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REDUCING THE RISK OF RAIN-DAMAGED HAY

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Introduction

Hay remains the most popular method for harvesting forage for feeding livestock but silage use has been increased by introduction of the round bale silage system in recent years. Dry hay is very stable and transports well but can suffer large losses of yield and quality during storage. Rapid removal of moisture from the hay crop minimizes the probability that rain damage will occur during the harvest process.

The Drying Process

When plants are growing, it is to their advantage to limit moisture losses. They do this in several ways. The outer surface of plants is covered with a waxy layer called the cuticle. The cuticle is very effective at limiting the loss of water. The great majority of water that plants use when they are intact and growing moves out through pores called stomates in the outer layer. Stomates can be opened or closed as necessary to control the movement of water and gasses from the plant. Stomates are found mostly on the leaves and although they are very numerous, cover only 1-2% of the total surface area. These well-developed systems for restricting the loss of water in growing plants cause problems in obtaining fast hay curing. Due to all of these factors, moisture loss during hay curing has two distinct phases. The first and the most rapid phase covers the first 20% or so of the total drying time but accounts for up to 75% of the total water loss. During this phase, water is lost from leaf surfaces and through open stomates. British research indicates that after moisture concentration reaches about 60%, the stomates close and drying rate slows drastically. Moisture is also lost through the cut ends of the stems but this is not very effective. Mechanical conditioning is effective because it physically breaks this cuticle layer which allows additional water loss through this otherwise nearly waterproof layer.

Environment strongly affects hay drying. High levels of solar irradiance, low humidity levels and wind speeds of 10-15 mph are desirable. We can take advantage of all the sun that is available by making the swath as wide as possible, covering 75% or more of the surface area. If the soil is wet, it may be best to make a slightly narrower swath to let the bare area dry and then turn the hay after it dries on top.

Solar Radiation

About 20% of the incident solar radiation is reflected back into the atmosphere; the remainder is absorbed and aids in the evaporation of water. The sunshine intercepted by plants is dissipated mainly either by heating the forage material or evaporating water. However, the sun's radiation does not really penetrate very far into the hay windrow or swath. It has been estimated that less than one-half of the radiation penetrates beyond a 1-inch depth. This is a major reason for the emphasis placed on maintaining the maximum swath surface area during drying. This increases the proportion of the forage mass that is affected by the sun's rays. Temperatures on the surface of a mowed swath may be as much as 40oF higher than that of the surrounding air on a sunny day.

The layer of air nearest the plant surface is called the boundary layer. The air nearest the surface of the alfalfa is more humid, and the air further away is less humid. Mixing this humid air with the surrounding, less humid air, improves drying because the moisture in the hay can move more readily into drier air. The presence of a roughness layer, such as plant hairs, increases the thickness of the boundary layer and reduces turbulence. We now believe that this may be one reason red clover hay dries more slowly than some other species, especially if it is not conditioned well.

A good way to visualize the impact of the weather on hay drying is that weather sets upper limit for how quickly a crop can dry. Other factors, such as forage species, mechanical or chemical conditioning etc. determine how close we come to achieving that potential.

Mechanical Conditioning

Mechanical conditioning hastens drying by physically breaking the cuticle layer discussed previously. This helps to defeat the plant's tendency to retain the water it contains. Mechanical conditioning is considered to be an effective way to improve the drying rate of all types of hay. In some cases, a good job of conditioning may actually halve the time required for hay curing.

Just after mowing, drying occurs primarily at surfaces exposed to the atmosphere and, thus, exposed to solar radiation. The humidity level within the swath is probably near 100% just after cutting, but as drying proceeds the humidity within the swath declines and eventually approaches levels in the outside atmosphere. Increasing surface area by making a wide swath helps to intercept more sunlight and hastens drying. Swath structure, and thus drying rate, may be adversely affected by severe crushing treatments due to increased difficulty in achieving and maintaining a low-density swath. Tedding may aid in maintaining a loose structure and maximum surface area. Tedding should be done shortly after mowing or early enough in the day that some moisture remains in the leaf to prevent excessive losses.

Under high humidity, relatively cool conditions, hay does not dry as rapidly as under low humidity high temperature conditions. A good corollary is found in the way in which tobacco leaves become moist and pliable under high humidity conditions. Likewise, under high humidity conditions hay may not by able to reach the 20% moisture level recommended for baling dry hay regardless of the time spent in the field. At a relative humidity of 80% alfalfa would not dry below 25 to 27% moisture. It is because of this problem and in order to reduce the likelihood of rain damage that alfalfa hay is sometimes baled at moisture levels above 20%. Our data comparing alfalfa hay storage in round and rectangular bales indicates that for storage without heat damage, alfalfa in round bales should be slightly drier (18% moisture) than similar alfalfa in rectangular bales.

Chemical Desiccants

Potassium carbonate and sodium carbonate may be applied as a water solution to hasten hay drying. Legume hay benefits more from the application of these desiccants than grasses. Success with chemical desiccants is greatly affected by the achievement of good distribution of the material over the alfalfa stems. This requires 30 gal/acre or more of material per acre. The need for such a large volume of water for best application of these materials has been an important factor limiting their adoption. Research is under way with lower-volume alternatives for applying the chemical desiccants.

Potassium carbonate (K2CO3) has been widely studied in recent years as a chemical conditioning agent to hasten hay drying. This material and similar compounds like sodium carbonate increase drying rate when applied in water solutions at the time of cutting. Apparently they act in some way to render the cuticle layer less restrictive to water movement. Field research with potassium carbonate in recent years indicates that the response is greatest on cuts other than the first and under conditions of lower rather than higher humidity. The latter situation is not surprising since we depend upon the air surrounding the hay swath to remove hay moisture. If this air is already near its moisture holding capacity, moisture moves out of the hay less rapidly.

Tedders

Tedding hay after it has been cut mixes the crop to break up clumps of forage and distributes the crop over the entire surface area. Distribution over a greater surface area increases interception of sunshine, leading to more rapid drying. Research indicates that tedding can increase hay-drying rates by 20-40%, possibly reducing the curing period by one day. The initial tedding can be done after a brief wilting period following cutting. Clumps of forage seem to break up more effectively after 2 to 4 hours of wilting than immediately after mowing. To avoid excessive leaf loss from legumes like alfalfa, tedding should not be done when the leaf component is brittle. Tedding causes the loss of some dry matter, between 3 and 10% or so, depending upon the moisture content of the leaf component. Tedding can also be done after the first day as long as it is done before the leaf dries out.

Hay Storage

Losses

Large losses in yield and quality can also occur during storage of hay prior to feeding. Losses during hay storage can exceed 40% under the most severe conditions and commonly average 25% for round bales stored outside on the ground during one season. Round bale storage losses are greater than is commonly understood, due partly to the cylindrical shape of the package.

Generally the greatest proportion of the total loss on bales stored outside on the ground occurs on the bottom, due to wicking of moisture from the soil. An inexpensive solution that may reduce losses from approximately 25% of the dry matter yield down to 16-18% is to break soil/bale contact by elevating bales on crushed rock, poles, pallets or some other means of providing air space between the bottom of each bale and the soil surface. Elevation is not necessary for bales covered in solid plastic since the plastic layer provides a barrier against moisture movement from the soil. Our research suggests that elevation would be beneficial even for netwrapped bales.

Storage losses affect the cost of hay even if it is produced on the farm. Assuming that weathered hay is lost, since it is not consumed, the cost per ton of hay actually consumed increases proportionally with the increase in weathering. Production costs for good quality legume hay are $50 per ton or more depending on yields, production inputs and other factors. When the quantity of hay available is reduced by storage losses, these production costs must then be apportioned over a smaller amount of hay, thus increasing the unit cost.

Storage Options for Round Bales

Bale Binding Materials. Plastic mesh wrap (netwrap) and solid plastic wrap binding materials can be used in place of sisal or plastic twine. Application of these materials costs $1.50 - $2.25 per bale but, since they are binding materials, twine cost is reduced about $0.50 per bale. Both also reduce bale tying time compared with twine. Our research showed that solid, self-adhesive plastic wrap on tall fescue round bales reduced losses to levels not different from bales stored inside. Across two trials, bales stored on the ground had an average of 4.4” of weathered material. These 5 x 4 foot bales averaged about 0.4 tons each, so the cost per ton for solid plastic would be approximately $3.75. Disposal of used plastic materials is an environmental and cost factor to be considered.

Inside Storage. The cost of inside storage does not differ greatly from that of some other storage options. Hay sheds adequate to store 250 5x4 foot bales can be constructed for approximately $7,500. With a ten-year life and 10% interest, the annual cost per bale stored would be $3.30 at full capacity.

Tarps, Covered Stacks. Tarps can be an economical means of covering stacks of round bales. Bale row covers reduce losses to levels comparable to inside storage if the bales are also elevated off the ground. Hay moisture is a consideration in determining which bales should be covered or stored inside. Research and observations indicate that hay baled at moistures much above 20% and placed in stacks immediately is more prone to molding and heating than would otherwise be the case. Tarps and bale row covers must be secured very well to remain in place during several months of storage.

Round Bale Silage

A recent development that shows promise for further reducing field and storage losses of forage is round bale silage. Silage is produced by forage, between about 45 and 65% moisture, and wrapping the bales in 4 layers of stretch-wrap plastic. Some producers effectively preserve forage at lower moisture levels that use 6 layers of plastic but the shelf life may be shorter.