USING VARIETIES OR CUTTING SCHEUDULES TO ACHIEVE QUALITY HAY —WHAT ARE THE TRADEOFFS?

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ABSTRACT

The use of 'high quality' varieties has been proposed as a method to achieve high forage quality. However, there is strong evidence that high quality often comes at the expense of yield. Studies conducted at UC Davis indicate the powerful influence of Fall Dormancy (FD) on both yield potential and forage quality. More dormant varieties (FD 2-4) produce lower fiber (approximately 2 points ADF) and higher protein forage (approximately 2 points CP on the average) than nondormant lines (FD 8-10). However, yields were almost always lower with the more dormant varieties. The average yield penalty for each unit of FD ranged from about 0.3 tons/acre to 0.6 tons/acre per year in these studies—total annual yield differences of up to 3.5 tons/A between some varieties. Cutting intervals varying from approximately 24 days to 33 days between cuts had a stronger influence on quality than did variety. *Early* cutting schedules resulted in 85% production in the 'Premium' and 'Supreme' categories, whereas *Medium* and *Late* cutting schedules resulted in 53% and 45% of the production in those categories, respectively in 2002 (average of 18 varieties). Growers need to determine the amount of yield loss that can be sacrificed for higher quality under different market conditions, since under some market conditions the yield sacrifice is justified while in other market conditions it is not. While selecting varieties with lower FD has the potential to improve quality, the tradeoff between yield and quality are fundamental issues when choosing a variety for improved forage quality.

Keywords: forage quality, variety selection, economics, harvest schedules, TDN, ADF, CP,

INTRODUCTION

Forage quality of alfalfa hay produced in California has been of major importance in recent years. Differences between hay quality categories on the order of $40-$70 per ton (difference between top to bottom categories) have been observed. The 'premium' for high quality hay is especially intense in so-called 'down' years, when hay supplies are plentiful in relation to demand (such as 2002-2003). Unrelenting pressure for high quality hay by California dairies has caused many growers to scramble for any method that allows them to achieve a high quality hay product.

Important factors for choosing alfalfa varieties in approximate order of importance:

- Yield Potential
- Fall Dormancy
- Disease Resistance
- Stand Persistence
- Forage Quality Potential
- Price

There are a number of agronomic practices which affect quality, the most important of which are cutting schedule, harvest

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management, and weed control (Putnam et al., 2000). However, several other factors influence quality as well, including time of day for harvesting, insect pressure, soil type, and choice of alfalfa variety. This paper reviews the potential influence of variety on forage quality, its interaction with cutting schedule, and suggests approaches to understanding variety choice in relationship to forage quality.

WHAT IS IMPORTANT FOR VARIETY SELECTION?

Yield performance, fall dormancy (FD), disease resistance, stand persistence and forage quality are important criteria for variety selection, in approximate order of importance (see companion article in the symposium by Poole et al., 2003). Current yield performance of alfalfa varieties in California is routinely reported at http://alfalfa.ucdavis.edu. The use of yield as the primary criteria for variety selection is usually justified, given the large impact of crop yield on profitability. Yield potential (over multiple years) integrates many factors, including stand persistence, fall dormancy and disease resistance. However, forage quality has become a much more important factor affecting profitability in recent years—we estimate over $300 million in value is ascribed to quality factors in California alone. There has been a trend in recent years in the Sacramento Valley and Northern San Joaquin Valley to plant lower dormancy varieties (3-4) in order to obtain higher forage quality, even if these varieties may be lower yielding. Growers have perceived the demand for high quality to be so intense that sacrifice in yield may be justified in order to maintain marketability of the product. In some market years (2003 being a good example), *Medium* and low quality hay simply does not sell.

Cutting schedules also have a profound effect on forage quality. This raises the question as to which strategy is more profitable: select a nondormant variety for optimum yield and obtain high quality only through shorter cutting schedules or select a more dormant variety which may allow longer cutting schedules while still achieving high quality. This second approach would result in fewer cuttings, lowering harvesting costs. Furthermore, since more dormant varieties grow more slowly, these may allow a larger window of opportunity for high quality cuttings during very busy periods of the year.

VARIETY ADAPTATION

Alfalfa is produced over a wide range of climatic zones. Thus, the optimum variety for one location is often not the optimum variety for another location, especially in California with its widely divergent growth regions. Fall dormancy is an important characteristic which helps define the adaptation of a variety to a region. Fall Dormancy is defined as the reduction in growth in the fall due to decreasing temperatures and daylength, a characteristic which differs greatly among alfalfa cultivars. Fall Dormancy scores range from 1 to 11, with the lower numbers exhibiting less growth (dormant varieties) and the high numbers showing more growth in the fall (non-dormant varieties). Fall Dormancies traditionally grown in the intermountain region range from 2-4 (with an occasional 5), Sacramento Valley 6-8, San Joaquin Valley 7-9, and Imperial Valley 8-11. The poor winter hardiness of FD 7-11 varieties precludes growing these varieties in cold regions. On the other hand, more dormant varieties can be grown in warmer regions, giving growers in the Sacramento Valley, San Joaquin Valley and other warm areas more options in terms of variety selection. In these areas, dormancy groups from 1-11 could theoretically be grown (but are not necessarily recommended).

Some growers in recent years have elected to plant more dormant varieties in these areas with the desire to produce higher quality hay. However, shorter cutting schedules can also be used to achieve the same result with the more traditional semi- or non-dormant varieties. Unfortunately, yield and quality are typically negatively correlated, in respect to both cutting schedules and variety selection. Optimum profitability does not often occur at maximum yield or maximum quality, complicating the variety selection question. The trade-off between yield potential and quality potential is a critical consideration.

The tradeoff between yield and quality when examining alfalfa varieties was readily apparent from variety research data collected in 2001-2001. Large differences in yield were observed due to Fall Dormancy of the varieties (Figure 1). These differences were approximately 0.58 tons/acre per year for each unit of fall dormancy, for a total of nearly 3.5 tons/acre yield differences across the range of dormancy groups grown in this UC Davis trial. There are exceptions for individual varieties, of course, but the influence of Fall Dormancy on yield was unmistakable.

High yielding varieties unfortunately were not the highest in forage quality. Data from Cut 5 (Figure 2) of this same trial showed the relationship between yield and ADF content; the varieties highest in yield were lowest in quality (highest in ADF), and the varieties lowest in yield were typically the highest in quality (lowest in ADF). The range of ADF levels in this trial spanned the hay marketing categories used in California, from ‘Fair’ to ‘Supreme’, due only to variety choice—all varieties were cut on the same schedule.

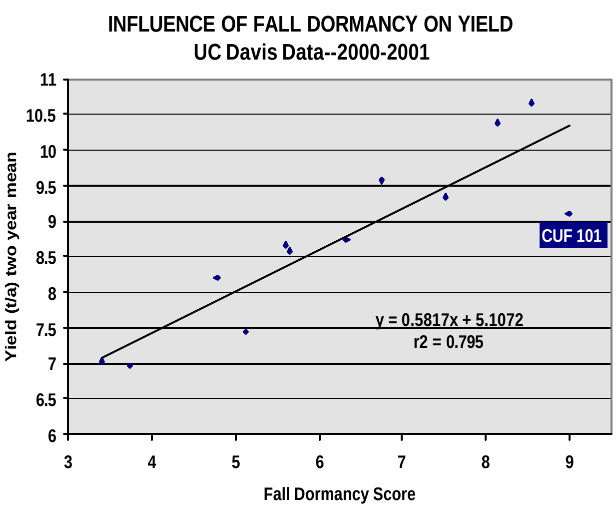


Figure 1. Fall Dormancy effects on yield. Average change in yield was 0.58 ton/acre penalty for every unit decrease in Fall Dormancy (Two year data, 1999 UC Davis trial).

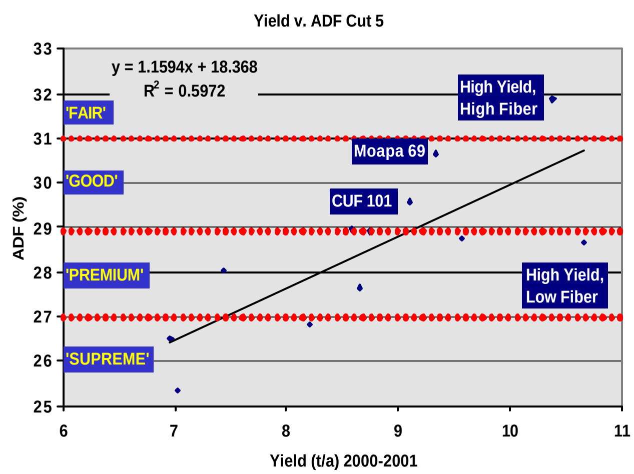
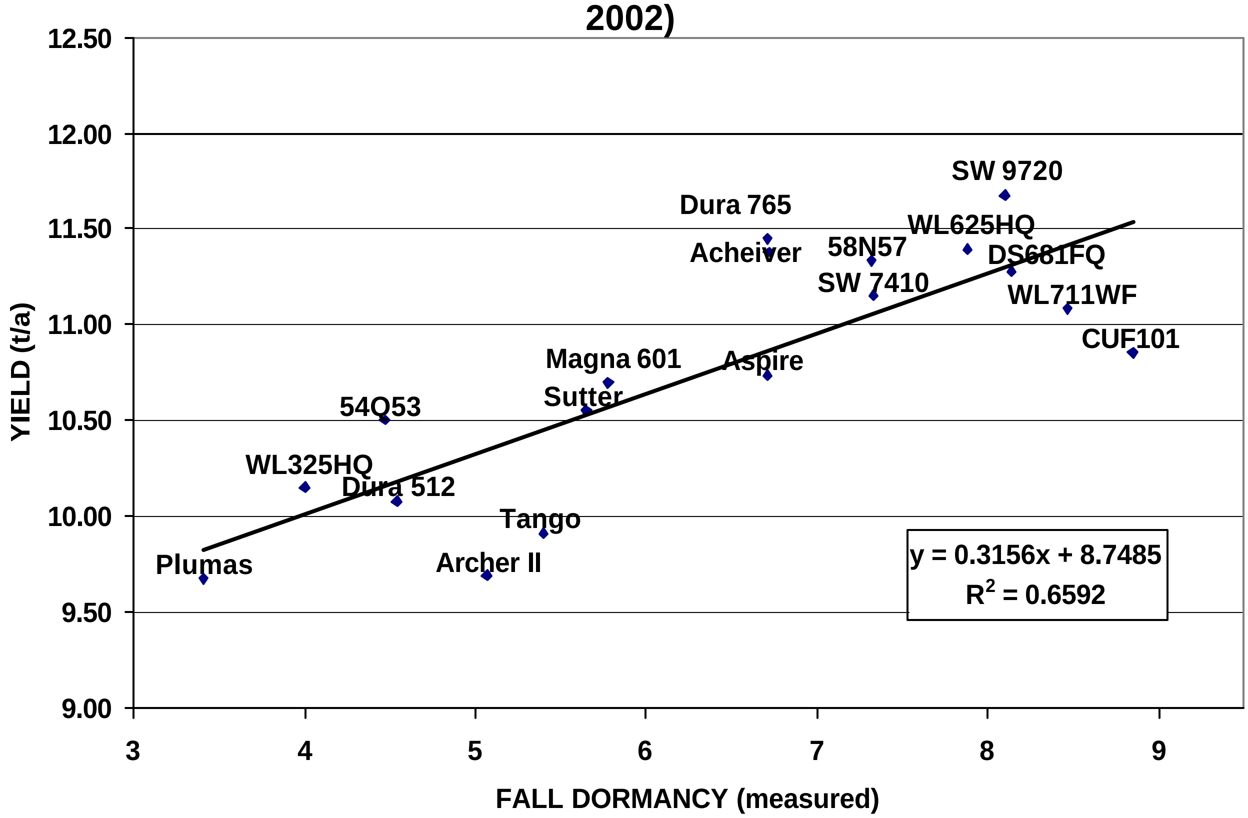


Figure 2. ADF concentration of alfalfa varieties, Cut 5, 2001, as a function of the yield of those varieties (1999-grown UC Davis trial). ‘Fair’ to ‘Supreme’ represents USDA hay marketing categories.

2001 FIELD STUDIES

A field trial was planted on the UC Davis Campus in fall, 2001 with 3 cutting schedules and 18 varieties, ranging from Fall Dormancy 2 to Fall Dormancy 10. The study was planted using a research-plot grain drill. A Randomized Complete Block design with a split plot restriction was used (varieties were sub-plots, cutting schedules main plots). Treatments were replicated three times. This study has been conducted for two years (2002 and 2003), but this report will only consider the data from year 1, since the forage quality analysis from year 2 is not completed as of this date. Fall Dormancy ratings reported are actual field measurements measured by L. Teuber and K. Taggard (Putnam, et al., 2002), which may differ somewhat from those reported by seed companies. This should be considered a preliminary report since 2003 quality samples has not been analyzed.

Figure 3. EFFECT OF FALL DORMANCY ON YIELD (UCD 2002)



EFFECT OF VARIETY ON YIELD

The varieties used in this study varied in yield by as much as 2 tons/acre, averaged across replications and cutting schedules (Figure 3). The relationship between fall dormancy and yield was similar to that observed in an earlier trial (Figure 1), but the effect of dormancy was not as pronounced as in the 1999 study. These yield differences are typical of those commonly observed in alfalfa variety trials in California's Central Valley (see http://alfalfa.ucdavis.edu for current alfalfa variety information). Each unit of Fall Dormancy reduced yield an average of approximately 0.32 tons in 2002 (Figure 2).

It should be noted that fall dormancy explains much, but not all, of the yield differences between varieties—there were several varieties with FD of 6-7 that produced yields similar to, or greater than, varieties with FD of over 9 (Figure 2). In the Sacramento Valley and upper San Joaquin Valley, varieties with mid-level dormancy (6-8) are typically recommended (when only yield is considered); since they often have yields as high as FD 8-9 varieties, but persist better in this environment.

EFFECT OF VARIETY ON FORAGE QUALITY

Alfalfa variety had a significant effect on forage quality in this study. Forage quality is estimated using several lab measurements, including Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), and Crude Protein (CP). The ADF concentrations of the 18 varieties in this 2002 trial are shown in Figure 4. Levels ranged from 27.2 to 29.8, averaged across cuttings, harvest schedules, and replications. A range of CP and NDF levels were observed with a spread of about 2 percentage points (Figures 5 and 6). On average CP decreased about one-third of a percentage point with each number increase in fall dormancy score, while NDF increased by about one-third percentage point with each number increase in fall dormancy score. It should be pointed out that other sources of variation were also important, including the harvest (cut), and the cutting schedule.

Figure 4. FALL DORMANCY EFFECT ON ADF- UCD, 2002

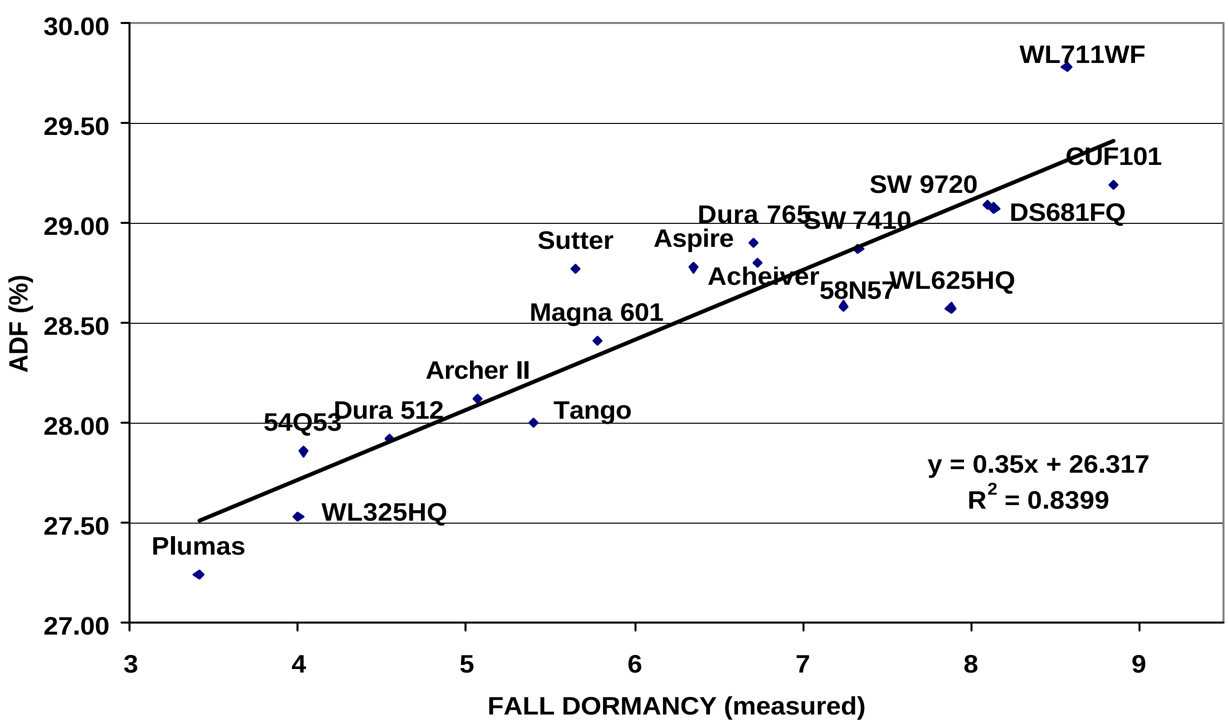


Figure 5. EFFECT OF FALL DORMANCY ON CRUDE PROTEIN - UCD, 2002

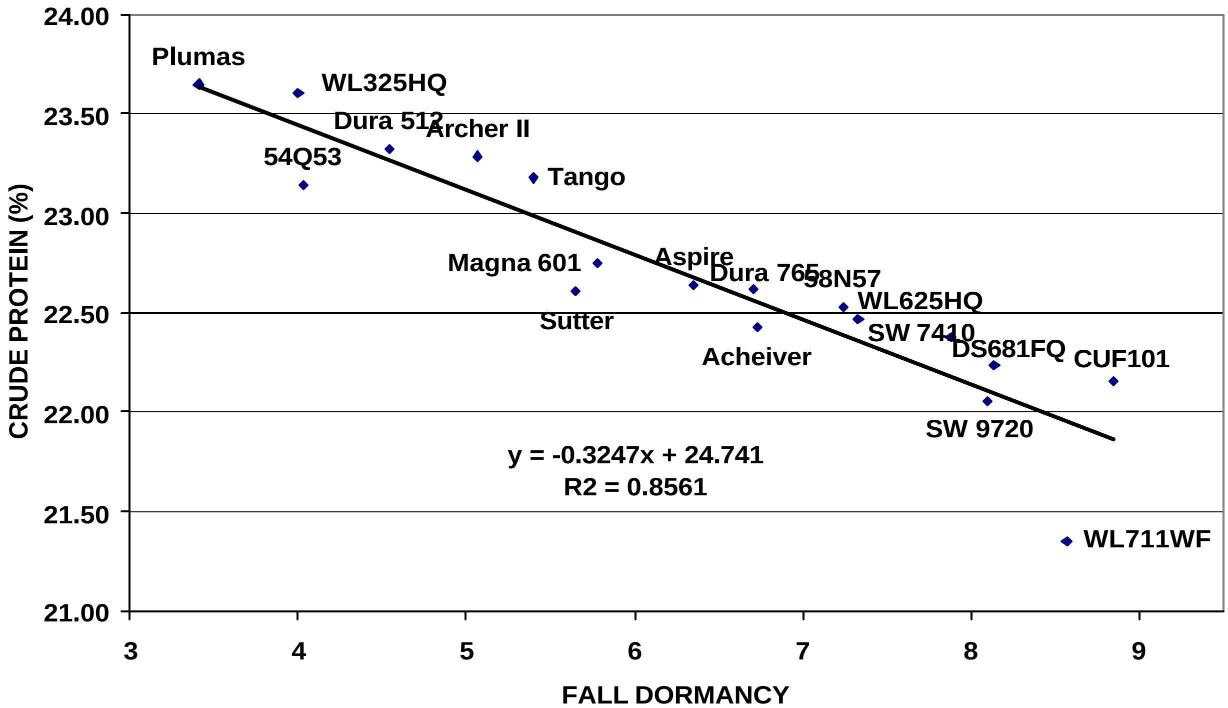
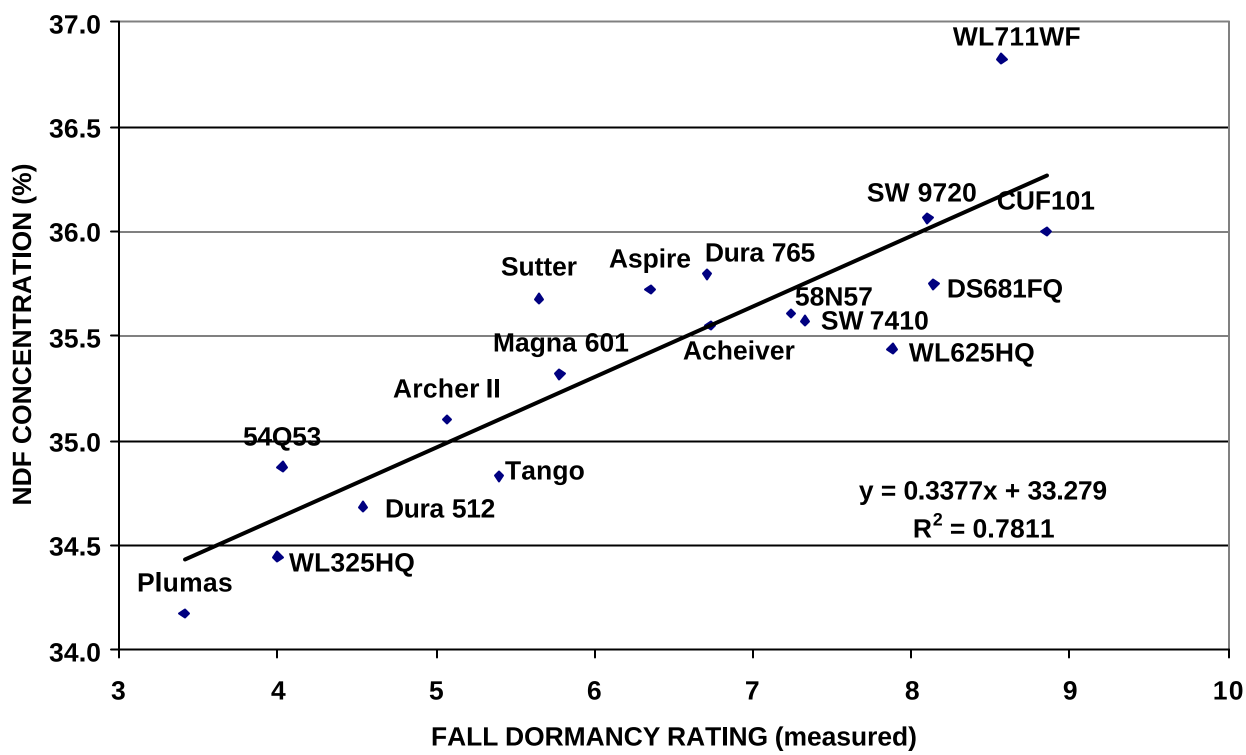


Figure 6. FALL DORMANCY EFFECT ON NDF - UCD 2002

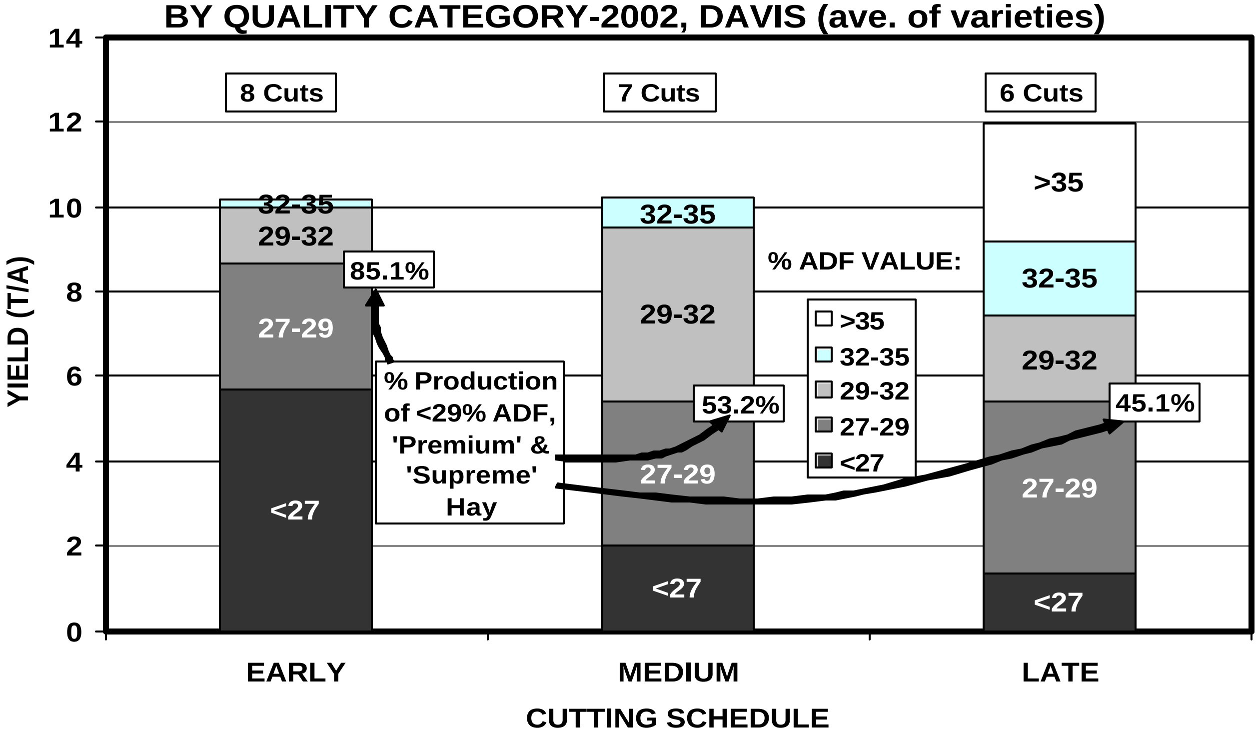


There are several interesting ideas that can be gleaned from the forage quality data from this trial (Figures 4-6). First, Fall Dormancy appears to be a very powerful predictor of forage quality, explaining about 80% or more of the variation between varieties in all three quality measurements (ADF, CP, and NDF). The second is that there are some varieties that appear to be 'exceptions from the rule'. These are the individual lines which do not fall near or upon the regression lines shown in Figures 4-6. These 'deviations' may be important when understanding the genetic influences on quality measurements, since characteristics other than FD may have an effect on quality. From a grower's perspective, it is important to find varieties that exhibit better-than expected quality for their dormancy group

EFFECT OF CUTTING SCHEDULE ON YIELD AND FORAGE QUALITY

Cutting schedules had a dramatic effect on 2002 yields in this trial (Figure 7). The three cutting schedules in this trial represented three strategies: *Early* (23-24 days between harvests, resulting in 8 cuts for the year), *Medium* (approximately 28 days between harvests, resulting in 7 harvests for the year), and Late (approximately 33-34 days between harvests, resulting in 6 harvests for the year). In the Northern San Joaquin and Sacramento Valleys, the most common cutting schedule is clearly the '*Medium*' schedule, with most growers aiming for about 4 weeks between harvests. However, individual growers practice various strategies, including very severe cutting schedules (21-24 days) to obtain high quality, to long cutting schedules (35-40 days) to maximize yield for non-dairy markets or due to logistical restrictions (weather and irrigation schedules).

Figure 7. EFFECT OF CUTTING SCHEDULE ON YIELD BY QUALITY CATEGORY-2002, DAVIS (ave. of varieties)



Total yields were significantly greater for the '*Late*' cut in 2002, but the '*Early*' and '*Medium*' cutting schedules were not significantly different (Figure 7). The lack of significance between these two treatments (*Early* and *Medium*) belies a more complex result. The quantity of alfalfa that could be considered 'Dairy Quality' (generally hay products with ADF values of 29% and below) was significantly different between the three cutting schedules. While 85% of the hay produced with the '*Early*' cutting schedule had ADF values less than 29%, only 53% of the *Medium* and 45% of the *Late* cutting schedules had ADF values less than 29%. With incentives up to $70 per ton for Premium hay in some years, it is not surprising that some growers employ very severe cutting schedules in order to produce higher returns. However, costs of production are not equal between these cutting schedules. Additionally, this is only 1 year of production; the effects of *Early* cutting may be compounded over years and can affect stand persistence. Also, other studies have shown greater yield reductions from severe cutting schedules (Marble, V. 1990) than those seen in Figure 7, so caution should be used in interpreting these data. But the powerful effects of cutting schedules on forage quality can be readily seen in this study. These results are similar to those from published studies documenting the trade-off between yield and quality due to changes in cutting schedules

INTERACTIONS BETWEEN CUTTING SCHEDULE AND FORAGE QUALITY

While it is clear from these data and other published research that both cutting schedules and varieties affect yield and quality, what about the interaction between choice of variety and cutting schedule? Do some varieties perform better on longer vs. shorter cutting schedules? Should variety choice be circumscribed by the cutting schedule under which it is grown? Under what cutting schedules do varieties appear to have an impact upon quality?

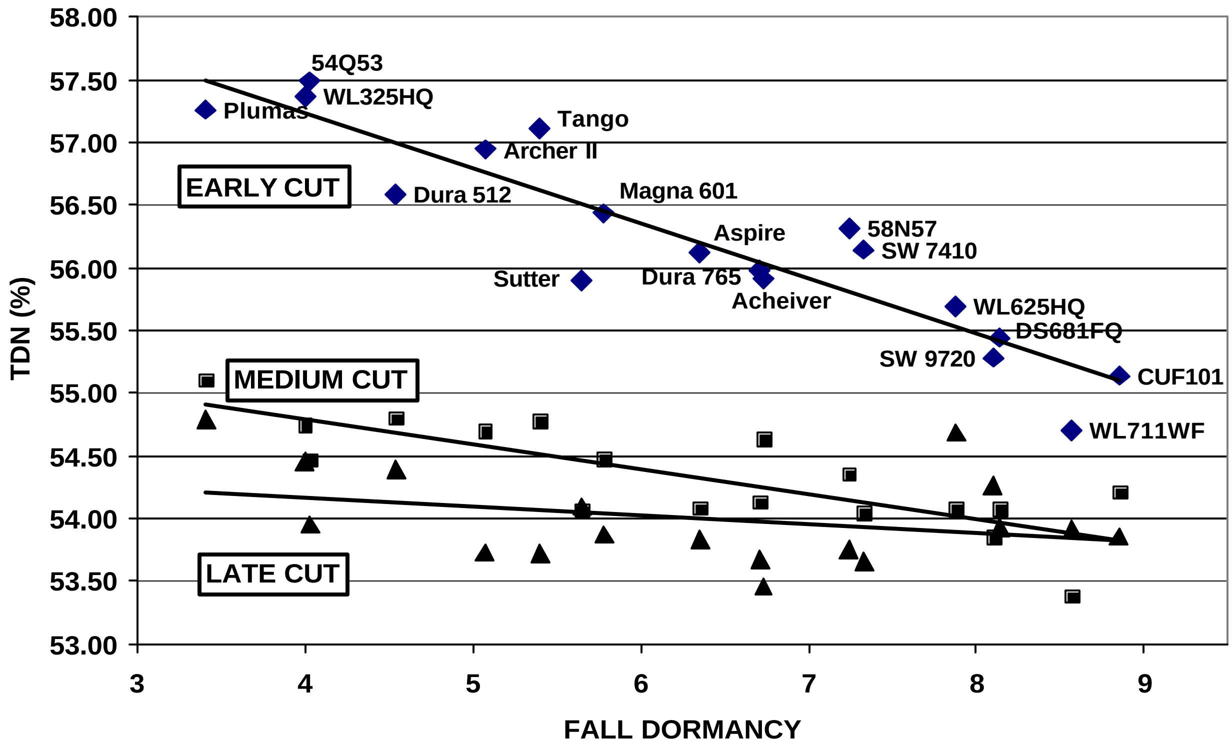
STRATEGIES FOR ATTAINING QUALITY USING VARIETIES AND CUTTING SCHEDULES

Several strategies appear to be reasonable when choosing an optimum variety and cutting schedule. One strategy would be to choose a variety based primarily upon yield potential (along with disease and insect resistance, persistence, and other adaptation considerations). High quality would be attained primarily by shortening the cutting schedule. Another approach would be to choose a more dormant variety that, using a 'standard' cutting schedule, might provide higher quality compared with a more non-dormant variety. Additionally, growers who plant more dormant varieties claim that they provide a 'wider window' for improved forage quality, since they grow more slowly. Research has shown rapid losses in quality of alfalfa during a growth period, particularly in the summer months (Ackerly et al., 2000).

The interaction between variety and cutting schedule and their influence on total digestible nutrients (TDN) are shown in Figure 8. In this figure, the clear advantage of *Early* harvests was seen across all alfalfa varieties, representing a range of fall dormancies. However the effect of Fall Dormancy on forage quality (averaged over cutting schedules in Figures 4, 5 and 6) was much more pronounced in the *Early*-cut treatment compared with the later-cut treatments (note the steeper slope of the line for the *Early* cut treatment in Figure 8). A change of approximately 2.5 percentage points TDN were seen due to varieties in the *Early* cutting schedule, whereas a change of only about 1 percentage point TDN was observed at *Medium* and *Late* cutting schedules. In most cases, more dormant varieties were higher in quality than less dormant varieties, although exceptions occurred for individual varieties.

These results provide some support for the strategy of choosing a high-yielding (semi-dormant or non-dormant) variety and cutting at *Early* cutting schedules. A few of the non-dormant varieties cut at *Early* schedules had TDN values similar to dormant varieties cut at *Medium* schedules.

Figure 8. EFFECT OF FALL DORMANCY AND CUTTING SCHEDULE ON TDN
Average of Cuttings, UC Davis, 2002

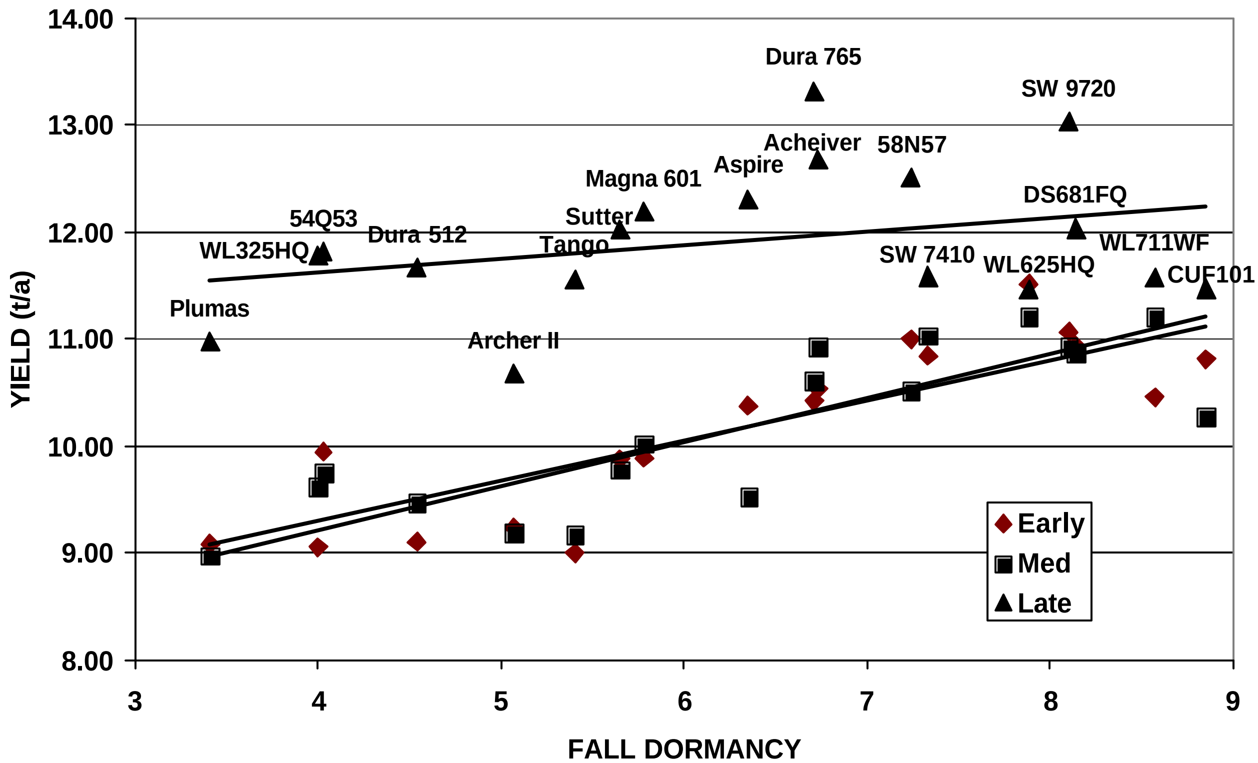


However, these were the exception; almost all of the non-dormant varieties cut at the *Early* cutting schedule exhibited superior TDN compared with any of the varieties harvested at longer cutting schedules (Figure 8). Dormant varieties improved forage quality at the *Early* and *Medium* cutting schedules, but had negligible effects at the *Late* cutting schedule.

YIELD INTERACTIONS BETWEEN VARIETY AND CUTTING SCHEDULE

As Figure 3 indicates, Fall Dormancy of alfalfa variety influenced yield in this experiment. However, there appeared to be a stronger relationship between FD and quality than FD and yield. Fall dormancy of the variety explained 65% of the variation in yield while FD explained over 80% of the variation in several quality parameters (Figures 3-6). When considering cutting schedules and variety, Fall Dormancy had a stronger effect on yield in the *Early* and *Medium* cutting schedule treatments than in the *Late* cutting schedule (Figure 9). The difference in yield between dormant and non-dormant varieties averaged approximately 2 tons/acre in the *Early* and mid cutting schedules—there was a fairly clear yield advantage for non-dormant varieties compared with dormant lines. Differences were closer to 1 ton/acre in the *Late* cut system, and there was no clear advantage to non-dormant varieties compared with most semi-dormant lines. In fact, several semi-dormant lines (FD 6-7) were superior in yield to non-dormant standards such as CUF 101 (Figure 9).

Figure 9. EFFECT OF CUTTING SCHDULES AND VARIETY ON YIELD - UC Davis, 2002



ECONOMICS AND OTHER BOTHERSOME ISSUES

While this research provides a preliminary indication to guide the cutting schedule/variety selection decision, it does not completely answer the question. While severe cutting schedules are widely known to produce superior quality hay, they also usually result in shorter stand persistence. 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. Reduced stand density from frequent cutting leads to weed encroachment compared with longer schedules (Marble, 1990). Frequent harvests reduce the life of the stand, increasing the costs of production (which are already higher with more cuttings per year). Thus, a yield-quality tradeoff question is further complicated by a yield-quality-stand persistence tradeoff question.

If that were not sufficiently complex, the relative economic value of yield vs. quality must be determined. General relationships are not sufficient to completely resolve the question of different production strategies. 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.

UNDERSTANDING THE YIELD QUALITY TRADEOFF

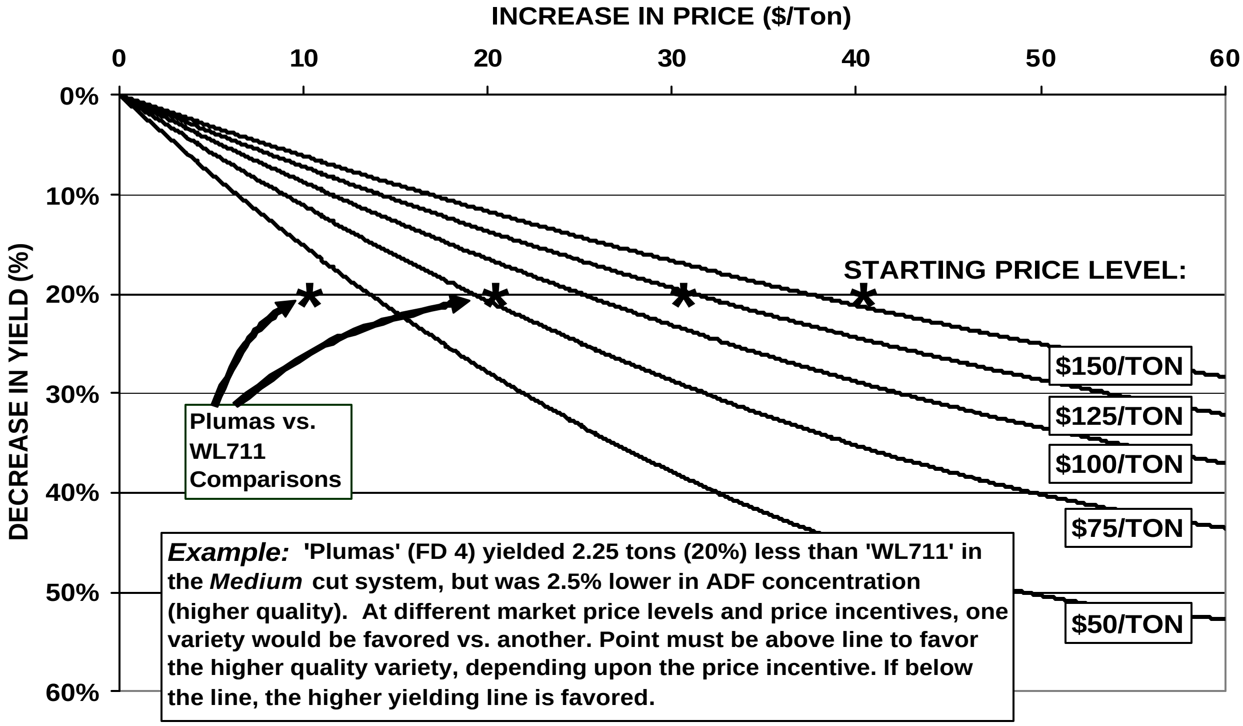
While we cannot completely resolve this quandary over cutting schedule and variety selection in this article, the following approach may be helpful. The yield-quality tradeoff, whether caused by differences in cutting schedules or differences in variety, can be thought of in purely theoretical (but hopefully useful) terms. Although increases in yield affect gross returns per acre through increased number of units (more hay to sell), increases in quality improve the value of each unit (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?

How much yield can I afford to loose? Figure 10 shows the allowable decrease in yield that justifies an improvement in price. Each curve shows the 'break even' level, where the income lost due to a decrease in yield matches the improvement in price (at different starting price levels per ton). A management strategy (whether variety, cutting strategy, or other management strategy), which results in an improvement in value per ton can be compared at the line for the current starting market value (Figure 10). The resulting point should be above a given isoline for that strategy to be considered beneficial.

It may not be immediately obvious, but the allowable reduction in yield for each increase in value per ton changes based upon the starting price level (Figure 10). With $50/ton hay, growers should be willing to sacrifice up to about 33% of their yield in favor of a strategy which produces an additional $25/ton of hay. However, when hay is $150 per ton, growers should be willing to sacrifice only up to about 13% of their yield for the same improvement in value. In short: there are much greater incentives for improvement in value per ton in 'down' price years, a fact well known to alfalfa producers.

Interpretation of Figure 10 in terms of the variety comparison may be easier using an example from the yield and quality data from the Cutting Schedule trial conducted at UC Davis. A grower may be trying to decide whether to plant a very non-dormant variety (WL711) or alternatively a very dormant variety (Plumas) in the Sacramento Valley. In our trials, WL711 yielded 11.22 tons/A and Plumas 8.97 tons/A, a difference of 20% (decrease in yield) in the *Medium* cutting schedule. However, the forage quality of Plumas was superior to WL711 (Figure 4 and Figure 8). In the *Medium* cutting schedule, Plumas was 2.6 percentage points lower in ADF concentration than WL711 (across the season averaged 30.7% vs. 28.1% ADF). Under most market conditions in California, this difference is sufficient to increase the value per ton significantly (USDA market categories would categorize the first as 'Good', the latter as 'Premium').

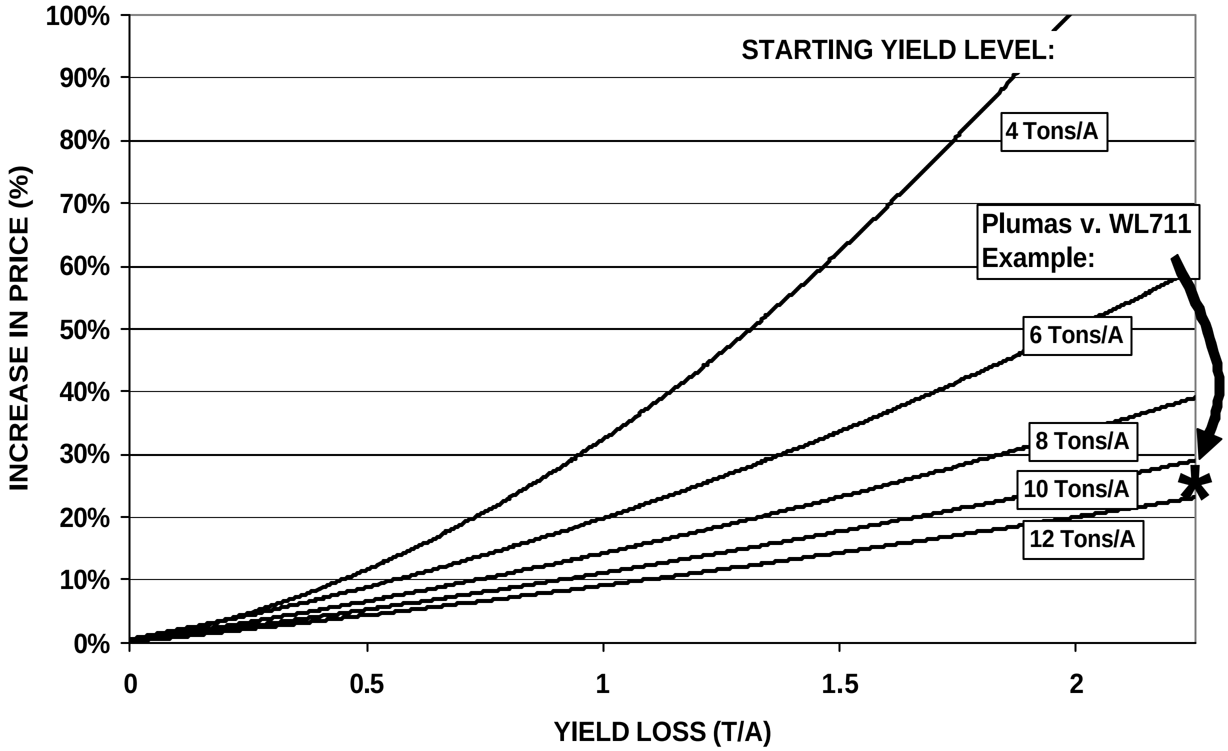
Figure 10. ALLOWABLE DECREASE IN YIELD FOR EACH INCREASE IN PRICE



In Figure 10, if a producer believes that the improved quality of Plumas is sufficient to improve the price $10 per ton, there are no market conditions where this choice would be reasonable. The yield penalty is greater than the break-even line, even at 50$/ton hay (the point is lower than any isoline, Figure 10). However if a $20/ton price incentive is realized through improvements in quality, this choice would be reasonable at 50$/ton hay prices, perhaps 75$/ton prices, but not $100 or greater hay prices. At the lower hay price, the price improvement more than makes up for the loss in yield, but at higher hay prices, the yield loss is too great. If a $30/ton improvement were to result from this 2.6 percentage point improvement in ADF value, the choice would be worthwhile at $100 hay price levels, and if the incentive were $40/ton, the choice would be worthwhile at all price levels given in Figure 10.

How much price increase will I need to sustain a yield loss? Another way to look at this issue is provided in Figure 11. Using this perspective, the incentive to accept a yield loss in favor of a forage quality increase (and improved value) can be calculated. The requirement for an increase in price to compensate for a yield loss is shown at various yield levels in this graph. For example, a 1 ton loss with a 4 ton yield level (a 25% loss), requires a 33% increase in price to compensate for that loss, and a 2 ton loss at 4 tons/a requires a 100% increase in price (cutting yields in half had better be compensated by at least a doubling of the price!). Yield losses at higher yield levels are not as devastating as at lower yield levels. In the comparison between

Figure 11. PRICE INCREASE REQUIRED TO COMPENSATE FOR YIELD LOSS AT VARIOUS YIELD LEVELS



Plumas and WL711 in the *Medium* cutting schedule cited in the previous paragraph, approximately a 25% or better improvement in price is required to compensate for the 2.25 tons/A yield difference between the two varieties (at a starting yield level of 11.22 tons/acre—see Figure 11). If the grower believes that the improved quality will result in a 25% or greater increase in price, the higher quality variety should be grown, if not, the higher yielding variety should be grown.

A range of economic conditions prevail over the life of an alfalfa stand. This complicates the issue of variety choice. It is possible or even likely that no one strategy will be the winning strategy under all market conditions. Thus, similar to the choosing of 'staggered' cutting schedules reported by Orloff et al., 2000, we speculate that combinations of both strategies may be a reasonable approach. Plant more dormant varieties with a greater probability of producing high quality hay on some fields and on other fields plant less dormant varieties selected primarily for yield. However, this concept requires further thought and research. 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

The research reported here should be viewed with some caution since data from additional years need to be summarized. However, several clear trends are apparent. Fall dormancy (FD) has a large effect on both yield and quality of alfalfa. Dry matter yield increased 0.3 to 0.6 tons/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—FD of the variety explained 80% or greater of the variation between varieties in forage quality parameters. 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. Varieties claimed as 'high quality' may also be lower in yield, possibly resulting in overall reduced returns. 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.

REFERENCES

Ackerly, T., D.H. Putnam, and S. Orloff. 2000. Quantifying the yield-quality tradeoff. IN Proceedings, 2000 National Alfalfa Symposium, Las Vegas, NV, UC Cooperative Extension, University of California, Davis.

Marble, V. 1990. 1990. Factors to Maximize Production in the 1990s. IN Proceedings, 20th California Alfalfa Symposium, December, 1990, Visalia, CA. University of California Cooperative Extension, University of California, Davis, CA 95616.

Orloff, S.B. D.H. Putnam, S. Blank, and T. Ackerly. 2000. Cutting Schedules to Maximize Profit. IN Proceedings, 2000 National Alfalfa Symposium, Las Vegas, NV, UC Cooperative Extension, University of California, Davis.

Putnam, D.H. S. Orloff and T. Ackerly. 2000. Agronomic Practices and Forage Quality. IN Proceedings, 2000 National Alfalfa Symposium, Las Vegas, NV, UC Cooperative Extension, University of California, Davis.

Poole, G., D.H. Putnam, and S. B. Orloff. 2003. Methods for Choosing Alfalfa Varieties Using Information Resources. IN Proceedings, 33rd California Alfalfa Symposium, December 17-19, 2003, Monterey, CA. University of California Cooperative Extension, University of California, Davis, CA 95616.