HUMIDITY, HAY MOISTURE AND HARVEST MANAGEMENT

Paul W. Brown[1]

ABSTRACT

Low moisture hay is vulnerable to increased loss of leaf material during raking and baling operations. Growers in the Desert Southwest regularly face challenges associated with low moisture hay due to the region's intense dryness. This paper provides a general overview of the humidity-hay moisture issue including some background on the relationship between hay moisture and relative humidity, the results of some initial Arizona studies on this subject and some thoughts on how growers might use this relationship to their advantage when harvesting hay during periods with low humidity.

Key words: alfalfa hay moisture, hay monitors, relative humidity, equilibrium moisture curves, humidity and hay management

INTRODUCTION

Low humidity conditions make production of high quality alfalfa hay a challenge during the late spring and early summer in many parts of the Desert Southwest. Low humidity levels and intense sunlight can rapidly dry cut hay to levels considered suboptimal for manipulation and baling, leading to less leafy and lower quality hay. Alfalfa producers clearly understand that higher humidity levels translate to higher quality hay and perform many of their haymaking operations after dark or shortly after sunrise when humidity levels are highest. The relationship between humidity and hay moisture was first evaluated in the 1930s (Zink, 1937) and published equilibrium moisture curves are available from a number of sources (Zink, 1937; Dexter et al. 1947; Hill et al., 1977; ASAE, 1998). However, most of this work has been completed in humid regions where excess hay moisture is a common challenge when processing and baling hay. Efforts to examine the humidity-hay moisture relationship and possible ways this relationship can be used in hay management have not be addressed to any great extent in the Desert Southwest. This paper provides a general overview of the humidity-hay moisture issue in the Desert Southwest, then summarizes some initial studies related to humidity and hay moisture and concludes with some thoughts on how growers might use this relationship to their advantage when harvesting hay during periods with low humidity.

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EQUILIBRIUM MOISTURE CONTENT: ALFALFA HAY

A number of sources have addressed the question of how humidity impacts the moisture content of alfalfa hay (Zink, 1937; Dexter et al., 1947; Hill et al., 1977; ASAE, 1995; Collins and Coblenz, 2007). This relationship is typically presented as an equilibrium moisture curve (EMC) wherein hay moisture is plotted as a function of relative humidity (RH; Figure 1). Such curves are developed by placing hay in controlled humidity environments and then measuring moisture content once the hay has reached moisture equilibrium. The equilibrium RH associated with a given hay moisture content provides an indication of the energy status of the water in hay. The energy status of water, often referred to as water potential or water activity, determines how water moves in the environment with movement always from high to low energy. Temperature impacts the equilibrium moisture relationship as well which explains why there are multiple curves in Figure 1. At a given equilibrium level of RH, hay moisture declines with increasing temperatures. Note, however, that the impact of temperature (e.g., 95°F vs 70°F) is far less important than the impacts of relative humidity which can vary by a factor of three (e.g., 70% in morning and 20% in afternoon) over the course of typical day in the Desert Southwest.

The basic shape and accuracy of these published EMCs have been confirmed in lab studies over the past two years at the University of Arizona. These studies also confirmed the work of Dexter et al. (1947) that similar curves can be used for both stems and leaves.

Equilibrium moisture curves such as the ones presented in Figure 1 provide some guidance on the RH levels required for selected hay operations. For example, many growers in Arizona bale hay when the moisture levels range from 12-15% (wet basis). The EMCs indicate the RH associated with this level of hay moisture ranges from 50-70%. The fact that maximum RH in the Desert Southwest often fails to reach this range during the late spring and early summer months (Figure 2) explains why it is difficult for producers to limit leaf loss when baling at this time of year.

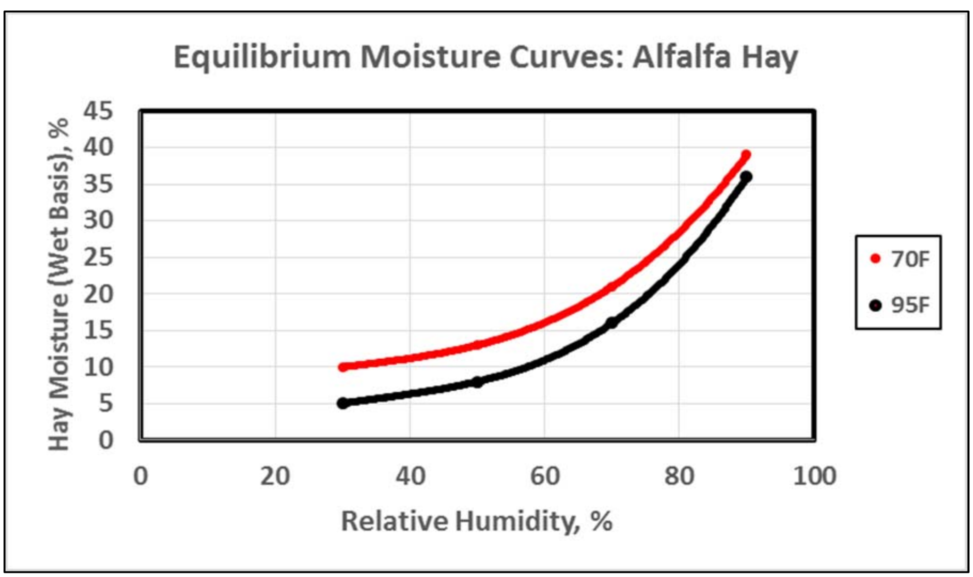

Figure 1. Equilibrium moisture curves for alfalfa hay at 70°F and 95°F. Adapted from Collins and Coblentz (2007)

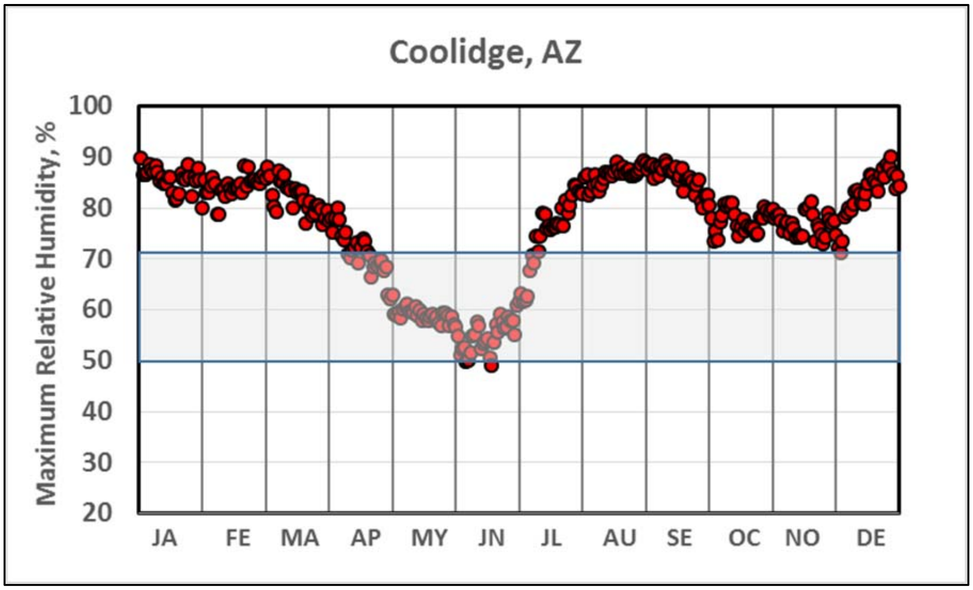

Figure 2. Average maximum RH near Coolidge in central Arizona. Shaded area represents equilibrium RH for alfalfa hay with a moisture content of 12-15%.

While the results in Figure 2 suggest the likelihood of suboptimal haymaking conditions in central Arizona during late spring and early summer, it is important to note that standard measurement height for temperature and humidity (e.g., CIMIS or AZMET weather stations) is typically five to six feet above the surface. Temperature and humidity vary with height above the surface, and in most cases change in a manner that results in higher humidity near the surface of hay fields during the nighttime hours when many haymaking operations take place. Following sunset energy is lost from the surface through emission of long wave radiation which leads to surface cooling. Air in contact with this cooler surface also cools causing air temperatures to decrease. This process leads to the development of a temperature inversion wherein temperatures are coolest near the surface and increase, often rather quickly, with elevation above the surface. This cooling near the surface results in an increase in RH even without the addition of water vapor due to the strong dependence of RH on temperature. On a typical night with clear skies and light winds, RH is highest at the surface and decreases with elevation above the field. In addition, some evaporation continues after sunset which adds more moisture to the near surface air, further increasing near-surface RH. Humidity measurements made in Arizona suggest RH values increase 5-20% between standard weather station measurement height and the near-surface zone where hay resides. Adding further to the potential for moisture improvement is that temperatures at the surface typically run 2-5°F cooler.

Two meteorological phenomena can disrupt this trend of increased near-surface RH and hay moisture on a given night. The most obvious to hay producers is wind which through turbulent transfer blends the warm, dry air aloft with the cooler and more humid near surface air, leading to warmer and much drier conditions at the surface of the field. Clouds, represent the second factor that can prevent or minimize the formation of the nocturnal inversion. Clouds reduce the net loss of long wave radiation, leading to less surface cooling and weak or non-existent inversions.

HAY MOISTURE STUDIES IN ARIZONA

During the past few years we have been developing the equipment and capability to better understand the humidity-hay moisture dynamic in Arizona. One very useful piece of equipment that has been developed is the automated field scale that can measure the change in weight as the moisture content of hay fluctuates (Figure 4). Metal storage shelves lined with aluminum window screen serve as trays to hold hay samples. The trays are suspended from a pair of load cells that are attached to frame made of 1" diameter PVC pipe. Picture frame wire is used to connect the trays to the load cells with wire length adjusted so the trays remain close to the surface without touching the stubble. A combination temperature/relative humidity sensor is attached to the frame to provide local measurements of these important meteorological variables. The development of these scales has lessened the time required to monitor hay moisture in the field and have improved the accuracy of moisture measurements that were previously obtained using manual sampling techniques. Larger versions of the scale (depicted in Figure 4) that can handle wider and taller swaths/windrows are under development.

Figure 3. Small, portable field scale used to measure changes in hay moisture after harvest.

Figure 4 provides an example of the type of information that can be obtained using these field scales. The data presented show the drying process of hay cut late in the day (5:30pm) in September in central Arizona. Differential shading in Figure 4 identifies the day and night periods during the dry down event. Note that bulk of the water lost during the dry down process occurs during the daylight hours. Aside from the first night after cutting when hay moisture was above 60%, moisture levels remained static or increased during the night hours. The rapid loss of water during the daylight hours is due to the energy input from the sun combined with a greater daytime water vapor gradient between the hay and the atmosphere caused by low daytime

RH. At night with no solar energy to enhance evaporation and increased RH due to cooling temperatures, there is little or no evaporation and often an increase in moisture.

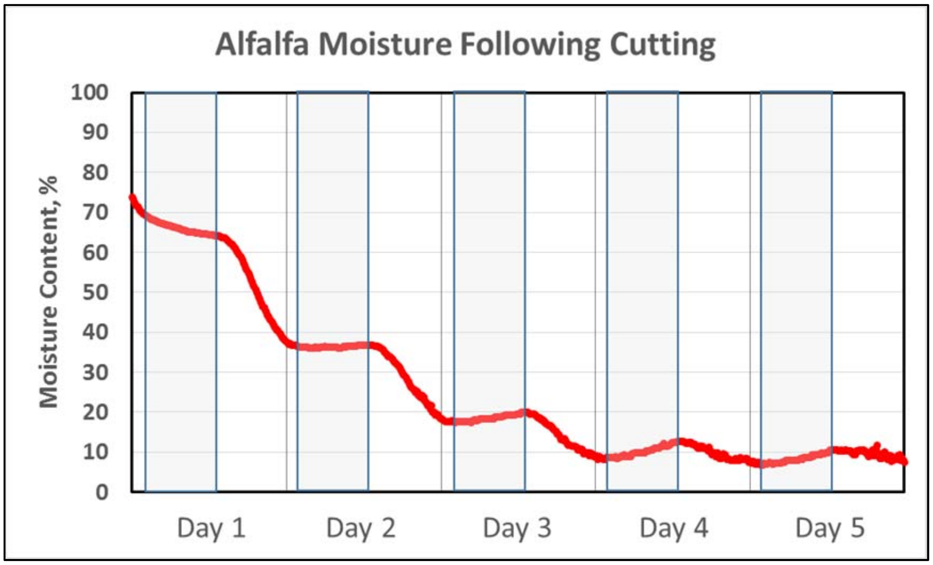

Figure 4. Hay moisture (fresh weight basis) plotted as a function of days after cutting. Nighttime periods indicated by grey shading.

Recent work with the hay scales has provided some initial results regarding the applicability of using RH and/or EMCs to assist with hay management. Several companies sell hay monitors that consist of a humidity sensor, data logger and telecommunications device that can contact field crews via cell phone or text messaging when RH reaches a user-identified level (Ottman and Brown, 2015). The challenge with using a hay monitor is identification of the appropriate RH level that triggers the telecommunications event. Initial studies suggest an instantaneous or current RH value is not a good predictor of hay moisture. However, when RH is averaged over the nighttime hours, a rather strong relationship with hay moisture results (Figure 5) and this relationship resembles the EMC (Figure 6). It is not surprising that average RH serves as a better predictor of hay moisture than current RH as the averaging process provides an assessment of atmospheric moisture over an extended period. While more work is clearly warranted to better understand how to use RH in hay management, the results of these initial field studies suggest RH-based hay monitors may be an effective hay management tool with only minor adjustments in engineering/design.

MANAGING HAY MOISTURE DURING PERIOD OF LOW RELATIVE HUMIDITY

While the previous paragraphs and figures provide some insight on how RH impacts hay moisture, guidance is still needed on how to improve hay moisture during periods with low RH. Aside from applying small amounts of water to the windrow (Orloff and Mueller, 2008) or using humidification equipment in front of balers, are there any other options for improving hay moisture during dry periods? Our initial drying studies suggest stem moisture helps humidify the swath/windrow the first day or two after cutting which could lessen leaf loss during raking operations. The general recommendation is to rake hay when hay moisture is above 40% to avoid high rates of leaf loss (Rotz and Muck, 1994). Leaf moisture can decrease below 40% the day of cutting during hot and dry weather conditions. Stems dry more slowly and generally retain sufficient moisture after the first day to produce an equilibrium RH in the 90-100% range (Figure 1) which means stem moisture can help rehydrate the much drier leaves during the evening hours. To take advantage of this process raking operations would need to be scheduled in the early morning hours, preferably the first day or two after cutting. Once stem moisture dries to low levels the atmosphere must supply the bulk of the moisture to moisten the swath (both leaves and stems).

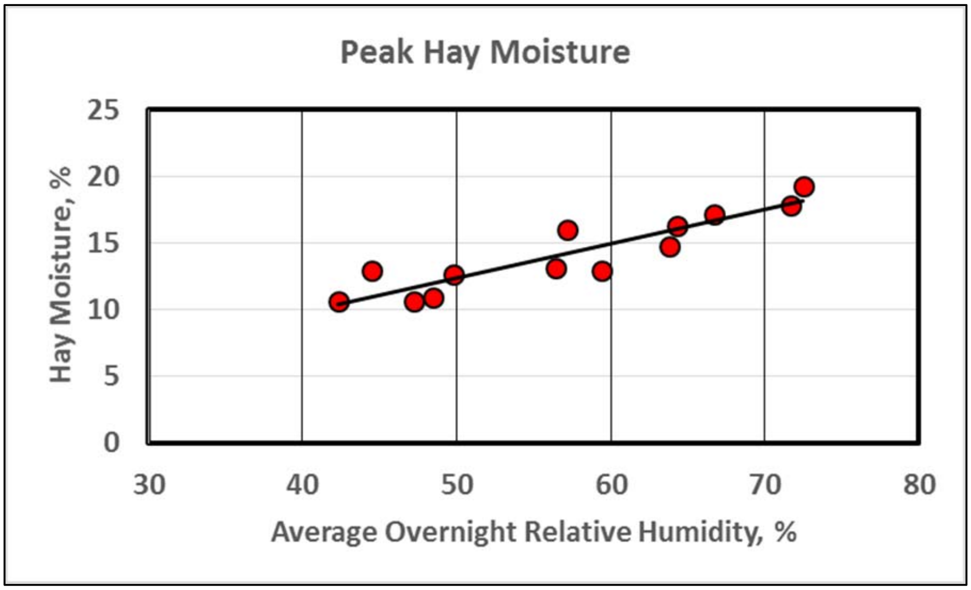

Figure 5. Peak hay moisture content at dawn plotted as a function of average overnight RH.

Another management option that may improve RH levels above hay fields is soil moisture. In humid regions higher underlying soil moisture is associated with slower drying and/or wetter hay (Iwan et al., 1993). All hay fields in the Desert Southwest are irrigated which opens the possibility of adjusting irrigation schedules to enhance soil moisture. Hay fields are generally quite dry when cut to lessen the chances that equipment will get bogged down in wet areas and to minimize problems with soil compaction. It is important to note, however, that the equilibrium RH associated with soil dried to the wilting point approaches 98%. Soil moisture moves upward toward the surface at night, driven both by capillary and thermal factors and some of this water is lost to evaporation which humidifies the air just above the surface. Our very preliminary assessment of this question suggests altered irrigation schedules that result in higher soil water contents at harvest could enhance movement of water vapor from the soil to atmosphere, resulting in enhanced hay moisture. The challenge in using this approach is finding the balance point that provides enhanced moisture but avoids excessive soil wetness that could inhibit field operations and/or increase compaction. This balance point will vary with soil type and would surely require some trial and error to implement if warranted. Growers using sprinklers and subsurface drip irrigation might find these adjustments easier to deploy than those using flood and furrow irrigation.

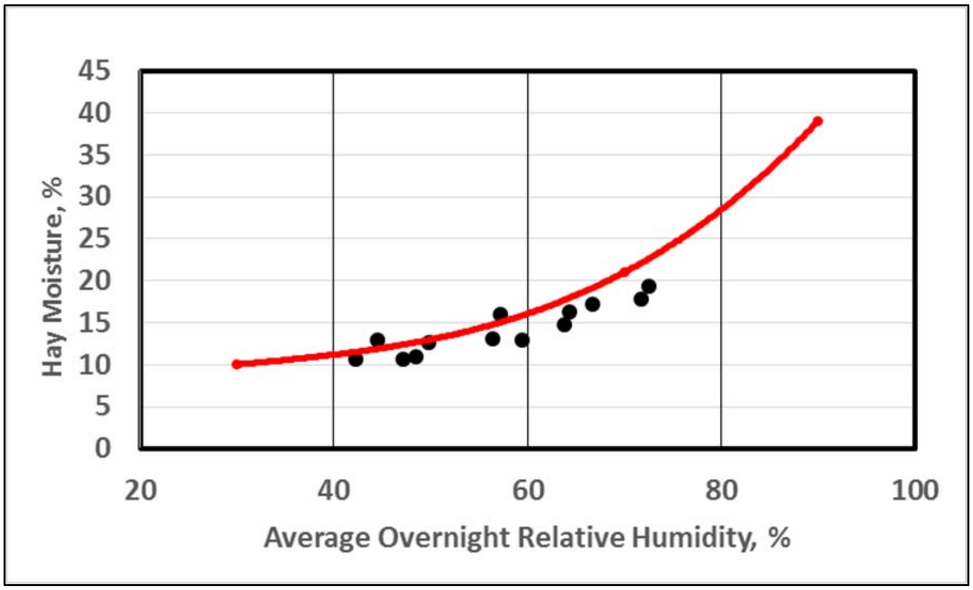

Figure 6. Data in Figure 5 closely follow the EMC (red curve) for alfalfa hay.

Windrow management/geometry may also provide options for improved moisture during dry periods. Wider swaths and less dense windrows are commonly recommended to enhance drying rates (Savoie et al., 1984; Orloff and Meuller, 2008); the wider swaths exposing more hay to solar radiation and air flow. Given the humidity-temperature dynamics during the nighttime hours in the Desert Southwest, wider swaths and windrows that have less vertical height may keep the hay in a cooler and higher humidity environment that could enhance hay moisture content. Wider swaths and windrows may also collect more of the water vapor moving upward from the soil surface, further enhancing hay moisture.

CONCLUDING REMARKS

Results gathered to date from studies conducted in Arizona indicate utilization of field level RH data can assist with hay management during periods of low RH in the Desert Southwest. More recent, albeit preliminary studies, suggest adjustments in cultural practices such as irrigation management and windrow geometry may also improve moisture conditions during dry weather. Further studies are planned for 2016 to assess: 1) whether adjustments in cultural practices can have a measureable effect on hay moisture and 2) how better to use RH data and hay monitors to manage hay operations.

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