replaced, roughage or grain. In growing calf diets, replacing 7.5% alfalfa hay with glycerol produced beneficial performance for calves as the energy density increased (Hales et al., 2013). Krehbiel (2008) noted that ruminal microorganisms adapted to increased levels of glycerol rapidly when glycerol was fed. Adding glycerin to CaO treated stover may have the ability to improve cattle performance.

Grazing Alternative Forage Crops

Benefits of cover crop

Crops that cover the soil and provide a forage source for livestock enable the producer to harvest a cash crop and maintain soil cover. Koch et al. (2002) noted that brassicas are a good secondary crop that can be grown after a small grain and are a high quality, cost-effective source for fall grazing. An additional reason to grow turnips is to rejuvenate a poorly performing pasture (Jacobs et al., 2004).

Planting date

The time of year that the brassica is planted plays a role in how much forage is produced. Bringing animals into the feedlot after weaning can be a difficult transition in terms of gain and health. The opportunity to graze the livestock on a brassica mix can have a positive effect on performance (Koch et al., 2002). Koch et al. (2002) planted a turnip crop in July, which produced 3,900 kg dry matter / ha, while August planted turnips produced an average of 2,500 kg dry matter / ha. They observed a reduction in yield each week, so it could be expected that mid-August would have half the growth as a crop planted in July. Between species, the radish produced more aboveground biomass, while the turnip produced more below ground biomass in the root. This is due to the movement of the dry matter from top to root as the crop matured and was grazed later (Koch et al., 2002).

Wiedenhoeft and Barton (1994) explain that once forage is cut, the regrowth tends to be higher in protein and lower in fiber. Planting the brassicas later leads to a greater protein concentration in forage as much as 8 percentage units. Earlier planted forage will have a greater NDF compared to later planted forage, due to the maturity of the forage (Wiedenhoeft and Barton, 1994). Wiedenhoeft and Barton (1994) also observed that younger regrowth contains greater concentrations of minerals such as Mg and Ca. Phosphorus remained consistently the same, regardless of planting date in turnips. However, the level of P increased when planting was delayed. They iterated that protein and fiber content of forage is negatively correlated. Neutral detergent fiber ranged from 14 to 42% across planting dates and ADF ranged from 11 to 36%, but overall brassicas are comparable to a good quality corn silage. Fall planted brassicas tend to have lower

NDF than summer planted (Wiedenhoeft and Barton, 1994). The greatest growth rate in Vollenda turnips was between 5 to 8 weeks after planting, but noted that one site had potential to continue growing as growth factors were not limiting (Jacobs et al, 2004).

With planting dates in the late summer, forage growth may be limited depending on the environmental factors. As documented by Van Soest (1991), forages in the summer undergo environmental stress which correlates to lower quality nutritive values of the forage, in December, Wiedenhoeft and Barton (1994) reported that the nutritive content of forages remained high quality. In warm temperatures, fiber contents increased and protein declined, making the regrowth cut from a later planting date to be higher quality compared to the regrowth cut from an earlier planting date (Wiedenhoeft and Barton, 1994). However, a delay in planting meant that the crop was less productive. A later planting date did not allow for greater dry matter accumulation (Koch et al., 2002). The nutritive value of the crop could be greater if the volunteer ryegrass emerged, but the competition was at the cost of the brassicas' germination (Koch et al., 2002).

Economics

Economically, being able to plant and utilize a second crop enables a producer to maximize available resources and produce a high quality forage in the fall season (Koch et al., 2002). McFerran et al. (1997) noted that the cost to feed turnips per kg DM was 7 cents, whereas pasture totaled 3 to 5 cents per kg DM. In 2002, Koch et al. noted that it costs approximately $220 to 250 per hectare to grow and graze turnips and radishes, which equates to $0.72 to 0.79 per kg of gain. Koch et al. (2002) seeded turnips at 2 to 3 kg / ha and radishes at 25 to 28 kg / ha. The crop was planted on several dates from July 17 to August 12. Turnip grazed lambs were compared to other brassicas grazed lambs, and it was noted that the brassica groups performed similarly, but when compared to lambs in the drylot, the brassica lambs had poorer performance (Koch et al., 2002). Jacobs et al. (2004) reported that it costs $576 / hectare to grow dryland turnips, including, fertilizer, seed and chemical costs. The costs of production vary based on what resources are available, in addition to the environmental conditions.

Livestock grazing cover crops

The ability to graze livestock on cover crops becomes an important benefit for livestock producers looking for crop ground to graze. Forages containing a greater concentration of readily fermentable carbohydrates to structural carbohydrates are digested more quickly in the rumen (Barry, 2013). The readily fermentable carbohydrates (CHO) of brassicas are in the form of water soluble carbohydrates (WSC). The high WSC, low NDF predict the risk of subacute acidosis due to the readily fermentable carbohydrates causing a lower ruminal pH (Westwood and Mulcock, 2012).

Rowe and Neilsen (2011) showed that early on in brassica growth, there is a greater leaf to root ratio, but as the plant matures and the tuber develops, the ratio declines. Yun et al. (1999) noted that from the month of October to November, radish shoot growth declined from 77% to 66%, and the percentage shoot growth for turnip shoots dropped from 55% to 30%. Jacobs et al. (2004) mentioned that irrigation of a crop can be used to determine the amount of forage for grazing as irrigation allows an increase in leaf and root DM content. They commented that farmers assume a 10% DM content when grazing turnips (Jacobs et al., 2004). McFerran et al. (1997) acknowledged that increasing the proportion of turnip in a pasture-based system may allow for an improvement in cow condition, but increasing the level to greater than 50% of the diet may lead to repercussions, such as tainted milk and deficiencies in NDF.

Nutrient quality of brassicas

Turnips and radishes can be variable in terms of nutritive value. Time of year and maturity change the nutrient composition. Koch et al. (2002) found that turnip tops averaged 11.5 to 17.7% crude protein (CP), while the root averaged a bit lower (7.2-13.2% CP). Radish tops averaged 11.9% CP. From late October to early January, CP decreased in both the tops and roots. Turnips lost 3.4 percentage units in the tops and 1.1 percentage units in roots. The brassicas tend to be lower in fiber and higher in CP (Koch et al., 2002). For brassica production, the limiting nutrient is nitrogen, which in turn, dictates the crude protein concentration in the forage (Koch et al., 2002). Yun (1999) reported that from October to November turnip tops declined 4.5 percentage units (11.5 to 7.0%) and radish tops declined 4.4 percentage units (12.7 to 8.3%).

When considering dryland versus irrigated forage crops, Rowe and Neilsen (2011) reported that irrigated Barkant turnips showed an increase in leaf WSC and nitrogen uptake when water was supplied at vegetative stages as compared to rainfed turnips; however, a decrease in CP resulted. The low levels of CP indicate that there was a nitrogen availability issue (Rowe and Nielsen, 2011). Jacobs et al. (2004) found that as more nitrogen was applied (50 kg N/ha), the Ca content decreased in the leaf, but Ca and S content increased in the root. Crude protein contents of dryland turnip leaf ranged from 11 to 24%, while the root ranged from 6 to 17% CP (Jacobs et al., 2004). Providing more nitrogen to the plants allows an increase in leaf CP, but a decrease in leaf WSC. Yun et al. (1999) noted that greater CP occurred in low density plant populations, resulting in better N utilization. This could be advantageous as a higher protein diet is needed for growing calves.

As the amount of NDF increases in the forage, the intake of the crop decreases. Turnips tops and roots had a NDF content of 23.8 and 20.9%, respectively (Koch et al., 2002). For the leaf, the average NDF reported by Rowe and Neilsen (2011) was 16.4-27.5%, while the root averaged 13.3-23.7% NDF in spring sown turnips. Jacobs et al. (2004) found that NDF ranged from 22-34% and 18-27% for leaf and root, respectively. McFerran et al's (1997) belief may be the most correct pertaining to the turnips that the maturity of the forage is the reason why there are differing NDF values. Overall, brassicas have a lower fiber content, this causes a higher IVDMD. The turnip top and root averaged 85.7 and 86.4%, respectively (Koch et al., 2002).

The ADF content of the turnip tops and roots was 19.8 and 17.2%, respectively (Koch et al., 2002). The digestibility of the diet decreased as the ADF content increased due to the increase in the amount of mature fibrous components (Koch et al, 2002). Yun et al. (1999) writes that a high rate of forage digestion happens when there is low ADF, and with a low NDF, there is a greater intake potential. From October to January, the NDF and ADF content of the turnip tops increased 4 percentage units (Koch et al., 2002). Again, the perception of McFerran et al. (1997) is that the difference in turnip NDF values is most likely due to the maturity of the forage, whether the turnip is grazed early or late in the season, affects the nutrient content of the diet.

Cassida et al. (1994) discussed previous literature and concluded that turnips provide the same effect in the rumen as a high concentrate diet when considering the decreased cellulytic activity due to the lowered ruminal pH. The high water and low fiber content of the brassicas may explain the faster rate of passage through the rumen. Supplying hay to a brassica diet may offset the anti-quality factors consistent in the nutrient makeup as well as increase the fiber and DM intake of the diet (Cassida et al., 1994).

Anti-quality factors

Brassicas are known for having compounds that are known as ‘anti-quality factors’ meaning a compound depresses the quality of the forage crop chemically. Secondary S-containing compounds in brassicas, such as S-methyl cysteine sulfoxide (SMCO), glucosinolates and nitrates can cause reduced feed intake as these compounds are converted to toxins. The effects are not well defined, but the physical evidence is that feed intake is lowered (Barry, 2013). Barry (2013) reported that turnips contained 0.69% sulfur. The maximum tolerable level for dietary sulfur in cattle is 0.40% (NRC, 1996). Goitrogens affect the thyroid gland by tying up iodine, making the animal unable to regulate the thyroid due to iodine deficiency (Barry, 2013), thereby goiter is the body’s way of dealing with low iodine in the diet (Knowles and Grace, 2015). Iodine supplementation can help to reduce the effects of goiter and is recommended in goitrogenic plant diets (Knowles and Grace, 2015).

Barry (2013) explained that the availability of Cu decreases as inorganic sulfate is reduced to sulfide in the rumen as the two minerals interact. The sulfide compound is also thought to interact with proteins, thereby tying up the protein in the diet. Protein metabolism is affected by dimethyl disulfide causing low amino acid absorption. This could be reasoned as to why there is decreased animal growth when animals consume solely brassicas (Barry, 2013). Gustine and Jung (1985) recommended not feeding brassicas as the sole feed source due to the antagonistic properties of the glucosinolate and SMCO.

Other crops can also have anti-quality factors that must be considered when developing a mix. If sorghum is in the crop mix, the anti-quality factor it is noted for is hydrocyanic acid (HCN). The level of HCN in sorghum decreases after a frost or freezing occurs as the plant dies and nutrient uptake ceases (Wattenbarger et al., 1968). Wattenbarger et al. (1968) said the HCN ppm reached zero 2-5 days following a frost, therefore, if grazing sorghum, it may be best to wait at least a week before putting cattle out on a sorghum pasture. Ensuring that the mix contains enough fiber and knowing when to graze crops with anti-quality factors can help to ensure that animal performance is maintained or improved (Lambert et al., 1987).

Performance on brassicas

Barry (2013) reported that when feeding brassicas as the sole forage source in a growing lamb's diet, the animals had lower performance than expected. Koch et al. (2002) reported lambs gaining 0.183 kg per day, while the average gain for lambs on turnips was 308 kg / ha. Yun et al. (1999) observed that lambs gained about 277 and 329 kg / ha on turnips in a two year study. They also observed that lambs on radishes gained 266 and 298 kg / ha with 0.13 and 0.17 kg ADG between two locations (Yun et al., 1999). Yun et al. (1999) reported that when comparing lambs grazing turnips to those in the feedlot, in the first 5 to 6 weeks, the grazing lambs had similar gains as feedlot lambs on a 35% corn, 35% barley and 30% alfalfa hay diet. Once 60-75% of forage is consume by growing lambs, they suggested that grazing animals with a lower nutritional requirement should be used to completely utilize the forage. Thus, indicating that the higher proportion of nutrients are found in the leaves (Yun et al., 1999).

Since brassicas are a low fiber crop, Lambert et al. (1987) indicated that fiber additions to the diet improved performance. Koch et al. (2002) compared lambs on a feedlot diet to lambs grazing turnips and observed no difference in gain (0.20 and 0.18 kg/d, respectively). Westwood and Mulcock (2012) reported that when feeding a diet solely composed of brassicas, the NDF content was too low to meet optimal rumen function. The minimum NDF content to support optimal rumen function should range from 27-30% DM (Westwood and Mulcock, 2012). McFerran et al. (1997) reported that in order to balance a summer pasture and turnip diet, the effective NDF content must be greater than 65%. Due to the low NDF content, the turnips may possibly be digested faster than forage grasses as there is less fiber to digest (McFerran et al., 1997).

Conclusions and Research Needs

There are a number of opportunities for feeding growing calves with corn residues and DGS. However, the system must meet the needs of the soil, plant and animal for the most sustainable and profitable outcome. Crop and cattle producers will have to settle terms that will allow for benefits for each party in order to best manage the resources present. With the multitude of corn residue on fields, producers can graze a portion of it, bale some to remove residue off the field and then use it as a feed source in growing calf diets, or graze a double-cropped forage after a cash crop is harvested. The following research enables both livestock and crop producers to evaluate the benefits or challenges to utilizing by-products such as, corn residue, distillers grains and brassica mixes in a system that manages the resources and provides beneficial outcomes for both parties.

LITERATURE CITED

Ahern, N.A., B.L. Nuttelman, T.J. Klopfenstein, J.C. MacDonald, G.E. Erickson, and A.K. Watson. 2016. Comparison of wet or dry distillers grains plus solubles to corn as an energy source in forage-based diets. Prof. Anim. Sci. In press.

Barry, T.N. 2013. The feeding value of forage brassica plants for grazing ruminant livestock. Anim. Feed Sci. and Technol. 181(1), 15-25.

Blanco-Canqui, H., R. Lal, W.M. Post, and L.B. Owens. 2006. Changes in long-term no-till corn growth and yield under different rates of stover mulch. Agron. J. 98(4), 1128-1136.

Bremer, M. L., A.K. Watson, D.B. Burken, J.C. MacDonald, and G.E. Erickson. 2014. Energy value of de-oiled modified distillers grains plus solubles in a forage-based diet. Nebraska Beef Cattle Rep. MP99. 32-33.

Burken, D.B., T.J. Klopfenstein, and G.E. Erickson. 2013a. Economics of feeding elevated levels of corn silage in finishing diets containing MDGS. Nebraska Beef Cattle Rep. MP98:76-77.

Burken, D.B., J.L. Harding, A.L. McGee, T.C. Hoegemeyer, T.J. Klopfenstein, and G.E. Erickson. 2013b. Effects of corn hybrid, plant density, and harvest time on yield and quality of corn plants. Nebraska Beef Cattle Rep. MP98:42-43.

Burken, D.B. 2013c. Effects of Corn Hybrid, Plant Density, and Harvest Time on Yield and Quality of Corn Plants. MS Thesis. University of Nebraska-Lincoln.

Burken, A.J. 2014. Changes in Corn Residue Quality throughout the Grazing Period and Effect of Supplementation of Calves Grazing Corn Residue. MS Thesis. University of Nebraska-Lincoln.

Cassida, K.A., B.A. Barton, R.L. Hough, M.H. Wiedenhoeft, and K. Guillard. 1994. Feed intake and apparent digestibility of hay-supplemented brassica diets for lambs. J. Anim. Sci. 72(6), 1623-1629.

Carlson, Z.E., C.J. Bittner, D.B. Burken, G.E. Erickson, and J.C. MacDonald. 2016a. Modifying different components of distillers grains and the impact on feedlot performance. Nebraska Beef Cattle Rep. MP101:128-131.

Carlson, Z.E., G.E. Erickson, J.C. MacDonald, and M.K. Luebbe. 2016b. Evaluation of relative contribution of protein in distillers grains in finishing diets on animal performance. Nebraska Beef Cattle Rep. MP101:132-134.

Clark, J.T., J.R. Russell, D.L. Karlen, P.L. Singleton, W.D. Busby, and B.C. Peterson. 2004. Soil surface property and soybean yield response to corn stover grazing. Agron. J. 96(5), 1364-1371.

Conroy, B.B., C.J. Bittner, J.C. MacDonald, M.K. Luebbe, and G.E. Erickson. 2016. Effects of feeding isolated nutrient components in MDGS on growing cattle performance. Nebraska Beef Cattle Rep. MP101:29-30.

Crookston, R.K., and J.E. Kurle. 1989. Corn residue effect on the yield of corn and soybean grown in rotation. Agron. J. 81(2), 229-232.

Cummins, D.G. 1970. Quality and yield of corn plants and component parts when harvested for silage at different maturity stages. Agron. J. 62(6), 781-784.

Daynard, T.B. and W. Duncan. 1969. The black layer and grain maturity in corn. Crop Sci. 9(4), 473-476.

DeLoughery, R.L., and R.K. Crookston. 1979. Harvest index of corn affected by population density, maturity rating, and environment. Agron. J. 71(4), 577-580.

Drewnoski, M.E., J.C. MacDonald, G.E. Erickson, K.J. Hanford, and T.J. Klopfenstein. 2016. Long-Term Corn Residue Grazing Improves Subsequent Soybean Yields in a Corn–Soybean Rotation. Crop, Forage and Turfgrass Mgt. 2(1).

Duckworth, M.J., A.S. Schroeder, D.W. Shike, D.B. Faulkner, and T.L. Felix. 2014. Effects of feeding calcium oxide on growth performance, carcass characteristics, and ruminal metabolism of cattle. Prof. Anim. Sci. 30:551-560.

Erickson, G.E., T.J. Klopfenstein, D.C. Adams, and R.J. Rasby. 2005. General overview of feeding corn milling co-products to beef cattle. Corn processing co-products manual, 3.

Fernandez-Rivera, S., and T.J. Klopfenstein. 1989. Diet composition and daily gain of growing cattle grazing dryland and irrigated cornstalks at several stocking rates. J. Anim. Sci. 67(2), 590-596.

Filya, I. 2004. Nutritive value and aerobic stability of whole crop maize silage harvested at four stages of maturity. Anim. Feed Sci. and Technol. 116(1), 141-150.

Fluharty, F.L., and S.C. Loerch. 1997. Effects of concentration and source of supplemental fat and protein on performance of newly arrived feedlot steers. J. Anim. Sci. 75(9), 2308-2316.

Gramkow, J.L., C.J. Bittner, M.L. Jolly, D.B. Burken, G.E. Erickson, and J.C. MacDonald. 2016. Effects of processing treated corn stover and distillers grains on total-tract digestion and performance of growing cattle1. Prof. Anim. Sci. 32(2), 183-191.

Gunn, P.J., M.K. Neary, R.P. Lemenager, and S.L. Lake. 2010. Effects of crude glycerin on performance and carcass characteristics of finishing wether lambs. J. Anim. Sci. 88(5), 1771-1776.

Gustad, K.H., T. J. Klopfenstein, G.E. Erickson, K.J. Vander Pol, J.C. MacDonald, and M.A. Greenquist. 2006. Dried distillers grains supplementation of calves grazing corn residue. Neb. Beef Cattle Rep. MP88-A:36-37.

Gustine, D.L., and G.A. Jung. 1985. Influence of some management parameters on glucosinolate levels in Brassica forage. Agron. J. 77(4), 593-597.

Gutierrez-Ornelas, E., and T.J. Klopfenstein. 1991. Changes in availability and nutritive value of different corn residue parts as affected by early and late grazing seasons. J. Anim. Sci. 69(4), 1741-1750.

Hales, K.E., R.G. Bondurant, M.K. Luebbe, N.A. Cole, and J.C. MacDonald. 2013. Effects of crude glycerin in steam-flaked corn-based diets fed to growing feedlot cattle. J. Anim. Sci. 91(8), 3875-3880.

Hammerbeck, A.L., S.J. Stetson, S.L. Osborne, T.E. Schumacher, and J.L. Pikul. 2012. Corn residue removal impact on soil aggregates in a no-till corn/soybean rotation. Soil Sci. Soc. Am. J. 76(4), 1390-1398.

Hoskinson, R.L., D.L. Karlen, S.J. Birrell, C.W. Radtke, and W.W. Wilhelm. 2007. Engineering, nutrient removal, and feedstock conversion evaluations of four corn stover harvest scenarios. Biomass and Bioenergy, 31(2), 126-136.

Jacobs, J.L., G.N. Ward, and G. Kearney. 2004. Effects of irrigation strategies and nitrogen fertiliser on turnip dry matter yield, water use efficiency, nutritive characteristics and mineral content in western Victoria. Anim. Prod. Sci. 44(1), 13-26.

Jaeger, S.L., M.K. Luebbe, C.N. Macken, G.E. Erickson, T.J. Klopfenstein, W.A. Fithian, and D.S. Jackson. 2006. Influence of corn hybrid traits on digestibility and the efficiency of gain in feedlot cattle. J. Anim. Sci. 84(7), 1790-1800.

Johnson, J.M., W.W. Wilhelm, D.L. Karlen, D.W. Archer, B. Wienhold, D.T. Lightle and A.D. Halvorson. 2010. Nutrient removal as a function of corn stover cutting height and cob harvest. Bioenergy Research, 3(4), 342-352.

Johnson, J. F., R.R. Allmaras, and D.C. Reicosky. 2006. Estimating source carbon from crop residues, roots and rhizodeposits using the national grain-yield database. Agron. J. 98(3), 622-636.

Jones, M., J.C. MacDonald, G.E. Erickson, T.J. Klopfenstein, and A.K. Watson. 2014. Effect of distillers grains supplementation on calves grazing irrigated or non-irrigated corn residue. Nebraska Beef Cattle Rep. MP99, pp. 48-49.

Jones, M., J.C. MacDonald, G.E. Erickson, T.J. Klopfenstein, and R. Bondurant. 2015. Dried Distillers Grains Supplementation of Calves Grazing Irrigated Corn Residue. Nebraska Beef Cattle Rep. MP101, pp.25-26.

Kaar, W.E., and M.T. Holtzapple. 2000. Using lime pretreatment to facilitate the enzymic hydrolysis of corn stover. Biomass and Bioenergy, 18(3), 189-199.

Kenney, I., H. Blanco-Canqui, D.R. Presley, C.W. Rice, K. Janssen, and B. Olson. 2015. Soil and crop response to stover removal from rainfed and irrigated corn. GCB Bioenergy, 7(2), 219-230.

Knowles, S.O. and N.D. Grace. 2015. Serum total iodine concentrations in pasture-fed pregnant ewes and newborn lambs challenged by iodine supplementation and goitrogenic kale. J. Anim. Sci. 93(1), 425-432.

Klopfenstein, T. 1978. Chemical treatment of crop residues. J. Anim. Sci. 46(3), 841-848.

Klopfenstein, T. 1996. Distillers grains as an energy source and effect of drying on protein availability. Anim. Feed Sci. and Technol. 60(3), 201-207.

Klopfenstein, T. J., G.E. Erickson, and V.R. Bremer. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86(5), 1223-1231.

Krehbiel, C.R. 2008. Ruminal and physiological metabolism of glycerin. J. Anim. Sci. 86(E-Suppl. 2):392. (Abstr.)

Koch, D.W., C. Kercher, and R. Jones. 2002. Fall and winter grazing of Brassicas-a value-added opportunity for lamb producers. Sheep and Goat Research J. 17(2), 1-13.

Lambert, M.G., S.M. Abrams, H.W. Harpster, and G.A. Jung. 1987. Effect of hay substitution on intake and digestibility of forage rape (Brassica napus) fed to lambs. J. Anim. Sci. 65(6), 1639-1646.

Larson, D.M., J.L. Martin, D.C. Adams, and R.N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. J. Anim. Sci. 87(3), 1147-1155.

Loy, T., T.J. Klopfenstein, G.E. Erickson, and C. Macken. 2003. Value of dry distillers grains in high-forage diets and effect of supplementation frequency. Nebraska Beef Cattle Rep. MP85, pp. 8-10.

Magdoff, F.R. 1978. Influence of manure application rates and continuous corn on soil-N. Agron. J. 70(4), 629-632.

McFerran, R.P., W.J. Parker, V. Singh, and S.T. Morris. 1997. Incorporating turnips into the pasture diet of lactating dairy cows. In PROCEEDINGS-NEW ZEALAND SOCIETY OF ANIMAL PRODUCTION (Vol. 57, pp. 161-164). NEW ZEALAND SOCIETY OF ANIMAL PROD PUBL.

McGee, A.L., M. Johnson, K.M. Rolfe, J.L. Harding, and T.J. Klopfenstein. 2012. Nutritive value and amount of corn plant parts. Nebraska Beef Cattle Rep. MP95:11-12.

McGee, A.L., J.L. Harding, S. van Donk, T.J. Klopfenstein, and L.A. Stalker. 2013. Effect of Stocking Rate on Cow Performance and Grain Yields When Grazing Corn Residue. Nebraska Beef Cattle Rep. MP98:36-37.

Musgrave, J., J.A. Gigax, L.A. Stalker, T.J. Klopfenstein, M. Stockton, and K.H. Jenkins. 2011. Effect of corn hybrid on amount of residue available for grazing. Nebraska Beef Cattle Rep. MP94:38-39.

Nebraska Corn Board. 2016. "Corn Production." http://www.nebraskacorn.org/corn- production-uses/corn-production/

NRC. 1996. Nutrient requirements of beef cattle. 7th rev. ed. (update 2000). Natl. Acad. Press, Washington, DC.

Nuñez, A.J.C., T. L. Felix, R.P. Lemenager, and J. P. Schoonmaker. 2014. Effect of calcium oxide inclusion in beef feedlot diets containing 60% dried distillers grains with solubles on ruminal fermentation, diet digestibility, performance, and carcass characteristics. J. Anim. Sci. 92:3954-3965.

Oglesbee, R.A., C.J. Bittner, F.H. Hilscher, G.E. Erickson, J.C. MacDonald, and M.K. Luebbe. 2016. Evaluation of distillers grains components singly or in combination in a calf fed feedlot study. Nebraska Beef Cattle Rep. MP103:124-127.

Oji, U.I., D.N. Mowat, and J.E. Winch. 1977. Alkali treatments of corn stover to increase nutritive value. J. Anim. Sci. 44(5), 798-802.

Perlack, R.D. and A.F. Turhollow. 2003. Feedstock cost analysis of corn stover residues for further processing. Energy, 28(14), 1395-1403.

Peterson, S.J., B.L. Nuttelman, D.B. Burken, J.C. MacDonald, M.K. Luebbe, and G.E. Erickson. 2014. Use of a pelleted corn residue complete feed in receiving diets. Nebraska Beef Cattle Rep. MP 99:64-66.

Peterson, S.J., A.L. Shreck, B.L. Nuttelman, C.J. Schneider, D.B. Burken, C.N. Macken, W.A. Griffin, J.L. Harding, G.E. Erickson, T.J. Klopfenstein, and J.C. MacDonald. 2015. Effects of alkaline treatment and pelleting of crop residues on performance of growing calves. Prof. Anim. Sci. 31(6), 552-558.

Russell, J.R., D.D. Loy, J. Anderson, and M. Cecava. 2011. Potential of chemically treated corn stover and modified distiller grains as a partial replacement for corn grain in feedlot diets. Anim. Industry Rep. 657(1), 10.

Pordesimo, L.O., W.C. Edens, and S. Sokhansanj. 2004. Distribution of aboveground biomass in corn stover. Biomass and Bioenergy, 26(4), 337-343.

Prince, S.D., J. Haskett, M. Steininger, H. Strand, and R. Wright. 2001. Net primary production of US Midwest croplands from agricultural harvest yield data. Ecological Applications, 11(4), 1194-1205.

Row, C.A., R.G. Bondurant, A.K. Watson, J.L. Harding, J.C. MacDonald, T.K. Klopfenstein, and G.E. Erickson. 2016. Effect of corn plant maturity on yield and nutrient quality of corn plants, 2-year summary. Nebraska Beef Cattle Rep. MP101:79-80.

Rowe, B.A., and J.E. Neilsen. 2011. Effects of irrigating forage turnips, Brassica rapa var. rapa cv. Barkant, during different periods of vegetative growth. 2. Nutritive characteristics of leaves and roots. Crop and Pasture Sci. 62(7), 571-580.

Schroeder, A.R., M. Iakiviak, and T.L. Felix. 2014. Effects of feeding dry or modified wet distillers grains with solubles with or without supplemental calcium oxide on ruminal metabolism and microbial enzymatic activity of beef cattle. J. Anim. Sci. 92:3997-7907.

Sewell, J.R., L. L. Berger, T. G. Nash, M. J. Cecava, P. H. Doane, J. L. Dunn, M. K. Dyer, and N. A. Pyatt. 2009. Nutrient digestion and performance by lambs and steers fed thermochemically treated crop residues. J. Anim. Sci. 87(3), 1024-1033.

Shinners, K.J., B.N. Binversie, R.E. Muck, and P.J. Weimer. 2007. Comparison of wet and dry corn stover harvest and storage. Biomass and Bioenergy, 31(4), 211-221.

Shreck, A.L., B.L. Nuttelman, C.J. Schneider, D.B. Burken, J.L. Harding, G.E. Erickson, T.J. Klopfenstein and M.J. Cecava. 2015a. Effects of grind size when alkaline treating corn residue and impact of ratio of alkaline-treated residue and distillers grains on performance of finishing cattle. J. Anim. Sci. 93(7), 3613-3622.

Shreck, A.L., B.L. Nuttelman, J.L. Harding, W.A. Griffin, G.E. Erickson, T.J. Klopfenstein, and M.J. Cecava. 2015b. Digestibility and performance of steers fed low-quality crop residues treated with calcium oxide to partially replace corn in distillers grains finishing diets. J. Anim. Sci. 93(2), 661-671.

Stalker, L.A., H. Blanco-Canqui, J.A. Gigax, A.L. McGee, T.M. Shaver, and S.J. van Donk. 2015. Corn residue stocking rate affects cattle performance but not subsequent grain yield. J. Anim. Sci. 93(10), 4977-4983.

Stock, R.A., J.M. Lewis, T.J. Klopfenstein, and C.T. Milton. 2000. Review of new information on the use of wet and dry milling feed by-products in feedlot diets. J. Anim. Sci. 77(E-Suppl), 1-12.

Sulc, R.M., and A.J. Franzluebbers. 2014. Exploring integrated crop–livestock systems in different ecoregions of the United States. European J. Agron., 57, 21-30.

Tracy, B.F., and Y. Zhang. 2008. Soil compaction, corn yield response, and soil nutrient pool dynamics within an integrated crop-livestock system in Illinois. Crop Sci. 48(3), 1211-1218.

Vander Pol, K.J., M.K. Luebbe, G.I. Crawford, G.E. Erickson, and T.J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87(2), 639-652.

van Donk, S., A.L. McGee, T.J. Klopfenstein, and L.A. Stalker. 2012. Effect of corn stalk grazing and baling on cattle performance and irrigation needs. Nebraska Beef Cattle Rep. MP95:8-10.

Van Soest, P.J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597.

Wattenbarger, D.W., E. Gray, J.S. Rice, and J.H. Reynolds. 1968. Effects of frost and freezing on hydrocyanic acid potential of sorghum plants. Crop Sci. 8(5), 526-528.

Westwood, C.T., and H. Mulcock. 2012. Nutritional evaluation of five species of forage brassica. In Proceedings of the New Zealand Grassland Association (Vol. 74, pp. 31-38).

Wiedenhoeft, M.H., and B.A. Barton. 1994. Management and environment effects on Brassica forage quality. Agron. J. 86(2), 227-232.

Wiersma, D.W., P.R. Carter, K.A. Albrecht, and J.G. Coors. 1993. Kernel milkline stage and corn forage yield, quality, and dry matter content. J. Prod. Ag. 6(1), 94-99.

Wilhelm, W.W., J.W. Doran, and J.F. Power. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron. J. 78(1), 184-189.

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.

Wortman, S.E., T.D. Galusha, S.C. Mason, and C.A. Francis. 2012. Soil fertility and crop yields in long-term organic and conventional cropping systems in Eastern Nebraska. Renew. Ag. and Food Sys. 27(03), 200-216.

Yun, L., D.W. Koch, F.A. Gray, D.W. Sanson, and W.J. Means. 1999. Potential of trap-crop radish for fall lamb grazing. J. Prod. Ag. 12(4), 559-563.

Zinn, R.A., and A.P. Jorquera. 2007. Feed value of supplemental fats used in feedlot cattle diets. Veterinary clinics of North America: Food Animal Practice, 23(2), 247-268.

CHAPTER II. Effect of Grazing or Baling of Corn Residue on Subsequent Crop Yields across Eastern Nebraska

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ABSTRACT

The amount of corn residue in the Midwest has increased with increased corn production. Cattle producers have utilized this resource as a feedstuff for grazing in the fall and winter and as a baled feed resource for future feeding. The objectives of this 2 year study were to determine how grazing or baling of corn residue affects subsequent grain yield, harvest index, and nutrients removed in multiple regions across Nebraska. At each location, there were 3 treatments: no bale-no graze (CON), baled (BLD), and grazed (GZD) with 2-3 reps per treatment per location. Hand harvest yield estimates were collected once the corn reached black layer stage of maturity. Harvest index was calculated based on the percentage of dry grain out of total biomass (grain plus stover). Data were analyzed using the MIXED procedure of SAS with location (nested within year) and treatment as fixed effects. No differences were observed among treatments for grain yield with CON having 14,050 kg grain DM/ha, BLD having yields of 15,034 kg grain DM/ha, and GZD with 14,750 kg grain DM/ha. There was no difference in stover yield among treatments (8,764, 8,977, and 9,193 kg / ha stover DM for CON, BLD, and GZD, respectively). There was no difference in harvest index among treatments (mean = 61.5%). Nitrogen removal in the form of anhydrous ammonia by baling varied considerably among cooperators, 10.1 to 117 kg / ha, while the amount of corn residue removed by baling ranged from 1, 174 to 7, 886 kg / ha. Results indicate that in the short term, removing corn residue provides a potential feed resource with no negative impact on grain yield or harvest index.

Keywords: corn residue, grazing, baling

INTRODUCTION

The amount of corn residue in the Midwest has increased with increased corn production over the years. According to the Nebraska Corn Board in 2015, corn yields averaged 10,613 kg per ha in 2015 and 34.7 million kg are produced in the state (2016). Perlack and Turhollow (2003) state that according to resources in 2000, the availability of corn stover and wheat straw averages 136 million metric dry tons with 28 million corn hectares harvested every year in the United States. Opportunities exist to remove the corn residue from the field as bales for feeding later, or grazing residue in the field. However, crop producers are concerned that corn residue removal will negatively affect the subsequent year's yield.

Clark et al. (2004) noted that cows winter grazing corn residue on a corn-soybean rotated field caused shallow soil compaction but negative effects on the subsequent grain yields are not common. Drewnoski et al. (2016) grazed cattle on corn residue in the fall and spring on fields in a corn-soybean rotation and concluded that there was no effect of grazing on subsequent corn yields, and soybean yields actually increased with the grazing of corn residue. Van Donk et al. (2012) found that yield differences were not evident on subsequent grain yields on fields under continuous corn management following the removal of corn residue by grazing, baling or leaving residue on fully irrigated fields in a two year study. Likewise, Stalker et al. (2015) found that on a no-till, continuous corn field, baling did not affect subsequent yields over a 5-year period. However, several studies have evaluated the effect of removing residue by baling and concluded baling large quantities (>50%) may affect crop yields (Blanco-Canqui and Lal, 2007; Karlen et al, 2014; Wilhelm et al. 1986). Blanco-Canqui and Lal conducted an 8-year study over three differing soil types and Karlen et al. summarized data on several different soil types across seven states, while Stalker et al. conducted their experiment over a 5-year period on one soil type.

Soil characteristics may be affected by removal of corn residue, which could affect subsequent crop production. Wilhelm et al. (1986) commented that residue plays key roles in soil protection, soil temperature control, and providing plants with nutrients. With grazing the main concern has been compaction of the soil when cattle are grazing and temperatures are above freezing (Franzluebbers and Stuedemann, 2008; Clark et al., 2004). However, with baling concerns about impacts on the soil, there is a wider range in results. The amount of residue removed may impact the soil aggregate stability and thus erodibility, which may lead to reduced soil organic matter (Hammerbeck et al., 2012). Blanco-Canqui et al. (2006) observed negative impacts on crop production on certain soil types in the short term if excessive amounts of residue were removed. On the other hand, higher yielding fields, on average 9.12 – 12.05 Mg / ha (9,120 – 12,050 kg / ha), may benefit from residue removal as large quantities of residue suppress subsequent grain yields (Karlen et al., 2014).

Baling and grazing of corn residue also differ in the amount of residue and nutrients removed. Removing the residue from the soil by baling results in the nutrients associated with residues being removed and if these nutrients are limiting in the soil they will require replacement by fertilization, while grazing means much of the nutrients removed are recycled back through manure and urine. Thus with baling, it is important to determine the amount of nutrients removed per hectare from the field to better determine additional costs that may be incurred through increased fertilizer needs.

The objectives of this 2-year study were to determine how grazing or baling of corn residue affects subsequent grain yield how the harvest index changes at multiple locations across Nebraska, and to calculate the amount of nutrients removed by baling of corn residue.

MATERIALS AND METHODS

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

In year 1, there were four locations in Nebraska (Ainsworth, Norfolk, Odessa, and Scottsbluff) and in year 2, two additional Nebraska locations (Nebraska City and Clay Center) were added. At each location, there were 3 treatments: no grazing or baling control (CON), baled (BLD), and grazed (GZD) with 2 replications per treatment in a single field. This was true for all locations, except for the Nebraska City location, which had two fields: one field having 2 reps of each treatment and the other having 3 reps per treatment and the Clay Center location which had 3 fields with each field having one replication per treatment.

Each field was in a continuous corn rotation, except for the Nebraska City, which was in a corn-soybean rotation and Scottsbluff that was in a corn, dry bean, and sugar beet rotation (Table 1). The Nebraska City location was rain-fed, Odessa had sub-surface drip irrigation and the other four sites were pivot irrigated. All locations were no-till, except for the Ainsworth site, which was disked.

Plant population was calculated by averaging the number of plants that had emerged in early spring (May or June) in two 5.33 meter rows and multiplying by 2,470 to obtain plants per hectare. All locations had a 76 cm row spacing for corn and the plant population ranged from 59,280 to 83,980 plants per hectare in year 1 and 48,165 to 81,510 plants per hectare in year 2. The median corn population across both years was 72,865 plants per hectare. Nebraska City had a soybean row spacing of 38 cm and a plant population of 96,330 to 153,140 plants per hectare with a median of 132,145 plants per hectare.

Grazed areas were fenced off, and cows were stocked based on corn yield with the target of 50% removal of husk and leaf (or 12% of total residue produced). It was assumed that there are 6.8 kg of husk and leaf per 25.4 kg of corn grain produced and that cows will consume 2% of their body weight per day (Fernandez-Rivera and Klopfenstein, 1989). Stocking rate was determined using the University of Nebraska's corn stalk grazing calculator (Stockton et al., 2013). Across all sites, the stocking rate was 4.3 animal unit months (AUM) per hectare with the range in cattle weight being 251 - 636 kg and the average grazing period being 41 d. Each site was stocked based on average cattle weight at that location and projected grazing days.

The baling was conducted by the cooperating farmer following corn grain harvest The bales from each replication were counted and weighed. Bales were sampled by taking a core from each bale, and core samples were composited into a bag for each replication. Half of baled corn residue samples were sent to Ward Laboratories, Inc (Kearney, NE) for analysis of N, Ca, P, and K by NIR spectrophotometry. This analysis was used to determine kg of NH_3, $CaCO_3$, MAP, and K_2O removed per hectare. Nutrient concentration of the corn residue sample was multiplied by a conversion factor (1.21 for NH_3, 2.5 for $CaCO_3$, 1.92 for MAP, and 2.29 for K_2O) to determine the amount of fertilizer that would have to be added to replace nutrient removed by baling.

The other half of the baled corn residue sample was ground through a 1 mm screen in the Wiley mill (Thomas Scientific, Swedesboro, NJ) prior to lab analysis. Samples were analyzed for ash and OM by placing the samples in crucibles and leaving in the 600°C muffle furnace for 6 hours (AOAC, 1999; Method 4.1.10). Neutral detergent fiber was determined using the procedure developed by Van Soest et al. (1991). Crude protein was determined using the combustion chamber (TruSpec N Determinator, Leco Corporation, St. Joseph, MI; AOAC, 1999; Method 990.03). To determine *in-vitro* digestibility of the samples, procedures followed a modified Tilley and Terry method (1963) where ruminal fluid and McDougall's Buffer were mixed at a 1:1 ratio with 1 g urea / L of McDougall's Buffer (Weiss, 1994). Ruminal contents were collected at hour 1200, from two donor steers that were fed the same diet consisting of 30% dried distillers plus solubles grains and 70% brome hay at hour 1500, and strained through 4 layers of cheesecloth (Grade 40, Veratec). Rumen fluid was mixed at a 1:1 ratio with McDougall's buffer (McDougall, 1948) and then 30 ml of the mixture was pipetted into 50-ml plastic tubes for incubation in 39 °C water bath for 48 hours. Three tubes for each sample were capped with rubber stoppers and swirled morning and evening to simulate mixing of digesta in rumen. After 48 hours, fermentation was ended by adding 6 mL hydrochloric acid and 2 mL of 5% pepsin solution per tube, and then replaced in the 39°C water bath with the rubber caps tightly fitted for an additional 24 hours. Tubes were then removed and placed in a freezer. Tubes were thawed in 39°C water bath for 15 minutes and filtered through Watman 541 filter paper (22 µm pore size), dried for 24 hours in a 100°C oven, and weighed to determine IVDMD. Blanks were included in each *in vitro* run in order to adjust for any feed particles that might have come from the rumen inoculum.

Additionally, three standards were included in each *in vitro* run. Each of these standards had an in vivo digestion value determined from previous studies (Updike et al. (2016), King et al. (2016), and Conway et al. (2017)), which could be used to adjust the *in vitro* digestibility to an in vivo digestibility. The adjustment was done by averaging all three *in vitro* digestibility values and subtracting it from the average of the three in vivo values. The difference between the in vitro and in vivo (4.63 percentage units) was added back to the in vitro value (i.e. adjusting it to in vivo).

Hand harvest

Hand harvest was done once corn reached black layer stage of maturity. Corn plants were cut from 5.33 meter rows (3 rows per replication) at the top of the crown root node (Lauer, 2002), corn ears (gain and cob) were removed, and then the ear and remaining plant stover (husk, leaf, and stalk) were weighed separately. Subsequently, three cornstalks and three ears were taken as a subsample from each 5.33 meter bundle for dry matter analysis at 60°C. Ear corn samples were dried in a forced air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) at 60°C for 48 hours to determine DM content (AOAC, 1965, Method 935.29), then the corn grain was shelled. Cobs and grain went back into the oven separately for another 24 hours or until dry for corn grain yield determination. Cob weights were included in the dry stover yields. Dry matter measurements from the grain and stover were used to calculate corn grain yield and stover (total biomass minus the grain) yield per hectare. Harvest index was calculated based on the percentage of dry grain in total dry biomass (grain plus stover). Equations for determining baled nutrient, residue removed and harvest index are listed in the Appendix.

Nebraska City had two fields that rotated between corn and soybeans, and the year after corn residue grazing, soybeans were hand harvested once soybeans reached about 13% moisture. Hand harvest yield of soybeans utilized similar methods as corn harvesting (Lauer, 2002), which consisted of cutting two-5.33 meter rows at the base of the plant at ground level. Rows were bundled and each subsample was dried at 60°C until threshing of the soybeans. At threshing, samples of grain and stover were collected and dried in an oven at 60°C to measure dry matter. Dry matter oven weights for the grain and stover were used to calculate soybean grain yield and stover (total biomass minus the grain) yield per hectare for the field.

In the spring following application of treatments in the fall, the amount of residue remaining on the ground was measured in each treatment by randomly throwing a 1 m^2 frame on the ground and collecting all of the corn residue within the frame including corn stalks which were cut to ground level.

Data were analyzed using the MIXED procedure of SAS with the response variables being yield, harvest index, nutrient removed by baling and residue remaining with location (nested within year) and treatment as fixed effects. The models for the baled nutrient content and residue remaining included: year, location, and the year by location interaction as fixed effects. The model for soybean yield included treatment and field (nested within year) as fixed effects. Treatment means were separated using the pdiff statement when the F-test was significant. Significance was noted at $\alpha = 0.05$.

RESULTS

Crop yields

There were no interactions (*P* > 0.11) between location and treatment for all corn yield and harvest index analyses, but the main effect of location was significant (*P* < 0.01). Corn grain yields ranged from 9,543 to 17,387 kilograms per hectare across locations. Stover yields ranged from 5,864 to 11,740 kilograms DM per hectare across locations. However, no differences were observed among treatments (*P* = 0.14) for corn grain yield (Table 2). Likewise, there was no difference (*P* = 0.58) in corn stover yield or harvest index (*P* = 0.44; SEM = 0.62%) among treatments (61.0, 62.3, and 61.3% for CON, BLD, and GZD respectively).

The amount of corn residue remaining in the spring following application of treatments in the fall ranged from 2,150 – 17,237 kg DM / ha across locations and treatments (*P* < 0.01). The CON had 1,498 kg DM / ha or 14% more residue than the GZD, and BLD had 6,576 kg DM /ha less than the CON. Relative to the CON, the percent of residue remaining on the ground in the spring was 35% for the BLD (*P* < 0.01) and 86% remaining for the GZD as compared to the CON (*P* < 0.01).

The Nebraska City soybean grain yield (*P* = 0.83) and soybean stover produced (*P* = 0.61) did not differ among treatments (Table 3).

Baled nutrients

Among the six cooperator sites over the three years of baling, the amount of corn residue removed per hectare by baling ranged from 1,174 – 7,886 kilograms DM per hectare with the average removed being 4,931 (SD = 1,768) kilograms DM per hectare (Table 5). The percent removed by baling varied by location (Figure 1). The percent removed by baling ranged from 16.9 to 91.5% across locations with Odessa had less residue removed by baling throughout both years and Nebraska City had the highest percentage removal by baling. The amount of residue removed and percent residue removed by location and year is listed in the Appendix.

The nutrient content of the baled samples from all locations is listed in Table 4. There was not a location by year effect for OM ($P = 0.23$); however, the OM differed by location ($P = 0.02$) with Clay Center, Nebraska City, Odessa and Scottsbluff having similar OM (89.5% - 91.7% OM), which was greater than Ainsworth and Norfolk (78.5% OM for both locations). The NDF of the baled samples had an interaction between the location and year ($P < 0.01$) with the location not being different ($P = 0.56$). The range in NDF content among locations was 78.1 to 82.1% NDF. The CP content had a location by year effect, ($P < 0.01$), with the location effect being listed in Table 4. The CP varied among locations with Scottsbluff and Clay Center having the greatest CP in baled samples (6.68% and 6.17% CP, respectively). The range in CP among cooperators was from 5.02 to 6.68% CP. The IVOMD had a location by year effect, ($P < 0.01$); however, each location did not differ ($P = 0.12$). The locations ranged from 49.4 – 58.3% IVOMD. The digestible organic matter (DOM) of the baled samples had a location by year, ($P < 0.01$), and a location effect ($P = 0.04$). Scottsbluff had the highest DOM, 51.9%, followed by Ainsworth, Odessa and Clay Center (about 46% DOM), and then the lowest DOM noted at Nebraska City and Norfolk at 44.1% DOM and 39.3% DOM, respectively.

The concentration of nutrients and kilograms of compounds removed on a fertilizer basis are listed in Table 5. The concentration of N in the baled residue ranged from 0.68 to 1.18% with an average of 0.96 ± 0.162%. The concentration of Ca in the bales ranged from 0.24 to 0.53% with an average of 0.37 ± 0.09%. The concentration of P in the baled residue ranged from 0.04 to 0.19% with an average of 0.08 ± 0.033% P and the K in the baled residue averaged 1.11 ± 0.45% with a range of 0.51 to 1.91% K.

The amount of fertilizer to be applied to replace the nutrients removed by baling of the corn residue varied across location ($P < 0.01$) ranging from 10.1 to 117 kg anhydrous NH_3 / hectare with an average of 58.5 ± 24.6 kg removed per hectare. The amount of Ca removed ranged from 7.81 to 85.1 kg $CaCO_3$ / hectare with an average of 45.6 ± 18.9 kg $CaCO_3$ / hectare. Phosphorus removal ranged from 0.90 to 16.1 kg MAP / hectare with an average of 7.70 ± 4.31 kg MAP / hectare. Lastly, K removed ranged among locations being 19.5 to 418 kg K_2O / hectare with an average of 144 ± 98.4 kg K_2O / hectare.

DISCUSSION

Grazing

Most locations were irrigated, therefore, the effects of residue cover on soil moisture may not have been observed. Grazing in the present study occurred during the fall and winter as opposed to the spring. Stalker et al. (2015) agreed that yield differences were not evident on subsequent grain yields following the removal of corn residue by winter grazing, baling or leaving residue on fully irrigated fields in a two year study. Stalker et al. (2015) observed corn yields for the control at 9.3 Mg / ha (9,300 kg / ha), and 9.5 and 9.7 Mg / ha (9,500 and 9,700 kg / ha, respectively) for light grazed versus heavy grazed, respectively.

In the present study, corn grain yields were greater than those of Stalker et al. (2015). Clark et al. (2004) conducted a three year study to evaluate the effect of corn residue fall/winter grazing on the subsequent year's soybean yield and observed that there were minimal reductions in soybean yield, with soybean yields ranging from 2,775 – 3,338 kg / ha across grazing and tillage treatment. Clark et al. (2004) measured 5- two week periods over 3 years and had one 2 week period when grazing reduced soybean yield. Their suggestion was that the 8 percentage unit reduction in soybean yield was noted in a no-till system when cattle grazed when the ground was thawed (Clark et al., 2004). In a 16-year study conducted near Mead, NE, corn and soybeans were rotated and corn residue grazing occurred in the spring. Soybean yields were improved from 3,889 kg / ha for not grazed to 3,990 kg / ha for spring grazed; however, corn yields did not differ for spring grazed versus not grazed, 13,439 kg / ha for both treatments (Drewnoski et al., 2016). Based on the present soybean yield data, there is no evidence that baling, grazing, or leaving residue will affect grain yield in the short term.

Drewnoski et al. (2016) considered 10 years of treatments under no till management which compared grain yield when grazed in the fall/winter or spring versus not grazing. They observed that grazing corn residue in fall or spring did not impact the subsequent corn yields, where not grazing residue was 12,999 kg / ha, spring grazed was 13,125 kg / ha, and fall grazed was 13,250 kg / ha; however, grazing improved soybean yields (4,178, 4,272, 4,407 kg / ha for not grazed, spring grazed and fall grazed, respectively). In the present study with short term application of treatments, soybean yields were not affected by baling or grazing.

Concerns arise about the amount of corn stover left as cover for the soil. Blanco-Canqui et al. (2006) applied 0 - 200% (0 – 10,000 kg DM / ha) of corn stover on fields that yielded 6,100 – 7,400 kg DM / ha of stover to observe how subsequent grain and stover yields as soil properties changed based on the amount of residue left on the field. Blanco-Canqui et al. (2006) indicated that removing greater than 50% of the corn residue (2,500 kg / ha) can negatively impact crop production on certain soil types in the short term. In the present study, corn residue remaining on the field following grazing was 8,676 kg DM / ha, while residue remaining on the field following baling was 3,598 kg DM / ha. However, areas with high yields of residue may benefit from the removal of residue as emergence of the following crop may be delayed or uneven. Sulc and Franzluebbers (2014) wrote a review of managing integrated cropping systems and explained that the most detrimental part of grazing residue is to the soil surface. However, managing the time of grazing can prevent the destruction of soil properties and the effect on grain yields (Sulc and Franzluebbers, 2014). A unpublished review by Rakkar et al. concluded that long-term corn residue grazing (16-years) under high stocking rates (9.3 to 13.0 AUM / ha) or in the spring when freeze-thaw cycles do not occur had little to no detrimental effects on soil properties, and the small changes had no effect on crop yields (Rakkar et al., unpublished data)

Baling

The present study illustrated how much residue is left on the field when baled versus grazed. In the following spring, the BLD had a lower amount of corn stover left on the field (3,598 kg DM / ha) while the CON had 10,714 kg DM / ha remaining. In the present study, when calculating the percent of residue removed as a function of the bale weights and percent DM in the fall, there was substantial variation among locations in the amount of residue removed by baling relative to the total residue produced per hectare with a range from 16.9 to 91.5%, suggesting that there were considerable differences in baling methods (Table 5). Locations may differ based on the time that the location was baled. If not baled immediately, some locations experienced high winds, so there is potential for residue to blow off the treatments, thereby not being a part of the bales that were weighed or windrowed. The extent of raking seemed to vary by location. Frame measurements taken the following spring after harvest indicated that the BLD had on average 35% residue cover (64% residue removed), while the GZD had on average 86% residue cover as compared to the CON at 100% of the residue remaining. The GZD had a range of 55 to 127% with an average of residue remaining on the field as compared to the CON, while the BLD ranged from 5 to 66% across locations. Having greater than 100% present on the field in the GZD could be due to wind loss from another treatment over the winter, dirt contamination as some residue may have been stuck in the mud, or even corn residue from the previous year remaining and being collected in the frame measurements. For CON, the amount of corn residue remaining is greater than the amount of corn stover produced as calculated based on corn hand harvest (Table 2). This may be due to all corn residues within the frame being collected, meaning that any corn residue left from last year may have been collected as well. The numbers were based off of DM percent rather than being analyzed for OM, therefore, there could have been soil contamination of the sample causing an inflation of the numbers. Some locations experienced high winds, so corn residue could also have shifted from one area to another. Leaf loss prior to or during the hand harvesting process may have occurred and been picked up in the frames.

As expected, the amount of residue left in the field in the BLD was the lowest compared to GZD or CON, which is agreeable to the findings by Stalker et al. (2015), where baled treatments in March had 35% residue remaining after baling relative to the control treatments, and grazed treatments had 95% (light grazed) and 92% (heavy grazed) residue remaining relative to the control at the time of measurement in the spring. Less ground cover may enable the ground to warm up earlier, which would affect grain yield. Nitrogen is needed to degrade C, and with less residue being recycled, a short term bump in yields may be recorded.

Van Donk et al. (2012) indicated that 3,681 kg / ha of residue were removed by baling (6,545 kg / ha remaining) on average over the course of a three year study. Corn yields were not presented in the study. The range in residue cover in the van Donk study is variable due to the residue cover measurements being taken at multiple times through the year. In the spring (April), the percent residue cover on baled treatments was 30%, 53%, and 41% across years 1, 2, and 3, while the November measurement (pre-baling) was 84% residue cover on the baled treatments (van Donk et al., 2012). Measurements were taken in the spring and fall. Throughout the year, the least amount of ground cover was observed on baled treatments ranging from 20 – 84% ground cover, while the grazed treatments averaged 44 – 88% and 47 – 80% ground cover due to residue for heavy grazed and light grazed, respectively (van Donk et al., 2012).

Wilhelm et al. (1986) conducted a 4 year study in Lincoln, NE where he evaluated the additions of corn residue at 0, 50, 100, and 150% of total corn residue produced (on average, 5,800 kg / ha) back to the soil on corn-soybean rotated fields. Overall grain yield was 3, 400 kg / ha (Wilhelm et al., 1986). It should be noted that these corn yields are lower, and over the past two decades, there has been an increase in corn yields. They concluded that with 1,000 kg of residue removed from the soil, grain yields decreased by 0.10 Mg / ha (100 kg / ha) and subsequent residue yields decreased by 0.30 Mg / ha or

300 kg / ha (Wilhelm et al., 1986). However, the present study demonstrates that grazing corn residue does not reduce soil cover as much as baling does and that a significant amount of cover remains after grazing. Stalker et al. (2015) found that in a five year study completed near Brule, NE, baling using a traditional rake and bale system (29% of residue remained on field) did not affect subsequent yields on a no-till, continuous corn field that had an average grain yield of 9.2 Mg / ha (9,200 kg / ha) across baled treatments compared with leaving residue which resulted in 9.3 Mg / ha (9,300 kg / ha).

Harvest index

Harvest index is a measure of the percentage of grain produced relative to plant biomass. The harvest index is affected by planting density, as planting density increases the harvest index decreases (DeLoughery and Crookston, 1979). Burken et al. (2013) concluded that the effect of plant population on the harvest index is less influential; the grain percentage changed 1 unit from 49,400 to 93,860 plants per hectare in fields that yielded from 10, 437 to 13,247 kg grain / ha, respectively. Across both population density and harvest time points for corn silage (early harvest, late harvest and corn grain harvest at black layer), harvest index averaged 0.55 (Burken et al., 2013). In the present study, the proportion of corn grain was roughly two-thirds of the plant aboveground biomass produced, but ranged from 55.1 to 66.0% across locations. Similar to a study done in 2012, 18 days prior to black layer, the corn harvest index was 0.40, but 4 days prior rose to 0.64. After black layer, the harvest index dropped to 0.37 indicating that once black layer is reached, the degradation of the sugars in the kernel occurs, therefore, the quality of the corn decreases (Burken, 2014). The Norfolk location had the most variable harvest index due to the site receiving hail in 2014. The harvest index range without the 2014

Norfolk data ranged from 54.5 to 66.7% corn grain. Based on the U.S. National Agricultural Statistics Service's corn yield data from the U.S. Midwest, Prince et al. (2001) suggested the harvest index for fields averaging 9,514 kg / ha corn of 0.53 for corn grain, and based on a sensitivity analysis, the harvest index should not vary more than 10 percentage units, even with different climatic condition and management resources.

Nutrient removal

Nutrient removal from baling corn residue means that nutrients will eventually need to be replaced due to limitations to plant growth. Nitrogen, P, K, and Ca are four major nutrients that plants need for growth. Cooperators in the present study applied the same fertility management across all treatments and therefore did not replace in nutrient removed in the baled treatment. Stalker et al. (2015) suggested that the removal of corn residue by baling results in no nutrient replacement through residue, while grazing corn residue results in essentially 100% additions of P and K when non-lactating, mature cows are utilized. Hoskinson et al. (2007) reported that nitrogen removed from harvesting corn stover (residue cut by combine head blown into a forage wagon) ranged from 34 to 42 kg per hectare, depending on the height of the cut (10 to 75 cm remaining). Dry corn grain yields ranged from 9,740 to 10,470 kg / ha with dry stover yield being 1,710 to 6, 680 kg / ha. Hoskinson et al. (2007) observed that P and K removal by stover averaged 3.9 kg / ha (equivalent of 7.49 kg MAP/ha) and 34 kg / ha (equivalent to 77.9 kg K_2O kg/ha), respectively. However, Wortman et al. (2012) reported that K removed from the soil by the crop for grain equaled 76 to 79 kg per hectare (174 to 181 kg K_2O equivalents), while P removed by the corn averaged 70 to 73 kg per hectare or 134 to 140 kg MAP / ha. The present study observed lower MAP removals, 0.90 to 16.1 kg / ha, compared to Wortman et al. (2012) but similar to Hoskinson et al. (2007). The present study also observed K_2O removal of 19.5 to 418 kg / ha, while Hoskinson et al. (2007) and Wortman et al. (2012) were under 181 kg K_2O / ha equivalents.

CONCLUSIONS

Results indicate that, in the short term, removing corn residue through grazing or baling provides a potential feed resource with no negative impact on grain yield. However, baling results in more loss of ground cover than does grazing. Baling also results in removal of N, P, K, and Ca. Nutrient removal by baling varied considerably among cooperators and among year within cooperators. These data demonstrate that it is important to weigh and sample bales to have an accurate estimate of the amount of nutrients that need to be replaced after baling of corn residue.

LITERATURE CITED

AOAC. 1965. Official Methods of Analysis. 10th ed. AOAC, Washington, D.C.

AOAC. 1999. Official method of analysis. 16th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Blanco-Canqui, H., and R. Lal. 2007. Soil and crop response to harvesting corn residues for biofuel production. Geoderma, 141(3), 355-362.

Blanco-Canqui, H., R. Lal, W.M. Post, and L.B. Owens. 2006. Changes in long-term no-till corn growth and yield under different rates of stover mulch. Agron. J. 98(4), 1128-1136.

Burken, A.J. 2014. Changes in Corn Residue Quality throughout the Grazing Period and Effect of Supplementation of Calves Grazing Corn Residue. MS Thesis. University of Nebraska-Lincoln.

Burken, D.B., J.L. Harding, A.L. McGee, T.C. Hoegemeyer, T.J. Klopfenstein, and G.E. Erickson. 2013. Effects of corn hybrid, plant density, and harvest time on yield and quality of corn plants. Nebraska Beef Cattle Rep. MP98:42-43.

Clark, J. T., J.R. Russell, D.L. Karlen, P.L. Singleton, W.D. Busby, and B.C. Peterson. 2004. Soil surface property and soybean yield response to corn stover grazing. Agron. J. 96(5), 1364-1371.

Conway, A., T.M. King, M.L. Jolly-Breithaupt, J.L. Harding, J.C. MacDonald, T.J. Klopfenstein, and M.E. Drewnoski. 2017. Effect of Harvest Method and Ammoniation on Digestibility and Intake of Corn Residue. Nebraska Beef Cattle Rep. MP104:61-62.

Crookston, R.K., and J.E. Kurle. 1989. Corn residue effect on the yield of corn and soybean grown in rotation. Agron. J. 81(2), 229-232.

DeLoughery, R.L., and R.K. Crookston. 1979. Harvest index of corn affected by population density, maturity rating, and environment. Agron. J. 71(4), 577-580.

Drewnoski, M.E., J.C. MacDonald, G.E. Erickson, K.J. Hanford, and T.J. Klopfenstein. 2016. Long-Term Corn Residue Grazing Improves Subsequent Soybean Yields in a Corn–Soybean Rotation. Crop, Forage and Turfgrass Mgt. 2(1).

Fernandez-Rivera, S., and T.J. Klopfenstein. 1989. Diet composition and daily gain of growing cattle grazing dryland and irrigated cornstalks at several stocking rates. J. Anim. Sci. 67(2), 590-596.

Franzluebbers, A.J., and J.A. Stuedemann. 2008. Early response of soil organic fractions to tillage and integrated crop–livestock production. Soil Sci. Soc. Am. J. 72(3), 613-625.

Hammerbeck, A.L., S.J. Stetson, S.L. Osborne, T.E. Schumacher, and J.L. Pikul. 2012. Corn residue removal impact on soil aggregates in a no-till corn/soybean rotation. Soil Sci. Soc. Am. J. 76(4), 1390-1398.

Hoskinson, R.L., D.L. Karlen, S.J. Birrell, C.W. Radtke, and W.W. Wilhelm. 2007. Engineering, nutrient removal, and feedstock conversion evaluations of four corn stover harvest scenarios. Biomass and Bioenergy, 31(2), 126-136.

Karlen, D.L., S.J. Birrell, J.M. Johnson, S.L. Osborne, T.E. Schumacher, G.E. Varvel, R.B. Ferguson, J.M. Novak, J.R. Fredrick, J.M. Baker, J.A. Lamb, P.R. Adler, G.W. Roth and E.D. Nafziger. 2014. Multilocation corn stover harvest effects on crop yields and nutrient removal. BioEnergy Research, 7(2), 528-539.

King, T.M., R.G. Bondurant, J.L. Harding, J.C. MacDonald and T.J. Klopfenstein. 2016.

Effect of Harvest Method on Residue Quality. Nebraska Beef Cattle Rep. MP103:81-83.

Lauer, J. 2002. Methods for calculating corn yield. Available online: http://corn.agronomy. wisc.edu/AA/pdfs A, 33. Nebraska Corn Board. 2016. "Corn Production." http://www.nebraskacorn.org/corn-production-uses/corn-production/

Perlack, R.D., and A.F. Turhollow. 2003. Feedstock cost analysis of corn stover residues for further processing. Energy, 28(14), 1395-1403.

Prince, S.D., J. Haskett, M. Steininger, H. Strand, and R. Wright. 2001. Net primary production of US Midwest croplands from agricultural harvest yield data. Ecological Applications, 11(4), 1194-1205.

Rakkar, M.K., H. Blanco-Canqui, M.E. Drewnoski, J.C. MacDonald, T.J. Klopfenstein, and R. Drijber. Impacts of cattle grazing of corn residues on soil properties after 16 years**.** Soil Sci. Soc. Am. J. Unpublished data.

SAS Institute. 2011. The SAS system for Windows. No. 9.3. SAS Inst., Cary, NC.

Stalker, L.A., H. Blanco-Canqui, J.A. Gigax, A.L. McGee, T.M. Shaver, and S.J. van Donk. 2015. Corn residue stocking rate affects cattle performance but not subsequent grain yield. J. Anim. Sci. 93(10), 4977-4983.

Stockton, M., R. Wilson and A. Stalker. 2013. Corn Stalk Grazing CowQLator. http://beef.unl.edu/learning/cornstalkgrazingcalc.shtml

Sulc, R.M., and A.J. Franzluebbers. 2014. Exploring integrated crop–livestock systems in different ecoregions of the United States. European J. Agron. 57, 21-30.

Tilley, J.M.A., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. Grass and Forage Sci. 18(2), 104-111.

Tracy, B.F., and Y. Zhang. 2008. Soil compaction, corn yield response, and soil nutrient pool dynamics within an integrated crop-livestock system in Illinois. Crop Sci. 48(3), 1211-1218.

Updike, J, L.J. Phillips, M.L. Jolly-Breithaupt, J.L. Harding, T.J. Klopfenstein, and J.C. MacDonald. 2016. Effect of Harvest Method on In Vitro Digestibility of Corn Residues. Nebraska Beef Cattle Rep. MP103:76-78.

van Donk, S., A.L. McGee, T.J. Klopfenstein, and L.A. Stalker. 2012. Effect of corn stalk grazing and baling on cattle performance and irrigation needs. Nebraska Beef Cattle Rep. MP95:8-10.

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. Dairy Sci. 74:3583–3597. doi:10.3168/jds.S0022-0302 (91)78551-2.

Weiss, W.P. 1994. Estimation of digestibility of forages by laboratory methods. Page 644 in Forage Quality, Evaluation and Utilization. G. C. Fahey Jr., ed. Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, WI.

Wilhelm, W.W., J.W. Doran, and J.F. Power. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron. J. 78(1), 184-189.

Worrell, M.A., D.J. Undersander, and A. Khalilian. 1992. Grazing wheat to different morphological stages for effects on grain yield and soil compaction. J. Prod. Ag. 5(1), 81-85.

Wortman, S.E., T.D. Galusha, S.C. Mason, and C.A. Francis. 2012. Soil fertility and crop yields in long-term organic and conventional cropping systems in Eastern Nebraska. Renew. Ag. and Food Sys. 27(03), 200-216.

Table 1. Years and management of crop fields at cooperator locations

Location[1]	Rotation	Irrigation	Reps	Years[2]	Corn seeding rate[3]
Ainsworth	continuous corn	Pivot	2	2	79, 040
Norfolk	continuous corn	Pivot	2	2	71, 630
Odessa	continuous corn	Sub-surface drip	2	2	81, 510
Clay Center	continuous corn	Pivot	3	1	80, 275
Nebraska City[4]	corn-soybean	Rain-fed	5	1	74, 100
Scottsbluff	corn - dry bean - sugar beet	Pivot	3	2	88,920

[1]Soil series for each location: Ainsworth- Johnstown loam, 0-2% slope; Norfolk- Thurman loamy, 0-2% slope; Odessa- Holdredge silt loam, 1-3% slope; Clay Center- Crete silt loam, 0-2% and Butler silt loam, 0-1%; Nebraska City- Aksarben silty clay loam, 2-6% slope; Scottsbluff- Tripp very fine sandy loam, 1-3% slope.

[2]Number of years treatments were applied and subsequent crop yield data was collected

[3]Corn seeding rate in seeds per hectare. Nebraska City also had soybean seeding rate of 395,200 seeds per hectare.

[4]Measurements at Nebraska City were taken over a two-year period in different fields with treatments only being applied once in each field.

Table 2. Corn grain and stover yield and harvest index for 4 cooperators in eastern Nebraska[1]

	Treatment[2]				
Item	CON	BLD	GZD	SEM[3]	*P*-value
Corn grain yield, kg DM / ha	14,050	15,034	14,750	320	0.14
Corn stover yield, kg DM / ha	8,764	8,977	9,193	242	0.58
Harvest index, %[4]	61.0	62.3	61.3	0.62	0.44
Corn stover remaining, kg DM / ha[5]	10,174	3,598	8,676	449	< 0.01

[1]Four sites: Ainsworth, Clay Center, Norfolk and Odessa.
[2]Treatments: CON = No bale-no graze, BLD = Baled, GZD = Grazed
[3]SEM = Pooled standard error mean for response variable
[4]Harvest index is the measure of the percentage of corn grain to total biomass (grain + stover).
[5]Amount of stover remaining based on frame measurements taken in the following spring.

Table 3. Soybean grain and stover yields (kg DM/ha) from cooperator in south eastern Nebraska (Nebraska City)[1]

	Treatment[2]				
Item	CON	BLD	GZD	SEM	*P*-value
Soybean grain yield, kg DM / ha	4,151	4,106	3,958	232	0.83
Soybean stover yield, kg DM / ha	3,006	3,325	2,922	294	0.61

[1]Soybean grain and stover yield are from a field in corn-soybean rotation.
[2]Treatments: CON = No bale- no graze, BLD = Baled, GZD = Grazed

Table 4. Nutrient analysis of baled corn residue samples from locations across eastern Nebraska

	Nutrient				
Location[1]	OM, %	NDF, %	CP, %	IVOMD, %	DOM, %[2]
Ainsworth	78.5[b]	81.8	5.02[bc]	52.8	45.5[ac]
Clay Center	90.8[a]	79.8	6.17[ad]	52.2	46.9[ab]
Nebraska City	89.5[a]	81.1	5.86[c]	49.4	44.1[bc]
Norfolk	78.5[b]	82.1	5.66[bcd]	49.7	39.3[c]
Odessa	91.7[a]	80.0	5.17[bc]	50.8	46.5[ab]
Scottsbluff	91.0[a]	78.1	6.68[a]	58.3	51.9[a]
SEM	3.69	1.87	0.335	2.52	2.82
P-value	0.02	0.56	< 0.01	0.12	0.04

[a,b,c,d]Means within column with differing superscripts are different ($P < 0.05$).

[1]Clay Center was not set up until year 2.

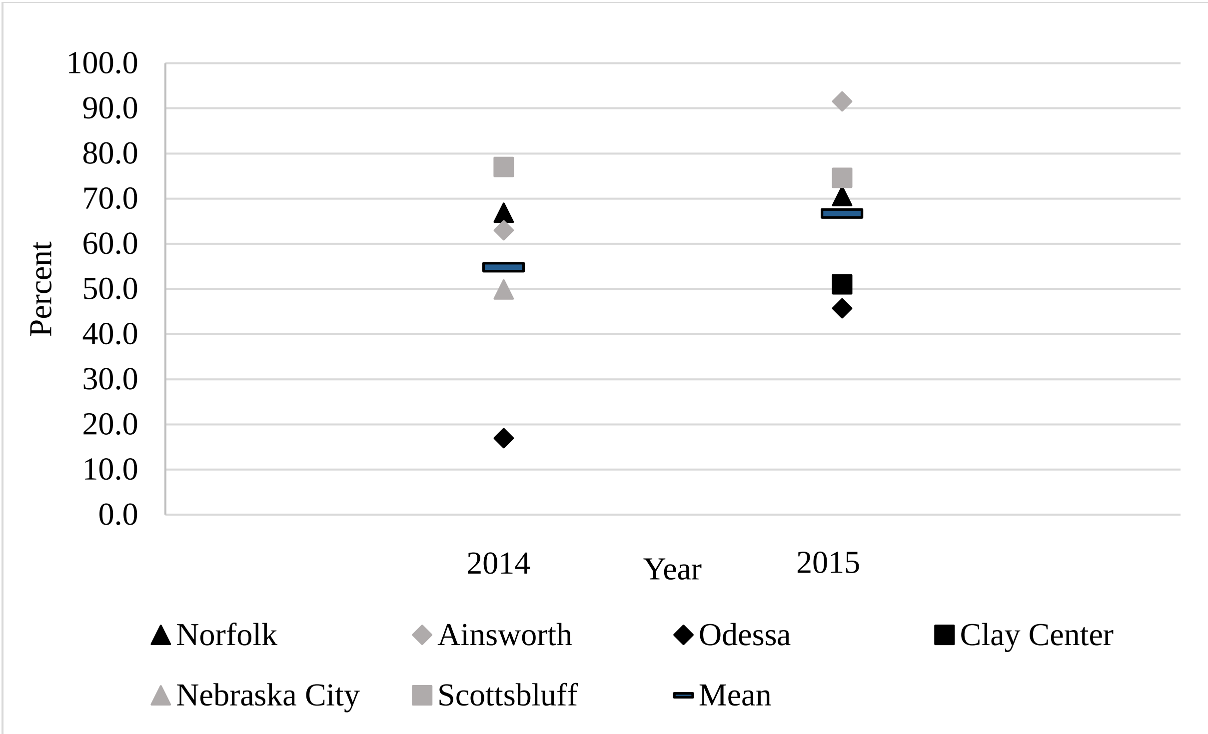
[2]Digestible Organic Matter was calculated by taking the corrected IVOMD percentage and multiplying by the OM content.

Table 5. Summary of nutrient concentrations and fertilizer compounds removed (kg / hectare) by baling corn residue

Item	Mean	Median	Range	Standard Deviation
Corn residue removed, kg DM / hectare[1]	4,931	4,760	1,174 - 7,886	1,768
Corn residue removed, %[2]	56.9	57.0	16.9 – 91.5	21.8
Nitrogen concentration, %	0.96	0.96	0.68 – 1.18	0.162
Anhydrous NH_3 removed, kg / hectare	58.5	60.2	10.1 – 117	24.6
Phosphorus concentration, %	0.08	0.07	0.04 – 0.19	0.033
MAP removed, kg / hectare	7.70	7.06	0.90 – 16.1	4.31
Calcium concentration, %	0.37	0.34	0.24 – 0.53	0.09
$CaCO_3$ removed, kg / hectare	45.6	48.1	7.81 – 85.1	18.9
Potassium concentration, %	1.11	0.95	0.51 – 1.91	0.45
K_2O removed, kg / hectare	144	103	19.5 - 418	98.3

[1]Corn residue removed by baling the residue as determined by bale weight and DM content of the bales.
[2]Calculated based on the amount of residue produced from all hand harvested locations and how much was removed by baling at those locations.

Figure 2.1. Percent residue removed by baling across locations and years[1]



[1]Nebraska City and Clay Center only had one year of data.

CHAPTER III. Evaluation of Different Byproduct Combinations along with Treated Corn Stover on Growing Steer Performance

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ABSTRACT

Changes in ethanol production, including secondary fermentation of fiber, may result in the use of other fibrous materials such as CaO-treated corn residue **(TCR)**, to carry distillers solubles **(DS)** and protein in distillers grains. Addition of crude glycerin **(CG)** and DS to corn residue have been shown to improve performance of growing cattle. The objectives of this research were to evaluate distillers grains-based products with different concentrations of DS and CG on the performance of growing steers. An 81-day growing study utilized 300 yearling steers (initial BW = 311, SD = 15 kg) in a randomized block design with 15 head per pen and 5 replications per treatment. All steers were fed 46% brome hay with 4% supplement. Treatments consisted of control diet containing 50% modified distillers grains plus solubles **(CONT)**; treated stover-based product; treated stover and high solubles product, and treated stover with solubles and glycerin product. Steers consuming TCR had greater DMI, but lower ADG compared to steers fed MDGS, which was reflected in reduced G:F, and ending BW. The TCR steers in this study, however, had similar ADG whether or not solubles was increased or glycerin was included. *In-vitro* OM digestibility did not differ among treatments, while gas production was greatest for CONT diet as compared to TCR diets. Rate of gas production was greatest for CG diet and least for CONT diet. Utilizing TCR, regardless of inclusion of CDS or GLY, as a replacement for distillers grains in a brome hay diet reduced steer ADG.

KEYWORDS: by-products, growing, treated stover

INTRODUCTION

Distillers grains plus solubles (DGS) fed to growing cattle have 136% the energy of corn (Ahern et al., 2016). With increasingly available corn residue, opportunity exists to couple the two resources (Watson et al., 2015). Peterson et al. (2015) observed that chemical treatment of the corn residue using CaO or Ca $(OH)_2$ increases ADG and further noted that pelleting the stover product increased DMI.

Carlson et al. (2016) evaluated different components of DGS in finishing diets with one diet replacing bran in anticipation that the fiber in DGS may be fermented in ethanol. However, when the treated stover (STV) product was compared to DGS, animal performance was reduced. Lundy et al. (2015) evaluated a co-product from secondary fermentation of the corn kernel fiber in the cellulosic ethanol industry against traditional wet distillers grains at 30% inclusion in a finishing diet. They observed that growth performance of cattle was similar, except feed efficiency was greater for the traditional wet distillers grains than the cellulosic wet distillers grains.

Solubles may increase the energy density of high forage diets. As the concentration of solubles increased in forage diets, feed efficiency improved (Jolly et al., 2013). Corrigan et al. (2009) observed that at a moderate level of DDG supplementation (0.5% BW), an increase in the solubles concentration in the DDG resulted in increased ADG, suggesting the addition of solubles boosted the energy density. Furthermore, Hales et al. (2014) substituted glycerin at 7.5% of diet DM for steam-flaked corn (SFC) and noted that there was no difference observed in ADG, suggesting that the energy density in the diet remained the same when glycerin replaced the SFC.

Increasing the level of DS to form a high soluble stover product or including glycerin in the stover product may result in cattle performance equal to DGS. Therefore, the objectives of this study were to evaluate CaO treated stover products (TCR) compared to modified distillers grains plus solubles (MDGS) to determine if increasing the concentration of DS or including crude glycerin (CG) could improve growing cattle performance in TCR diets.

MATERIALS AND METHODS

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

An 81-day growing study utilized 300 yearling crossbred steers (initial BW = 311, SD = 15 kg) in a randomized block design at the Eastern Nebraska Research and Extension Center (ENREC; Mead, NE). Steers previously grazed corn residue and were limit fed a common diet consisting of 50% Sweet Bran (Cargill Wet Milling, Blair, NE) and 50% alfalfa hay diet at 2.0% of BW for 5 d prior to and upon completion of the trial to reduce the effects of gut fill on weights (Watson et al., 2013). After being limit fed a common diet for 5 days, two consecutive day weights were collected and averaged to determine initial BW and ending BW (Stock et al., 1983). Steers were poured with 15 ml insecticide (StandGuard, Elanco Animal Health, Greenfield, IN) on d 0 and implanted with 36 mg of zeranol (Ralgro, Merck Animal Health, De Soto, KS) on d 1 of the trial. The steers were blocked into 1 of 2 blocks based on the first day weight. The heavy weight block had 1 replication (initial BW= 335 kg) and the light weight block had 4 replications (initial BW= 304 kg). Within a block, cattle were stratified by BW, assigned randomly to pen with 15 head per pen and five replications per treatment.

All diets contained 46% brome hay (11% CP, 2% ether extract (EE), 77% NDF, 92% OM) and 4% supplement which provided 200 mg / hd daily (DM basis) monensin (Rumensin, Elanco Animal Health, Indianapolis, IN). Treatments imposed on the remaining 50% of the diet included: 1) a control diet containing 50% modified distillers grains plus solubles (CONT); 2) a treated stover-based diet (STV) consisting of 18.75% DS, 12.50% TCR, 18.75% High protein distillers (HPD); 3) a treated stover with high solubles (SOL) consisting of 30% DS, 12.50% TCR, 7.50% HPD; 4) a treated stover with solubles and glycerin (GLY) consisting of 25% DS, 5% CG, 12.50% TCR, 7.50% HPD. The CaO treated corn stover products were provided by Pellet Technology, USA (Gretna, NE). The dietary treatments are presented in Table 1, and the nutrient content of each CaO treated corn stover product is provided in Table 2. Diets were formulated to meet RDP requirements and were supplemented with urea if deficient. The treated stover with high solubles diet had 0.74% urea (DM basis) and GLY had 1.13% urea (DM basis) added to the supplement to match STV ruminally degradable protein (RDP) supply. Limestone was added to meet Ca:P requirements of cattle (NRC, 1996). Each of the three supplements were formulated and mixed at the University of Nebraska feed mill.

Cattle bunks were read every morning at 0630 to ensure that calves were provided ad libitum feed. If orts were present, they were removed from the bunk as needed and dried at 60°C for 48 hours to determine accurate DMI. Diets were mixed on the feed truck (Roto-Mix, Dodge City, KS). Due to the high intakes and bulkiness of diet, the calves were fed once a day at 0700 hour for the first 17 days, and twice a day at 0700 hour and 1400 hour for the rest of the period in order to fit the feed in the bunk. Feed samples were collected weekly and analyzed each month to determine nutrient composition of the diet. Feed samples were dried in a forced air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) to determine DM content (AOAC, 1965, Method 935.29). The samples were then ground through a 1 mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) prior to lab analysis. Samples were analyzed for ash and OM by placing the samples in crucibles and leaving in the 600°C muffle furnace for 6 hours (AOAC International, 1999; Method 4.1.10). Neutral detergent fiber was determined using the procedure developed by Van Soest et al. (1991), and the Van Soest (1963) method was used to determine ADF. Ether extract was determined using the biphasic lipid extraction procedure by Bremer et al. (2010). Crude protein was determined by analyzing the samples using the combustion chamber (TruSpec N Determinator, Leco Corporation, St. Joseph, MI; AOAC International, 1999; Method 990.03). Sulfur was determined in feed samples using a combustion-type chamber (TruSpec Sulfur Add-On Module, Leco Corporation, St. Joseph, MI; AOAC International, 1999). Samples were sent to Ward Laboratories, Inc (Kearney, NE) to determine Ca and P concentration using mineral analysis by Inductively Coupled Plasma-Optical Emission Spectrometer (ICAP).

To determine *in-vitro* digestibility of the diets (CONT, STV, SOL, and GLY), procedures followed a modified Tilley and Terry method (1963) where ruminal fluid and McDougall's Buffer were mixed at a 1:1 ratio with 1 g urea / L of McDougall's Buffer to ensure adequate rumen degradable protein was provided to the microbes in the rumen fluid (Weiss, 1994). Approximately a 0.50 gram samples was weighed into each 50 mL tube, where 40% of each diet was brome hay, 50% of each diet was the corresponding treatment, and the remaining 4% was the corresponding supplement. Ruminal contents were collected at hour 1200, from two donor steers that were fed the same diet consisting of 30% dried distillers grains plus solubles and 70% brome hay at hour 1500, and strained through 4 layers of cheesecloth (Grade 40, Veratec). Rumen fluid was mixed at a 1:1 ratio with McDougall's buffer (McDougall, 1948) and then 30 ml of the mixture was pipetted into 50-ml plastic tubes for incubation in 39 °C water bath for 48 hours. Three tubes for each sample were capped with rubber stoppers and swirled morning and evening to simulate mixing of digesta in rumen. After 48 hours, fermentation was ended by adding 6 mL hydrochloric acid and 2 mL of 5% pepsin solution per tube, and then tubes were replaced in the 39°C water bath with the rubber caps tightly fitted for an additional 24 hours. Tubes were then removed and placed in a freezer. Tubes were thawed in 39°C water bath for 15 minutes and filtered through Watman 541 filter paper (22 µm pore size), dried for 24 hours in a 100°C oven, and weighed to determine IVDMD and IVOMD. Blanks were included in the *in vitro* digestibility runs in order to adjust for any feed particles that might have come from the rumen inoculum. For *in vitro* VFA concentration, tubes were removed after 48 hours in water and placed in a freezer. Tubes were thawed in 39°C water bath for 15 minutes and prepped for VFA analysis using the procedure developed by Erwin et al. (1961) with crotonic acid used as the internal standard. Volatile fatty acid concentration was measured using a Trace 1300 (Thermo Fisher Scientific Inc., Omaha, NE) fitted with a Zebron capillary column (Phenomenex, Torance, CA). Inoculum used in the i*n-vitro* gas production was the same as the inoculum used in the *in-vitro* digestibility. In addition to analyzing mixed diet samples for IVDMD, mixed diet samples were analyzed for *in vitro* gas production via the ANKOM RF gas production system (ANKOM Technology; Macedon, NY). The diets were mixed in the tubes (Table 1). There were 3 replicates of each diet plus 1 blank per run.

Approximately 1 g of mixed diet was weighed into a 250 mL glass gas production bottle. All bottles were flushed with CO_2 and received 100 ml of a 1:1 blend of separated rumen fluid and McDougall's buffer mixture. Bottles were swirled twice daily. An Ankom gas production module (Ankom Technology, Macedon, NY 14502) was fitted tightly to the bottle and then placed in 39 °C water bath for 48 hours with measurements taken continuously.

Performance data (BW, DMI, ADG, G:F) were analyzed with the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with pen as the experimental unit and block treated as a fixed effect with the model including treatment and block. Treatment means were separated using the pdiff statement when the F-test was significant. Significance was set at $\alpha = 0.05$. One steer died during the study of cause unrelated to the dietary treatments administered and was removed from the data set. For i*n vitro* data, there were three tubes per sample per run, except for IVNDFD, which had five tubes per sample per run, and two runs completed. Data were analyzed using the average of the three tubes per run as the experimental unit.

RESULTS AND DISCUSSION

As DGS were displaced by CaO treated corn stover in the diet, NDF content increased 1 percentage unit and 2 percentage units for STV and GLY, respectively, compared to the CONT diet (Table 1). As DGS were displaced with the TCR product, the CP content decreased, in addition, SOL and GLY had a 1 percentage unit increase in CP as solubles were increased compared to STV. As treated stover displaced DGS, the ADF content increased in STV, SOL, and GLY compared to CONT. The corn stover product used in a study by Gramkow et al. (2016) had similar OM and NDF (88.01% and 55.42%, respectively) but lower CP (15.18%) compared to the STV (86.9% OM, 56.4% NDF, and 19.0% CP) in the present study. Calcium content was greater in treated stover product diets than CONT, but remained similar among treated stover products. With CaO utilized to treat the corn stover, it would be expected that the product would be higher in Ca. Sulfur content increased as DS were added to the diet, but across the diets, the S content averaged 0.41%.

Similar ending BW was observed for all 3 TCR diets ($P > 0.25$). The treatment STV, which contained more HPD, had similar DMI to GLY ($P = 0.12$), but less DMI as compared to SOL, which had 30% solubles and 7.50% HPD ($P = 0.01$). Diets containing CaO treated stover (STV, SOL, and GLY) had lower ADG than CONT calves ($P < 0.01$). As a result, CONT calves had greater ending BW ($P < 0.01$) than STV, SOL, or GLY (Table 3). There was no difference in ADG among the 3 products ($P \geq 0.40$). As a result, feed efficiency for SOL was poorer than STV. The hypothesis was that displacing DGS with DS would improve the feeding value of the TCR product. These data do not support the hypothesis but suggest that DS was detrimental to G: F. The addition of DS increased the DMI of the treated corn stover; however, all TCR treatments remained similar for gain and feed efficiency. The TCR treatment calves had lower OM intakes (9.17 kg / day vs. 9.77 kg / day) than the CONT calves ($P < 0.01$). The addition of crude glycerin in GLY did not significantly improve ADG over SOL. Although replacing solubles with 5.0% CG resulted in a 4.6% improvement in G:F, the treatment comparison was not significant ($P = 0.12$).

The CONT diet had an IVDMD that tended ($P = 0.07$) to be greater than the 3 TCR diets; the IVOMD was similar among all treatments ($P = 0.32$). This suggests a higher ash content in the TCR diets as compared to the MDGS diet, but overall, the OM digested remained similar, which is supportive of CaO improving the digestibility of corn stover. However, the IVDMD data agreed with the performance observed in the study, where CONT had a significantly greater digestibility (68.6%) and ADG of 1.61 kg as compared to the TCR digestibility (60.6-61.6%) and ADG of 1.37-1.40 kg. Ash may have diluted the energy of the feed, even though fiber digestion of the stover was likely improved. Klopfenstein (1978) noted that untreated corn stalks were 50% digestible. Shreck et al. (2015) noted that alkaline treated corn stover total tract DM was 74.5% digestible, while total tract OM digestibility was 78.4%. Gramkow et al. (2016) reported that a 60% CaO treated stover diet with 18% MDGS and 18% solubles had a total tract OM digestibility of 71.7%. The Gramkow et al. (2016) data for OM digestibility is 10 percentage unit higher, however, the TCR digestibility of the present study only accounts for the *in vitro* rumen digestibility and not the total tract digestibility. Getachew et al. (2004) noted that the *in vitro* true digestibility of distillers grains fraction was 89.4%. Watson et al. (2015) fed a 20% modified distillers grains plus solubles diet with CaO treated stover and reported a 46.2% DM digestibility and 53.5% OM digestibility. The *in vitro* OM digestibility for the CONT diet was 68.6% IVOMD in the present study, which is significantly lower than 89.4% *in vitro* digestibility found by Getachew et al. (2004). In the present study, the treated corn stover, solubles and glycerin had a digestibility of 60.6 – 61.6% IVOMD. The *in vitro* neutral detergent fiber digestibility (IVNDFD) was similar among TCR diets but greater than the CONT diet ($P = 0.04$). These results indicate that the fiber in the TCR diets (45.5, 43.3, and 44.0% IVNDFD for STV, SOL, and GLY, respectively) had a greater digestibility compared to the CONT diet suggest the CaO treatment of corn stover was effective. Watson et al. (2015) reported a 48.7% NDF digestibility for the CaO treated stover and distillers grain diet.

The CONT diet resulted in greater gas production, 156 ml / gram of DM, than the TCR diets (*P* < 0.01); however, the rate of gas produced was greater for the GLY diet and SOL diets, followed by the STV diet with the CONT diet having the slowest gas rate (Table 4). Gas production likely reflects rumen fermentation, so the TCR steers may have had more rapid rumen fermentation as compared to the CONT steers. The *in-vitro* volatile fatty acid (VFA) profile indicated that the TCR diets had similar total concentrations of VFAs to the CONT diets, 110.8 m*M* and 113 m*M* on average, repectively (Table 5). The percent of acetate, propionate and butyrate within each diet was similar (*P* > 0.69). The CONT had a similar ratio of acetate to propionate present to the STV, SOL, and GLY diets, 2.73, 2.68, 2.64, and 2.62, respectively.

It was hypothesized that adding more solubles to the diet would increase the energy density of the treated corn stover product, and thereby, increase cattle performance. Jolly et al. (2013) fed normal or de-oiled condensed distillers solubles (DS) to growing calves on a brome hay and sorghum silage diet. Condensed distillers solubles were included at 0, 20, and 40% of the diet and observed a quadratic response from the addition of DS. As more solubles were included in the diet, whether it be from full-fat or de-oiled solubles, there was a quadratic decrease (*P* = 0.06) in feed efficiency (Jolly et al., 2013). The TCR steers in this study, however, had similar performance whether or not solubles was increased or glycerin substituted. The difference noticed between the present study and Jolly's is that Jolly et al. (2013) replaced hay with DS, while the present study displaced HPD with DS. Replacing hay with solubles would mean an improvement in the energy of the diet, while displacing HPD with solubles means protein is removed from the diet. Replacing a fiber source rather than a protein source with solubles changes the relative performance of the steers. The SOL steers had similar ADG but poorer feed efficiency compared to the STV treatments. The expectation was that the SOL treatment would result in greater efficiency than STV.

Corrigan et al. (2009) noted that replacement of a moderate level of DDG supplement with solubles increased steer gain; however, that was not observed in the current study. Work by Corrigan et al. (2009) noted an increase in gain from the increased proportion of DS (0, 5.4, 14.5, 19.1, and 22.1%) of DDG. The study showed a quadratic response (P = 0.02) in ADG as DS was included. At a moderate level of DDG supplementation, 0.5% BW, increased solubles caused an increase in ADG meaning the addition of solubles boosted the energy density (Corrigan et al., 2009). Contradictory to Jolly et al. (2013), where the addition of DS improved feed conversion in growing diets, DS did not provide comparable energy to HPD in these growing diets. The HPP product had 27.8% CP, while the HS product with more solubles had 25.6% CP. The results from this study were not as expected when solubles are increased in a treated corn stover diet. Castillo-Lopez et al. (2013) reported that protein in DGS has 63% ruminally un-degraded protein (RUP). Excess RUP contributes to energy in a distillers grains diet as the carbon skeleton is being utilized in the TCA cycle (Conroy et al., 2016). The displacement of HPD with DS results in less excess RUP, therefore decreasing the amount converted to energy for the animal.

Control steers fed MDGS had greater ending BW attributing to greater ADG as compared to TCR calves. This is congruent with the results that Carlson et al. (2016) reported when comparing a component diet composed of 18.75% solubles, 12.5% isolated bran and 18.75% HPD to a 50% MDGS diet. In another treatment, Carlson et al. (2016) substituted 12.5% CaO treated corn stover for the isolated bran with the expectation that bran may be used for ethanol production. He noted that the diet containing a composite of isolated ingredients did not provide similar performance to diets containing solely MDGS. Furthermore, feeding a treated stover product in place of the isolated bran did not provide the same performance as the steers fed either MDGS or the composite diet containing isolated bran. Both the study by Carlson et al. (2016) and the present study agree that replacing MDGS with a TCR product reduces animal performance, even though Carlson et al. (2016) fed a HMC-based finishing diet, while the present study was a growing ration containing primarily brome hay. While there could be different responses in forage and concentrate diets due the differing microbial populations in the finishing diet as compared to a forage based diet, both studies responded to TCR similarly.

Steers fed GLY had similar gains and efficiency to both the STV and SOL steers. Gunn et al. (2010) conducted a study where 1, 5, 10, 15, and 20% dietary crude glycerin was added to a starch-based diet. They found that supplementing up to 15% crude glycerin in the diet improved performance of wethers. Feeding 20% crude glycerin caused a decrease in G:F and ADG (Gunn et al., 2010). Hales et al. (2014) evaluated the level of glycerin inclusion as well as the type of feed for which glycerin should be substituted. In Exp. 1, Hales et al. (2014) fed 0, 2.5, 5, 7.5 and 10% DM inclusion of glycerin to growing calves and observed a quadratic response in ADG (*P* = 0.04), increasing from 0-7.5% glycerin and declining from 7.5-10% glycerin, indicating that the appropriate level of glycerin in the diet DM to solicit a desired performance response was 7.5% glycerin. In a second experiment, Hales et al. (2014) fed 7.5% glycerin (% of diet DM) to determine whether substituting glycerin for forage or concentrate affected performance. Glycerin was substituted at 7.5% for steam flaked corn (SFC) or alfalfa hay (AH), and results indicated that a glycerin response was observed based on the source it replaced. Replacing AH with glycerin resulted in ADG of 1.89 kg compared to the control without glycerin, 1.72 kg (*P* = 0.03). If glycerin replaced SFC, there was no difference observed in ADG, perhaps suggesting that the energy density in the diet remained the same when glycerin replaced the SFC. In the present study, there was no difference in ADG among the 3 TCR products ($P \geq 0.40$). The steers fed GLY had the same ADG and efficiency as SOL meaning that replacing some of the DS with glycerin provided the same performance response, thereby concluding that glycerin has similar energy densities to DS. Krehbiel (2008) noted that ruminal microorganisms adapted to increased levels of glycerol rapidly when glycerol was fed. The steers on the present GLY diet had a faster rate of gas production *in vitro* as compared to STV. Nevertheless, cattle performance and *in vitro* digestibility remained similar among TCR steers, regardless of the addition of glycerin to the diet.

IMPLICATIONS

Utilizing up to 30% DS, 5% CG, and 12.50% TCR to displace DGS in a brome hay diet did not provide the same performance or feeding value as MDGS. Replacing HPD with DS increased intake, but decreased efficiency in SOL steers versus STV.

Replacing 5% of the DS with CG did not improve calf performance compared to STV, however, there was a slight tendency for improved feed efficiency when solubles were displaced with glycerin. Combining protein, solubles and glycerin components with treated corn stover does not provide the same performance response as modified distillers grains plus solubles.

LITERATURE CITED

Ahern, N.A., B.L. Nuttelman, T.J. Klopfenstein, J.C. MacDonald, G.E. Erickson, and A.K. Watson. 2016. Comparison of wet and dry distillers grains plus solubles to corn as an energy source in forage based diets. Prof. Anim. Sci. In press.

AOAC. 1965. Official Methods of Analysis. 10th ed. Assoc. Off. Anal. Chem., Washington, DC.

AOAC International. 1999. Official Method of Analysis. 16th ed. AOAC Int., Arlington, VA.

Bremer, V.R., C. D. Buckner, A.W. Brown, T. P. Carr, R.M. Diedrichsen, G.E. Erickson, and T.J. Klopfenstein. 2010. Method for lipid and NDF analysis of ethanol byproduct feedstuffs. J. Anim. Sci. 88(Suppl. 3):263. (Abstr.).

Carlson, Z.E., C.J. Bittner, D.B. Burken, G.E. Erickson, and J.C. MacDonald. 2016. Modifying different components of distillers grains and the impact on feedlot performance. Nebraska Beef Cattle Rep. MP101:128-131.

Castillo-Lopez, E., T.J. Klopfenstein, S.C. Fernando, and P.J. Kononoff. 2013. In vivo determination of rumen undegradable protein of dried distillers grains with solubles and evaluation of duodenal microbial crude protein flow. J. Anim. Sci. 91(2), 924-934.

Conroy, B.B., C.J. Bittner, J.C. MacDonald, M.K. Luebbe, and G.E. Erickson. 2016. Effects of feeding isolated nutrient components in MDGS on growing cattle performance. Nebraska Beef Cattle Rep. MP101:29-30.

Corrigan, M.E., T.J. Klopfenstein, G.E. Erickson, N.F. Meyer, K.J. Vander Pol, M.A. Greenquist, M.K. Luebbe, K.K. Karges, and M.L. Gibson. 2009. Effects of level of condensed distillers solubles in corn dried distillers grains on intake, daily body weight gain, and digestibility in growing steers fed forage diets. J. Anim. Sci. 87(12), 4073-4081.

Erwin, E.S., G.J. Marco, and E.M. Emery. 1961. Volatile fatty acid analyses of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44(9), 1768-1771.

Hales, K.E., R.G. Bondurant, M.K. Luebbe, N.A. Cole, and J.C. MacDonald. 2014. Effects of crude glycerin in steam-flaked corn-based diets fed to growing feedlot cattle. J. Anim. Sci. 91(8), 3875-3880.

Getachew, G., P.H. Robinson, E.J. DePeters, and S.J. Taylor. 2004. Relationships between chemical composition, dry matter degradation and in vitro gas production of several ruminant feeds. Anim. Feed Sci. Technol. 111(1), 57-71.

Gramkow, J.L., C.J. Bittner, M.L. Jolly, D.B. Burken, G.E. Erickson, and J.C. MacDonald. 2016. Effects of processing treated corn stover and distillers grains on total-tract digestion and performance of growing cattle1. Prof. Anim. Sci. 32(2), 183-191.

Gunn, P.J., M.K. Neary, R.P. Lemenager, and S.L. Lake. 2010. Effects of crude glycerin on performance and carcass characteristics of finishing wether lambs. J. Anim. Sci. 88(5), 1771-1776.

Jolly, M.L., B.L. Nuttelman, D.B. Burken, C.J. Schneider, T.J. Klopfenstein, and G.E. Erickson. 2013. Effects of modified distillers grains plus solubles and condensed distillers solubles with and without oil extraction on finishing performance. Neb. Beef Cattle Rep. MP98:64-65.

Klopfenstein, T. 1978. Chemical treatment of crop residues. J. Anim. Sci. 46(3), 841-848.

Krehbiel, C.R. 2008. Ruminal and physiological metabolism of glycerin. J. Anim. Sci. 86(E-Suppl. 2):392. (Abstr.)

Lundy, E.L., D.D. Loy, and S.L. Hansen. 2015. Influence of distillers grains resulting from a cellulosic ethanol process utilizing corn kernel fiber on nutrient digestibility of lambs and steer feedlot performance. J. Anim. Sci. 93(5), 2265-2274.

McDougall, E. I. 1948. Studies on ruminant saliva. 1. The composition and output of sheep's saliva. Biochem. J. 43(1), 99.

NRC. 1996. Nutrient Requirements of Beef Cattle. Natl. Acad. Press, Washington, DC.

Peterson, S.J., A.L. Shreck, B.L. Nuttelman, C.J. Schneider, D.B. Burken, C.N. Macken, W.A. Griffin, J.L. Harding, G.E. Erickson, T.J. Klopfenstein, and J.C. MacDonald. 2015. Effects of alkaline treatment and pelleting of crop residues on performance of growing calves. Prof. Anim. Sci. 31(6), 552-558.

SAS Institute. 2011. The SAS system for Windows. No. 9.3. SAS Inst., Cary, NC.

Stock, R., T. Klopfenstein, D. Brink, S. Lowry, D. Rock, and S. Abrams. 1983. Impact of weighing procedures and variation in protein degradation rate on measured performance of growing lambs and cattle. J. Anim. Sci. 57(5), 1276-1285.

Tilley, J.M.A. and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. Grass and Forage Sci. 18(2), 104-111.

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.

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. Dairy Sci. 74:3583–3597. doi:10.3168/jds.S0022-0302 (91)78551-2.

Watson, A.K., J.C. MacDonald, G.E. Erickson, P.J. Kononoff, and T.J. Klopfenstein. 2015. FORAGES AND PASTURES SYMPOSIUM: Optimizing the use of fibrous residues in beef and dairy diets. J. Anim. Sci. 93(6), 2616-2625.

Watson, A.K., B.L. Nuttelman, T.J. Klopfenstein, L.W. Lomas, and G.E. Erickson. 2013. Impacts of a limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91(11), 5507-5517.

Weiss, W.P. 1994. Estimation of digestibility of forages by laboratory methods. Page 644 in Forage Quality, Evaluation and Utilization. G. C. Fahey Jr., ed. Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, WI.

Table 3.1. Ingredient composition of diets fed to growing steers (DM basis)

	Treatment			
Ingredient	CONT	STV	SOL	GLY
Brome hay	46.00	46.00	46.00	46.00
MDGS[1]	50.00	-	-	-
HPP[2]	-	50.00	-	-
HS[3]	-	-	50.00	-
GLC[4]	-	-	-	50.00
Supplement[5]				
Fine ground corn	2.101	2.101	1.487	1.479
Limestone	1.424	1.424	1.300	1.130
Urea	-	-	0.740	0.918
Salt	0.300	0.300	0.300	0.300
Tallow	0.100	0.100	0.100	0.100
Pre-mix, Tr. Mineral[6]	0.050	0.050	0.050	0.050
Premix, Vitamin[7]	0.015	0.015	0.015	0.015
Rumensin[8]	0.010	0.010	0.008	0.008
Nutrient Composition				
OM, %	88.4	86.9	84.9	85.9
CP, %	22.0	19.0	20.0	20.6
NDF, %	55.5	56.4	55.2	57.1
ADF, %	30.0	36.5	35.7	36.9
Ether Extract, %	5.21	4.05	3.99	3.47
Ca, %	0.95	1.58	1.60	1.44
P, %	0.74	0.71	0.85	0.58
S, %	0.413	0.366	0.453	0.390

[1]MDGS= 50% modified distillers grains plus solubles.

[2]HPP= 37.50% Distillers solubles, 25% Treated corn stover, and 37.50% High-protein distillers. Ingredients delivered together as a product from Pellet Technology Inc. (Gretna, NE).

[3]HS= 60% Distillers solubles, 25% Treated corn stover, and 15% High-protein distillers. Ingredients delivered together as a product from Pellet Technology Inc. (Gretna, NE).

[4]GLC = 50% Distillers solubles, 25% Treated corn stover, and 15% High protein distillers, 10% crude glycerin. Ingredients delivered together as a product from Pellet Technology Inc. (Gretna, NE).

[5]Supplement comprised 4% of dietary DM.

[6]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co

[7]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E·g^{-1}

[8]Formulated to supply 200 mg / head / day

Table 3.2. Nutrient composition of modified distillers grain plus solubles and CaO treated products (DM basis)[1]

	Treatment[2]			
Nutrient	MDGS	HPP	HS	GLC
OM, %	95.0	85.0	81.0	82.0
CP, %	34.0	27.8	25.6	24.7
NDF, %	39.9	41.8	39.5	43.2
ADF, %	17.7	28.8	27.2	30.0
EE, %	8.94	6.67	6.55	5.51

[1]Nutrient content of CaO treated stover products prior to inclusion in diet

[2]MDGS = 50% modified distillers grains plus solubles; HPP= 37.50% Distillers solubles, 25% Treated corn stover, and 37.50% High-protein distillers; HS= 60% Distillers solubles, 25% Treated corn stover, and 15% High-protein distillers; GLC = 50% Distillers solubles, 25% Treated corn stover, and 15% High protein distillers, 10% crude glycerin.

Table 3.3. Effects of distillers solubles and crude glycerin additions to CaO treated corn stover diets on cattle performance

	Treatment[1]					*P*-value
	CONT	STV	SOL	GLY	SEM	
Initial BW, kg	319	320	319	320	0.44	0.27
Ending BW, kg	450[a]	433[b]	430[b]	434[b]	2.14	< 0.001
DMI, kg / day	10.7[a]	10.8[a]	11.4[b]	11.1[a,b]	0.14	0.01
OMI, kg / day[2]	9.77[a]	9.19[b]	9.21[b]	9.11[b]	0.12[b]	< 0.01
ADG, kg / day	1.61[a]	1.40[b]	1.37[b]	1.40[b]	0.03	< 0.001
Gain:Feed	0.152[a]	0.130[b]	0.121[c]	0.126[bc]	0.003	< 0.01

[1]CONT= 50% modified distillers grains plus solubles; STV= 37.50% Distillers solubles, 25% Treated corn stover, and 37.50% High-protein distillers; SOL= 60% Distillers solubles, 25% Treated corn stover, and 15% High-protein distillers; GLY = 50% Distillers solubles, 25% Treated corn stover, and 15% High protein distillers, 10% crude glycerin. Each treatment also contained 46% brome hay and 4% supplement.

[2]Organic matter intake calculated by multiplying dry matter intake for each pen by organic matter content of diet.

[a,b,c]Means within a row with different superscripts differ ($P < 0.05$)

Table 3.4. *In-vitro* digestibility and gas production of dietary treatments composed of modified distillers grains or CaO treated stover products

	Treatment[1]					
Item	CONT	STV	SOL	GLY	SEM	*P* - value
IVDMD, %	68.6[a]	61.6[b]	61.1[b]	60.6[b]	1.44	0.07
IVOMD, %	68.2	62.8	62.5	62.4	2.11	0.32
IVNDFD, %	38.2[b]	45.5[a]	43.3[a]	44.0[a]	0.95	0.04
Total gas production, mL / g of DM	156.4[a]	126.9[b]	123.0[b]	129.3[b]	3.78	< 0.01
Rate of gas production, mL / hr	7.61[c]	8.01[b]	8.14[ab]	8.40[a]	0.10	< 0.01

[1]CONT= 50% modified distillers grains plus solubles; STV= 37.50% Distillers solubles, 25% Treated corn stover, and 37.50% High-protein distillers; SOL= 60% Distillers solubles, 25% Treated corn stover, and 15% High-protein distillers; GLY = 50% Distillers solubles, 25% Treated corn stover, and 15% High protein distillers, 10% crude glycerin. Each treatment also contained 46% brome hay and 4% supplement.

[a,b,c]Means within a row with different superscripts differ ($P < 0.05$)

Table 3.5. *In-vitro* volatile fatty acid profile of dietary treatments composed of modified distillers grains or CaO treated stover products

Item	Treatment[1] CONT	STV	SOL	GLY	SEM	*P* - value
Total Concentration, m*M*	110.8	109.0	113.5	115.8	5.24	0.81
Acetate[2]	48.2	43.5	43.4	44.4	3.96	0.81
Propionate[2]	17.9	16.5	16.6	17.2	1.25	0.86
Butyrate[2]	8.22	7.43	7.51	7.12	0.64	0.69
Acetate:Propionate	2.73	2.68	2.64	2.62	0.033	0.27

[1]CONT= 50% modified distillers grains plus solubles; STV= 37.50% Distillers solubles, 25% Treated corn stover, and 37.50% High-protein distillers; SOL= 60% Distillers solubles, 25% Treated corn stover, and 15% High-protein distillers; GLY = 50% Distillers solubles, 25% Treated corn stover, and 15% High protein distillers, 10% crude glycerin. Each treatment also contained 46% brome hay and 4% supplement.

[2]Presented as a molar proportion of total VFA.

[a,b,c]Means within a row with different superscripts differ ($P < 0.05$)

CHAPTER IV. Observations of Forage Production and Calf Gain when Grazing Double Cropped Forages Following Wheat and Corn Harvest

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ABSTRACT

Two experiments were conducted to evaluate the yield and grazing potential of annual forages planted after harvest in cropping systems. In Experiment 1, a brassica-based 5 species mix was drilled following wheat harvest on August 17 in year 1 and August 15 in year 2. Above ground forage production measured in late October was 2257 (SEM = 270) and 3991(SEM = 270) kg DM / ha in year 1 and 2, respectively. In both years, the field was split into three 2 ha paddocks and stocked according to above ground forage yield at 909 kg DM per steer. In year 1, 15 steers (initial BW = 205; SD = 16 kg) were divided into 5 hd groups and grazed for 48 d. In year 2, 26 steers (initial BW = 266; SD = 4 kg) were divided into 8 to 10 hd groups and grazed for 52 days. Grazing began in mid-November and ADG was 1.00 (SEM = 0.019) and 0.70 (SEM = 0.073) kg / hd in year 1 and 2, respectively. In Experiment 2, half of a corn field was harvested as corn silage (CS) and half as high moisture corn (HMC). In year 1, a mixture of oats and turnips was drilled on September 9 after CS harvest yielding 1,047 (SEM = 65) kg / ha and on September 18 the same mix was drilled after HMC yielding 487 (SEM = 117) kg / ha in late October. In year 1, there was no grazing of the oat-turnip mixture due to herbicide restrictions. In year 2, oats were drilled on September 3 after CS harvest yielding 3,200 (SEM = 93) kg DM / ha whereas oats drilled on September 17 after HMC harvest yielded 586 (SEM = 95) kg DM / ha. In year 2, grazing began in mid-November with 2 groups of 10 steers per treatment (initial BW= 212; SD = 74 kg) grazing for 62 days. Steers grazing after CS were allocated 795 kg oat forage DM / hd. Steers grazing after HMC were allocated 181 kg oat forage DM and 1,229 kg corn husk and leaf DM / hd. Steer ADG did not differ (*P* = 0.27; SEM = 0.12) among treatments, 0.59 and 0.33 kg

for CS and HMC, respectively. Gain per hectare of HMC (63 kg) and CS (147 kg) did not differ (P = 0.13; SEM = 25.9). Fall forage production after grain harvest is sufficient to provide cover and adequate forage for growing calves.

KEYWORDS: cover crop forages, brassicas, ADG

INTRODUCTION

The ability to graze livestock on cover crops may be beneficial for livestock producers looking for additional forage resources. Planting annual forages in August after wheat harvest may provide producers with an alternative grazing source for backgrounding spring born calves in the winter. Crops that cover the soil and provide a forage source for livestock enable producers to harvest a cash crop and maintain soil cover. Koch et al. (2002) noted that brassicas are a good secondary crop that can be grown after a small grain and are a high quality, cost-effective forage source for fall grazing. Brassicas having a high proportion of readily fermentable carbohydrates relative to structural carbohydrates which leads to quicker degradation in the rumen making the brassica similar to corn in rate of digestion (Barry, 2013). Cassida et al. (1994) concluded that brassica additions to the diet caused decreased fiber digestion and decreased cellulytic activity due to the lowered ruminal pH, much like a high concentrate diet. Since brassicas are a low fiber crop, Lambert et al. (1987) indicated that fiber additions to the diet improved performance. This makes adding a fiber source like planting oats in with brassica based cover crops a plausible combination.

In order to produce greater forage yields, cover crops need to be planted earlier in the season. Koch et al. (2002) reported that July planted turnip crops in Wyoming produced 3,900 kg DM / ha, while August planted turnips produced an average of 2,500 kg DM / ha. However, earlier planted forage will have a lower NDF compared to later planted forage, due to the maturity of the forage (Wiedenhoeft and Barton, 1994). Koch et al. (2002) found that turnip tops averaged 11.5- 17.7% crude protein (CP), while the root was lower (7.2-13.2% CP). The opportunity to graze the livestock on a brassica mix can have a positive effect on gain and produce similar performance to drylot lambs (Koch et al., 2002). Yun et al. (1999) observed that lambs grazing radishes gained 266 and 298 kg / ha with 0.13 and 0.17 kg ADG between two locations. Koch et al. (2002) reported lambs grazing turnips gained 0.183 kg per day, and the average gain for lambs on turnips was 308 kg / ha. Research evaluating calf performance on brassica mixes is not readily available. Matching harvest cash crop system with annual forage system is important because annual fall grazed forage crops need adequate number of days for growth to occur. Economically, being able to plant and utilize a second crop enables a producer to possibly increase net return per hectare and produce a high quality forage in the fall season (Koch et al., 2002). It may cost approximately $220-250 / hectare to grow and graze turnips and radishes, which equates to $0.72- 0.79 / kg of gain for lambs (Koch et al., 2002).

The objective of this study was to determine forage production and growing steer performance from double cropped annual forages planted following wheat harvest (WH), corn silage (CS), or high moisture corn (HMC) and grazed from November to January.

MATERIALS AND METHODS

Experiment 1

Field and planting details

A dryland wheat field at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE was planted to a brassica-based 5 species annual mix (brassicas, oats, and sorghum) on August 17, 2013 and August 15, 2014 following wheat harvest in July (Table 1). Three treatments with three replications per treatment were applied: grazed cover crops (double crop annual forage; DCAF), ungrazed cover crops, and no cover crop. Within year, the same brassica-based 5 species annual mix was utilized for the double cropped forage and the cover crop (Table 1). In year 1, there was no N applied to the field, and in 2014, 95.3 kg N from liquid beef feedlot manure from a confinement barn was applied to the field (to provide N needs of the subsequent corn crop that was planted the following spring).

Forage production measurements

Initial forage mass was measured in the last week of October in both years. In 2013, only above ground forage mass, which did not include roots of brassicas, was determined. In year 2, the forage was separated by species, and the roots of the radishes and turnips were separated from the leaf material such that, in addition to above ground biomass, total biomass production which included the roots of the turnips and radishes, and production of each species could be determined. To measure biomass, three randomly selected 1.00 x 0.71 m areas in each paddock were sampled. Samples were dried in a forced air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) at 60°C for 48 h to determine DM content (AOAC, 1965, Method 935.29) to determine stocking rate. After the 2014 grazing, measurements of post-graze biomass were determined by taking frames 0.91 x 0.38 m from 4 locations within the paddock. All leaf material was clipped to ground level and brassica roots were pulled.

Stocking rate and grazing

To determine cattle grazing groups, steers were limit fed a 50:50 diet of alfalfa hay and Sweet Bran (Cargill Wet Milling, Blair, NE) for five days, and then weighed three consecutive days prior to grazing to adjust for rumen fill (Watson et al., 2013). After two days of weighing, steers were assigned to paddocks based on weight blocks.

On day three of weighing, steers were implanted with 36 mg of zeranol (Ralgro, Merck Animal Health, De Soto, KS) in both years. In both years, grazing was initiated in mid-November and steers were provided free choice mineral supplement (Table 2). In year 1, steers were provided access to the entire paddock; while in year 2, steers were initially given access to half of their paddock, and 22 days later (Dec. 4th) the interior fences were removed and calves were given access to the whole paddock. This was because there was concern that the calves would not completely utilize all the forage, especially the roots that were above the ground.

In 2013, the steers (initial BW= 204 kg; SD = 16) were stocked at 1 steer per 909 kg DM of aboveground forage mass which was equal to 1.1 steer per hectare (504 kg BW / ha). In 2014, steers (initial BW= 266 kg; SD = 4) were stocked 909 kg DM per steer of above ground biomass (excluded radish and turnip tubers), which was equal to 1.9 steers per hectare (1,114 kg BW / ha). Calves grazed for 48 days in year 1 and 52 days in year 2. At termination of grazing, steers were returned to the feedlot and limit fed a 50:50 alfalfa and Sweet Bran (Cargill Wet Milling) diet for five days followed by weighing three consecutive days to determine final body weight (Watson et al., 2013).

Forage quality measurements

In year 1, quality samples were taken in October prior to grazing. In year 2, quality samples were collected on Oct. 28, Nov. 11, Nov. 25, and Dec. 17, 2014 and Jan. 8, 2015 by randomly clipping the grasses and brassica tops to ground level and pulling tubers at fifteen locations within the ungrazed paddocks. Samples were separated by species, and the radishes and turnips were separated into leaf and root.

All forage samples used for quality analysis were freeze dried at -20°C (Vitris Freezemobile 25ES, Life Scientific Inc., St. Louis, MO). The samples were then ground through a 1 mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) prior to lab analysis. Samples were analyzed for ash and OM by placing the samples in crucibles and leaving in the 600°C muffle furnace for 6 h (AOAC International, 1999; Method 4.1.10). The Ankom filter bag technique (Ankom Technology, Macedon, NY 14502) was used to determine NDF and ADF. Crude protein was determined by analyzing the samples using the combustion chamber (TruSpec N Determinator, Leco Corporation, St. Joseph, MI; AOAC International, 1999; Method 990.03). Sulfur was determined using a combustion-type chamber (TruSpec Sulfur Add-On Module, Leco Corporation, St. Joseph, MI; AOAC International, 1999). Total 80% ethanol-soluble carbohydrates (TESC) were measured using the 80% ethanol extraction method outlined by Hall et al. (1999).

To determine *in-vitro* digestibility of the samples, procedures followed a modified Tilley and Terry method (1963) where ruminal fluid and McDougall's Buffer were mixed at a 1:1 ratio with 1 g urea / L of McDougall's Buffer (Weiss, 1994). Ruminal contents were collected at hour 1200, from two donor steers that were fed the same diet consisting of 30% dried distillers plus solubles grains and 70% brome hay at 1500, and strained through 4 layers of cheesecloth (Grade 40, Veratec). Rumen fluid was mixed at a 1:1 ratio with McDougall's buffer (McDougall, 1948) and then 30 ml of the mixture was pipetted into 50-ml plastic tubes for incubation in 39 °C water bath for 48 hours. Three tubes for each sample were capped with rubber stoppers and swirled morning and evening to simulate mixing of digesta in rumen. After 48 hours, fermentation was ended by adding 6 mL hydrochloric acid and 2 mL of 5% pepsin solution per tube, and then tubes were replaced in the 39°C water bath with the rubber caps tightly fitted for an additional 24 hours. Tubes were then removed and placed in a freezer. Tubes were thawed in 39°C water bath for 15 minutes and filtered through Watman 541 filter paper (22 μm pore size), dried for 24 hours in a 100°C oven, and weighed to determine IVDMD. Blanks were included in the *in vitro* run in order to adjust for any feed particles that might have come from the rumen inoculum. There was only one run conducted on the forage samples for *in vitro* digestibility with three tubes per forage sample.

Statistical analysis

Forage nutrient data and steer performance were analyzed with the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with paddock as experimental unit. The forage nutrient model used repeated measures with sample repeated within Julian date and the covariate type being AR (1). Treatment means were separated using the pdiff statement when the F-test was significant. Significance was set at $\alpha = 0.05$.

Experiment 2

Field and planting details

Pivot irrigated fields at the Eastern Nebraska Research and Extension Center (ENREC) near Mead NE were drilled with 67 kg / hectare of Horsepower oat and 6 kg / hectare purple top turnips in a 19-cm row spacing on September 9, 2014 after corn silage (CS) harvest (Table 3). On September 18, 2014 after high moisture corn (HMC) harvest, Horsepower oat and purple top turnips were drilled at the same row spacing at 84 kg / hectare and 6 kg / hectare respectively. This higher seeding rate in year 1 after HMC was due to assumption that corn residue biomass may impede emergence. To avoid herbicide restrictions, in year 2, turnips were removed from the mix and solely oats were planted, which lead to a higher seeding rate of oats in year 2. In year 2, 101 kg / hectare of Horsepower oat were drilled with a 19-cm row spacing on September 3, 2015 and September 17, 2015 following CS and HMC harvest, respectively (Table 3). Across the years, the 40.5-hectare field was split in half, and corn and soybeans were rotated between each 20.2 ha half. The 20.2 ha of corn were further split into replications for corn harvest treatments. Corn and soybean yields were collected by hand harvest methods (Lauer, 2002) to determine the crop production following the application of the treatments. Two treatments with two replications (3.37 ha per rep) per treatment were applied to the corn acres: forage grazing following HMC harvest (6.73 ha) and forage grazing following CS harvest (6.73 ha). The final 6.73 ha were not planted and not grazed as part of a soils experiment not presented here. The seeding rate of the annual forage and percentage of full seeding rate can be found in Table 3. Two treatments with two replications per treatment were applied: oats grazing following high moisture corn harvest and oats grazing following corn silage harvest. In year 1, 28% urea-ammonium nitrate (UAN) fertilizer was applied at 50.4 kg / ha, while in year 2, a 32% UAN fertilizer was applied at a rate of 44.8 kg / ha.

Forage production measures

Initial forage mass was measured in the last week of October. To measure total biomass, three randomly selected 0.91 x 0.57 m areas in each grazed paddock were sampled. All standing biomass was harvested at ground level, dried, and weighed. In year 1, there was no grazing of the oat-turnip mixture due to restrictions of herbicides use on the corn and the carryover effects on the cover crop. In year 2, steers were stocked on each silage treatment paddock based on the amount of oat forage available in October.

Based on previous research, it was assumed that the corn residue in the high moisture corn treatment amounted to 3.63 kg leaf and husk residue per 25.4 kg of corn material with a corn yield of 13,860 kg per hectare (Wilson et al., 2004). Calves were provided access to the entire paddock. After termination of grazing, post-graze biomass measurement were taken by using a transect. A 30.5 meter tape was stretched across the field at 5 locations. At each 0.30 meter on the tape, it was recorded whether there was corn or oat residue at the 0.30-meter (1-foot) mark. Then, the total points for each transect were divided by 30.5 to determine the percentage post-graze biomass cover.

A forage quality sample was collected on October 27 by randomly clipping oats within the ungrazed paddocks. All forage samples were freeze dried (Vitris Freezemobile 25ES, Life Scientific Inc., St. Louis, MO) and then ground through a 1 mm screen in the Wiley mill prior to lab analysis. Samples were analyzed for OM, NDF, ADF, CP, S, and *in vitro* digestibility using the same methods as described for Exp. 1.

The number of day that the crop has to grow can be determined by calculating growing degree days (GDD). Growing degree days are calculated by subtracting 32 from the average daily temperature for each day from planting date to date of biomass measurements, and then taking the sum of the GDD for the entire growing period.

Cash crop yields

Yields of HMC and corn silage, as well as subsequent soybean crop, were collected on three treatments with three reps per treatment: annual forage drilled and grazed (CovGR), annual forage drilled and ungrazed (CovNG), and no annual forage drilled or grazed (NCNG). Corn hand harvest dates in 2015 were September 1 and 14 for CS and HMC, respectively. Soybeans were hand harvested October 7, 2014 and October

8, 2015 following corn residue grazing the previous year. Once soybeans reached approximately 13% moisture, soybeans were harvested. For hand harvest yields of corn, corn plants were cut from 5.33 meter rows (3 rows per replication) at the top of the crown root node. For HMC, corn ears were removed, and then the ear and remaining plant stover (husk, leaf, and stalk) were weighed separately. Subsequently, three cornstalks and three ears were taken as a subsample from each 5.33 meter bundle for drying in a forced air oven at 60°C for 48 h to determine DM content. Ear corn samples were dried in the 60°C oven for 48 hours, and then the corn grain was shelled. Cobs and grain went back into the oven separately for another 24 hours or until dry for corn grain yield determination. Cob weights were included in the dry stover yields. Dry matter measurements from the grain and stover were used to calculate corn grain yield and stover (total biomass minus the grain) yield per acre. Harvest index was calculated based on the percentage of dry grain in total dry biomass (grain plus stover).

Corn silage utilized the same hand harvesting method, except that each 5.33 meter row of stalks harvested was bagged in the field, transported to the university, and the entire plant (minus corn ears) was chopped in a chipper shredder (model #D11334 AC, Troy Built, MTD Products, Valley City, OH). The shredded stalks were then subsampled and dried in 60°C forced air oven for 48 hours to determine the amount of dry matter per hectare. Corn ears were removed and dried in 60°C forced air oven for 48 hours separately from stalks. Once DM calculations were determined, the corn ear DM and stalk DM were added together to evaluate the DM kg of silage produced per hectare.

Hand harvest yield of soybeans consisted of cutting two-5.33 meter rows at the base of the plant at ground level. Rows were bundled and each subsample was dried in a drying room at 60°C until threshing of the soybeans. At threshing, samples of grain and stover were collected and dried in forced air oven at 60°C to measure dry matter. Dry matter oven weights for the grain and stover were used to calculate soybean grain yield and stover (total biomass minus the grain) yield per hectare for the field.

Stocking rate and grazing

To determine cattle grazing groups, corn silage steer calves (initial BW= 212 kg; SEM = 5) and HMC steer calves (initial BW= 212 kg; SEM = 9) were limit fed a 50:50 diet of alfalfa hay and Sweet Bran (Cargill Wet Milling) for five days, and then weighed three consecutive days prior to grazing to adjust for rumen fill. On day two of weighing, calves were assigned to paddocks based on weight blocks. On day three of weighing, calves were implanted with 36 mg of zeranol (Ralgro, Merck Animal Health). Grazing was initiated on November 13th and pulled off pasture January 4th once forage became limiting. Forage was noted limiting when visually there appeared to be no leaf or stem available.

In year 1, there was no grazing of the oat-turnip mixture due to herbicide restrictions. In year 2, grazing began in mid-November with 2 groups of 10 steers per treatment grazing for 62 days. Steers grazing after CS were allocated 795 kg oat forage DM / hd. Steers grazing after HMC were allocated 181 kg oat forage DM and 1,229 kg corn husk and leaf DM / hd. Corn yield was 13,809 kg grain / ha, and available residue was calculated as 3.6 kg residue per 63 kg DM corn available. At termination of grazing, calves were brought back to the feedlot and limit fed a 50:50 alfalfa and Sweet Bran (Cargill Wet Milling) diet for eight days followed by weighing three consecutive days to determine final body weight.

Economics

A partial budget was conducted to evaluate the costs of each backgrounding system on oats as compared to distillers' supplementation. The feed cost in the budget included oat seed plus seeding rate cost ($ / hd) and N fertilizer ($ / hd) for oat systems. A yardage cost was charged for fencing and water maintenance at $ 0.10 / hd / d. The cost per kg gain was estimated for calves on corn residue and distillers supplementation as an alternative opportunity for the corn ground: projected distillers supplement ($/ hd), residue cost ($ / hd), and $0.20 for yardage (additional $0.10 / hd / day for extra labor to feed supplement). All numbers exclude vet cost, interest and transportation cost. Gain data was utilized from steer performance on DCAF after HMC or CS in the present study.

Statistical analysis

Calf performance data and forage nutrient data were analyzed with the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with paddock as experimental unit for calf performance and nutrient data. The calf performance model included treatment as a fixed effect. The forage nutrient model included the date by treatment interaction as a fixed effect. Treatment means were separated using the pdiff statement when the F-test was significant. Significance was set at $\alpha = 0.05$.

RESULTS

Experiment 1

Forage production

For Exp. 1, the first year's aboveground forage mass was 2,257 kg DM / ha (SD = 270), however; in year 2, there was a numerically greater yield at 3,991 kg DM / ha (SD = 270; Table 4). In addition, the number of seeds per hectare (as indicated by the percentage of the full seeding rate of each specific species as compared to planting 100% of a monoculture of that specific species) for the pastures was about 1.5 times as much year 2 compared to year 1 (Table 1). In year 2, total belowground biomass (top growth and tubers of brassicas) was approximately 1,571 kg DM / ha (SD = 780). Therefore, above ground biomass was 72% of the total biomass produced. The production of DM that each species contributed to the total biomass is shown in Figure 1. In 2014, the radish produced the most biomass accounting for 60% of the total biomass, followed by turnip at 17%, oats at 16% and sorghum at 10%. Safflower was not detectable. In Figure 1, oats planted in early August yielded 713 kg DM / ha, while sorghum yielded 398 kg DM / ha. Radish leaf growth (2,004 kg DM / ha; SEM = 106) was greater than turnip leaf growth (837 kg DM / ha). The radish tuber growth, 1049 kg DM / ha was similar to the turnip leaf growth. The turnip tuber had the lowest yield at 351 kg DM / ha.

The post-graze data from Exp. 1 grazed treatments are not shown. However, the post-graze data ranged from 1,867 to 3,022 kg DM / ha with an average of 2,404 kg DM / ha ($P = 0.07$; SEM= 282) left after grazing was terminated.

Forage quality

For Exp. 1, the nutrient content of the 2013 and 2014 brassica-based 5 species mix in late October is reported in Table 5. The mix had a relatively low ADF content. Both the 2013 and 2014 forage were moderate in CP (12.2 and 19.6 % CP, respectively). The sulfur contribution can be attributed mostly to the radishes (leaf and tuber) and turnip leaf as each component had sulfur levels greater than 0.52% S (Figure 2). The grasses, sorghum and oats, had lower levels averaging 0.22% S.

The components of the brassica mix are separated out in Figures 3-9 by nutrient. There was a significant sample by date interaction ($P < 0.01$) for all nutrients analyzed: OM, NDF, ADF, CP, S, and IVDMD, except IVOMD, where $P = 0.04$. The OM of the components ranged from 63-87% OM in October and increasing to 70-95% OM in the oats and sorghum (Figure 3). Sorghum had the lowest OM (63-70%) in the mix as compared to the other components (oats: 84-92% OM, radish leaf: 76-88% OM, turnip leaf: 78-86% OM, radish tuber: 84-92% OM, and turnip tuber: 86-87% OM). The NDF and ADF results of each component are shown in Figure 4 and 5, respectively. The brassicas' leaf and tubers were significantly lower in NDF than the grasses (oat and sorghum). From October to January, the components increased in both NDF and ADF as the plant matured and more structural fibrous material developed. The grasses had the greatest amount of NDF, sorghum at 63-70% NDF and Oats at 52-67% NDF. Radish leaf and turnip leaf contained 32% NDF and then increased to 42% and 47% NDF, respectively. The tubers both had 16% NDF in October, however, as time progressed, the radish tuber contained twice as much NDF as the turnip tuber (41% and 21% NDF, respectively).

Sorghum had the greatest ADF, averaging 42.0% ADF over time (Figure 5). The ADF content of the oats and radish leaf did not differ in November, 29.8 and 25.9% ADF, respectively; however, oats had a greater ADF content than radish top over time. The ADF content of the radish tuber had a greater increase in ADF over time as compared to the turnip tuber (28% and 16% ADF in January for radish tuber and turnip tuber, respectively). However, the radish leaf and turnip leaf decreased in ADF until late November and then increased thereafter.

The brassica components contained at least 15% CP throughout the entire grazing period (Figure 6). The oats and sorghum contained on average 15 and 17% CP, respectively. By the end of the grazing period, the radish leaf and turnip leaf still contained 26 and 24% CP. The turnip leaf had a significant decrease in CP in late November (19% CP), while the radish leaf remained consistent at approximately 25% CP.

Total 80% ethanol soluble carbohydrates (TESC) were in the greater quantities in the tubers of brassicas averaging 46% and 43% TESC in radish and turnip tubers, respectively, at the start of grazing (Figure 7). Brassica tubers followed similar suit with concentrations reaching 41 and 60% TESC in radishes and turnips, respectively, before dropping in the winter months. Radish tubers dropped from 46% to 17% TESC, whereas the turnip tubers dropped from 43% to 39% TESC. As the forage was grazed later in the season, the TESC percentage declined rapidly in leaf and grass components; however, the tubers contained greater than 16% TESC in January. Oats peaked at 23.0% TESC in late November, while sorghum TESC was similar across the grazing period. Brassica leaves accumulated TESC until late November, 17 and 20% TESC in radishes and turnips, respectively, before starting to decline.

The IVDMD and IVOMD digestibilities of the forage components are shown in Figure 8 and 9, respectively. The IVDMD was greatest in the brassica components (73-87% IVDMD) as compared to the oats and sorghum components (59-70% IVDMD). Turnip tubers *in-vitro* digestibility of organic matter (IVOMD) increased until November for all components, except sorghum, and then began to decline through January (P = 0.04). Radish tubers increased IVOMD from October to November (88-90% IVOMD) and declined until January (85% IVOMD). The IVOMD remained the same from October to January for turnip tubers (88-90% IVOMD). Radish and turnip leaf were similar in October at 88% IVOMD, and then followed to decline to 85% IVOMD for radish tuber and 90% IVOMD for turnip tuber.

Cattle performance

In Exp. 1, the steers from year 1 had an ADG of 1.00 kg (SD = 0.019), while the steers from year 2 had an ADG of 0.70 kg (SD = 0.073) (Table 4). Due to the greater forage production and stocking density in year 2, gain per hectare was numerically greater in year 2 (153 kg / ha; SD = 7) than year 1 (109 kg / ha; SD = 4).

Experiment 2

Forage production

For Exp. 2, the first year the oat and turnip mix drilled after CS harvest yielded 1047 kg DM / ha (SEM = 75) and after HMC yielded 487 kg DM / ha (SEM = 117) in late October. Growing degree days (GDD) equaled 1358 for the oats-turnip planted after CS, while GDD for oats-turnip planted after HMC was 1142. In year 2, oats drilled after CS harvest yielded 3200 kg DM / ha (SEM = 93) whereas oats drilled after HMC harvest yielded 586 kg DM / ha (SEM = 95).

Post-graze ground cover measurements are not shown; however, there was 63.2% ground cover by oat stubble after grazing on the CS paddocks, while there was 81.9% ground cover due to corn residue and minimal oat stubble after grazing HMC treatment. The HMC treatment had more ground cover ($P < 0.01$; SEM = 2.68) than CS.

Forage quality

For Exp. 2, the clipped forage consumed by growing calves was on average similar quality for CS and HMC calves (Table 6). The oats grazed by CS and HMC steers had similar CP ($P = 0.35$) with 22.5 and 18.7% CP in year 1, and 18.0 and 23.2% CP in year 2, respectively. The HMC treatment had a greater percentage of OM (86.5% vs. 84.8%) as compared to CS, as well as a lower ADF content (21.6% vs. 24.7% ADF). In year 1, there was no difference in the IVOMD of oat-turnip mix planted after CS and HMC, 82.1 and 82.2% IVOMD, respectively ($P = 0.87$). However, the oats planted after HMC in year 2 had greater IVDMD (80.6 vs. 76.0% IVDMD, respectively) and IVOMD (84.6 vs. 78.9% IVOMD, respectively) than oats planted after CS ($P = 0.03$).

Overall, the nutrient content of the oats-turnip mix in year 1 and the oats in year 2 did not substantially differ due to planting date (CS vs. HMC). The nutrient analysis shows that fall planted oats, with or without turnips, are high in protein, ranging from 18 to 23% CP and high in energy with ADF ranging from 22 to 26% and IVOMD ranging from 84.6% to 78.9%.

Cash crop yields

All cash crop yields are listed in Table 7. Cash crops harvested from treatment areas did not differ based on the subsequent crop or annual forage drilled ($P \geq 0.30$). There was a year effect ($P < 0.01$) for the soybean yield and soybean biomass yield as there were two years of hand harvest data collected, while HMC and CS hand harvests were collected only during 2015. Soybean grain yield was not different ($P = 0.32$) between treatments with an average of 4,812 kg DM / ha. The kg of biomass DM per hectare did not differ ($P = 0.98$) between treatments with an average of 3,889 kg DM / ha overall. Corn silage yield did not differ (*P* = 0.30) across treatments with an average yield of 17,396 kg DM / ha. The HMC grain yield was not different (*P* = 0.64) with an average of 15,549 kg DM / ha across treatments. The stover yields from the HMC treatments did not differ (*P* = 0.87) with an average of 8,621 kg DM / ha.

Calf performance

In Exp. 2, the steer ADG did not differ (*P* = 0.26; SEM = 0.12) among treatments, 0.59 and 0.33 kg for CS and HMC, respectively (Table 8). Gain per hectare of HMC (63 kg) and CS (147 kg) did not differ (*P* = 0.13; SEM = 25.9).

Economics

A partial budget was conducted to evaluate the costs of each backgrounding system on oats as compared to distillers supplementation (Table 9). Distillers supplementation of 0.21 kg DM / d (14 kg / steer for the entire period) would give similar gain but cost roughly $2.30 / steer at $0.165 / kg of DDGS. Similarly, steers grazing oats after CS gained 0.59 kg / d. If that corn field had been harvested as HMC instead of CS and calves were allowed to graze cornstalks with distillers supplementation of 1.04 kg DM (84 kg / steer for entire period), it would cost $14 / steer to achieve similar gains as grazing the oats. Cost of gain for CS steers was $ 1.03 / kg gain, while cost of gain for HMC steers was $2.87 / kg gain. If HMC/DDGS was provided at 1.04 kg DM / hd daily to target a medium gain (0.59 kg), cost of gain would be $0.95 / kg gain. If provided for a lower targeted ADG (0.33 kg), 0.21 kg DM / hd, the cost of gain would be $1.28 / kg gain.

DISCUSSION

Forage quality and production

The NRC requirement (2000) for a 227 kg growing calf is 9.8% CP in the diet for 0.454 kg of gain. The protein content of brassica mixes is high enough to provide enough protein to the growing animal, regardless of grazing time during October to January (NRC, 2000). In this study, the nutrient analysis of the brassica mix forage for crude protein ranged from 12.2-19.6% CP in the growing calf diet. This leaves ample room for the calf to meet its growing requirements. Brassica mixes are also high in fiber with an average of 42% NDF observed in calf diets over two years.

The low ADF content observed in the 2013 brassica mix suggests the forage was highly digestible and thus, high in energy. However, the high S content of the 2014 brassica mix may be a concern due to the brassicas having greater than 0.52% S, while the grasses, sorghum and oats, had lower levels averaging 0.22% S. Since steer ADG in Exp. 1 ranged from 0.70 – 2.00 kg /d, the compilation of the forage species may have been enough to offset any sulfur toxicity.

In Exp. 1, the ADF content increases with plant maturity as more cellulose and lignin, structural plant components, are formed (Van Soest, 1963). Therefore, the energy content of the forage is reduced as ADF content increases. In 2014, the ADF content of the radish tuber (21.8% ADF) did not differ from the radish or turnip leaf (25.9 and 25.2% ADF, respectively) but was greater than the turnip tuber (11.8% ADF). This may suggest the turnip tuber provides a significant amount of energy when consumed due to the low ADF contribution. Sorghum had the greatest ADF, averaging 42.0% ADF over time, and thus, may have contributed the least amount of energy to the mix.

In Exp. 2, the CS oat and turnip mix was more mature than the HMC mix, therefore, one would expect the ADF to be greater. In forages, lower ADF values suggest greater digestibility and thus greater energy as ADF is a measure of the less digestible and indigestible portions of fiber. With a higher IVOMD for HMC in year 2, this further suggests that oats planted after HMC had a greater energy value as compared to the CS oats. These annual forage crops containing oats and turnips have greater digestibility than corn residue, which ranges from 50-60% IVOMD (Wilson et al., 2004), meaning that the annual forages are a high quality forage for growing calves. The rapid loss in brassica tuber WSC could be due to the freeze and thawing of the biomass.

Wiedenhoeft and Barton (1994) found that protein and fiber content of forage is negatively correlated. Neutral detergent fiber ranged from 14-42% NDF across planting dates and ADF ranged from 11-36% ADF, but overall brassicas are comparable to a good quality corn silage. Fall planted brassicas tend to have lower NDF than summer planted (Wiedenhoeft and Barton, 1994). Earlier planted forage will have a higher NDF than later planted forage, due to the maturity of the forage (Wiedenhoeft and Barton, 1994; Jacobs et al., 2004).

Westwood and Mulcock (2012) described the readily fermentable carbohydrates of brassicas as being in the form of WSC. The high WSC, low NDF content predict the risk of subacute acidosis due to the readily fermentable carbohydrates causing a lower ruminal pH (Westwood and Mulcock, 2012). In Exp. 1, total 80% ethanol soluble carbohydrates (TESC) were in the highest quantities in the tubers of brassicas averaging 46.3 and 52.3% TESC in radish and turnip tubers, respectively, in the first month of grazing. As the forage was grazed later in the season, the TESC percentage declined.

Oats peaked at 23.0% WSC in late November, while sorghum TESC was similar across the grazing period. Brassica leaves accumulated TESC until late November, 17.0 and 20.2% TESC in radishes and turnips, respectively, before starting to decline. Brassica tubers followed similar suit with levels reaching 41.2 and 60.3% TESC in radishes and turnips, respectively, before dropping in the winter months. The majority of the biomass is in the leaf, but the tuber has the greatest concentration of TESC.

Given the relatively low seed cost of the brassicas, the high DM yield and the high quality of the forage; brassicas appear to be an excellent feed source for growing cattle. However, the high S (0.56 to 0.71% S) and low NDF (16.7 to 41.7% NDF) of the brassicas may be reason to include a grass in the mix to possibly reduce sulfur toxicity issues. The maximum tolerable level for dietary sulfur is 0.40% S (NRC, 2000). Sulfur estimated in the turnips and radishes in Exp. 1 was agreeable to what Barry (2013) reported, in that turnips contained 0.69% S. The present study found that turnip leaf contains 0.73% S in October and declines to 0.52% S by January. The radish leaf peaked in November with estimates of 0.86% S present. Secondary compounds, such S-methyl cysteine sulfoxide, glucosinolates and nitrates, in brassicas can cause reduced feed intake as these compounds are converted to toxins. The effects are not known precisely, but the physical evidence is that feed intake is lowered (Barry, 2013). The high S content of the mix is caused by the contribution of the leaf and tuber of the brassicas as the brassicas range from 0.31 - 0.57 percentage units greater than sorghum (radish and turnip, respectively; Figure 5). Westwood and Mulcock (2012) reported if feeding a diet solely composed of brassicas, the NDF content was too low to meet optimal rumen function. The minimum NDF content to support optimal rumen function should range from 27-

30% DM (Westwood and Mulcock, 2012). Having on average 55% NDF from oats and 67% NDF from sorghum may be a reason that sulfur toxicity was not observed in the present study.

Koch et al. (2002) reports brassicas have a low fiber content, resulting in a high IVDMD. The turnip top and root averaged 85.7 and 86.4% IVDMD, respectively (Koch et al, 2002). Villalobos and Brummer (2015) indicated that in-vitro true digestibility ranged from 85.5-92.9% in forage brassicas harvested mid-November. Keogh et al. (2012) agreed that the digestibility of forage brassicas is estimated to be greater than 90%. In Exp. 1 of the present study, the IVDMD ranged from 73-87% IVDMD in brassica components, while the oats and sorghum components ranged from 59-70% IVDMD as time progressed. The IVOMD remained the same from October to January for turnip tubers (88-90%). Radish and turnip leaf were similar in October at 88% IVOMD, then declined to 85% for radish tuber and 90% IVOMD for turnip tuber. These data are consistent with what Koch et al. (2002) and Villalobos and Brummer (2015) found.

Post-grazing and yield

Koch et al. (2002) reported July planted turnip crops produced 3,900 kg DM / ha, while August planted turnips produced an average of 2,500 kg DM / ha. There was a reduction in yield each week, so it could be expected that mid-August would have half the growth as a crop planted in July. Between species, the radish produced more aboveground biomass, while the turnip produced more below ground biomass in the root. This is due to the movement of the dry matter from top to root as the crop matured and was grazed later (Koch et al, 2002).

Koch et al. (2002) indicated that a delay in planting meant that the crop was less productive. The later planting date does not allow for greater dry matter accumulation. When planting in early August, oats yield 315 kg DM more than sorghum, which only yields 398 kg DM. Radishes produced 1,167 kg DM / ha more leaf growth than turnip leaves; however, the radish tuber growth, 1,049 kg DM / ha was similar to the turnip leaf growth. The turnip tuber had the lowest yield, however, when considering the amount produced as compared to the plant itself, turnip tuber growth is similar to radishes (30% and 34% tuber, respectively).

Greater oats production on CS paddocks as compared to the HMC paddocks in Exp. 2 was likely due to the earlier planting and thus the greater accumulation of GDD for fall growth (1714 vs. 1162 GDD, after CS and HMC, respectively). After determining the amount of forage available and grazing utilization, the question comes up of how much forage is left upon completion of grazing. The post-graze data from Exp. 1 ranged from 1,867 to 3,022 kg DM / ha with an average of 2,404 kg DM / ha left after grazing was terminated. The post-graze measurements using the transect method in Exp. 2 of the current study showed significant difference between treatments with average ground cover being 82% and 63% for HMC and CS, respectively. The HMC treatments had greater coverage as the stalks were counted in the appearance of ground cover, but were not calculated into the corn residue that was grazed by steers. These data show that after 62 days of grazing, there is enough forage residue for ground cover.

These data suggest that there is an opportunity for forage production after wheat harvest for grazing. The brassicas (daikon radish and purple top turnip) produced high quality forage (low ADF and moderate CP). Cassida et al. (1994) claims that supplying hay to a brassica diet may offset the anti-quality factors consistent in the nutrient makeup as well as increase the fiber and DM intake of the diet (Cassida et al., 1994).While no sulfur toxicity issues were observed in the current experiment, the high S and low NDF of brassicas may increase risk of sulfur toxicity. More research on grazing high-sulfur brassicas is needed before accurate recommendations can be developed.

Performance and economics

Steer ADG on annual forages ranged from 0.70-1.00 kg after wheat harvest and 0.33-0.59 kg after corn harvest in the present study. Steer grazing oats following HMC and CS did not differ, 0.33-0.59 kg (P = 0.26). However, given the low number of replicates (n = 2) in Exp. 2, ADG did not statistically differ among treatments (Table 8). Koch et al (2002) reported lambs gaining 0.183 kg, while the average gain for lambs on turnips was 308 kg / ha. Lambs gained about 277 and 329 kg / ha on turnips in a two year study done by Yun (1999). Lambs on radishes gained 266 and 298 kg / ha with 0.13 and 0.17 kg ADG between two locations (Yun et al., 1999). Since brassicas are a low fiber crop, Lambert et al. (1987) indicated that fiber additions to the diet improved performance. In Exp. 1 of the present study, oats and sorghum were available in the mix, thereby allowing for greater fiber in the diet. Koch et al. (2002) showed drylot versus turnip grazing lambs having no difference in gain. Some data exist which evaluate cows grazing brassica mixes, however, the majority of animal performance data that is available is on growing lambs.

The economics from Exp. 2 indicate that supplementing distillers to corn stalk grazed calve provides the best cost of gain ($0.95 / kg gain and $1.28 / kg gain for 0.59 kg gain and 0.33 kg gain, respectively). The cost of gain for oats planted after corn silage was $1.03 / kg, while planting oats after HMC cost $2.87 / kg gain. In a previous experiment, (Tibbits et al., 2016) calves grazing corn residue with no supplement lost 0.08 kg of ADG. The present study grazed oats in HMC and the data suggests that the low amount of oats produced increased gains. With the stocking rate used in the present study, the seed plus seeding would have cost $24 / steer. Koch et al. (2002) seeded turnips at 2-3 kg / ha and radishes at 25-28 kg / ha and calculated that the total cost to grow and graze turnips to be $220-250 / ha, amounting to the cost being $0.72- 0.79 / kg of gain. McFerran et al. (1997) noted that the cost to feed turnips per kg DM was 7 cents, whereas pasture totaled 3-5 cents per kg DM. This demonstrates that from an economic standpoint, supplementing distillers on cornstalks may provide a cheaper gain for producers.

IMPLICATIONS

Grazing an annual forage mixture, consisting mainly of brassicas and oats, after summer wheat harvest provides moderate gains for growing calves for 50 d in early winter. Grazing oats after corn harvest provides moderate gains and forage yield; however, due to the greater number of GDD, planting after CS seems to provide a greater quantity of forage for growing calves in winter.

LITERATURE CITED

AOAC. 1965. Official Methods of Analysis. 10th ed. Assoc. Off. Anal. Chem., Washington, DC.

AOAC International. 1999. Official Method of Analysis. 16th ed. AOAC Int., Arlington, VA.

Barry, T.N. 2013. The feeding value of forage brassica plants for grazing ruminant livestock. Anim. Feed Sci. and Technol. 181(1), 15-25.

Cassida, K.A., B.A. Barton, R.L. Hough, M.H. Wiedenhoeft, and K. Guillard. 1994. Feed intake and apparent digestibility of hay-supplemented brassica diets for lambs. J. Anim. Sci. 72(6), 1623-1629.

Hall, M.B., W.H. Hoover, J.P. Jennings, and T.K.M. Webster. 1999. A method for partitioning neutral detergent-soluble carbohydrates. J. Sci. of Food and Ag. 79(15), 2079-2086.

Jacobs, J.L., G.N. Ward, and G. Kearney. 2004. Effects of irrigation strategies and nitrogen fertiliser on turnip dry matter yield, water use efficiency, nutritive characteristics and mineral content in western Victoria. Anim. Prod. Sci. 44(1), 13-26.

Keogh, B., T. McGrath, and J. Grant. 2012. The effect of sowing date and nitrogen on the dry-matter yield and nitrogen content of forage rape (Brassica napus L.) and stubble turnips (Brassica rapa L.) in Ireland. Grass and Forage Sci. 67(1), 2-12.

Koch, D.W., C. Kercher, and R. Jones. 2002. Fall and winter grazing of Brassicas-a value-added opportunity for lamb producers. Sheep and Goat Research J. 17(2), 1-13.

Lambert, M.G., S.M. Abrams, H.W. Harpster, and G.A. Jung. 1987. Effect of hay substitution on intake and digestibility of forage rape (Brassica napus) fed to lambs. J. Anim. Sci. 65(6), 1639-1646.

Lauer, J. 2002. Methods for calculating corn yield. Avaliable online: http://corn. agronomy. wisc. edu/AA/pdfs A, 33.

McDougall, E.I. 1948. Studies on ruminant saliva. 1. The composition and output of sheep's saliva. Biochem. J. 43(1), 99.

McFerran, R.P., W.J. Parker, V. Singh, and S.T. Morris. 1997. Incorporating turnips into the pasture diet of lactating dairy cows. In PROCEEDINGS-NEW ZEALAND SOCIETY OF ANIMAL PRODUCTION (Vol. 57, pp. 161-164). NEW ZEALAND SOCIETY OF ANIMAL PROD PUBL.

NRC. 2000. Nutrient requirements of beef cattle. 7th rev. ed. Update 2000. Natl. Acad. Press, Washington, DC.

SAS Institute. 2011. The SAS system for Windows. No. 9.3. SAS Inst., Cary, NC.

Tibbits, B.J., J.C. MacDonald, R.N. Funston, C.A. Welchons, R.G. Bondurant, and F.H. Hilscher. 2016. Effects of supplemental energy and protein source on performance of steers grazing irrigated corn residue. Nebraska Beef Cattle Rep. MP103:31-32.

Tilley, J. M.A. and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. Grass and Forage Sci. 18(2), 104-111.

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.

Villalobos, L.A. and J.E. Brummer. 2015. Forage Brassicas Stockpiled for Fall Grazing: Yield and Nutritive Value. Crop, Forage and Turfgrass Mgt. 1(1).

Watson, A.K., B.L. Nuttelman, T.J. Klopfenstein, L.W. Lomas, and G.E. Erickson. 2013. Impacts of a limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91(11), 5507-5517.

Weiss, W.P. 1994. Estimation of digestibility of forages by laboratory methods. Page 644 in Forage Quality, Evaluation and Utilization. G.C. Fahey Jr., ed. Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, WI.

Westwood, C.T. and H. Mulcock. 2012. Nutritional evaluation of five species of forage brassica. In Proceedings of the New Zealand Grassland Association (Vol. 74, pp. 31-38).

Wiedenhoeft, M.H. and B.A. Barton. 1994. Management and environment effects on Brassica forage quality. Agron. J. 86(2), 227-232.

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.

Yun, L., D.W. Koch, F.A. Gray, D.W. Sanson, and W.J. Means. 1999. Potential of trap-crop radish for fall lamb grazing. J. Prod. Ag. 12(4), 559-563.

Table 4.1. Seeding rate of cover crop/double cropped annual forage by year

Forage Type	2013 Seeding Rate (% of full seeding rate)[1]	2014 Seeding Rate (% of full seeding rate)
Crimson Clover	1 kg/ha (10%)	--
Daikon Radish[2]	--	3 kg/ha (30%)
Oats	17 kg/ha (13%)	17 kg/ha (13%)
Purple Top Turnip	2 kg/ha (40%)	3 kg/ha (60%)
Sorghum	1 kg/ha (3%)	7 kg/ha (17%)
Sunflower	2 kg/ha (22%)	--
Safflower[3]	--	4 kg/ha (44%)
Total	23 kg/ha (88%)	34 kg/ha (161%)

[1]Percentages indicate the percent of the full seeding rate of each species (based on the number of seeds per 0.454 kg.) as compared to planting a 100% of a monoculture of that specific species
[2]Changed crimson clover to daikon radish in 2014
[3]Changed sunflower to safflower in 2014

Table 4.2. Composition of free choice mineral provided to Exp. 1 cattle (DM basis)

Guaranteed Analysis	
Calcium (Ca)	18.90-22.70%
Phosphorus (P), minimum	1.50%
Salt (NaCl)	15.70-18.90%
Magnesium (Mg), minimum	2.00%
Copper (Cu), minimum	1.000 ppm
Selenium (Se), minimum	26.40 ppm
Zinc (Zn), minimum	3.750 ppm
Vitamin A, minimum	220,264 IU/kg
Vitamin D_3, minimum	22,026 IU/kg
Vitamin E, minimum	110 IU/lb
Active Drug Ingredient	
Monensin (as Monensin Sodium)	1200 ppm

Table 4.3. Seeding rate of annual oat forage for Exp. 2

	2014 Seeding Rate (% of full seeding rate)[1]		**2015 Seeding Rate (% of full seeding rate)[1]**	
Forage Type	CS[2]	HMC[2]	CS[2]	HMC[2]
Oats	67 kg / ha (52%)	84 kg / ha (60%)	101 kg / ha (77%)	101 kg / ha (77%)
Turnips	6 kg / ha (40%)	6 kg / ha (40%)	--	--
Total	73 kg / ha (92%)	90 kg /ha (100%)	101 kg / ha (77%)	101 kg / ha (77%)

[1] Percentages indicate the percent of the full seeding rate of each species (based on the number of seeds per 0.454 kg.) as compared to planting a 100% of a monoculture of that specific species

[2]Treatments: CS = Following corn silage, HMC = Following high moisture corn

Table 4.4. Steer performance and forage yield (DM-basis) of brassica-based 5 species mix in Exp. 1[1]

Item	2013	2014
Calf performance		
Initial BW, kg	205 ± 16	266 ± 4
Ending BW, kg	252 ± 18	301 ± 14
ADG, kg / d	1.00 ± 0.019	0.70 ± 0.073
Gain per hectare, kg	109 ± 4.4	154 ± 6.7
Forage production		
Above ground biomass, kg / ha	2,257 ± 270	3,991 ± 270
Below ground biomass, kg / ha	--	1,571 ± 780

[1]Due to differences between two years, data were not able to be statistically analyzed across years; however, means reported with standard deviations were used to determine variability between groups.

Table 4.5. Mean (SEM) nutrient composition of brassica-based 5 species mix in late October prior to the start of grazing in Exp. 1 (DM basis)

	Year	
Nutrient	2013	2014
OM, %	86.5 (0.79)	82.0 (1.14)
NDF, %	49.1 (4.77)	35.0 (1.65)
ADF, %	23.1 (1.73)	25.1 (1.09)
CP, %	12.2 (2.30)	19.6 (1.42)
S, %	0.63 (0.06)	0.55 (0.04)
IVDMD, %	74.0 (3.17)	77.7 (1.13)
IVOMD,%	79.0 (2.88)	80.6 (1.22)

Table 4.6. Cash crop yields (kg DM / ha) following oat-turnip and oat mix in Exp. 2

	Treatment[1]				
Item[2]	CovGR	CovNG	NCNG	SEM	*P* - value
Soybean Grain Yield	4,690	4,769	4,914	114	0.32
Soybean Biomass Yield	3,758	3,901	3,887	132	0.68
Corn Silage Yield	18,503	16,905	16,780	790	0.30
HMC Grain Yield	16,043	15,186	15,417	643	0.64
HMC Stover Yield	8,778	8,510	8,574	372	0.87

[1]Treatments include CovGR – annual forage crop grazed by livestock, CovNG – annual forage crop ungrazed, NCNG – annual forage crop not drilled or grazed

[2]All crop yields are estimated in kg DM per hectare.

Table 4.7. Nutrient analysis of forage mixes planted after corn silage or high moisture corn for both years for Exp. 2 (DM basis)

	Treatment[1]			
	CS	HMC	SEM	*P*-value
Year 1[2]				
OM, %	84.8	86.5	0.26	0.05
CP, %	22.5	18.7	2.25	0.35
NDF, %	43.7	45.1	0.58	0.23
ADF, %	24.7	21.6	0.66	0.08
IVOMD, %	82.1	82.2	0.61	0.87
Year 2				
OM, %	83.8	84.4	0.39	0.36
CP, %	18.0	23.2	2.15	0.23
NDF, %	43.7	37.5	2.18	0.18
ADF, %	25.6	22.1	0.74	0.08
IVOMD, %	78.9	84.6	0.66	0.03

[1]CS: Forage grazed after corn silage harvest; HMC: forage grazed after high moisture corn harvest.

[2]Year 1 mix composed of 67 kg / ha oats and 6 kg / ha turnips after corn silage and 84 kg / ha oats and 6 kg / ha turnips in HMC treatment. Year 2 composed of 101 kg / ha oats planted after corn silage and HMC.

Table 4.8. Performance of steers grazing oats after corn harvest in Exp. 2

Item	Treatment[1]		SEM	*P*-value
	CS	HMC		
Initial BW, kg	212	213	0.35	0.42
Final BW, kg	249	233	7.8	0.28
ADG, kg / day	0.59	0.33	0.12	0.26
Gain, kg / ha[2]	147	63	25.9	0.13

[1]CS = Forage grazed after corn silage harvest; HMC = forage grazed after high moisture corn harvest

[2]Gain indicates the total weight gain received from grazing each group per hectare over 62 day period.

Table 4.9. Cost of gain calculated for double cropped forage compared to grazing corn residue with distillers supplementation for 62 d in the winter

			HMC/DDGS[1]	
Item	**CS/Oats**	**HMC/Oats**	**Medium gain**	**Low gain**
ADG, kg / d	0.59	0.33	0.59	0.33
Stocking rate, hd / ha	4.2	3.2	3.2	3.2
DDGS, kg / hd / d	--	--	1.04	0.21
Costs ($ / hd)				
Yardage[2]	6.20	6.20	12.40	12.40
Seed plus seeding[3]	18.06	23.62	--	--
Fertilizer plus application[4]	13.34	17.45	--	--
Corn residue[5]	--	11.54	11.54	11.54
DDGS[6]	--	--	10.76	2.20
Total cost $ / hd	37.60	58.80	34.70	26.10
Cost per kg gain, $ / kg	1.03	2.87	0.95	1.28

[1]HMC/DDGS: Hypothetical scenario where steers grazed corn residue after high moisture corn with a level of distillers' supplementation for a predetermined gain.

[2]Yardage includes fence and water at $0.10 / hd/ d and supplement delivery at $0.10 / hd/ d

[3]Oat seed cost at $51.16 / ha ($20.70 / ac) and seeding at $24.71 / ha ($10.00 / ac)

[4]Nitrogen fertilizer applied at rate of 45 kg / ha at $0.864 / kg ($0.392 / lb) with application cost of $17.30 / ha ($7.00 / ac)

[5]Corn residue priced at $37.5 / ha ($15 / ac)

[6]DDGS priced at $0.165 / kg ($150 / ton)

Figure 4.1. Total biomass yield (kg DM/hectare) of forage components from Exp. 1 in October 2014 prior to start of grazing

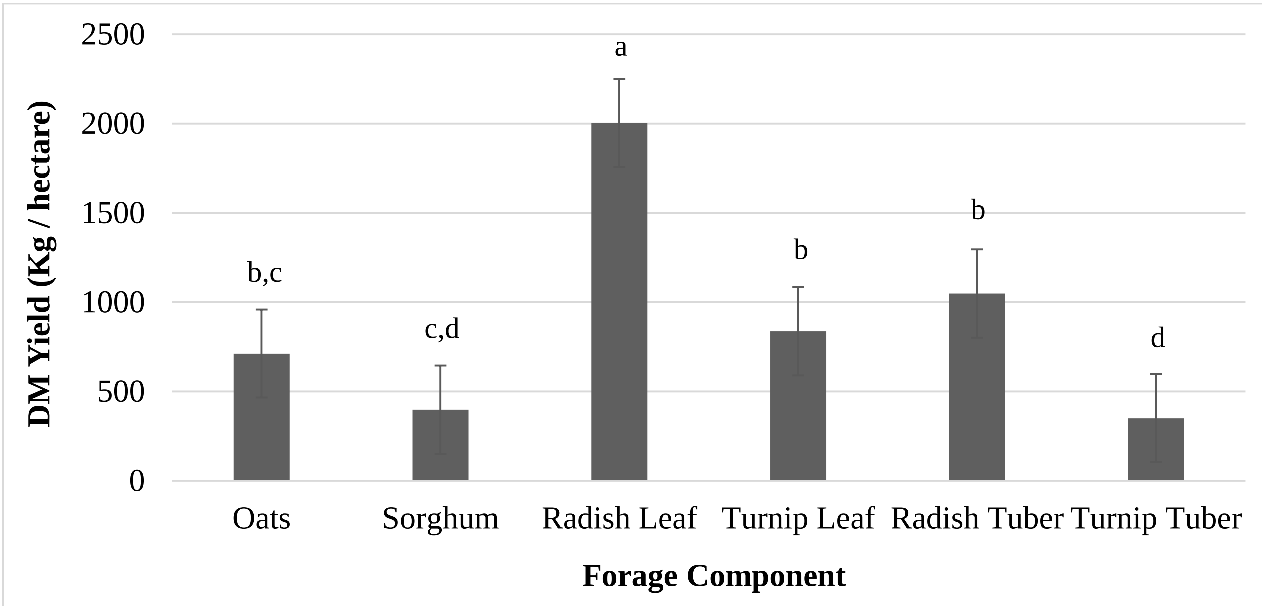


Figure 4.2. Sulfur (S) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

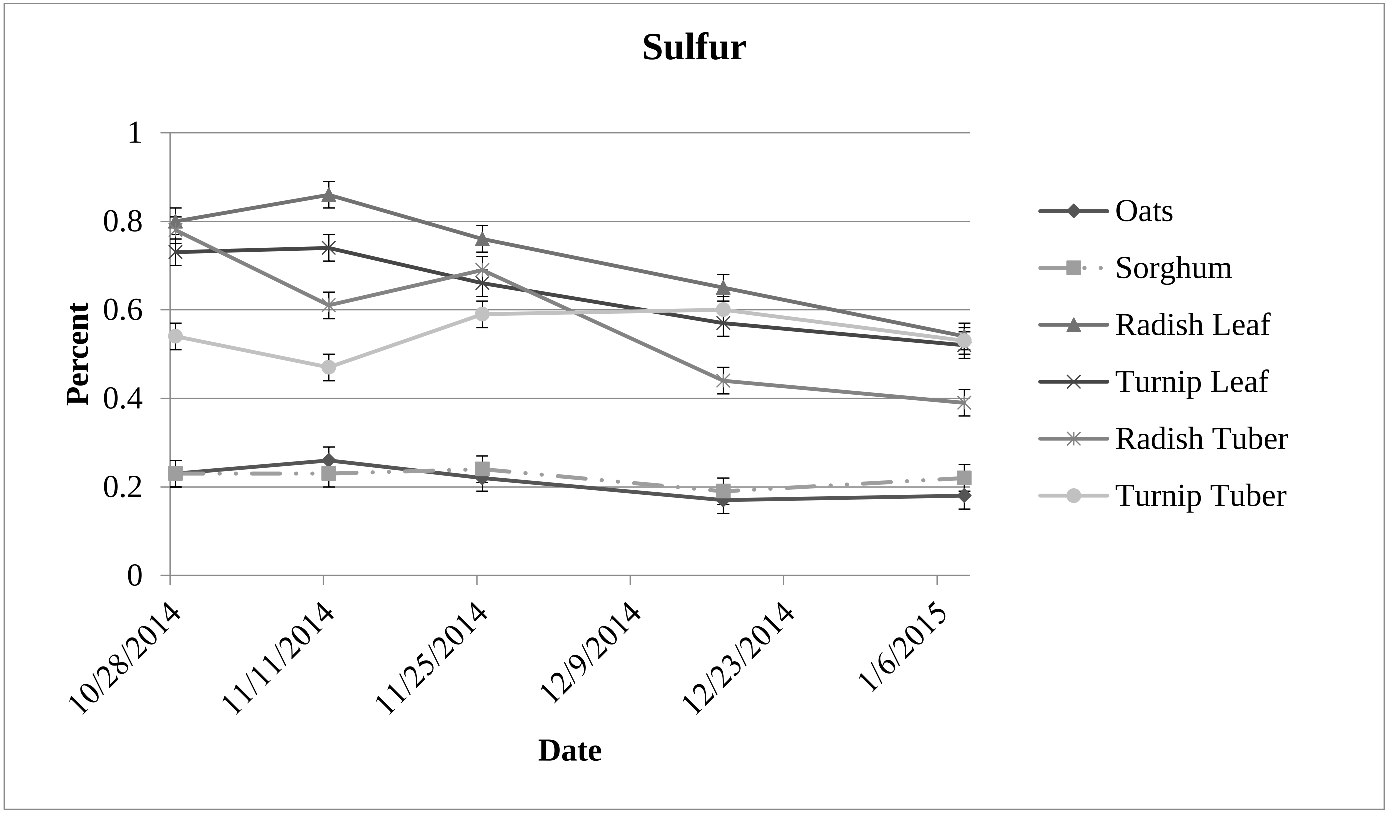


Figure 4.3. Organic matter (OM) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

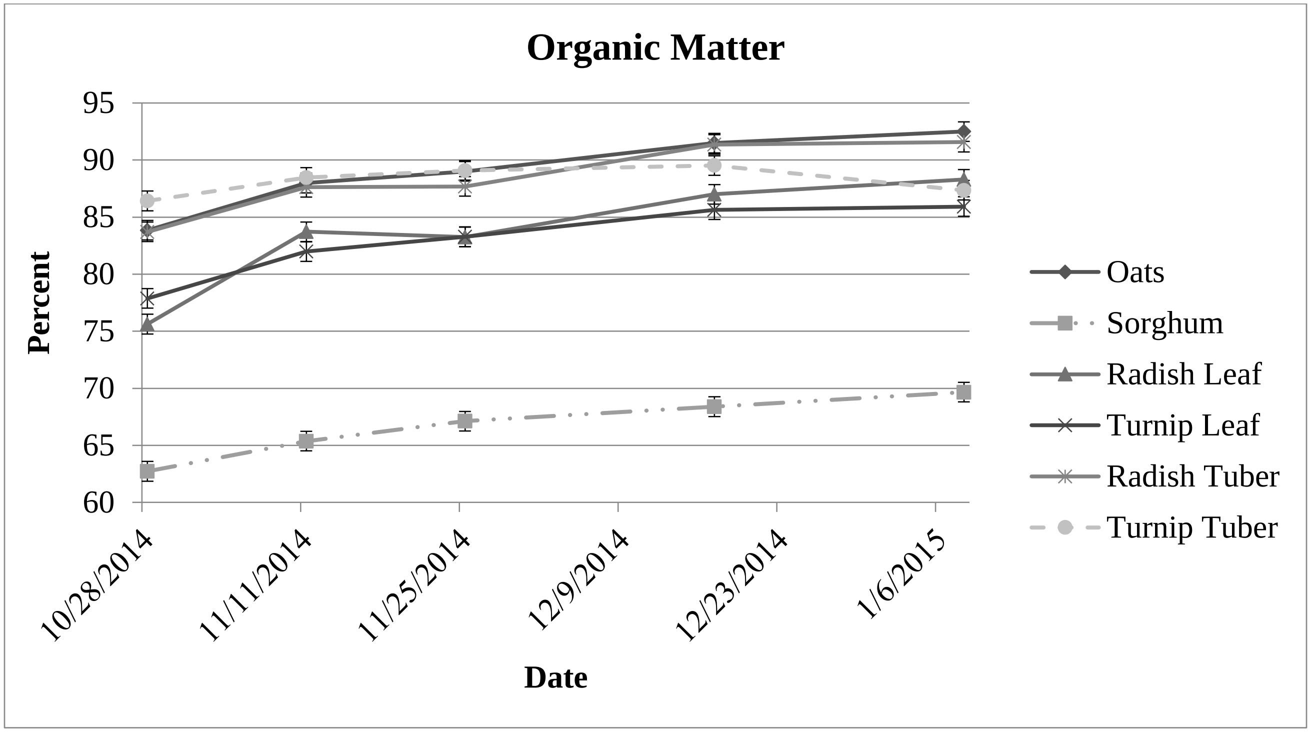


Figure 4.4. Neutral detergent fiber (NDF) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

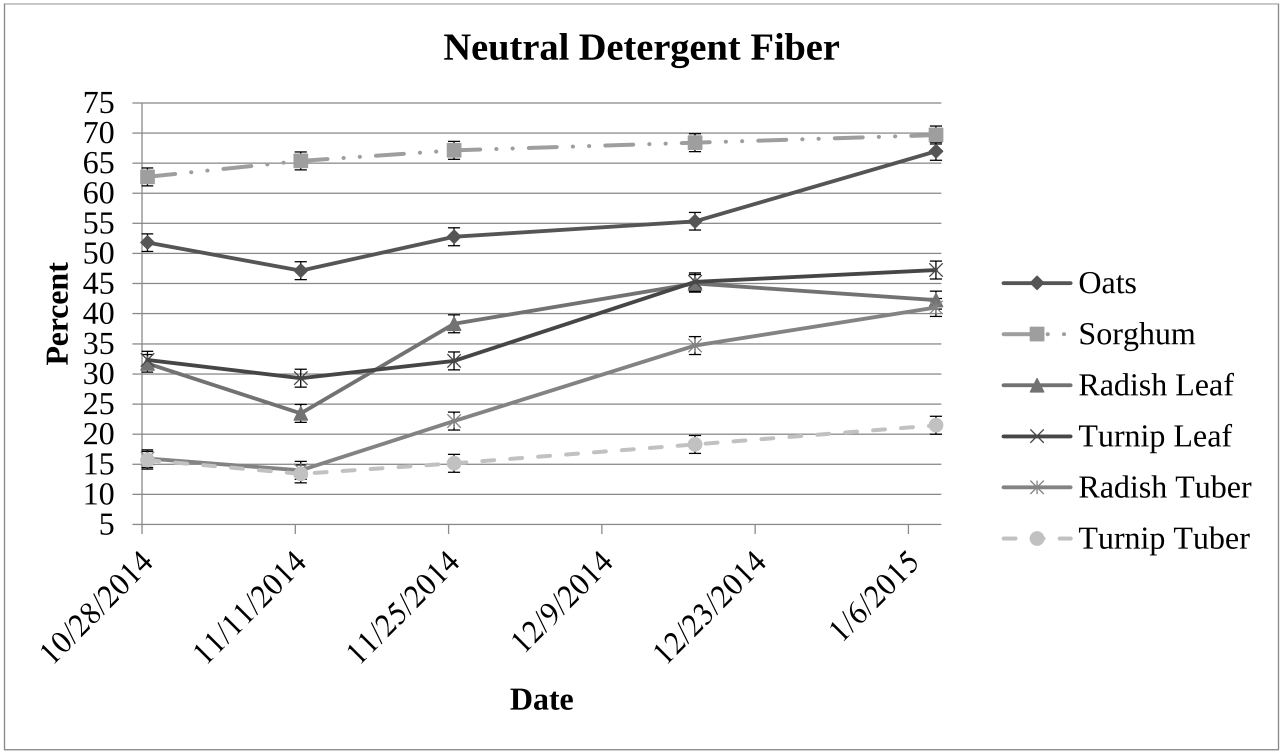


Figure 4.5. Acid detergent fiber (ADF) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

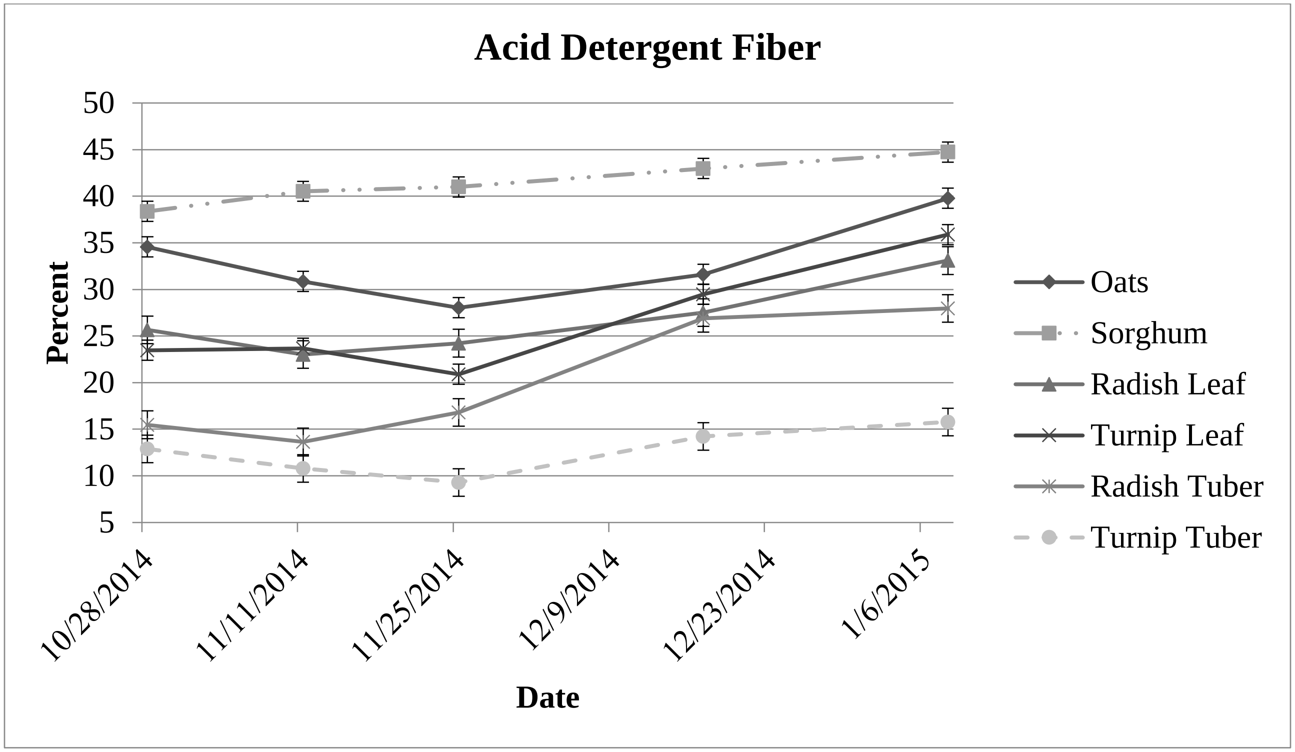


Figure 4.6. Crude protein (CP) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

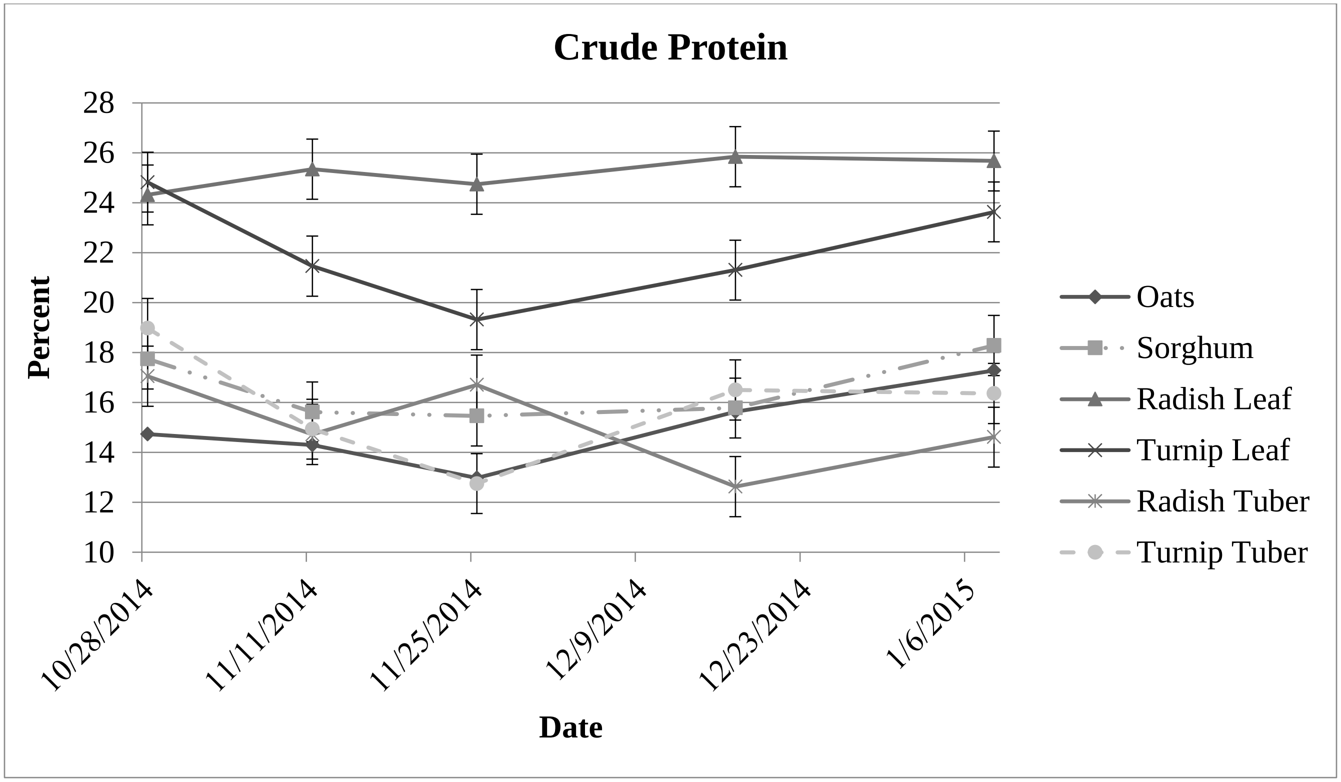


Figure 4.7. Total ethanol soluble carbohydrates (TESC) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

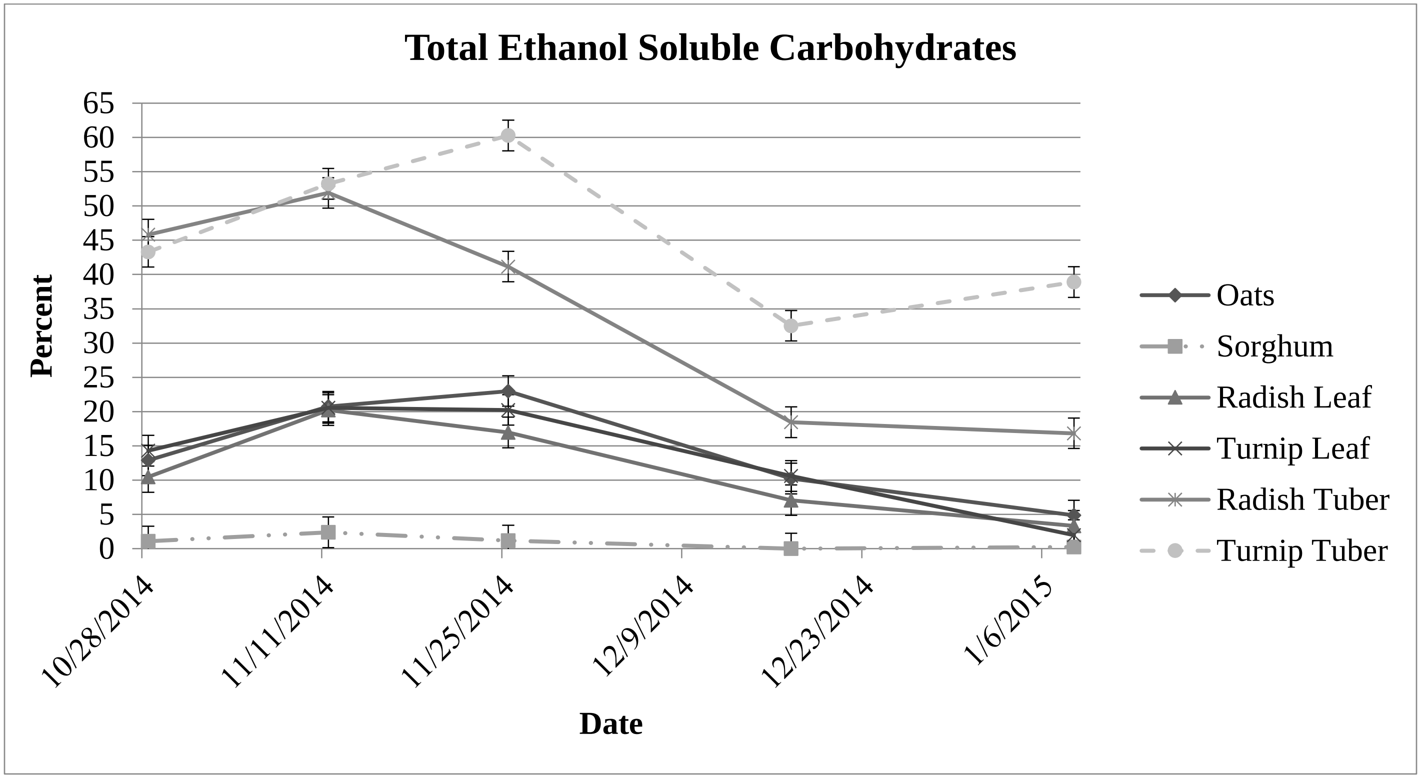


Figure 4.8. In-vitro dry matter digestibility (IVDMD) over time of individual forage component in brassica mix in Exp. 1 (DM basis)

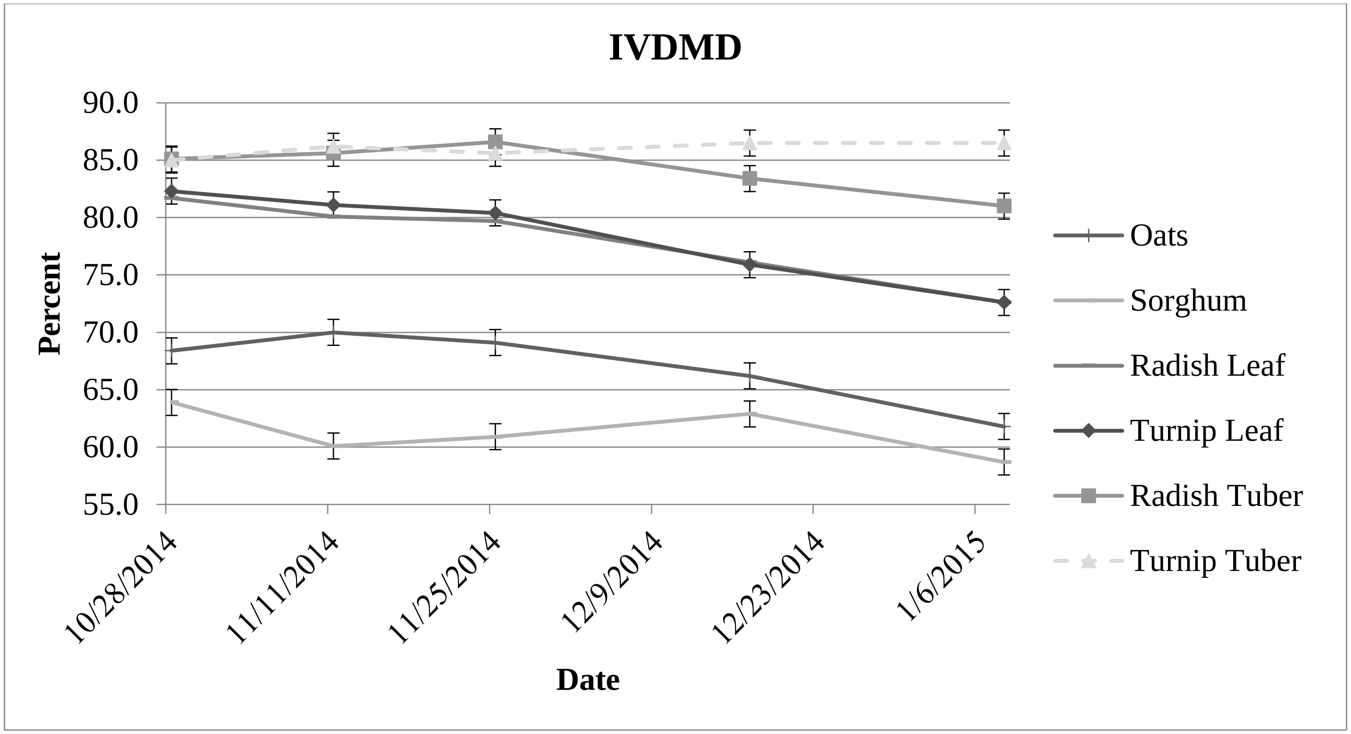
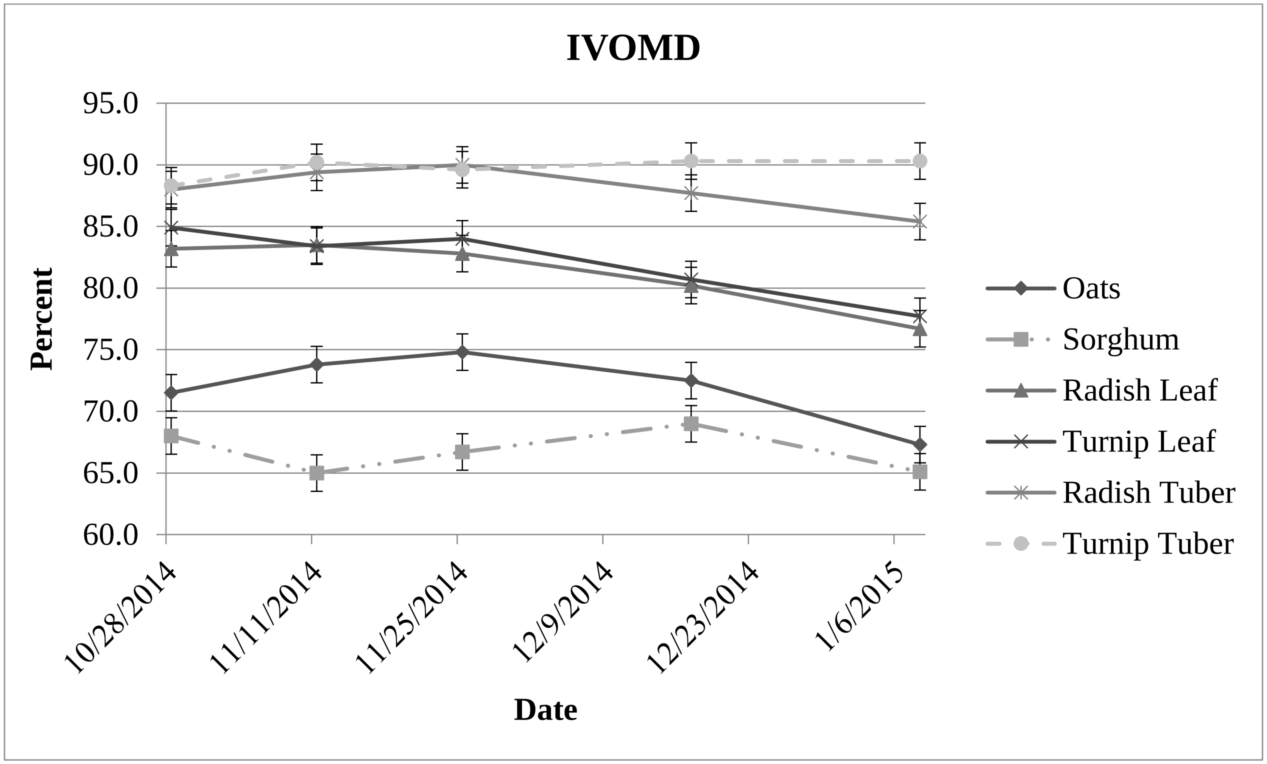


Figure 4.9. In-vitro organic matter digestibility (IVOMD) over time of individual forage component in brassica mix in Exp. 1 (DM basis)



APPENDIX

I. Calculations utilized for baled nutrient, residue removed and harvest index

Bale and Mineral

1) Bale Weight on DM basis= Bale weight (kg.) * %DM
2) Average kg. residue removed per rep = Bale weight on DM basis
3) Average kg. residue removed per hectare= Average kg. residue removed per rep ÷ hectares per rep
4) %Nitrogen = %Crude Protein ÷ 6.25
5) Kg. of nutrient per hectare= Kg. nutrient per rep ÷ hectare per rep
6) Kg. $CaCO_3$ removed per hectare= Kg. Ca removed per hectare * 2.5
7) Kg. P_2O_5 removed per hectare= Kg. P removed per hectare * 1.20
8) Kg. K_2O removed per hectare= Kg. K removed per hectare * 2.29

Residue Removed

A. Hand Harvested:
    1) Kg. of residue removed per hectare= Total bale weight per rep (kg. DM) ÷ Hectares per rep
    2) Average kg. of residue removed per hectare = average of rep 1 and 2
    3) Kg. Stover produced per hectare = (Total Stover Weight ÷ 2.79 m^2) * (4047 $meter^2$/1 hectare)
    4) Kg. Stover left per hectare = Kg. stover produced per hectare – Kg. of residue removed per hectare
    5) % residue removed = Total bale weight per rep (kg. DM) ÷ Kg. stover produced per rep

Harvest Index

1. Total DM of crop (Kg.) = Kg. grain at 15.5% moisture + Total Kg. stover per hectare
2. % grain in total DM crop= Kg. grain at 15.5% moisture ÷ Total DM of crop (Kg.) * 100
3. % stover in total DM crop = Total Kg. stover per hectare ÷ Total DM of crop (Kg.) * 100
4. Harvest Index= Average of % grain in total DM crop of 3 cooperators

II. Amount of residue removed and percent of residue removed by baling location and year

	Year				
Location[1]	2013	2014	2015	SEM	*P*-value
Residue removed, kg / ha					
Ainsworth	3,876[c]	8,182[a]	5,862[b]	541	< 0.01
Clay Center	---	6,402	5,136	442	0.36
Nebraska City	3,842[a]	1,173[b]	4,545[a]	541	< 0.01
Norfolk	5,187	4,337	5,127	541	0.28
Odessa	4,757[a]	4,579[a]	1,980[b]	541	0.01
Scottsbluff	4,321[b]	6,601[a]	7,684[a]	766	0.01
Residue removed, %					
Ainsworth	44.4[c]	91.5[a]	63.0[b]	2.24	< 0.01
Clay Center	---	62.3	51.0	4.32	0.20
Nebraska City	63.2[a]	14.0[c]	47.6[b]	3.88	0.02
Norfolk	74.1	70.6	66.9	6.24	0.75
Odessa	47.4[a]	45.7[a]	16.9[b]	3.83	0.05
Scottsbluff	58.3[c]	67.9[b]	80.2[a]	2.09	< 0.01

[a,b,c]Means within row with differing superscripts are different ($P < 0.05$).

[1]Location*year effect was significant ($P < 0.01$) for the amount of residue removed and percent residue removed.

III. Anhydrous ammonia removed as NH_3 removed by baling corn residue across locations and years in eastern Nebraska

Cooperator	Nitrogen Removal[1] 2013	2014	2015	SEM[2]	*P*-value
Ainsworth	55.6[b]	114.9[a]	63.5[b]	3.60	< 0.01
Norfolk	63.8	61.7	66.5	1.63	0.26
Odessa	44.1[a]	53.6[a]	17.0[b]	4.21	0.02
Nebraska City[3]	43.8[a]	14.9[b]	49.2[a]	3.21	< 0.01
Clay Center[4]	---	89.9	64.3	9.29	0.12
Scottsbluff[5]	41.3[b]	71.7[a]	63.8[a]	6.89	0.05

[ab]Means within row with differing superscripts are different ($P < 0.05$).
[1]Nutrient removed by baling in kg / hectare
[2]SEM = Pooled standard error mean for response variable
[3]Two fields in rotation each year at Nebraska City. Field rotates each year, so same field not used every year
[4]Clay Center site was not set up until year 2.
[5]Field rotates each year, so same field not used every year.

IV. Calcium removed as $CaCO_3$ by baling corn residue across locations and years in eastern Nebraska

Cooperator	$CaCO_3$ Removal[1]			SEM[2]	*P*-value
	2013	2014	2015		
Ainsworth	32.5[b]	66.5[a]	48.7[ab]	4.82	0.04
Norfolk	67.3	57.4	61.5	3.81	0.32
Odessa	35.1[a]	30.3[a]	11.9[b]	1.87	< 0.01
Nebraska City[3]	49.6[a]	12.9[b]	38.0[a]	3.77	< 0.01
Clay Center[4]	---	51.8	42.1	8.05	0.44
Scottsbluff[5]	37.8	59.8	65.9	14.1	0.33

[ab]Means within row with differing superscripts are different ($P < 0.05$).
[1]Nutrient removed by baling in kg / hectare
[2]SEM = Pooled standard error mean for response variable
[3]Two fields in rotation each year at Nebraska City. Field rotates each year, so same field not used every year
[4]Clay Center site was not set up until year 2.
[5]Field rotates each year, so same field not used every year.

V. Phosphorus removed as MAP by baling corn residue across locations and years in eastern Nebraska

	MAP Removal[1]				
Cooperator	2013	2014	2015	SEM[2]	*P*-value
Ainsworth	14.1	15.7	11.9	0.91	0.12
Norfolk	7.75	6.66	5.91	0.67	0.29
Odessa	5.94	6.25	2.47	1.20	0.19
Nebraska City[3]	4.87	3.80	1.58	1.53	0.39
Clay Center[4]	---	12.4	9.43	2.14	0.39
Scottsbluff[5]	7.47	8.44	5.57	3.58	0.64

[ab]Means within row with differing superscripts are different ($P < 0.05$).
[1]Nutrient removed by baling in kg / hectare
[2]SEM = Pooled standard error mean for response variable
[3]Two fields in rotation each year at Nebraska City. Field rotates each year, so same field not used every year
[4]Clay Center site was not set up until year 2.
[5]Field rotates each year, so same field not used every year.

VI. Potassium removed as K_2O by baling corn residue across locations and years in eastern Nebraska

	K_2O Removal[1]				
Cooperator	2013	2014	2015	SEM[2]	*P*-value
Ainsworth	78.5[c]	228[a]	175[b]	11.4	< 0.01
Norfolk	61.0	82.7	81.8	8.89	0.29
Odessa	99.1[b]	152[a]	36.3[c]	6.54	< 0.01
Nebraska City[3]	52.1[b]	24.6[c]	80.2[a]	4.32	< 0.01
Clay Center[4]	---	279	223	33.6	0.31
Scottsbluff[5]	107	191	319	69.9	0.10

[abc]Means within row with differing superscripts are different ($P < 0.05$).
[1]Nutrient removed by baling in kg / hectare
[2]SEM = Pooled standard error mean for response variable
[3]Two fields in rotation each year at Nebraska City. Field rotates each year, so same field not used every year
[4]Clay Center site was not set up until year 2.
[5]Field rotates each year, so same field not used every year.