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Effect of Residue Removal on Subsequent Year Quality and Quantity of Corn Residue and Cattle Performance While Grazing Corn Residue at Different Stocking Rates

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By

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Two studies evaluated the impact of residue removal; study 1, grazed in the fall or spring, study 2, removed by grazing at two stocking rates, light (LG), heavy (HG), or baled(B). There were no differences in pre-grazing treatments for digestibility, CP, NDF, plant fraction as a percent of residue and kg/25.5 kg of grain. Digestibility was highest in husk and lowest in stem. CP was greatest in leaf blade and lowest in husk. NDF was highest in the leaf sheath and lowest in the cob while stem is the greatest percentage of the plant and husk the smallest. The fractions cattle consumed yielded 6-7 kg of residue per 25.5 kg of grain. LG cattle had greater BCS ($P < 0.01$) and BW ($P = 0.03$) post-grazing. Soybean yields were greater following corn residue grazing ($P \leq 0.01$) in both fall and spring grazed treatments compared to un-grazed. Study two found no effect of residue removal on grain yield ($P = 0.31$).

An additional study evaluated the effect of plant density and maturity, moderately early maturing (MEM) hybrids or moderately late maturing (MLM) hybrids. All fractions had greater kg of DM/ha in MLM hybrids. Percent of husk and leaf blade were higher in MLM hybrids. Leaf blade and stem were only fractions with greater NDF in MLM

hybrids. NDFD of stem and husk were only fractions greater in MLM hybrids. MEM hybrids had greater CP in leaf sheath and stem only. As plant densities increased kg DM/ha increased for all fractions but cob. Percentage of cob and husk in total residue decreased with increased plant densities. The kg of leaf blade/25.5 kg of grain was only fraction to increase with the increasing densities. CP decreased for all plant fractions as planting density increased. NDF increased for all fractions as planting density increased. NDFD only decreased for leaf sheath as planting density increased.

Dedication

I would like to dedicate this thesis to my wife and parents. Lida Fay, you have been supportive of me throughout my Master's program, from helping me weigh samples in the lab to listening to my presentations so many times you were probably able to present them by memory. Mom and Dad, you have supported me through every phase of my life, and your love and support has meant more than you will know.

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Introduction

Using corn residue as a winter forage source for cattle has been a common practice for many years in Nebraska and the Midwest. With the large number of acres planted to corn and a large cow herd, grazing corn residue is a way to decrease the high winter feeds costs from either feeding harvested forages or from feeding a concentrate diet to cows (Klopfenstien, 1987). With the increase in the price of corn more acres of marginal land has been shifted from grass and some pulled out of CRP programs and planted to corn. With this shift in land use comes fewer acres of grass to stockpile and graze during the winter but also provides the opportunity to increase the amount of cows grazing corn residue. One of the biggest problems with grazing corn residue is the logistical factor that is associated with it. Most of the cows are not in the same areas as the majority of corn is planted (Klopfenstein, 1987). This creates a logistical problem of whether to move the corn residue to the cattle in the form of bales or to move the cattle to the residue; either way there is an increased cost due to the amount of transportation that is required. In recent years the use of corn residue as a feedstock for the biofuels industry has gained a lot of attention. As the price of corn increases due to short supply and the increasing demand for corn, more interest is created in increasing the use of cellulosic ethanol.

Use of Corn Residue for Bioenergy

In 2000 the Biomass Research & Development Act of 2000 was passed, creating the Biomass Research & Development Technical Advisory Committee which reports to

both the Secretary of Energy and the Secretary of Agriculture about research and development of Biomass energy, and how to further develop domestic forms of energy to lower the United States dependence on foreign oil and move towards producing a greater amount of the energy needs for the United States from domestic renewable energy sources. In 2002 the Biomass Research and Development Technical Advisory Committee released the "Vision for Bioenergy and Biobased Products in the United States". This publication set goals for using biomass to produce 10% of transportation fuels, 5% of electricity and heat, and 18% of chemicals and materials made in the U.S. by 2020. Accomplishing these goals would require 907.2 million tonnes of cellulosic feedstock annually (English, 2002; Perlack, 2005). A follow up report released in April of 2005 "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply"(Perlack, 2005) evaluated the feasibility of producing this 907.2 million tonnes annual supply, identified possible sources of feedstock, and how much each source would be capable of supplying. These sources were evaluated using several different scenarios. The first was with no land use change, using only what is there today and assuming no advances in technology. The second scenario considered the sustainability of producing the 907.2 annual tonnes with no land use changes but assuming changes in technology and plant breeding. The third scenario evaluated both changes in land use and increases in technology to produce higher yielding feedstock of both conventional crops and perennial crops. There are two primary sources of biomass that can be used as a feedstock, forest products and agricultural sources such as corn stover, wheat straw, and perennial grasses like switchgrass. This report suggested, using scenario one, that of the resources available

forest sources could produce 334 million dry tonnes a year and agricultural resources could produce 905 million dry tonnes of feedstock per year. Of the agricultural sources, corn stover is reported to be able to supply 68 million dry tonnes of biomass feedstock and is considered a major untapped resource for Bioenergy and Bioproduct feedstock (Perlack, 2005). Using scenario one, biomass for bioenergy or bioproducts would use approximately 16% of the total dry plant material produced on agricultural lands (Perlack, 2005)

Impact on Soil Quality

For many years the predominant uses of crop residue have been for grazing, erosion control, to improve soil organic matter, or to improve water infiltration. After the Biomass Research and Development Technical Advisory Committee released their reports a large number of studies were conducted to determine exactly how much residue can be removed and the impact that removal has on the soil and crops. Andrews (2006), in a white paper report, mentions that in some regions the amount of residue produced due to crop type and moisture combined with tillage method create an excessive amount of residue. The amount of excess residue has increased to the point that it is starting to have negative effects on the crop grain yield and removal of at least part of the residue would be beneficial. Andrews supported this conclusion citing studies conducted by Swan et al. (1987), and Dam et al. (2005) showing poor germination, delayed silking, and low emergence when residue remained intact compared to those fields where it had been removed. Wilhelm (2004) also reports a study by Swan et al. (1994) showing poor seed placement, excessively cold and wet soils and poor germination resulting in loses in grain yield. This research is further supported by Blanco-Canqui et al. (2006) who found that

by removing the residue from the field they shortened the amount of time required for emergence by 3 days compared to fields with no residue removal. The difference in emergence is probably due to the warmer soils in the plots with residue removed compared to the cold wet soils found in the plots with all of the residue retained and those with residue added to them to equal two times the original amount of residue . This early growth continued until about 50 days where the other treatments caught up to the residue removal treatments which the authors attribute to the decreased soil moisture and increased soil temperature.

Impact on Erosion

A review article by Wilhelm (2004) indicated from research conducted by Nelson et al.,(2002) and McAloon et al., (2000), the amount of residue that could be removed and still maintain enough cover for protection from soil and water erosion ranged from 20-30% of the total residue. Furthermore, Weinhold et al. (2010) found removing all of the cob showed a slight increase in the amount of time to initiate runoff on a dry, unsaturated soil, but they concluded that there was no effect on runoff or the nutrient content of the runoff when adequate residue remained. There are several concerns with removing residue from the field including effects on erosion, soil structure, soil organic matter, loss of nutrients contained in the residue, and the effect on yields. Erosion is one of the biggest concerns when removing residue from the field as there is no buffer to slow down and diminish the impact of the rain drop on the soil surface and slow water runoff. When there is nothing to slow the runoff and protect the soil from the wind, there is a greater risk of removing the valuable top layer of the soil where a majority of the organic matter and nutrients are contained. Johnson et al. (2010) listed some general guidelines

for when residue removal would be acceptable and when it would not be advised. They suggested only removing residue on low to moderate erosion risk soils as long as the soil organic matter is measured and maintained. Johnson (2010) further suggested that maintaining soil organic matter should be the primary decision tool about whether to remove corn residue. Soil organic carbon plays a large role in the fertility and structure of the soil. As the corn residue decomposes it provides a source of organic matter that increases the amount of soil organic carbon and plays a vital role in water infiltration, nutrient retention and soil tilth (Wilhelm 2007). Due to tillage methods and continuous cropping systems the amount of organic matter in U.S. soils has been reduced by 30-50% from precultivation levels (Schlesinger, 1985) making it a top priority to maintain or increase soil organic matter. Very few studies have quantified the effect of residue removal on soil organic matter or provide an estimate of how much residue needs to be retained to improve or maintain soil organic matter. Part of the reason for this is the complex interactions between residue removal and tillage method. Numerous studies cited in both Wilhelm (2004) and Andrews (2006) suggest that while residue is an important source of soil organic matter, the most important consideration is the interaction of residue removal and tillage method, with no-till no residue removal having the most soil organic matter accumulation and moldboard plowed high residue removal having the least amount of soil organic matter accumulated. These studies suggest that the amount of residue removal is not the only factor affecting soil organic matter accretion, the tillage method used may have just as big an impact as residue removal.

Nutrient Loss

Another consideration in the decision about residue removal is the amount of nutrients lost from the field when the residue is baled and removed from the field. Johnson et al. (2010) reported that at grain harvest, the above ear section of the corn plant contained 43.3% C, 0.745% N, 0.124% P, and 0.866% K; the below ear section of the plant contained 42.8% C, 0.641% N, 0.101% P, and 1.071% K; and the cob section contained 45.0% C, 0.546% N, 0.005% P, and 0.625% K. Furthermore they determined that it would cost $52.76, $36.23, and $11.66 per ha to replace the N, P, and K in the field when the above ear fraction, below ear fraction, and cob were removed respectively. The removal of these nutrients can be very costly for a producer if the nutrients are completely removed from the field. However when cattle graze corn residue they only utilize about half of the organic matter that they take in and re-apply the other half back to the field reducing the amount of nutrients that need to be replaced.

Impact on Subsequent Grain Yield

One of the most immediate economic considerations for the removal of corn residue is the impact on grain yield over time. When residue is removed, the impact on grain yield is not very well understood and varies considerably from one study to another. In his review article Wilhelm (2004), citied work from Wilhelm (1986), Maskina (1993), and Power (1998) which suggests that when returning residue at 0, 50, 100, and 150% of the residue produced, grain yield is negatively affected. However Wilhelm also citied work by Barber (1979) and an unpublished study by Wilts showing the opposite, that is no change in yield with varying levels of residue removal even with the Wilts study

covering 29 years of grain yields. The authors suggest that differences in grain yields may be due to the combination of tillage type along with the residue removal. This suggests the amount and type of tillage can have as much or more of an impact on the change in grain yields as the removal of the residue does similar to the effect it has on soil organic matter. Residue removal is a very complicated issue that involves numerous considerations such as soil moisture, grain yield, slope of field, tillage method, and crop. These considerations all play a role in determining how to remove the residue, by grazing or baling, and the amount of residue that can be removed.

Impact of Increasing Planting Density

With the increasing cost of grain and the increasing use of cellulosic ethanol, corn producers have been trying to determine the optimum planting density and how this affects grain yield. This is especially important to cattle producers as the increase in plants per acre could impact the amount of residue available and could also increase the quality of the residue by changing the ratio of leaf and husk to stem. In a three year study by Shapiro et al. (2006) evaluating the effects of plant densities (ranging from 61,800 to 86,520 plants/ha), and row spacings (0.51 and 0.76 m) they found the biomass dry weight and grain yield stayed relatively the same across density levels. When they just looked at the main effect of row spacing, the biomass dry weight remained similar across both row spacing while grain yields were statistically higher for the 0.51m row spacing in 1996 and 1997 and not different in 1998. However, in a study by Widdicombe (2002) investigating the effects of row widths ranging from 38-76 cm and planting densities ranging from 56,000 to 90,000 plants/ha on six hybrids, as the row narrowed from 76 cm to 56 cm there was a 2% increase in grain yield but a 4% increase when the row narrowed

from 76 to 38 cm. They also determined as the plant density increased there was a significant increase in grain yield, suggesting increasing planting density and narrowing the row spacing increases grain yields. The authors also mentioned, due to the linear relationship of increasing plant densities, the optimum plant density level may have not been reached. In a 3 year study conducted by Van Roekel et al. (2011) comparing different planting dates and 6 plant densities ranging from 38,400 to 107,900 plants/ha, they found as plant density increased, stalk diameter significantly decreased, and a significant quadratic increase in grain yields with the yields plateauing at a density of 94,000 plants/ha. They found the stalk diameter decreased in a quadratic fashion with a 17% decrease in diameter from 38,400 to 80,100 plant/ha but only a 7% decrease in stalk diameter when increasing the density from 80,100 to 107,900 plants/ha. As with Widdicombe (2002), Van Roekel (2011) found an increase in lodging due to increasing plant densities. These studies suggest that there is still room to increase the planting density and narrow the row spacing's up to a point without decreasing the grain yield. By doing this we could not only produce more grain on fewer acres but would also produce a greater amount of residue. This residue could then be used as a feedstock for ethanol, reducing the number of acres needed to fuel the ethanol plants or as a winter forage for cattle allowing more cattle to graze corn residue and reducing the winter feeding cost for cattle producers. As discussed earlier, by increasing the planting density and narrowing the row spacing we may increase the amount of residue on the field which may have a detrimental effect on grain yield.

Impact of Grazing Livestock on Corn Residue

Introduction

One of the largest and most economical uses for corn residue is as a winter forage source for livestock (Klopfenstein, 1987). Most corn residue is grazed by mature cows particularly in the fall, starting in October or November and they remain on the residue until January and February of the following year. Mature cows grazing corn residue are very selective in the fractions of the corn residue they remove. Fernandez-Rivera et al, (1989b) measured the percentage of each plant part in two different production settings, dryland or rainfed corn field or an irrigated corn field. They found in the dryland cropping system, the amount of leaf and husk made up about 51% of the residue, stem about 33%, cob about 12%, and downed grain about 4%. For irrigated corn, leaf and husk made up about 45% of the residue, stem makes up about 40%, cob about 11%, and grain about 4%. The ratio of leaf and husk to stem is very important to grazing livestock as several studies at the University of Nebraska-Lincoln (Lamm 1981, Gutierrez-Ornelas 1991, Fernandez-Rivera, 1989b) have demonstrated cattle select the more digestible parts of grain, leaf, and husk first and will only eat the stalk and cob when the decreased amounts of the other three parts forces them to.

Selectivity of Cattle

Guiterrez-Ornaelas et al. (1991) in a study investigating the effects of early season grazing, demonstrated that over time, grain is the first to go and when grain is almost completely removed the rate of removal of the leaf blade increases dramatically while husk is removed at a fairly constant, rapid rate. Furthermore, Lamm et al. (1981)

reported that in ungrazed exclosures collected in March, 35.2% of the residue DM was husks and leaves, 11.2% grain, 9.1% cobs, and 39.8% stalk compared to the grazed section where cattle were grazing for 85 days, which was composed of 30.6% husk and leaves, 1.4% grain, 13.1% cobs and 54.8% stalks. This further supports the results of Gutierrez-Ornelas (1991), and Fernandez-Rivera (1989b) showing that as cattle graze they select grain, husk, and leaf and for the most part ignore the stalk and cob. Because cattle are such selective grazers, the overall utilization of corn residue has been low but within individual fractions of the plant cattle have very high utilization rates. Fernandez-Rivera et al. (1989b) reported that of the residue utilized, husk and leaf made up 65% and 72% of the DM when grazed by calves on both irrigated and dryland corn residue, respectively. They also found total residue DM utilization over dryland and irrigated and across several stocking rates to range from 18% to 45%, which is similar to values found by Gutierrez-Ornelas et al. (1991) with overall DM disappearances ranging from 18.9% for dryland corn residue to 27.4% disappearance for irrigated corn residue. Similarly, they also found that leaf blade and husk were utilized the most. They found utilization values for husk of 72% and 51.7%, and leaf blade of 43.5% and 53.9% in dryland and irrigated corn residue respectively. Similarly, Fernandez-Riveria et al (1989c) using esphogeally fistualated steers found that in cattle who had previous experience grazing corn residue, downed grain made up almost 70% of their diet at start of grazing and decreased rapidly through the first part of grazing as the down ears were consumed first. However, when cornstalks were grazed by steers not accustomed to grazing corn residue, the amount of starch found in the diet was reduced to 50% of those who had previous experience (Fernandez-Rivera, 1989a, 1989c). This indicates there is a learning curve for

cattle consuming corn residue to determine what parts are the most palatable and what fractions to consume first.

Quality of Corn Residue

Cattle are very selective grazers and only remove certain parts of the residue, particularly the down ears, husk, and leaf, leaving most of the stem and cob in the field. The bottom part of the stem, which remains upright, and the top part of the stem and cob laying on the ground, provide protection for the soil from wind and water erosion as well as trap snow in the field and increase soil moisture. The residue that remains in the field also helps to increase the soil organic matter, improve the soil structure, and improve the infiltration rate of water into the soil which helps to improve the quality of the soil and maintains soil productivity and grain yield. One of the biggest problems with corn residue as a forage for cattle is the low digestibility and protein content of the residue (Klopfenstein, 1987) and in particular the decline in quality the longer the residue remains in the field. Lamm et al. (1981) found that IVOMD of husks and leaves prior to grazing (Oct. 22) was 66.2% and then fell to 47.9% by the spring (Mar. 22). Similarly, they found that leaves, husks, and cob all increased in NDF, ADF, and ADL from the fall collection to the spring collection while ADF and ADL values for stalks remained similar for both collections. Similarly, Fernandez-Rivera et al. (1989b) found that crude protein, digestibility, and NDF in the leaf and husk changed from pre-grazing to post-grazing. In an irrigated corn residue field, CP changed from 5.6% to 4.8% from pre-grazing to post grazing, and was similar in dryland corn residue with CP changing from 7.5% to 5.7%. IVDMD also decreased from pre-grazing to post-grazing in both irrigated and dryland corn residue fields, with digestibilities changing from 45.2% to 40.8% in irrigated corn

and from 45.6 to 43.7% in dryland corn from pre-grazing to post-grazing respectively. NDF content changed very little in dryland residue from pre to post grazing and only decreased about 2% in irrigated corn residue. In a different trial, Fernandez-Rivera et al. (1989b) found that in irrigated and dryland corn residue the total amount of CP found was 3.4% of the DM and 6.2% of the DM for irrigated and dryland residue respectively. When broken out into the different parts, leaf and husk had the greatest amount of CP of the forage fraction of the corn residue with irrigated corn residue being 3.7% CP and dryland being 6.4%, stem followed (3.4%, 5.9%), and cob contained the least (2.6%, 4.6%) in irrigated and dryland corn residue respectively. The NDF content was significantly decreased between type of field, either irrigated and dryland, for all the parts except the corn grain, with irrigated residue having a higher percent NDF with leaf and husk being 85% NDF, stem 84.4%, and cobs 94.1%, while dryland leaf and husk was 81.1% NDF, stem 80.9%, and cobs 90.0%. They also noted a change in IVDMD between the two types of corn residue with irrigated leaf and husk being 51.6% digestible compared to 49.7% in dryland residue, stem 42.6% in irrigated compared to 47.8% in dryland, and cob showing the same trend as stem was 33.6% in irrigated but was 36.2% in dryland residue.

Effect of Weathering on Corn Residue

Weathering of the corn residue and losses due to the environment can have a large impact on the amount of residue available to the animals. Guiterrez-Ornelas et al. (1991) found that weathering played a bigger role in damaging the leaf blade than it did in the other parts of the plant with a loss of 364kg/ha of leaf blade in 30 days. This loss of DM is probably due to the leaf blade fraction being blown off by wind. Losses due to plant

parts being removed by wind and the effect of the environment on the residue can have a large effect on the quality of the diet the animals are selecting as well as the nutrients that are being removed from the field. Russell et al. (1993) using exclusion cages found 48.3% of the increase in ash and 55.0% of the decrease in IVOMD from pre grazing to post grazing was due to weathering. In order to ensure the highest quality diet on corn residue, start grazing as soon as possible to capitalize on less time for leaf and husk to blow away and reducing the impact of weathering on the highly digestible plant parts.

Protein Supplementation

One of the most common ways to account for the nutrient needs of cattle and decreasing quality of the corn residue is to feed a protein supplement. Fernandez-Riveria et al (1989c) using esphogeally fistualated steers, found the CP of the diet slowly decreases for the first 4-5 weeks of grazing and then levels off and maintains a similar level throughout the remainder of the grazing period. The authors concluded protein was the first limiting nutrient in corn residue when grazed by growing cattle based on the gain response they found from protein supplementation. The protein level in the diet leveling off after 4-5 weeks supports the assumption cattle were consuming grain and other higher protein fractions of the plant first. Once these were consumed they were forced to eat a diet that was lower in protein and quality and they would benefit from protein supplementation. This is similar to research reported by Ward et al. (1978) citing work from White (1973), Lamm (1976), and Schmitz (1976), showing when cattle are supplemented with 0.23 kg of CP there was an increase of 0.08 kg ADG compared to unsupplemented. However, due to the higher protein content in the forage parts at the beginning of the season and the large consumption of down ears within the first couple

weeks of grazing, it was suggested by Ward (1978), and supported by research from Fernandez-Riveria (1989c) that supplementation of cattle can be withheld for the first couple weeks of the grazing season due to high digestibilities and protein levels. As these levels fall off over time the digestibilites combined with the lower protein content of the forage drops the protein level below the cow's nutrient requirements (Ward, 1978). Fernandez-Rivera et al. (1989a) also found the protein content of esophogeally fistualated steers decreased as grazing moved later into the season from 6.6% CP on Nov 19th to 5.0% CP on Dec 27. Intake also tended to follow a similar pattern with these same steers consuming 8.54 kg/day at the start of the grazing season (Nov. 19th) to 6.70 kg/day at the end (Dec. 27th). In a more recent, 5-year study by Warner et al. (2011) investigating the effect of protein supplementation on cows grazing corn residue, their research suggests that the small body weight and BCS change provided by supplementation of CP to mature cows in the third trimester entering corn residue with an adequate body conditions score (≥5) may not be enough to be economically useful given the current high cost of supplements.

Effect of Stocking Rate on Cattle Performance

Stocking rate can play a large role in cattle performance when grazing corn residue. Corn residue is unique in the fact that all the forage for a season is available and at the highest quality on day one. Due to this and the typically low utilization of corn residue, there have been numerous studies attempting to determine the best way to increase the utilization of corn residue. Most of these studies focus on how the increase in stocking rate effects the utilization of corn residue. Irlbeck et al. (1991), using two stocking rates of either 4.94 hd/ha or 2.47 hd/ha across three hybrids found that by

lowering the stocking pressure there was an increase in calf gain. They also found that the digestibility of the hybrid and the stocking rate had an effect on calf gain (digestibility*stocking rate interaction P = 0.15). They found that the higher digestibility hybrid when stocked at 2.47 hd/ha, increased gain but it had the opposite effect when stocked at the heavier rate by reducing calf gain compared to the other hybrids. This suggests the benefit of a higher digestibility hybrid is only useful when stocked at a lower stocking rate since the cattle will consume a greater amount of the more digestible variety and thereby reduce the amount of leaf and husk available to graze earlier in the grazing period forcing them to eat the lower quality plant fractions instead. Russell et al. (1993) in a 3 year study, tested 3 allotments of 0.41, 0.82, and 1.64 ha/cow with the cows grazing for 51-56 days depending on the year. They found that only the cattle stocked at the 1.64 ha/cow allowance did not lose weight. When cattle were allotted 0.41, 0.82, and 1.64 ha/cow they had a body weight change of -0.06, -0.01, and 0.41 kg/d. This effect on body weight is supported by the ruminal diet sample CP values which had a faster rate of decline as stocking rate increased from 1.64 to 0.41 ha/cow. This drop in CP due to decreasing allowance per head is also demonstrated by work from Fernandez-Rivera et al. (1989c) who found a linear decrease in dietary CP as time in the field and stocking rate increased. They credited this to the fact that at the lower stocking rates the more digestible, higher quality parts are available for a longer period of time and this allows the dietary CP to stay at a higher level longer. Furthermore Russell et al. (1993) found as they increased the stocking rate they removed more OM from the field, with the cows stocked at 1.64 ha/cow removed 2,081 kg/ha and those stocked at 0.41 ha/cows removed 3,531 kg/ha. This would also play a role in the diet quality as suggested by Fernandez-

Rivera et al. (1989c) as the more digestible parts are consumed faster due to more cows consuming it and when allowed to graze for the same amount of time would reduce the quality of the diet as they were forced to eat the lower quality parts. Cattle may also have lower forage intakes therefore reducing the amount of energy the cattle could put towards maintaining body weight which would also support the decrease in cow body weight over time in corn residue fields. Similarly, Fernandez-Rivera et al. (1989b) found in their study with yearlings grazing corn residue, when the residue was stocked at higher rates there was a dramatic increase in the leaf and husk that was removed. In an irrigated field stocked at 2.47 hd/ha the cattle only removed 624 kg/ha compared to those stocked at 4.69 hd/ha which removed 867 kg/ha. Cattle on dryland corn residue consumed a similar amount of leaf and husk, when stocked at the same rate, as their contemporaries grazing irrigated corn residue, with those grazing dryland residue removing 689 kg/ha when stocked at 2.47 hd/ha. Since there is less corn residue available, particularly leaf and husk, in dryland corn residue, the stocking rate has to be decreased to make sure cattle performance doesn’t suffer. The cattle in dryland corn residue had 437 kg/ha of leaf and husk remaining in January which is very similar to the amount of leaf and husk remaining in January when irrigated corn residue was grazed at 4.69 hd/ha. This suggests that stocking rates should be based on yield and the type of irrigation that is provided to the field either as a dryland/rainfed field or irrigated field. The amount of palatable residue has a very close relationship to the amount of grain produced.

Quantity Measures of Corn Residue

Fernadez-Rivera and coworkers (1989b), reported the relationship between the amount of grain and the palatable fractions of the residue, leaf blade, leaf sheath, and

husk, is 7.25 kg of residue per bushel of grain. However part of this residue is removed from the field by the environment and part is unusable due to cattle trampling as they move around the field. The losses due to the environment and trampling can account for approximately 50% of the residue available immediately after harvest. This makes it very easy to calculate the amount of forage available for cattle to graze. Simply by multiplying the amount of grain produced, in bushels, by 3.13 provides the amount of residue to base the stocking rate on to ensure that cattle are primarily consuming the palatable and most nutritious parts and not forcing them to eat the lower quality stem and cob.

Another way to improve the utilization of crop residue is through the use of a strip grazing system. In this system cattle are limited to a particular area and not allowed to move from that area. They are then given additional area at set intervals to allow them access to additional residue. This is possibly a way to improve the utilization of corn residue by reducing the amount that cattle walk over as they hunt for all the down ears first in a field before settling for leaf and husk. In a normal continuous grazing system cattle will have a linear decline in quality as demonstrated earlier by the work of Russell et al. (1993) and Fernandez-Riveria et al (1989c). When grazed in a strip grazing system it is assumed cattle will have access to additional high quality parts whenever they are moved. This would make a wave pattern of diet quality over time as their diet quality would theoretically go up each time they were given a new area but would decline faster due to the small amount of area. Over the entire grazing season total diet quality would be expected to decline at a slower rate which better meets the cows nutrient requirements with little additional supplementation. In a study comparing both a continuous and a strip

grazing system stocked at the same rate of 0.41 ha/cow Russell et al., (1993) found diet samples taken from cows in a strip grazing system had a 5.5% increase in IVOMD compared to their continuous grazing contemporaries. When they compared the weight change between cows in the two systems they found numerically that body weight loss was doubled with the strip grazing cattle losing -0.12 kg/d compared to the -0.06 kg of the continuous stocked cattle though this change was not statistically significant (P = .81). They found weather to have an impact on the performance of cattle in the two grazing systems depending on the amount of snow or sleet. During a normal year the body weight losses were similar but during a year with abundant precipitation, especially in the form of snow or sleet, they had greater BW losses in the strip grazing systems. The authors credited this to most of the forage being covered up and the cows being unable to get to the high quality parts and subsequently reducing the quality of the diet that they were consuming.

Effect of Grazing on Grain Yields

Over the past several years the University of Nebraska has completed several studies (Jordon, 1997; Leosing, 1996; Erickson, 2001; Wilson, 2003) investigating the effect of residue removal, primarily from grazing, on grain yields. Jordon et al. reported grain yields for a three year study when yearling cattle were stocked at 2.97 hd/ha and grazed for about 60 days. In this study grazed ridge till was compared to ungrazed ridge till. Corn grain yields were 5399 (86), 7784 (124), and 4959 (79) kg/ha (bu/ac) for grazed ridge till areas in 1993, 1994, and 1995 respectively. For the ungrazed ridge till treatment the yields were 6340 (101), 7533 (120), and 5148 (82) kg/ha (bu/ac) for 1993, 1994, and 1995 respectively. They also tested this in a conventional tillage setting with corn grain

yields for 1993, 1994, and 1995 grazed fields being 4896 (78), 7470 (119), and 5650 (90) kg/ha (bu/ac) compared to values of 4896 (78), 7973 (127), and 5587 (89) kg/ha (bu/ac) for the ungrazed sections in the same years respectively. The authors of this study commented that the grain yields were variable and there appeared to be no definite trends in grain production based on whether the field was grazed or not. Leosing et al. (1996) also found grain yields to be inconsistent from year to year. However they did report grain yields for 1993 and 1994 in corn residue grazed by yearlings at a stocking rate of 7.41 hd/ha for 30 days and then by ewes later in the winter. Soybean grain yields the year after corn residue was grazed, were 2260 (36) and 3453 (55) kg/ha (bu/ac) while ungrazed soybean yields were 2574 (41) and 3202 (51) kg/ha (bu/ac) for the winters of 1993 and 1994 respectively. They also reported corn grain yields for grazed sections in 1993 and 1994 respectively of 11739 (187) and 13748 (219) kg/ha (bu/ac), and ungrazed sections for the same years of 11300 (180) and 13120 (209). Leosing et al. (1996) also reported a separate trial that resulted in yields of 7973 (127) and 12932 (206) kg/ha (bu/ac) for 1993 and 1994 in grazed sections of a continuous corn system, while the ungrazed sections of the same system and same years resulted in grain yields of 8286 (132) and 12806 (204) kg/ha (bu/ac) for 1993 and 1994 respectively. In this same trial they reported soybean yields in the year preceding corn residue being grazed and found values of 2699 (43) and 2574 (41) kg/ha (bu/ac) for grazed and ungrazed sections respectively and similar results when grain sorghum was grazed the year previous with soybean yields showing the same trend with yields of 2950 (47) and 2825 (45) kg/ha (bu/ac) for grazed and ungrazed respectively.

Impact of Time of Grazing on Grain Yields

Winter grazing of corn residue is relatively common in the Midwest, but the impact of grazing residue in the spring is not as well defined. During the winter/fall when cattle are on corn residue the soil is usually frozen and the freeze and thaw effect in the spring should help to eliminate any compaction effect that the cattle had on the field, however during the spring months of Feb. – May, the soil is thawing and mud is typically present and the effect of compaction would be expected to have a greater impact on grain yield the following growing year. Erickson et al.(2001) reported that across several tillage methods when corn residue fields were grazed in the spring (Feb-April), grazed pastures had higher subsequent grain yields (P = 0.01) reporting average soybean yields of 3666 (58) and 3572 (57) kg/ha (bu/ac) for grazed and ungrazed pastures respectively when stocked at 0.32 ha/hd. Wilson et al. (2003) in 2000 and 2001 found in a follow up study to Erickson et al. (2001) that when yearling cattle grazed for 75 and 68 days in 2000 and 2001 respectively and stocked at 0.79 hd/ha there was no difference in either soybean yields (P = 0.40) or corn yields (P = 0.45) when corn residue was grazed the year before soybeans and corn yields represent the second year after grazing. However in 2000 and 2001 using the same field and the same treatments they found the grazed pastures soybean grain yields to be significantly increased (P = 0.01) and the corn yields to be similar (P = 0.11) for grazed and ungrazed.

Conclusion

The removal of corn residue has many issues that need to be considered especially from the agronomic aspect such as the impact of removal on erosion potential, both wind

and water, effect on soil organic matter, the cost to replace the nutrients that were removed from the field when the residue was removed, and the impact of residue removal on subsequent grain yields. Similarly when corn residue is removed by grazing there are several factors that need to be considered as well. The timing of when grazing occurs, the number of animals that are allowed on the field, whether to provide protein or not, and how are the cattle going to be managed, either on a continuous stocking system or some sort of intensive management system to increase the utilization of corn residue.

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Quality and Quantity of Corn Residue and the Impact of Grazing on Grain Yield in Eastern Nebraska

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Abstract

Corn residue is a relatively inexpensive winter forage source that can help producers reduce costs. However, there is very little recent work evaluating the quality and quantity of corn residue and the impact of grazing on subsequent crop grain yields. Utilizing three grazing treatments: 1) fall grazed, 2) spring grazed, and 3) un-grazed there were no differences between treatments for IVDMD, NDF, and CP. The digestibility of corn residue varies depending on the plant part, with husk being the most digestible at 61% and decreases to 34% digestibility in the bottom 2/3 of the stem. The NDF content ranged from 90% in the leaf sheath to73% in the cob and CP ranged from 9% in the leaf blade to 3% in the cob. Leaf blade, leaf sheath and husk only make up about 39% of the residue or about 6 kg of residue per 25.5 kg of corn grain produced. Implementing these grazing treatments over a 16 year period resulted in an increase in subsequent year soybean grain yields for the fall grazed ($P < 0.01$) and spring grazed ($P = 0.01$) treatments compared with the un-grazed treatment and no effect on corn grain yield two years following residue removal for fall ($P = 0.14$) or spring grazed ($P = 0.45$) residue.

Introduction

With the rising cost and demand for corn, more acres are being removed from pasture and converted to crop ground (NASS, 2012), decreasing the amount of available winter forage for cattle and increasing interest in grazing corn residue. One of the largest reasons for not grazing corn residue is the unknown effect of grazing on subsequent year

grain yield. Wilhelm (2004) noted there is variation in the impact of grazing corn residue on the subsequent year's grain production. Producers are worried that any decrease in yield caused by grazing could be unprofitable.

Cattle producers need to know the quantity and quality of the corn residue to be able to make informed decisions about stocking rate on their corn residue. Quantity and quality of corn residue has been reported previously (Fernandez-Rivera et al., 1989; Fernandez-Rivera and Klopfenstein, 1989a; Fernandez-Rivera and Klopfenstein, 1989b; Gutierrez-Ornelas, 1991), however corn genetics and management have changed since then. The quantity and quality of corn residue may have changed due to the advances in corn genetics and improved management strategies. This experiment is a continuation of a long term study investigating the effect of grazing in the fall or spring in a corn/ soybean rotation on grain yield as well as the quality of the corn residue.

Materials and Methods

A 40 ha irrigated corn field located at the Agriculture Research and Development Center located near Mead, NE was used. Half of the area is planted to corn and the other half is planted to soybeans and crops are alternated yearly so that corn is grown in the portion of the field that grew soybeans the previous year and soybeans are grown in the portion of the field that grew corn the previous year (Fig.1). Three grazing treatments have been maintained on these same plots since 1996: 1) fall grazed (Nov.-Feb.), 2) spring grazed (Feb. –Mid April), and 3) ungrazed. These fields are grazed yearly by an average of 20 yearling steers in the fall and 8 steers in the spring. Corn residue is the only residue that is grazed and the immediate impact on grain yield from grazing corn

residue is reflected in the soybean yields the subsequent year and to a lesser extent in the corn grain yield that is two years removed from the residue removal.

An irrigation access road runs east to west in the middle of the field with two replications located on the north side and two replications located on the south side of the road. Fall grazing paddocks are on the outside, spring grazed paddocks are in between-the fall grazed paddocks and two ungrazed plots in the middle of the two spring grazed pastures (Fig. 1). All samples were collected less than a week prior to grain harvest. Each ungrazed strip was sampled on two separate rows to provide all three treatments within each replication. Each of the two replications on the north and the south side of the road were sampled at both the east and the west end of the corn field. One row was selected from each field for each treatment to be in the middle of each treatment pasture and away from the irrigation wheel tracks to avoid any loss of plant parts from the irrigation system. Prior to harvest 10 consecutive, productive (had fully developed ears) plants were selected for each sample. The samples were taken 238 plants from the end rows. The ears and leaf blade were removed in the field and placed in separate bags for transport. This was done to prevent the loss of leaves and ears during transport. The stalk was cut off at the top of the crown roots, bundled together as a group, and stored in an open air barn as a bundle to air dry. The leaf blade was placed in the same open air barn and the bags opened to allow air to circulate and dry the leaf blade. Ears were husked and separated into shank, husk, and ear, with grain still attached, and placed in individual bags by sample and plant part and left open inside a climate controlled building to allow the plant parts to dry. The grain was removed from the ears prior to determination of dry matter. Each stalk, after air drying, had the leaf sheath removed and

placed in an airtight bag. Each individual stalk was measured for overall length, divided into the bottom two-thirds of the plant and top one-third and then separated. The bottom 2/3 of the stem and the top 1/3 of the stem were weighed separately by sample and replication. Top 1/3 of the stem, bottom 2/3 of the stem, cob, and leaf blade were all chopped using the Ohio Mill to reduce the particles into a smaller more manageable particle size to ensure equal drying of each part for the determination of the sample dry matter. After being air dried each sample was placed into an individual air tight bag by treatment, replication, and plant part, weighed to determine the amount of material available and were then all dried in duplicate tin pans in a 60° C oven for 48 hours. Grain collected from each sample was dried as described earlier, and used to calculate the amount of residue per 25.5 kg of corn grain. After DM was calculated, a portion of each plant fraction, except grain, was ground to pass a 1mm screen using a Willey mill. Each sample was analyzed for IVDMD using the Tilley and Terry method (1963) modified by adding 1g urea/ml of buffer (Wiess, 1994). Rumen fluid was collected from two separate steers fed a forage based diet and samples were placed in a 39° C water bath for 48 hours and swirled every 12 hours. After the 48 hour fermentation, HCL and Pepsin were added and the samples were allowed to sit in the water bath for an additional 24 hours before being removed and frozen. The residue was then filtered and the filters placed in a 100° C oven for 12 hours before being weighed. Five forage standards with known in vivo values were included in each IVDMD run. The standards were compared to In Vivo values to develop regression equations to compare values between runs based on the procedure of Giesert et al. (2007). Neutral detergent fiber was analyzed using the procedures developed by Van Soest (1991), and CP was measured on the Leco Nitrogen

analyzer (Leco FP-528, Leco Corp, St. Joseph, MI). Kilograms of plant part/ 25.5 kg of corn grain produced were calculated using the initial DM weight of the corn grain collected from the samples and the initial DM weights collected for each plant fraction. Grain yield values were measured by the grain yield monitor located on the combine. Values were analyzed using the Glimmix model of SAS (SAS Inst., Inc., Cary, N.C.) as a 3 x 7 factorial with grazing treatment as the first factor and plant fraction as the second. Grain yield was analyzed as a control vs. experiment treatment design with the ungrazed section being the control and adjusted using the Dunnett adjustment. The Dunnett adjustment was used to provide a more conservative estimate of the differences and provide better type I error control.

Results and Discussion

For each plant fraction there was no difference among the three treatments for IVDMD, NDF, CP, percent of total plant made up by each plant fraction and kg of plant part per 25.5 kg of corn grain produced (Table 1). The values for IVDMD, NDF, and CP for each plant fraction found by Fernandez-Rivera and Klopfenstein, (1989b) and Gutierrez-Ornelas et al (1991) are reported in Table 2. Husk was the most digestible (61.16%) followed by shank (49.15%), leaf blade (44.94%), cob (41.34%), leaf sheath (40.80%), top 1/3 of the stem (37.22%), and bottom 2/3 of the stem (33.97%). These values are similar to those of Fernandez-Rivera and Klopfenstein (1989b) who reported husk and leaf blade are the most digestible and stem and cob are the least digestible. However these values represent unadjusted IVDMD values and have variation due to the run which has not been accounted for. The NDF content was the greatest in the leaf sheath (90.59%), followed by leaf blade (90.08%), bottom 2/3 of the stem (79.77%), husk

(79.27%), top 1/3 of the stem (79.12%), shank (76.11%), and the least in cob (73.07%). These values are very close to that found by Fernandez-Rivera and Klopfenstein (1989b) suggesting that even with the genetic changes in the plant there has been little change in the fiber content of the plant.

Leaf blade had the greatest amount of CP (8.73%) followed by shank (7.57%), leaf sheath (6.94%), top 1/3 of the stem (4.65%), bottom 2/3 of the stem (3.94%), cob (3.94%), and finally husk (3.30%). The amount of CP in the plant follows the same trend as found by Fernandez-Rivera and Klofenstein (1989b) and Gutierrez-Ornelas (1991) with leaf blade being the greatest and husk and cob being the least. The actual values have changed with an increase in the CP of the leaf blade and in the cob, but remaining similar for both husk and stem. For all quality measures there was very little difference between the top 1/3 of the stem and the bottom 2/3 of the stem, suggesting there is little, if any, change in quality in the stem and no reason to continue to separate these two parts. Even though the shank is relatively digestible and high in CP, the negligible amount available and the varying attachment after harvest (sometimes attached to the stem and sometimes attached to the husk or cob) suggests the shank may not have a large impact on the cattle diet. Leaf sheath was consistently lower than leaf blade by about 3-4 percentage units in digestibility, 2-3 percentage units in NDF and about 2 percentage units in crude protein. Since these values were consistently lower than leaf blade, and the leaf sheath makes up almost the same percentage of the plant as leaf blade, they should be considered separately to get a better picture of what the cattle are actually eating and the quality of the diet.

There were no differences among treatments for the percentage of the total plant made up by each individual part (Table 1). The bottom 2/3 of the stem made up the greatest percentage of the plant based on total weight of each fraction divided by the total weight of the plant. The bottom 2/3 of the stem made up 41.83% of the plant, followed by leaf blade (18.72%), cob (14.68%), leaf sheath (12.60%), husk (7.48%), top 1/3 of the stem (3.60%), and the shank (1.09%) accounted for the least amount of the plant. Fernandez-Rivera and Klopfenstein (1989b) also recorded the relative composition of the plant and found similar values (Table 2). Previous work by Fernandez-Rivera (1989b), Lamm (1981), and Gutierrez-Ornelas (1991) indicates cattle prefer to eat the grain, leaf blade, leaf sheath, and husk. If these are the only plant fractions that are removed, and assuming cattle remove 100% of these plant parts, grazing cattle only remove 38.8% of the residue. According to Fernandez-Rivera and Klopfenstein (1989b), only 65% of the leaf and husk available are utilized with the remainder being trampled or lost from the field (i.e. wind). If the 65% utilization figure is applied to the residue removal calculation only 25.2% of the residue is removed. This degree of residue removal is within the limits suggested by Wilhelm et al (2004) to be necessary to protect soil from wind and water erosion.

The amount of each plant fraction available per 25.5 kg of corn grain corrected to 15.5% moisture immediately after harvest is presented in Table 3. The fractions most often consumed by the cattle, leaf, leaf sheath, and husk, amounted to 6.06 kg/25.5 kg of corn grain produced. This value is lower than previously found by Fernandez-Rivera and Klopfenstein (1989b). This lower estimate is probably due to the effects of a hail storm about two weeks prior to our collection. The plants were not badly damaged due to the

storm but some of the upper leaves and upper stem, tassel in particular, were lost due to the hail.

Using grain yield, amount of leaf blade, leaf sheath, and husk available and assuming one animal unit (AU) will consume 9.9 kg/day, the number of cows each corn field will support without forcing cattle to eat the lower quality fractions of the residue can be determined.

Soybean grain yields were greater in both the spring grazed ($P = 0.01$), and fall grazed ($P < 0.01$) plots when compared to the ungrazed control (Table 3). Soybean grain yield increased 31.88 kg/ha and 50.49 kg/ha over the control for spring and fall grazed respectively. There was no difference in corn grain yields for either the spring grazed ($P = 0.45$) or fall grazed ($P = 0.14$) when compared to the ungrazed control. However there was a numerical increase in both spring grazed and fall grazed of 36.72 kg/ha and 79.05 kg/ha for spring and fall grazed respectively.

Implications

Even with the increased focus on improving the grain yield potential in corn plants there has been little change in the quality of corn residue available for cattle to graze. The estimate suggested by Fernandez-Rivera and Klopfenstein (1989b) of 7.26 kg of highly digestible plant fraction/25.5 kg of corn grain seems to still be a very good estimate of the amount of residue available for cattle to graze. Even though the grain yield has increased significantly since this estimate was made, it appears that there has been little change in the forage to grain ratio. The increase in the amount of residue has created some problems with yields in certain areas (Andrews, 2006). With the increase in yield but

little change in the forage to grain ratio certain areas are producing more residue than is needed to protect from erosion. The increased amount of residue can impair the grain yields. This provides cattle producers additional opportunities for grazing and a cost effective way to reduce litter for the corn producer. Grazing in the fall or in the spring does not decrease grain yield. Removing residue actually increased soybean yield the year following grazing of corn residue. Due to the length of this study, it is safe to say that there is no negative impact of grazing corn residue in an irrigated corn/soybean rotation in eastern Nebraska.

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Figure 1. 2010 Linear Move Fencing Diagram

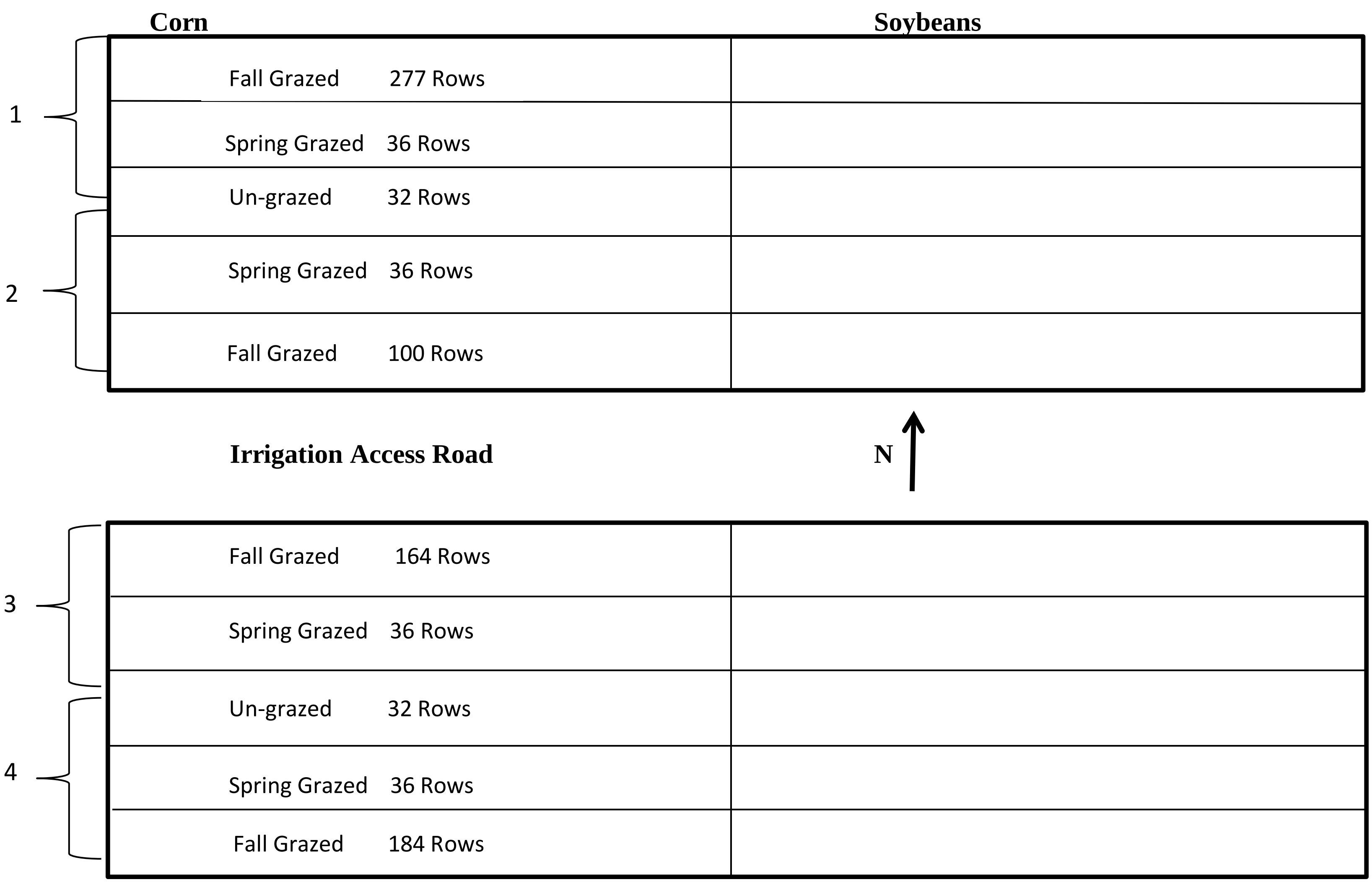

Table 1. IVDMD (%), NDF (%), CP (%), Plant Fraction as a Percent of Total Residue, Kg of Plant Fraction/25.5 kg of grain, and kg of Plant Fraction/ha.

	IVDMD(%)	NDF(%)	CP(%)	% of Residue[a]	Kg/25.5 kg of Grain[b]	Kg/ha
Husk	60.54	79.26	3.30	7.48	1.14	700.36
Leaf Blade	44.71	90.08	8.73	18.72	2.86	1753.39
Leaf Sheath	39.77	90.58	6.94	12.60	1.91	1183.26
Top 1/3 Stem	35.96	79.11	4.65	3.60	0.55	338.67
Bottom 2/3 Stem	32.55	79.77	3.94	41.83	6.40	3931.35
Cob	40.86	72.87	3.94	14.68	2.24	1375.05
Shank	46.65	76.11	7.57	1.09	0.17	102.31
SEM	0.80	0.31	0.13	0.22	0.07	38.00
Treatment P Value	0.79	0.82	0.88	1.00	0.25	0.65
Part P Value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Treatment*Part P Value	0.98	0.83	0.97	0.50	0.87	0.99

[a] kg of DM collected for each plant part/total forage DM collected
[b] Grain at 15.5% moisture, 25.5 kg is equivalent to one 56 lb bu.

Table 2. Previous research values for IVDMD (%), NDF (%), and CP (%)

Item	Leaf Blade	Husk	Leaf and Husk	Stem	Cob
Fernandez-Rivera Trial 1[a]					
IVDMD[b]	-	-	51.6	42.6	33.6
NDF[b]	-	-	85.0	84.4	94.1
CP[b]	-	-	3.7	3.0	2.6
Percentage of Plant	-	-	45.5	37.2	13.5
Fernandez-Rivera Average of 13 Hybrids					
IVDMD	44.9	67.0	-	-	-
NDF	77.3	91.6	-	-	-
Crude Protein	7.8	2.2	-	-	-
Gutierrez-Ornelas[bc]					
IVDMD	48.3	60.9	-	46.2	29.2
Crude Protein	5.9	4.1	-	4.8	2.5

[a] Irrigated fields (Fernandez-Rivera and Klopfenstein, 1989b)
[b] Mean of four cuts prior to grazing
[c] Sheaths included with the stem

Table 3. Soybean and Corn Grain Yields 1996-2011.

Grazing Treatment	Yield Estimate 28.6 kg/ha[a]	Yield Difference from Un-grazed	SE (Diff)	Dunnett Adjusted P Value
Soybeans[b]				
Fall Grazed	62.40	1.98	0.56	0.0016
Spring Grazed	61.68	1.26	0.42	0.0086
Un-grazed	60.42	-	-	-
Corn[c]				
Fall Grazed	208.86	3.10	1.71	0.1359
Spring Grazed	207.20	1.44	1.29	0.4469
Un-grazed	205.76	-	-	-

[a] Equivelant to bu/ac
[b] 27.2 kg at 13.0% moisture
[c] 25.5 kg at 15.5% moisture

Effect of Residue Removal on Quality and Quantity of Corn Residue and the Impact on Cattle Performance and Subsequent Grain Yield.

A. L. McGee, L. A. Stalker, T. J. Klopfenstein

Abstract

A study conducted at the West Central Water Resources Field Lab, near Brule NE, investigated the effect of stocking rate on cattle performance grazing corn residue and impact of residue removal on grain yield, quality, and quantity of residue available. The study consisted of four removal treatments: no removal, baled, light grazing at 2.48 AUM/ha, or heavy grazing at 4.98 AUM/ha. Clipped samples of residue were collected at two time points; pre- and post-grazing, using 0.5 M^2 quadrats and 10 samples per pasture. Residue was separated into 5 fractions: stem, cob, leaf blade, leaf sheath, and husk. There was no pre-grazing interaction between fraction and removal treatment for CP, IVOMD, plant fraction as a percent of total residue, kg/ha, or kg/25.5 kg of corn grain. The stem fraction had a treatment*time interaction for IVOMD ($P < 0.01$), both treatment and time effects for CP, kg/ha, and percent of residue ($P < 0.05$), and an effect of time on IVOMD ($P < 0.01$). Husk had a treatment* time interaction for CP, kg/ha, and percent of residue ($P \leq 0.05$). Leaf blade had a treatment*time interaction for kg/ha and percent of residue ($P \leq 0.01$) and an effect of time on IVOMD ($P = 0.01$). Leaf sheath had a treatment*time interaction for kg/ha ($P = 0.02$), treatment effect for kg/ha ($P = 0.04$), and an effect on time for kg/ha and percent of residue ($P < 0.01$). Cob had a treatment*time for percent of residue ($P < 0.01$) and an effect of time for kg/ha ($P < 0.01$). The fractions cattle consume yielded 7 kg/25.5 kg of grain. Light grazing treatment cattle had greater post-grazing BCS ($P < 0.01$) and BW ($P = 0.03$).

Esophageal diet CP was similar for the two grazing treatments and IVOMD was greater post-grazing in the light grazing treatment (*P* = 0.04). Subsequent grain yields were not different across all four residue removal treatments (*P* = 0.31).

Introduction

With the increased interest in utilization of corn residue , there have been a lot of questions about how the removal of corn residue, by baling or grazing, impacts the subsequent grain yield, soil and plant characteristics. The impact of residue removal on grain yields is variable within the literature as demonstrated by Wilhelm (2004) citing several studies that had differing impacts on grain yields. Wilhelm (2004) attributed most of the differences in the results of these studies to the interaction of residue removal and tillage method. A 16-year study at the Agriculture Research and Development Center near Mead Nebraska investigating grazing in the fall or spring in a corn/soybean rotation has shown an increase in soybean yields the year following both fall and spring grazing but no difference in corn yield the second year after grazing (McGee, 2013). Weinhold et al. (2013) reported in an irrigated, no tillage, continuous corn production system, the removal of residue from the soil surface improves grain yields. However, in a rain-fed system they found a slight decrease in grain yields over a 10 year period. These differing results and the importance of grazing corn residue to the beef industry in Nebraska prompted the initiation of this study.

The primary objectives of this study were to determine the impact of corn residue removal either by grazing or by baling on grain yield, and quality of the residue. A second objective was to determine the impact of stocking rate on cattle performance

when grazing corn residue. A further objective was to determine the degree to which cattle utilize each plant fraction.

Materials and Methods

This study was conducted at the West Central Water Resources Field Laboratory near Brule, NE. A full center pivot (53 ha) irrigated corn field was divided into four treatments starting in 2008, light grazing (2.47 AUM/ha), heavy grazed (4.94 AUM/ha), baled, and ungrazed. This field is in continuous corn, no-till management. Rows are planted east to west across the field and they cross all four treatments so that all the treatments are planted and managed the same regardless of removal treatment. The pasture is divided into 8 paddocks with two replications for each residue removal treatment (Figure 1).

Pre-grazing plant samples were collected in mid-October both years about one week prior to grain harvest. By collecting prior to harvest whole plants were collected which allowed better quantification of residue available to the animals and plant fraction. Each pasture was randomly sampled at ten locations using GPS coordinates. Each pre-grazing sample consisted of the number of plants within 81.6 cm of row spacing, and any current year residue lying on the ground. Plants were cut just above the crown roots and separated into 8 plant fractions in year one (2010), and 6 plant fractions in year two (2011). In year 1, whole plants were separated into grain, cob, husk, leaf blade, leaf sheath, shank, top 1/3 of the stem, and bottom 2/3 of the stem. In year 2, shank, top 1/3 of the stem, and bottom 2/3 of the stem were combined into the same category (stem). Due to the small percentage of the plant made up by shank and not knowing whether it is

consumed by cattle, shank was included with the stem the second year. We included shank with the stem to avoid affecting the values of the other plant fractions and to provide a more conservative estimate of how much residue is consumed by cattle. In year 1 the top 1/3 of the stem was determined by estimation in the field and kept separate from the other samples to allow them to be sorted separately from the other fractions.

Post-grazing samples were collected in mid-March each year. All post-grazing quadrats were located immediately adjacent to the pre-grazing location resulting in contiguous sampling sites. A 0.5 m^2 quadrat was used that was 81.6 cm by 76.2 cm and was centered on the row. All residue on the ground, within the quadrat was collected and sorted.

Residue in the baled treatments were raked into windrows and then baled immediately after grain was harvested. Bales were stored at the edge of the field until sold, and were weighed at the local feedlot where they were sold.

All samples after being sorted into plant fractions were allowed to air dry for a few weeks. All parts were weighed to determine initial weights and then stored in airtight bags. Stem, cob, and leaf blade were processed using an Ohio Mill prior to being weighed to make a more manageable particle size. A sample of each plant part was dried in duplicate in a 60° C oven for 48 hours and immediately weighed back to determine DM content of the sample, and allowed to air equilibrate for 24 hours before being sealed into an airtight bag. After determining DM, all samples, except grain, were composited by plant fraction and field using the sub sampling method as described by Anderson et al. (2007). For all plant fractions except grain, the composited sample was then ground to

pass either a 2 mm or 1 mm screen using a Willey Mill. The 1mm sample was then analyzed for IVOMD, OM and CP. Each sample was analyzed for IVOMD using the Tilley and Terry method (1963) modified to provide 1g urea/ml of buffer (Wiess, 1994). Rumen fluid was collected from two separate steers fed a forage based diet and samples were placed in a 39° C water bath for 48 hours and swirled every 12 hours. After the 48 hour fermentation HCL and Pepsin were added and the samples were allowed to incubate in the water bath for an additional 24 hours before being removed and frozen. The residue was then filtered and the filters placed in a 100° C oven for 12 hours before being weighed. Five forage standards with known in vivo values were included in each run. The standards were compared to in vivo values to develop regression equations to compare values between runs based on the procedure of Giesert et al. (2007). Protein was measured using a Leco Nitrogen analyzer (Leco FP-528, St. Joseph, MI) and corrected for OM content. Samples from all plant fractions at both pre- and post-grazing time points and in vitro filters were ashed for 6 hours in a 600° C ash oven and then allowed to cool to between 100° and 200° C before being weighed to determine the percent OM. The crude protein and in vitro values were expressed on an OM basis to account for soil or saliva contamination within the sample.

All experimental procedures and facilities were approved by the University of Nebraska Institutional Animal Care and Use Committee. Mature cows in mid gestation with previous corn grazing experience grazed the light grazed and heavy grazed paddocks from November 6th to January 7th in year 1 and from December 8th to February 13th in year 2. Cows were stratified by BW and assigned randomly to treatment each year. Cow BW and body condition score (BCS) was assessed at the Gudmundsen Sandhills

Laboratory, near Whitman NE, pre- and post-grazing. Cow BCS was assessed using a 1-9 scale (1 being emaciated and 9 being obese) and was the average score of two technicians. Cows were stocked at 2.47 AUM/ha in the light grazing paddocks and 4.94 AUM/ha in the heavy grazing paddocks with 8 and 16 head/paddock respectively. Cattle were fed the daily equivalent of 0.45 kg/cow per day of a 32% CP supplement delivered 3 d/wk. Diet samples were collected using esophageally fistulated cows pre- and post-grazing. Diet samples were ground and analyzed for IVOMD and CP as described earlier. Impact of residue removal on subsequent year grain yields was determined by the grain yield reported by the yield monitor on the combine for three years of the study following the residue removal treatments being applied.

Residue quality values, amount of total residue made up by each plant fraction was analyzed using the Glimmix procedure of SAS. The interaction of plant fraction and residue removal treatment was tested on pre-grazing samples only. This interaction was tested separately to limit unnecessary interactions between plant fractions and time. The interaction between residue removal treatment and time were analyzed within each plant fraction. Esophageal diet samples were analyzed separately by time, pre or post grazing, using the Glimmix procedure of SAS. Grain yield and kg of plant fraction/25.5 kg of grain yield were analyzed as a control versus experiment treatment design with the un-grazed removal treatment being considered the control. The Mixed procedures of SAS was used to analyze the cow BW and cow body conditions scores with cow, and paddock included as random variables and year being included as a random variable across all analyses.

Results and Discussion

There was no pre-grazing interaction between plant part and residue removal treatment for CP (*P* =0.75; SEM 0.57), IVOMD (*P* = 0.96; SEM 2.71), percent of residue made up by a plant fraction (*P* = 0.93; SEM 0.69), kg/ha (*P* = 0.98; SEM = 106.26), and kg/25.5 kg of corn grain (*P* = 0.98; SEM = 0.31). For the stem plant fraction there was an effect of both residue removal treatment (*P* < 0.01) and time of collection (*P* < 0.01) on CP (Table 4). The baled residue removal treatment had the greatest amount of CP and the ungrazed treatment had the lowest CP value. The baled treatment was the only treatment that was significantly different from the ungrazed and light grazed treatments, however there is only a 0.88 percentage unit difference between the four treatments and it is most likely not biologically relevant. The stem fraction also had an effect of time of collection on IVOMD with the post grazing values being greater than the pre-grazing values (Table 4). This is most likely an effect of variation within the field causing sampling error as we would have expected the digestibility to decrease in the samples due to the effect of weathering.

Kg/ha in the stem fraction had a significant residue removal treatment by collection time interaction (Table 4). The heavy grazed and baled treatments had a greater amount of residue in the pre-grazed sample compared to the post grazed samples; however there was a greater difference between the two collection times for the baled treatment as compared to the heavy grazed treatment. The other two treatments both had greater values in the post grazing collection compared to the pre-grazing collection, but this difference is most likely due to sampling error. Part of the reason for this sampling error could have to do with the size of the quadrat used. Russell et al. (1993) in their

collection used a 4 m^2 quadrat and Fernandez-Rivera et al (1989a), used a 7.7 m^2 quadrat to collect their residue samples. By using the larger quadrat the variation within the sample would have been reduced. With corn residue, there is a large amount of variation within each paddock, even though pre- and post-grazing sampling locations were contiguous, the number of plants within each sub sample may have been different giving us a different value for the amount of residue in the field after grazing. The post grazing baled sample is the only sample that is not statistically similar to the other treatments and time collections. This suggests that the baled treatment is the only residue removal treatment that showed any difference between pre- and post-grazing. This would suggest that the cattle ate very little, if any, of the stem and left most of this fraction in the field. However, when the residue is baled a lot of this plant fraction is removed from the field. Stem is a large part of the residue and removing a large amount of this from the field results in a greater possibility for soil losses due to both wind and water erosion. There was a tendency for a residue removal treatment by plant fraction interaction in the stem fraction for the percent of the residue made up by the stem fraction (Table 4). The baled treatment had the smallest change in the percentage of the residue made up by the stem only increasing by about 7.4 percentage units while the other three treatments increased by 14-15 percentage units. This supports the kg/ha results showing a small change in the amount for the un-grazed, light grazed, and heavy grazed treatments but a significant difference in baled treatment. Since the percentage of the residue didn't change a lot the baler most likely removed equal amounts of all the plant fractions.

Husk CP had a significant residue removal treatment by time of collection interaction (*P* = 0.05) (Table 5). Husk CP in the baled treatment at the post-grazing

collection was different and this difference is most likely due to variation in the field causing a sampling error. Digestibility of the husk shows no difference between any of the treatments or either of the collection times (Table 5). There was a residue removal treatment by collection time interaction for both of the quantity measures of kg/ha ($P < 0.01$), and percent of the total residue made up by husk ($P = 0.01$). Kg/ha was similar at the pre-grazing collection for the ungrazed, light grazed, and heavy grazed treatments, and the baled treatment was statistically similar to the light grazed and heavy grazed treatments. The post-grazing samples follow the same order as the pre-grazing samples yet the differences between the pre-grazing and post-grazing values vary. The smallest difference between the two collection points is for the ungrazed treatment with a difference of 305 kg. The light grazing treatment also had a small difference between the pre and post grazing samples with a difference of 457 kg. Both the ungrazed and the light grazed treatments are statistically different from each other and all the other treatments. The heavy grazed and the baled treatments are statistically similar in their values and have a similar difference from pre-grazing to post- grazing. These values suggest that while a large amount of the husk blew away from the field, the cattle consumed a large amount of the residue since both the light grazed and the heavy grazed treatments were statistically different from the un-grazed treatment. It also suggests that the heavy grazed treatment, with the increase in cattle, consumed a larger amount of the husk than the cattle at the lighter stocking rate. This difference could suggest that the cattle at the heavier stocking rate spent more time searching for husks and therefore consumed a greater amount of them or since husk is the first plant fraction consumed

(Gutierrez-Ornelas et al., 1991) the increase in the number of cattle simply picked up a greater amount of the husk at the beginning before it could be trampled.

The percent of the residue that is made up of husk was similar across all of the grazing treatments at the pre-grazing collection. Since the husk in the ungrazed treatment makes up a smaller percentage of the residue in the post-grazing collection compared to the pre-grazing collection at least some of the husk was removed from the field, most likely from the wind blowing the husk out of the field. Since the husk is the most digestible fraction of the plant it is important in order to preserve the quality of the corn residue, that cattle graze the corn residue as early as possible to take advantage of the husk and grain that is in the field before it is blown off the field or consumed by wildlife.

There was no effect of either time of collection or residue removal treatment on the amount of CP found in the leaf blade (Table 6). Leaf blade has the greatest amount of CP of all of the plant fractions and is one of the moderately digestible plant fractions that cattle like to consume (Guiterrez-Ornelas 1991). There was an effect of time of collection on the IVOMD of the leaf blade with the post-grazing samples being about 2 to 4 percentage units higher than the pre-grazing estimates (Table 6). This difference while statistically significant is not biologically relevant. Like the husk, there is a residue removal treatment by time of collection interaction for both kg/ha ($P < 0.01$), and percent of the total residue made up of leaf blade ($P < 0.01$, Table 6). Leaf blade follows a similar pattern to that of husk, with all the pre-grazing samples being statistically similar. The interaction between the residue removal treatment and the time of collection is in the difference between the two collection times. The un-grazed treatment lost approximately 500 kg/ha of leaf blade, presumably due to the wind blowing it from the field, and was

different from the heavy grazed and the baled treatment but was similar to the light grazed treatment.

The two grazing treatments are also statistically similar though the heavy grazed treatment has a numerically greater difference between pre- and post-grazing collections. The percentage of the total residue made up by the leaf blade is similar across all residue removal treatments for the pre-grazing collection but similar to the kg/ha measurement the biggest difference between the residue removal treatments is change in the percentage from the pre-grazing collection to the post-grazing collection. The post-grazing collection value is similar for the un-grazed, light grazed, and heavy grazed residue removal treatments, suggesting that while cattle consume a large amount of the leaf blade, the amount they consume is not much different from the amount that would have been removed by nature. The biggest change in the percentage of leaf blade in the total residue is in the baled treatment. Leaf blade making up 13% of the residue at pre-grazing makes a large contribution to the corn residue bale, and this process removes dramatically more than would have been removed by either grazing or simply leaving the residue lay on the field.

Leaf sheath CP is similar across all residue removal treatments and collection times and is approximately 4% CP. While there are slight tendencies towards a difference in IVOMD due to both residue removal treatment ($P = 0.14$) and time of collection ($P = 0.13$), the leaf sheath values are similar enough to not be biologically relevant (Table 7). Leaf sheath has a statistically significant interaction for residue removal treatment and time of collection for kg/ha. Similar to both leaf blade and husk, the kg/ha of leaf sheath at the pre-grazing collection time are not statistically different

from each other at about 2000 kg/ha (Table 7). Also similar to leaf blade and husk, the un-grazed treatment and light grazed treatment are statistically similar for the post-grazing amount, with a slightly lower numeric value for the light grazed treatment. The estimates for the two grazed treatments are also not statistically different from each other, although there is a large numeric difference of about 200 kg/ha. The greatest difference between the two collection times is found in the baled treatment with a difference from pre- to post-grazing collection of 1478 kg/ha. This large difference suggests that the leaf sheath most likely remained attached to the stem and was removed from the field along with the stem during baling. Residue removal treatment had no effect of leaf sheath as a percentage of the total residue, however the effect of the time of collection was significant. Across all the residue removal treatments, there was no difference between the pre-grazing values and all the post-grazing values were statistically similar as well, with the only difference being between the two collection times.

The CP content and IVOMD of cob were not affected by either residue removal or the time of collection maintaining around 3% CP and 47% IVOMD (Table 8). Kg/ha of cob was affected by the time of collection with the pre-grazing samples being greater than the post-grazing samples, but remaining similar across all removal treatments for each collection (Table 8). The percentage of the residue made up by cob had a significant residue removal treatment by time of collection interaction ($P < 0.01$). The pre-grazing samples were similar across all removal treatments but the percentage of the residue made up by cob at the post-grazing collection was the lowest for the un-grazed treatment and greatest for the baled treatment with the two grazed treatments intermediate. The increase in the percentage of the residue made up of cob at the post-

grazing collection implies cob, being a denser fraction, most likely landed on the ground after harvest and the baler was unable to pick a majority of this fraction up. This would continue to supply the soil microbes with a source of organic matter even after most of the other plant fractions have been removed from the field.

From the post grazing kg/ha and the percentage of the residue made up by each plant fraction it appears that the cattle ate predominantly the husk, leaf blade, and leaf sheath while not consuming very much of the stem or cob fractions. This is similar to what was found by previous research of Gutierrez-Ornelas and Klopfenstein (1991) and Fernandez-Rivera and Klopfenstein (1989a).

The values found in this study are comparable to the values found in previous work. Fernandez-Rivera and Klopfenstein (1989a), found in one trial, the leaf and husk fraction in irrigated corn residue to have a CP value pre-grazing of 5.6% and a statistically significant lower value for post-grazing of 4.8%. However, Fernandez-Rivera and Klopfenstein (1989a) in a separate trial found CP content of irrigated corn residue was not different pre-grazing (4.7% and 4.9% CP) and post-grazing (5.1% and 4.7% CP) under stocking rates of 2.47 and 4.69 hd/ha respectively. The values from the present experiment show a similar relationship with slightly lower values for the post-grazing samples compared to the pre-grazing samples.

One of the concerns with grazing corn residue is the removal of the nutrients from the field and the additional cost that is required to put these nutrients back into the soil. The parts that cattle readily consume range in digestibility from about 51% to 70%, meaning that 49% to 30% of the OM is returned to the soil surface. In contrast, when

residue is baled a greater amount of the residue is removed and none of the nutrients are returned to the soil surface.

The amount of residue produced per 25.5 kg of corn grain yield differed by plant fraction (Table 6). Stem was the greatest fraction per 25.5 kg of corn grain (7.3 kg) followed by leaf blade(3.8 kg), cob (2.7 kg), leaf sheath (2.3 kg), and husk had the least amount (1.5 kg). Of the three components of the stem fraction that were measured only in year one the bottom 2/3 of the stem had the greatest amount per 25.5 kg of corn grain (6.0 kg), followed by top 1/3 of the stem (0.6 kg), and shank had the least amount (0.3 kg) . Cattle consume mostly leaf blade, leaf sheath and husk and only consume about half of that with the other half lost to trampling or other losses (Gutierrez-Ornelas, 1991). Using these assumptions, there should be 7.6 kg/25.5 kg of corn grain, with only 3.8 kg/25.5 kg of corn grain being utilized. Knowing this number will allow producers to make stocking rate decisions based on the amount of the palatable, moderately digestible fractions that are in the field and can help to avoid overgrazing and forcing cattle to consume the less digestible fractions.

The baled treatment removed an average of 2,304 and 4,243 kg/ha from each baled paddock in 2010 and 2011 respectively. When the weight of the bales is divided by the pre-grazing kg/ha estimates, we get an estimate of 40.8% and 56.3% of the residue removed in each paddock for 2010 and 2011 respectively. Due to variation within the field and variation between pre and post-grazing samples, utilization for light grazing and heavy grazing treatments are not reported.

The objective in separating the top 1/3 of the stem from the bottom 2/3 of the stem was to determine if there was a change in digestibility and CP between the lower thicker part of the stem to the upper smaller diameter top of the stem. From this trial it appears that there is no difference in CP ($P = 0.18$) but there are differences in digestibility ($P < 0.01$). However, in a separate trial (McGee, 2012) the digestibility was similar between the top and bottom portions of the stem. Because of the small difference in nutrient content of the two parts of the stem and the relatively small amount of top 1/3 of the stem that was in the residue the two parts were combined into one fraction. Shank is a very unique plant fraction with a moderate digestibility, and relatively high CP content, yet it makes up a very small amount of the actual plant residue, creating a problem as to what plant fraction category this part should be included in or if it should be considered as a fraction by itself. It was decided to include it with the stem because it was such a small fraction of the residue and the variability in what other plant part it was attached to in the residue (husk, cob, stem). There is little indication that cattle consume the shank and if it were included in cob or husk, the high protein content combined with the small percentage of the residue made up of husk or cob, could have an effect on the values reported.

Pre-grazing BW ($P = 0.35$) and BCS ($P = 0.63$) were similar. At the end of the grazing period, both treatments gained BW, but cattle in the light grazing treatment gained more ($P = 0.03$) weight than their heavy grazed contemporaries, with light grazing cattle gaining 35.7 kg and the heavy grazing cattle only gaining 23.8 kg over the grazing period (Table 10). There was a similar relationship between treatments for BCS, where the light grazing cattle increased 0.05 BCS units while the heavy grazing treatment cattle

lost 0.22 BCS units (Table 10). These values are similar to values reported by Irlbeck (1991), and Russell (1993). Irlbeck (1991) measured the ADG of yearling steers, when stocked at either 2.47 hd/ha or 4.94 hd/ha. The cattle stocked at 2.47 hd/ha had the greatest gains with ADG across three hybrids of 1.48, 1.38, and 1.58 compared to ADG of 1.16, 1.10 and 0.92 in these same hybrids respectively for the steers stocked at 4.94 hd/ha. Russell (1993) found similar results, with cattle provided a grazing allowance of 1.64 ha/hd being the only treatment to not lose BW. This would be expected as there were more cattle in the heavy grazed treatment paddocks and they would have consumed a greater amount of the better quality fractions of residue earlier in the period, reducing the amount the cattle would be able to consume later in the grazing period. Removing the highly palatable fractions forces the cattle to either spend more time hunting for leaf blade, leaf sheath, and husk and less time eating, or to start consuming more of the lower quality, less digestible parts. As shown earlier husk is the most digestible fraction of the plant and even though cattle consume a great deal of leaf blade and leaf sheath, they are not highly digestible fractions. Gutierrez-Ornelas (1991) showed that husk and grain are consumed the fastest and when the majority of the grain is gone cattle start consuming a greater amount of the leaf blade. Since the leaf blade is a less digestible part and toward the end of the grazing season begins to make up a larger percentage of their diet, the quality of the diet begins to fall off and they use a greater percentage of the energy that they consume to meet their maintenance energy requirements.

Esophageal diet samples were similar in IVOMD for pre-grazing ($P = 0.49$) but were different at the post grazing sample ($P = 0.04$) with diet samples collected from the light grazing paddocks being more digestible than those collected in the heavy grazing

paddocks with digestibilities of 63.38% and 55.34% for light grazing and heavy grazing treatments respectively (Table 11). Crude protein was not different at pre-grazing (P = 0.06) or post-grazing (P = 0.10) between the light grazed and heavy grazed treatments (Table 11). The diet samples support the performance results we found in the cattle, with the light grazing cattle having a greater BW gain and BCS as they were consuming a higher quality more digestible diet. Fernandez-Rivera et al. (1989a) used esophageally fistulated steers and found the CP content decreased from the pre-grazed values to the post grazed values. They also found IVDMD of the diet from these steers linearly decreased with time. Since only pre and post grazing measurements were taken there were not enough measurements to fit a regression equation to the lines but they seem to agree with the digestibility trends in this study.

Corn grain yields in 28.6 kg/ha units (equivalent to bu/ac) for the 3 years following the implementation of the residue removal treatments are listed in Table 10 along with the grain yields averaged across all three years. The average grain yields, in units of 28.6 kg/ha, for the three years the removal treatments have been applied are 143.8, 144.3, 143.8, and 149.4 for no residue removal, baled, light grazing, and heavy grazing treatments respectively. There is no statistical difference between the removal treatments (P = 0.31) for the three years of this study (Table 12). These grain yields suggest that removing corn grain residue from a fully irrigated corn residue field has no effect on the subsequent grain yield, consistent with values previously reported in an eastern Nebraska study looking at grain yield differences in a corn/soybean rotation (McGee, 2013).

Implications

From the results found in this study, leaf blade, leaf sheath, and husk are the most highly digestible fractions of the plant and they make up about 43% of the residue that is in the field immediately after harvest. Cattle when stocked at 2.47 AUM/ha will be able to maintain their body condition score and will gain more weight than those stocked at higher rates. Producers can expect 7.57 kg of leaf blade, leaf sheath, and husk/25.5 kg of corn grain and can set cattle stocking rates so that cattle are only consuming the most nutritious plant fractions.

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Figure 2. Layout of Treatments on Corn Residue Field at the West Central Water Resources Laboratory

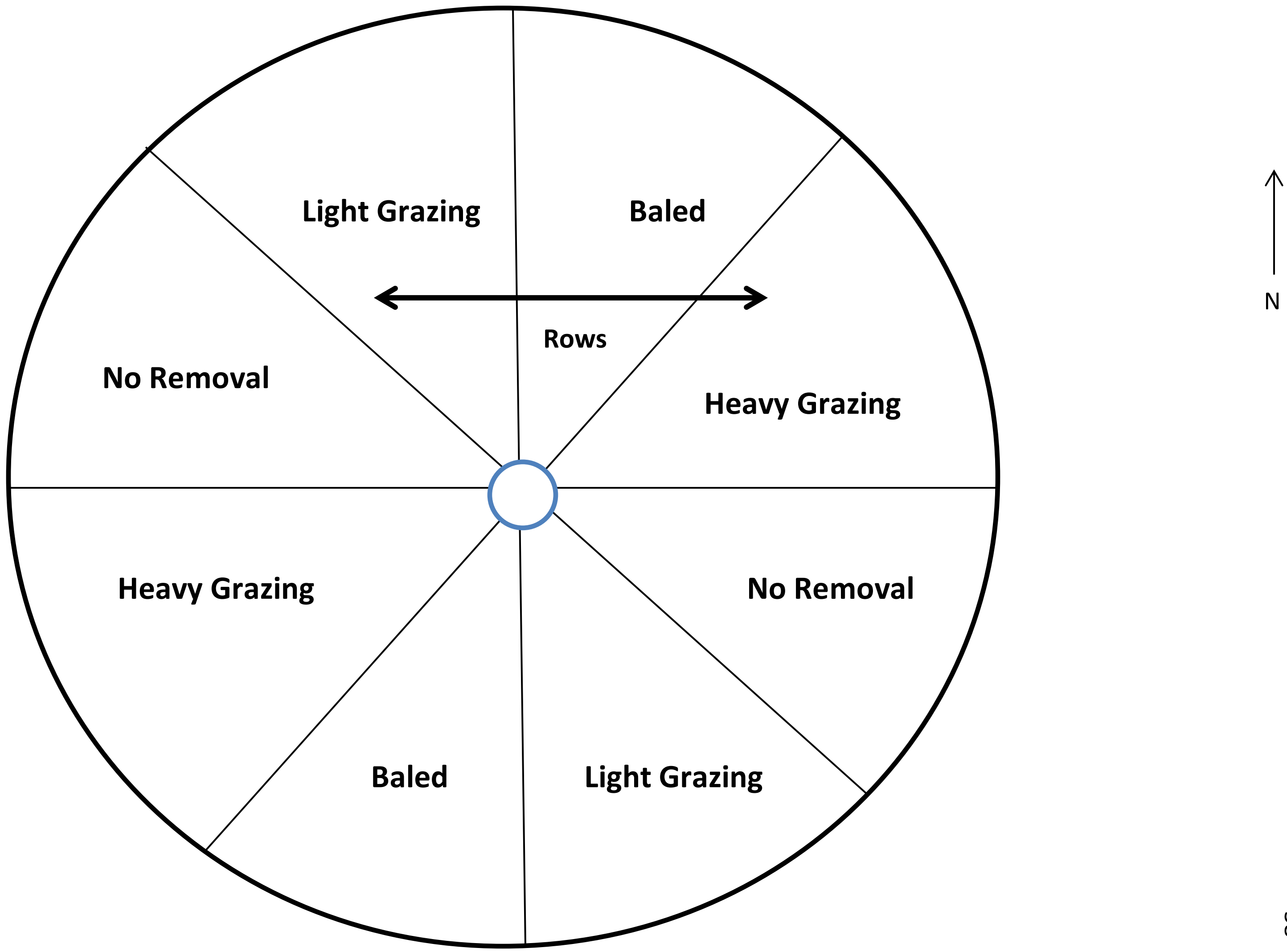

Table 4. Effect of Time x Treatment on CP (%), IVOMD (%), Kg/ha, and Percent of Residue on Stem[f]

	Ungrazed	Light Grazed	Heavy Grazed	Baled	Treatment P Value	Time P Value	Trt x Time P Value	SEM
CP[g] (%)								
Pre-Grazed	4.45[bc]	4.55[bc]	4.99[ab]	5.33[a]	< 0.01	< 0.01	0.58	0.33
Post-Grazed	3.87[de]	3.75[e]	3.88[de]	4.39[dc]				
IVOMD[g] (%)								
Pre-Grazed	37.04[c]	37.00[c]	38.17[bc]	37.11[c]	0.80	< 0.01	0.80	3.48
Post-Grazed	42.53[a]	44.27[a]	43.09[a]	37.11[ab]				
Kg/ha								
Pre-Grazed	3960.11[a]	3772.86[a]	4082.43[a]	3853.81[a]	< 0.01	0.05	< 0.01	456.10
Post-Grazed	4411.74[a]	4021.86[a]	3626.51[a]	1630.24[b]				
% of Residue								
Pre-Grazed	41.59[c]	41.21[c]	42.31[c]	41.93[c]	0.10	< 0.01	0.12	1.67
Post-Grazed	55.76[a]	55.21[a]	57.63[a]	49.40[b]				

[abcde] values within an analysis (8 values) that do not have a common subscript are different P < 0.05

[f] Stem is the weighted average of Top 1/3 of stem, Bottom 2/3 of the stem, and Shank in year 1 and measured as one sample in year 2.

[g] Values are on an OM basis

Table 5. Effect of Time x Treatment on CP (%), IVOMD (%), Kg/ha, and Percent of Residue on Husk

	Ungrazed	Light Grazed	Heavy Grazed	Baled	Treatment P Value	Time P Value	Trt x Time P Value	SEM
CP[f] (%)								
Pre-Grazed	3.04[b]	3.28[b]	3.02[b]	3.38[b]	0.01	< 0.01	0.05	0.33
Post-Grazed	3.33[b]	3.21[b]	3.94[b]	5.07[a]				
IVOMD[f] (%)								
Pre-Grazed	70.33	69.58	70.37	69.02	0.57	0.88	0.94	1.34
Post-Grazed	70.69	70.57	70.15	68.47				
Kg/ha								
Pre-Grazed	856.03[a]	777.46[ab]	765.26[ab]	703.73[b]	< 0.01	< 0.01	< 0.01	50.50
Post-Grazed	551.37[c]	319.73[d]	127.26[e]	67.65[e]				
% of Residue								
Pre-Grazed	9.01[a]	8.52[ab]	7.96[ab]	7.66[ab]	< 0.01	< 0.01	0.01	0.58
Post-Grazed	7.00[b]	4.70[c]	2.07[d]	2.07[d]				

[abcde] values within an analysis (8 values) that do not have a common subscript are different P < 0.05
[f] Values are on an OM basis

Table 6. Effect of Time x Treatment on CP (%), IVOMD (%), Kg/ha, and Percent of Residue on Leaf Blade

	Ungrazed	Light Grazed	Heavy Grazed	Baled	Treatment P Value	Time P Value	Trt x Time P Value	SEM
CP[e] (%)								
Pre-Grazed	6.70[a]	6.15[ab]	6.33[ab]	6.33[ab]	0.43	0.17	0.79	1.48
Post-Grazed	6.26[ab]	5.89[ab]	5.62[b]	6.33[ab]				
IVOMD[e] (%)								
Pre-Grazed	51.44[b]	51.10[b]	50.73[b]	51.63[b]	0.39	0.01	0.24	1.95
Post-Grazed	54.30[ab]	55.78[a]	53.44[ab]	51.03[b]				
Kg/ha								
Pre-Grazed	1255.54[a]	1181.98[a]	1271.89[a]	1219.77[a]	< 0.01	< 0.01	< 0.01	57.74
Post-Grazed	858.44[b]	708.01[cb]	586.72[c]	160.99[d]				
% of Residue								
Pre-Grazed	13.22[a]	12.92[ab]	13.18[a]	13.30[a]	< 0.01	< 0.01	< 0.01	0.83
Post-Grazed	11.00[bc]	10.19[c]	9.73[c]	4.93[d]				

[abcd] values within an analysis (8 values) that do not have a common subscript are different P < 0.05
[e] Values are on an OM basis

Table 7. Effect of Time x Treatment on CP (%), IVOMD (%), Kg/ha, and Percent of Residue on Leaf Sheath

	Ungrazed	Light Grazed	Heavy Grazed	Baled	Treatment P Value	Time P Value	Trt x Time P Value	SEM
CP[e] (%)								
Pre-Grazed	4.16[b]	5.23[a]	4.18[b]	3.97[b]	0.29	0.34	0.17	0.93
Post-Grazed	4.22[b]	4.10[b]	4.04[b]	4.26[b]				
IVOMD[e] (%)								
Pre-Grazed	54.11[a]	53.60[ab]	53.91[a]	52.53[ab]	0.14	0.13	0.66	2.33
Post-Grazed	54.58[a]	52.05[ab]	51.89[ab]	50.26[b]				
Kg/ha								
Pre-Grazed	1964.35[a]	1997.54[a]	2044.17[a]	2017.80[a]	0.04	< 0.01	0.02	118.55
Post-Grazed	1300.06[b]	1073.91[bc]	895.71[c]	539.08[d]				
% of Residue								
Pre-Grazed	20.63[a]	21.83[a]	21.22[a]	21.90[a]	0.67	< 0.01	0.50	1.37
Post-Grazed	16.57[b]	15.24[b]	14.56[b]	16.26[b]				

[abcd] values within an analysis (8 values) that do not have a common subscript are different $P < 0.05$
[e] Values are on an OM basis

Table 8. Effect of Time x Treatment on CP (%), IVOMD (%), Kg/ha, and Percent of Residue on Cob

	Ungrazed	Light Grazed	Heavy Grazed	Baled	Treatment P Value	Time P Value	Trt x Time P Value	SEM
CP[d] (%)								
Pre-Grazed	3.04^{ab}	3.65^{a}	2.97^{b}	3.18^{ab}	0.61	0.46	0.17	0.24
Post-Grazed	3.31^{ab}	2.97^{b}	3.08^{ab}	3.00^{b}				
IVOMD[d] (%)								
Pre-Grazed	45.85	47.25	46.49	49.81	0.49	0.34	0.64	4.30
Post-Grazed	47.81	48.60	48.64	48.50				
Kg/ha								
Pre-Grazed	1470.40^{a}	1414.80^{ab}	1478.46^{a}	1392.60^{a}	0.53	< 0.01	0.48	211.32
Post-Grazed	761.56^{c}	1074.34^{bc}	1076.31^{bc}	904.67^{c}				
% of Residue								
Pre-Grazed	15.55^{b}	15.50^{b}	15.33^{b}	15.21^{b}	< 0.01	0.16	< 0.01	2.11
Post-Grazed	9.67^{c}	14.65^{b}	16.00^{b}	27.34^{a}				

[abc] values within an analysis (8 values) that do not have a common subscript are different $P < 0.05$
[d] Values are on an OM basis

Table 9. Kg of Plant Fractions/25.5 kg of Grain Yield

Plant Fraction	kg/25.5 kg of grain[a]	SEM
Leaf Blade[c]	3.79	0.55
Leaf Sheath[c]	2.32	0.55
Husk[c]	1.46	0.55
Stem[bc]	7.31	0.55
Cob[c]	2.67	0.55
Top 1/3 of the stem[d]	0.58	0.19
Bottom 2/3 of the stem[d]	5.96	0.19
Shank[d]	0.25	0.19

[a] 25.5 kg is equivalent to 1 bu of corn grain at 15.5% moisture
[b] Measured as a whole fraction in year 2 is the weighted average of Top 1/3 of the stem, Bottom 2/3 of the stem and shank.
[c] Plant fraction*treatment ($P = 0.98$) Plant fraction ($P < 0.01$) Treatment ($P = 0.48$)
[d] Measured in year one only; Plant fraction*treatment ($P = 0.89$) Plant fraction ($P < 0.01$) Treatment ($P = 0.90$)

Table 10. BCS and BW of Cattle Grazing Corn Residue.

	Heavy Grazed	Light Grazed	SEM	P Value
BCS[a]				
Pre Grazing	5.27	5.34	0.20	0.35
Post Grazing	5.05	5.39	0.08	< 0.01
Body Weight (kg)				
Pre Grazing	418.17	421.15	11.87	0.63
Post Grazing	442.01	456.85	14.29	0.03

[a] On a scale of 1-9 with 1 being emaciated and 9 being obese

Table 11. CP[a] (%) and IVOMD (%) of Diet Samples Collected Pre and Post Grazing

	Heavy Grazed	Light Grazed	SEM	P Value
Crude Protein				
Pre-grazing	3.34	4.02	0.40	0.06
Post-grazing	3.88	3.23	0.40	0.10
IVOMD				
Pre-grazing	67.75	66.41	2.64	0.48
Post-grazing	55.34	63.38	4.87	0.04

[a] CP as a % of organic matter

Table 12. Corn grain yield 28.6 kg/ha[a]

	No Removal	Baled	Light Grazed	Heavy Grazed	SEM	P Value
2009[b]	124.4	124.2	127.8	133.2	6.57	0.75
2010	141.1	142.4	143.9	145.3	2.98	0.77
2011	165.9	166.3	159.7	169.7	3.82	0.42
Average	143.8	144.3	143.8	149.4	11.2	0.31

[a] Equivalent to bu/ac at 15.5% moisture
[b] Grazing treatments were applied to the 2008 crop

Impact of Planting Density on Quality and Quantity of Corn Residue

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Abstract

The rising price of corn has caused many producers to look for ways to increase grain yield. One way to do this is by increasing the planting density. This study evaluated the impact of increasing planting density on the quality measures of CP, NDF, Neutral Detergent Fiber Digestibility (NDFD) and the quantity measures of kg/ha, kg/25.5 kg of corn grain, and percent of total residue made up by each plant fraction. This study used 10 hybrids with 5 hybrids considered moderately early maturing and 5 hybrids considered moderately late maturing, and 5 plant fractions, leaf blade, leaf sheath, husk, stem, and cob. For the quality measures there were statistical differences between maturities and plant fraction by density but not biologically significant. Crude Protein was different for each plant part with estimates ranging from 3.27 in moderately early maturity husk to 9.54 in moderately late maturing leaf blade. Neutral Detergent Fiber also showed a maturity by plant fraction interaction with estimates ranging from 58.33 in moderately early maturing stem to 85.37 in moderately early maturing husk. Neutral Detergent Fiber Digestibility values also had a maturity by plant fraction interaction with values ranging from 20.25 in moderately late maturity cob to 49.90 in moderately late maturing husk. There is a quadratic relationship between plant density and plant fraction for kg of residue/ha. The kg/ha values increased for stem and leaf blade but remained the same or decreased for the other fractions. Kilograms of plant fraction/25.5 kg of grain had a quadratic trend across densities with leaf blade and leaf

sheath remaining similar across densities but a decrease in stem, cob, and husk as the density increased. The percent of the residue made up by each plant fraction increased in stem, leaf blade, and leaf sheath as the density increased but decreased for husk and cob.

Introduction

With the increasing population and the decreasing amount of land available for agricultural production, the ability to produce a greater amount of grain on the same amount of acres becomes increasingly important. Several studies have been conducted evaluating the impact of increasing planting density on grain yield (Shapiro, 2006; Widdicombe, 2002; Van Roekel, 2011) with results varying by study from no effect on grain yield to a linear increase in grain yield as planting density increased and plateauing at 94,000 plants/ha. One of the objectives of this study was to determine how the increased plant density would affect the amount of residue available for cattle to graze. Van Roekel (2011) found that as the density increased, the diameter of the stem decreased quadratically, but none of the other studies have evaluated this effect. The second objective of this study was to determine if the increase in planting density had any effect on the quality and quantity of corn residue.

Materials and Methods

This study was conducted at a test plot located near York, Nebraska as a split plot design. This test plot contained nine Hoegemeyer Hybrids and one Pioneer hybrid. This site had 10 separate hybrids (Table 13), with half of the hybrids being moderately early maturing varieties (107-111 day maturity) and half being moderately late maturing (112-117 day maturity) varieties. These hybrids were each planted at 4 plant densities, 49,419,

64,245, 79,071, and 93,897, plants/ha. and were replicated three times. Each plot was under full irrigation and was fertilized with 90.72 kg of N, 18.13 kg of P_2O_5, and 0 kg of KCl. Five whole competitive plants, cut just above the crown roots, were removed from the fields after being wrapped in cloth to prevent loss of plant fractions. After being removed from the field, leaf blade, leaf sheath, and ear were removed from the stem and placed in an airtight plastic bag and labeled with hybrid, density, and replication. Stems were bound together, labeled with hybrid, density, and replication, and both the stems and other plant parts were transported back to Lincoln to dry. Stems, still in bundles, were stacked vertically and allowed to air dry for about a month before being weighed. They were chopped using an Ohio Mill, and a sample sealed in an air tight bag for analysis. The other plant parts, upon arrival at Lincoln, were opened to allow air to circulate around the plant parts and dry. The plant parts were separated as soon as possible into leaf blade, leaf sheath, husk, cob, grain, and shank, placed into individual bags by plant fraction and allowed to continue to dry. Once all the fractions were dry, each sample was weighed, and sealed in an air tight bag until DM could be determined. After being weighed, leaf blade, stem, and cob were all processed using the Ohio Mill to reduce the plant fractions into a more manageable size for analysis and provide for a complete drying of the plant fraction.

All samples were dried in duplicate pans in 60° C forced air ovens for 48 hours to determine DM. After DM was determined, samples were placed in air tight bags and stored until ground through a 2mm screen using a Wiley Mill. Each sample was analyzed for In Situ NDF digestibility using recommendations from Vanzant (1998). Samples were placed in a 5 cm x 10 cm Dacron bags with a pore size of 50µm and heat sealed.

One bag from each sample was placed into each of two ruminally fistulated steers maintained on a high forage diet. Sample bags were placed inside a larger bag with weights attached to ensure samples were not trapped in the mat layer. Samples were incubated in the rumen of the steer for 28 hours before removal. After being removed from the steer, the samples were rinsed, and then frozen. Values within each run were adjusted by steer using the average difference between the two steers for each plant fraction and adding half of that value to the steer with the lower average estimate and subtracting half from the steer with the greater average estimate for that plant fraction. Initial samples and in situ digested samples were analyzed for NDF using the Ankom Fiber analyzer (Ankom Technology Corp., NY). Samples were placed in NDF solution for 1 hour at 100° C then rinsed with distilled water for five minutes three separate times. Grain yields were determined from grain collected from the 5 sample plants. Crude protein was analyzed using a combustion Nitrogen analyzer (Leco FP-528, St. Joseph, MI) using 2mm samples.

Most producers calculate grain yield based on the bushels of grain produced. To provide an easy calculation, the kg of DM for each plant fraction was divided by the expected grain yield. The grain yield for this calculation was determined by taking the amount of grain produced in the five sample plants, dividing by the DM of the grain by 21.8 kg (21.8 kg = to 25.5 kg at 15.5% moisture which is equivalent to 1 bu. of corn). This value was then multiplied by the planting rate to determine the grain yield in 25.5 kg units per ha. This assumes that all the seeds that are planted germinate and produce a productive ear that is similar to the ears that we collected. Grain yields for each hybrid are reported in Table 1 and were determined by the yield monitor on the combine.

Undigested NDF was calculated by dividing the residue that remained after in situ digestion and NDF analysis by the initial sample DM weight multiplied by the initial NDF concentration of the sample. To get to NDFD undigested NDF was then subtracted from one.

Due to the improvements in plant breeding over the past several years, new hybrids are developed and released each year, creating a short life span for most hybrids and making estimates of differences between hybrids useful for only a couple years. Most hybrids, both older varieties and new varieties, fit a maturity category and the category day lengths remain relatively constant from year to year. In this study only differences between maturities were analyzed to provide a better long term picture of the impact of increasing the planting density and the impact that it has on the variety of corn planted.

Results and Discussion

For kg/ha there was a significant interaction for plant fraction*maturity ($P < 0.01$) and plant fraction*density ($P < 0.01$). Across all plant fractions the moderately late maturity varieties produced more kg/ha than the moderately early maturity varieties (Table 14). However the difference between the two different maturities varied depending on the plant fraction with the greatest differences being found in the leaf blade and stem fractions. The smallest difference between the two maturities was seen in the cob fraction. Due to the close relationship of the cob to the grain this small difference could be accounted for as both maturities produced similar amounts of grain.

To be able to estimate the amount of residue that would be available as the density changed a regression equation was fit to the data and found that the relationship between density, plant fraction, and maturity had a quadratic shape with separate slopes and intercepts for both plant fraction and maturity (Table 17). The stem fraction had the greatest increase across densities and the leaf blade showed a similar, yet not quite as large, increase with the increasing plant densities (Table 15). Husk and cob remained very similar across all four densities suggesting that as the planting density increases we see very little change in the amount of ear even with the increase in the number of plants per ha. Leaf sheath showed a small increase as the number of plants increased. These trends suggest that there is little if any decrease in the amount of stem and leaf blade that each plant produces even with the increasing competition from more plants occupying the same amount of space.

Percent of the residue made up by each plant fraction had a maturity*plant fraction interaction ($P = 0.01$) and a plant fraction*density interaction ($P < 0.01$). All of the plant fractions were similar between the moderately late and moderately early maturing varieties with a difference of 0.03, 1.13, 0.05, 0.52, and 0.59 between moderately early and moderately late maturities for husk, leaf blade, leaf sheath, stem, and cob respectively (Table 14). These values are relatively similar suggesting that there is little difference in the percent of the plant residue between the different maturities. The percent of the corn residue made up by each plant fraction had a quadratic response and needed a separate intercept, linear, and quadratic slopes for each plant fraction (Table 18). The plant fractions that are associated with the ear (i.e. husk and cob) decreased as a percentage of the plant (Table 15). The stem and leaf sheath had only slight increases as

a percentage of the plant as the density increased, which would be expected as the stem will most likely stay the same height but there might be a slight decrease in the diameter of the stem as the density increases, as suggested by van Roekel (2011) but that would make a very slight difference in the percentage of the plant made up by each plant fraction. Most plants are going to produce the same number of leaves no matter what the planting density is and will therefore produce the same amount of leaf sheath. Leaf blade was the fraction that increased the most of all the plant fractions. It is most likely that the plant made the same amount of leaf blade but since the other parts decreased it was a larger percentage of the plant (Graph 3).

The amount of residue produced per 25.5 kg of corn grain (25.5 kg is equivalent to a 56 lb bu) followed a similar patter to kg/ha and percentage of the plant made up by each plant fraction. There was a maturity by plant fraction interaction ($P = 0.01$) and plant fraction by density interaction ($P = 0.01$). However, there are only slight differences between the moderately early and moderately late maturing hybrids for kg/25.5 kg of residue by plant fraction. For all the plant fractions, except cob, the moderately late maturing variety had a greater amount of residue per 25.5 kg or corn grain than the moderately early maturing variety. However, the differences between the two plant fractions was very small with the greatest difference between the two hybrid maturities being found in the leaf blade fraction with a difference of 0.30 kg/25.5 kg of corn grain (Table 14). The differences that we found between the two maturities, due to the small differences between maturities within each plant fraction, is most likely not biologically significant.

The kg of each plant fraction per 25.5 kg of corn grain had a quadratic shape to the line as the plant density increased, with a separate intercept and linear slope for each plant fraction but a common quadratic slope (Table 17). Each plant fraction behaved a little differently as the densities increased with leaf blade and leaf sheath remaining constant across the increasing densities (Table 15). Cob and husk both decreased as the plant density increased, while the stem showed a slight decrease at the lower plant densities but remained similar across the remaining three densities (Graph 2). From research by Gutierrez-Ornelas et al. (1991), cattle prefer to consume leaf blade, leaf sheath, and husk. Using the averages of these plant fractions for each density we can assume that for every 25.5 kg of corn grain produced there will be 7.63 kg, 7.23 kg, 7.11 kg, and 7.16 kg of these plant fractions when the planting density is 49,000, 64,000, 79,000, and 94,000 plants per hectare respectively. These estimates suggest that the plant fractions that cattle want to consume decrease slightly as we increase the planting density, yet they still tend to have a close relationship with the corn grain yield.

Percentage of NDF within the plant had a maturity*plant fraction interaction (P < 0.01) and a plant fraction*density interaction (P < 0.01). The percentage of NDF in each plant fraction had only minor differences with most of the differences being less than one percentage unit of NDF, suggesting that any differences in NDF between these two maturities is most likely due to sampling or analyzing errors due to variation within the field. The only plant fraction that had a difference greater than 1 percentage unit of NDF was the stem with the moderately late maturing variety being 3.52 percentage units greater than the moderately early maturing variety. This difference, even though it is the greatest difference found, is still most likely not biologically relevant (Table 14). As the

plant density increased there was a linear shape to the line with different intercepts and linear slopes needed for each plant fraction (Table 18). The percentage of NDF in each plant fraction varied very little among the densities (Table 16) and most of the change in NDF is most likely due to sampling error caused by variation within the field.

For NDFD, like the other analyses, there was a maturity*plant fraction ($P < 0.01$) and a plant fraction*density interaction ($P < 0.01$). Like the other analyses there were very small differences among the maturities for each plant fraction but there are greater differences among plant fractions. The moderately early maturity hybrids were less than 2 percentage units greater than the moderately late maturing hybrids for husk, leaf sheath, and cob, however leaf blade and stem were the opposite and the moderately late maturing hybrids were less than 2 percentage units greater than the moderately early maturing hybrids (Table 14). These differences, though significant, are most likely due to variation within the field and due to the closeness of the difference between the two maturities is most likely not biologically significant. The shape of the line for density had a significant maturity*plant fraction*density interaction, with different linear slopes and intercepts for each plant fraction*maturity combination (Table 19). Even with these differences there does not appear to be any real biological difference between the two maturities but there does appear to be a difference between the plant fractions (Table 16). Previous research on the digestibility of corn residue has utilized the in vitro method developed by Tilley and Terry (1963). This method uses a set incubation time period of 48 hours and is conducted using a test tube in the lab. The in situ method utilized does not have a set incubation time period and is conducted using ruminally fistulated cattle. The NDFD values presented here follow a similar ranking compared to the in vitro

values, but the difference between the samples is very different. It appears that some plant fractions, particularly husk, are digested differently depending on the method used. The values found in this study appear lower and most likely the main reason for the low values is due to the length of time the samples fermented in the rumen. This study was done in conjunction with an additional study (Burken, 2013) utilizing more immature plants that would be more digestible and have a faster rate of passage. Due to a lack of research indicating the passage rate of each plant fraction and for better comparisons between the immature plants, the amount of fermentation time was kept constant. In unpublished data from this study (Sudbeck, personal communication), samples of leaf blade, leaf sheath, stem, and husk were incubated in the same steers for 22, 28, and 34 hours and had 34 hour NDFD values of 54.96, 40.76, 43.58, and 49.82 for leaf blade, leaf sheath, stem, and husk respectively (Table 20). These values more closely mimic the data found in other digestibility studies. Due to the low quality of corn residue, feeding samples of each plant fraction to get passage rate would be difficult and hard to study making the amount of fermentation time allowed debatable. Therefore, we used a common time point with the joint study to make for a better estimate of the change in NDFD over time.

CP had a maturity *plant faction interaction ($P < 0.01$) and a plant fraction*density interaction ($P < 0.01$). The moderately early maturing hybrids had a greater CP content in the leaf sheath and stem fractions of the plant while the leaf blade, husk, and cob fractions had a greater CP content in the moderately late maturing hybrids (Table 14). While there were differences, most of the differences between the maturities were less than one percentage unit and most likely not biologically relevant. As densities

increased there was a liner relationship in the amount of CP found in each plant fraction (Table 16) with separate intercepts and linear slopes for each plant fraction (Table 18).

Implications

Hybrid maturity had very little effect on the quality measures of NDF, NDFD, and CP. There was very little impact of density with only slight linear or quadratic changes that were for the most part not biologically significant. The greatest differences in quality measures is seen between the plant fractions as has been noted in previous research (McGee, 2012; McGee, 2013). Density had the greatest impact on the amount of residue that was available with changes in the amount of residue per ha, and the percentage of the plant that is made up of each plant fraction. The changes in the quantity of residue available but not in the amount of residue available per 25.5 kg of grain suggests that even as the density increases the relationship of amount of palatable parts to the amount of grain still hold a very close relationship.

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Table 13. Hybrid Characteristics and Grain Yields

Hybrid Number	Hybrid Name	Maturity	Grain Yield[ab]
1	HPT7616 HXLLRR	Moderately Early	11,912
2	7726 3000GT	Moderately Early	11,436
3	HPT7998 HXLLRR	Moderately Early	11,865
4	HPT8041 HXLLRR	Moderately Early	11,781
5	P1151 HR	Moderately Early	13,069
6	8360 3111 VP	Moderately Late	12,032
7	HPT8345 HXLLRR	Moderately Late	13,225
8	6203 VTRR	Moderately Late	11,022
9	HPT8505 HXLLRR	Moderately Late	12,879
10	HPT8803 HXLLRR	Moderately Late	13,387

[a] Reported in kg/ha and determined by the yield monitor of the combine
[b] Value is averaged across all four densities

Table 14. Effect of Maturity and Plant Fraction

	Husk	Leaf Blade	Leaf Sheath	Stem	Cob	SEM
Kg DM/Ha[a]						
Early Maturity	763.21	2494.80	1245.05	5620.73	1413.92	50.82
Late Maturity	838.59	2858.59	1346.64	6065.57	1451.72	50.82
Percent of Residue[ad]						
Early Maturity	6.71	21.58	10.78	48.70	12.23	0.17
Late Maturity	6.74	22.71	10.73	48.18	11.64	0.17
Kg/25.5 kg of Grain[ae]						
Early Maturity[b]	1.22	3.92	1.96	8.87	2.24	0.06
Late Maturity[c]	1.26	4.22	2.00	8.98	2.16	0.06
NDF[af] (%)						
Early Maturity	85.37	61.41	72.05	58.33	84.00	0.42
Late Maturity	84.70	62.34	71.68	61.85	83.60	0.42
NDFD[ag] (%)						
Early Maturity	49.73	44.54	35.76	20.85	21.96	0.54
Late Maturity	49.90	43.36	33.29	22.69	20.25	0.54
CP[ah] (%)						
Early Maturity	3.27	9.14	4.03	4.67	3.38	0.09
Late Maturity	3.53	9.54	3.42	4.31	3.41	0.09

[a] m*fraction $P < 0.01$
[b] Average moderately early maturing hybrid corn grain yield 11,971 kg/ha
[c] Average moderately late maturing hybrid corn grain yield 12,511 kg/ha
[d] Percent of forage residue made up by each plant part prior to harvest
[e] Represents kg of plant fraction DM/ 25.5 kg of corn grain at 15.5% moisture (equivalent to 1 bu of corn grain)
[f] Neutral Detergent Fiber as a percent of DM; in situ values incubated for 28 hours
[g] Neutral Detergent Fiber Digestibility as a percent of DM
[h] Crude Protein as a percent of DM

Table 15. Effect of Density x Plant Fraction Interaction on kg DM/ha, Percent of Residue, and kg DM/25.5 kg of Corn Grain

	Husk	Leaf Blade	Leaf Sheath	Stem	Cob	SEM
Kg DM/Ha[a]						
49,000	881.0	2288.2	1143.2	5228.1	1400.1	71.9
64,000	792.5	2572.3	1257.7	5642.6	1424.2	71.9
79,000	754.0	2782.3	1333.4	6027.3	1415.0	71.9
94,000	776.2	3064.0	1449.1	6474.6	1492.0	71.9
Percent of Residue[ad]						
49,000	8.06	20.91	10.44	47.79	12.80	0.24
64,000	6.83	21.98	10.76	48.23	12.20	0.24
79,000	6.10	22.58	10.82	49.00	11.49	0.24
94,000	5.89	23.10	10.99	48.75	11.26	0.24
Kg DM/25.5 kg of Grain[ae]						
49,000	1.56	4.05	2.02	9.27	2.48	0.08
64,000	1.24	4.02	1.97	8.84	2.23	0.08
79,000	1.10	4.06	1.95	8.83	2.07	0.08
94,000	1.05	4.14	1.97	8.75	2.02	0.08

[a] Plant fraction*density $P < 0.01$
[d] Percent of forage residue made up by each plant part prior to harvest
[e] Represents kg of plant fraction DM/ 25.5 kg of corn grain at 15.5% moisture (equivalent to 1 bu of corn grain)

Table 16. Effect of Density x Plant Fraction Interaction on CP (%), NDF (%), and NDFD (%)

	Husk	Leaf Blade	Leaf Sheath	Stem	Cob	SEM
CP[a] (%)						
49,000	3.81	9.87	4.11	5.02	3.17	0.14
64,000	3.41	9.68	3.78	4.65	3.34	0.14
79,000	3.21	8.96	3.47	4.17	3.53	0.14
94,000	3.16	8.85	3.53	4.10	3.55	0.14
NDF[ab] (%)						
49,000	83.43	60.31	69.69	56.99	84.03	0.59
64,000	84.54	61.58	72.10	59.91	83.59	0.59
79,000	85.64	62.43	72.25	60.34	83.42	0.59
94,000	86.55	63.18	73.43	63.12	84.16	0.59
NDFD[ae] (%)						
49,000	47.38	42.99	35.33	21.61	19.09	0.75
64,000	50.96	43.83	35.84	21.65	20.57	0.75
79,000	50.13	44.23	33.55	21.46	21.44	0.75
94,000	50.80	44.75	33.38	22.35	23.30	0.75

[a] Plant fraction*density $P < 0.01$
[b] Crude Protein as a percent of DM
[c] Neutral Detergent Fiber as a percent of DM; in situ values incubated for 28 hours
[d] Neutral Detergent Fiber Digestibility as a percent of DM

Table 17. Estimates of Plant Fraction x Density Intercept and Slope for kg/25.5 kg Grain Yield and kg/ha[a]

	Intercept	SEM	Linear	SEM	Quadratic	SEM
Kg/25.5 kg of Corn Grain						
Early Maturity						
Husk	3.11	0.79	-0.43	0.16	0.02	0.01
Leaf Blade	4.99	0.79	-0.32	0.16	0.02	0.01
Leaf Sheath	3.17	0.79	-0.34	0.16	0.02	0.01
Stem	11.26	0.45	-0.50	0.12	0.02	0.01
Cob	4.21	0.79	-0.44	0.16	0.02	0.01
Late Maturity						
Husk	3.10	1.62	-0.43	0.27	0.02	0.01
Leaf Blade	4.98	1.62	-0.27	0.27	0.02	0.01
Leaf Sheath	3.11	1.62	-0.32	0.27	0.02	0.01
Stem	10.24	0.79	-0.34	0.16	0.02	0.01
Cob	3.82	1.62	-0.40	0.27	0.02	0.01
Kg/ha						
Early Maturity						
Husk	1416.07	721.74	-166.24	148.65	9.93	7.11
Leaf Blade	814.05	721.74	333.10	148.65	13.00	7.11
Leaf Sheath	809.69	721.74	60.57	148.65	0.04	7.11
Stem	2769.36	408.57	597.54	106.01	-26.35	7.11
Cob	1307.1	721.74	24.08	148.65	-1.21	7.11
Late Maturity						
Husk	1711.08	1477.80	-232.77	251.60	14.68	7.11
Leaf Blade	2095.47	1477.80	12.61	251.60	12.48	7.11
Leaf Sheath	847.42	1477.80	68.20	251.60	0.21	7.11
Stem	5337.49	721.74	-151.95	148.65	33.64	7.11
Cob	1873.04	1477.80	-156.84	251.60	12.98	7.11

[a] Estimates were regressed using densities of plants/ha divided by 10,000

[b]Represents kg of plant fraction DM/ 25.5 kg of corn grain at 15.5% moisture (equivalent to 1 bu of corn grain)

Table 18. Estimates of Plant Fraction x Density Intercept and Slope for CP (%), NDF (%), Percent of Residue[a] (%)

	Intercept	SEM	Linear	SEM	Quadratic	SEM
CP (%)						
Husk	4.43	0.72	-0.14	0.10	-	-
Leaf Blade	11.14	0.72	-0.25	0.10	-	-
Leaf Sheath	4.70	0.72	-0.14	0.10	-	-
Stem	6.03	0.30	-0.22	0.04	-	-
Cob	2.77	0.72	0.09	0.10	-	-
NDF (%)						
Husk	80.06	3.20	0.69	0.43	-	-
Leaf Blade	57.36	3.20	0.63	0.43	-	-
Leaf Sheath	66.44	3.20	0.76	0.43	-	-
Stem	51.11	1.30	1.26	0.18	-	-
Cob	83.70	0.32	0.01	0.43	-	-
Percent of Residue[b] (%)						
Husk	15.68	6.42	-2.12	1.87	0.11	0.13
Leaf Blade	15.75	6.42	1.36	1.87	-0.06	0.13
Leaf Sheath	9.11	6.42	0.36	1.87	-0.02	0.13
Stem	43.04	2.66	1.33	0.77	-0.08	0.05
Cob	16.42	6.42	0.93	1.87	0.04	0.13

[a] Estimates were regressed using densities of plants/ha divided by 10,000
[b] Percent of the total forage fraction of the residue made up by a plant fraction

Table 19. Estimates of Plant Fraction x Density Intercept and Slope of NDFD[ab] (%)

	Intercept	SEM	Linear	SEM
Early Maturing				
Husk	45.86	5.64	0.54	0.77
Leaf Blade	42.43	5.62	0.30	0.77
Leaf Sheath	39.33	5.62	-0.50	0.77
Stem	19.12	2.34	0.24	0.32
Cob	14.21	5.62	1.11	0.77
Late Maturing				
Husk	44.74	13.58	0.72	1.85
Leaf Blade	40.09	13.55	0.46	1.85
Leaf Sheath	37.47	13.55	-0.58	1.85
Stem	22.52	5.62	0.02	0.77
Cob	15.29	13.55	0.69	1.85

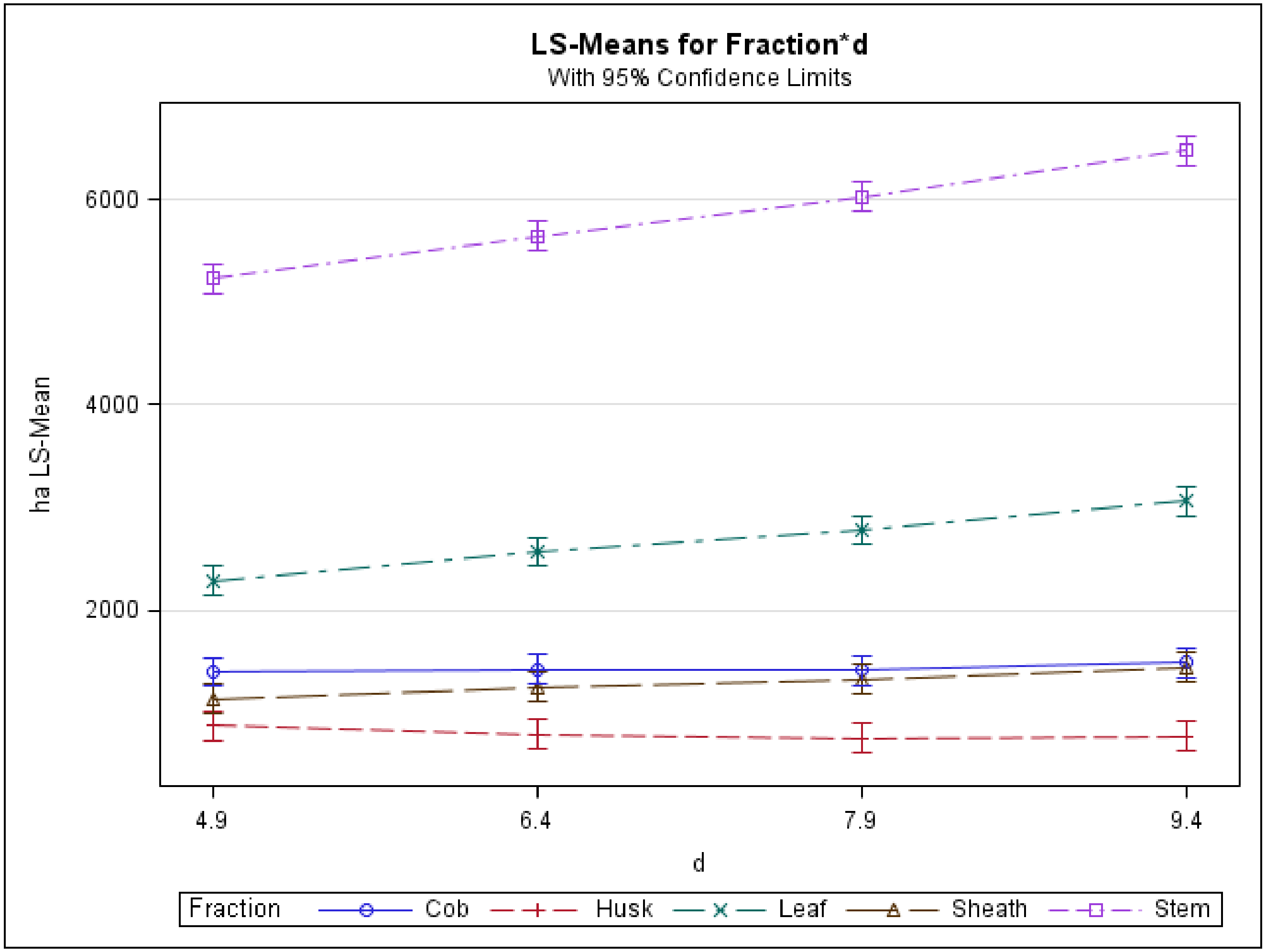
[a] Estimates were regressed using densities of plants/ha divided by 10,000
[b] Neutral Detergent Fiber Digestibility in situ values incubated for 28 hours

Table 20. Sudbeck NDFD[a](%) Values.

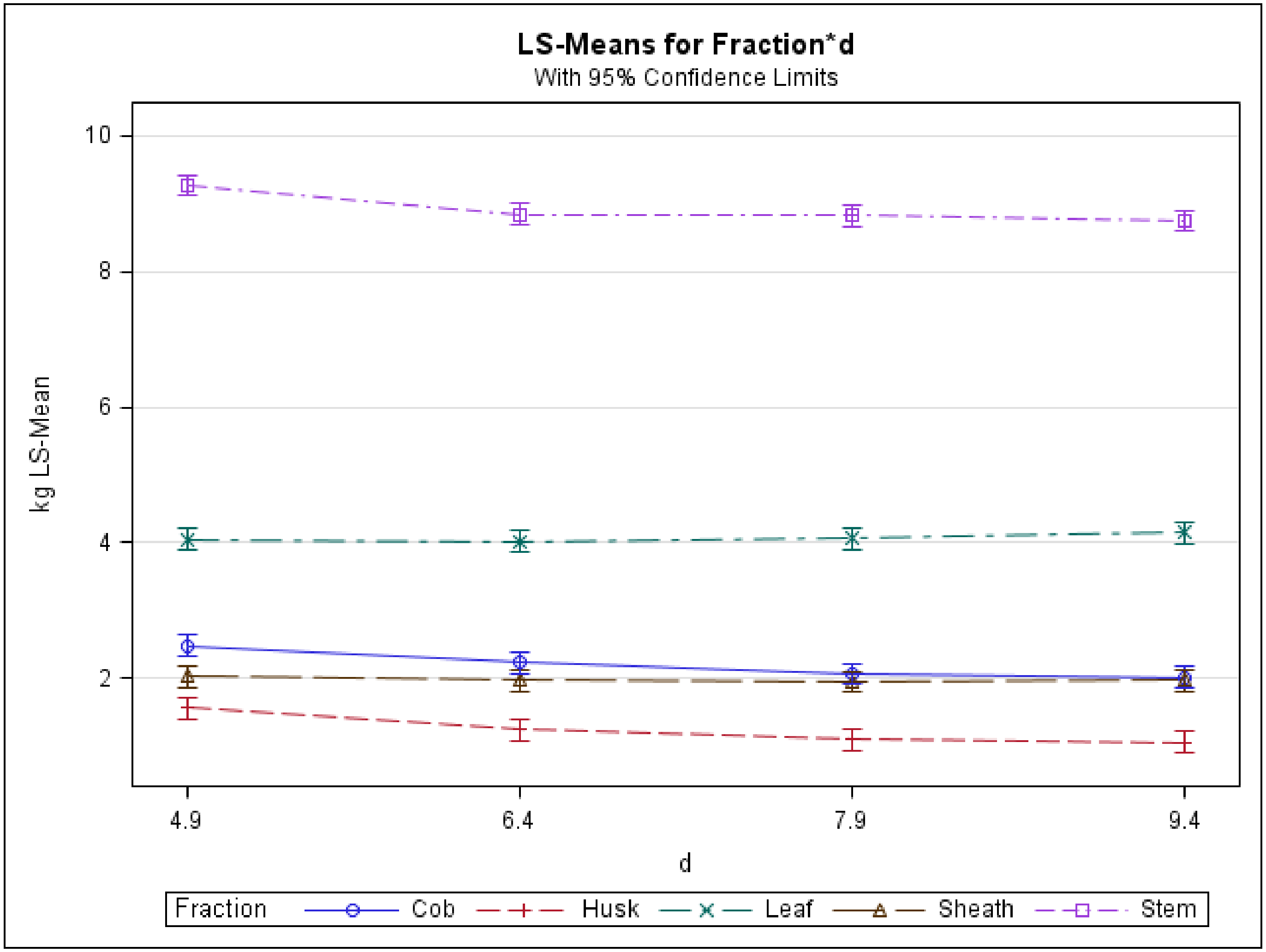
	22 hrs	28 hrs	34 hrs
Stem	37.45	40.73	43.58
Leaf Blade	44.35	50.34	54.96
Leaf Sheath	30.17	35.50	40.76
Husk	33.50	43.22	49.83

[a] Neutral Detergent Fiber Digestibility

Graph 1. Effect of Planting Density on Kg DM/ha of each Plant Fraction



Graph 2. Effect of Planting Density on Kg DM of each Plant Fraction/25.5 kg of Corn Grain at 15.5% Moisture



Graph 3. Effect of Planting Density on Each Plant Fraction as a Percent of Total Residue