STRATEGIES FOR BALANCING QUALITY AND YIELD IN ALFALFA USING CUTTING SCHEDULES AND VARIETIES

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ABSTRACT

The interactions between cutting schedule and variety were examined in a 3-year study with 18 varieties and 3 cutting schedules on the UC Davis campus. Cutting intervals ranging from 24 days to 33 days between cuts generally had a stronger influence on yield and quality than did variety. *Early* cutting schedules resulted in significantly lower yield, but 75-85% of the production was <29%ADF ('Premium' and 'Supreme' quality categories) compared with the medium or late schedules, which had lower quality. Fall Dormancy (FD) of the variety was an important predictor of quality. More dormant varieties were almost always higher in quality. Average change in ADF per unit FD was 0.62 %, with similar changes in NDF and CP. Under some market conditions the yield sacrifice is justified to obtain high quality, while in other market conditions it is not. We speculate that a 'mixed' strategy, with some high yielding/lower quality varieties, along with some higher quality/lower yielding varieties may be appropriate. A mixed cutting schedule which favors quality for some harvests and yield for others may be warranted and improve stand life. High quality varieties or short cutting schedules should not be chosen without giving full consideration to the effect of those practices on yield.

INTRODUCTION

Greater than 95% of the alfalfa in western US regions is grown as a cash crop. Since gross returns are a function of both tons/acre and price per ton, profitability is dependent upon both yield and quality factors. While yield has always been important for profitability, forage quality has taken on increased economic importance in recent years. Changes in price due to forage quality may be 25-70$/ton, depending upon the year (Putnam, 2004).

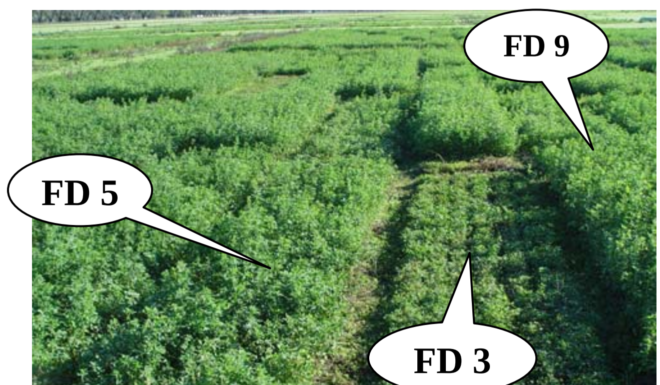

Figure 1. Fall Dormancy characteristics of alfalfa varieties is mostly expressed in the late fall (Photo December, 2003, UC Davis)

Growers must consider both long-term and short-term strategies to improve the forage quality of their harvests. Short term strategies primarily involve early cutting. However, some

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ABBREVIATIONS: CP = Crude Protein, ADF = Acid Detergent Fiber, NDF = Neutral Detergent Fiber, TDN = Total Digestible Nutrients, commonly expressed in California on a 90%DM basis (TDN = 82.38 –(0.7515*ADF))

seed companies have sold alfalfa varieties with claims of superior quality. Some growers have chosen low dormancy varieties (Figure 1) with the aim of improving quality, but questions remain as to the extent of yield loss from planting these varieties. Is it better to choose the highest yielding variety and cut early for high quality, or to choose a higher quality variety (thereby improving value) and accept lower yields?

THE IMPORTANCE OF FALL DORMANCY

Fall Dormancy (FD) is an important trait of alfalfa varieties, describing their growth in the fall due to decreasing temperatures and daylength (Teuber et al., 1998). FD scores range from 1 to 11, with the lower-numbered varieties exhibiting less growth in the fall. Typical adaptation for alfalfa varieties are as follows: FD scores of 1-4 for colder regions (Intermountain, northern US); FD 5-7 scores are typical for mild temperate regions (e.g. Sacramento Valley); varieties with FD 7-9 for warmer and Mediterranean regions (e.g. southern San Joaquin Valley); FD 8-11 varieties for hot desert zones (e.g. Arizona, Imperial Valley, Mexico). Fall dormancy clearly influences stand persistence, adaptation, and performance. For example, non-dormant (FD 8-11) varieties will typically be killed by winter temperatures in the Northern US, whereas more dormant varieties typically have greater persistence.

In the Mediterranean environment of California's Central Valley, it is possible to successfully grow a wide range of alfalfa *(Medicago sativa L.)* varieties, from very dormant to very non-dormant lines. There is low risk of stand loss due to winter conditions in this region. Non-dormant lines (FD 7-9) typically yield more, but some producers have planted much more 'dormant' varieties (FD 2-4) in attempts to improve the quality of their harvests. This research was undertaken to 1) Quantify the yield – quality tradeoff as affected by Fall Dormancy characteristics of alfalfa, 2) Understand the interactions between cutting schedule and alfalfa variety as it influences the yield-quality tradeoff, and 3) Assess the economic ramifications of different strategies.

Table 1. Fall Dormancy Ratings of 18 varieties used in the cutting schedule trial, UC Davis.

Cultivar	Fall Dormancy*
Plumas	3.08
WL325HQ	3.44
54Q53	3.49
Dura 512	4.07
Archer II	4.35
Tango	4.63
Sutter	4.66
Magna601	4.96
Dura 765	6.06
Acheiver	6.13
Aspire	6.35
SW7410	6.75
58N57	6.86
DS681FQ	7.00
WL625HQ	7.13
SW9720	7.39
WL711WF	8.36
CUF101	8.46

**Average Rating determined under multiple years, multiple locations at Davis, Kearney, and El Centro, CA. Note: these may differ from FD ratings provided by seed companies.*

RESEARCH WORK

An experiment was planted September 17, 2001 at Davis, CA to examine the interactions between cutting schedule and variety. Eighteen alfalfa varieties ranging from FD 3 to 10 were harvested at approximately 24, 28, and 34 day cutting intervals (approximately 8, 7 and 6 cuts/year) in Davis, CA in 2002-03. Varieties were chosen to represent a wide range of Fall Dormancy Levels (Table 1). Cutting schedules were designed to represent an early harvest schedule (23-24 days), a medium harvest schedule (28 days), and late harvest schedule (33-34 days). The most common harvest schedule in California is 28 days, and growers frequently harvest on a calendar basis, not a specific growth stage, due to logistical constraints. Experimental design was a Randomized Complete Block with a Split Plot restriction, with the 3 cutting schedules as main plots, and the 18 varieties as sub-plots.

Individual variety sub-plots were approximately 3 X 16 feet. Alfalfa seed was sown in rows 6 inches apart at the rate of approximately 25 lbs seed/acre with a cone-type experimental plot seeder. Plots were sprinkle-irrigated until fully germinated, and subsequently flood-irrigated according to typical grower irrigation schedules. Irrigation scheduling was adjusted in all plots to match the cutting schedule. Irrigation amounts were sufficient to avoid water stress in all plots. Cutting schedule intervals varied slightly but followed the target schedule as close as possible. Plots were harvested at approximately 3 inches height using a cutter-bar type forage harvester and plot yields weighed. Whole plant samples were taken from each plot for Dry Matter (DM) determination and forage quality analysis. Samples were analyzed for forage quality using Near Infrared Spectroscopy (NIRS). A calibration developed for hand-clipped, oven dried research samples was used to predict the ADF, NDF, and CP concentration of the samples from this study. A total of over 3,500 samples were analyzed for this study.

CUTTING SCHEDULE INFLUENCE ON YIELD AND QUALITY

Cutting schedule generally had a stronger influence on seasonal yield and quality than did variety. Cutting schedule results from all three years of the study are provided in Figure 2. The average yield penalty for early cutting compared with late cutting was 1.79, 1.33 and 3.26 tons/acre in 2002, 2003, and 2004, respectively (Figure 2). In general, the longer the cutting schedule the higher the total yield. The Medium cutting schedule of 28 days was intermediate in yield, with the exception of the first year of production (2002), where the early and medium yields were the same (Figure 2).

Cutting schedules also had a large effect on forage quality. Early schedules produced 75-85% forage with ‘premium’ and ‘supreme’ quality forage (<29%ADF), whereas the late schedule produced only 24-45% ‘premium’ or ‘supreme’ forage. Although forage quality is a continuous variable, 29% ADF (TDN value of approximately 54.5) is often considered the ‘cutoff’ for dairy quality hay in the California marketplace.

VARIETY EFFECTS ON YIELD AND QUALITY

The effect of variety on yield and quality averaged over the three years and cutting schedules is shown in Figure 3. This graph clearly shows the tradeoff between yield and quality as affected by the Fall Dormancy of the variety. Correlations of FD with forage quality were stronger than for yield, but both yield and quality were closely related to Fall Dormancy. Exceptions are the very non-dormant varieties (e.g. CUF 101 and similar FD 9 lines) which were not as high yielding as several lower-dormancy lines (FD 7). The average annual yield penalty was 0.36

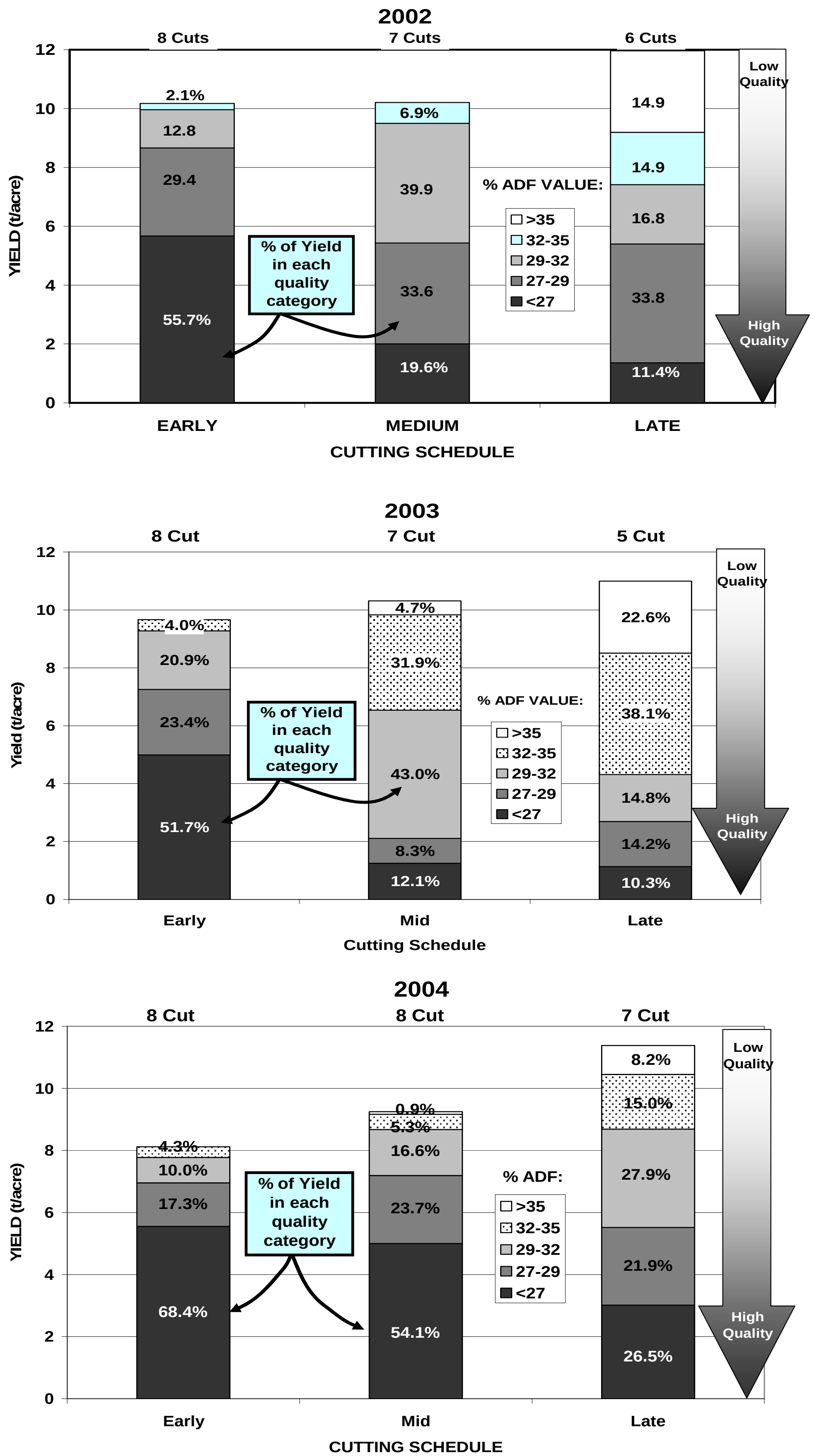


Figure 2. Effect of Cutting Schedule on the yield performance of alfalfa, 2001-2004, UC Davis. Shaded boxes represent hay quality categories; the darker shaded areas represent higher quality harvests. Data averaged across varieties. Number of cuts varied from year to year due to seasonal weather patterns.

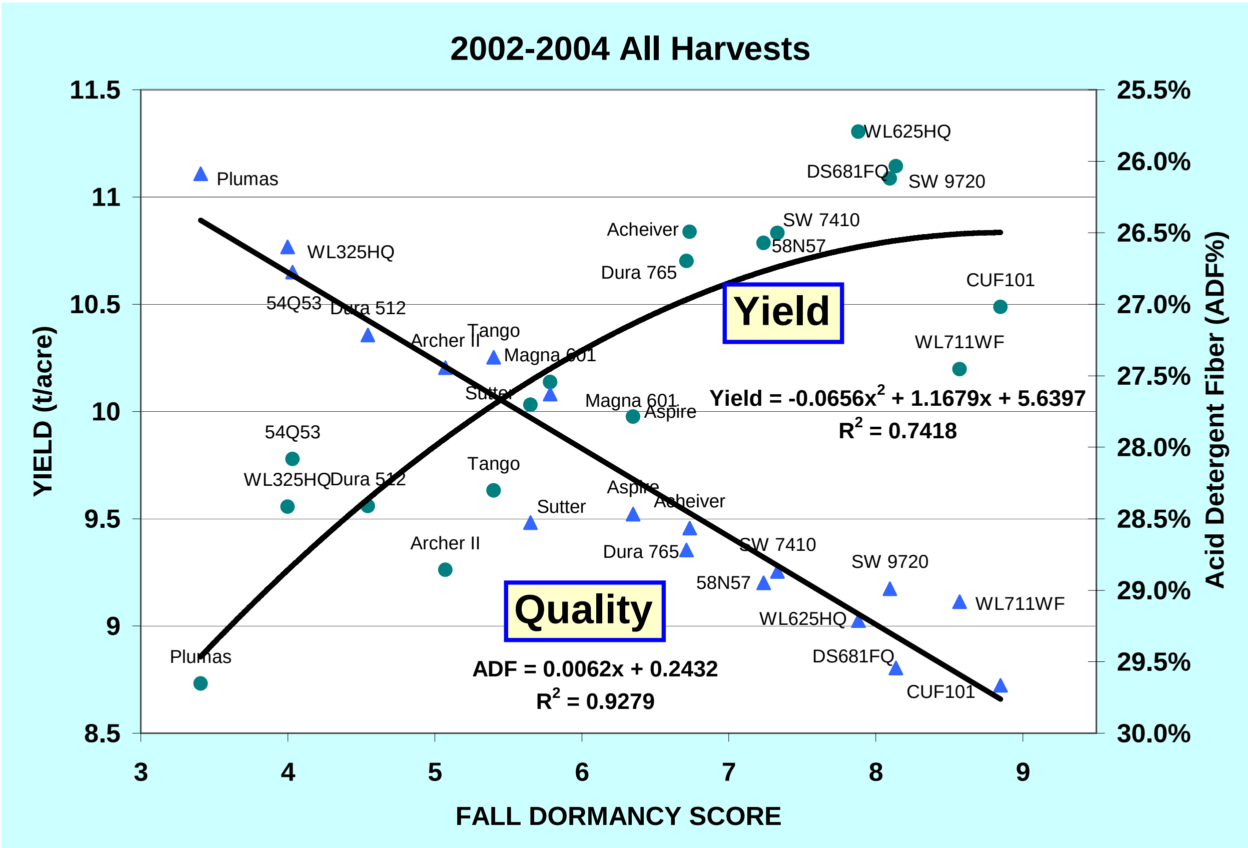


Figure 3. Effect of Fall Dormancy of 18 alfalfa varieties on yield and ADF concentration, averaged over 3 cutting schedule, average of 2003-2004, Davis, CA

tons/acre for each unit decrease in FD. Fall Dormancy explained approximately 74% of the variation in yield (Figure 3).

Fall Dormancy rating of the variety was an excellent predictor of forage quality factors. Fall dormancy explained 93% of the variation in ADF between variety means (averaged over years and cutting schedules). In 2002-04, each unit change in FD resulted in an average change of approximately 0.6% ADF (Figure 3). Similar levels of change were seen for CP and NDF. This means that a 5 point change in FD resulted in approximately a 3 point change in ADF. This average change over 3 years of production would be considered highly significant in California markets in terms of price per ton. However, sometimes small changes in ADF result in much greater changes in value due to the 'dairy cutoff' view of some buyers (see Putnam, 2004 for a thorough discussion of markets and quality).

Initially, these data would appear to support the contention that choosing a more dormant variety for higher quality and value per ton is more profitable. However, consideration of only quality does not take into account the yield penalty associated with higher quality varieties (Figure 3).

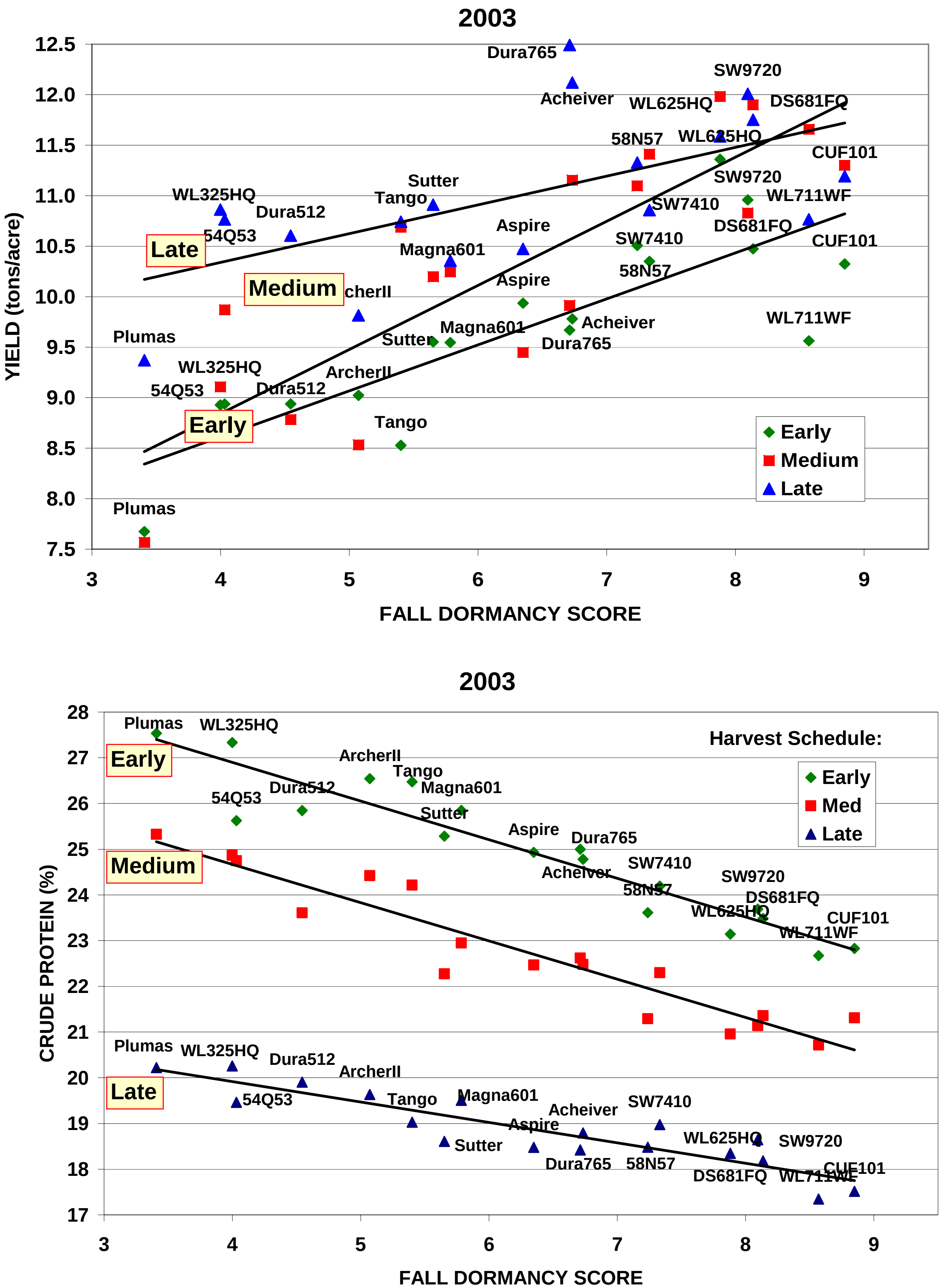
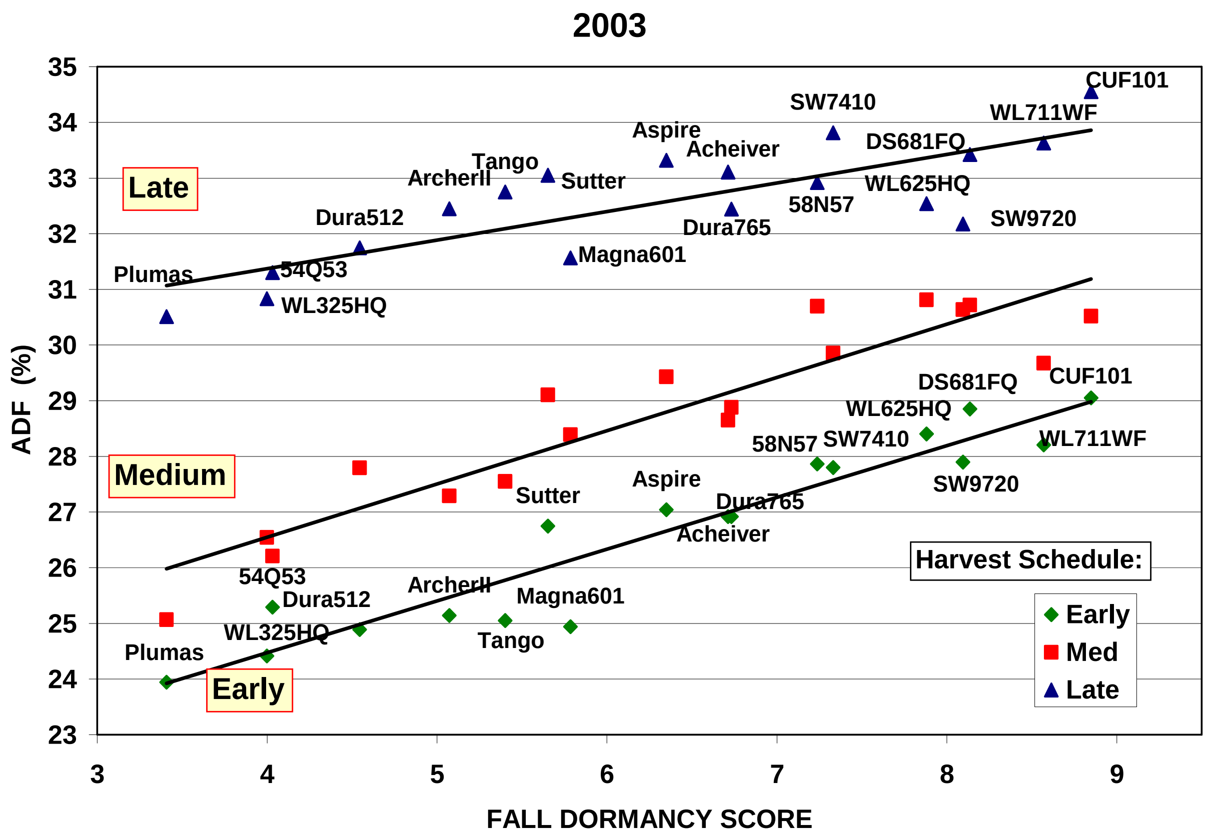


Figure 4. Yield and Crude Protein Concentration of alfalfa as influenced by Cutting Schedule and Variety (2003 data).



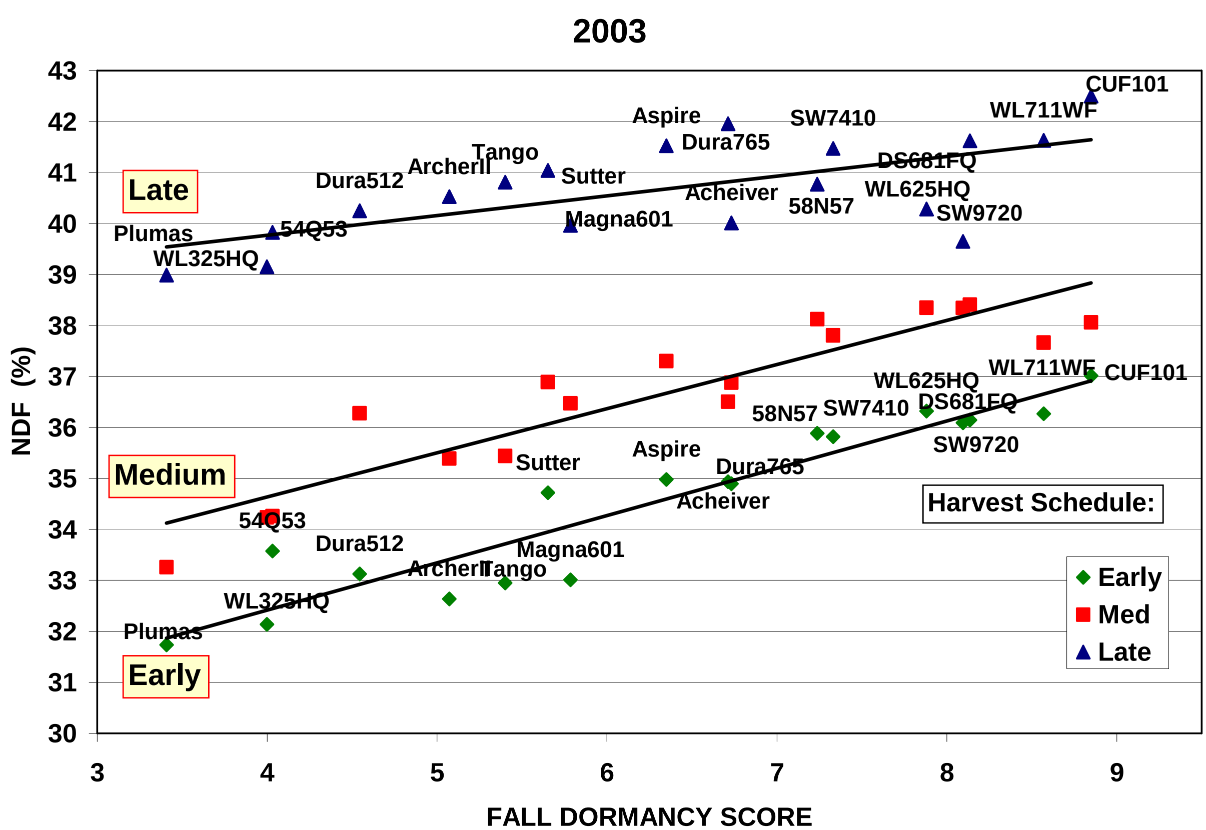


Figure 5. ADF (top) and NDF Concentration of alfalfa as influenced by Cutting Schedule and Variety (2003 data).

VARIETY AND CUTTING SCHEDULE INTERACTIONS

Yield. The yield advantage of the late cutting schedules and non-dormant varieties can be readily seen in Figure 4 (top graph) for the 2003 data. We chose to present just one year for simplicity. The highest yielding varieties in the trial yielded similarly in the Medium and Late cutting schedules, but not in the early cutting schedules. Higher yielding varieties may compensate to some degree for yield loss under short cutting schedules (Figure 4). In many cases the higher yielding non-dormant lines in the early cutting schedule were equal or superior to the yields of the dormant lines in the late cutting schedule (Figure 4). Yield was not as closely related to the FD of the varieties as was quality, since some of the highest yielding varieties were FD 6-7, not FD 9. This trend is more readily seen in the multi-year summary (Figure 3) where CUF 101 and WL711WL (the most non-dormant lines) showed lower yields than slightly more dormant lines.

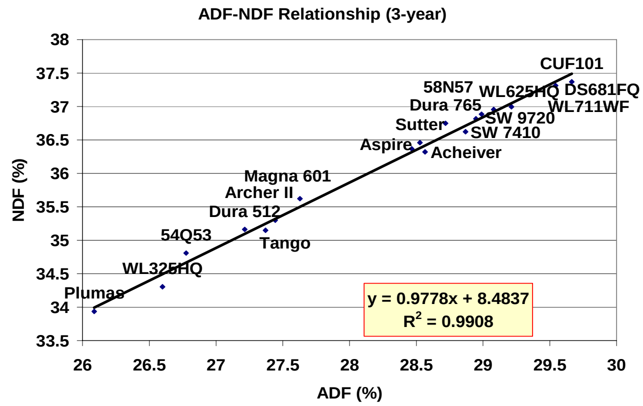
Quality. The highest CP concentration harvests were obtained in the early cutting schedule, followed by the Medium cutting schedule, and the lowest in the late cutting schedule (Figure 4). Fall dormancy of the variety has a major effect on the CP concentration within all three cutting schedules (early, medium late). Fall dormancy of the variety had more of an effect in the early and medium cuts than in the late cut system. Average change in CP percentage was 0.84 percentage points per unit FD in the early and medium schedules, whereas change in the late schedule was 0.44 percentage points per unit of FD.

ADF and NDF responded similarly to CP, but in the opposite direction (Figure 5), with values increasing with increased FD score. Late cutting schedules were dramatically higher in ADF and NDF) than early or medium cutting schedules. Non dormant varieties (FD 7-8-9) always had higher fiber concentration than the more dormant varieties (FD 3-4-5). Similar to the results for protein, Fall Dormancy of the variety had a greater effect in the early and mid cutting schedule compared with the late schedules. Average change in NDF or ADF per unit of Fall Dormancy was approximately 0.9 % for every unit change in Fall Dormancy in the early and medium cutting schedules, whereas it was 0.4 to 0.5% for every unit FD in the late cutting schedule.

Harvest schedule had a more powerful effect on both yield and quality than did variety.
Choice of higher quality (low FD) varieties reduced but did not overcome the negative effect of late cutting schedule on quality.

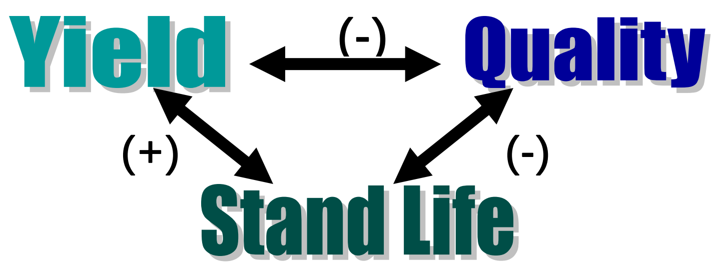
The fact that varieties made less of a difference in the late cut system than in the early or medium cut system is likely related to the growth patterns of the varieties. Most dormant (FD 2-4) varieties recover from cutting more slowly than their non-dormant counterparts. This typically means that stem development, lignification and increases in cell wall content are frequently slower in these lines compared with the faster-growing non-dormant cousins. Thus at early and medium cutting schedules, they are harvested at a significantly less mature stage than the non-dormant lines. However, by 33 days under California weather conditions (usually hot), these lines my ‘catch up’ to the non-dormant lines, lessening the differences between varieties. Visual differences between varieties and plant height (data not shown) were also not as pronounced under the Late cutting regime compared with the Early and Medium cutting schedules.

ADF-NDF are strongly correlated. ADF was very highly correlated with NDF (R^2 = 0.99%) in this study, a common phenomenon for western-grown alfalfa hays (see right graph). Thus, it is not likely to be necessary to measure both ADF and NDF in pure alfalfa hays such as these. Nutritionists have tended to favor NDF over ADF for ration balancing. We must keep in mind that other measurements (e.g. ash, NDF digestibility) may also be very important in determining quality.



HOW TO RESOLVE THE YIELD-QUALITY QUANDRY?

These data reveal a fundamental yield-quality tradeoff that is affected by both variety and cutting schedule. While it might be tempting to think that there is one definitive answer to this question (e.g. pick the highest yielding variety and cut early, or pick the highest quality variety with long cutting schedules), it is obvious that a series of challenging and complex tradeoffs are presented to us. Other factors such as stand persistence and economic value must also enter into the equation.



Stand Persistence. While this trial was not designed to measure stand persistence, it is a factor that is difficult to ignore when considering the cutting schedule/variety issue. The tradeoff between yield and quality is more accurately described as a tradeoff between yield, quality and stand persistence (see figure). While yield and quality are almost always negatively correlated, cutting for quality tends to deteriorate stands, and good stands usually contribute to higher yields.

We did evaluate stand persistence in this trial, and several clear trends were apparent (data not shown):

1) The 'Late' Cutting schedule exhibited the best overall persistence of the three treatments after three years of cropping. There was severe stand loss in the 'Early' cutting schedule while the 'Medium' schedule showed an intermediate level of stand loss. The ability of the 'Late' cutting schedule to re-grow in the spring was dramatically improved over the two other schedules in the spring of 2004 and 2005.
2) Non-dormant varieties generally suffered stand loss much more than dormant varieties. This has been a common observation in trials at UC Davis, and in other seed company trials in the Sacramento Valley. In the early cutting schedule especially, stands of several of the non-dormant varieties were not acceptable after three years of harvests. Crowns of remaining non-dormant lines were smaller than the more vigorous dormant crowns.

Frequently harvesting reduces the plants' ability to replenish root carbohydrate and proteins reserves, causing death of plants, or weaker plants that are more susceptible to disease. Frequent harvests reduce the life of the stand, increasing the costs of production (which are already higher with more cuttings per year). Weed invasion is a consequence. Thus, the yield-quality tradeoff question is further complicated by a yield-quality-stand persistence tradeoff question.

How important is Stand Persistence? It is difficult to evaluate the importance of stand persistence in this region, since grower expectations vary widely. Some growers wish to rotate quickly to another crop, such as tomato or cotton; thus a 3 year rotation is completely acceptable. Other growers would like to extend stand life as long as possible, and would like to see a 4, 5 or 6 year stand life. Due to the frequent harvests, traffic injury, irrigation, and compaction of heavy soils, it is rare for alfalfa stands in California's Central Valley to last more than 4-5 years. This differs from the Intermountain area or Midwest US, where growers expect a 6-8 year stand life (these are 3-4 cut systems).

Weeds are another important variable when determining the long-term health of a stand. We observed much greater weed presence in the early cutting schedule in this trial, and with those varieties with significant stand loss by the third year of production. This study was very much in line with the results of Vern Marble in his classic study of cutting schedules from the 1970s, which clearly showed the same yield-quality tradeoff, as well as the influence of cutting schedule on stand persistence and weed intrusion (Table 2).

Table 2. Effect of Maturity at harvest and harvest interval on alfalfa yield, quality, and leaf percentage weeds and stands life; study conduced in the early 1970s.

Maturity at Harvest	Harvest Interval (days)	Yield T/acre	TDN	ADF	CP	Leaf	Weeds	Stand
			-----------------------------%---------------------------------					
Pre-Bud	21	7.5	56.3	26.3	29.1	58	48	29
Mid-Bud	25	8.8	54.2	29.5	25.2	56	54	38
10% Bloom	29	9.9	52.4	32.2	21.3	53	8	45
50% Bloom	33	11.4	52.0	32.7	18.0	50	0	56
100% Bloom	37	11.6	50.1	35.5	16.9	47	0	50

Source: V.L. Marble, 1974. Proceedings, 4th CA Alfalfa Symposium, Dec. 4-5, 1974. UC Cooperative Extension.

ECONOMICS

If the above considerations were not sufficiently complex, the relative economic value of yield vs. quality (and persistence) must be determined. It is clear that yield and quality are inversely related. Determination of the extent of yield changes and the degree of quality changes in relationship to price is necessary. Price and the premium paid for high quality alfalfa hay are constantly changing from month to month and year to year, further complicating these relationships.

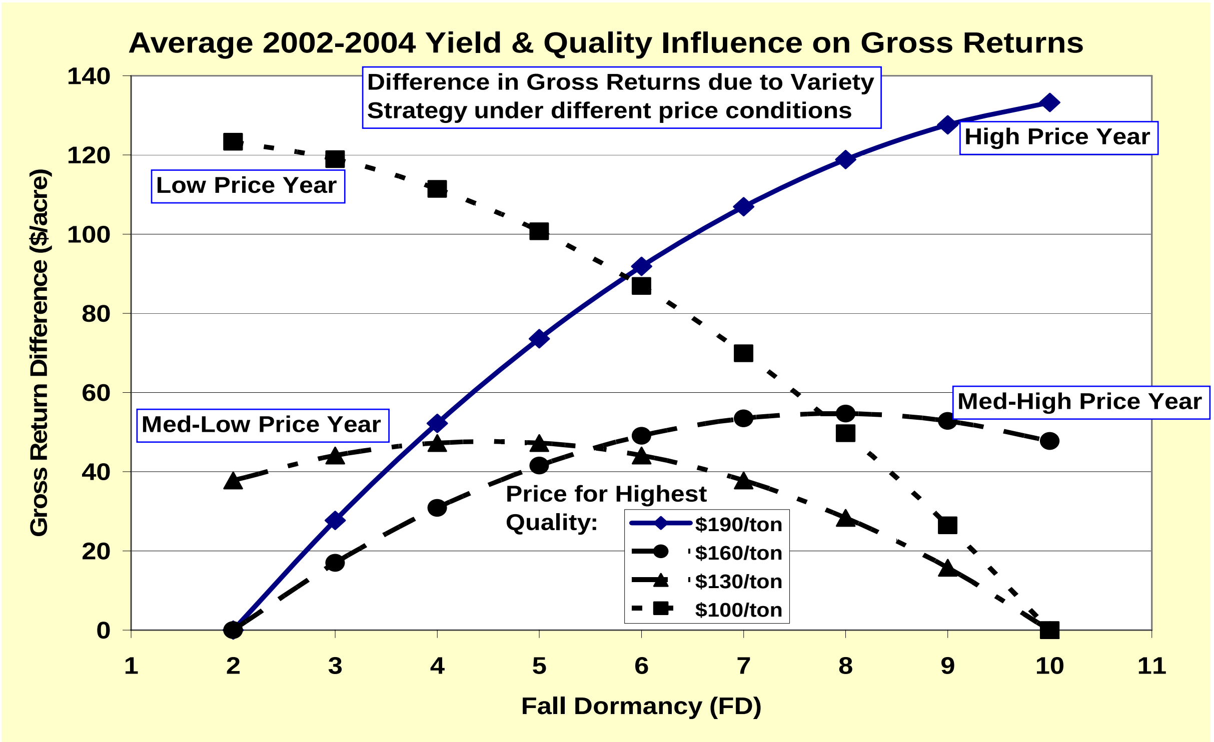


Figure 6. Average differences in gross returns due to variety choice, Davis, CA. These returns are based on the average yield and ADF response to Fall Dormancy (Figure 3), averaged over 3 years, 3 cutting schedules and 3 replications. Quality is valued at $7.19 per ton per unit of ADF, which was calculated from 8 years of California market data (Putnam, 2004). Starting price for highest quality alfalfa in this graph ranged from $100 to $190/ton.

In an 8-year dataset presented at the National Alfalfa Symposium in 2004, the average difference in price due to quality was estimated at slightly over $7.00/ton per unit of ADF (TDN, the most common expression for quality in California, calculated directly from ADF).

If one assumes this rate of change in price ($7.19/ton/unit of ADF), and assumes the yield-quality tradeoff due to variety as in Figure 3, the differences in gross returns due to the FD of the variety can be estimated (Figure 6). Of course, returns are always greater in high price years, but the difference in returns is what is pertinent to the question of variety choice, since this affects marginal returns. Keep in mind that this calculation does not encompass stand persistence factors, and assumes that all varieties are equal in other production costs.

Plant High-yielding Varieties for High Priced Years. It is clear that choosing high-yielding, lower quality varieties is highly advantageous in high-priced years (Figure 6), years such as 2005, when Premium (27-29% ADF) or Supreme (<27% ADF) hay is selling for $170-$190/ton. In those types of years, it often does not pay a grower to strive for very high quality harvests, since even medium quality hay sells for a good price.

Plant High-Quality Varieties for Low-Price Years. However, it is also clear that choosing higher-quality varieties is advantageous in a low priced years, even if they are lower yielding (Figure 6). These are years when supply exceeds demand, and dairies are much more picky when it comes to purchases. Growers report that some hay, especially lower quality hay, does not sell during these years. The risk of not selling hay is often an important factor that growers must weigh when determining their yield-quality strategy.

Table. 3. Miniumum percentage price improvement required to justify a yield decline due to variety choice or cutting schedule on an annual or a per-cutting basis.

Starting Yield	Reduction in Yield (Per Cutting Basis, t/a)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
t/a	*Minimum Price Improvement Required*									
0.4	33.3%	100.0%	300.0%							
0.6	20.0%	50.0%	100.0%	200.0%	500.0%					
0.8	14.3%	33.3%	60.0%	100.0%	166.7%	300.0%	700.0%			
1	11.1%	25.0%	42.9%	66.7%	100.0%	150.0%	233.3%	400.0%	900.0%	
1.2	9.1%	20.0%	33.3%	50.0%	71.4%	100.0%	140.0%	200.0%	300.0%	500.0%
1.4	7.7%	16.7%	27.3%	40.0%	55.6%	75.0%	100.0%	133.3%	180.0%	250.0%
1.6	6.7%	14.3%	23.1%	33.3%	45.5%	60.0%	77.8%	100.0%	128.6%	166.7%
1.8	5.9%	12.5%	20.0%	28.6%	38.5%	50.0%	63.6%	80.0%	100.0%	125.0%
2	5.3%	11.1%	17.6%	25.0%	33.3%	42.9%	53.8%	66.7%	81.8%	100.0%
2.2	4.8%	10.0%	15.8%	22.2%	29.4%	37.5%	46.7%	57.1%	69.2%	83.3%
2.4	4.3%	9.1%	14.3%	20.0%	26.3%	33.3%	41.2%	50.0%	60.0%	71.4%
2.6	4.0%	8.3%	13.0%	18.2%	23.8%	30.0%	36.8%	44.4%	52.9%	62.5%
2.8	3.7%	7.7%	12.0%	16.7%	21.7%	27.3%	33.3%	40.0%	47.4%	55.6%
3	3.4%	7.1%	11.1%	15.4%	20.0%	25.0%	30.4%	36.4%	42.9%	50.0%

Starting Yield	Reduction in Yield (Annual Basis, t/a)									
	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	3.5
t/a	*Minimum Price Improvement Required*									
4	5.3%	11.1%	17.6%	25.0%	33.3%	60.0%	100.0%	166.7%	300.0%	700.0%
5	4.2%	8.7%	13.6%	19.0%	25.0%	42.9%	66.7%	100.0%	150.0%	233.3%
6	3.4%	7.1%	11.1%	15.4%	20.0%	33.3%	50.0%	71.4%	100.0%	140.0%
7	2.9%	6.1%	9.4%	12.9%	16.7%	27.3%	40.0%	55.6%	75.0%	100.0%
8	2.6%	5.3%	8.1%	11.1%	14.3%	23.1%	33.3%	45.5%	60.0%	77.8%
9	2.3%	4.7%	7.1%	9.8%	12.5%	20.0%	28.6%	38.5%	50.0%	63.6%
10	2.0%	4.2%	6.4%	8.7%	11.1%	17.6%	25.0%	33.3%	42.9%	53.8%
11	1.9%	3.8%	5.8%	7.8%	10.0%	15.8%	22.2%	29.4%	37.5%	46.7%
12	1.7%	3.4%	5.3%	7.1%	9.1%	14.3%	20.0%	26.3%	33.3%	41.2%
13	1.6%	3.2%	4.8%	6.6%	8.3%	13.0%	18.2%	23.8%	30.0%	36.8%
14	1.4%	2.9%	4.5%	6.1%	7.7%	12.0%	16.7%	21.7%	27.3%	33.3%

How to use this table: This table can be used to estimate short-term and long-term tradeoffs between yield and quality. For example if a 'Late' cutting schedule would normally yield 1.4 tons/acre, and a grower wants to cut early for quality, he should require a minimum of 27.3% improvement in price (top part of table) if his yield is reduced by 0.3 t/a by that earlier cutting strategy. If a higher yielding variety has an 8 ton/acre yield potential, a variety that yields 1.5 tons/acre less should return a minumum of 23.1% greater price through improved quality (lower part of table) to justify choosing that variety.

Choosing a Mixed Strategy for Variety Selection. Since there is no single strategy for variety selection that appears to be advantageous under all price conditions, how does a grower resolve this question? When considering yield and quality, the probability of high vs. low priced years must be considered. Individual markets may differ; some growers may be less sensitive to forage quality than others. Additional factors, such as stand persistence potential, pest resistance, and soil adaptation must also enter into the decision.

Variety chose is typically a decision that endures 3 to 4 years. Hence, variety selection is not a management decision that can be used to respond to the yearly, much less monthly, fluctuations in the marketplace. However, having a range of dormancies (high-yielding lower quality non-dormant varieties as well as lower-yielding high quality dormant varieties) gives the grower greater flexibility to adapt to ever changing market conditions.

CALCULATING THE YIELD-QUALITY TRADEOFF

While we cannot completely resolve this quandary over cutting schedule and variety selection in this article, the following approach may be helpful. The yield-quality tradeoff, whether caused by differences in cutting schedules or different varieties, can be thought of in purely theoretical (but hopefully useful) terms. Although increases in yield affect gross returns per acre (more hay to sell), increases in quality improve the value (price per ton). Both affect gross returns. Since quality usually comes at the expense of yield in alfalfa (whether the mechanism is shorter cutting schedules or more dormant varieties), one must ponder how much yield one can afford to sacrifice for each incremental increase in price. If one chooses a higher quality strategy, one may be forced to sacrifice yield, but the question is: how much is too much?

A generalized approach to the economics of this choice might be helpful. Table 3 will enable a producer to project and compare the value of yield vs. quality, and make judgments as to the probability of a higher price resulting from a lower-yielding but higher value strategy. It may not be immediately obvious, but the allowable reduction in yield for each increase in value per ton changes based upon the starting yield level (Table 3). To take an obvious example, a 1 ton loss in yield for a given cutting schedule or variety strategy requires a 33% improvement in price at a 4 ton yield level, but just an 11% improvement in price at a 10 ton yield level (Table 3).

Table 4. Example comparing yield and quality of two varieties, average of 3 years, 3 cutting schedules, Davis, CA

Variety	Yield	ADF (%)
Plumas	8.7	26.1%
WL625HQ	11.3	29.1%
Difference	2.6 t/a	3.0 %

Comparing Two Varieties. This approach may be used to compare variety performance from this trial. A grower may be trying to decide whether to plant a very non-dormant variety (for example WL625HQ) or alternatively a very dormant variety (Plumas) in the Sacramento Valley. In our trials, WL625HQ yielded 11.3 tons/acre, and Plumas 8.7 tons/a, a difference of 2.6 t/acre decrease in yield (Table 4). However, the forage quality of Plumas was superior to WL625HQ (Table 4). Averaged over 3 years, Plumas was 3 percentage points lower in ADF concentration than WL625HQ, significant in CA markets. Using Table 3, starting with a variety yielding about 11 tons/acre per year, one would need a minimum of about 30% increased value, averaged across all cuts to justify planting a variety which yielded 2.5 tons/acre less (Table 3, lower table). A grower can then determine the probability of that price increase occurring.

High Yield & Early Cut vs. High Quality and Late Cut? Although a range of variety/cutting schedules are possible, two basic strategies might be 1) choose the highest yielding variety and cut early, or 2) choose a high quality variety and cut late. If we take the two varieties as examples above and compare them at the different cutting schedules, we may come up with different answers. If a grower chose the highest yielding variety (625HQ), but decided to cut at an early cutting schedule, the average yield might be 11.4 t/acre, with an ADF of 28.4% (Table 5). In most cases, this is frequently considered high enough quality for 'dairy quality hay'. 'Plumas' in this trail was a lower yielding variety, but always produced a higher quality hay (Table 5, Figures 3, 4, 5). However, 'Plumas' grown at a late cutting schedule was still 2 tons less than the highest yielding variety (525HQ) cut early, and it was higher in ADF (lower in quality). According to Table 3, a variety yielding 2 tons less than 625HQ, would require at least a 22% increase in price. It is hard to believe that 'Plumas would bring a greater price, since it was actually lower in quality in the late cutting than 625 HQ cut early (Table 5). However, what about comparing 625 HQ with 'Plumas cut at 28 days? The difference in yield in this case is 3.8 tons/acre, with an average difference of 3.3 points difference in ADF. This would require an average increase in price of over 46% (Table 3). Taking an average change in price per ADF of $7, it is difficult to believe that an approximately $21 increase in price/ton would be sufficient to justify this loss of yield.

Table 5. Comparison of 2 extreme examples (highest vs. lowest yielding) varieties at three different cutting schedules (2003 data, UC Davis), illustrating the yield-quality tradeoff.

	Yield			ADF		
Variety	Early	Mid	Late	Early	Mid	Late
		t/a			%	
Plumas	7.7	7.6	9.4	23.9	25.1	30.5
625 HQ	11.4	12.0	11.6	28.4	30.8	32.5
Difference	3.7 t/a	4.4 t/a	2.2 t/a	4.5%	5.6%	2.0%

However, these two varieties are probably the most extreme situations. There are a range of intermediate varieties and cutting schedules in both yield and quality which may very well justify choosing a lower-yielding variety in exchange for higher quality. Table 3 can be used to assist in this decision.

BALANCING MULTIPLE CONSIDERATIONS

The yield-quality tradeoff as affected by the variety-cutting schedule decision, presents a challenge. A range of economic conditions prevail over the life of an alfalfa stand, yield and quality are clearly inversely related. Stand persistence as an additional factor cannot be ignored. It is possible or even likely that no one strategy will be the winning strategy under all market conditions. Thus, we speculate that a mixed strategy might be reasonable. Plant more dormant varieties with a greater probability of producing high quality hay on some fields and plant less dormant varieties selected primarily for yield on other fields.

Similarly, cutting schedules also present a yield-quality tradeoff. Many growers instinctively lengthen their cutting schedules during 'up' years, a practice that is quite rational given this analysis (Figure 6). They feel forced to cut at ever-shorter schedules during times of intense pressure for quality (usually during moderate or low priced years), a decision which also appears rational, but oftentimes growers do not calculate the yield penalties from such practices. Although a 28 day schedule is the most common in California, examination of the cut-by-cut data shows that in many cases this schedule produced hay that was 'just short' of high quality expectations (detailed data not shown). Agronomically, there are many benefits to longer cutting schedules. A 'mixed' cutting schedule strategy, which allows at least 2 cuts per year to 'go long', to replenish root reserves may be beneficial (Marble, 1990). A 'staggered' cutting schedule produced by varying the sequence of field cuts may allow growers to target some cuts for 'yield' and other cuts for 'quality' (Orloff & Putnam, 2004). The development of a better understanding of the economic tradeoffs between yield and quality is critical to selecting the most profitable variety/cutting schedule combination for different market conditions.

CONCLUSIONS

Several clear trends are apparent from this study. Fall dormancy (FD) of the variety has a large effect on both yield and quality of alfalfa. Dry matter yield increased an average of about 0.4 t/acre per unit of FD rating in UC Davis trials. Quality factors (CP, ADF, and NDF) were also influenced by FD score in a dramatic fashion, explaining 80% or greater of the variation between varieties. Generalizing the relationship between alfalfa FD and yield and quality enables these factors to be analyzed economically, and allows the use of FD score as a guide for rational variety selection decisions. Cutting schedule, however, had a larger effect on the quality of the final product than did variety. Early cutting schedules resulted in the production of more 'dairy quality' hay compared with later cutting schedules, regardless of variety. Analysis of the yield-quality tradeoff of alfalfa is fundamental to selecting the optimum variety as well as the optimum cutting schedule. It seems axiomatic that the forage quality potential of alfalfa varieties should not be viewed in isolation from their yield potential. A complete analysis of the value of yield vs. quality under different market conditions is important toward understanding the question of variety contribution to forage quality and profitability under different cutting schedules.

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