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Impact of Forage Conditioner Systems on the Harvesting of Alfalfa

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IMPACT OF FORAGE CONDITIONER SYSTEMS ON THE HARVESTING OF ALFALFA

by

Derrick Hendry

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ABSTRACT

Impact of Forage Conditioner Systems on the Harvesting of Alfalfa

by

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Utah State University, 2023

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This project examined the impact of seven swather conditioner rollers on dry-down rates and forage quality at the USU Cache Junction Farm. The seven conditioner rollers included: (1) Case New Holland (CNH) single steel, (2) CNH rubber, (3) CNH high contact, (4) CNH counter-rotating rubber, (5) AGCO single steel, (6) AGCO double steel, and (7) John Deere single steel. The experiment was set up as a two-factor factorial experiment using a Randomized Complete Block Design (RCBD) with four replications. Each conditioner roller was evaluted at two widths, a wide windrow ~ 2.4 meters wide and a narrow windrow 1.5 meters wide. After the forage was harvested, each windrow was measured to assess the height, width, and distribution by weight. Each 0.9 meter cross-section was divided into three sections: left, center, right, and weighed. A grid frame was utilized to measure the height and width each day. The moisture content and dry down rate were determined by cutting 7.6 centimeter cross sections from each experimental unit daily, and then dried in an oven. Samples were collected at the same time, each day. A Koster moisture tester was used to determine the moisture of the forage before baling. The forage was baled within 24 h once it was dry enough for baling. Plant condition was evaluated by cutting another 0.9 meter cross-section from the narrow windrows in only one replication. This was analyzed by dividing the stems into whole stems, half stems, partial stems, and scraps. Once divided, 110 full stems were randomly selected, and the plant quality was visually assessed for leaves, crushed stems, broken tips, and number of crimps. Photos were taken immediately after harvest, raking, and baling to determine machine-caused leaf loss. The percentage of leaf loss was determined. Colored frames were placed on the forage and photos were taken daily to determine sun bleaching effects. Alfalfa quality was determined in two ways: (1) instant analysis from the baler near infared (NIR) sensor. and (2) bale core samples that were analyzed using an NIR machine.

(98 pages)

PUBLIC ABSTRACT

Impact of Forage Conditioner Systems on the Harvesting of Alfalfa

Derrick S. Hendry

This study analyzed three major brands of conditioner rollers and determined how they performed in drying the forage crop alfalfa. Each type of conditioner roller would cut a wide and narrow windrow. All the windrows were tested and analyzed the same. The study was concluded once the forage was baled.

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Derrick S. Hendry

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CHAPTER 1

INTRODUCTION

Agricultural equipment has gotten bigger and more efficient, which has benefited farmers by allowing them to cover more acres and increase production. Consistent innovation and product development have advanced the equipment producers use with technology such as automated driving, which allows farmers to be more effective and efficient. As the equipment changes and improves, farmers must determine which piece of equipment will provide the most benefit for their operation. This study focused on the conditioner roller systems used when harvesting the forage crop, alfalfa (*Medicago sativa*). Alfalfa is an important economic crop with a value of $8.5 billion being produced in the Western U.S. in 2018 (Yost et al., 2020).

Getting alfalfa to dry down quickly is the key to producing high-quality alfalfa hay. The faster the alfalfa dries, the less chance the crop will be rained on which greatly reduces the alfalfa quality. Faster dry time also minimizes leaf loss and allows for earlier irrigation and faster turn-around to the next harvest (Mathews et al., 2020).

A specialized tractor called a swather is used to harvest alfalfa. A swather has a component called a conditioner roller that crimps the forage to help it dry faster. There are several different types of conditioner rollers, including rubber, steel, and high contact.

Many studies have examined why it is important to dry alfalfa quickly, why the quality is important, and why leaf loss is critical to maintaining forage quality. Little research has been conducted on how the current conditioner rollers impact the harvest and dry down of alfalfa. This study examines seven conditioner rollers and their impact on the rate of dry down and alfalfa forage quality.

Seven conditioner rollers representing the three major companies: (1) Case New Holland (CNH) single steel, (2) CNH rubber, (3) CNH high contact, (4) CNH counter-rotating rubber, (5) Massey Ferguson (AGCO) single steel, (6) AGCO double steel, and (7) a John Deere single steel conditioner roller were examined. Forage distribution, stem condition, windrow width and height, rate of dry down, leaf loss, hay forage quality, and sun bleaching effects were examined.

CHAPTER 2

REVIEW OF LITERATURE

Equipment

Alfalfa, a crop that is harvested multiple times each year, requires careful management when harvesting. If harvested incorrectly, both yield quality and quantity losses can occur (Orloff, 1992). Farmers face the difficult task of getting the right balance of quantity and high-quality alfalfa. If the crop is cut too early, higher quality hay will be produced, but the quantity will be reduced. Low-level reserves in the crown can also result in poor regrowth rates. If harvested later, the inverse occurs, and the feed quality goes down, but the yield is increased by 100-200 lbs of dry matter/day (Lorenzo et al., 2020; Undersander, 2006). Being able to quickly cut, dry, and bale the alfalfa, and minimize respiration, sun bleaching, and avoid leaf and dry matter loss should be the approach to harvesting alfalfa (Undersander, 2006). This is where each operation varies, and each operation should consider the various types of swathers and conditioner rollers that will produce the best quality and quantity for their conditions and situations.

There are two main types of swathers (self-propelled or pull-type swathers), and two options for cutting (a sickle head or a disc mower head). As the alfalfa is cut, it is fed through conditioner rollers that crimp the stem and aid in the dry down before being placed in a windrow in the field. The process of going through crimpers greatly speeds up the drying time (Adams, 1996; Mathews et al., 2020; Rotz, 1993; Rotz et al., 1987). Crimping is the process of mechanically squashing or bending the stem. This cracks the cuticle, which protects the outside surface of the stem, and allows moisture to leave the plant. This in turn helps the forage dry faster since the stem is the slowest part of the plant to dry down (Idowu et al.,2013; Orloff & Putnam, 2012).

Obtaining high-quality alfalfa starts with having your swather and conditioner rollers set up correctly so the crop can dry faster when the environmental conditions are favorable. One of the major factors in drying alfalfa is solar radiation (Rotz, 1993). Drying is less correlated with air temperature, humidity, and soil moisture level (Shinners & Herzmann, 2006).

After the alfalfa is harvested and goes through the cutting and conditioning process it is dried until it reaches a moisture content of 35-40%, two windrows are then raked together and the alfalfa is dried until it reaches 14 to 18% depending on bale size (Orloff & Putnam, 2012; Undersander, 2006). Baling below 12% moisture should be avoided because excessive leaf shatter is possible (Orloff & Putnam, 2012). During each of these steps, there can be a loss in the total quantity and quality of the alfalfa (Greenlees et al., 2002).

Dry Down

The alfalfa quality is the highest at the time it is cut: it only decreases from there. Therefore, the objective is to dry the alfalfa as uniformly and as quickly as possible. Under normal drying conditions, dry matter (DM) loss can be anywhere from 15% to 25%, with rain damage increasing the loss greatly, another 30% or more. If the rain delays the drying and requires the alfalfa to be in the field longer than two weeks, it often becomes unsuitable for animal feed and could be a total loss (Rotz et al., 1987; Rotz & Muck, 1994). It is not just about the amount of rain that falls, but the time of day during which it rained and the relationship between when the crop was cut to the time it rained. The drier the crop before the rain, the more the negative effect the rain has on it.

Each step of the harvest also contributes to DM loss (Rotz & Muck, 1994; Orloff & Putnam, 2012). Dry matter loss occurs every day that the alfalfa is left in the field. Additionally, the longer alfalfa stays out in the field, the longer it is exposed to the sun, which can reduce the quality and quantity of the product (Orloff, 1992; Shinners & Herzmann, 2006).

Conditioner rollers are the most beneficial in the first and second-crop harvests as the stems are typically larger and more difficult to dry (Rotz, 1993). The use of conditioner rollers increased the drying constant (sped up the rate of drying) by 80% for the first crop and 36% for the second crop (Rotz et al., 1987).

Windrow Width

Along with the conditioner rollers, the windrow width can impact dry-down rates. The windrow is what the swather produces out the back of the machine (see Figure 2.1.) Wide windrows dry faster than narrow windrows (Idowu, 2013; Orloff, 1992; Orloff & Putnam, 2012; Rotz, 1993; Shinners & Herzmann, 2006). Getting the windrow as wide as possible has some limitations, especially in self-propelled models such as disc or rotary swathers, where the windrow can only be as wide as the width of the wheels so as to not run over the alfalfa and compact the windrow (Rotz, 1995; Shinners & Herzmann, 2006).

Figure 2.1

John Deere, Massey Ferguson, and Case New Holland Swathers Leaving Behind Test Windrows Immediately Before the Start of the Study

Wide windrows may increase the possibility of the alfalfa becoming sun bleached due to more surface area of the windrows being exposed to the sun versus a narrow windrow, which has less surface area to become bleached (Orloff, 1992). Alfalfa that is laid out in thin wide swaths requires three to five days of drying, whereas heavier windrows may require six to seven days (Rotz & Muck, 1994).

The windrow width is the most important factor in determining the drying time of alfalfa and preserving important starches and sugars (Undersander, 2006). The fastest drying rate occurs when the crop is placed as wide as the cutting platform, with narrow windrows drying 34% slower than wide windrows (Shinners & Herzmann, 2006).

The windrow width is one of the key factors that can be controlled. The ratio of the cutting width to the windrow width influences the drying time. A windrow that is 70% of the cut width will reduce the drying time by 25 to 40% compared to a windrow that is 45% of the cut width (Orloff & Putnam, 2012). Shinners (2002) observed that the wide width can reduce the drying rate by 6 hours, while Rotz (1993) reported that a narrow swath requires about eight more hours of drying than a thin, wide windrow. Drying time increases as thickness and density increase (Rotz, 1995). Most conditioner rollers are about 2.7 meters (nine feet) wide, so the widest windrow is about 2.4 meters (eight feet) wide. As cutting heads on swathers get bigger, the ratio of cut width to windrow width decreases, and the density of the windrow is increased. Shinners also reported that for every half meter (~1.5 feet) of cutting width greater than 2.7 meters (9 feet) the drying time increased by about one hour. Going, from a 2.7 meter (9 foot) cutting head to a 3.6 meter (12 foot) cutting head, the crop would take roughly two additional hours to dry to baling moisture due to the increase in windrow density (Shinners, 2002).

Getting the alfalfa to dry rapidly and uniformly is important for producing high-quality alfalfa hay. Rapid drying time reduces quality losses due to sun bleaching, rain damage, and leaf loss. Faster drying rates also allow for earlier removal of the bales, which in turn allows for quicker irrigation and improved crop regrowth. This is primarily accomplished by properly adjusting the conditioner rollers and producing wider and thinner windrows (Orloff, 1992).

Forage Quality

Alfalfa is one of the most valuable forage crops in North America because it can be used by many different industries and animals and has superior nutrient characteristics. It also has the highest feeding value of all commonly grown hay crops and produces more protein per hectare than other grain or oil seed crops (Shinners & Herzmann, 2006).

The primary goal when harvesting alfalfa is to maintain protein and conserve digestible fiber (Undersander, 2006) and as much dry matter and other nutrients as possible with minimal loss. The loss of dry matter is influenced by the size and type of equipment used.

Forage loss during harvest and storage can be considerable, which can lead to monetary losses. Yield and leaf loss during swathing can be around two to three percent; but, the other parts of harvest, raking, baling, and storage can result in losses of up to 21% (Orloff & Mueller, 2008).

Losses in alfalfa include the physical detachment of forage material and internal depletion or degradation of plant nutrients (Rotz & Muck, 1994). These can happen at all stages of harvest: 1% to 3% at cutting, 1% to 2% during tedding, 3% to 6% at raking, and 2% to 10% at baling, with losses being related to the speed of the operation as well as the moisture content of the alfalfa (Rotz et al., 1987). Maintaining as much dry matter and leaf material as possible is the key to producing a good quality alfalfa crop and having a profitable operation. If alfalfa has a monetary value of $250/per ton at a 21% yield loss, the grower could lose $50/per ton (Idowu et al., 2013), so by decreasing loss, they can increase profit.

Cellular respiration results in the loss of sugars and carbohydrates (respiration loss) which reduce forage quality and protein content. The respiration rate is related to crop temperature and moisture. Respiration ceases when the plant reaches 40% moisture (Rotz et al., 1987). Dry matter losses caused by respiration are difficult to measure during harvest; for alfalfa dried under good weather drying conditions, respiration losses appear to be 3 to 4% (Rotz & Muck, 1994)

The time of day that the forage is harvested impacts forage quality because the plant is photosynthesizing and producing sugars during the day. At night, the plant respires using up some sugars and valuable nutrients that it accumulated during the day. Harvesting later in the day is beneficial to alfalfa quality (Orloff & Putnam, 2012). Cattle, sheep, and goats can distinguish between alfalfa harvested at sundown versus the morning, eating up to 30% more afternoon-harvested alfalfa than morning-harvested alfalfa. This increase in consumption increased milk production (Shewmaker & Mayland, 2001).

CHAPTER 3

MATERIALS AND METHODS

This study was performed at the Utah State University farm in Cache Junction, Utah from July 6-11, 2021. Seven different conditioner rollers and two windrow widths were evaluated in a two-factor factorial, randomized complete block design (RCBD) with four replications. The impact of the conditioner roller type on the forage quality and rate of dry down was monitored.

Seven types of conditioner rollers representing three brands were analyzed. Four of them were from the Case New Holland (CNH) manufacturer. These conditioner rollers were rubber, steel, high contact (flat), and a rubber roller with a counter-rotating set-up. Two other conditioner rollers came from AGCO (Allis Gleaner Corporation/ Massey Ferguson): their conditioner rollers were a single steel conditioner roller, and a double steel conditioner roller (two sets of conditioner rollers back-to-back). The seventh and final conditioner roller was from John Deere. It was a single steel conditioner roller.

Three swathers were available for this study, one for each brand. Conditioner rollers were swapped out when more than one conditioner for a brand was being examined. The conditioner rollers were set up and adjusted before the study, and then swapped out, as needed, by a team of mechanics provided by Case New Holland (Figure 3.1). An AGCO representative verified that the settings for the AGCO conditioners were correct. A local producer provided the John Deere machine and conditioner unit. Both the producer and the team of mechanics verified that the John Deere machine settings were correct. The settings used for each machine/conditioner system are listed (Table 3.1). The

Figure 3.1

Mechanics Unload A Swather Head for an AGCO Machine

Table 3.1

Showing the Setup for Each Conditioner Roller for Wide and Narrow Windrows

	Conditioner settings								
Header type	Roll gap	Roll tension	Swath gate	Windrow shield	Fluffing baffle	Wedges	Fins	Ground speed	Disc speed
MY22 Rubber Chevron Rolls Wide	3mm	24	8	1	7	center	Outside	10	1800
MY22 Rubber Chevron Rolls Narrow	3mm	24	1	1	7	Center	Outside	10	1800
MY22 Steel Rolls Wide	6mm	20	8	1	7	Center	Outside	10	1800
MY22 Steel Rolls Narrow	6mm	20	1	1	7	Center	Outside	10	1800
MY22 Hi Contact Rolls Wide	2mm	20	8	1	7	Center	Outside	10	1800
MY22 Hi Contact Rolls Narrow	2mm	20	1	1	7	Center	Outside	10	1800
Agco 9316 Double Rolls Wide	6mm	900	7	Out	N/A	N/A	N/A	10	2000
Agco 9316 Double Rolls Narrow	6mm	900	1	Out	N/A	N/A	N/A	10	2000
Agco 9252 Single Rolls Wide	5mm	1200	7	Out	N/A	N/A	N/A	10	2000
Agco 9252 Single Rolls Narrow	5mm	1200	1	Out	N/A	N/A	N/A	10	2000
John Deere 500R Wide	6.5mm	Mid	Up	Out	N/A	N/A	N/A	10	2250
John Deere 500R Narrow	6.5mm	Mid	Down	Out	N/A	N/A	N/A	10	2250

CNH counter-rotating head was an experimental setup added at the end of the day. No settings were recorded for the counter-rotating conditioner roller.

Each conditioner roller was tested under two windrow widths. The narrow windrow was set at 1.5 meters wide (5 feet), and the wide windrow was set as wide as each conditioner roller could disperse the alfalfa without running over the forage, approximately 2.4 meters (8 feet). To minimize the number of times the conditioner rollers needed to be swapped out, both windrow widths were processed when the conditioner unit was on the swather. The order in which the windrow width was processed was randomly selected for each conditioner unit. Each experimental unit included two windrows (a pass up and back in the field), which were later raked together into one windrow and then baled.

The data collected for each treatment included: forage distribution; forage stem condition and the number of stem crimps; windrow width and height; moisture content; rate of dry down; leaf loss after cutting, raking, and baling; forage quality as measured by near infared (NIR; e.g., CP, ADF, NDF, FAT, and sun bleaching.

Forage Distribution

After the windrows were cut and labeled (Figure 3.2), the uniformity in the distribution of the forage across the windrow was examined. To evaluate the forage distribution, a 0.9 meter (3 foot) cross-section was cut using an EGO POWER+ Multi-Head System with a Stens Power Rotary Scissors attachment and a frame marking the length of the cross-section. The cross-section was cut in one windrow for each

Figure 3.2

Marking Each Windrow with the Type of Conditioner Roller Used

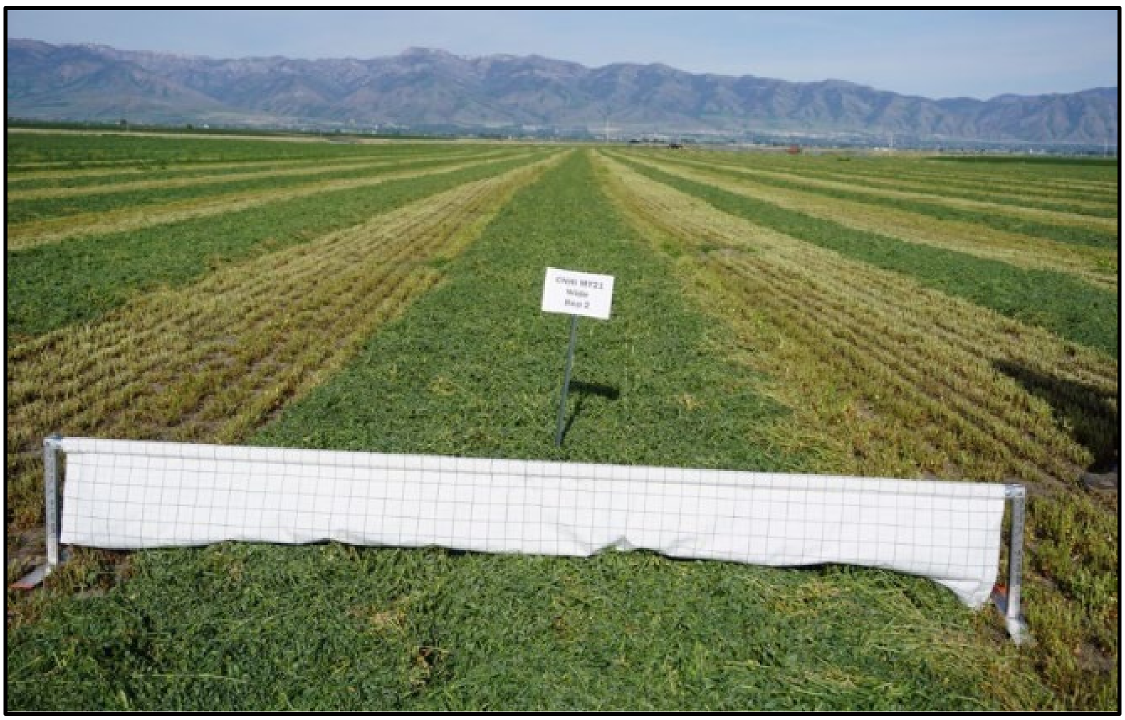
experimental unit and divided into three equal parts parallel with the windrow and identified as north, center, and south. The forage for each portion was then placed into bags and weighed. Forage distribution samples were obtained only on the first day.

Windrow Width and Height

Each windrow was evaluated to determine the windrow width and height using grid frames. The grid frames were aluminum frames that spanned the wide and narrow windrows. Weighted gridded sheets that covered the entire width of the windrow were hung from the frame (Figure 3.3). Pictures were taken to document the height and width of the windrow. This was done each day until the windrows were raked together. To ensure that the grid frame was placed in the same location, marking paint was used to mark where the legs of the grid frame were positioned on the first day. The frame was placed in the same location each day after that.

Figure 3.3

Grid Frame was Used to Measure the Height and Width of the Wide and Narrow Windrows



Plant Condition

Another 0.9 meters (3-foot) cross-section was cut in the other windrow of the experimental unit, but only in one replication, narrow windrows only, for a visual assessment of the plant material after going through the swather and conditioner unit. To prevent excessive wilting and deterioration of the plant material, the samples were collected immediately after cutting, placed on cardboard, wrapped in cloth sheets, and placed in plastic totes with ice packs in the bottom. The samples were then taken back to Logan and placed in a walk-in cooler. This sample was used to evaluate the plant stem condition and determine the number of crimps in the stems after going through the conditioner roller. The stems were sorted into full stems 68 cm or greater (>27 inches), half-stems 68 to 45 cm (27-18 inches), partial stems 45-10 cm (18-4 inches), and scraps 7.62 cm or less (< 3 inches) (Figure 3.4). Once each treatment was sorted, the forage material in each category was weighed.

Figure 3.4

Sorting the Stems of Alfalfa into Different Lengths

After the stems were sorted, full-length stems were evaluated further to assess how the conditioner roller treated the alfalfa. One hundred and ten (110) full-length stems were randomly selected and evaluated for leaf loss and stem conditions (e.g., crushed or broken stems), broken tips, and the number of crimps (Figure 3.5). The same person evaluated all full-length stems for each treatment to minimize experimental error.

Figure 3.5

An Example of a Stem of Alfalfa Used for the Crimp Count that had Been Over-Crimped

Leaf Loss

Leaf loss was analyzed at each stage of harvest (cutting, raking, and baling) by placing a frame on the ground and taking a picture for later analysis. After cutting the frame was placed next to the windrow. After raking the frame was placed in the middle of one of the two windrows raked together into one windrow. After baling, the frame was placed in the middle of the windrow that was baled. Photos were later evaluted for leaf loss and scored (to the nearest 10%) based on the percentage of ground covered with leaf material from that operation. All photos were individually scored by two people, and any differences resolved.

Sun Bleaching

For each experimental unit, photos were taken of the forage for each treatment to observe how much sun bleaching occurs as the alfalfa dries down (Figure 3.6). Photos were taken the day the forage was cut towards the end of the day; subsequent photos were taken daily at around 10 to 11 AM. Photo frame mats painted with acrylic paint that matched samples from Munsell Color Charts for Plant Tissues, and Adobe InDesign, were used to determine how the color of the alfalfa changed over time.

Figure 3.6

Colored Frames Were Used to Determine the Sun Bleaching of the Alfalfa

Dry Down

A 15.2-centimeter (6-inch) cross-section was randomly cut from a representative section of the windrow in each experimental unit every day using the EGO POWER+ Multi-Head System with Sten Power Scissors attachment and a frame to measure the length of the cross-section. On the day of harvest, the cross-section was cut shortly after the harvest. After that, the cross-section was cut at approximately 10:00 am each day. The samples were gathered, placed into bags, and weighed as quickly as possible, then they were taken to a drying oven set at 60 degrees Celsius (140 Fahrenheit) at the Utah State University Greenville Farm. After drying, the samples were reweighed to determine the percentage moisture and dry matter percentage. The rate of dry-down was determined for each treatment.

Baler Near Infared

To ensure that forage quality was not impacted by the timing of raking and baling, each treatment was evaluated separately. A twist test by the farm manager and a Koster moisture test (Figure 3.7) was used to verify when the forage was ready to be baled.

The wide windrows were all baled on July 10, 2021, using a Case IH LB 424 XL Baler. The narrow windrows were all baled on July 11, 2021.The Case IH LB 424 XL Baler was equipped with an Evonir 4.0 sensor by Dinamica Generale. This sensor was tested and set up by Brian Rawson, a technician with Dinamica Generale. This sensor gave real-time NIR analysis of the alfalfa as it was passing through the baler storing data every two seconds. Data on alfalfa moisture, crude protein (CP), Neutral Detergent Fiber

Figure 3.7

Koster Moisture Tester is Being Used to Determine if Alfalfa is Ready to be Baled

(NDF), Acid Detergent Fiber (ADF), Ash Content (ASH), and crude fat (FAT) were recorded.

Bale Cores

After baling, the bales were marked with spray paint to identify the corresponding treatment. Bale cores were obtained using a drill with a coring drill attachment. Cores were taken from each end of each large bale. Bale number and core sample numbers were recorded for each core (Figure 3.8).

Figure 3.8

Bale Core Samples Being Placed in Bags and Labeled

Forage Quality

After the bale core samples were obtained, the samples were ground down using a one-millimeter (0.04 inch) screen size on two different types of mills. First, samples were run through a Thomas-Wiley Mill Model 4 which produced a coarse grind sample. Samples were analyzed for forage quality using a NIR machine. The coarse grind samples were then run through a Udy Corporation Cyclone Sample Mill using a one-millimeter (0.04 inch) screen which produced a fine grind sample that was analyzed using a NIR machine. For each grind size, the bale core samples were run through a Foss NIRS DS 2500 F forage analyzer to measure the forage quality focusing on alfalfa moisture, crude protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), ASH, and crude fat (FAT). Samples were analyzed using the USUAL lab testing procedures. To verify that the machine was working properly, a known test sample was run first. All samples were analyzed three times, one week apart, and the average of those runs was calculated. The effect of grind size on the forage quality readings was evaluated.

Statistical Analysis

Data was analyzed using Minitab software. A full factorial analysis was used to analyze forage distribution, windrow width and height, leaf loss, baler NIR, and bale cores. A single one-way ANOVA was used on Day 4 for measuring the height and width of the narrow windrows due to the wide windrows being baled that day. A two-sample *t* test was used to look at the difference sun bleaching had on wide versus narrow windrows. Dry down rates were determined using a linear regression to evaluate how fast the alfalfa dried over time.

CHAPTER 4

RESULTS

Minitab statistical software was used to analyze the results. Analysis of variances (ANOVAs) were used to evaluate most of the research since we had seven conditioner rollers. Linear regression was used to determine dry-down rate between the wide and narrow windrows, and the sun bleaching results were analyzed using a two-sample t-test.

Forage Distribution

Forage distribution data compared the percentage of forage in each portion (north, center, and south) of the windrow to determine if there were any differences in distribution (Tables 4.1, 4.2, and 4.3). The ANOVA showed that windrow width significantly affected ($p = 0.024$) the percentage of forage in the north portion of the windrows, with a trend towards differences ($p = 0.088$) in the south portion of the windrow. Roller type exhibited a trend towards differences ($p = 0.066$) for the center portion of the windrow. Interaction effects were significantly different for the center and south portions of the windrows, but not for the north portion.

Windrow Width and Height

Windrow Width

For the wide windrow treatment, the conditioner rollers were set as wide as they could physically distribute the alfalfa. A one-way ANOVA was used to analyze the differences between the seven conditioner rollers (Table 4.4). The *p* value (< 0.001) in the

Table 4.1

Factorial Forage Distribution, North Percentage

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	714.55	44.66	1.21	0.306
Blocks	3	67.98	22.66	0.61	0.610
Treatments	7	407.75	58.25	1.58	0.172
Roller	6	232.90	38.82	1.05	0.408
Width	1	204.27	204.27	5.54	0.024
Roller*Width	6	331.89	55.32	1.50	0.206
Error	37	1365.15	36.90		
Total	53	2079.69			

Table 4.2

Factorial Forage Distribution, Center Percentage

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	1080.20	67.512	2.78	0.005
Blocks	3	46.07	15.356	0.63	0.598
Treatments	7	321.68	45.954	1.90	0.098
Roller	6	319.23	53.205	2.19	0.066
Width	1	6.77	6.772	0.28	0.600
Roller*Width	6	728.71	121.452	5.01	0.001
Error	37	897.22	24.249		
Total	53	1977.42			

Table 4.3

Factorial Forage Distribution, South Percentage

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	1303.90	81.49	1.83	0.064
Blocks	3	33.29	11.10	0.25	0.861
Treatments	7	524.17	74.88	1.68	0.143
Roller	6	388.25	64.71	1.45	0.221
Width	1	136.66	136.66	3.07	0.088
Roller*Width	6	771.45	128.57	2.89	0.021
Error	37	1645.68	44.48		
Total	53	2949.59			

Table 4.4

Analysis of Variance of Wide Windrow Width

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Roller	6	618.9	103.14	8.17	0.000
Error	21	265.0	12.62		
Total	27	883.9			

analysis of variance shows that significant differences were observed between the conditioner rollers. The Tukey comparison (Table 4.5) and the boxplot (Figure 4.1) show these differences. The John Deere conditioner roller at an average width of 2.546 meters (100.25 inches) was significantly wider than most of the others, while the AGCO single conditioner was the narrowest at 2.172 meters (85.50 inches) among the conditioner rollers examined.

Table 4.5

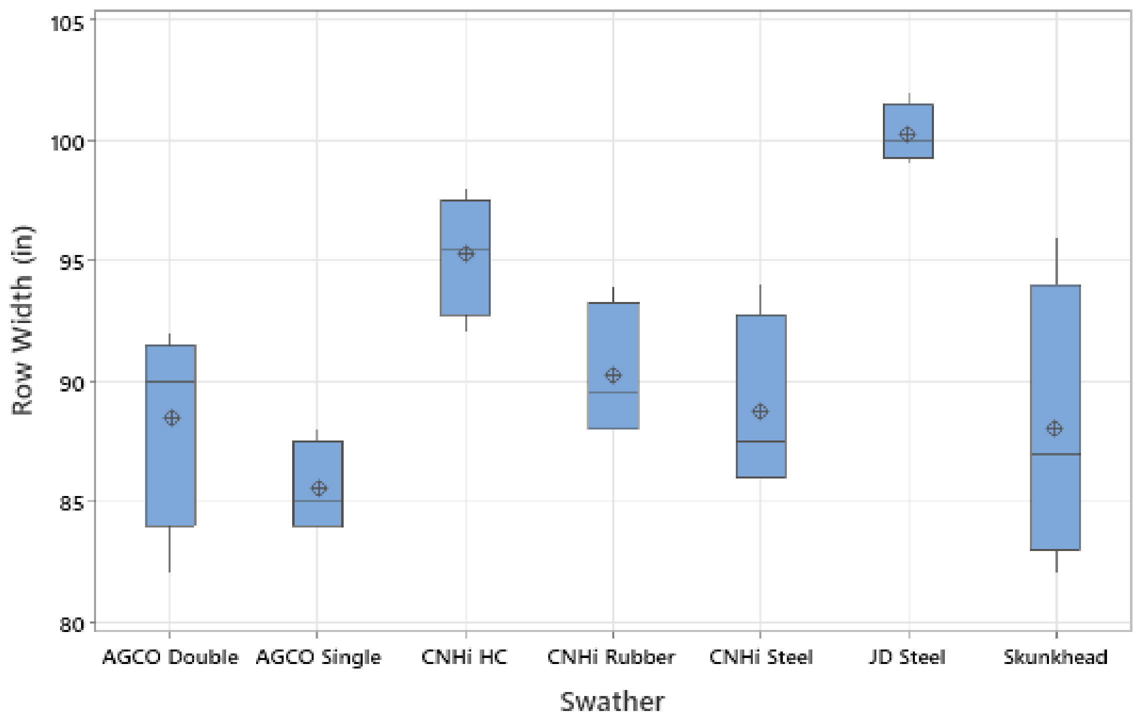
Wide Windrow Width (inches) Tukey Comparison

Roller	*N*	Mean	Grouping		
JD Steel	4	100.250	A		
CNHi HC	4	95.250	A	B	
CNHi Rubber	4	90.250		B	C
CNHi Steel	4	88.750		B	C
AGCO Double	4	88.500		B	C
Skunkhead	4	88.000		B	C
AGCO Single	4	85.500			C

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

Figure 4.1

Boxplot Showing Relationship Between Wide Conditioner Rollers



The narrow windrow width was set at 1.5 meters (five feet) for each conditioner roller. The analysis of variance (Table 4.6) showed that there were no significant differences between the conditioner rollers. All the conditioner rollers set for a narrow windrow produced a similar windrow width and they were all in the same group in the Tukey comparison (Table 4.7, Figure 4.2).

Table 4.6

Analysis of Variance of Narrow Windrow Width

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Roller	6	200.0	33.34	1.92	0.129
Error	19	329.5	17.34		
Total	25	529.5			

Table 4.7

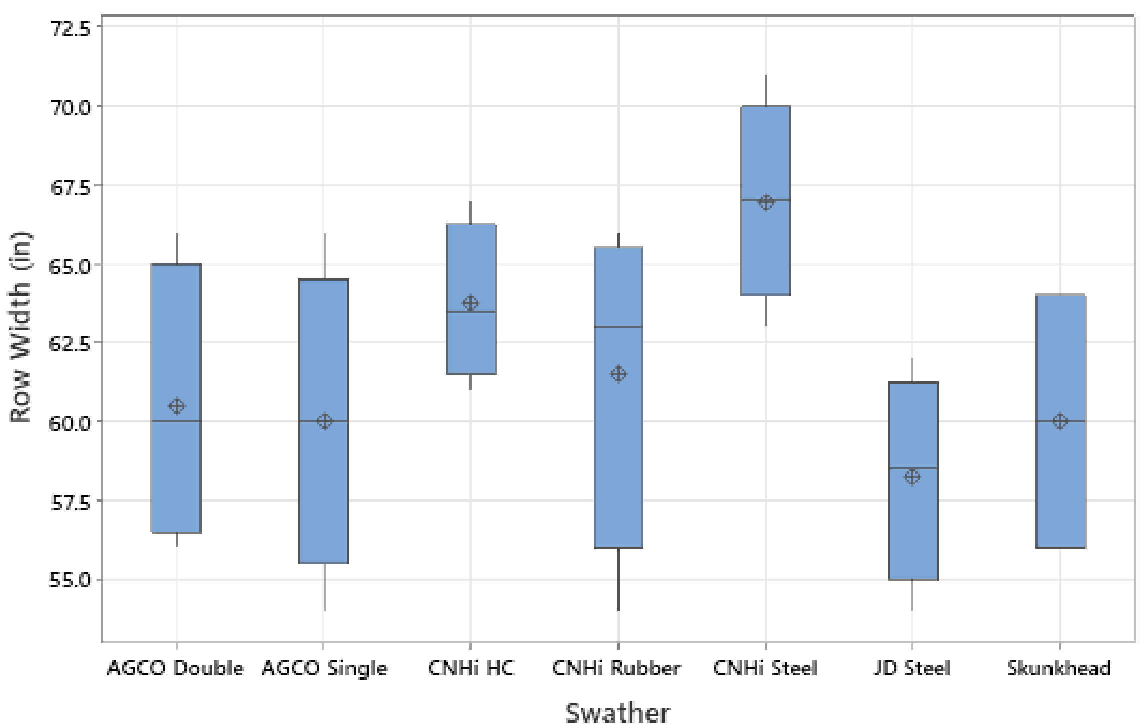
Narrow Windrow Width (inches) Tukey Comparison

Roller	*N*	Mean	Grouping
CNHi Steel	4	67.00	A
CNHi HC	4	63.75	A
CNHi Rubber	4	61.50	A
AGCO Double	4	60.50	A
Skunkhead	2	60.00	A
AGCO Single	4	60.00	A
JD Steel	4	58.25	A

Note. Grouping Information Using the Tukey Method and 95% Confidence.
Means that do not share a letter are significantly different.

Figure 4.2

Boxplot Showing Relationship Between Conditioner Rollers for Narrow Windrows



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Windrow Height

Windrow height was evaluated every day until raking to look at how the windrow compressed as it dried. Both wide and narrow windrow widths were examined. Windrow height for days 0-3 (Tables, 4.8- 4.11) all showed similar statistics. All exhibited significant differences at the .05 level of probability for roller, no significant differences for height based on windrow width, and highly significant interaction effects. The Tukey comparision (Table 4.12) showed limitied differences among treatments. We anticipated that the narrower windrow would be taller since more forage material was laid down in a smaller area, and the wide windrow would be shorter than the narrow windrow because the alfalfa was more spread out. Overall, the wide windrows were taller than the narrow windrows. This height difference could have been from the weight of the forage in the narrow windrows pushing the alfalfa down into the stubble whereas the wide windrows laid on top of the stubble because of less weight. The Skunkhead, AGCO Double, and John Deere (Figure 4.3) swathers all produced narrow windrows that were taller than

Table 4.8

Day Zero Windrow Height ANOVA

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	51.0620	3.1914	4.57	0.000
Blocks	3	12.0394	4.0131	5.75	0.002
Treatments	7	10.3853	1.4836	2.12	0.065
Roller	6	9.8811	1.6469	2.36	0.050
Width	1	0.2308	0.2308	0.33	0.569
Roller*Width	6	26.8859	4.4810	6.42	0.000
Error	37	25.8356	0.6983		
Total	53	76.8976			

Table 4.9

Day One Windrow Height ANOVA

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	46.3690	2.8981	4.98	0.000
Blocks	3	4.1513	1.3838	2.38	0.085
Treatments	7	11.5087	1.6441	2.83	0.018
Roller	6	10.7542	1.7924	3.08	0.014
Width	1	0.7545	0.7545	1.30	0.262
Roller*Width	6	30.7091	5.1182	8.79	0.000
Error	39	22.6959	0.5819		
Total	55	69.0650			

Table 4.10

Day Two Windrow Height ANOVA

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	42.3740	2.6484	4.40	0.000
Blocks	3	7.1632	2.3877	3.97	0.015
Treatments	7	10.9556	1.5651	2.60	0.026
Roller	6	10.3480	1.7247	2.87	0.021
Width	1	0.6076	0.6076	1.01	0.321
Roller*Width	6	24.2552	4.0425	6.72	0.000
Error	39	23.4549	0.6014		
Total	55	65.8289			

Table 4.11

Day Three Windrow Height ANOVA

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	36.6820	2.2926	3.97	0.000
Blocks	3	4.5797	1.5266	2.64	0.063
Treatments	7	8.9974	1.2853	2.23	0.053
Roller	6	8.5945	1.4324	2.48	0.040
Width	1	0.4029	0.4029	0.70	0.409
Roller*Width	6	23.1049	3.8508	6.67	0.000
Error	39	22.5192	0.5774		
Total	55	59.2013			

Table 4.12

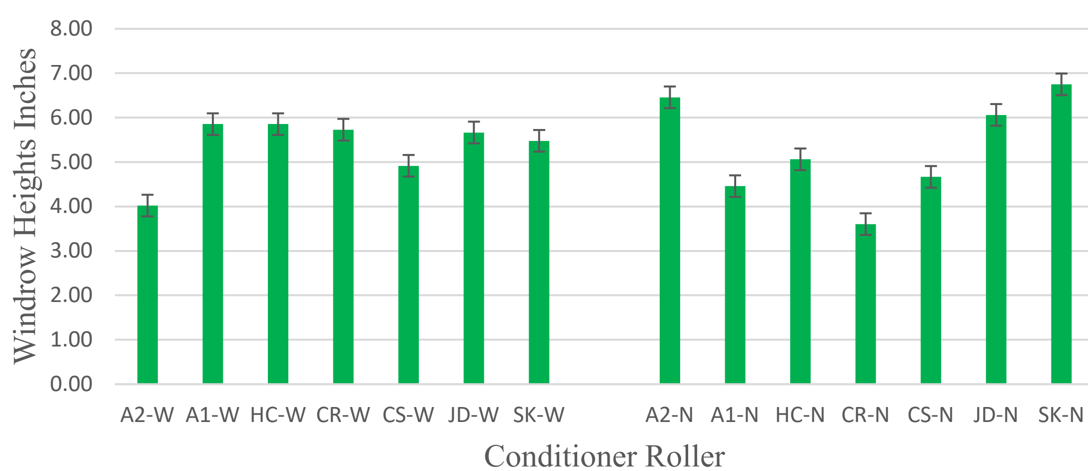
Tukey Comparison of Widrow Height (Inches) On Day Zero

Roller	*N*	Mean	Grouping	
CNH Skunk/N	2	6.75000	A	
AGCO Double/N	4	6.45833	A	
John Deere/N	4	6.06250	A	
AGCO Single/W	4	5.85417	A	B
CNH High Contact/W	4	5.85417	A	B
CNH Rubber/W	4	5.72917	A	B
John Deere/W	4	5.66667	A	B
CNH Skunk/W	4	5.47917	A	B
CNH High Contact/N	4	5.06250	A	B
CNH Steel/W	4	4.91667	A	B
CNH Steel/N	4	4.66667	A	B
AGCO Single/N	4	4.45833	A	B
AGCO Double/W	4	4.02083	A	B
CNH Rubber/N	4	3.60417		B

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

Figure 4.3

Comparison of Windrow Height Day Zero



their wide windrow counterpart. The CNH Rubber swather produced a narrow windrow that was shorter than all of the other windrows.

Plant Condition

Because plant conditions were evaluated from only one replication of the narrow windrows, statistical analysis is not possible. Descriptive data are presented.

The forage gathered from the 0.92 meters (36") cross-section was sorted into four different stem lengths: full stems, half stems, partial stems, and scrap. Each portion was weighed, and a percentage of the overall weight was determined (Table 4.13). The CNH rollers had ~82% of the forage sample being full and half-stems, whereas the AGCO and John Deere rollers had ~75% of the forage as a full or half-stem. This indicates that the AGCO and John Deere rollers cut, or broke, some of the full stems into smaller portions. The scrap pieces, those less than 10 cm (4"), were further sorted into pieces that had stem portions (scraps) and pieces with no stem such as individual leaflets and bits of leaves (debris). The CNH High Contact roller produced the smallest percentage of scrap pieces, followed by the CNH Rubber roller. The John Deere roller produced the highest percentage of scrap pieces. The AGCO Double roller produced the largest amount of debris, followed by the CNH High Contact roller. The CNH Steel, CNH Rubber, and the John Deere rollers produced no, or almost no debris. Many of the scrap pieces are likely lost when raking and baling. The debris material is almost certainly lost when raking and baling.

Table 4.13

Crimp Count Stem Length Percentage

Treatment	**Full stem %**	**Half stem %**	**Partial stem %**	**Scrap %**	**Debris %**	**Full + half stems %**	**Partial stems + scraps %**
CNH Steel	24.21	57.80	8.47	9.52	0.00	82.01	17.99
CNH Rubber	20.08	60.95	11.51	7.46	0.01	81.03	18.97
CNH High Contact	44.47	37.85	8.11	9.56	3.49	82.32	17.68
AGCO Single	15.89	61.70	12.61	9.80	1.38	77.59	22.41
AGCO Double	44.03	30.16	10.42	15.39	6.31	74.19	25.81
John Deere	48.54	26.03	12.14	13.29	0.00	74.58	25.42
Skunkhead	59.96	23.83	5.62	10.59	1.52	83.80	16.20

After sorting, 110 full stems were randomly selected for further analysis (Table 4.14, The full stem length varied based on the conditioner roller (Figure 4.4). The AGCO Single roller produced the shortest stems, whereas the Skunkhead roller produced the longest stems.

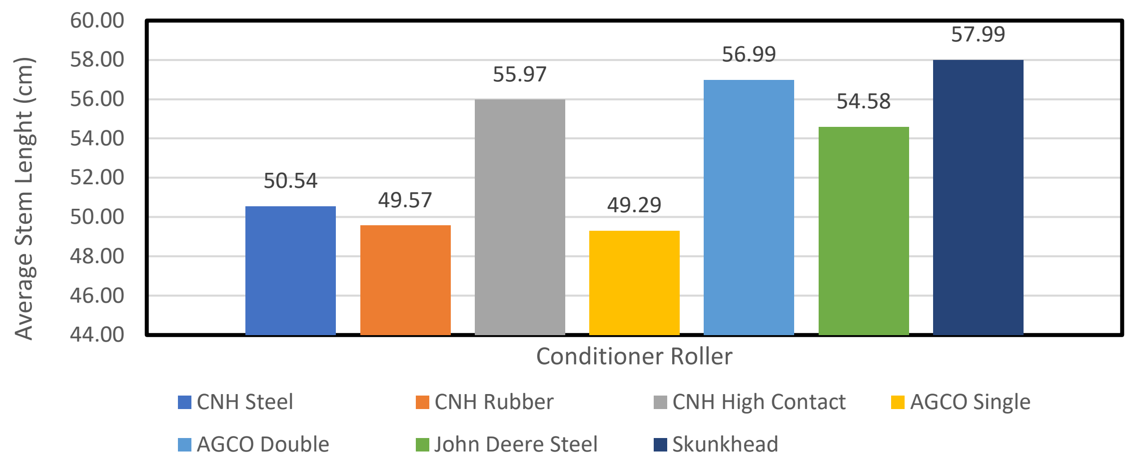
Table 4.14

A Summary of the Stem Condition Data

Treatment	Avg stem length (cm)	Avg # shreds/stem	Avg # broken tip/stem	Avg # breaks/stem	Avg # crimps/stem
CNH Steel	50.54	0.01	0.04	0.13	1.41
CNH Rubber	49.57	0.02	0.05	0.14	3.49
CNH High Contact	55.97	0.00	0.01	0.02	5.24
AGCO Single	49.29	0.00	0.00	0.28	2.64
AGCO Double	56.99	0.15	0.27	0.69	5.35
John Deere Steel	54.58	0.01	0.19	0.39	2.99
Skunkhead	57.99	0.02	0.14	0.21	4.12

Figure 4.4

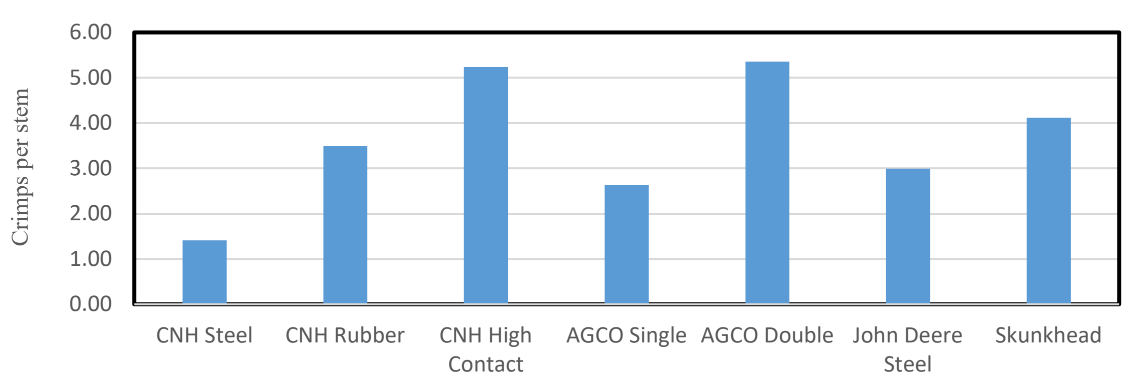
Stem Lengths by Conditioner Rollers



Four conditioner rollers produced three to four crimps per stem, two rollers (CNH High Contact, AGCO Double) averaged more than five crimps per stem, and one conditioner roller (CNH Steel) averaged just over one crimp per stem (Figure 4.5). The three conditioner rollers with the greatest number of crimps also had the longest average stem length.

Figure 4.5

Average Number of Crimps by Conditioner Rollers



Leaf Loss

Leaf loss was analyzed after each stage of harvesting the alfalfa, cutting, raking, and baling. The tables below show that leaf loss varied based on the stage of harvest. The average amount of leaf loss after cutting was 10%, after raking it was 41%, and after baling it was 84%. After cutting, significant differences (p = 0.04) were found for roller type but not width (Table 4.15). Tukey analysis (Table 4.16) showed significant

Table 4.15

Leaf Loss After Cutting

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	1264.29	79.02	1.89	0.053
Blocks	3	91.07	30.36	0.72	0.543
Treatments	7	1001.79	143.11	3.42	0.006
Roller	6	985.71	164.29	3.92	0.004
Width	1	16.07	16.07	0.38	0.539
Roller*Width	6	171.43	28.57	0.68	0.665
Error	39	1633.93	41.90		
Total	55	2898.21			

Table 4.16

Tukey Chart for Conditioner Roller for Leaf Loss After Cutting

Roller	*N*	Mean	Grouping	
CNH Skunk	8	17.50	A	
AGCO Single	8	12.50	A	B
AGCO Double	8	12.50	A	B
John Deere	8	8.75	A	B
CNH High Contact	8	6.25		B
CNH Rubber	8	6.25		B
CNH Steel	8	5.00		B

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

differences in leaf loss after cutting among the CNH conditioner rollers. The Skunkhead roller lost more leaves than the other CNH conditioner rollers but was not significantly different from the AGCO Single, AGCO Double, and John Deere rollers.

After raking, only the width of the windrow provided statistical differences (Table 4.17). No significant differences were observed for the conditioner roller.

Table 4.17

Leaf Loss After Raking

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	17007.1	1062.9	8.77	0.000
Blocks	3	21.4	7.1	0.06	0.981
Treatments	7	15700.0	2242.9	18.50	0.000
Roller	6	1235.7	206.0	1.70	0.147
Width	1	14464.3	14464.3	119.30	0.000
Roller*Width	6	1285.7	214.3	1.77	0.131
Error	39	4728.6	121.2		
Total	55	21735.7			

During raking, the narrow windrows lost significantly more leaves than the wide windrows (Figure 4.6), which was not expected. The narrow windrows are more compact, which should help keep the leaves in the windrow, whereas the wide windrows are spread out more.

After baling, roller type, windrow width, and the interaction (roller*width) were all significantly different for leaf loss at the 0.01 level of probability (Table 4.18).

Tukey analysis showed that the AGCO conditioner rollers produced the greatest amount of leaf loss after baling, whereas the John Deere roller produced the least amount of leaf loss (Table 4.19).

Figure 4.6

Leaf Loss After Raking by the Windrow Width

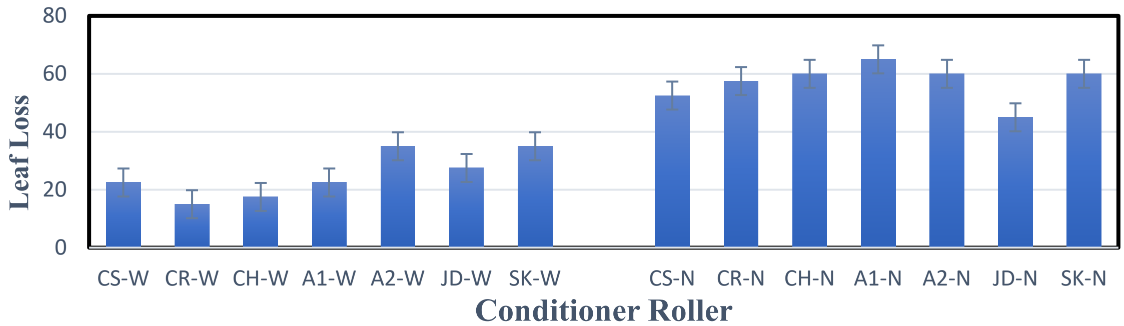


Table 4.18

Leaf Loss After Baling

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	6935.7	433.5	4.19	0.000
Blocks	3	614.3	204.8	1.98	0.133
Treatments	7	4135.7	590.8	5.71	0.000
Roller	6	2071.4	345.2	3.34	0.009
Width	1	2064.3	2064.3	19.95	0.000
Roller*Width	6	2185.7	364.3	3.52	0.007
Error	39	4035.7	103.5		
Total	55	10971.4			

Table 4.19

Tukey Chart for Conditioner Roller for Leaf Loss After Baling

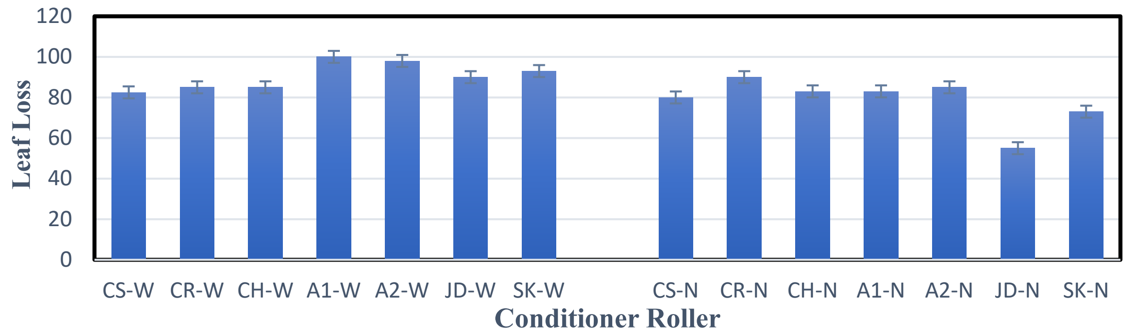
Roller	*N*	Mean	Grouping	
AGCO Double	8	91.25	A	
AGCO Single	8	91.25	A	
CNH Rubber	8	87.50	A	B
CNH High Contact	8	83.75	A	B
CNH Skunk	8	82.50	A	B
CNH Steel	8	81.25	A	B
John Deere	8	72.50		B

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

Figure 4.7 shows that after baling the wide windrows generally had more leaf loss than the narrow windrows.

Figure 4.7

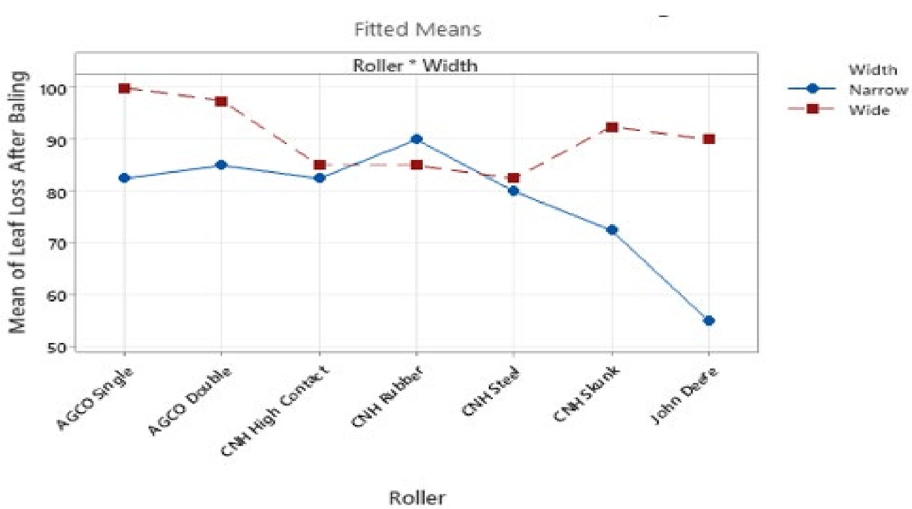
Leaf Loss After Baling



The interaction plot (Figure 4.8) shows that the CNH Steel, CNH Rubber, and CNH High Contact rollers all exhibited similar leaf loss levels in both the narrow and wide windrows. The AGCO double, AGCO Single, Skunkhead, and John Deere

Figure 4.8

Interaction Plot for Leaf Loss After Baling



conditioner rollers exhibited larger differences between the wide and narrow windrows, with the wide windrows exhibiting greater leaf loss than the narrow windrows. The wide windrows showed some consistency among the conditioner rollers, but the narrow windrows had one big outlier with the John Deere conditioner roller having significantly less leaf loss than the other conditioner rollers.

Sun Bleaching

Sun bleaching effects based on windrow width were evaluated by taking the difference in the CMYK (Cyan, Magenta, Yellow, and Black) readings of the forage when baled compared to the CMYK readings of the Goldenrod color on the color frame. The results were compared for each color of the CMYK readings using a two-sample *t* test (Tables 4.20 – 4.23). No significant differences were observed for Cyan ($p = 0.569$), Magenta ($p = 0.162$), Yellow ($p = 0.198$), and Black ($p = 0.137$).

Table 4.20

Sun Bleaching for Cyan Color Content

Null hypothesis	Alternative hypothesis	*t* value	DF	*p* value
H_0: $\mu_1 - \mu_2 = 0$	H_1: $\mu_1 - \mu_2 \neq 0$	-0.58	30	0.569

Table 4.21

Sun Bleaching for Magenta Color Content

Null hypothesis	Alternative hypothesis	*t* value	DF	*p* value
H_0: $\mu_1 - \mu_2 = 0$	H_1: $\mu_1 - \mu_2 \neq 0$	-1.42	44	0.162

Table 4.22

Sun Bleaching for Yellow Color Content

Null hypothesis	Alternative hypothesis	t value	DF	p value
H_0: $\mu_1 - \mu_2 = 0$	H_1: $\mu_1 - \mu_2 \neq 0$	-1.30	52	0.198

Table 4.23

Sun Bleaching for Black Color Content

Null hypothesis	Alternative hypothesis	t value	DF	p value
H_0: $\mu_1 - \mu_2 = 0$	H_1: $\mu_1 - \mu_2 \neq 0$	-1.51	53	0.137

Dry Down

Linear regression was run to calculate a dry down rate for wide and narrow windrows (Figures 4.9 and 4.10) with the p value < 0.001 showing significance between the two windrows. The forage equation showed that the narrow windrows dried at a rate of 16.60% each day, while the wide windrows dried at a rate of 18.31% each day.

Baler Near Infared

Baler NIR data focused on forage moisture, and five forage quality traits: crude protein, ADF, NDF, ASH, and crude fat.

Moisture Percentage

This analysis of variance showed that the conditioner roller had no significant effect on the moisture percentage of the alfalfa , producing a p value of 0.909 (Table 4.24). Windrow width conversely had a major impact on the moisture content of the

Figure 4.9

Fitted Line Plot for Wide Windrows

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	46918.8	46918.8	167.35	0.000
Error	110	30839.2	280.4		
Total	111	77758.0			

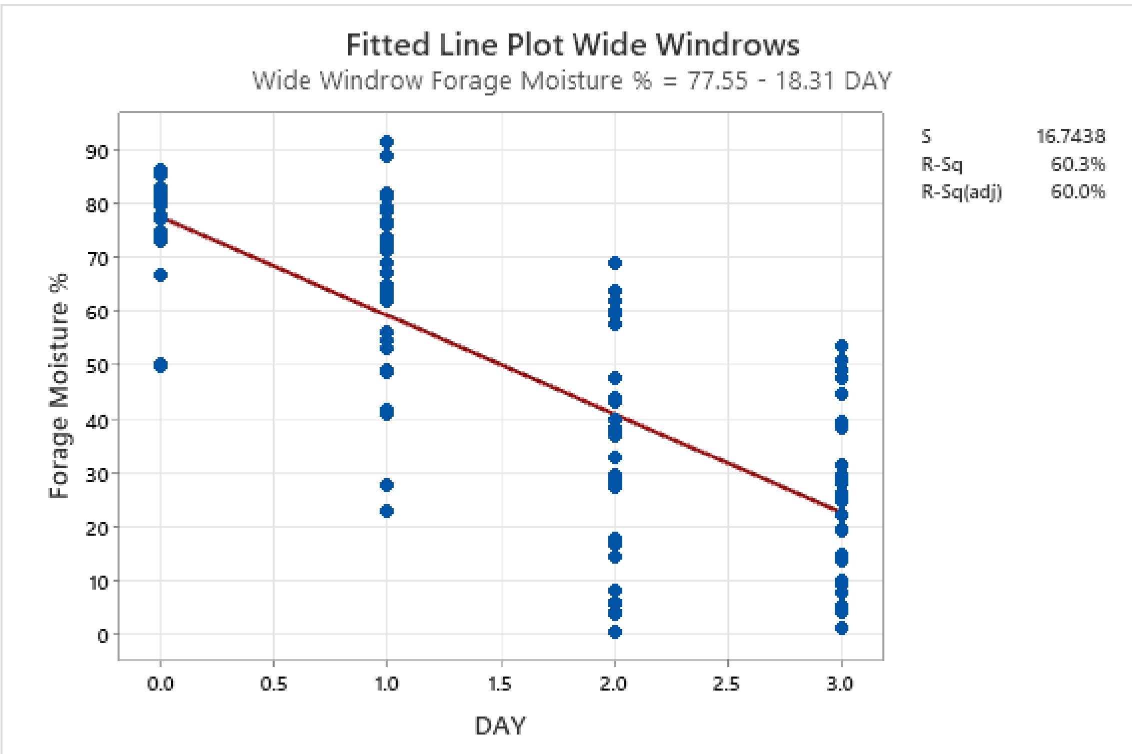


Figure 4.10

Fitted Line Plot for Narrow Windrows

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	38589.6	38589.6	130.88	0.000
Error	110	32432.3	294.8		
Total	111	71022.0			

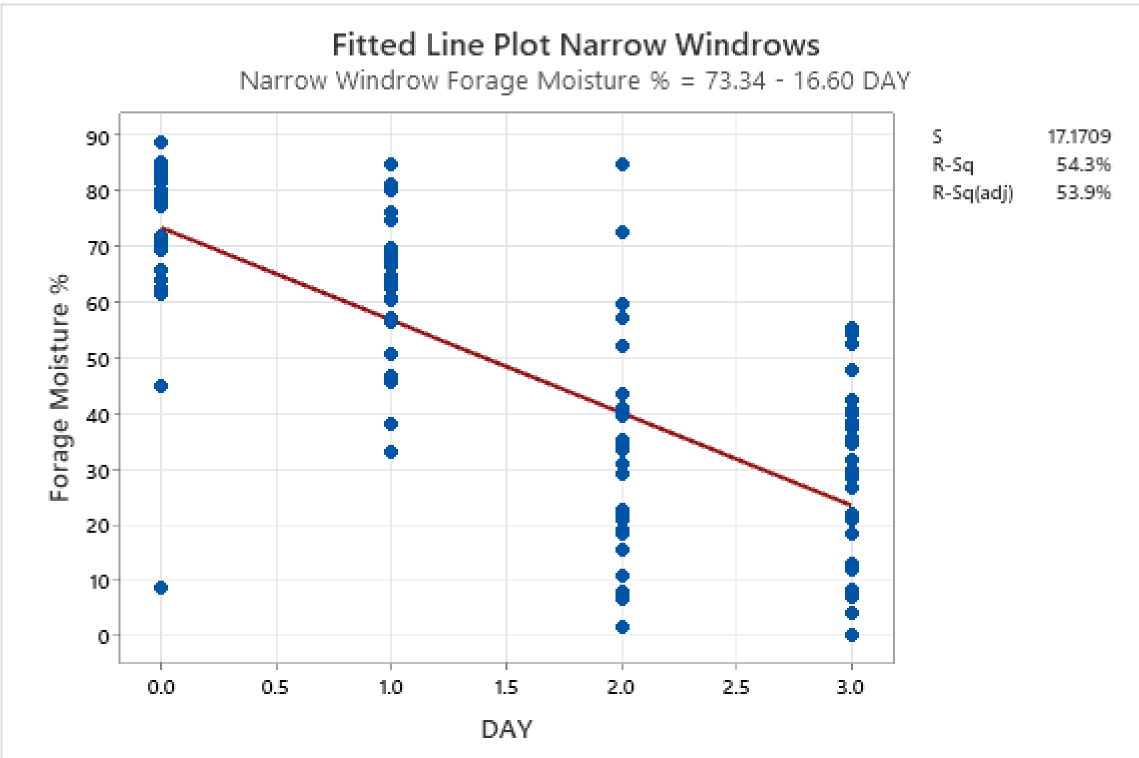


Table 4.24

Alfalfa Moisture Percentage

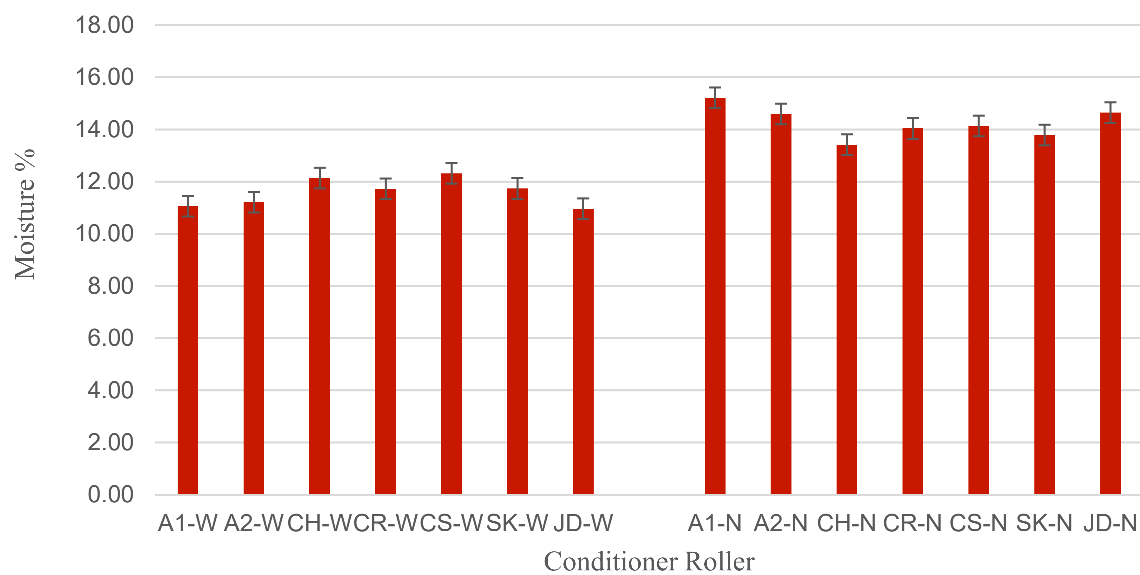
Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	95.514	5.9696	8.98	0.000
Blocks	3	6.338	2.1127	3.18	0.035
Treatments	7	62.814	8.9735	13.50	0.000
Roller	6	1.372	0.2286	0.34	0.909
Width	1	60.147	60.1472	90.49	0.000
Roller*Width	6	22.959	3.8265	5.76	0.000
Error	37	24.593	0.6647		
Total	53	120.107			

alfalfa, producing a p value of < 0.001. Interactions effects were also significant (p = < 0.001).

The narrow windrows (Figure 4.11) consistently had a higher moisture percentage than the wide windrows.

Figure 4.11

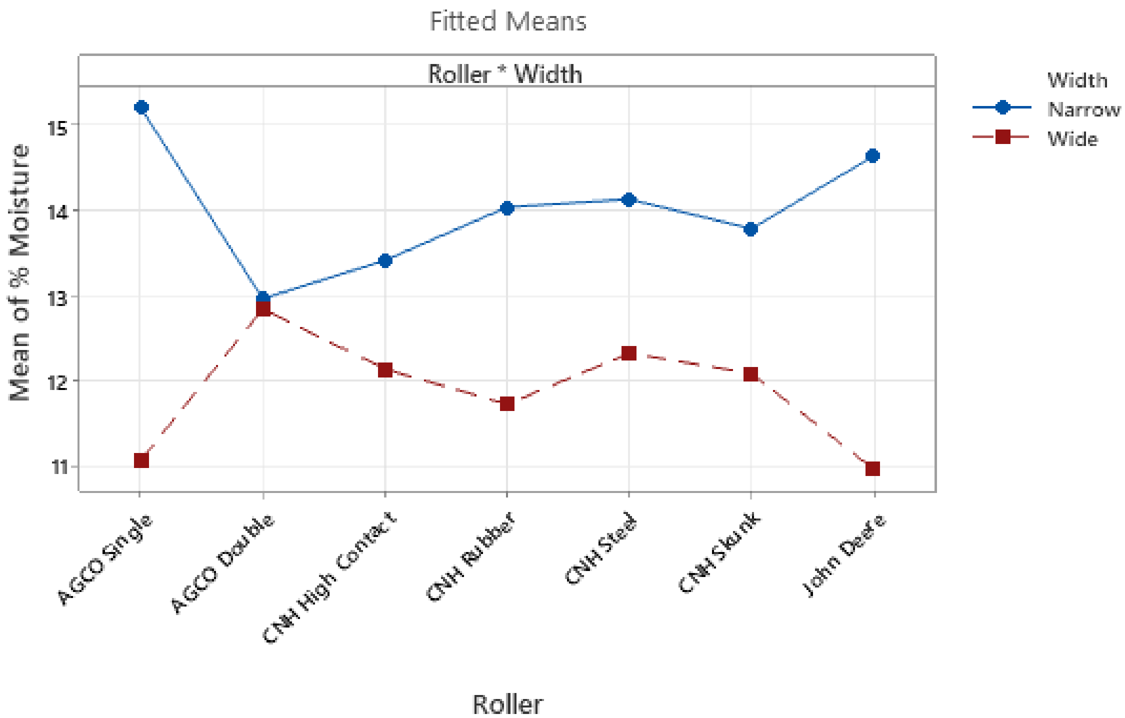
Baler NIR Alfalfa Moisture Percentage



The interaction (Figure 4.12) effects between the conditioner roller and width was extreme for the AGCO Single and John Deere, whereas the AGCO Double had almost the same moisture.

Figure 4.12

Interaction of Baler NIR Moisture Percentage



Crude Protein

Crude protein (CP) exhibited significant differences based on the roller (p = 0.018), windrow width (p = 0.001), and the interaction of roller and windrow width (p = < 0.001; Table 4.25).

Tukey analysis (Table 4.26) showed all the conditioner rollers were in the same group even though statistical differences were indicated in the ANOVA.

Table 4.25

Baler Near Infared Crude Protein

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	36.574	2.2859	8.66	0.000
Blocks	3	12.849	4.2829	16.22	0.000
Treatments	7	8.692	1.2417	4.70	0.001
Roller	6	4.698	0.7830	2.97	0.018
Width	1	3.193	3.1929	12.09	0.001
Roller*Width	6	15.679	2.6132	9.90	0.000
Error	37	9.770	0.2640		
Total	53	46.344			

Table 4.26

Baler Near Infared Crude Protein Tukey Table

Roller	*N*	Mean	Grouping
CNH Skunk	6	24.5110	A
AGCO Double	8	24.4867	A
John Deere	8	24.3183	A
AGCO Single	8	24.2048	A
CNH Steel	8	24.1979	A
CNH Rubber	8	23.9229	A
CNH High Contact	8	23.7125	A

Note. Grouping Information Using the Tukey Method and 95% Confidence.
Means that do not share a letter are significantly different.

Figure 4.13 and interaction plot (Figure 4.14) shows that the AGCO rollers and the John Deere roller exhibited big differences between the wide and the narrow windrows, whereas the CNH rollers exhibited much smaller differences.

Acid Detergent Fiber

The ANOVA showed that the conditioner roller did not have a significant effect on the ADF but a trend toward differences based on roller type was exhibited (Table 4.27). Windrow width and the interaction of the windrow width*conditioner roller were

Figure 4.13

Baler Near Infared Crude Protein Wide vs Narrow Windrows

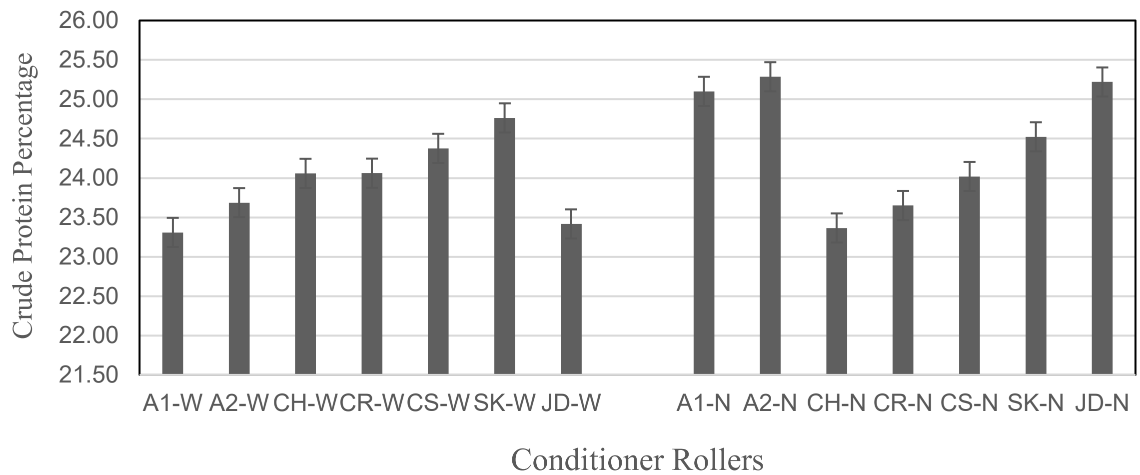


Figure 4.14

Baler Near Infared Crude Protein

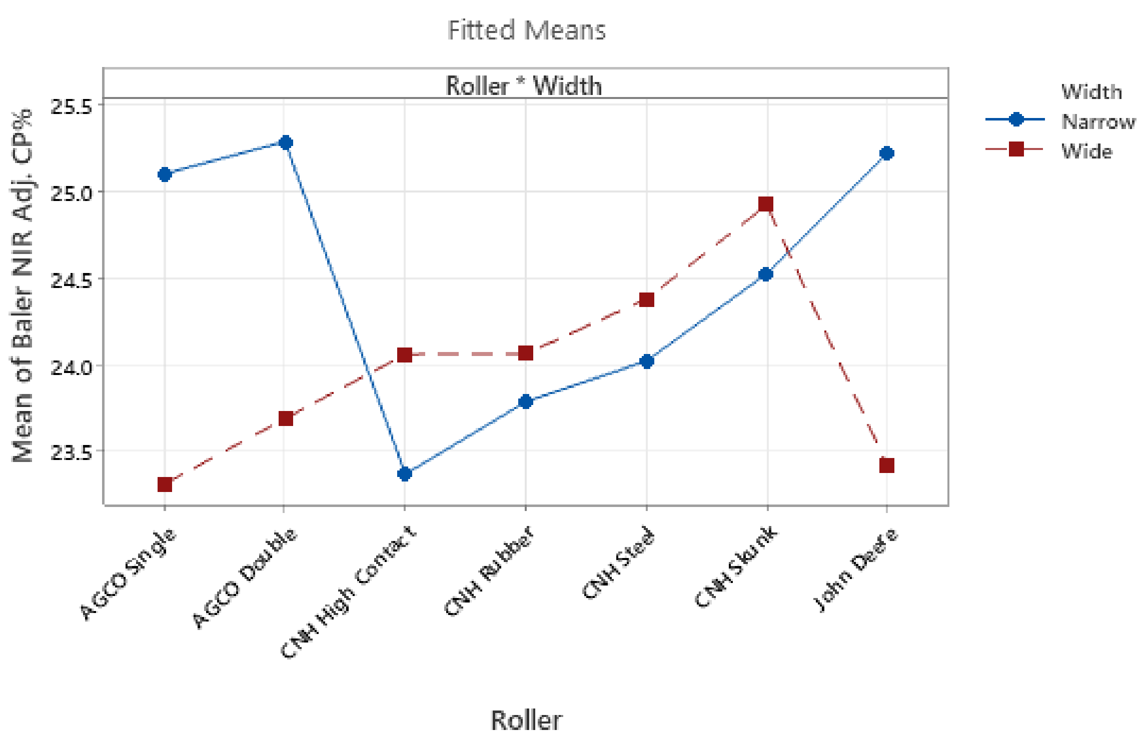


Table 4.27

Baler Near Infared Acid Detergent Fiber Values

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	265.61	16.601	6.37	0.000
Blocks	3	107.75	35.918	13.79	0.000
Treatments	7	53.50	7.642	2.93	0.015
Roller	6	33.43	5.571	2.14	0.072
Width	1	22.20	22.202	8.52	0.006
Roller*Width	6	94.51	15.751	6.05	0.000
Error	37	96.36	2.604		
Total	53	361.97			

both significantly different at the 0.01 level of probability. Wide windrows had a higher ADF value than narrow windrows (Figure 4.15). The interaction results are similar to the results observed for the CP interaction (Figure 4.16). AGCO conditioner rollers and the John Deere roller showed big differences in ADF% between the wide and narrow windrows, while the other rollers were closer in values.

Figure 4.15

Baler Near Infared Acid Detergent Fiber Percent Wide vs Narrow Windrows

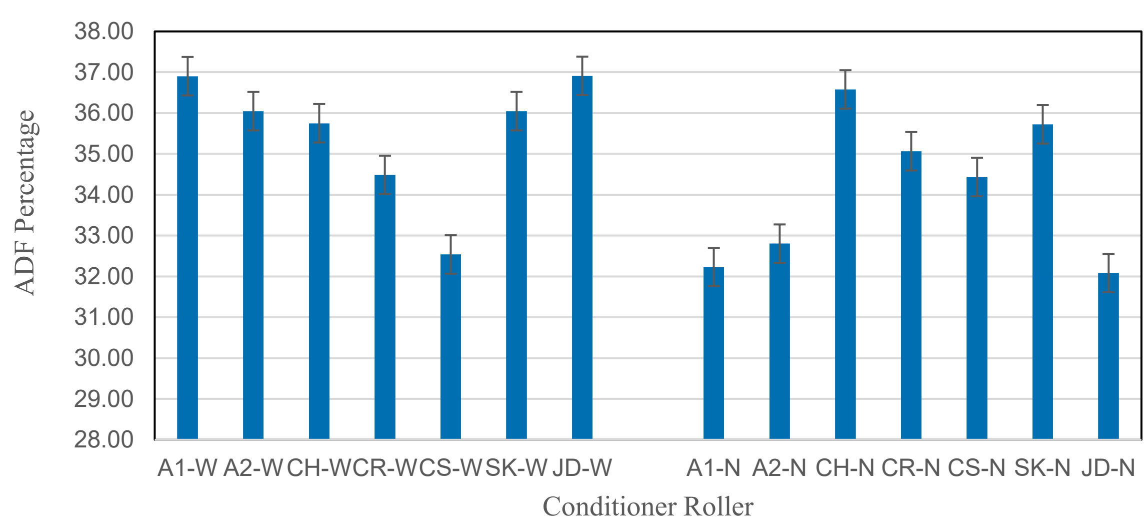
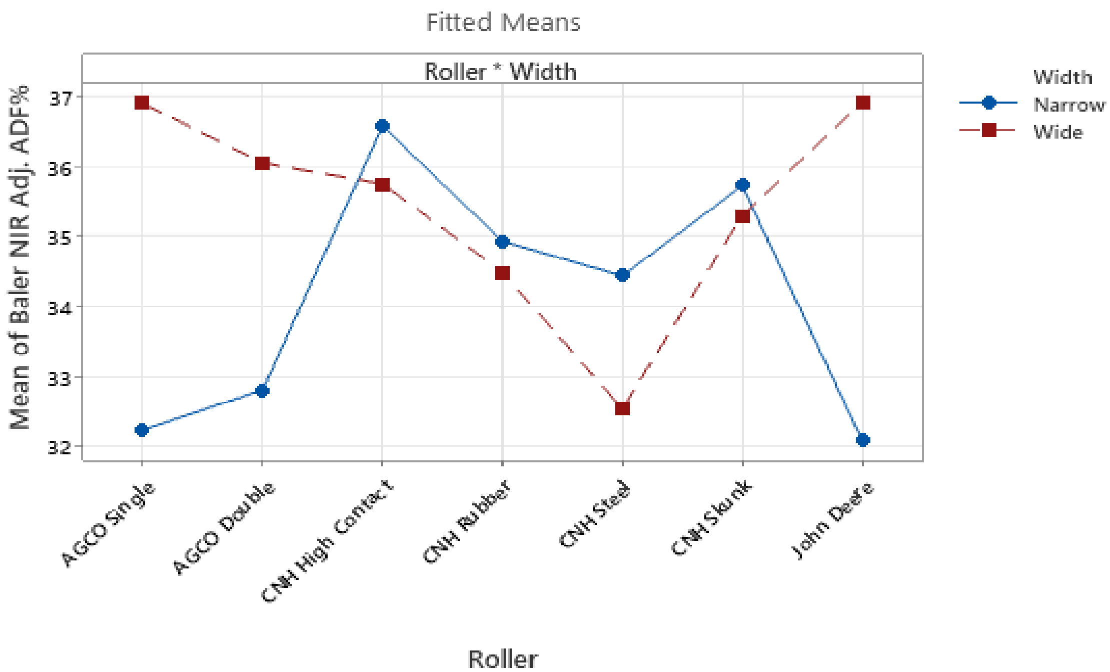


Figure 4.16

Baler NIR Acid Detergent Fiber



Neutral Detergent Fiber

NDF values were all significantly affected by the conditioner roller, windrow width, and the interaction between the two (Table 4.28 and 4.29, Figure 4.17). NDF results were similar to ADF and the relationships between some of the conditioner rollers. AGCO as well as the John Deere roller again had very large gaps between the wide and narrow windrows, with the wide windrows having higher values.

NDF NIR analysis showed that the conditioner rollers were significantly different, but looking at the Tukey table we see that all the conditioner rollers are in the same grouping. NDF (Figure 4.17) shows how the windrow width impacted NDF. The narrow windrows consistently had lower values of NDF while the wide windrows had higher values of NDF.

Table 4.28

Baler NIR Neutral Detergent Fiber Values

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	442.84	27.678	8.62	0.000
Blocks	3	179.29	59.762	18.61	0.000
Treatments	7	124.04	17.720	5.52	0.000
Roller	6	65.09	10.849	3.38	0.009
Width	1	63.99	63.990	19.93	0.000
Roller*Width	6	122.23	20.371	6.34	0.000
Error	37	118.82	3.211		
Total	53	561.66			

Table 4.29

Baler NIR Neutral Detergent Fiber Tukey Comparison

Roller	*N*	Mean	Grouping
CNH High Contact	8	50.5299	A
CNH Skunk	6	50.2345	A
CNH Rubber	8	48.9934	A
AGCO Double	8	48.2668	A
John Deere	8	48.0455	A
CNH Steel	8	47.3892	A
AGCO Single	8	47.3227	A

Note. Grouping Information Using the Tukey Method and 95% Confidence.
Means that do not share a letter are significantly different.

The interaction plot (Figure 4.17) for the NDF results was like the ADF results. The AGCO rollers as well as the John Deere roller exhibited (Figure 4.18) big differences between the wide and narrow windrows, with the wide windrows having higher values.

ASH Content

Conditioner rollers and windrow width both exhibited significant differences at the 0.01 level of probability (Table 4.30) for ASH content. The interaction between the

Figure 4.17

Baler NIR Interaction Neutral Detergent Fiber Values

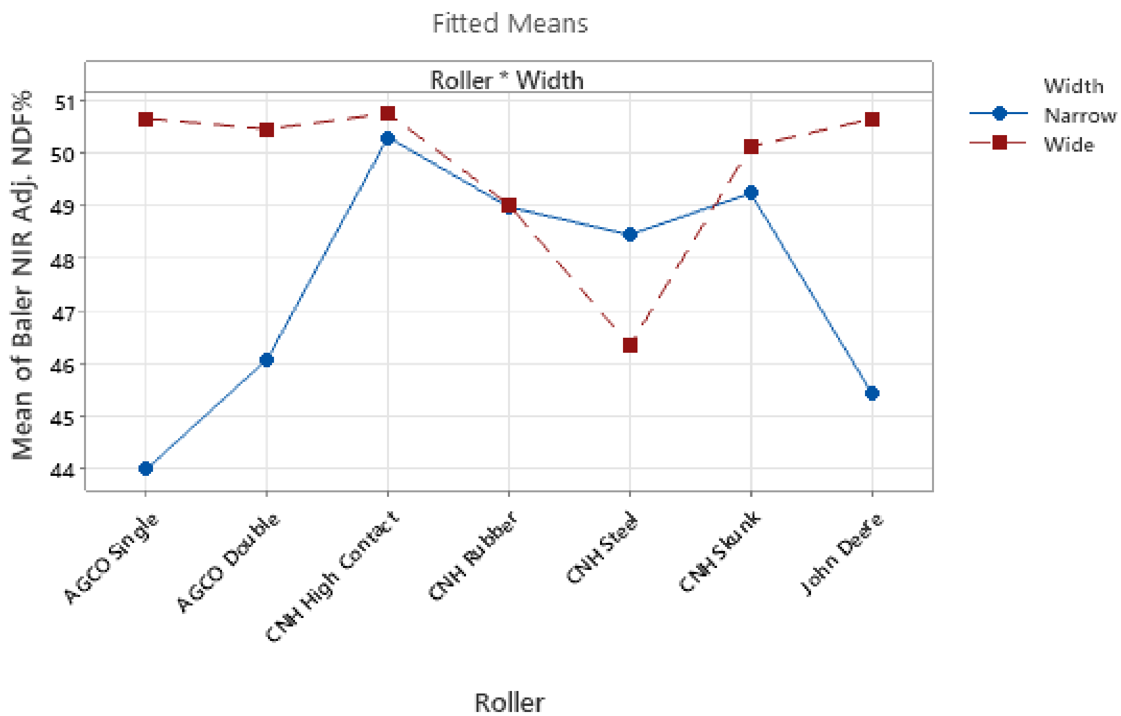


Figure 4.18

Bale NIR Neutral Detergent Fiber Percent Wide vs Narrow Windrows

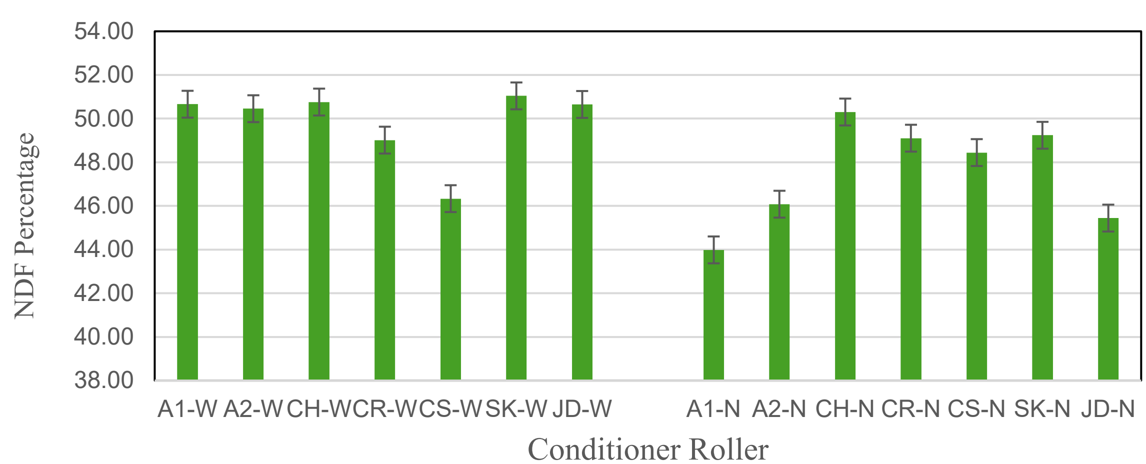


Table 4.30

Baler NIR ASH Content Values

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	11.9587	0.74742	8.74	0.000
Blocks	3	1.3319	0.44398	5.19	0.004
Treatments	7	10.4274	1.48962	17.41	0.000
Roller	6	8.5223	1.42039	16.60	0.000
Width	1	1.1189	1.11894	13.08	0.001
Roller*Width	6	0.6702	0.11169	1.31	0.279
Error	37	3.1651	0.08554		
Total	53	15.1238			

two was not statistically different. Tukey analysis (Table 4.31) shows the CNH Skunkhead and AGCO Single being in the grouping with the highest ASH content, and significantly different than CNH Rubber, CNH High Contact, John Deere, and AGCO Double. The John Deere and AGCO Double rollers had the lowest ASH content. The narrow windrows had a higher percentage of ASH than the wide windrows (Figure 4.19).

Table 4.31

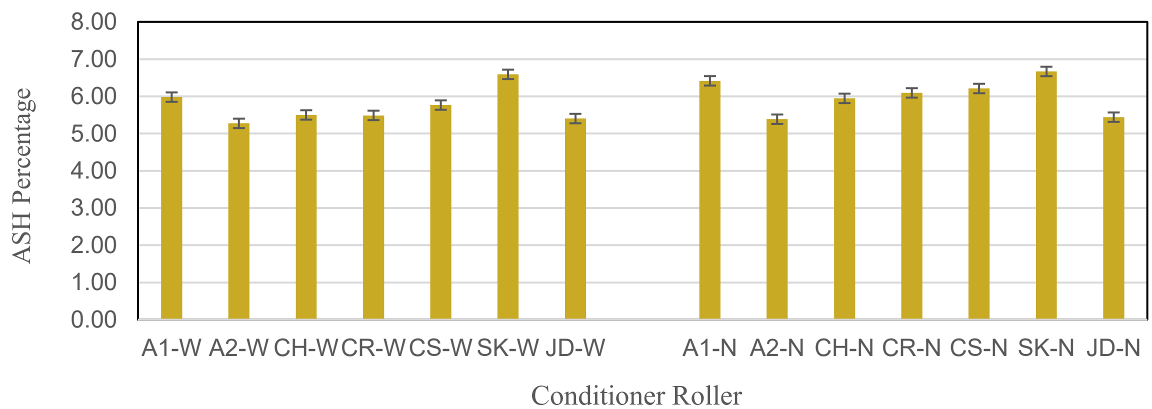
Baler NIR Tukey Analysis for ASH Content

Roller	*N*	Mean	Grouping		
CNH Skunk	6	6.58789	A		
AGCO Single	8	6.19705	A	B	
CNH Steel	8	5.98738		B	
CNH Rubber	8	5.79368		B	C
CNH High Contact	8	5.72230		B	C
John Deere	8	5.42134			C
AGCO Double	8	5.32895			C

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

Figure 4.19

Windrow Width Effects Baler NIR ASH Content



Crude Fat

There was a trend for differences based on roller type for crude fat ($p = 0.069$) (Table 4.32). Windrow width was significantly different at the 0.01 level of probability, and the interaction was significantly different at the 0.05 level of probability. Narrow windrows had a higher fat content than wide windrows. Interaction graphs (Figures 4.20 and 4.21) show that the AGCO single and John Deere rollers produced larger differences in crude fat content between wide and narrow windrows than the CNH rollers.

Table 4.32

Baler NIR Crude Fat Values

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	0.39378	0.024611	6.73	0.000
Blocks	3	0.18291	0.060972	16.67	0.000
Treatments	7	0.14334	0.020477	5.60	0.000
Roller	6	0.04745	0.007909	2.16	0.069
Width	1	0.09506	0.095057	26.00	0.000
Roller*Width	6	0.05345	0.008909	2.44	0.044
Error	37	0.13529	0.003657		
Total	53	0.52907			

Figure 4.20

Baler NIR Fat Values

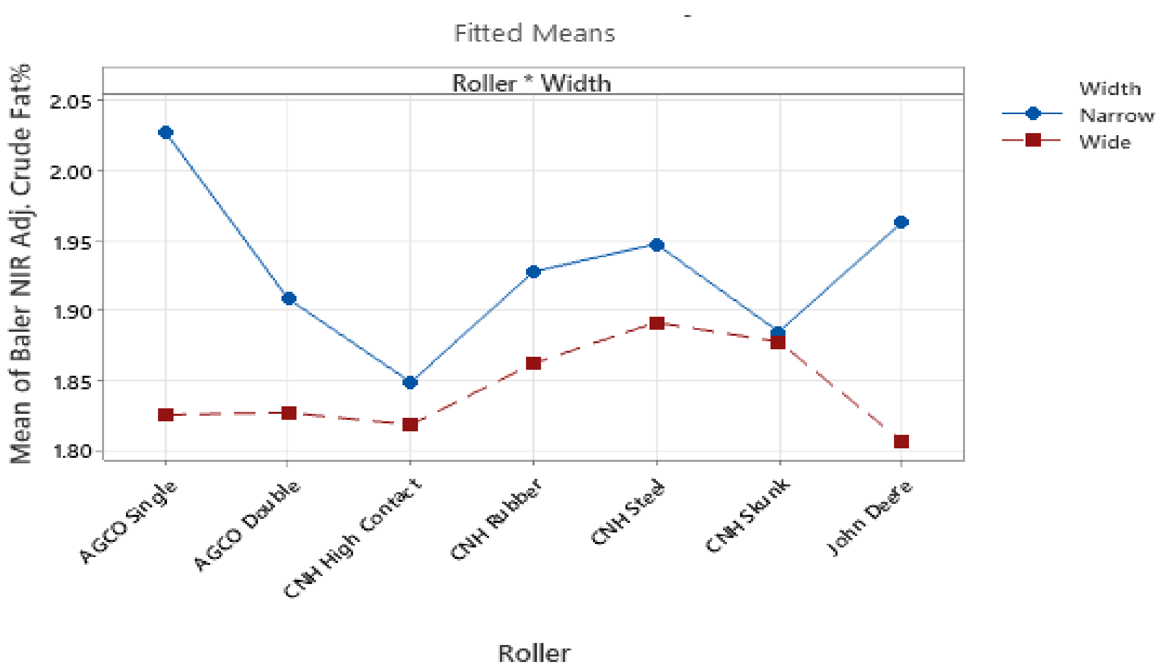
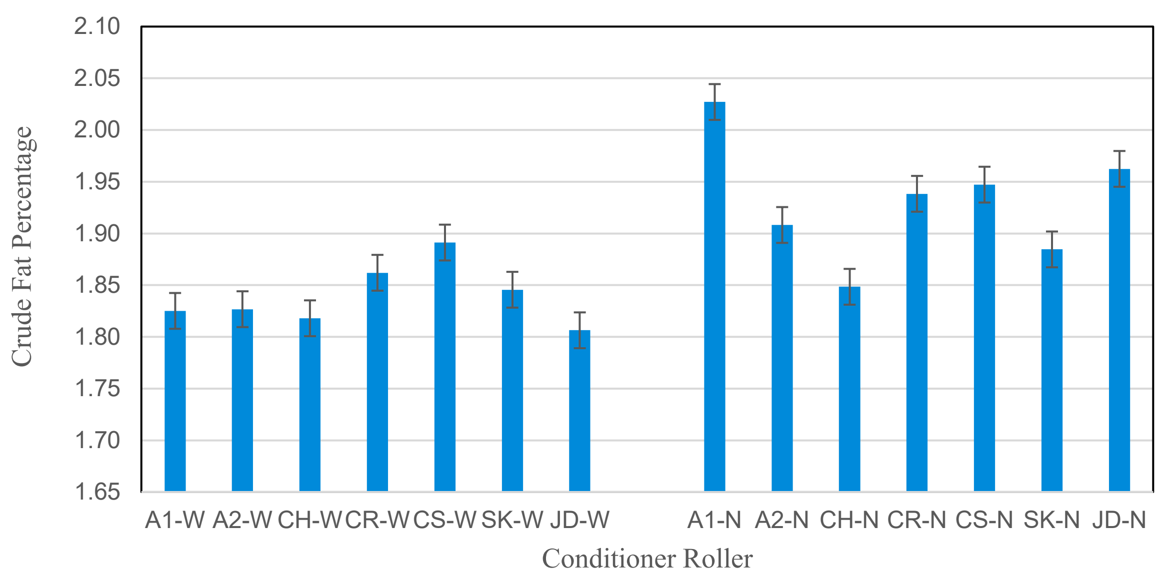


Figure 4.21

Windrow Width Effect On Crude Fat



Bale Cores

Bale cores were analyzed in two parts, first looking at just the impact of conditioner roller and width and how that affected the alfalfa quality, then grind size was added to see how that affected the NIR readings. The bale core samples were used to examine five forage quality traits of alfalfa. These characteristics were the same that the baler NIR examined. Those were crude protein, ADF, NDF, ASH, and crude fat.

Crude Protein

The ANOVA examined the effect of the conditioner roller and windrow width on alfalfa CP content (Table 4.33). Significant differences at the .01 level of probability were observed for the swather and the conditioner roller*width interaction (Figure 4.22). No significant differences were observed for windrow width.

Table 4.33

Bale Core Crude Protein

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	286.881	17.930	8.84	0.000
Blocks	3	120.744	40.248	19.84	0.000
Treatments	7	81.952	11.707	5.77	0.000
Roller	6	79.855	13.309	6.56	0.000
Width	1	2.097	2.097	1.03	0.310
Roller*Width	6	84.185	14.031	6.92	0.000
Error	319	647.244	2.029		
Total	335	934.124			

The Tukey analysis (Table 4.34) showed all the conditioner rollers were in one group except for the CNH Skunkhead roller, which was in a group by itself. The interaction plot supports the Tukey analysis showing that the CNH Skunkhead conditioner roller had low values of crude protein in both the wide and narrow windrows.

Table 4.34

Tukey Analysis for Bale Core Crude Protein

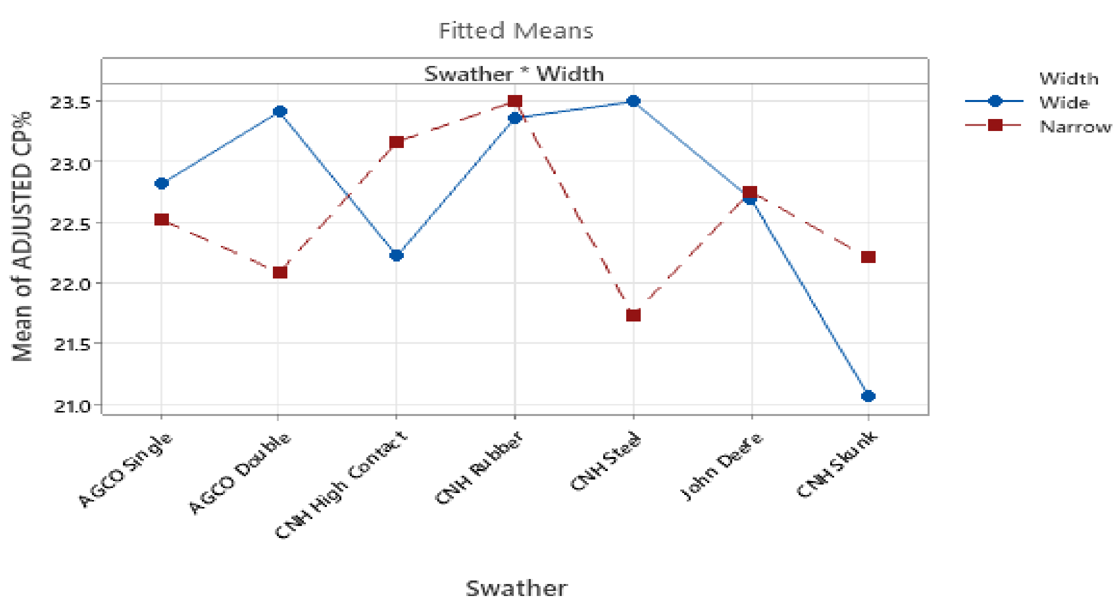
Roller	*N*	Mean	Grouping	
CNH Rubber	48	23.4322	A	
AGCO Double	48	22.7499	A	
John Deere	48	22.7270	A	
CNH High Contact	48	22.6941	A	
AGCO Single	48	22.6704	A	
CNH Steel	48	22.6146	A	
CNH Skunk	48	21.6339		B

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

The leaf loss during baling most likely increased as the day progressed due to the heat and extreme dryness. Although the order of baling varied for the other treatments, the Skunkhead treatment was baled last for both the wide and the narrow windrows, which may explain some of the leaf loss observed.

Figure 4.22

Bale Core Crude Protein



Acid Detergent Fiber

For ADF, significant differences at the 0.01 level of probability were observed for the conditioner roller and the interaction of the conditioner roller and windrow width (Table 4.35).

Table 4.35

Bale Core Acid Detergent Fiber

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	1166.37	72.898	10.68	0.000
Blocks	3	431.71	143.904	21.09	0.000
Treatments	7	449.59	64.227	9.41	0.000
Roller	6	434.21	72.369	10.61	0.000
Width	1	15.37	15.373	2.25	0.134
Roller*Width	6	285.08	47.513	6.96	0.000
Error	319	2176.46	6.823		
Total	335	3342.84			

Tukey (Table 4.36) groupings put the CNH Skunkhead all by itself. AGCO Single, CNH Steel, and John Deere were significantly different than CNH Rubber.

Table 4.36

Tukey Analysis for Bale Core Acid Detergent Fiber

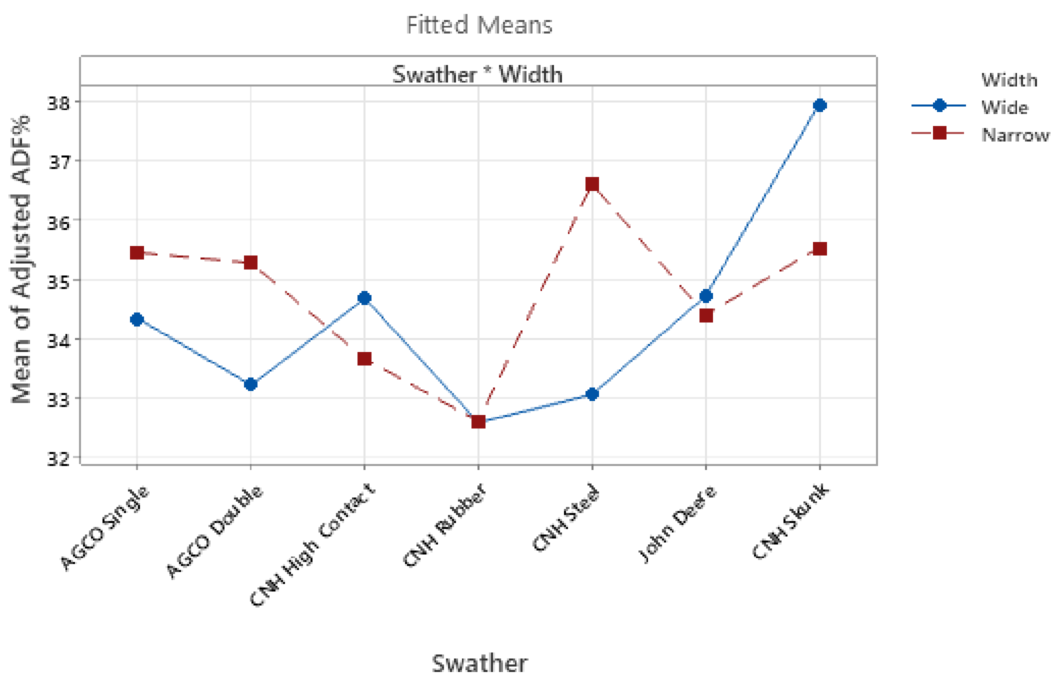
Roller	*N*	Mean	Grouping		
CNH Skunk	48	36.7447	A		
AGCO Single	48	34.8984		B	
CNH Steel	48	34.8349		B	
John Deere	48	34.5637		B	
AGCO Double	48	34.2505		B	C
CNH High Contact	48	34.1726		B	C
CNH Rubber	48	32.6004			C

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

The interaction plot (Figure 4.23) did not show any consistent differences based on the conditioner roller, or windrow width.

Figure 4.23

Bale Core Acid Detergent Fiber



Neutral Detergent Fiber

Factors that demonstrated statistical significance for NDF were the conditioner roller ($p = < 0.001$), and the interaction of swather and windrow width ($p = < 0.001$) (Table 4.37). Tukey analysis (Table 4.38) showed that CNH Skunkhead, CNH Steel, and AGCO Single conditioner rollers produced alfalfa with higher NDF content than the John Deere, AGCO Double, CNH High Contact, and CNH Rubber. No consistent pattern was observed in the interaction graph (Figure 4.24).

Table 4.37

Bale Core Neutral Detergent Fiber

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	1208.96	75.560	8.23	0.000
Blocks	3	400.44	133.479	14.54	0.000
Treatments	7	470.33	67.190	7.32	0.000
Roller	6	452.12	75.354	8.21	0.000
Width	1	18.21	18.208	1.98	0.160
Roller*Width	6	338.20	56.366	6.14	0.000
Error	319	2927.97	9.179		
Total	335	4136.94			

Table 4.38

Bale Core Neutral Detergent Fiber Tukey Table

Roller	*N*	Mean	Grouping		
CNH Skunk	48	40.4988	A		
CNH Steel	48	38.6596	A	B	
AGCO Single	48	38.5950	A	B	
John Deere	48	38.1563		B	C
AGCO Double	48	38.0066		B	C
CNH High Contact	48	37.9436		B	C
CNH Rubber	48	36.2667			C

Note. Grouping Information Using the Tukey Method and 95% Confidence. Means that do not share a letter are significantly different.

ASH Content

ASH effects differed from the previous traits. Swather and windrow width alone did not have any significant effect on the quality of ASH in the forage (Table 4.39). However, the interaction (Figure 4.25) between the swather and the windrow was significantly different. The interaction shows that the Skunkhead roller had a much lower ASH content in the wide windrow.

Figure 4.24

Bale Core Neutral Detergent Fiber

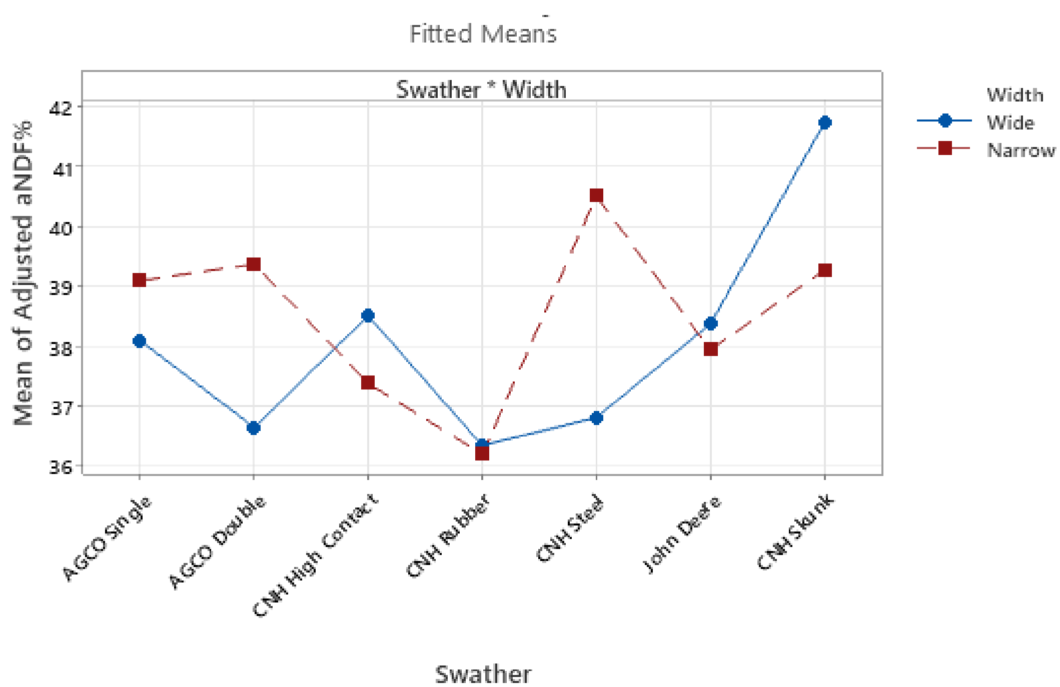


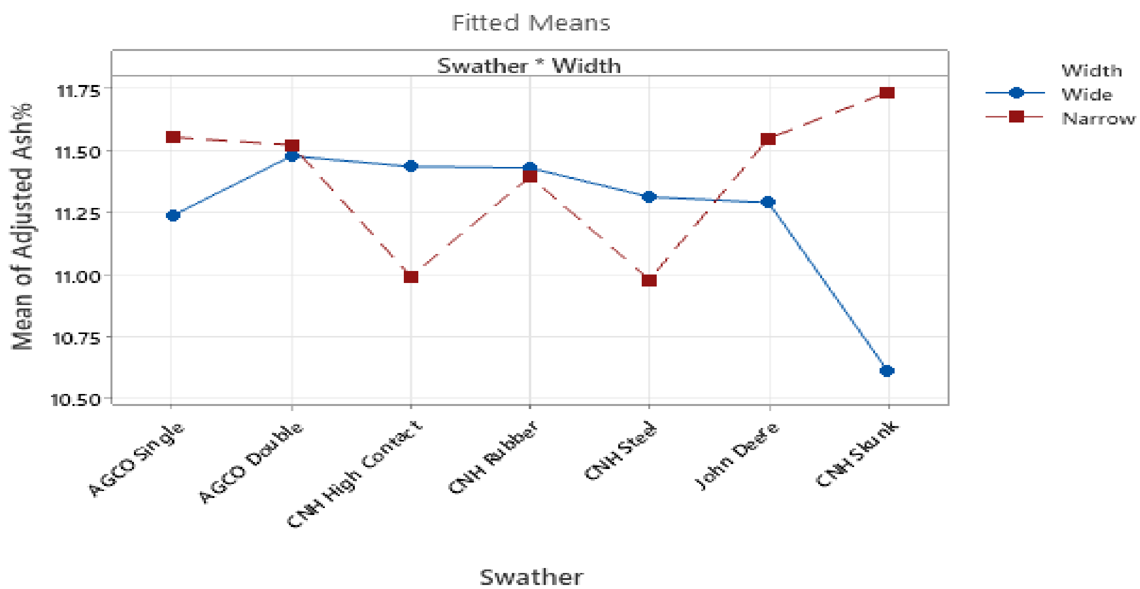
Table 4.39

Bale Core Ash Content

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	30.751	1.9219	1.53	0.086
Blocks	3	4.052	1.3508	1.08	0.358
Treatments	7	7.253	1.0361	0.83	0.565
Roller	6	5.754	0.9590	0.77	0.597
Width	1	1.499	1.4986	1.20	0.275
Roller*Width	6	19.446	3.2410	2.59	0.018
Error	319	399.495	1.2523		
Total	335	430.246			

Figure 4.25

Bale Core Ash Content



Crude Fat

The analysis of variance for crude fat showed no significant differences for the swather roller, or the interaction of roller*width (Table 4.40) Windrow width was significantly different at the 0.05 level of probability. Figure 4.26 shows that the wide windrows had more crude fat content than the narrow windrows.

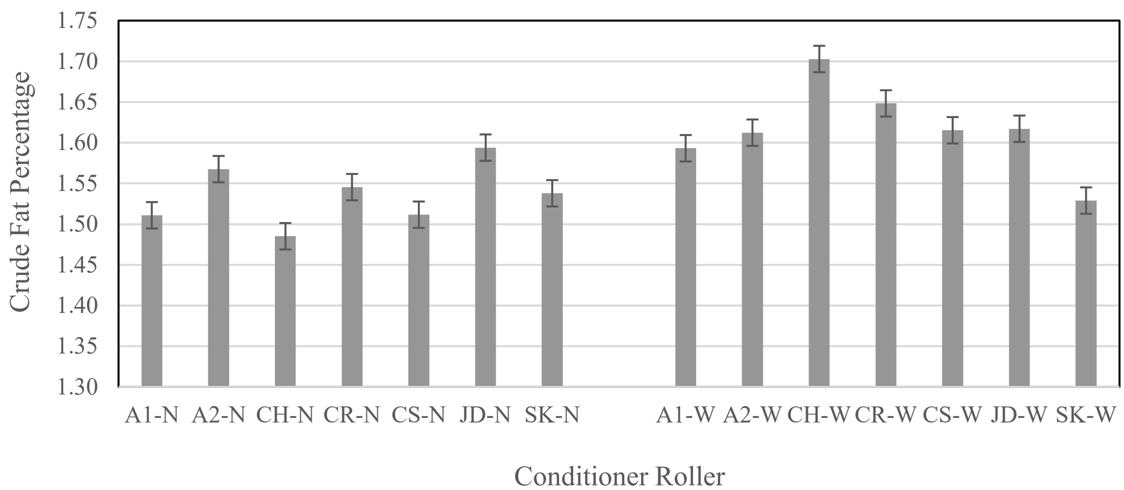
Table 4.40

Bale Core Fat

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	16	0.42829	0.02677	1.57	0.075
Blocks	3	0.06624	0.02208	1.30	0.276
Treatments	7	0.22952	0.03279	1.93	0.065
Roller	6	0.16382	0.02730	1.60	0.146
Width	1	0.06570	0.06570	3.86	0.050
Roller*Width	6	0.13252	0.02209	1.30	0.258
Error	319	5.43230	0.01703		
Total	335	5.86058			

Figure 4.26

Bale Core Crude Fat Wide vs Narrow Windrows



Grind Size

Even though the screen size was the same, one millimeter (.04 inch), the type of grinder used (UDY Mill vs. Thomas Wiley Mill) affected the grind size. The Thomas Wiley mill produced a visibly coarser grind. Since the roller and windrow width treatment analyses were presented in the previous section, only the grind size effects will be presented in this section. All results presented in the bale core NIR section were based on the fine grind readings of the NIR machine, which was suggested by the manufacturer.

Crude Protein

The effect of grind size on bale core NIR readings was evaluated (Table 4.39). ANOVA results for CP showed significant differences (p = < 0.001) for the conditioner roller, grind size (Table 4.41), and interaction effects Conditioner Roller*Width and Conditioner Roller*Grind Size (Figure 4.27). The fine grind generally produced a lower CP reading (Figure 4.28).

Table 4.41

Three-Way Factorial ANOVA for Bale Core Crude Protein

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	30	362.823	12.0941	6.46	0.000
Blocks	3	120.744	40.2479	21.49	0.000
Treatments	8	110.531	13.8164	7.38	0.000
Roller	6	79.855	13.3092	7.11	0.000
Width	1	2.097	2.0969	1.12	0.291
Grind Size	1	28.579	28.5791	15.26	0.000
2-Way Interactions	13	115.105	8.8543	4.73	0.000
Roller*Width	6	84.185	14.0308	7.49	0.000
Roller*Grind Size	6	30.535	5.0892	2.72	0.014
Width*Grind Size	1	0.385	0.3854	0.21	0.650
3-Way Interactions	6	16.443	2.7404	1.46	0.191
Roller*Width*Grind Size	6	16.443	2.7404	1.46	0.191
Error	305	571.302	1.8731		
Total	335	934.124			

Figure 4.27

Bale Core Crude Protein Interaction Plots by Grind Size

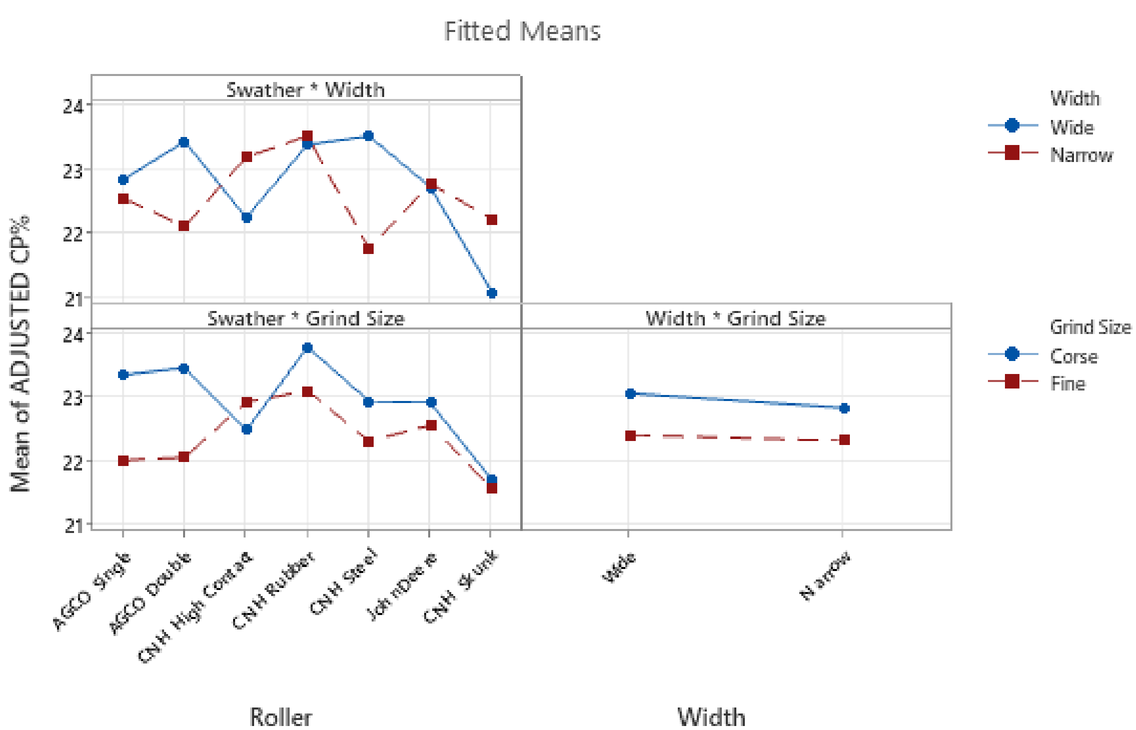
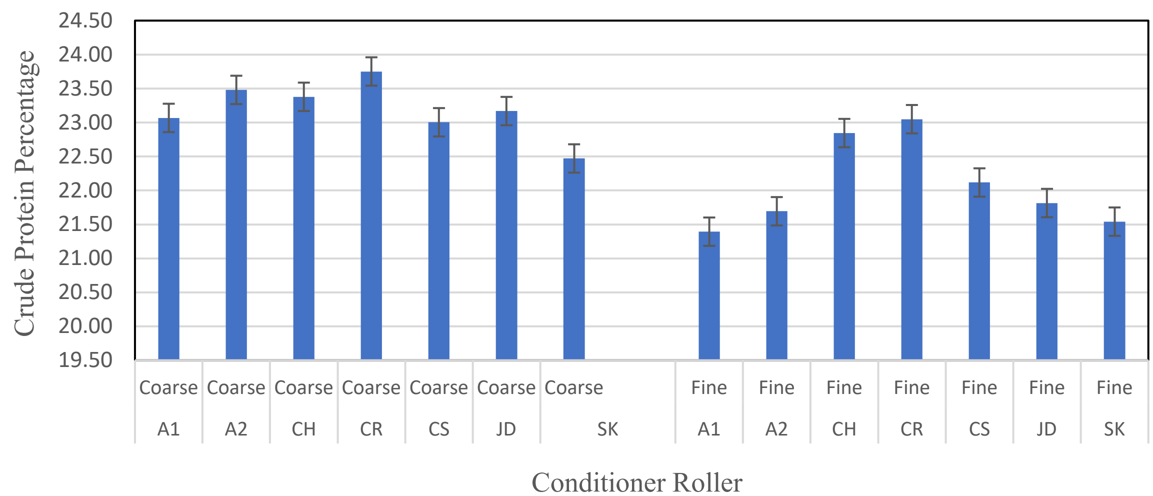


Figure 4.28

Bale Core Grind Size Effects on Crude Protein



Acid Detergent Fiber

The three-way factorial analysis for ADF showed significant effects for the conditioner roller with a $p < 0.001$. Conditioner*width interaction was significant at the 0.05 level of probability (Table 4.42). No effects for grind size were observed.

Neutral Detergent Fiber

NDF followed the same pattern as ADF with significant differences only being observed for conditioner roller ($p = 0.025$) and conditioner roller*width interaction ($p = 0.012$) (Table 4.45). No effects from grind size were observed.

ASH Content

ASH was significantly impacted by the grind size having a p-value of < 0.001. No other treatment showed any significant differences (Table 4.44). The NIR readings on the coarse grind produced a higher ASH content than the fine grind (Figure 4.29).

Table 4.42

Three-Way Factorial ANOVA for Bale Core Acid Detergent Fiber

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	30	433.052	14.4351	2.57	0.000
Blocks	3	169.415	56.4716	10.04	0.000
Treatments	8	166.587	20.8234	3.70	0.001
Roller	6	155.651	25.9419	4.61	0.000
Width	1	11.097	11.0974	1.97	0.164
Grind Size	1	0.244	0.2443	0.04	0.835
2-Way Interactions	13	109.858	8.4506	1.50	0.134
Roller*Width	6	99.256	16.5427	2.94	0.012
Roller*Grind Size	6	5.926	0.9877	0.18	0.983
Width*Grind Size	1	4.373	4.3733	0.78	0.381
3-Way Interactions	6	5.904	0.9839	0.17	0.983
Roller*Width*Grind Size	6	5.904	0.9839	0.17	0.983
Error	81	455.587	5.6245		
Total	111	888.639			

Table 4.43

Three-Way Factorial ANOVA for Bale Core Neutral Detergent Fiber

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	30	474.50	15.817	2.19	0.003
Blocks	3	163.01	54.337	7.51	0.000
Treatments	8	181.37	22.672	3.13	0.004
Roller	6	163.81	27.301	3.77	0.002
Width	1	15.10	15.102	2.09	0.152
Grind Size	1	2.37	2.369	0.33	0.569
2-Way Interactions	13	143.79	11.061	1.53	0.125
Roller*Width	6	127.96	21.326	2.95	0.012
Roller*Grind Size	6	6.71	1.118	0.15	0.988
Width*Grind Size	1	8.44	8.442	1.17	0.283
3-Way Interactions	6	8.03	1.339	0.19	0.980
Roller*Width*Grind Size	6	8.03	1.339	0.19	0.980
Error	81	586.17	7.237		
Total	111	1060.67			

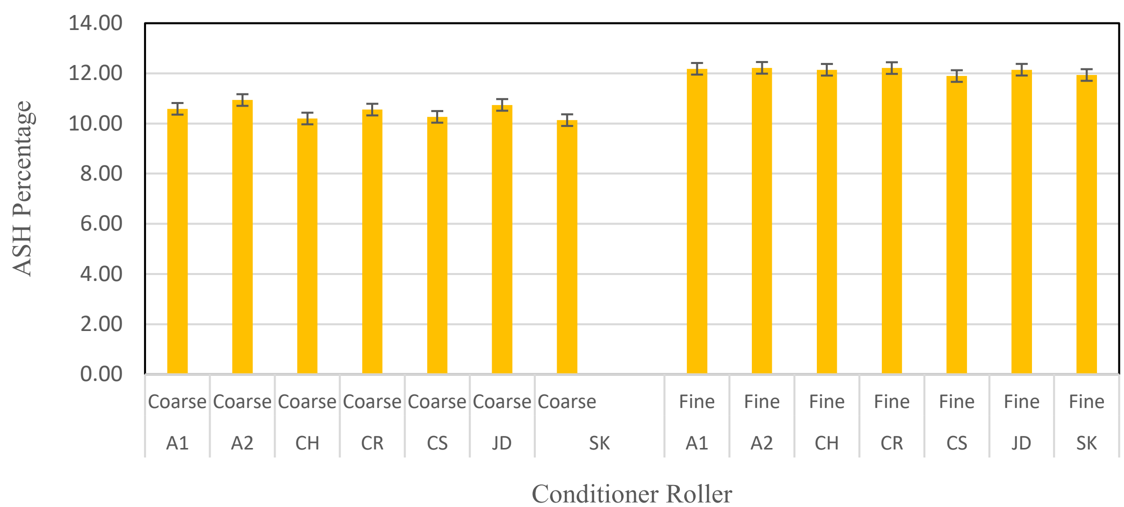
Table 4.44

Three-Way Factorial ANOVA for Bale Core ASH Content

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	30	38.381	1.2794	1.60	0.050
Blocks	3	1.515	0.5050	0.63	0.597
Treatments	8	22.946	2.8682	3.58	0.001
Roller	6	2.482	0.4136	0.52	0.794
Width	1	0.038	0.0376	0.05	0.829
Grind Size	1	20.692	20.6915	25.84	0.000
2-Way Interactions	13	13.741	1.0570	1.32	0.219
Roller*Width	6	8.998	1.4997	1.87	0.095
Roller*Grind Size	6	5.138	0.8563	1.07	0.388
Width*Grind Size	1	0.006	0.0064	0.01	0.929
3-Way Interactions	6	0.962	0.1604	0.20	0.976
Roller*Width*Grind Size	6	0.962	0.1604	0.20	0.976
Error	81	64.852	0.8006		
Total	111	103.234			

Figure 4.29

Bale Core Grind Size Effects on ASH Content



Crude Fat

Crude fat produced similar results as ASH, where the only significant difference observed was for grind size ($p = 0.001$; Table 4.45). The coarse grind produced crude fat readings that were higher than the fine grind (Figure 4.30).

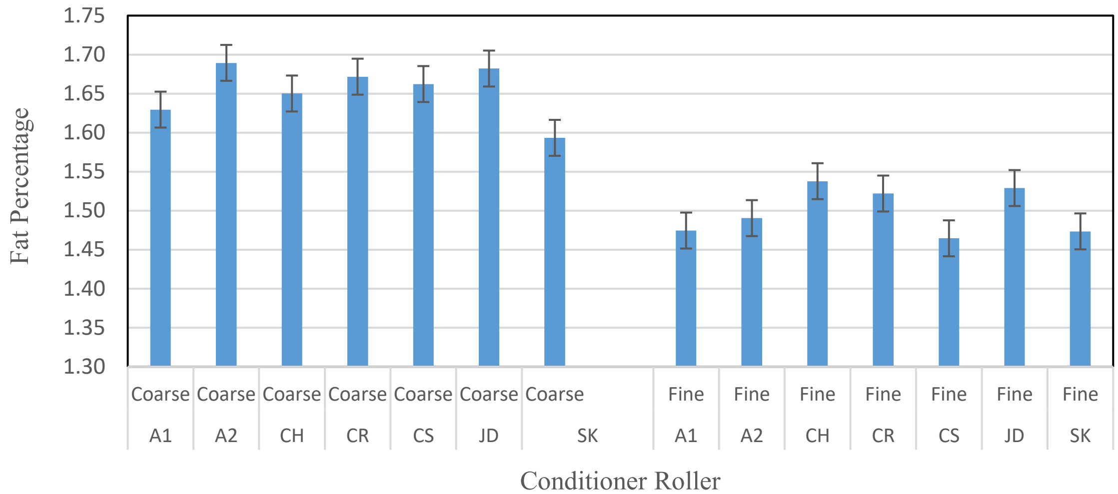
Table 4.45

Bale Core Crude Fat Grind Size

Source	DF	Adj SS	Adj MS	*F* Value	*P* value
Model	30	0.33688	0.011229	0.78	0.779
Blocks	3	0.01369	0.004564	0.32	0.814
Treatments	8	0.24956	0.031195	2.16	0.039
Roller	6	0.06839	0.011399	0.79	0.582
Width	1	0.02401	0.024011	1.66	0.201
Grind Size	1	0.15820	0.158202	10.94	0.001
2-Way Interactions	13	0.04302	0.003309	0.23	0.997
Roller*Width	6	0.01691	0.002818	0.19	0.977
Swather*Grind Size	6	0.01872	0.003121	0.22	0.971
Roller*Grind Size	1	0.00575	0.005750	0.40	0.530
3-Way Interactions	6	0.03751	0.006251	0.43	0.855
Roller*Width*Grind Size	6	0.03751	0.006251	0.43	0.855
Error	81	1.17104	0.014457		
Total	111	1.50792			

Figure 4.30

Bale Core Grind Size Effects on FAT Content



CHAPTER 5

DISCUSSION AND CONCLUSIONS

The study showed that plant condition was affected by the conditioner rollers. The width of the windrow impacted how fast the windrows dried, but produced no significant differences in windrow height. Leaf loss increased with each process of the alfalfa harvest. Wide and narrow windrows had no difference in sun bleaching differences. Baler NIR generally exhibited higher forage qualities than the bale core samples.

Forage Distribution

The forage distribution results, which measured the uniformity of the forage as it was laid out on the ground, showed that the conditioner roller itself did not have an impact on how the forage was distributed. The north one-third of the windrow was affected solely by the width of the windrow, while the other two-thirds of the windrow were affected only by the interaction of the windrow width*conditioner roller. Differences in the distribution were not anticipated as each company strives to ensure uniformity in the windrow to aid in the dry-down. The difference observed for the north portion of the sample may have been an artifact of the variation in the field, such as a pivot track or a bad stand of the alfalfa, which could result in less forage on one side of the swather.

Windrow Width and Height

Windrow width and height produced some of the most interesting results of this study. Looking just at the wide windrow data, if a farmer is looking for the widest windrow possible, they would want to go with the John Deere conditioner roller or the CNH High contact as their wide windrows were 95 to 100 inches wide. The AGCO Single windrow was the smallest at 85 inches wide. The narrow windrows were all set to be at five feet, and all of the conditioner rollers stayed consistent at that width, showing no differences among the five-foot windrows.

The biggest difference between wide and narrow windrows was that the wide windrows were baled a full 24 hours before the narrow windrows were baled and the wide windrows were still ~2.66 percent drier on average at the time of baling than the narrow windrows (Figure 4.9). Under less favorable drying conditions, one would expect the difference in drying time to increase. This is consistent with the research that was conducted by Shinners and Herzmann in 2006 showing that setting the windrow width as wide as the conditioner roller could go would decrease the drying time. As a farmer having a faster dry down is a big advantage for harvesting alfalfa. The faster you get the crop harvested the faster you can start growing the next crop.

The surprising result was in the windrow height. All days exhibited significant differences in windrow height based on roller type and the interaction of the width*conditioner roller; with the Tukey breaking it down into two groupings. There were three narrow windrows that were grouped alone, but then the next five tallest windrows were all wide windrows that were followed by a mixture of wide vs. narrow windrows, with only the John Deere having both the narrow and wide windrows in the top half while the other six treatments were more scattered.

We anticipated that the narrower windrow would be taller since more forage material was laid down in a smaller area, and the wide windrow would be shorter than the narrow windrow due to the alfalfa being more spread out. However, no significant differences were observed, and the narrow windrows were actually slightly shorter in height than the wide windrows. We surmise that the weight of the additional forage material per square foot pressed the cut forage further into the stem stubbles effectively reducing the height of the windrow. Reducing the amount of open space in the stubble likely contributes to the slower dry-down of the narrow windrows.

Plant Condition

Crimps are a very important factor in the drying of alfalfa as crimping helps break the cuticle allowing the stem to release more moisture. However, there is a fine line between crimping to aid in dry down and over-crimping thereby damaging the alfalfa. Table 4.14 shows the percentage of full and half stems, and partial and scrap stems. Both AGCO rollers (single and double) and the John Deere roller produced more partial and scrap material than the CNH rollers. The John Deere, AGCO Single, and AGCO Double rollers produced 25.42%, AGCO 22.41%, and 25.81% partial stems and scraps, respectively, while the CNH Steel, CNH Rubber, CNH High Contact, and the Skunkhead rollers produced 17.99%, 18.97%, 17.68%, and 16.20% partial stems and scraps, respectively.

The John Deere roller had the second-highest percentage of full stems but had fewer crimps than the other rollers that also produced a high percentage of full stems.

From my experience of running the same style of John Deere conditioner roller the conditioner roller disc speed was set too high. Although the producer and the CNH technician thought the disc speed was appropiate, a local John Deere service technician, stated that he recommends the RPM be set between 1500 to 2000 RPM. The John Deere had the highest conditioner roller RPM (2250), which may have caused excessive shredding of the alfalfa, resulting in the John Deere roller producing more partial and scrap stems.

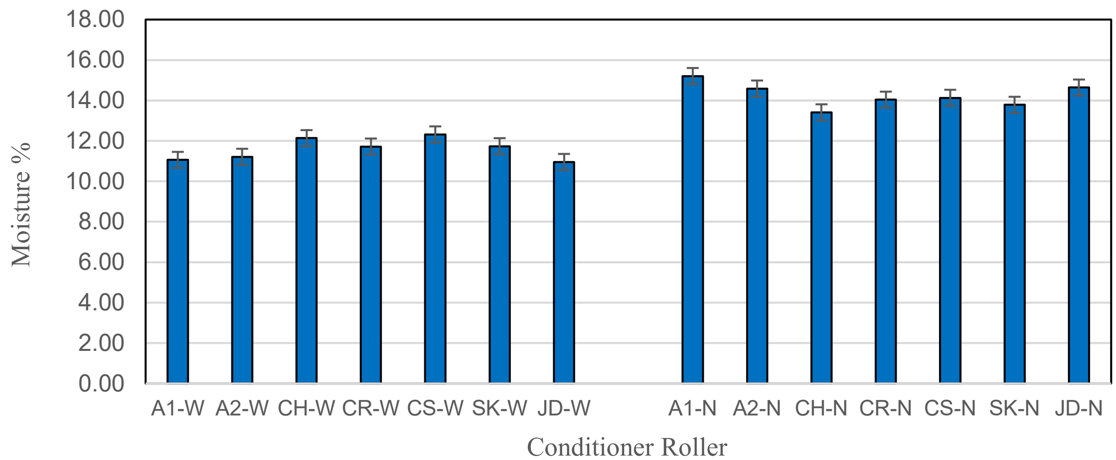
Leaf Loss

The wide windrows exhibited more leaf loss after baling than the narrow windrows. The wide windrows were, on average 2.66% drier when baled than the narrow windrows (Figure 5.1). There was no dew either day when baling so the drier the forage the more likely there would be shattering leaf loss. The higher leaf loss obsevered for the wide windrow may be a result of how quickly it dried and the moisture percentage of the forage when it was baled.

The weather played a big part in this study and probably contributed greatly to leaf loss. The USU weather station at Cache Junction, which is within a mile of where the study was performed, showed that the air temperature from July 6th to July 10th was 95.5, 100.2, 99.5, 97.3, and 91.9. with low dew points and with an average wind speed of about 4.5 mph with high wind gusts from 8 to 18 mph (Appendix A). The weather led to an extremely fast dry down of the alfalfa.

Figure 5.1

Figure Showing Conditioner Rollers vs Moisture Percentage



The time of day for harvest affects forage quality (Orloff & Putnam, 2012) as well as the physical detachment of forage material (Rotz & Muck, 1994). Each stage of the harvest results in the loss of forage material (Rotz & Abrams, 1987) as we observed with our leaf loss data after cutting, raking, and baling.

Sun Bleaching

The sun bleaching data showed that there were no significant differences in forage color between the wide and narrow windrows. With the wide windrows drying more than 24 hours faster than the narrow windrows it did not really matter that there was more surface area of the wide windrows exposed to the sun and possibly fading.

Dry Down

Rotz and Muck (1994), as well as Rotz and Abrams (1987), stated that the goal is to uniformly dry the alfalfa so dry matter loss can be reduced. The sunny hot and windy weather that occurred during this study led to extremely fast dry-down rates that dried the hay uniformly and dried the wide windrows faster with less moisture, while the narrow windrow dried slower but had more moisture. Rotz (1993) reported that solar radiation has a great impact on how quickly alfalfa can dry if there is extremely consistent heat, as observed in this study.

The linear regression formula showed that the narrow windrows dried down at a rate of 16.60% per day while the wide windrows dried at 18.31% each day for a difference of 1.71%. A fast dry down is important for producers both in preserving forage quality and getting the forage growing again.

Baler Near Infared

The baler NIR moisture percentage data as it related to the wide vs. narrow windrows was some of the most intriguing data in this study. For my operation I need my alfalfa to be baled at 10% to 12% moisture, so having the wide windrows dry a full day or more faster is a very important factor and very beneficial for the growth of the next crop. Because of study limitations, we had to bale during the daylight. A producer may have opted to bale the wide windrows during the night.

Although the ANOVA indicated that there were significant differences in CP% based on roller type, the Tukey analysis showed no differences among the rollers. Windrow width was also significantly different for the baler NIR data with the narrow windrows having a higher CP% than the wide windrows. This is most likely tied to the difference in moisture % at the time of baling.

Another effect that could have had an impact on the alfalfa traits was the time and order that the alfalfa was baled (Table 5.1).

Table 5.1

Baling Order for Wide and Narrow Windrows

Harvest order – wide	Harvest order - narrow
1. CNH steel	1. AGCO Single
2. CNH Rubber	2. John Deere
3. CNH High Contact	3. AGCO Double
4. AGCO Double	4. CNH Rubber
5. John Deere	5. CNH Steel
6. AGCO Single	6. CNH High Contact
7. Skunkhead	7. Skunkhead

The Table 5.2 shows some very interesting information on how the windrows reacted to the timing of being baled as well as the relationship between CP and partial stems and scraps. The wide windrows of the AGCO conditioner rollers and the John Deere were baled toward the end of the day and had lower CP, but they also had higher partial stems and scraps which could result in greater leaf loss. The opposite happened among the narrow windrows with the CNH rollers having lower CP while the AGCO and John Deere rollers had higher CP, which indicates that baling order most likely had a large effect on CP. To counter these observations on baling order, the Skunkhead roller had fairly high CP readings for both the wide and narrow windrows even though it was baled last both days.

Table 5.2

Table Showing Crude Protein and Moisture by Windrow Size

Conditioner roller	Moisture % - wide	Moisture % - narrow	Moisture % - overall	Adj. CP% - wide	Adj. CP% - narrow	Adj. CP% - overall avg	% Full + half stems	% part stems + scraps
Skunkhead	11.74	13.78	12.76	24.76	24.52	24.64	83.80	16.20
CNH Steel	12.32	14.13	13.23	24.38	24.02	24.20	82.01	17.99
CNH Rubber	11.72	14.04	12.88	24.06	23.65	23.86	81.03	18.97
CNH High Contact	12.13	13.41	12.77	24.06	23.37	23.71	82.32	17.68
AGCO Double	11.25	14.59	12.92	23.69	25.29	24.49	74.19	25.81
John Deere	10.96	14.64	12.80	23.42	25.21	24.31	74.58	25.42
AGCO Single	11.06	15.28	13.17	23.31	25.10	24.20	77.59	22.41

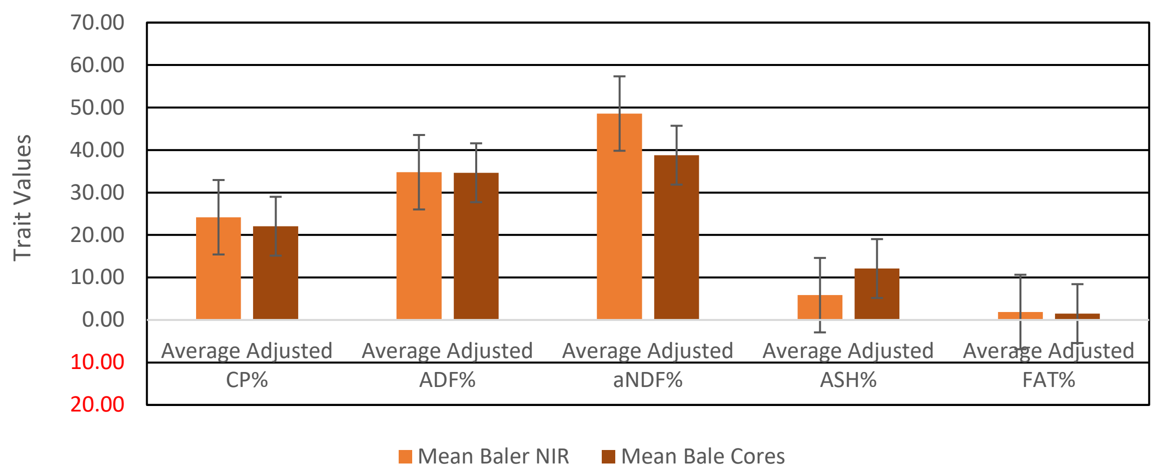
Bale Cores

Baler NIR results demonstrated highly significant differences for all forage quality traits (CP, ADF, NDF, ASH, and FAT) based on windrow width, and significant differences among the rollers for CP, NDF, and ASH. Bale core results generally showed no differences in the forage quality traits based on windrow width except crude fat which was significant at the 0.05 level of probability. Bale core analyses found significant differences among rollers for CP, ADF, and NDF.

Differences were observed between the baler NIR readings and the bale core NIR readings with the bale core NIR readings generally being lower than the baler NIR (see Figure 5.2 and Appendix B). ASH content was the only forage quality trait that was higher based on bale core NIR reading than the baler NIR readings. I find these results very interesting. The difference in readings could be a result of the timing of the NIR analysis. The baler NIR readings were taken on the day of baling, whereas the bale core samples were analyzed a few months after the cores were collected. These losses could have been due to bacteria that feed on the nutrients within the alfalfa (Idowu et al.,2013; Orloff and Putnam, 2012).

Figure 5.2

Bale Core vs Baler NIR



Grind Size

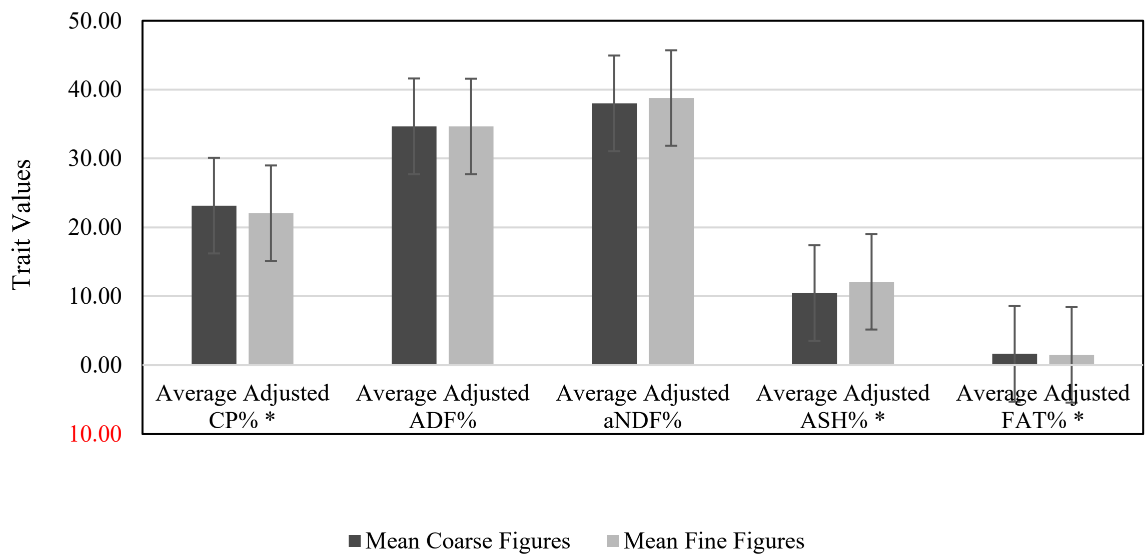
This section was added after some discrepancies were noticed based on the mill used to grind the samples. A few samples from each treatment were taken and ground on the UDY Corporation Cyclone Mill and analyzed by the NIR machine. The rest of the samples were ground using the Thomas-Wiley Mill Model 4. The screen sizes were the same for both mills. Once the NIR analysis started, it became apparent that the grind quality was noticeably different with the UDY Mill putting the alfalfa almost in a powder form and the Thomas-Wiley Mill being much coarser. Once this was discovered all the samples were run on the NIR with the coarse grind, then after those samples were analyzed, the samples were re-ground using the UDY mill and then re-analyzed on the

NIR to see if the qualities changed.

In general, the forage ground using the UDY Mill (fine grind) produced NIR readings that were lower than the coarsely ground material (Wiley Mill). This was observed for three of the five forage quality traits examined (Figure 5.3).

Figure 5.3

Bale Core Grind Size Means



In summary, we saw that plant condition was affected by the conditioner rollers that were examined in this study. Windrow width impacted many of the traits that were observed. One of the most surprising was that wide windrows were slightly taller, and not significantly different in height than the narrow windrow, which seemed counter-intutive as the narrow windrows had more material piled in a smaller area than the wide windrow having less material dispersed among a wider area. Width also impacted the dry down rate and how fast the alfalfa was ready for baling, with the wide windrows drying at a faster rate than the narrow windrows. No sun bleaching differences were observed based on windrow width, even though producers are often told that they should use narrow windrows to avoid sun bleaching.

Leaf loss increased dramatically during each process of harvesting the alfalfa. Figure 5.4 might explain why this there was so much leaf loss during the baling stage. In the photo you can see that the hitch drags right through the middle of the windrow and the middle of the windrow is where the leaf loss frame was placed to see how much new plant tissue material was lost. If more dew had been present that may have reduced some of the leaf loss during baling.

Figure 5.4

Baler Hitch Dragging Through the Windrow

Leaf loss was also observed during raking. Again there was no real dew to help prevent some of the leaf loss. Although not measured, the heights of the windrows after raking were noticablely different. This is most likely influenced by the percentages of the full and half-stems. Windrows that stood taller most likely experienced greater leaf loss when baling. A study to examine the impact of windrow height when baling would be informative.

Baler NIR readings also showed higher forage qualities than the bale core samples which could be due to the Baler NIR taking instant readings of the alfalfa, whereas the bale core samples were analyzed months later (Appendix B). A study examining how fast, and for how long, the alfalfa forage quality values decrease after cutting may also be warranted.

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APPENDICES

Appendix A

Weather Information from the USU Weather Station at Cache Junction

Table A-1

Weather Information from the USU Weather Station at Cache Junction

Weather Station	airt avg	airt min	airt max	rh max	rh min	winds avg	winds max
Station Name: Cache Junction							
Station ID: 124028							
7/6/2021 23:59	77	55	95.5	85	10	4.474	11.19
7/7/2021 23:59	78	54	100	81	9	4.474	17.9
7/8/2021 23:59	79	60	99.5	80	10	4.474	13.42
7/9/2021 23:59	77	57	97.3	68	6	4.474	17.9
7/10/2021 23:59	71	50	91.9	67	9	2.237	8.948

airt = air temperature
rh = relative humidity
winds = wind speed
min = minimum
max = maximum
avg = average

Appendix B

Baler Near Infared and Bale Core Near Infared Forage Quality Traits

Table B.1

Baler Near Infared and Bale Core Near Infared Forage Quality Traits

Roller	Adj. CP%	Adj. ADF %	Adj. NDF %	Adj Ash %	Adj. Fat %	Moisture %
Baler NIR						
A1 - W	23.31	36.90	50.66	5.98	1.83	11.06
A2 - W	23.69	36.05	50.45	5.27	1.83	11.21
CH - W	24.06	35.75	50.76	5.50	1.82	12.13
CR - W	24.06	34.49	49.01	5.49	1.86	11.72
CS - W	24.38	32.54	46.33	5.76	1.89	12.32
SK - W	24.76	36.05	51.04	6.59	1.85	11.74
JD - W	23.42	36.91	50.65	5.40	1.81	10.96
A1 - N	25.10	32.23	43.99	6.42	2.03	15.21
A2 - N	25.29	32.80	46.08	5.38	1.91	14.59
CH - N	23.37	36.58	50.30	5.94	1.85	13.41
CR - N	23.65	35.07	49.10	6.09	1.94	14.04
CS - N	24.02	34.43	48.44	6.21	1.95	14.13
SK - N	24.52	35.73	49.24	6.67	1.88	13.78
JD - N	25.22	32.08	45.44	5.44	1.96	14.64
Bale Cores						
A1 - W	22.55	34.82	38.67	11.25	1.59	5.53
A2 - W	22.96	33.57	37.34	11.65	1.61	5.47
CH - W	23.57	32.17	35.42	11.53	1.70	5.79
CR - W	23.78	31.81	35.21	11.72	1.65	5.58
CS - W	23.25	33.34	37.05	11.20	1.62	5.58
SK - W	21.46	37.37	40.98	10.59	1.53	5.07
JD - W	22.21	35.21	38.92	11.37	1.62	5.60
A1 - N	21.91	36.49	40.37	11.52	1.51	5.35
A2 - N	22.21	34.70	38.81	11.51	1.57	5.18
CH - N	22.65	34.82	38.80	10.82	1.49	5.47
CR - N	23.02	34.06	38.02	11.05	1.55	5.51
CS - N	21.87	36.68	40.50	10.96	1.51	5.03
SK - N	22.55	35.30	38.94	11.48	1.54	5.42
JD - N	22.78	34.58	38.06	11.52	1.59	5.36