Economic Sustainability: Genetic and cutting schedule influences on the yield-quality tradeoff in alfalfa *(Medicago sativa L)*

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Abstract

Although alfalfa *(Medicago sativa L.)* yield is often emphasized in plant breeding, animal productivity as well as economic return is dependent upon both forage yield and quality factors. Field studies were conducted at Davis, CA (a Mediterranean environment) to examine the interaction between cutting schedule and variety. Cutting intervals varying from approximately 24 days to 33 days between harvests had a stronger influence on quality and seasonal yield than did variety. Results indicated a powerful influence of Fall Dormancy (FD) rating of the variety on both yield potential and forage quality. Varieties with little fall growth (FD 2-4) produce lower fiber (approximately 25 g kg^{-1} Neutral Detergent Fiber) and higher protein forage than non-dormant varieties (FD 8-10). However, forage yields were almost always lower for the more dormant varieties. The average yield penalty for each unit of FD ranged from about 0.7 to 1.3 t ha^{-1} per year per unit FD in these studies—total annual yield differences was as much as 7.8 t ha^{-1} between some varieties. Choice of higher quality varieties did not reduce the negative effect of late cutting schedule on quality. Selecting varieties with lower FD scores (dormant varieties) or more frequent cutting schedules has the potential to improve quality, but this must be balanced against lower yield potential of these strategies. This yield-quality tradeoff requires fundamental economic understanding when designing efficient and sustainable alfalfa production systems.

Media summary

Since both yield and quality are related to animal production in alfalfa; studies on varieties and cutting schedules that analyse this trade-off in relation to economic return are presented.

Keywords

irrigated forages, forage quality, varieties, cutting schedule, economics, harvest schedules, TDN, ADF, NDF, CP

Introduction

Most alfalfa *(Medicago sativa L.)* breeding programs have focused on the attainment of disease and insect resistance and higher forage yield. However, forage quality is fundamental to animal performance, and economic return. California is the largest producer of alfalfa hay in the USA, and approximately 30% of the $1 billion value of the crop is determined by quality factors. California now produces about 20% of the nation's milk, and strong market pressure for high quality alfalfa has stimulated growers to seek methods that allow them to achieve high quality as well as high yield. There are a number of agronomic practices that affect quality (Putnam *et al.*, 2000), the most important of which are cutting schedule, harvest management, and weed control. However, choice of variety influences quality as well. Growers could choose simply the highest yielding varieties, then cut for yield, or alternatively select higher quality varieties. Our objectives were to quantify the yield-quality tradeoff and interactions between variety choice and cutting schedule from an economic perspective.

Variety Choice and Fall Dormancy

Fall Dormancy (FD) is an important characteristic defining the adaptation of a variety to a region. Fall Dormancy is defined as the reduction in growth in the fall (autumn) due to decreasing temperatures and daylength, a characteristic that differs greatly among alfalfa varieties (Teuber *et al.*, 1998, Poole *et al.*, 2003). 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 dormancy groups traditionally grown in different climatic regions are as follows: colder regions, 2-4 (with an occasional 5); intermediate temperature zones, 5-8; Mediterranean zones, 6-9; hot desert zones, 8-11. Fall dormancy clearly influences persistence, but may also influence both forage yield and quality.

Field Studies

A field trial was planted in Davis, CA in fall, 2001 with 3 cutting schedules and 18 varieties, ranging from FD 3 to10. A Randomized Complete Block design with a split-plot restriction and three replicates was used (cutting schedules main plots, varieties were sub-plots). This study was conducted for three years (2002-2004), with detailed measurements of yield and quality, but this report will only consider the data from year 1. Fall Dormancy ratings reported are actual field measurements averaged over 3 locations in California (Teuber *et al.*, 1998).

Variety and cutting schedule effects on Yield

The varieties used in this study varied in yield by as much as 4.5 t/ha, averaged across replicates and cutting schedules (Figure 1). These yield differences are typical of those commonly observed in alfalfa variety trials in California's Central Valley (see http://alfalfa.ucdavis.edu for detailed alfalfa variety trial information). Each unit of FD reduced yield by an average of 0.72 t/ha in 2002 (Figure 1). 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 1). In the Sacramento Valley and the Northern San Joaquin Valley of CA, varieties with mid-level dormancy (6-8) are typically recommended (when only yield is considered).

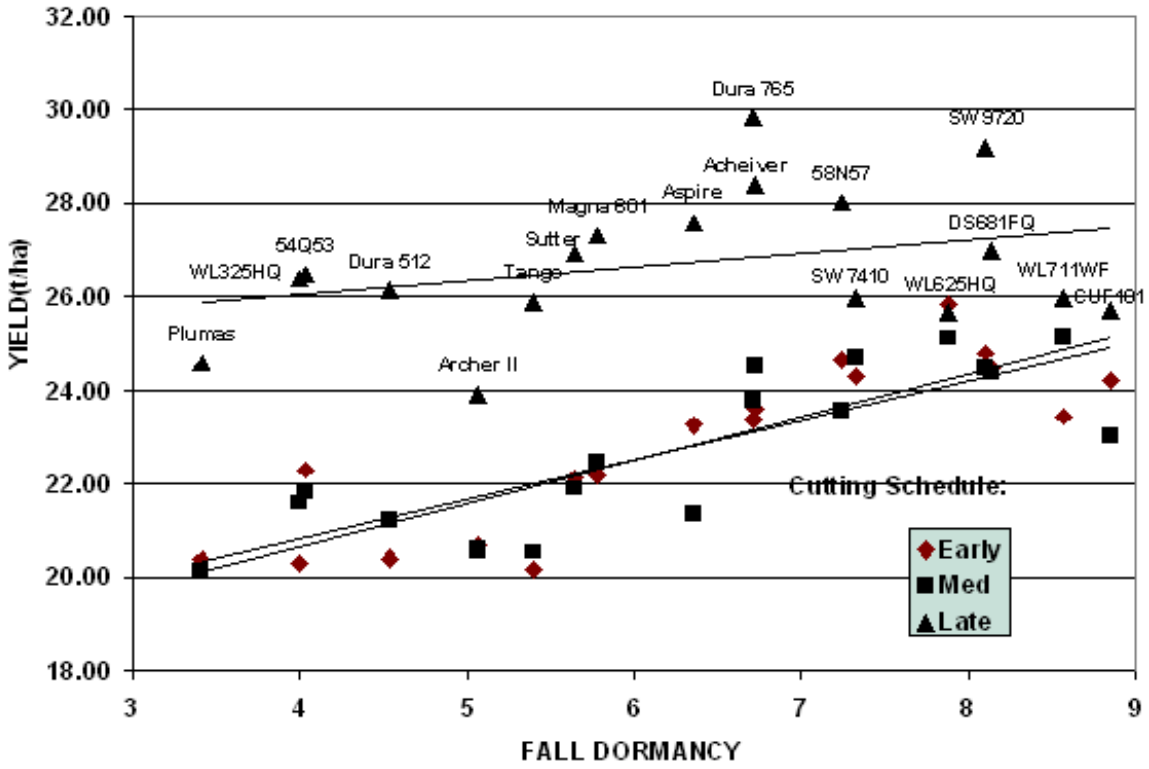

Figure 1. Effects of Variety and Cutting Schedule on alfalfa forage yield when grown under irrigation in the Sacramento Valley of California, USA.

Cutting schedules had a profound effect on both forage yield and quality (Figure 1). Late cutting schedules (35 days) averaged 26.8 t/ha vs. 22.8 t/ha for early (23 day) cutting schedules. However, the quantity of alfalfa produced of varying quality values was significantly different. While 85% of the early cutting schedule yield was considered 'premium' or better (27% ADF or below), only 53% and 45% of the production in the medium and late schedules, respectively, was considered premium or better.

Fall dormancy of a variety affects forage quality

Within a cutting schedule (frequency), fall dormancy rating is a very powerful predictor of forage quality, explaining 80% or more of the variation among varieties for all three quality measurements (ADF, CP, and NDF, Figure 2). On average, CP decreased about one-third of a percentage point with each number increase in fall dormancy rating, while NDF increased by about one-third percentage point with each unit increase in fall dormancy rating. Nevertheless, there are some varieties that exhibit 'exceptions from the rule' (Figure 2). These ''exceptions' 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 and yield potential.

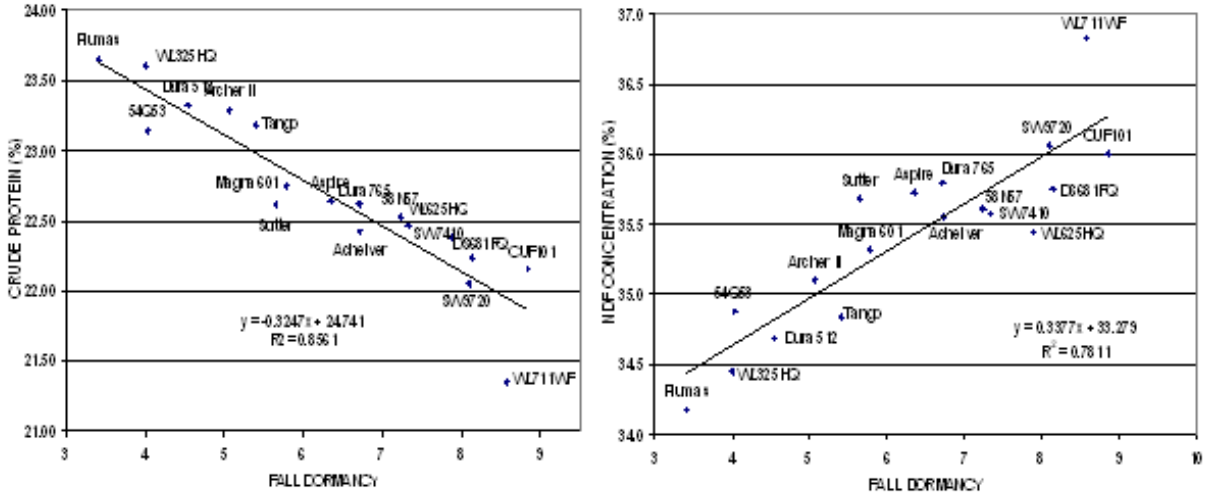

Figure 2. Effect of Variety on Forage Quality (Crude Protein and Neutral Detergent Fiber) of alfalfa varieties grown in the Sacramento Valley of California, USA, in 2002 (average of all cutting schedules).

Quantifying the yield-quality tradeoff

These data reveal a strong interaction or tradeoff between forage yield (Figure 1) and quality (Figure 2) in alfalfa, as influenced by both variety and cutting schedule. This is known by forage growers, but they seldom consider this when analyzing economic returns from crop production or efficiency measurements such as Water Use Efficiency. While this research provides a preliminary guide for the cutting schedule/variety selection decision, it does not completely resolve the question. While severely short cutting schedules are widely known to produce superior quality hay, they also usually result in reduced stand life. In this study stands were severely reduced after 2 years of production at early cutting schedules vs. late. Frequent harvests reduce the plants' ability to replenish root carbohydrate and protein reserves, causing death of plants, or weaker plants that are more susceptible to disease. Frequent harvests increase the costs of production (which are already higher with more cuttings per year).

While we cannot completely resolve the quandary over choice of cutting schedule and variety selection the following approach may be helpful for part of the solution. Figure 3 shows the allowable decrease in yield that can be tolerated with an improvement in price to achieve the same return. 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 tonne). Management strategies (whether variety, cutting strategy, or other management alternatives), that result in an improvement in value per tonne can be compared at the line for any starting market value (Figure 3). In this example, Plumas (higher quality variety, but lower yielding) and WL711 (high yield, low quality) are compared. Since Plumas is 20% lower yielding than WL711, a greater than $20/t increase in price is needed to justify planting that variety at 75$/t price. This added value is presumably adjusted by the buyer due to the higher quality of that variety. A $30/t increase is required if the price is $125/t, and so on. Generally with higher prices, quality is less meaningful. In systems like California where alfalfa is a cash crop, growers would be better off emphasizing yield. With lower prices, quality differences become more important. However, if the forage producer feeds his own animals, a more complex nutritional model should be used.

A range of economic conditions prevail over the life of an alfalfa stand. This complicates the issue of variety choice. It is likely that no one strategy will be best under all market conditions or production systems. Thus, we speculate that combinations of both strategies may be reasonable, perhaps staggering cutting schedules as well as planting some high yielding and some high quality varieties. However, these concepts require further thought and research. The development of a better quantitative understanding of the economic tradeoffs between forage yield and quality is critical to selecting the most profitable variety/cutting schedule combination for different market conditions.

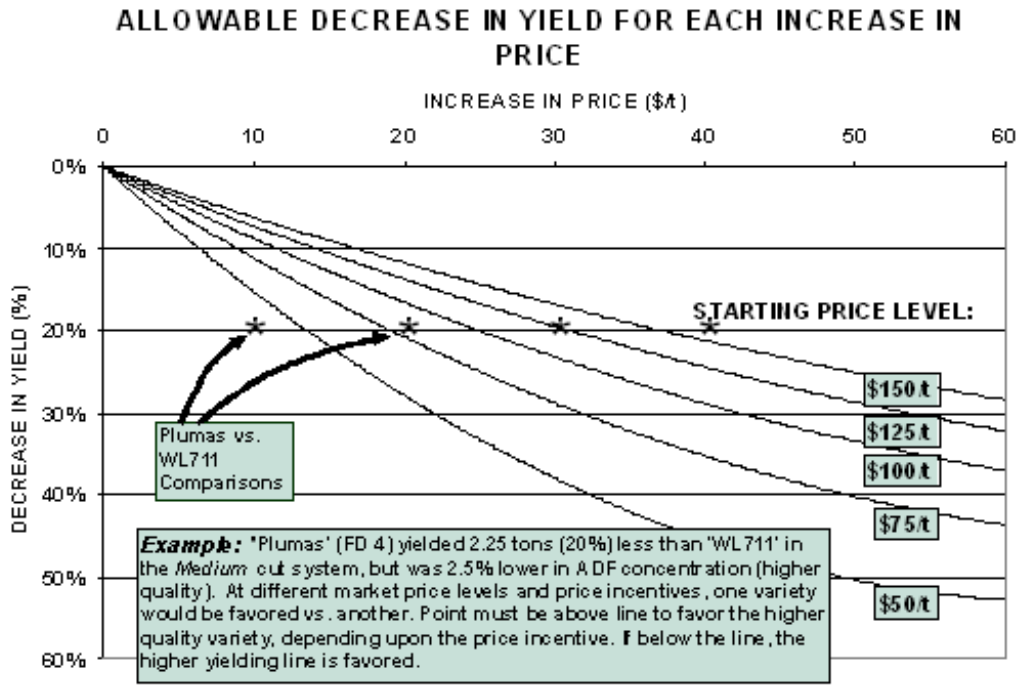

Figure 3. Quantification of the allowable decrease in yield for every increase in price for alfalfa, since yield and quality are inversely related. A Choice must be above the isoline to be acceptable. Comparison of two varieties from real data is shown.

Conclusion

Quality factors (CP, ADF, and NDF) are influenced by Fall Dormancy rating in a dramatic fashion—FD of the variety explained 80% or greater of the variation among varieties in forage quality parameters. Cutting

schedule, however, had a larger affect on the quality of the final product than did variety. Early cutting schedules resulted in the production of more 'high quality' alfalfa forage 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. Forage quality potential of alfalfa varieties should not be viewed in isolation from their yield potential. The implications of the yield-quality tradeoff are essential to understanding economic sustainability for alfalfa, resource-use efficiency, and other broader crop production issues.

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