A Comparison of Four Mower Conditioners on Drying Rate and Leaf Loss in Alfalfa and Grass

W. J. Greenlees, H. M. Hanna, K. J. Shinners, S. J. Marley, T. B. Bailey

Abstract. *Mechanical conditioning of forage can be accomplished by passing the crop through fluted intermeshing rolls or by passing the crop over the tines of an impeller rotor. Three impeller conditioners and one intermeshing roll conditioner were compared in field experiments. The impeller conditioners differed on the type of tine used on the rotor. Hood position and impeller speed were the two adjustments made on all impeller conditioners. The linear load on the rolls was the only adjustment made on the intermeshing roll conditioner. The effect of the conditioning mechanisms and their adjustments on drying rate and leaf loss in alfalfa and grass crops was measured. Comparisons were made exclusively among impeller conditioners using all adjustment combinations and among all machines with specific aggressive and nonaggressive adjustments selected. In alfalfa, among impeller conditioners exclusively, the fast rotor speed caused about 7.3% leaf loss, which was 1.1 percentage point greater than the leaf loss caused by the slow rotor speed. With respect to hood position, the maximum average leaf loss was 6.77% and varied by less than 0.1 percentage point. Incidentally, in the first day of drying, alfalfa conditioned with the fast impeller speed exhibited a 3% greater drying rate constant than the drying rate constant of alfalfa conditioned with the slow impeller speed. In the first day of drying, grass conditioned with the fast impeller speed exhibited a 13% greater drying rate than the drying rate of grass conditioned with the slow impeller speed. In addition, drying rates in alfalfa varied less than 8% and drying rates in grass varied less than 10% in the first day of drying with respect to hood position. When comparisons were made exclusively among impeller conditioners, statistically significant differences in drying rate and leaf loss were only exhibited between the fast and slow impeller speeds. In the first day of drying, forage (both grass and alfalfa) conditioned by aggressively-set impeller machines exhibited drying rates 23 to 63% greater than drying rates of forage conditioned by the aggressively-set intermeshing roll conditioner. Also in the first day of drying, forage (both grass and alfalfa) conditioned by nonaggressively-set impeller machines exhibited drying rates 49 to 60% greater than the drying rates of forage conditioned by the nonaggressively-set intermeshing roll conditioner. Results also suggest that aggressively-set impeller machines, caused 1.7 to 3.4 percentage points more leaf loss than the aggressively-set intermeshing roll machine, and nonaggressively-set impeller machines caused 1.2 to 2.2 percentage points more leaf loss than the nonaggressively-set intermeshing roll machine.*

Keywords. *Forage, Drying, Mower conditioner, Alfalfa, Leaf loss, Impeller conditioning.*

Field processes for dry forage harvesting and storage involve cutting, conditioning, field drying, raking, and baling. During these processes, losses of quantity and quality often occur. It is important to minimize losses to maximize quality and nutritive value. Losses are typically grouped into those due to fragmentation or shatter, leaching of soluble constituents during rainfall, and respiration (Savoie et al., 1993). Rees (1982) estimated field losses to vary between 18 and 30% of total dry matter. Total forage losses are reduced and quality enhanced by rapid field drying (Rotz and Muck, 1994). The largest harvest losses and quality changes occur during field drying, primarily due to damage from rainfall (Rotz and Muck, 1994). Therefore, mower-conditioner systems that enhance forage drying rate while minimizing fragmentation losses have potential to improve forage quality.

It is widely known that more aggressive conditioning creates greater fragmentation losses but also increases field drying rate (Barrington and Bruhn, 1970; Straub and Bruhn, 1975; Hellwig et al., 1977; Rotz and Sprott, 1984). Losses at the mower-conditioner typically are reported to vary between 1 and 5% of total dry matter (Savoie et al., 1982; Koegel et al., 1985; Savoie, 1988; Shinners et al., 1991). Through much of the last three decades, the most widely used mower-conditioner in North America was configured with a sickle cutterbar, a cam-actuated reel, and intermeshing conditioning rolls. This machine

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configuration was considered the most acceptable for harvesting alfalfa. The disk cutterbar machine with impeller conditioner was developed in Europe because of the need to harvest fine-stemmed grasses. The disk cutterbar mower-conditioner was adapted to North America by replacing the impeller conditioner with intermeshing rolls. However, impeller conditioners often provide better airflow from the disk cutterbar, which helps improve crop flow off the cutterbar, and thereby improves cutting performance. Therefore, impeller conditioners are becoming increasingly popular on North American disk cutterbar machines.

Disk cutterbar machines equipped with roll conditioners produce about the same fragmentation losses as similar machines with sickle cutterbars (Rotz and Sprott, 1984; Koegel et al., 1985; Shinners et al., 1991). A disk cutterbar machine with an impeller conditioner adjusted for very aggressive conditioning (typically used when harvesting grass) produced almost twice the loss of a similar machine with an intermeshing roll conditioner (Koegel et al., 1985). Recent disk cutterbar machines equipped with impeller conditioners offer two adjustments to control the aggressiveness of conditioning: impeller speed and hood position. For leafy crops such as alfalfa, slowing impeller speed can reduce the impeller impact force. The hood, which controls how closely the crop is held to the impeller as it passes through the machine, can be raised so that conditioning is less aggressive. Because of the rise in popularity of disk cutterbar machines with an impeller conditioner and new impeller designs, additional research is needed to quantify forage losses and drying rates.

This study compared the effect of four disk cutterbar mower-conditioners equipped with different conditioners on drying rate and leaf loss in alfalfa and grass crops. Three machines were variations on an impeller conditioner design and the fourth was a conventional intermeshing roll design. The three impeller designs differed in the type and shape of the impeller tine.

The specific objectives of this study included the following:

- Compare the drying rate constants of forage harvested by the impeller machines at different settings of impeller speed and hood position in both alfalfa and canary grass.
- Compare the leaf loss created by each impeller machine during cutting at different settings of impeller speed and hood position in alfalfa.
- Compare drying rate constants of the forage material and leaf loss of alfalfa among all impeller and intermeshing roll machines at aggressive and nonaggressive settings.

METHODS

Four machines, numbered 1 through 4, were used in the experiment. All machines were variations of a John Deere model 930 mower-conditioner. Figures 1a, 1b, and 1c show the shapes of the tines on the impeller machines. Machine No. 1 used flat steel "Y"-shaped tines on the impeller (fig. 1a), Machine No. 2 used round steel "U"-shaped tines (fig. 1c), Machine No. 3 used plastic "U"-shaped tines (fig. 1b), and Machine No. 4 used intermeshing rolls. The centerlines shown on the tines of figures 1a and 1c imply

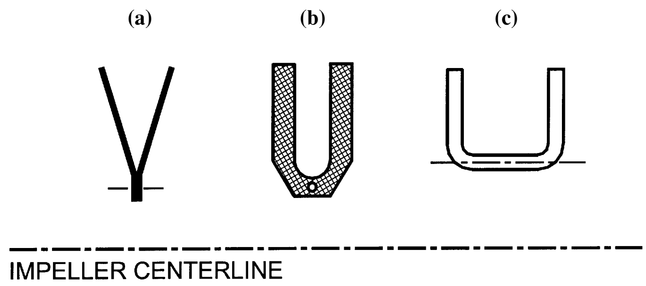

Figure 1–Shapes of impeller tines. (a) Steel "Y"-shaped tine made from flat bar stock, free to pivot; (b) molded plastic "U"-shaped tine, rigidly affixed; (c) steel "U"-shaped tines made from round bar stock, free to pivot. Each tine configuration had same dynamic radius.

that each individual tine could pivot freely about its attachment to the impeller rotor. However, each plastic tine in figure 1b was rigidly affixed to the impeller rotor. All three impellers were designed to have the same dynamic radius.

Each impeller mower conditioner had six possible settings. There were three settings, distant, intermediate, and close, for hood position. When set at the distant position, the hood was located approximately 11 cm (4.5 in.) above the tips of the impeller tines. The intermediate setting placed the hood at 8 cm (3 in.) above the tips of the tines, and the close setting placed the hood at 4 cm (1.5 in.) above the tips of the tines. Each hood setting was operated at two impeller speeds: 620 rpm and 790 rpm. The intermeshing roll mower conditioner had two settings for linear load on the rolls: 3500 N/m (20 lb_f/in.) and 5200 N/m (30 lb_f/in.). The cutting width of all machines was 3.4 m (11 ft).

EXPERIMENTAL DESIGN

Two separate experiments were conducted at the Iowa State University Armstrong Farm near Lewis, Iowa. Experiment No. 1 used crop moisture data to determine drying rate constants. Experiment No. 2 determined alfalfa leaf loss. Both experiments used a randomized complete block, split-plot design with the four individual machines randomly assigned to the main plots and different machine settings randomly assigned within split plots inside each of the main plots. Blocks used for replication in the drying experiment were various combinations of crop (alfalfa or canary grass) and cutting (e.g., first cutting of alfalfa). Blocks used for replication in the leaf loss experiment were two different cuttings of alfalfa. For each cutting (i.e., each block), the machine operator completed cutting with all settings of a randomly selected machine before operating another machine.

This design was selected so that the crop in each block could be cut within approximately 40 min. Cutting the entire crop within one replicated block during a short time period was desirable so that all treatments would receive approximately the same drying conditions. Unfortunately, when machines were varied across the main plots, but not within the split plots, some ability to differentiate between machine treatment means was sacrificed because main plot experimental error was usually larger than the split plot experimental error used to detect differences in machine settings. Figure 2 shows a typical plan view of the experimental design for a single replicated block. Machines

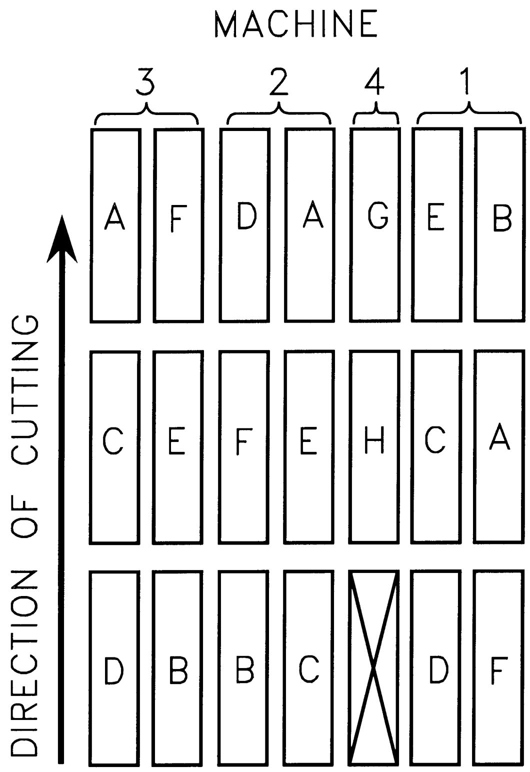

Figure 2–Typical plan view of a single experimental block. Three blocks were used in alfalfa and two blocks in grass for the drying rate experiment. Three separate blocks were used in alfalfa for the leaf loss experiment. The arrow indicates the cutting direction for all treatments.

No. 1 through No. 3 occupied two-column main plots, and machine No. 4 had only a single column main plot. Split plots, labeled A, B, C, D, E, and F, represent the six possible speed and hood combinations for the impeller machines. Split plots labeled G and H represent the two possible linear loads on the rolls for the intermeshing roll machine. The split plot with an "X" represents a blank treatment from which no data were collected. The blank split plot was needed so that no standing crop remained within the experiment. The long axis of figure 2 was parallel to the cut swath.

The original intention was to use a first and second cutting each of both alfalfa and grass for replicated blocks in the drying rate experiment and a first and second cutting of alfalfa for replicated blocks of the leaf loss experiment. However, inclement weather prevented some data acquisition and forced the unanticipated data collection from a third cutting of alfalfa. For first crop grass, excessive rainfall prevented the collection of the midday moisture content data of day two and it prevented the collection of all moisture data for day three. For second crop alfalfa, wind and rain destroyed moisture data for day three as well as all leaf loss data. For the drying rate experiment, the data used to calculate the first and second day's drying rate constant were from the first three cuttings of alfalfa and the first two cuttings of grass. Data used to calculate the third day's drying rate constant were from the first and third cuttings of alfalfa and the second cutting of grass. For the leaf loss experiment, data used to calculate leaf loss were from the first and third cuttings of alfalfa.

Moisture Content Data Collection

Prior to cutting the crop, numbered flags were placed along the edge of the plots in random order. Each numbered flag represented a specific day and sampling time. Plots were mowed parallel to each adjacent plot with the machines and the appropriate settings. Mowing was started by 9:00 A.M. and was completed before 10:00 A.M. Moisture content samples were collected at 10:00 A.M., 1:00 P.M., and 4:00 P.M. on the day of cutting, and at similar times during the following two days. Thus, moisture content samples were collected at 1, 4, 7, 25, 28, 31, 49, 52, and 55 h after cutting. Table 1 provides information about the replications and calendar dates used in the drying rate experiment. Table 1 also provides information about precipitation and data collection. Unfortunately, solar radiation, wind speed, and ambient air temperature were not measured during the experiment.

A small, self-propelled, flail-chopper harvester was used to collect samples of the crop by traveling perpendicular to the cut swath along a sampling path marked by a numbered flag. As the harvester crossed the swath, it harvested a sample of the crop approximately 0.9 m (3 ft) wide. The total volume collected from each swath depended upon the crop yield. The sample was deposited into a large container, with each split plot having its own container. Two representative subsamples were collected from the container and placed into paper bags. These sample bags were labeled with treatment code information and then weighed within one hour to obtain a gross wet weight. The logistics of collecting the samples and transporting them from the field to the building where the stationary scale was located prevented immediate weighing.

The research farm did not have suitable forced-air drying equipment to accommodate the bagged samples

Table 1. Replications and calendar dates for drying rate experiment

Replication	Drying Day: Day One*	Day Two	Day Three
Alfalfa			
First cutting			
Calendar Date	11 Jun 1996	12 Jun 1996	13 Jun 1996
Moisture data collection (h)†	1, 4, 7	25, 28, 31	49, 52, 55
Precipitation (mm)	0	13	0
Second cutting			
Calendar Date	15 Jul 1996	16 Jul 1996	17 Jul 1996
Moisture data collection (h)	1, 4, 7	25, 28, N‡	N, N, N
Precipitation (mm)	3	11	13
Third cutting			
Calendar Date	7 Aug 1996	8 Aug 1996	9 Aug 1996
Moisture data collection (h)	1, 4, 7	25, 28, 31	49, 52, 55
Precipitation (mm)	0	0	0
Grass			
First cutting			
Calendar Date	19 Jun 1996	20 Jun 1996	21 Jun 1996
Moisture data collection (h)	1, 4, 7	25, N, 31	N, N, N
Precipitation (mm)	0	13	46
Second cutting			
Calendar Date	31 Jul 1996	1 Aug 1996	2 Aug 1996
Moisture data collection (h)	1, 4, 7	25, 28, 31	49, 52, 55
Precipitation (mm)	0	0	0

* Drying Day One was the same day as the cutting.
† Moisture data collections were 1, 4, 7, 25, 28, 31, 49, 52, or 55 h after cutting.
‡ The letter "N" indicates "No data," a moisture data collection that was rained out.

following weighing, so the samples were transported 30 km (20 miles) to a heated dry room at A&L Laboratories in Atlantic, Iowa, for temporary storage. This dry storage was intended to stabilize the sample by slowing organic respiration, and was required because the samples could not be transported to a forced-air dryer until the three-day data collection period for that particular crop or cutting (i.e., replication) was completed. After all samples for a replication were collected, they were transported 190 km (120 miles) to a forced-air dryer near Ames, Iowa, and subjected to 60ºC (140ºF) for 72 h in compliance with the American Society of Agricultural Engineers (ASAE) Standard S358.2 (1993). Upon removal from the forced-air dryer, the bags were weighed again to obtain a gross dry weight. Gross weights were taken because weight loss due to drying of the bag itself was assumed negligible. The dry basis moisture content was calculated from the wet and dry weights with equation 1 from ASAE Standard S358.2 (1993):

$$\mu = \frac{M_W - M_D}{M_D - M_T} \qquad (1)$$

where

μ = dry basis moisture content
M_W = gross wet weight of the sample
M_D = gross dry weight of the sample
W_T = dry tare weight of paper bag

In the data set, the two sub-samples for each sampling time within each treatment were averaged. Nine moisture content values, three values for each of three days, were plotted versus time. As expected, the data plotted in this fashion were nonlinear. Data were assumed to follow equation 2 (Rotz and Chen, 1985):

$$\mu_t = \mu_0 e^{-kt} \qquad (2)$$

where

μ_t = dry basis moisture content at time t
μ_o = dry basis moisture content at time 0
t = elapsed time, h
k = drying rate constant (h^{-1})

Data were transformed into a linear relationship by plotting the natural logarithm of moisture content versus time. For each day, a drying rate constant was determined from equation 3, a least squares fit of the three transformed data points (Eide et al., 1986):

$$k = \frac{n \sum t_i \ln \mu_i - \left(\sum t_i\right) \sum \ln \mu_i}{n \sum t_i^2 - \left(\sum t_i\right)^2} \qquad (3)$$

where

k = drying rate constant (h^{-1})
n = 3 observations in each day
t = elapsed time, h
μ = dry basis moisture content as a proportion

LEAF LOSS DATA COLLECTION

Before cutting each plot, a 30-m long (100 ft) × 3.7-m wide (12 ft) tarpaulin, rolled onto a spool, was mounted behind the machine directly below the swathing skirts. The free end of the tarpaulin was anchored to the soil with pins fashioned from No. 9 steel wire. Each corner at the free end of the tarp was tucked underneath one of the machine's tires. As the machine rolled forward through the plot, the tires rolled on the edge of the tarp as the spool unwound. The crop was deposited on the tarpaulin as it was cut. The tarpaulins were fabricated from semiporous woven polyethylene. After the plots were cut, more pins were used to anchor the tarp to the soil to reduce movement from wind.

On each plot, two sample locations were used to collect leaf loss data. The first was at 12 m (40 ft) from where the machine began cutting and the second at 18 m (60 ft) from where the machine began cutting. No sampling was done in the first 12 m (40 ft) of the plot because this portion was reserved to allow the machinery to reach equilibrium operating conditions. At each sample location, two cuts, 1.5 m (5 ft) apart, were made perpendicular to the swath with gasoline-powered hedge trimmers. The material between the cuts was carefully removed with a five-tine pitchfork. The same person operated the pitchfork at all sample locations on all of the plots. The "stem" material removed with the pitchfork was placed in a container and weighed to obtain a wet weight. A small, approximately 100-g, sample was collected from the container, and a moisture content analysis was performed on that sample to determine the dry mass of the material in the container. The material remaining on the tarp at a sample location was assumed to be leaves lost due to the cutting/conditioning operation. This "lost" material was collected with a hand broom by a single observer and a moisture content analysis was performed to determine its dry mass. The same observer collected the lost material for all treatments. The moisture content analyses performed on the stem and lost material involved the same procedures as those described for the drying rate experiment. Leaf loss resulting from the cutting/conditioning operation expressed as a percentage of the total swath dry mass was calculated from equation 4:

$$L_L = \frac{M_L}{\left(M_L + M_S\right)} \times 100\% \qquad (4)$$

where

L_L = leaf loss expressed as a percent
M_S = dry mass of the stems removed with a five-tine pitchfork
M_L = dry mass of the leaf material remaining after removal of stems

Table 2 provides information about the replications, cutting dates, and sampling dates used for the leaf loss experiment.

METHOD OF ANALYSIS

Two analyses were conducted for both the drying rate study and the leaf loss study. One was an analysis of the

Table 2. Replications and calendar dates for leaf loss experiment

Replication	Cutting Date	Leaf Loss Sampling Date
First cutting alfalfa	12 Jun 1996	13 Jun 1996
Second cutting alfalfa	16 Jul 1996	No data*
Third cutting alfalfa	8 Aug 1996	8 Aug 1996

* Severe wind and rain destroyed all data for this replication.

Table 4. Drying rate constants for all machines — grass and alfalfa

Treatment	Drying Rate Constant: Day One (h^{-1}) All	Agg.*	N†	Day Two (h^{-1}) All	Agg.	N	Day Three (h^{-1}) All	Agg.	N
Crop – both									
Machine style									
Steel "Y" tines	0.200	0.188bc‡	0.201a	0.113	0.140ab	0.119a	0.193	0.176	0.229a
Steel "U" tines	0.192	0.249a	0.199a	0.111	0.170a	0.084ab	0.192	0.180	0.194a
Plastic "U" tines	0.206	0.205ab	0.188a	0.101	0.054c	0.130a	0.183	0.196	0.210a
Intermeshing rolls	0.139	0.152c	0.126b	0.065	0.088bc	0.041b	0.130	0.188	0.072b
$LSD_{0.10}$§	0.084	0.053	0.053	0.077	0.075	0.075	0.141	0.069	0.069
Crop – alfalfa									
Machine style									
Steel "Y" tines	0.201	0.198	0.190	0.167	0.217	0.144	0.223	0.217	0.250
Steel "U" tines	0.204	0.256	0.228	0.173	0.244	0.097	0.235	0.230	0.250
Plastic "U" tines	0.200	0.178	0.180	0.153	0.150	0.205	0.186	0.220	0.201
Intermeshing rolls	0.136	0.161	0.111	0.107	0.126	0.087	0.105	0.142	0.068
Crop – grass									
Machine style									
Steel "Y" tines	0.198	0.173	0.217	0.044	0.025	0.082	0.132	0.093	0.188
Steel "U" tines	0.174	0.239	0.154	0.019	0.058	0.063	0.107	0.080	0.080
Plastic "U" tines	0.216	0.245	0.201	0.022	–0.091	0.018	0.178	0.148	0.228
Intermeshing rolls	0.144	0.139	0.150	0.002	0.032	-0.029	0.180	0.281	0.079

* Agg. represents aggressive machine settings.
† N represents nonaggressive machine settings.
‡ Different letters within each machine style in each column indicate statistically different values.
§ $LSD_{0.10}$ is least significant difference at a 90% confidence level.

Table 3. Drying rate constants for impeller machines — grass and alfalfa

Crop Treatment	Drying Rate Constant*: Day One (h^{-1}) B	A	G	Day Two (h^{-1}) B	A	G	Day Three (h^{-1}) B	A	G
Machine style									
Steel "Y" tines	0.200	0.201	0.198	0.118	0.167	0.044	0.193	0.223	0.132
Steel "U" tines	0.192	0.204	0.174	0.111	0.173	0.019	0.192	0.235	0.107
Plastic "U" tines	0.206	0.200	0.216	0.101	0.153	0.022	0.183	0.186	0.178
$LSD_{0.10}$†	0.038			0.021			0.077		
Impeller speed									
Slow	0.192	0.198	0.184	0.096a‡	0.144	0.024	0.187	0.213	0.135
Fast	0.206	0.205	0.208	0.124b	0.185	0.032	0.192	0.216	0.143
$LSD_{0.10}$	0.018			0.025			0.023		
Hood position									
Distant	0.202	0.207	0.195	0.106	0.156	0.031	0.188	0.203	0.159
Intermediate	0.205	0.205	0.205	0.116	0.176	0.026	0.197	0.228	0.136
Close	0.191	0.193	0.188	0.107	0.160	0.028	0.183	0.213	0.123
$LSD_{0.10}$	0.022			0.031			0.028		

* B = Both; A = Alfalfa; G = Grass.
† $LSD_{0.10}$ is least significant difference at a 90% confidence level.
‡ Different letters within each treatment in each column indicate statistically different values.

factorial treatment design for all settings of three impeller machines (excluding the intermeshing roll machine), and the other an analysis of all four machines. In the analysis of all four machines, statistical main plot error was used to detect differences among the machines. All settings together, aggressive settings, and nonaggressive settings were compared. Aggressive and nonaggressive settings of the impeller machines were considered as the fast rotor speed at the intermediate hood position and slow rotor speed at the intermediate hood position, respectively. For the intermeshing roll machine, the high linear load applied to the rolls was considered as the aggressive setting and the low linear load as the nonaggressive setting.

RESULTS

Least significant differences (LSD) were computed only for grass and alfalfa data combined. This was done because it was believed an insufficient number of observations existed to compute meaningful LSDs for one crop independent of the other. Thus, tables 3 and 4 report mean drying rate constants with LSDs for both crops together. Mean drying rate constants without LSDs are also reported for alfalfa independent of grass and for grass independent of alfalfa.

Analysis of drying rate differences of the three impeller machines according to machine style, impeller speed, and hood position are shown in table 3. The drying rate constants represent daily drying between 9:00 A.M. and 4:00 P.M. Drying rate constants differed significantly on the second day for impeller speed. The fast (790 rpm) impeller speed exhibited a drying rate constant 0.028 h^{-1} greater than the drying rate constant exhibited by the slow (620 rpm) impeller speed. The least significant difference was 0.025 h^{-1}. No other statistical differences were detected. Drying rate constants were lower for day two than for day three because there was additional moisture from rainfall. Rain fell during the first evening after cutting for first crop alfalfa, and rain fell during the second day after cutting for first crop grass.

When all settings of the impeller and intermeshing roll machines were analyzed together, no statistical differences were revealed as evidenced by the columns headed "All" of table 4. Although statistical differences could not be detected, the mean drying rate constants of impeller machines were consistently, numerically greater than the drying rate constants of the intermeshing roll machine. Inability to discern statistical differences is likely due to the large error term used to differentiate the machine effects in the main plots. In addition, table 4 compares drying rate constants for all machines considering aggressive settings, and nonaggressive settings. The columns listing this information are headed "Agg" for aggressive or "Nonagg" for nonaggressive.

Some statistical differences in drying rate can be detected when specific settings are compared for individual machines. For the first day of drying, forage conditioned by the steel "U"-shaped tine and plastic "U"-shaped tine impeller machines at the aggressive setting exhibited faster drying rates than the forage conditioned by the intermeshing roll machine at high linear load. Mean drying rate constants for these impeller machines on the first day were 0.053 to 0.097 h^{-1} greater than the mean drying rate constant shown for the intermeshing roll machine. Also in the first day, forage conditioned by all impeller machines at the nonaggressive setting exhibited drying rates 0.062 to 0.075 h^{-1} greater than the mean drying rate constant of the forage conditioned by the intermeshing roll machine at low linear load. On the second day, forage conditioned by aggressively set steel "Y"-shaped tine and steel "U"-shaped tine impeller machines exhibited a 0.086 to 0.116 h^{-1} greater drying rate constant than forage conditioned by the aggressively set plastic "U"-shaped tine impeller machine. Forage conditioned by the aggressively set steel "U"-shaped tine impeller machine showed an 0.082 h^{-1} greater drying rate constant than forage conditioned by aggressively set intermeshing rolls. At the nonaggressive setting, forage conditioned by steel "Y"-shaped tines or plastic "U"-shaped tines exhibited a 0.078h^{-1} or 0.089 h^{-1}, respectively, greater drying rate constant than the forage conditioned by the by intermeshing rolls. On the third drying day, forage conditioned by any of the three impeller machines at the nonaggressive setting exhibited a 0.122 to 0.157h^{-1} greater drying rate constant than the forage conditioned by the intermeshing roll machine operated at the low linear load. For specific, but not for all settings, data indicate forage conditioned by the impeller machines dried more quickly than forage conditioned by the intermeshing roll machine.

Table 5 shows leaf loss percentages for the three impeller machines and hood and speed settings in the factorial treatment analysis. Leaf loss was 1.08 percentage point greater for the faster rotor speed treatment than the lower rotor speed treatment. This was the only statistically significant difference detected. Leaf loss was statistically insensitive to hood position and impeller tine configuration.

Leaf loss analysis considering all four machines for all settings and for specific aggressive and nonaggressive settings are shown in table 6. When all settings of all four machines were considered using main plot error, no statistical differences between machines were detected. However, at the aggressive and nonaggressive conditioning levels, the intermeshing roll conditioner had 3.44 and 2.23 percentage points less leaf loss, respectively, than the impeller conditioner with steel "U"-shaped tines. These two differences were statistically significant. The plastic "U"-shaped and the steel "Y"-shaped tines at the aggressive and nonaggressive settings also caused greater leaf loss than the intermeshing roll conditioner, but those differences were less than 2.23 percentage points and were not statistically significant.

Table 5. Percentage leaf loss for impeller machines

Treatment	Leaf Loss (%)
Machine style	
Steel "Y" tines	6.31
Steel "U" tines	7.58
Plastic "U" tines	6.34
$LSD_{0.10}$*	1.94
Impeller speed	
Slow	6.20b†
Fast	7.28a
$LSD_{0.10}$	0.76
Hood position	
Distant	6.77
Intermediate	6.76
Close	6.69
$LSD_{0.10}$	0.93

* $LSD_{0.10}$ is least significant difference at a 90% confidence level.
† Different letters within each treatment in each column indicate statistically different values.

Table 6. Percentage leaf loss for all machines

	Leaf Loss (%)		
Treatment	All	Agg.*	Nonagg.†
Machine style			
Steel "Y" tines	6.31	6.21	6.15
Steel "U" tines	7.58	7.87a‡	7.15a
Plastic "U" tines	6.34	6.14	7.05
Intermeshing rolls	4.67	4.43b	4.92b
$LSD_{0.10}$§	3.62	2.23	2.23

* Agg. represents aggressive machine settings.
† Nonagg. represents nonaggressive machine settings.
‡ Different letters within each machine style in each column indicate statistically different values.
§ $LSD_{0.10}$ is least significant difference at a 90% confidence level.

Conclusions

A faster drying rate was achieved with the high rotor speed in the impeller machines. However, leaf loss in alfalfa was found to be statistically greater for the fast rotor speed than the slow rotor speed. When the intermeshing roll conditioner was included in the drying rate analysis with the impeller machines, there were cases where forage conditioned by the impeller machines exhibited significantly greater leaf loss than forage conditioned by the intermeshing roll machine. In those cases, however, the forage conditioned by the impeller machines dried more quickly than forage conditioned by the intermeshing roll machine. Although the large error term precluded the detection of statistical differences between the impeller machines and the intermeshing roll machine in all situations, the mean drying rate constants produced by the impeller machines were nearly always numerically greater than the drying rate constants produced by the intermeshing roll machine.

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