

Best practices to hasten field drying of grasses and alfalfa

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Introduction

Rapid drying of hay and haylage shortens the harvest window, enhances forage quality, and reduces the chance for rain damage. Forage generally has about 75% moisture when cut. This means a yield of two tons dry matter per acre must lose:

- 2.3 to 3 tons (550 to 720 gallons) of water per acre to dry to 60 to 65% moisture for haylage
- 5.7 tons (1,370 gallons) of water per acre to dry to 13% moisture for hay

Here we present the best research-based practices to hasten the dry down of hay and haylage. Furthermore we distill these practices into four steps to enhance field drying: proper mowing height, well-adjusted conditioning, laying wide swaths, and well-timed raking/merging.

Biology of drying

Initial drying occurs through natural pathways, including stomata in the leaves as well as the stems, and through conditioned parts of the plant (Figure 1). Leaf tissue is high in water content (about 85%) and contains about half of a plant's water. Leaf tissue has a high surface-to-volume ratio and numerous stomata, which promote rapid drying.¹ Stomata are the openings in the leaf surface that allow moisture loss to the air to cool the living plant and provide a path for carbon dioxide uptake from the air as the plant is growing. Stomata open in daylight and close in darkness or when moisture stress is severe.

The second route for moisture loss is through the stem surface. Stems, which are covered by a semi-impervious waxy layer, have a lower surface-to-volume ratio and fewer stomata. To promote water loss from the plant, this layer needs to be cracked or scraped in a process called **conditioning**. Conditioning the plant continues to enhance drying even after the stomata close.

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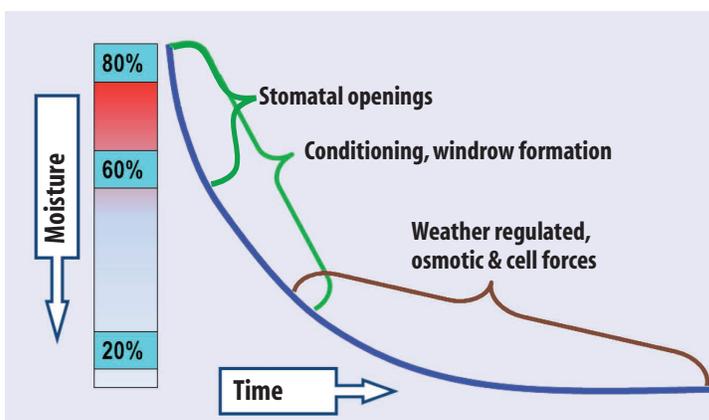


Figure 1. Initially, open stomata, conditioning, and drying in a wide swath promote rapid water loss. Later in the drying period, the rate of water loss is much less because osmotic forces hold water in the plant cells and weather conditions hinder water vapor movement from the stem.

Plants reach a maximum of starch and sugar content late in the afternoon. Even after cutting, forage plants maintain tissue growth and plant function by metabolizing sugars and starches in a process known as **respiration**. Respiration rate is highest at cutting and gradually declines with plant moisture content until it has fallen below 40%,² though microbial respiration may continue at lower moistures. Therefore, rapid initial drying to lose the first 20% of moisture will reduce loss of sugars and starches and result in more total digestible nutrients (TDN) retained in the harvested forage.^{3,4} Research has shown that cutting later in the day can result in higher concentrations of these compounds in the forage at cutting. However, increased respiratory losses overnight and longer total drying time may offset the benefit of afternoon cutting if forage does not lose at least 20% of its water by nightfall of the cutting day. Midwestern data has not shown any forage quality advantage to afternoon cutting.

Practice

In an extensive series of studies, Rotz and Chen collected 5,000 data points on conditioned alfalfa from 1977 to 1984 in East Lansing, MI.⁵ They recorded weather data including temperature, relative humidity, insolation (exposure to the sun's rays), and wind velocity as well as crop-related data such as maturity, cutting, soil moisture content, swath density (width and yield), and swath surface temperature. When finished, Rotz and Chen had an equation that described 75% of the variability associated with hay drying.

Their results state that hay drying is improved with increased plant surface area exposed to the sun, greater solar radiation, higher temperatures, and lower swath density. Their equation also states that drying is decreased with higher soil moisture. The factors not included in the model (such as wind speed and relative humidity) may also play a role in hay drying by either influencing other factors in the equation or making up the 25% of the variance not described by the equation.

Using this information we can design drying methodologies that reduce drying time, reduce rain damage to hay and haylage, and improve forage quality of the harvested hay. We recommend the following four steps:

1 Mow to proper height

Cutting height for alfalfa should be between 2 and 4 inches to maximize yield, whereas grass or legume/grass mixtures should be cut between 3 and 4 inches. Grasses (except ryegrasses and bluegrasses) need a slightly higher cutting height because of the energy that many store in the stem bases for regrowth, so cutting below 3 inches will shorten the life of the grass in the stand. These cutting heights are high enough to keep a wide swath off the ground so that air can move underneath to enhance drying by transporting moist air away. Putting cut forage into a windrow that settles to the wet soil increases drying time, because the windrow gains moisture from the humid air near the ground as well as through capillary action if the crop comes in contact with the soil.

2 Condition properly

Mechanical conditioning at the time of cutting can nearly double the drying rate.⁶ Forage is properly conditioned if the stems of legumes are scraped or broken every 2 to 4 inches and less than 5% of the leaves are bruised.

In general, **roll conditioners** are best suited for alfalfa and alfalfa/grass mixtures, and flail/impeller conditioners are best for grasses. Flail/impeller conditioners cause 1 to 4% more leaf loss from legumes, reducing forage quality, if adjusted to condition for similar drying rate to a roller conditioner.⁷

Rolls condition by crimping or crushing the stem. A **crimping roll** passes the crop between deep flutes on the intermeshing, non-contacting rolls. The deep flutes condition the stem by bending and cracking the stem at intervals. A **crushing roll** passes the crop through intermeshing rolls with small clearances, intermittently flattening the stem. In either case, plant moisture evaporates more easily from these breaks in the epidermis (Figure 2).

Flail/impeller conditioners use rotating fingers to scrape the wax and intermittently crack the stem.

Although conditioning breaks the pathway of water removal from the stem to the stomata, the act of conditioning makes many new exits for water to leave the stem. Conditioning improves drying rate whether the stomata remain open or closed. Research has demonstrated that no matter how wide the crop is laid in the swath, conditioning increases drying rate.⁸

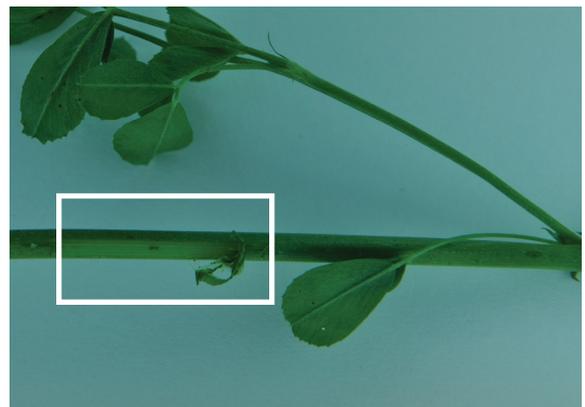


Figure 2. Roll conditioning (left) bends and cracks the stem and impeller conditioning (right) scrapes the stem. Both provide an exit route for moisture.

Roll conditioners: Determining correct clearance

Roll clearance is the spacing between the rolls—this clearance should be uniform across the full width of the rolls. Roll clearance should be slightly smaller than the stem diameter, which usually means setting the clearance at $\frac{1}{16}$ to $\frac{3}{32}$ inch. Larger clearance results in under-conditioning. Rolls that touch wear prematurely and cause excessive leaf loss.

Here's a quick-and-easy way to determine roll spacing:

1. Cut three pieces of household aluminum foil 18 inches in length. The foil strips should be at least 12 inches wide.
2. Form three separate rolls by wrapping foil into roll about half inch in diameter (see photo, top row).
3. **Lower the machine into cutting position, shut the tractor off, remove the key, and block the wheels.**
4. Place one foil roll in the center of the conditioning rolls and the remaining rolls about 1 foot from each end of the conditioning rolls.



Aluminum foil rolls before (top) and after (bottom two) passing through a roll conditioner.

5. Turn the rolls over by hand until the foil rolls come completely through the conditioning rolls. The conditioner rolls will crush the foil rolls (see photo, bottom rows).
6. Determine the minimum roll clearance by measuring the thickness of the crushed foil rolls at their thinnest points.

Adjust roller clearance to meet manufacturer recommendations. If the middle foil roll has greater thickness than the side foil rolls, the conditioning roll may be worn and need replacement.

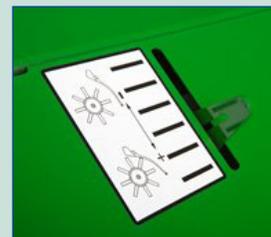
After roll clearance has been set, use roll pressure to increase or decrease the level of conditioning. Forage is properly conditioned if the stems of legumes are scraped or broken every 2 to 4 inches and less than 5% of the leaves are bruised (blackened). If the conditioning level is too low, increase the pressure. If the conditioning level is acceptable, try decreasing the roll pressure to ensure you are operating at the minimum roll pressure that will accomplish conditioning. Operating at too high a roll pressure will cause undue wear on the rolls, excessive power (fuel) use, and crop losses.

Impeller conditioners

Impeller (tine) conditioners have two major points of adjustment. First set your impeller speed to the low setting for alfalfa, usually about 600 RPM, to prevent leaf loss; grass physiology can withstand the higher speed (~1000 RPM), which further enhances drying. Impeller speed can be changed by way of a gearbox lever or by changing the size ratio of the sheaves that drive the impeller. Next, adjust the conditioning hood to abrade the crop, but take care to minimize leaf loss. The hood adjustment clearance will vary by manufacturer. Start with the maximum clearance and adjust to a smaller clearance until the desired level of conditioning is obtained. A properly adjusted impeller should abrade stems of both alfalfa and grass with minimal leaf loss.



The two points of adjustment on an impeller conditioner are impeller speed (above) and conditioning hood clearance (below).



3 Lay hay in a wide swath

Laying the crop in a wide swath that covers at least 60% of the cut area is the most important thing a producer can do to speed forage drying¹⁰ (Figure 3). It particularly enhances the initial 20% water loss to reduce plant respiration and preserve sugars. Conditioning is most effective when swath density is low and weather conditions are favorable.⁹ Thus, think about a mower-conditioner’s maximum swath width capability when making a purchase.

To reduce soil moisture, some allow the ground to dry before cutting or cut their hay in a narrow swath and allow the ground to dry before spreading the crop out. However, research indicates that valuable drying time is lost while allowing the ground to dry,^{8,11} and thus this practice is not recommended.

Wide swaths reduce swath density, increase the crop’s exposure to the sun, and increase crop surface temperature—all factors important to the rapid drying of hay. Additionally, wide swaths keep the crop off of wet soil more than narrow windrows do, since narrower windrows tend to settle through the stubble and make contact with the ground.

There are some drawbacks to wide swathing. First, the swath must be raked or merged to narrow it sufficiently to match the pick-up width of the forage harvester or baler, adding cost to the haying operation. However, the cost of raking or merging is offset by increased forage quality and the fact that today’s high-capacity forage harvesters need to consolidate their crop.^{12,13} Another drawback occurs when pull-type mower-conditioners are used: wide swaths are often run over by the tractor tires, which research shows to be detrimental to hay drying.¹⁴ A compromise is to make the swath width such that only one side of the tractor runs over the swath. This problem can be avoided with mounted or self-propelled mowers, depending on the swath-width and machine configuration.

Rapidly drying hay should reduce TDN losses due to respiration³ (Table 1). Research has shown that wider swaths always result in enhanced drying and therefore produce higher forage quality about 60% of the time. The improved quality occurs because faster drying reduces respiration losses.

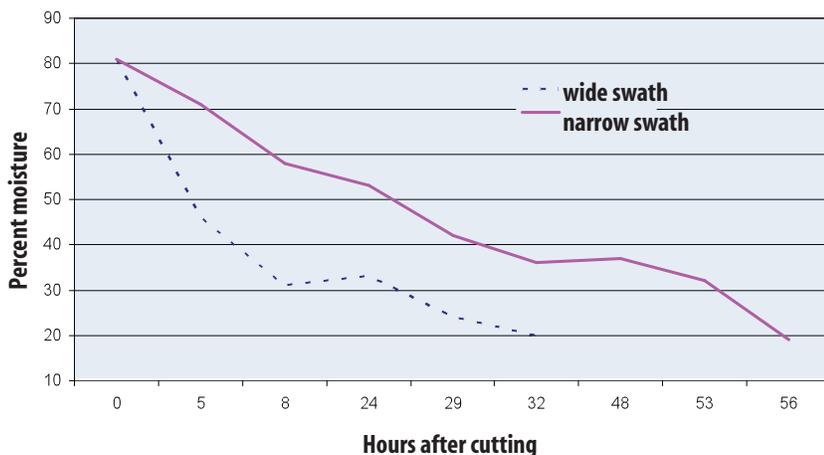
Research quantifies the impact of drying rate on haylage quality.⁴ In studies from Wisconsin (see table) and other states, haylage produced from forage that was dried more rapidly (e.g., wide swath) had higher non-fibrous carbohydrate (NFC). However, rapid drying due to swath width did not influence ash content or fiber digestibility.

Table 1. Post-ensiling composition of alfalfa haylage made from narrow and wide swaths (8 trials; UW Arlington & Marshfield; 2005–2007).

Factor	Wide swath	Narrow swath	Wide swath vs. narrow swath results
Hours to dry to 65% moisture	19.5	29.7	-10.2
Crude protein, %	19.3	18.7	0.6
NDF, %	39.7	40.9	-1.2
NFC, %	29.9	28.2	1.7
Ash, %	10.1	9.7	-0.4
Lactic acid, %	4.1	3.5	0.8
Acetic acid, %	1.7	1.9	-0.2
Relative forage quality	160	149	11

NDF = neutral detergent fiber; NFC = non-fiber carbohydrate

Figure 3. Representative drying curves for narrow and a wide swath widths.



Benefits of conditioning wide swaths when making haylage

- Haylage moisture is reached 0 to 4 hours faster than unconditioned wide swaths.
- A mower-conditioner can be used for both haylage and dry hay making.
- A mower-conditioner is capable of producing either swaths or windrows; windrows can help reduce losses when yields are low.
- A mower-conditioner is likely to have a higher resale value than a mower without conditioner.

Benefits of not conditioning wide swaths when making haylage

- Slower drying may be an advantage if the forage harvester cannot harvest fast enough to keep ahead of forage drying when drying conditions are very good.
- A mower without a conditioner can cost less.
- A mower without a conditioner will use 30 to 40% less power, resulting in fuel savings.

4 Rake/merge ahead of chopping or at a moisture content to minimize leaf loss for hay

Raking/merging is required to consolidate crops for today's high-capacity forage harvesters. Harvesting less than harvester capacity reduces energy efficiency, increases labor costs, and damages the stand because of the wheel traffic caused by more passes of the harvester on the field. When making haylage, ideally you should rake/merge just ahead of the forage harvester. In situations where the crop is getting too dry, raking/merging can be used to reduce the crop drying rate. However, large consolidated windrows that get rained on can be very difficult to dry out again.

Raking moves the crop off of wet soil, reorients the wet bottom layer toward the sun, and reforms the windrow, promoting air movement (Figure 4). To reduce leaf loss, you should rake/merge when alfalfa is above 40% moisture and grass is above 25% moisture. For alfalfa, this is generally 24 hours after mowing, but this depends on drying conditions. Grasses, which should be allowed to dry more in a wide swath, suffer less leaf loss when raked at the lower moisture content. Grasses may need to be tedded once ahead of raking to enhance drying. Raking increases the drying rate on the day of raking, but following the initial improvement, the heavy swath formed by raking can slow the drying rate.⁹



Figure 4. (Clockwise from top) Rotary, wheel, and parallel-bar rakes reorient the wet bottom layer of the crop toward the sun and re-form the windrow to promote air movement.



Fluffing or reorienting

Fluffing or reorienting has been used to mix the crop and improve drying. Research has shown that such reorientation improves drying rate on the day of treatment, but subsequent days do not show improvement.⁸ In most cases, fluffing does not have a significant positive effect on drying rate. Another technology, **windrow inversion**, has also been used to speed drying. Inversion moves the crop off the wet soil, reorients the wet bottom layer toward the sun, and re-forms the windrow, promoting air movement. Windrow inversion has been shown to increase drying rate right after the operation, but overall the crop does not achieve baling moisture in a significantly shorter time.^{15,16} Research has shown that windrow fluffed right after cutting has a more open structure than the windrow treatment, but within an hour or so this open structure is lost as the crop wilts. Generally, windrow inversion has not proven economical for legume crops.

Raking should be done so that tines minimally touch the soil to reduce soil incorporation into the windrow. Mergers may offer some benefit since they pick up hay and move the crop on a conveyer rather than across the ground, resulting in reduced leaf loss and soil contamination (Figure 5).

Tedding is the process of lifting and throwing the cut crop to hasten drying by increasing air circulation and exposing new surface areas of the plant to the sun. Proper tedding involves spreading the crop over the entire cutting width while avoiding running over the crop. Pattey¹¹ found that under favorable weather, tedding nearly doubled drying rate compared to narrow windrows but only slightly improved drying rate compared to wide swaths. Like conditioning, tedding is also influenced by drying conditions (weather); under more humid conditions, tedding's benefit is reduced by about half.

Tedding is recommended for grass hay since grasses tend to consolidate and need to be aerated for drying to baling moisture. Alfalfa also can benefit from tedding, but the gain is less and because alfalfa leaves can become brittle when dry, tedding can result in increased leaf loss. Tedding alfalfa just as the morning dew leaves the field helps maintain the leaves.

Because the tedding process requires an extra field pass, its ability to shorten drying time and the harvest window while producing higher quality hay/haylage must be weighed against the economic benefit of capturing this quality or avoiding loss due to rain.



Figure 5. Mergers pick up and move the crop on a conveyer rather than across the ground, reducing leaf loss and soil contamination.

Key points for drying hay and haylage

- Cut forage at a **3- to 4-inch height**.
- **Condition** to increase the drying rate of hay and haylage. While the positive impact of conditioning is less for haylage in wide swaths (see sidebar), conditioning is essential for making haylage in windrows and dry hay.
- **Lay your crop as wide as possible** (at least 60% of cut width).
- **Rake or merge** your crop into windrows to match the capacity of the harvester or baler. To minimize leaf loss and soil contamination:
 - Merge haylage just ahead of the harvester to avoid rain on a windrow. If the crop is getting too dry and rain isn't a concern, merge sooner to slow drying.
 - Rake dry hay when moisture is above 40% for alfalfa and 25% for grass, respectively. If these thresholds are missed, then rake with dew to minimize leaf loss.

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Resources

University of Wisconsin-Extension Team Forage website:
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