CUTTING SCHEDULES TO MAXIMIZE PROFIT

Steve Orloff, Dan Putnam, Steve Blank, and Tracy Ackerly

ABSTRACT

It is well known that the maturity of alfalfa when harvested has a greater effect on yield and forage quality than any other management factor. However, much less is known about the effect of cutting management on returns to the grower. Short cutting intervals improve forage quality and therefore price, but result in lower yield. Data showing the daily increase in yield and daily decrease in forage quality for California’s Intermountain area and the Central Valley were used to predict gross returns to the grower. Two distinct price situations were modeled, based on market data for the years 1997 and 1999, relatively high price and low price years, respectively. An equation was developed to assist growers with the harvest timing decision—whether it is better to aim for quality or aim for yield. Based on the analysis, there was no single best strategy for all situations. The optimum strategy varied depending on market conditions, primarily the amount of the price spread between the different grades of alfalfa. However, economically it appears to be better to produce alfalfa right at the cutoff value for dairy quality or to delay cutting to improve yield. The concept of a staggered cutting approach (alternating ‘Yield’ and ‘Quality’ harvests) is discussed.

Key Words: Alfalfa, Medicago sativa, harvesting, cutting management, economics, forage quality, ADF, TDN

INTRODUCTION

Relatively poor prices for alfalfa hay have prevailed in 1998-2000 due to an oversupply of alfalfa in the West. The drop in alfalfa price over the last few years is largely related to an increase in alfalfa acreage caused by the poor profitability of rotation crops. In addition to the somewhat sluggish market there has been an increase in the forage quality expectations for alfalfa to be considered ‘dairy quality’. The days are gone when 54% TDN (total digestible nutrients expressed on 90% dry matter basis) or 30% ADF (100% dry matter) alfalfa is considered dairy quality. The cutoff value for alfalfa to be classified as dairy quality crept up to 54.5 (29% ADF) then 55 (28.3% ADF) and has now risen all the way up to 56% TDN (27% ADF). For the alfalfa grower forage quality can mean the difference between alfalfa that sells itself and alfalfa that does not sell at all.
The Yield/Quality Tradeoff

The real dilemma for the alfalfa grower centers on the yield/quality tradeoff. Researchers and growers alike have long recognized that the frequency at which alfalfa is cut has a profound effect on both yield and quality. Cutting alfalfa at an immature growth stage (short interval between cuttings) results in relatively low yield but high forage quality. Conversely, cutting alfalfa at a mature growth stage (long interval between cuttings) results in high yield but low forage quality.

The daily changes in yield and forage quality that occur as the alfalfa plant matures were recently quantified for distinct alfalfa production areas in California (see Ackerly et al article in this proceedings). Data for all sites and all cuttings clearly demonstrated the existence of the yield quality tradeoff. However, the relationship between yield and quality with advancing maturity differed by location and season of the year. In general, the yield/quality tradeoff was most pronounced under warm environmental conditions—yield increased and quality decreased at more rapid rates.

Given the existence of the yield/quality tradeoff, the decision of when to harvest alfalfa for maximum profits is not easy. Growers face a tradeoff between a high price-low yield combination versus a low price-high yield combination. The optimal time to cut hay is when the grower can capture whichever of these two combinations generates the highest revenue. To complicate matters further, the price differential between premium dairy quality alfalfa and less digestible hay (typically hay used for beef cows or non-lactating dairy cows) varies significantly each year. The price differential depends primarily on the supply and demand for dairy quality alfalfa and the current price for dairy products. In some years weather conditions are such that it is very difficult to produce high quality alfalfa. Consequently, the supply of quality alfalfa is very low relative to poorer quality hay and a greater premium is paid for the higher quality alfalfa.

A procedure is clearly needed to help alfalfa producers select the most profitable cutting strategy given the dynamics of the yield/quality tradeoff for different seasons and environments which is complicated by ever-changing market conditions. The intent of this paper is to analyze the returns obtained when cutting alfalfa at different maturity stages and to develop a decision-making tool to assist growers with the harvest decision.

PROCEDURE

Historical Price Levels

Alfalfa price and the differential between premium dairy quality hay and fair hay vary significantly from year to year. While the alfalfa market is not as volatile as the market for other higher value commodities, the fluctuations are great enough to make the difference whether alfalfa as a crop option is profitable or not. Average annual prices from 1992 to 1999 for the different hay quality categories are presented in Tables 1 and 2. This paper focuses on alfalfa prices for northern California (the intermountain area) and for the western Fresno/Madera area of
California since data for the yield/quality tradeoff was developed for those areas. In addition, for comparison purposes they represent two distinct production and marketing areas. Prices paid for premium hay were higher in the Fresno area than in northern California in each of the eight years. Over the 8-year time period the average annual price of premium alfalfa hay varied from $89.62 to $129.79 per ton in northern California and from $98.19 to $148.33 per ton in western Fresno/Madera. Prices for fair quality hay were more similar between the two regions (Tables 1 and 2). The price differential between premium hay and fair hay tended to be greater in the Fresno/Madera area than in northern California (difference between the two grades averaged approximately $7 per ton greater in Fresno/Madera than in northern California).

Idealized Price Curves

The historic data provides an average annual alfalfa hay price for the three distinct categories, Premium (>54.5 TDN; <29 ADF), Good (52.5–54.5 TDN; 29–32 ADF), and Fair (50.5–52.5 TDN; 32–35 ADF). (The Supreme category was not created until 1998 so could not be included in the table.) Each category represents a grouping of forage quality. To analyze potential returns a more complete range of forage quality values along with corresponding prices are needed. Idealized price curves were developed for two distinct price years to show the change in price for each incremental change in TDN or ADF (Figures 1 and 2). These curves represented a high-price year with a relatively small Premium-to-Fair price differential and a low-price year with a large Premium-to-Fair price differential using 1997 and 1999 price years, respectively. The curves were based partly on real data from 1997 and 1999, and on discussions with growers and brokers about the behavior of the market.

Reflecting the behavior of the market in California, there are three distinct segments to the price curves. For TDN values of 56% and above there is very little change in price for each incremental change in TDN. Similarly, there is little drop in price associated with each change in TDN for alfalfa hay at the low quality end of the curves. However, the center portion of the curves, when alfalfa hay goes from 56 to 53 or 54 TDN, there is a precipitous drop in price. This is characteristic of the commonly observed ‘dairy hay’ cutoff perceived by the market. Under current market conditions and perceptions, alfalfa above 56% TDN is considered ‘dairy quality’—below that it is not.

Gross Returns per Acre

The relationships between yield and forage quality, measured in field trials conducted in the intermountain and Fresno areas of California, were used to calculate gross grower returns. These sites were chosen because of their differences. The yield (tons/A), with its corresponding forage quality, was simply multiplied by the price associated with that quality from the price curves in Figures 1 and 2 to calculate returns.

Our data suggest four possible outcomes for gross returns (Figure 3). With all outcomes it was not profitable to cut extremely early for super high-quality alfalfa, greater than 58 TDN (less than 24 ADF). The price premiums received did not compensate for the lower yields obtained at that early point in the production process. The first possible outcome (A) is where maximum yield always optimizes returns. In this case the price premium for ‘dairy quality’ alfalfa is so
low that the effect of increasing yield overrides any effect of forage quality on price. The second outcome (B) affords a large harvesting window. The drop in price associated with a reduction in forage quality is equally offset by an increase in yield so returns remain relatively constant. In the third outcome (C), gross returns are maximized by producing alfalfa with high forage quality just above the cutoff for ‘dairy quality’ alfalfa. The grower must cut for quality and capture the premium price. Any increase in yield after that point is insufficient to compensate for the large drop in price. In the last outcome (D) there are two potential points of maximum return. Returns peak first when alfalfa is cut for quality. After that point, a slight increase in yield is insufficient to compensate for the large drop in price so returns decline. However, if harvest is delayed long enough there is a significant yield increase that compensates for the price drop from Premium to Good or from Good to Fair quality hay.

There are variations on these outcomes, but these four represent the major possible results. Which of these four outcomes occurs depends on both the alfalfa market and the growing conditions. The actual results for the intermountain area are presented in Figure 4, and the Fresno results are presented in Figure 5. Gross returns were significantly higher in 1997 than in 1999 at both locations and for both cuttings. This is simply a reflection of higher prices that year. The primary point of interest is the shape of the return curves. The return curves can guide the alfalfa producer to selecting the most profitable cutting strategy.

Analysis of Intermountain Returns

First Cut
The high-price year example (1997) was a year with less price differential between the Premium and Fair hay. This curve is similar to outcome B in Figure 3 with a long harvest window. The situation was quite different in the low-price year example (1999), a year with a large price differential representing more current market conditions. Again, returns were lowest when alfalfa was harvested at a very early growth stage—when yield is low and forage quality is extremely high. Returns peaked in the range where alfalfa is generally considered to be ‘dairy quality.’ Returns then declined as harvest was delayed until returns began to increase again when the increase in yield nearly compensated for the decrease in quality. So, in this case, returns were highest in the ‘dairy quality’ range or when harvest was delayed much later to obtain maximum yield.

Second Cut
The relationship between day of harvest and returns per acre was different for second cutting, which is a mid-summer cutting in the Intermountain Region. Remember, yield increases and forage quality decreases at a faster rate for second cutting than for first (see Ackerly et al in preceding article). In the high-price year gross returns were highest at maximum yield (similar to outcome A). Only near the ‘cutoff’ for dairy quality hay did the increase even show signs of leveling off. However, after a few days delay in cutting the gross returns continued to increase rapidly by delaying harvest. In contrast, outcome D most closely resembled the shape of the return curve in the poor-price example (1999). If harvest was delayed long enough, returns were greater at maximum yield than at ‘dairy quality’.
Analysis of Fresno Returns

The Fresno yield and quality relationships and alfalfa price information yielded somewhat different results than the intermountain results. When interpreting these data it is important to remember that the price for Premium hay was higher for Fresno than the intermountain area and there was a greater price spread between Premium and Fair quality alfalfa. In addition, the rate of yield increase and quality decrease for the midsummer cutting in Fresno (4th cutting) was far more rapid than for the intermountain area.

In the “good price year” (1997) returns were highest with a cutting strategy to optimize yield over quality, outcome A, similar to the second cut results from the intermountain region. This was even more the case for second cutting where returns increased dramatically with advancing plant maturity. The situation was very different for the low-price example (1999) with a greater price differential. Returns peaked with ‘dairy quality’ and never reached the same level again (outcome C). The midsummer results for the 1999 example were slightly different, more like outcome D. Again, returns peaked in the ‘dairy quality’ range but, given enough time, yield eventually increased more than enough to compensate for the drop in price due to lower forage quality. The reason for the difference in harvest timing for optimum returns between 1st and the 4th cuttings is twofold. The daily change in yield and forage quality for 4th cutting is extremely rapid. In addition, the forage quality at a given yield level is lower in midsummer than early spring. For this reason many growers in the lower San Joaquin Valley opt for yield over quality on midsummer cuttings.

CAUTIONARY NOTES

While this type of analysis can be very revealing, the grower must recognize the conditions and assumptions that were used. The behavior of the market was based on data provided by the USDA Hay Market News. Local price data may vary. The analysis assumed current pricing behavior—a tremendous drop in price from 56 to 54 TDN hay. This is a description of the market in California and may not be a true reflection of the actual feeding ‘value’ of the hay. This analysis also assumed that price is determined solely by forage quality (measured by ADF or TDN). There are other factors that affect price, especially for non-dairy hay. Such factors include the overall physical appearance (color and the presence of weeds or mold) and the suitability of the hay for the export or horse market.

This analysis also assumed that the increase in alfalfa yield over time is linear. In our data sets this was only true within ‘normal’ cutting intervals. Eventually, as the alfalfa becomes overmature, the yield increase will level off. In addition, this analysis only examines the revenues from a single cutting. The timing of an individual cutting clearly influences the amount of growing time available for subsequent alfalfa cuttings. Therefore, to fully analyze different cutting management strategies it is necessary to consider the entire production season rather than just individual cuttings. This analysis also does not account for the long-term effect of cutting date on stand persistence and weed encroachment.
DECISION-MAKING EQUATION

The revenue curves show a generalized relationship between day of harvest and gross returns for two price scenarios. However, a method to compare gross returns between two relevant price/yield combinations for any given price differential would be helpful.

Identifying which price/yield combination will generate the highest revenue should normally be done when the alfalfa is immature, for example greater than 54.5 TDN (less than 29 ADF). Obviously, delaying the cutting decision until after forage quality falls below that level eliminates the option of producing dairy quality hay and receiving the high market price. Thus, it is at the time when quality is at the 58-54.5 TDN level that a producer must forecast the likely outcomes for the two market options: cut for quality now or cut later for yield.

Expressed as a breakeven point, the relationship between price (P) and yield (Y) is as follows. The first equation shows that revenues received at two points in time will be equal if the price differential between the two periods is equal to the yield differential. The equation can be used when comparing any two possible cutting times, time 1 (t1) and time 2 (t2).

\[
\frac{P_{t1} - P_{t2}}{Y_{t2} - Y_{t1}} = \frac{P_{t1}}{Y_{t1}}
\]

From this equation comes the decision rule to cut now (at time 1) for quality if:

(a) \[ \frac{P_{t1} - P_{t2}}{P_{t2}} \geq \frac{Y_{t2} - Y_{t1}}{Y_{t1}} \]

or to cut later for yield if:

(b) \[ \frac{P_{t1} - P_{t2}}{P_{t2}} < \frac{Y_{t2} - Y_{t1}}{Y_{t1}} \]

An example will illustrate how the decision rules in equations (a) and (b) can be applied. First, a hay grower in the intermountain area of northern California is at time 1: his hay tests at 54.5 TDN – the lowest level that will receive the Premium price. If this is the grower’s first cutting he will get approximately 2.12 tons per acre, according to the yield/quality relationship described in Ackerly et al. Assuming that the local hay market is offering the average prices listed in Table 1, the grower knows that he can get $112.14 per ton for Premium quality hay, but only if he cuts immediately. Delaying the cutting further risks having the hay quality fall below the 54.5 TDN level, which will result in a lower price. Thus, the grower must choose at that point in time to cut for quality and capture the premium price (P_{t1} = $112.14) with a yield (Y_{t1}) of 2.12 tons, or to wait until the yield increases enough to at least offset the lower price that will be received. To calculate the higher yield needed at time 2 to offset the lower price that will be received, the grower substitutes the current price for Premium hay into the equation as P_{t1} and the current
price for *Fair* quality hay as \( P_{12} \). Assuming that the market is again offering the average price in Table 1, \( P_{12} \) is $79.84. Calculating the left-hand side of equation 3 with these prices gives a price differential of 40.5%. This means to offset the 40.5% drop in expected price at time 2, the yield differential (increase) will have to be at least 40.5% of the current available yield. Thus, yield at time 2 will have to be at least 2.98 tons/acre to generate the same total revenue (assuming that the price for fair quality hay does not change) as is available at the present, time 1. A yield of 2.98 for the first cutting is often not possible. This means that the grower is better off to cut immediately for quality.

Fresno yield/quality data (cut 4) and price data (1996) will be used for another example. The same process would be used to find the best cutting decision. This example will be for a midsummer cutting and assumes the dairy industry is demanding 55 TDN or higher. The decision will be whether to produce *Premium* quality hay at an average price of $127.56 or go for higher yield of *Fair* quality. The grower would get 55 TDN quality hay (time 1) with a yield of 1.05 tons per acre. Assuming that the average price for *Fair* quality hay was $97.30, the differential would be 31.1%. This would require the grower to get a yield of at least 1.38 tons at time 2. According to the data in Ackerly et al, yield increased 180 lbs./day. Therefore, yield would exceed 1.38 tons per acre by delaying cutting 3 to 4 days. Therefore, the most profitable decision would be to delay cutting and cut for yield.

Thus, to justify cutting for the higher quality, the relevant price differential would have to exceed the yield differential calculated using the growth rates developed in the preceding paper (Ackerly et al). As shown in Table 1 and 2, the hay price differentials for individual years have ranged from 24.4% to 78.4%, meaning that the decision reached by a grower could be to cut for quality (when the differential is higher) or to cut for yield (when the differential is lower). No single strategy was always best. The best strategy depends on the price differential and the alfalfa growth rate at a given location.

**Narrow Window of Opportunity for Quality Hay**

The average daily decline in TDN presented in the previous paper (Ackerly et al) was 0.22 to 0.5 (0.33 to 0.74 % ADF). This means that TDN drops one point in just 2 to 4.5 days, depending on the area and cutting. This demonstrates that the window of opportunity to produce dairy-quality alfalfa is very short. With the equipment and labor constraints many growers have, it can take 3 weeks or longer to harvest a cutting. The window of opportunity for dairy-quality alfalfa hay is usually so short that it is impossible for most growers to produce ‘test hay’ from all fields every cutting. Often the alfalfa falls just short of the cut-off value to be classified dairy hay. Just missing the quality window is unfortunate; the grower does not receive the price increase for premium hay yet didn’t benefit from the full yield increase that occurs by delaying cutting.

With the current pricing structure for alfalfa hay, a common return curve looks like the one presented in Figure 6. Revenue is typically highest at two time periods—just before the cut-off for ‘dairy quality’ hay and then later, during the bloom stage. The times to avoid are an extremely early harvest—the price premium is rarely sufficient to compensate for the extremely low yield—and, just after the dairy hay quality cut off—the yield has not increased enough to offset the lower price.

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Staggered Harvests

Growers ordinarily harvest alfalfa fields in a fixed order. The order may be determined by habit, the field’s proximity to the headquarters, dryness of a field, dormancy of the alfalfa variety, or any number of other factors. Typically, fields are harvested in the same sequence for second cutting and each cutting thereafter. Therefore, if the alfalfa in the field cut first does not test dairy quality, it is unlikely that any of the fields cut afterwards will either. An alternative approach to scheduling the harvest of different fields may help growers maximize returns by producing most of their hay in the two more profitable time periods and avoid the least profitable periods (Figure 6).

This approach, referred to as staggered harvests, is to vary the strategy for harvests for each field, to alternate ‘Quality’ harvests with ‘Yield’ harvests. One way to accomplish this is to vary the harvest order so that 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 (see Figure 7). This helps assure that the alfalfa in the first fields cut will be immature enough to test dairy quality even in midsummer. Using this altered cutting sequence, fields cut first on first cutting have a longer interval between first and second cutting. These fields will obviously not test dairy quality. The intent is to maximize yield on these fields and give the plants an opportunity to recover from being cut at an immature growth stage on first cutting.

The staggered approach could be used on subsequent cuttings or the grower could return to a sequential cutting order. The decision depends on the growing conditions, season of the year, and current market conditions, primarily the price spread between dairy and non-dairy hay.

The intent of the staggered cutting approach is to target specific fields for high forage quality and other fields for high yield, avoiding the least profitable areas in Figure 6. High forage quality for the dairy market is the goal for some fields, while maximum yield for the horse or beef cow market is the goal for other fields. The end result of the staggered cutting approach is a relatively constant or predictable supply of ‘test’ and ‘non-test’ hay throughout the season, even during times of the year when it is typically very difficult to produce ‘high-test’ hay.

SUMMARY

There is no single best harvest strategy for all situations. Our analysis identified four primary outcomes to maximize gross returns: maximize yield, produce high quality hay, a large optimum harvest window for maximum returns, and two points of maximum returns. Which outcome is best depends on the cutting and the price differential between ‘dairy’ and ‘non-dairy’ hay. A small price differential simplifies the decision—it is best to maximize yield. However, a larger price differential makes the harvest timing decision more complex. Gross return curves and equations were developed to help growers determine which strategy is best for a given situation. A staggered cutting strategy to alternate ‘Quality’ harvests with ‘Yield’ harvests was suggested to avoid harvesting at times when returns were lowest. This approach is currently under investigation and results are forthcoming.
REFERENCES


Acknowledgement
The authors would like to thank Jack Getts, Federal Hay Market News Service, for his assistance obtaining information on historic alfalfa hay prices.
Table 1. Historic Alfalfa Hay Prices in Northern California (1992–1999).

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<tr>
<th>Year</th>
<th>Premium</th>
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<th>Premium vs Fair Differential</th>
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Source for prices: Agricultural Marketing Service.
Difference and differentials were computed in this study.

Table 2. Historic Alfalfa Hay Prices in the Western Fresno/Madera area of California (1992–1999).

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<tr>
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Source for prices: Agricultural Marketing Service.
Difference and differentials were computed in this study.
Figure 1. Idealized relationship between forage quality and alfalfa price ($/ton) for two example years, 1997 and 1999, for the intermountain area of California. Bars on left indicate the price spread.

Figure 2. Idealized relationship between forage quality and alfalfa price ($/ton) for two example years, 1997 and 1999, for the Fresno/Madera area of California. Bars on left indicate the price spread.
Figure 3. Four major outcomes for the effect of harvest timing on gross returns. Returns are highest at maximum yield (A). There is a large harvest window (B) for maximum returns. High forage quality (C) results in highest returns. There are two points of maximum return (D).
Figure 4. The effect of harvest timing on gross returns in the intermountain area of California for two example years, a high-price year with a small price differential (1997), and a low-price year with a large price differential. A) First cutting. B) Second cutting.
Figure 5. The effect of harvest timing on gross returns in the Fresno/Madera area of California for two example years, a high-price year with a small price differential (1997), and a low-price year with a large price differential. A) First cutting. B) Second cutting.
Figure 6. Typical return curve indicating normal harvest periods for maximum return—'dairy quality' harvest and maximum yield harvest. Two periods to avoid are extremely early harvest and just missing the dairy-quality cutoff.

Cutting Order for First Cutting

<table>
<thead>
<tr>
<th>1st</th>
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<td>B</td>
<td>C</td>
<td>D</td>
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Fields A, B, C, and D cut for quality
Fields E and F cut for yield

Cutting Order for Second Cutting

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Fields D, E, and F cut for quality
Fields A, B, and C cut for yield

Figure 7. Staggered Harvest Concept.
Assume a grower has six fields labeled A, B, C, D, E, and F. The fields are harvested in this sequence for first cutting. Because of the time required to cut all fields, fields E and F fall short of dairy quality and are cut for yield. Rather than staying with the same sequence at the second harvest, the order is interrupted and harvest begins with D, E, and F. These fields would be less mature and are harvested early to maximize quality. Fields A, B, and C will be harvested later and will have lower quality but higher yield. This ‘staggered’ harvest strategy should enable growers to target specific fields for high quality and others for high yield avoiding the least profitable areas in the figure above. This approach gives plants a ‘rest’ to replenish root reserves to improve vigor and stand persistence.