Title: The impact of tedding on the economic production of alfalfa silage

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Abstract. Two treatments, tedded and untedded, were applied to an alfalfa field to determine their impact on the quality of the resulting forage. The tedded treatment area was tedded after the cutting of the field, and the untedded treatment was left in its original swath. The tedded treatment area dried at a greater rate than the untedded treatment area in all cuttings and replications. Crude protein, water-soluble carbohydrates, ash content, and neutral detergent fiber were also observed to be different, with the tedded treatment having lower crude protein, higher water-soluble carbohydrates, lower ash, and higher neutral detergent fiber than the untedded treatment. A difference was not observed between the treatments for total digestible nutrients.

Introduction. Producers are looking not only for a high-yielding crop but also a high-quality crop. A major contributor to the quality of alfalfa is the drying rate. By reducing the time for the crop to dry, the plant losses due to cellular respiration are reduced as well as potential losses due to weather. The alfalfa crop losses due to cellular respiration cease at about 40% moisture content (Shinners and Herzmann, 2006). One way to enhance the drying rate of alfalfa is through tedding. Tedding has been shown to increase the drying rate of a narrow windrow by 77% and a wide swath by 22% during a 3-hour period (Pattey et al., 1988). Since tedding has been proven to increase the drying rate, the losses due to cellular respiration have decreased, helping to improve the quality. When the crop is placed in wider swaths, a higher quality forage is produced (Digman et al., 2011). Factors that are affected through drying time include water-soluble carbohydrates, crude protein and neutral detergent fiber, among others. The longer the amount of time it takes for the crop to wilt, the more water-soluble carbohydrates are lost, decreasing the quality of the alfalfa (Kung et al., 2010).

While tedding reduces the drying time of alfalfa, increasing the timeliness of the entire operation, this comes at an additional cost of adding a field operation. One remedy to this is attaching the tedder to the back of the mower and/or conditioner (Shinners and Herzmann, 2006). Another aspect to consider is the timing of tedding. Some people prefer to ted their crops the day after cutting to allow the ground between the swaths to dry out. This would add an additional cost as the tedding would need to be done separately. Also, this practice does not capture the full potential of the solar insolation during the first day. In eleven studies, tedding after cutting versus the day after produced a numerically greater drying rate every time and a statistically greater drying rate in three of the studies (Shinners, 2016).

In addition to adding another field operation, the mechanical action of tedding introduces field losses. If tedding is done on a crop with moisture above 50%, the losses are below 3%, but if tedding is done later when the crop has dried more, losses can be as much as 10% due to leaf shatter, reducing the overall quality of the crop (Rotz, 2005). In a similar study, tedding a field at 60%, 50%, and 40% moisture content resulted in 4%, 6%, and 8% losses, respectively (Savoie, 1988). As a general rule of thumb, it is best to avoid tedding a crop when the moisture is at 40% or less in order to reduce losses, especially those from leaf shattering (Rotz, 2005).

This research seeks to answer the question of the utility of tedding in the production of alfalfa silage. Past work to-date has not considered tedding for production of silage where the wetter crop should be less susceptible to loss. However, the benefits of tedding will be diminished by the shorter overall drying time associated with silage production. In this work, we proposed to test these variables through field trials comparing tedded and untedded regions of the same field.

Materials and Methods. An experiment was conducted to better understand the impact that a tedding operation had on the quality of harvested crop. This experiment was conducted on a 2-hectare alfalfa field, seeded in 2016 of the variety Harvxtra Driver, at the Mann Valley Farm located in River Falls, WI. Prior to harvesting the field, nine samples were taken across the field. This was done to provide a basis of yield and quality prior to harvest. The pre-harvest samples were taken on May 24, 2018, by using a 0.3 m square and shears to cut the alfalfa that was within the square. For second and third cutting, the number of pre-harvest samples was increased to sixteen and were taken on June 27, 2018, and July 23, 2018, utilizing the same process as used in first cutting.

First, second and third cuttings of alfalfa occurred on May 28, 2018, June 27, 2018, and July 23, 2018, respectively. Each cutting was done using a Case IH DC133 mower conditioner with a 4 m cut width. Immediately following the cutting of the field, the windrows were counted, and the field was divided. The headlands were disregarded for the study each time. The field was split up so that the middle eight windrows would be tedded, and the four rows on either side would be left in their original windrows. The field was split in this manner to minimize the field variability. In total, there were eight tedded and eight untedded 150 m long windrows. The windrows averaged a swath width of 1.7 m for first cutting, 1.4 m for second cutting, and 1.3 m for third cutting. After the field was split up to minimize the field variability, the eight middle windrows were tedded using a Kuhn model GF222T 2.6 m tedder. The tedder was operated at a ground speed of 5.6 kph and PTO speed of 540 rpm. For second cutting, the same procedure was done to split the field up to minimize field variability. However, this time the untedded windrows were the middle eight rows of the study, and the tedded were the four rows on each side of the untedded rows. For third cutting, the same procedure was followed as first cutting.

The day after cutting, the entire field was merged using a 2.7 m H&S model M9 Merger. For first cutting this occurred on May 29, 2018. The four untedded windrows on either side of the tedded region were merged so that two windrows were on either side of the tedded area. The tedded area was merged, resulting in four merged windrows. For second cutting, merging occurred on June 28, 2018, and for third cutting, this occurred on July 24, 2018.

After merging, the field was harvested using a New Holland model FP230 pull-type forage harvester. The field was then harvested after splitting up the field into four regions: north tedded, north untedded, south untedded, and south tedded. Each region was harvested into separate wagons and consisted of two merged windrows. From there, the wagons went to be unloaded into a bagger. At this point, samples of the forage were taken. For each cutting, twenty samples were taken from the tedded area, and another twenty were taken from the untedded areas. Therefore, ten samples were taken from each load that was brought in, weighed, and unloaded.

Once all the samples were collected, they were weighed and then placed in a drying oven for 48 hours at 50 C. After 48 hours, the samples could be analyzed for quality using near-infrared reflectance spectroscopy (NIRS). Quality characteristics that were predicted via NIRS analysis were crude protein (CP), neutral detergent fiber (NDF), water-soluble carbohydrates (WSC), ash, and total digestible nutrients (TDN). Samples that were not used for quality information were dried down at 103 C for 24 hours per ASABE 358.2 to provide moisture content of the samples.

Results and Discussion. Nutrient quality of wilted alfalfa was investigated for two different treatments, tedded and untedded, through on-farm observation. Standing alfalfa samples were collected prior to the cutting of the field to provide a basis for original nutrient content and yield prior to harvest. Weather data for each cutting is summarized in Table 1. In each case, the crop was harvested the day following cutting.

Table 1. Average and range of environmental conditions during first, second and third cuttings.

Cutting	Date	Temperature (C)		Relative Humidity (%)	
		Average	Range	Average	Range
1	28 May 18	31	23 - 38	45	26 - 64
	29 May 18	27	20 - 34	68	36 - 100
2	27 Jun 18	23	18 - 28	79	58 - 100
	28 Jun 18	25	19 - 30	75	57 - 93
3	23 Jul 18	24	18 - 29	74	55 - 93
	24 Jul 18	24	18 - 29	61	37 - 84

The composition and yield estimates of the standing alfalfa samples are summarized in Table 2. Using the information gathered from the samples taken prior to field cutting, the impact of the two treatments, tedded and untedded, could be determined.

Table 2. Composition of standing alfalfa.

Cutting	Yield	Crude protein	Neutral Detergent Fiber	Water Soluble Carbohydrates	Ash	Total Digestible Nutrients
	(Mg DM) ha^{-1}	g (kg DM)$^{-1}$				
1	3.1	267	335	87.0	109	713
2	2.5	231	390	71.0	112	671
3	2.4	227	345	91.1	94	679

The results of the two treatments impact on forage quality and moisture content were evaluated. First, second, and third cutting quality and moisture information can be found in Table 4. A summary of the averaged values of quality characteristics across the three cuttings is found in Table 5. In this study, a difference ($p<0.05$) was observed for the impact that un-tedded and tedded treatments had on moisture content. A ten percent difference in moisture content was found between the tedded and untedded treatments when averaged across each of the cuttings. The tedded treatment dried at a greater rate than untedded in each of the cuttings. After a 24-hour period, the tedded treatment was observed to have a lower harvested moisture compared to untedded by 11, 16%, and 5% w.b. for first, second, and third cuttings, respectively. The lower percent difference observed in third cutting could be attributed to the lower yield in the crop, allowing the untedded treatment to dry more quickly than in previous cuttings. Previous research determined an increase in drying rate of a narrow windrow by 77% and a wide swath by 22% during a 3-hour period through tedding (Pattey et al., 1988). Additionally, drying rate has been improved by 42% by tedding directly after cutting as compared to tedding crop left in a windrow (Shinners and Herzmann, 2006). In our study, the difference is not as dramatic, but this can be attributed to the shorter period from cut to harvest required for alfalfa silage production than dry hay.

Table 4. Composition of Tedded and Untedded Treatments Averaged Across Each Cutting of the Field Study

Cutting	Treatment	Harvest moisture content	Crude protein	Neutral Detergent Fiber	Water Soluble Carbohydrates	Ash	Total Digestible Nutrients
		%w.b.[1]	g (kg DM)$^{-1}$				
1	Un-tedded	69_a	219_a	411_a	53.8_a	105_a	659_a
	Tedded	58_b	214_b	413_a	61.7_b	106_a	661_a
2	Un-tedded	65_a	209_a	424_a	52.0_a	117_a	645_a
	Tedded	49_b	204_b	420_a	63.4_b	107_b	647_a
3	Un-tedded	52_a	223_a	327_a	88.6_a	108_a	673_a
	Tedded	47_b	215_b	351_b	95.2_b	93.7_b	670_a

[1]Rows within each cutting with different subscripts are statistically different ($p < 0.05$)

Crude protein was also observed to have a difference ($p<0.05$) between the tedded and untedded treatments for each of the three cuttings. Averaged across the three cuttings, values of CP were observed to be 211 and 217 g (kg DM)$^{-1}$ for tedded and untedded crop, respectively. Crude protein data indicate a small but consistent difference in crop quality. These small differences, however, were not observed in neutral detergent fiber (NDF) and total digestible nutrients (TDN). A difference ($p<0.05$) for NDF was observed when analyzing the entire field trial together where the tedded and untedded treatments had mean values of 395 and 388 g (kg DM)$^{-1}$, respectively. Conversely, when analyzing the cuttings individually, a difference ($p<0.05$) was observed only in the third cutting. And finally, a difference for TDN was not observed for any cutting.

Other quality factors considered were ash content and water-soluble carbohydrates (WSC) which were both observed to have a difference ($p<0.05$) between treatments. For ash content, a difference was observed in second and third cuttings only. For WSC, a difference was observed in each of the cuttings. Ash content had values of 102 and 110 g $(kg\ DM)^{-1}$ for tedded and untedded treatments respectively when averaging values across each of the cuttings. The source of the lower ash content could potentially be from the soil being adhered by the heavier swath than the lighter, fluffed-up tedded section. For WSC, the tedded and untedded treatment areas had values of 734 and 648 g $(kg\ DM)^{-1}$ respectively when averaged across each of the cuttings. WSC is a main contributor for fermentation and the quality of the silage produced. The values found from the field study are similar to that of previous research which determined a difference in WSC between wide and narrow swath treatments, resulting in values of 510 and 370 g $(kg\ DM)^{-1}$, respectively (Kung et al., 2010). This difference can be expected due to the reduced wilting period for the tedded treatment areas as compared to the swath areas, reducing the losses due to cellular respiration as a result.

Table 4. Composition of tedded and untedded treatments averaged across each cutting

Treatment	Moisture content	Crude protein	Neutral Detergent Fiber	Water Soluble Carbohydrates	Ash	Total Digestible Nutrients
	%w.b.	g $(kg\ DM)^{-1}$				
Un-tedded	62_a	217_a	388_a	64.8_a	110_a	659_a
Tedded	51_b	211_b	395_b	73.4_b	102_b	659_a

Rows within each cutting with differing subscripts are statistically different ($p < 0.05$)

The tedded treatment had a faster drying rate than the untedded treatment in each cutting observed. The resulting moisture content at harvest for the tedded and untedded treatments, averaged across the three cuttings, were 51% and 62%, respectively. A difference was observed in WSC with the values of the tedded and untedded treatments being 734 and 648 g $(kg\ DM)^{-1}$, respectively, when averaged across the three cuttings. A difference in ash content was observed in two of the three cuttings. Values of ash for the tedded and untedded treatments were 102 and 110 g $(kg\ DM)^{-1}$, respectively, when averaged across the three cuttings.

Decision Tool for Tedding Costs

In addition to the field trial, the research team worked on developing a user-friendly decision-tool for alfalfa producers to consider the costs of introducing tedding into their operation (Figure 3). In this decision-tool, tractors and implements have been set up for producers to use, but there is also the option for the user to add their own tractors and implements to better fit their operation. Producers can also change the assumptions made on acreage and more. As a result, the cost per hour, acre, and ton are calculated for each implement and tractor. The user can then create different scenarios with different combinations of implements and the total cost per hour, acre, and ton for the operation are computed for the user.

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