Chemical conditioning of mixed legume-grass hay

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Chemical conditioning of hay consists of spraying an aqueous solution of potassium and sodium carbonates on the crop at the time of mowing. It is known to increase the drying rate of legumes, especially alfalfa, but it has very little effect on grasses. Chemical conditioning was applied on a relatively pure alfalfa stand, on mixed alfalfa-grass and on pure grass (predominantly timothy). Under good weather conditions during the first cutting, the first-day drying rate of pure and mixed alfalfa increased by 13 and 9%, respectively. Timothy did not benefit from chemical conditioning. Over a 2-d period, the difference between pure and mixed alfalfa vanished; overall increase in the drying rate was 10%. During the second cutting and under humid weather, chemical conditioning had no positive effect on alfalfa. The treatment is very sensitive to weather and to management regarding the rate and efficiency of application.

INTRODUCTION

Field hay drying usually requires 3 or 4 days of good weather to evaporate excess water for safe storage (Savoie et al. 1984). Haymaking losses are generally proportional to the field-curing time and can be greater than 30% (Rees 1982). Mechanical treatments such as conditioning, raking and tedding can improve the drying rate and save perhaps half a day or even a full day of drying (Pattey et al. 1988), thus reducing the risk of getting rained-on, weathered hay. However, each additional mechanical treatment shatters leaves and can cause substantial loss. Savoie (1988) showed that a single tedding treatment in relatively dry alfalfa (40% moisture content) was responsible for 8% dry matter loss in addition to a drop in quality from 21.2% to 20.2% crude protein.

Chemical products that increase the drying rate of forage have the advantage of causing no additional mechanical loss. Tullberg and Minson (1978) were the first to report enhanced field drying of alfalfa sprayed at the time of mowing with a potassium carbonate ($K_2CO_3$) solution. Rotz et al. (1982) sprayed a potassium carbonate solution on alfalfa, clover and bromegrass in the laboratory; they measured drying rate increases of 42%, 20% and 0%, respectively. Chung and Verma (1986) also noted the absence of effect of potassium carbonate on another grass, ryegrass. Rotz et al. (1984) determined that roller-conditioners help spread the solution over the crop. Moreover, the chemical was more efficient on thin windrows in second and third cuttings, under good weather conditions (Rotz et al. 1987). These authors used a 2.8% $K_2CO_3$ aqueous solution applied at a rate of 470 L/ha during first cutting and 280 L/ha on later cuttings. Potassium carbonate is innocuous to animals and does not alter the quality of alfalfa (Johnson et al. 1983).

Practically all of the alfalfa grown in Eastern Canada is mixed in various proportions with grasses, most notably with timothy. The "conditioning" effect of alkaline carbonates is most evident on alfalfa and is negligible on grasses. It would be useful to know the efficiency of chemical conditioning on the drying rate of forages of various mixtures of alfalfa and grass.

The objective of this study was to measure the field drying rate of a mixed alfalfa-grass hay treated with alkaline carbonates at mowing. Sub-objectives included an assessment of the effects of yield, climate and the proportion of grass in the mixture, on the treatment response.

METHODOLOGY

Three fields from the Deschambault Research Station (Quebec) were chosen for the experiment: a practically "pure" alfalfa stand (cultivar Saranac), a mixed alfalfa (cv. Dekalb) and timothy (cv. Climax) stand, and an originally pure timothy (cv. Climax) grass stand. Chemical conditioning was applied at three dates during the first and second cuttings (18, 19 and 20 June and 4, 6 and 12 August 1986).

On each date, a 37-m wide by 50-m-long plot in each field was mowed in 12 side-by-side 50-m-long windrows. A Vicon KM 281 2.7-m-wide disk mower with rubber roll conditioners was used. Because of slight overlap between windrows, the actual average mowing width was 2.6 m; windrow width was 1.7 m. Three side-by-side windrows formed one experimental unit (EU). Two EU were treated with potassium carbonate at mowing and two EU were not treated. Treatment was randomized within the four EU in each plot.

Chemical conditioning consisted in applying at the time of mowing a 3% aqueous solution of alkaline carbonates ($K_2CO_3$ and $Na_2CO_3$) in the form of a commercial powder (ProDry, American Farm Products, Ypsilanti, MI). It was sprayed at a rate of 400 and 300 L/ha during the first and second cuttings, respectively. A 450-l tank was placed on the tractor frame.

The solution was sprayed through five nozzles spaced 500 mm apart on a boom installed between the mower disks and the roller-conditioners, at 670 mm above the ground. Immediately after mowing, two forage samples from each EU were gently lifted and deposited on a 0.90-m by 1.20-m wire-mesh screen for subsequent weighing and measurement of water evaporation. The samples were taken at two random distances along the middle windrow of each experimental unit. Trays were weighed at approximately 3-h intervals between 10:00 h (mowing time) and 20:00 h on the first day and between 09:00 h...
20:00 h on the second day. A 500-g forage sample was collected near each tray at the time of mowing to estimate initial moisture content. Another sample was taken directly from each tray at the end of the 2-d experiment to measure final moisture content. Samples were oven-dried at 65°C for 72 h in accordance with ASAE standard S358.1 (ASAE 1987). The dry matter on each tray was the average of estimates of dry matter based on initial and final moisture contents.

The forage yield of each plot was estimated by chopping four random strips of 5 m by 0.6 m, and adjusting for moisture content. Crop purity was determined by hand separation of two 1000-g samples taken from each plot at each date of mowing. Samples were composed of several random grab subsamples.

Water evaporation from each forage sample in the field was converted into a drying coefficient. This coefficient represents the combined effects of environment, crop physiological status and treatment on drying. Since the environment and the crop were relatively uniform on a given date in a given plot, differences in the coefficient reflected differences in the treatment. The drying coefficient was calculated in accordance with the model used by Rotz et al. (1984):

\[
k = \frac{1}{t} \ln \left( \frac{M}{M_0} \right)
\]

where:
- \(k\) is the drying coefficient (h\(^{-1}\)),
- \(t\) is the drying time interval (h),
- \(M\) is the final moisture content (g/g), and
- \(M_0\) is the initial moisture content (g/g).

This model is slightly different from the one used by Pattey et al. (1988). These authors assumed an equilibrium moisture content \(M_e\) of 0.15 g/g; whereas, the above model implicitly assumes \(M_e\) equal to 0. As indicated by Pitt (1984), the estimation of the drying coefficient during the wilting period \(M > 1.0\) g/g is not sensitive to the choice of equilibrium moisture content. This is also true when \(k\) is estimated over a long drying period.

The drying coefficients were calculated for the first day of drying \(k_1\) and for the first 2 d of drying \(k_2\) excluding night time (12 h were subtracted). These periods correspond to about 9 and 21 h of drying time, respectively. Analysis of the two coefficients allowed an assessment of the persistence of the treatment.

During the first cutting, the experiment consisted of three forage crops ("pure" alfalfa, mixed alfalfa, grass), two treatments (chemical conditioning, control), three dates (blocks), two replications at each date and two samples in each experimental unit. A total of 72 trays were used in a split-split block design. The first and second splits were dates and crops. During the second cutting, the same experimental design was used except it was reduced by one crop since grass yield was insufficient to justify harvest.

RESULTS

During the first cutting, the drying conditions were excellent with much sunshine and no rain. During the second cutting, two out of three replications were rained on; the total sunshine was reduced on account of cloudiness (Table I).

The Saranac alfalfa field was relatively pure, containing only 22 and 11% grass during the first and second cuttings, respectively

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature (°C)</th>
<th>Radiation (MJ/m(^2)/d)</th>
<th>Rain (mm)</th>
<th>Wind (m/s)</th>
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<tr>
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<td>20.0</td>
<td>0.0</td>
<td>2.5</td>
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<tr>
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<td>24.0</td>
<td>0.0</td>
<td>1.4</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
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<tr>
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<td>23.0</td>
<td>19.6</td>
<td>0.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>

(Table II). The Dekalb alfalfa field was closer to a half alfalfa-half grass mixture, containing 63 and 47% grass in the first and second cuttings. The Climax timothy field contained about 60% timothy and 40% other grasses (quackgrass and Kentucky blue grass). The initial moisture content of alfalfa was relatively high between 4.0 and 4.9 g of water per g of dry matter (80–83% on a wet basis). At the first cutting, alfalfa was at the bud stage and timothy at the heading stage; at the second cutting, alfalfa was in full bloom.

Drying coefficients during the first day are reported in Table III. During the first cutting, the chemical treatment increased the drying rate of "pure" alfalfa (Saranac) and of "mixed" alfalfa (Dekalb) by 13 and 9%, respectively, but it had no effect on timothy (actually a 2% decrease of the drying coefficient). The treatment effect was statistically significant \((p = 0.047)\). There was also a significant \((p = 0.024)\) triple interaction between treatment, mowing date and crop. The treatment was more efficient on "pure" alfalfa but the efficiency was not uniform over several days and cuttings. For example, on 18 June, the treatment increased the drying rate by 31%; whereas on 20 June, the treatment decreased the drying rate by 4%. During the second cutting, the chemical treatment had practically no effect on the alfalfa drying rate.

Table IV illustrates the effect of chemical conditioning over a 2-d period. Coefficients were calculated on the base of total diurnal time only; 12 h were subtracted for nighttime between the first and second day. The treated alfalfa dried 10% faster than untreated alfalfa in the first cutting, but only 3% faster than untreated timothy. The chemical treatment did not affect timothy (Table II).
in the second cutting. There was no difference between pure and mixed alfalfa. The treatment effect was statistically significant ($P = 0.001$). The triple interaction (treatment, mowing date, crop) was also observed over a 2-d period ($P = 0.025$).

On the basis of good weather conditions observed during the first cutting, chemical conditioning would save only 2 h of drying after 2 d. For example, alfalfa mown at 09:00 the first day would benefit of 22 h drying by 19:00 h on the second day. Considering an initial moisture content of 4.2 g/g (80.8% on a wet basis), the final moisture content calculated from equation (1) would be 0.373 g/g (27.2% wet basis) in treated alfalfa ($k = 0.110$ h$^{-1}$) and 0.465 g/g (31.8% wet basis) in untreated alfalfa ($k = 0.100$ h$^{-1}$). Untreated alfalfa would require an extra 2 h of drying to reach the same moisture content as the treated alfalfa. However, this could sometimes mean postponing hay baling to the following day and risking nighttime rain or dew on the hay with subsequent losses.

A linear correlation analysis was performed to identify other sources of variation in the drying coefficient (Table V). Initial moisture content and windrow thickness negatively affected the drying coefficients. Each of these two factors explained more variation than chemical conditioning itself. In the second cutting especially, chemical conditioning had no influence on the drying coefficients. The more humid conditions of the second cutting annihilated the effect of potassium carbonate on alfalfa drying.
be the case under very favorable drying conditions for alfalfa. A grass-alfalfa mixture would be expected to respond at an intermediate level depending on the proportion of grass (0% increase in the drying rate) and alfalfa (between 10 and 55% increase in the drying rate).

The potential reduction in field curing time is proportional to the increase of the drying coefficient. A 10% increase over a 2-d period means that drying time can be reduced about 2 h (based on 21 h of daytime between mowing at 10:00 h on the first day and harvesting at 19:00 h on the second day). For example, a crop initially at 80% moisture wet basis (4.0 g/g dry basis) will reach 33% moisture with \( k = 0.10 \) and 28% moisture with \( k = 0.11 \) by the end of the second day. If the strategy is to harvest hay below 30% moisture and barn-cure the wet hay, then it is possible to save a night and a few hours of exposure on the third day. However, in many practical cases, a 10% savings in drying time would decrease the exposure time only a small portion of the total harvest period.

Rotz (1985) considered the economics of chemical conditioning. At a price of $2.20/kg for potassium carbonate, which is the current price in Eastern Canada, the treatment costs $17 per hectare at an application rate of 200 L/ha. Benefits from decreased loss during field curing and increased quality were estimated at $18, $15, $25 and $23 per hectare for the first, second, third and fourth cuttings in Michigan based on simulated results over a 25-yr period. Chemical conditioning is economically beneficial only in later cuttings.

Since a smaller response to the one measured in Michigan (Rotz et al. 1987) was observed in these experiments, the economic viability is doubtful. The results also indicate that drying improvements are not observed uniformly with chemical conditioning. The application level is likely to require fine adjustments as a function of yield and purity of stand. Crop yield and initial moisture content negatively affected the drying rate and overshadowed drying improvements observed with chemical conditioning.

CONCLUSIONS

1. During the first cutting, under favorable weather conditions, chemical conditioning with an alkaline carbonate solution increased the first-day drying rate coefficient of pure alfalfa by 13%, of mixed alfalfa-grass by 9% and of pure grass by -2%. The drying rate increase persisted over 2 d but differences between pure and mixed alfalfa were not observed. The average drying rate increase in alfalfa over 2 d was 10%.

2. During the second cutting, under more humid weather conditions, chemical conditioning did not improve the drying rate of any crop.

3. Drying improvements with chemical conditioning were uneven during the field study. Higher crop yields and a higher initial moisture content decreased the drying rate. Variable yields and initial moisture contents frequently observed in the field explain the uneven response to chemical conditioning.

ACKNOWLEDGMENTS

We thank the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation for a contract related to the present work. The research was supported jointly by an operating grant from the Natural Science and Engineering Research Council of Canada and by Agriculture Canada, Sainte-Foy and Lennoxville Research Stations.

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