ALFALFA HARVEST MANAGEMENT PRINCIPLES

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ABSTRACT

The key elements to alfalfa harvest management are 1) Selection of proper harvest schedules, and 2) Use of proper harvesting techniques to preserve the quality of alfalfa after it is cut. The selection of the maturity at which alfalfa forage is harvested (cutting schedule) is unquestionably the most powerful technique under the grower's control to impact quality and to a considerable extent yield. Economic analysis of cutting schedules indicates that in years with a wide price spread between Supreme or Premium and Fair quality hay (typically low price years) it is more profitable to aim for high quality, while aiming for high yield is more profitable when the price spread between quality grades is small (typically high price years). Sound haymaking practices are important for rapid curing and to preserve forage quality. This includes proper conditioning at cutting, the use of wide swaths, and timely raking and baling.

Key Words: alfalfa, *Medicago sativa*, yield, forage quality, cutting frequency, haymaking, raking, baling, storage

INTRODUCTION

Proper harvest management is essential for profitable alfalfa production, particularly manipulation of quality and yield. The benefits of previous production practices (i.e., successful stand establishment, variety selection, sound pest management practices, etc.) can be negated if careful attention is not paid to harvest management practices. Proper harvest management is not limited to selecting a cutting schedule. Harvest management also encompasses the time of day when harvest and baling occurs, conditioning, windrow width, appropriate moisture levels for raking and baling, and the use of drying agents or preservatives. In addition to being cut at the proper time, the alfalfa must be rapidly dried to avoid respiration losses and preserve forage quality. Since leaf percentage is so critical for preserving quality, an important objective is to retain as many leaves as possible.

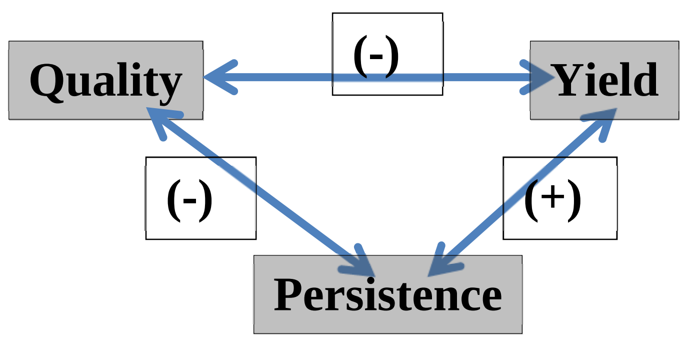

Figure 1. Proper harvest strategies are a complex compromise between obtaining high yields, high quality, and stand longevity. Generally, short cutting schedules which maximize quality result in lower yields and shorter stand persistence.

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The two major elements of proper harvest management are 1) Selection of a cutting schedule to maximize yield, quality and stand persistence, and 2) Harvest techniques to maximize quality of the harvested package.

CUTTING SCHEDULE STRATEGIES

Cutting frequency, or more precisely the maturity of the alfalfa when it is cut, has a more profound effect on forage quality and yield than perhaps any other single factor. Simply put, yield and forage quality are almost always inversely related (Figure 1, Figure 2). As the alfalfa plant matures, yield increases but forage quality decreases (referred to as the Yield/Quality Tradeoff, Figure 2). This phenomenon is the scourge of the alfalfa producer and is a major source of frustration. It is possible to achieve high yield or high forage quality, but ordinarily not both.

Why does forage quality change so dramatically in a matter of days of growth? That is because 1) as the crop grows and yield climbs, this increase in weight is primarily stems over leaves – thus lowering quality, 2) the stems become more lignified, e.g. much higher in fiber (ADF and NDF), and less digestible – further lowering quality. This is a very powerful mechanism for lowering quality from about 20 through 35 days of regrowth.

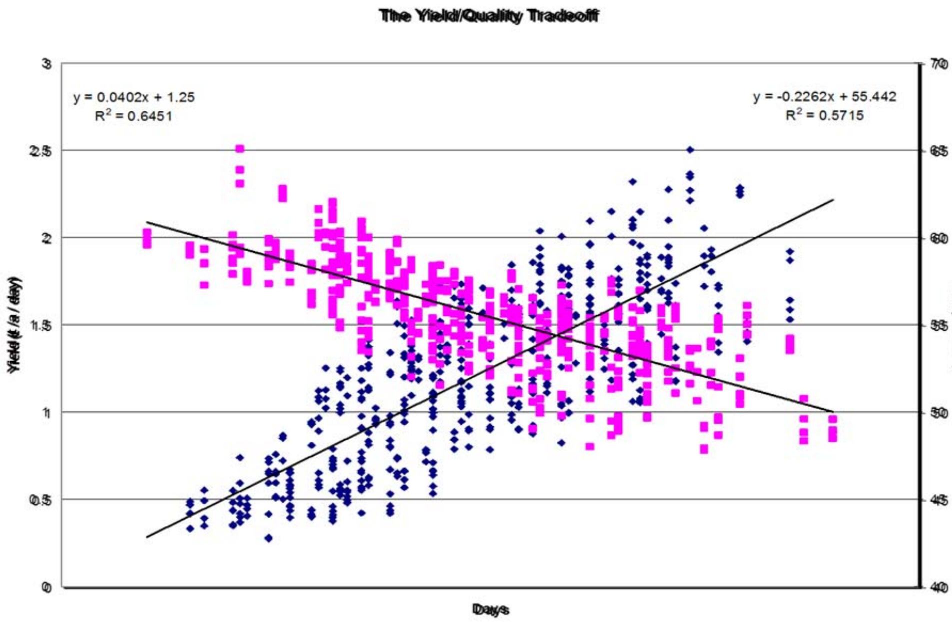

Figure 2. Tradeoff between yield and quality (TDN) as a function of harvest schedule is illustrated by this data from harvests every 2-3 days in Yolo County, CA. The scatter shows differences in cut (e.g. 1st, 3rd, 5th over 2 years, but higher quality harvests were always lower in yield.

A long interval between cuttings ordinarily results in a higher level of carbohydrate root reserves and a concomitant increase in plant vigor. This, in turn, results in higher total seasonal yield and longer stand persistence. Thus, the challenge for growers is to discover the compromise which gives high yield and good quality, along with good persistence, but not necessarily the highest yield or the highest quality possible.

Economics. Whether it is more profitable to aim for high quality or to sacrifice some quality for higher yield depends on market conditions and the price premium for "dairy" quality alfalfa in a given year. Generally speaking, the price premium is greater in overall low-price years than high-price years (Figure 3 and 4). In high price years the market is less discerning when it comes to quality and it is often more profitable to lengthen the cutting schedule and aim for high yield. In contrast, it is often more profitable in low price years to shoot for high quality because the premium is usually greater.

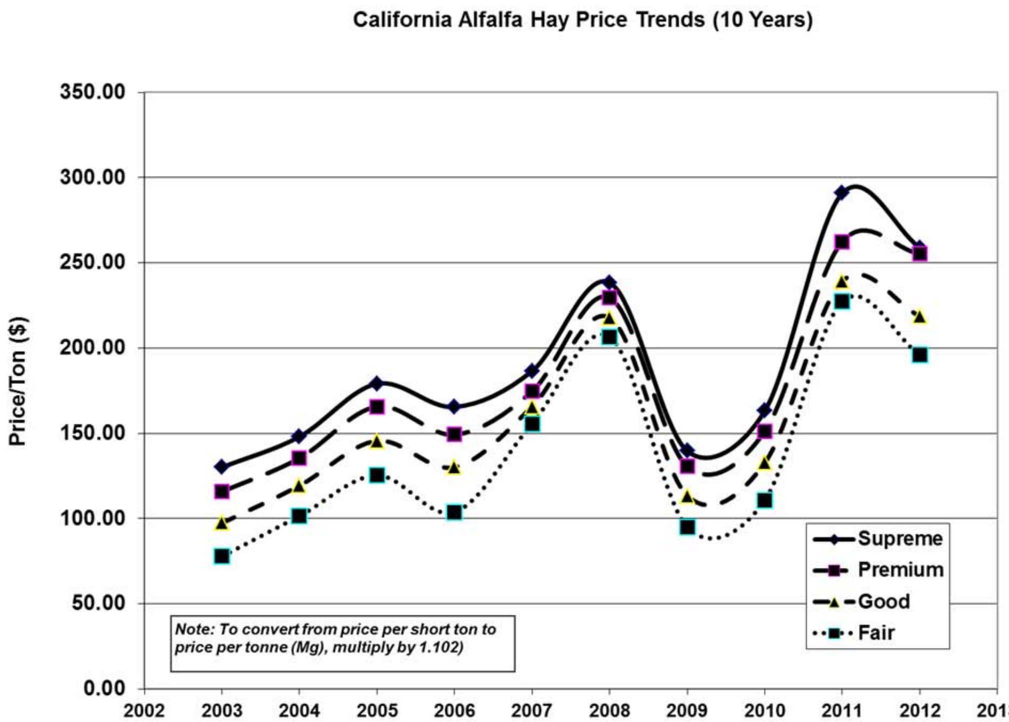

Figure 3. Average annual alfalfa hay price in California for *Supreme*, *Premium*, *Good* and *Fair* categories for 10-year time period from 2003 – 2012.

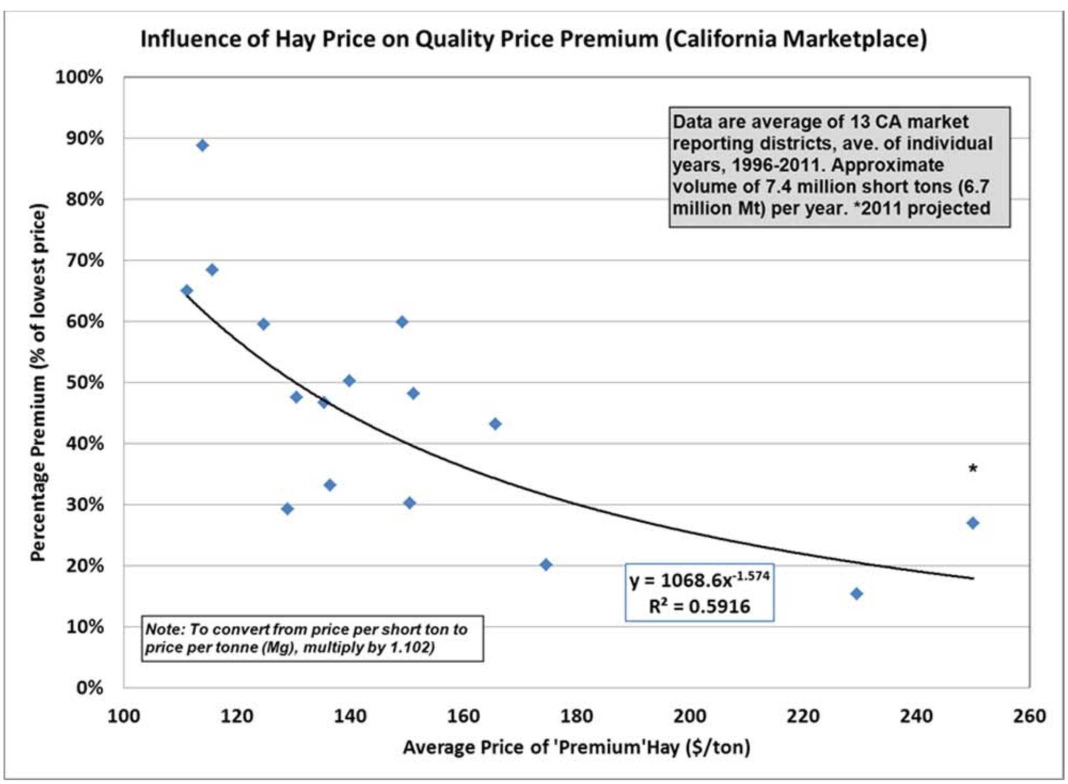

Figure 4. Relationship between the price of *Premium* quality alfalfa and the price premium (expressed as a percentage relative to the price for *Fair* hay). Note that the price premium is much greater when hay prices are low.

This generalization is borne out in an analysis conducted using cutting schedule data from the Central Valley and the Intermountain area comparing different numbers of cuttings per year. A strategy with fewer cuttings per year was more profitable in high-price years, while a strategy with more cuttings during the season was more profitable in a low-price year (Figures 5 and 6). A strategy with fewer cuttings per year, which led to higher total seasonal yield, was more profitable over the last 10 years at both locations. A word of caution… This analysis is based on the yield in field test plots under different cutting schedules. The response to cutting schedules in your fields may be somewhat different. It does suggest though that aiming for high yield may be profitable more often than frequent cutting to achieve high quality, provided you are able to sell the lower quality hay.

Flexible Cutting Schedule. Deciding on a cutting strategy does not have to be a simple choice between long- or short-cutting intervals for the entire season. Individual cuttings can be handled differently adding a level of sophistication to harvest management. One of the least profitable times to cut alfalfa is when the forage quality falls just short of attaining dairy quality premium standards. The price drops off precipitously at this point yet the yield has not increased enough to offset the lower price. Growers are better off to harvest earlier or delay harvest further to maximize yield. Therefore, growers should not be stuck on a rigid fixed cutting schedule with harvests set at a constant interval of 28 days for example (or longer in cool season areas). The cutting schedule should be flexible enough to respond to seasonal variation in weather and to account for the fact that specific harvest timings are more profitable than others. An attempt should be made to harvest fields when returns are highest thus avoiding time periods with low returns. Some fields can be harvested at the early bud stage to ensure dairy quality and the price premium associated with it, while harvest of other fields can be delayed to 10 percent or up to 50 percent bloom to maximize yield. Extending the cutting interval for a cutting(s) gives fields a "rest" period and allows the plants to build up root reserves which in the long run will improve plant vigor and stand persistence. This approach is preferred overly continually harvesting alfalfa on a fixed 26- to 28-day schedule.

This can be accomplished by using a staggered approach to cutting management. Ordinarily, the different fields on a farm are cut in sequential order, meaning the same order is followed from one cutting to the next. With a staggered approach, the field cut first on first cutting will not be the first one cut on second cutting. A field that was cut in the middle of the sequence on first cutting may be the first one cut on second cutting. The intent of this approach is for growers to maximize returns by producing most of their hay in the two more profitable time periods (right at dairy quality hay and for top yield) and avoid the least profitable periods. There is considerable flexibility in how this approach can be implemented. The key is to deviate from using the same cutting interval throughout the season and build in a rest period or periods during the season and in so doing maximizing the number of harvest during the most profitable time periods—right at the "dairy" quality cut-off or at maximum yield.

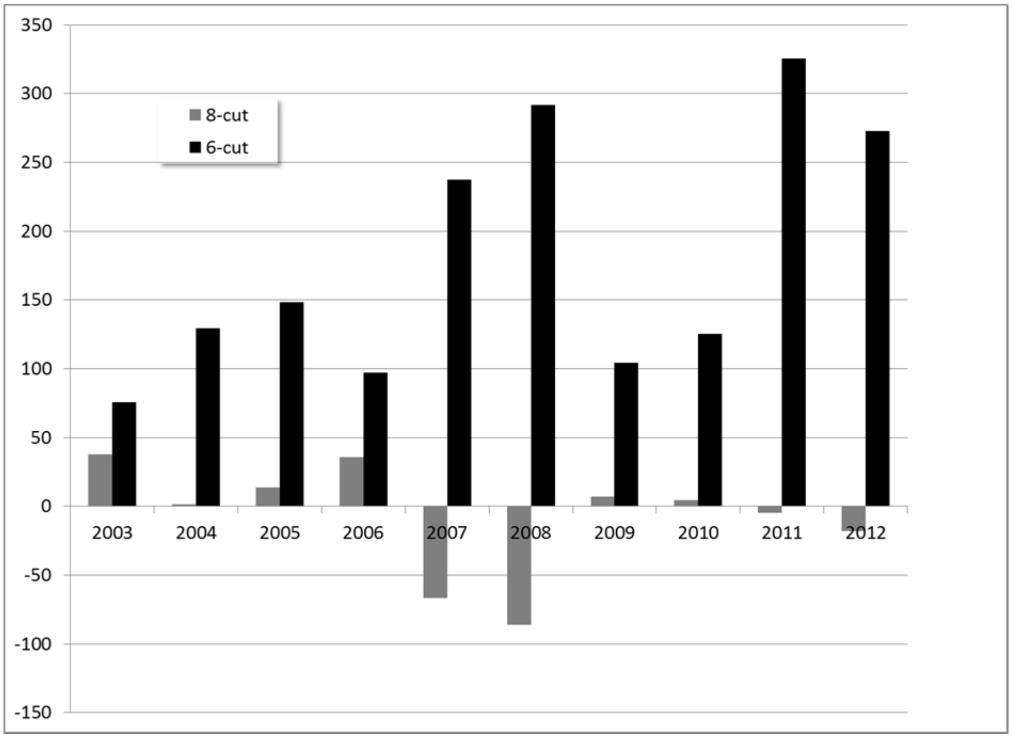

Figure 5. The <u>differences</u> in gross returns over the last 10 years for 6-cut and 8-cut schedules compared with a 7-cut schedule (the most popular schedule in the Central Valley) at Davis, CA. The baseline, or a zero value, is a 7-cut (28 day) schedule.

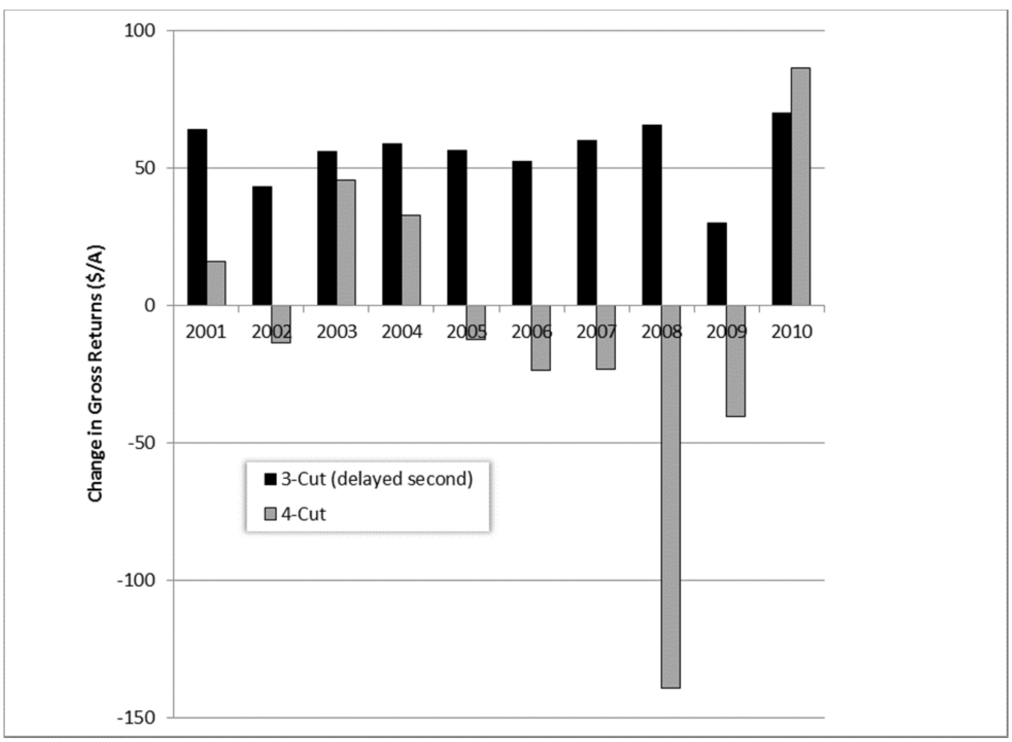

Figure 6. The <u>difference</u> in gross returns over the last 10 years for a 3-cut schedule with a delayed 2^{nd} cutting and a 4-cut schedule compared with a standard 3-cut schedule (the most popular schedule in the Intermountain area). The baseline, or a zero value, is a standard 3-cut schedule. Tulelake, CA.

INFLUENCE OF TIME-OF-DAY

The time of day when an alfalfa field is cut has been documented to impact forage quality. The theory is that late afternoon harvests can result in lower fiber, higher energy (TDN) hay because sugars and starches accumulate to higher levels after a day of photosynthesis than they would during morning hours, after a prolonged period of respiration. The rate of photosynthetic sugar production in leaves during afternoon hours is greater than the rate at which the sugars can be exported to other plant parts or converted into structural compounds like cellulose and lignin. Plants respire during nighttime hours reducing the level of these compounds come morning. When these soluble sugars and carbohydrates increase, fiber and crude protein concentration is reduced due to a dilution effect.

The practice harvesting late in the day to take advantage of this phenomenon has not been widely adopted because growers have limited ability to change the time of day when they cut alfalfa. Most operations start late morning when the morning dew/moisture has dissipated and cut through the day until late afternoon or early evening. While the concept of late-afternoon harvesting makes sense, it is oftentimes not logistically feasible for many growers because they lack the swather capacity to limit their harvest to the late afternoon window. Additionally, risk of rain, especially during 1st cutting, is a more important consideration for quality compared with the advantages of afternoon harvests. However, all other things being equal, afternoon harvests are preferred over early morning harvests, and may contribute somewhat higher quality due to greater soluble carbohydrates that are produced during bright afternoon conditions.

PRACTICES TO ACCELERATE DRYING

The forage quality of the alfalfa is greatest at the time of cutting and only goes down from there. Therefore, the goal is to dry the hay as quickly and uniformly as possible to reduce losses due to plant respiration, leaf loss, and weather damage. It is not just the drying rate that is important but uniform drying is critical as well because safe preservation and storage is limited by the wettest portion of the windrow rather than the average moisture content. Total dry matter losses during the haymaking process can be 25 percent or greater so particular attention should be paid to performing these operations at the proper moisture content.

Curing Process. An understanding of the drying process is helpful to evaluate the potential impact of different haymaking practices. The moisture content when alfalfa is cut is typically 84 to 75 percent and it must dry down to less than 14 to 18 percent moisture depending on bale size. The drying rate of alfalfa depends on environmental conditions including solar radiation, temperature, relative humidity, wind velocity, and soil moisture (solar radiation being the most important). There are two phases to the drying process. The first phase accounts for 75 percent of the moisture loss and occurs in only 20 percent of the total drying time. During this phase, moisture loss occurs through the pores or stomates on the leaves and through the cut ends and abrasions on the stem. The second phase commences at about 40 percent moisture and is far slower (1/100 of the original drying rate). Leaves dry much faster than stems do, and that is part of the challenge with hay drying.

Conditioning. Mechanical conditioning is a widely accepted practice to help accelerate the drying of alfalfa. Conditioning does not help the first phase of drying process when moisture loss is primarily through the stomates, but helps with the second slower drying phase. Conditioning rollers smash or crimp the forage creating cracks in the stem. Through this process the waxy layer (cuticle) on the alfalfa stems is disrupted allowing greater opportunity for water loss. There is little difference in the effectiveness of steel versus rubber rollers. The two main factors determining the effectiveness of conditioning are the tension, which affects the clearance between the rollers, and the spacing between the breaks on the stem. Too much clearance between the conditioning rolls and the stems can pass through unaffected. If the clearance is too small, leaves can be smashed and separated from the stem and plugging can be more prevalent. The spacing of the crimps should be approximately two inches apart. The effectiveness of conditioning can be assessed by holding up individual stems by the end and observing the breaks, which cause the stem to bend under the forces of gravity. Super conditioners crush the full length of the stem. Tests show these further accelerate the curing process. The drying time was reduced by one-third to one-half in an Oregon study and by 4 hours to a day in a Wisconsin study. The value of super conditioning depends on yield and the typical curing conditions at a particular farm.

Swath Width. The configuration of the swath (width and density) is the primary factor under the producer's control that affects alfalfa drying rate. Some producers believe that narrow windrows dry faster because they have less contact with the soil, and because they are taller wind can blow through them. However, research from across the country has shown that wide windrows dry quicker because they intercept more solar radiation, the primary factor affecting drying rate. Rapid drying in a wide windrow helps reduce the respiration rate which in turn reduces the loss of sugars and carbohydrates and preserve TDN.

In the past tall narrow windrows were common, but with equipment advances and a better understanding of the factors that affect drying rates, California growers over the years have gradually adopted wider windrows. Conditioning rollers around 9 feet are common and windrow width can be altered with the simple adjustment of a lever. Perhaps even more can be done in California to accelerate curing by using wider windrows than those currently used. Wider swath widths are used in some other areas of the country, like the Midwest. For example, research in Wisconsin has shown that laying the crop in swath (about 70% of cut width) reduces drying time by about 25 to 40% compared to laying in a windrow (about 45% of cut width). In these areas, the alfalfa is sometimes raked as soon as the day after cutting, something that is almost never seen in California.

Drying Agents. Potassium and/or sodium carbonate are sometimes used as drying agents, and can be sprayed on alfalfa at the time of cutting to accelerate drying. Up to 5 pounds of these drying agents are used per dry ton of alfalfa and they are diluted with water to a spray volume or 30 to 50 gallons per acre. They break down the waxy cuticle layer enhancing moisture dissipation from the cut plant. Drying agents have not been popular in California because of their cost, inconvenience of hauling around large volumes of water, and ordinarily most of California enjoys relatively good curing conditions for most of the year. In addition, drying agents work best under bright sunny conditions rather than cloudy conditions. Therefore, when cloudy conditions prevail and a storm is imminent, they do not function as well. Additionally, they absorb moisture (dew moisture or rainfall) more readily.

Raking. Most alfalfa hay in the West is raked prior to baling. Raking serves two primary functions: 1) expedite the drying process by transferring the alfalfa onto dry soil, and inverting the windrow so the wettest part of the windrow (the bottom) is on top; and 2) combine windrows or lay two windrows side-by-side to improve the efficiency of the baling and roadsiding operations. Growers are well aware of the importance of baling at the proper moisture content because the consequences of baling dry alfalfa are readily apparent—a dust cloud of ground up alfalfa leaves following the baler. However, many growers don't realize that even greater leaf loss occurs when alfalfa is raked too dry. It is not uncommon for some growers to rake the same day the hay is baled; however, greater than 20 percent leaf loss can occur from raking alfalfa hay at 20 percent moisture content. For the West the optimum moisture content for raking is considered to be 35 – 40 percent, but even higher moisture contents are recommended in the Midwest. Raking at too high a moisture content can twist (commonly called rope) the alfalfa rather than invert it and slow the drying rate. While care should be taken to avoid this, the authors believe that hay in California is more often raked too dry than too wet.

Table 1. Moisture effect on yield and leaf loss during harvest operations (Source: Pitt, 1990).

Operation	**Yield Loss[1] (%)**	**Leaf Loss (%)**
Mowing and conditioning	2	3
Raking		
At 60% moisture	2	3
At 50% moisture	3	5
At 33% moisture	7	12
At 20% moisture	12	21
Baling		
At 25% moisture	3	4
At 20% moisture	4	6
At 12% moisture	6	8

[1]Reported on a 100% dry-matter basis

BALING

Baling is one of the most critical steps in the haymaking process. There is a relatively narrow optimum range for baling to avoid excessive leaf loss on the dry side, and to avoid spoilage on the higher moisture side. Baling hay below 12 percent moisture should be avoided when possible due to excessive leaf shatter. Eight percent leaf loss is possible when hay is baled at 12 percent moisture (Table 1). The optimum moisture content depends on the bale size and density. The larger and denser the bale, the lower the moisture contest can be for safe storage. A general recommendation is to bale two-tie bales (no longer common in the West) at less than 20 percent moisture, three tie bales at less than 17 percent moisture, and large 3 x 4 foot or 4 x 4 foot bales at less than 14 percent moisture. Hay fires are becoming more common in California with the increasing popularity of large rectangular bales (typically 1200 to 1500 pounds). Special care should be taken to carefully monitor moisture content to avoid baling at unsafe moisture levels.

Hay Preservatives. As the name implies, hay preservatives are used to allow safe storage of hay at higher than normal moisture levels. Baling higher moisture hay can reduce field curing time and reduce leaf loss during the baling operation. This can be especially advantageous if it allows the grower to avoid rain damage. Propionic acid or propionic acid blend with acetic acid are the most common preservatives. They prevent mold growth and heating losses that occur in high-moisture hay by lowering alfalfa pH and retarding the growth of microorganisms that cause hay spoilage. Preservatives are not as widely used in California as in other parts of the country for many of the same reasons that drying agents are not popular—cost and curing conditions in California are generally favorable. However, with the increase in popularity of large rectangular bales, it may be worth reconsidering preservative use. Preservatives may be cost effective for large bales where moisture content is more critical, especially when used in conjunction with baler-mounted moisture sensors that allow for preservatives to be applied on an as-needed basis.

CONCLUSION

Harvest management is one of the most critical and challenging parts of alfalfa production, and it has a greater impact on quality and yields than perhaps any other production practice. Many consider haymaking to be both an art and science. While there may be "art" involved, proper harvest management primarily requires an understanding of the scientific principles involved. It is imperative that growers understand the *Yield Quality Tradeoff* in order to reach a profitable compromise between yield, quality and stand persistence and to be able to respond to constantly changing market conditions. Similarly, it is important to understand the alfalfa curing process and use proper haymaking techniques to preserve alfalfa quality to the highest degree possible and avoid harvest losses.

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