# AGRONOMIC FACTORS AFFECTING FORAGE QUALITY IN ALFALFA

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## ABSTRACT

There are a wide range of factors in the field that impact quality, the most powerful of which are plant maturity at harvest, weed management, environment (e.g. temperature), and harvesting methodology. Secondary factors include variety, soil type and fertility, irrigation management, insect, and disease damage. Biotechnological traits may have impacts on quality as well. Harvest scheduling is the single most powerful practice impacting quality. Quality should never be considered in isolation from yield goals due to the tradeoff between yield and quality that is observed in forage crops.

## INTRODUCTION

Demands for high-quality alfalfa by the marketplace have been relentless. This fall, the price signals for high quality hays have been particularly severe (Table 1) and often medium and lower quality hay simply does not sell. Although differences approaching $100/ton (Table 1) between high and low quality hay are somewhat extreme, these severe differences are actually typical of a 'down' price year. This is a particular problem throughout the West, where >90% of the hay enters the market. Although crop yield is still the primary economic factor determining income per unit of land area, forage quality has become a close second.

**Table 1.** Price of Alfalfa Hay at different Forage Quality Classications during a single week, mid-November, 2016.

| | Northern San Joaquin Valley | | Tulare, Hanford | | Modesto, Escolon, Turlock | |
|---|---|---|---|---|---|---|
| Quality Category | Volume (tons) | Price Range ($/ton) | Volume (tons) | Price Range ($/ton) | Volume (tons) | Price Range ($/ton) |
| Supreme | 1100 | $220-245 | 1700 | $240-253 | 1600 | $230-250 |
| Premium | 50 | $190-200 | 350 | $220-235 | 2500 | $210-240 |
| Good | 125 | $180 | 650 | $165-185 | 475 | $160-180 |
| Fair | 1075 | $145-150 | 1950 | $140-155 | 1600 | $135-150 |
| | USDA Hay Market News | | The Hoyt Report (prices delivered) | | | |

Sources: USDA Market News (https://www.ams.usda.gov/market-news/hay-reports) and The Hoyt Report (by subscription: http://www.thehoytreport.com )

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"Forage quality" is defined by the utility of a forage to elicit a response in the animal. Quality definition differs depending upon animal species, class (dairy producer, beef, dry cow, high vs. low production) and formulation of a ration, but key qualities include high levels of digestible energy, high intake levels, provision of protein, functional fiber, and minerals. Other factors such as freedom from noxious or low quality weeds, absence of molds or dust, leaf attachment, texture and odor are also important. In the majority of US alfalfa growing regions, alfalfa quality is most often defined by utilization by high producing dairy cows, which set guidelines for quality (Table 2). So how to produce a high-quality product? Here, we examine the influences of agronomic practices on forage quality.

## Table 2. Hay Quality Guidelines

| Definitions of Hay Product Categories | |
|---|---|
| Alfalfa Hay | – Consists of a minimum of 90% alfalfa hay |
| Mixed Alfalfa Hay | – Consists of greater than 50% and less than 90% alfalfa |
| Grass Hay | – Consists of a minimum of 90% grass hay, designated by species |
| Mixed Grass Hay | – Consists of greater than 50% and less than 90% grass |
| Rained on Hay | – May be any of the categories listed above, but must be designated as such |

| Hay Quality Descriptions for Alfalfa and Mixed Alfalfa Hay | |
|---|---|
| Supreme | Vegetative, prebud, or early bud, low in fiber, high in fiber digestibility, soft stems, very high energy and intake potential. Very good leaf attachment, free of grasses and weeds, no noxious weeds, no molds, well cured. |
| Premium | Prebud, bud or early bloom, low fiber with soft stems high energy and intake potential, good leaf attachments. Mostly free of grasses and weeds, no noxious weeds, no mold, well cured. |
| Good | Prebloom to mid-bloom, low to medium fiber with medium to soft stems, medium fiber and protein content, fair leaf attachment, can contain some palatable grasses weeds, no noxious weeds, well cured. |
| Fair | Mid to late bloom, medium to high fiber with coarse stems, low to medium energy and protein content, fair leaf attachment, low to moderate grass and weed content. No noxious weeds. |
| Low or Utility | Hay with serious fault or faults. This could be to conditioning problems, rain damage, high or noxious weed content, mold, poor curing, very high fiber, or other serious faults. These hays are generally not described by test. |

| Range of Hay Quality Analysis for Alfalfa Quality Marketing Groups | | | | |
|---|---|---|---|---|
| Supreme | | | | |
| Premium | | | | |
| Good | | | | |
| Fair | | | | |
| NDF% | <33 | 35 | 39 | >42 |
| NDFD% | >48 | 42 | 38 | <35 |
| CP | >22 | 20 | 18 | <16 |
| ADF% | <27 | 29 | 32 | >35 |
| Calculated Values: | | | | |
| RFV | >180 | 150 | 125 | 100 |
| TDN (90%) | 55.9 | 54.5 | 52.5 | 50.5 |

## HAY QUALITY GUIDELINES

The USDA–Hay Market News Service has developed guidelines for reporting hay as 'Supreme,' 'Premium,' 'Good,' 'Fair,' or 'Low' (Table 2). These are based partly on lab tests and partly on subjective evaluation of hay quality indicators by buyers and sellers, such as presence of extraneous materials, including weeds and molds. However, these are guidelines, not standards, and buyers and sellers freely define and redefine quality based on a range of factors, including class of animal and personal preference. Furthermore, marketing guidelines are likely to change as forage quality concepts change over time.

For those who have been paying attention, at his symposium and over the past >10 years we have argued that the concepts of forage quality need to be modified to incorporate the more dynamic aspects of forage quality, particularly digestibility of fiber (e.g. NDFD). Quality definitions should not rely solely on fiber content (ADF, NDF which entirely determine RFV and TDN – see text box for acronyms). Please see Combs, Mertens, Putnam et.al references below for a more thorough discussion of how and why forage analysis must change and Combs presentation this symposium.

Although the two most common methods for identifying quality in alfalfa markets (RFV and TDN) superficially appear to be different, there are actually quite similar, since they are both based on a measurement of fiber concentration. These are "fiber-based" marketing systems, and generally rank alfalfa hays similarly, since ADF and NDF are highly correlated in pure alfalfa hays. Crude protein (CP) is used less frequently in marketing alfalfa hay.

***Subjective Quality Factors*.** Subjectively determined quality factors remain important for predicting hay quality, since not all quality attributes can be predicted from laboratory analysis. Although observation methods are poor at predicting attributes such as fiber concentration, fiber digestibility, energy, or protein, hay must be examined visually to assess the importance of weeds (particularly poisonous or noxious weeds), molds or anti-palatability factors such as poor texture (hard stems or coarseness, or the presence of sooty molds, both of which affect palatability), evidence of heating, or unpleasant odor (Table 3). Several of these factors can have significant effects on nutritional value and animal health, and are not determined by common laboratory tests. Thus, a combination of visual and laboratory methods is recommended to fully assess the forage quality of alfalfa hay.

**Table 3.** Relative effectiveness of visual and laboratory methods of judging forage quality factors. Some quality factors are best evaluated visually, whereas other factors require a lab test. Both are used to predict animal performance.

| Quality Factor | Visual Examination | Lab Test |
|---|---|---|
| Leaf:Stem Ratio (Leaf %) | Good | Good |
| Leaf–Stem Attachment | Excellent | Poor |
| Mold/Dustiness | Excellent | Poor |
| Texture (coarse, soft) | Excellent | Poor |
| Weed Content | Excellent | Fair |
| Noxious Weeds | Excellent | Poor |
| Odor | Excellent | Poor |
| Fiber Concentration | Fair | Excellent |
| Fiber Digestibility | Poor | Excellent |
| Protein Concentration | Poor | Excellent |
| Protein Degradability | Poor | Excellent |
| Mineral Content | Poor | Excellent |

## AGRONOMIC FACTORS THAT INFLUENCE FORAGE QUALITY

The major agronomic factors that affect alfalfa quality are cutting schedules (plant maturity at harvest), weed and pest management, harvest effects, variety and seasonal or short-term weather patterns. Time of day of harvest, fertilizers, variety and irrigation can also impact quality. Sometimes these factors interact in complex ways, but these factors typically affect quality via a few fundamental mechanisms, including plant maturity at harvest, relative proportion of leaf and stem, presence of weeds, and environmental effects.

***Plant Maturity at Harvest.*** It is a universal axiom of alfalfa forage production that as a plant grows and matures, forage quality declines. Therefore, the stage at which the plant is harvested is usually the most critical factor determining forage quality. The change in forage quality due to plant maturity is the result of two major and powerful mechanisms in alfalfa: First, the leaf percentage declines as the plant grows and matures, as a percentage of the plant biomass (Figure 1). This is due primarily to the increase in stem weight that occurs during growth—since the plant produces mostly stem yield after about 12 to 15 days (Fig. 2). Second, the quality of the stem fraction declines precipitously as the

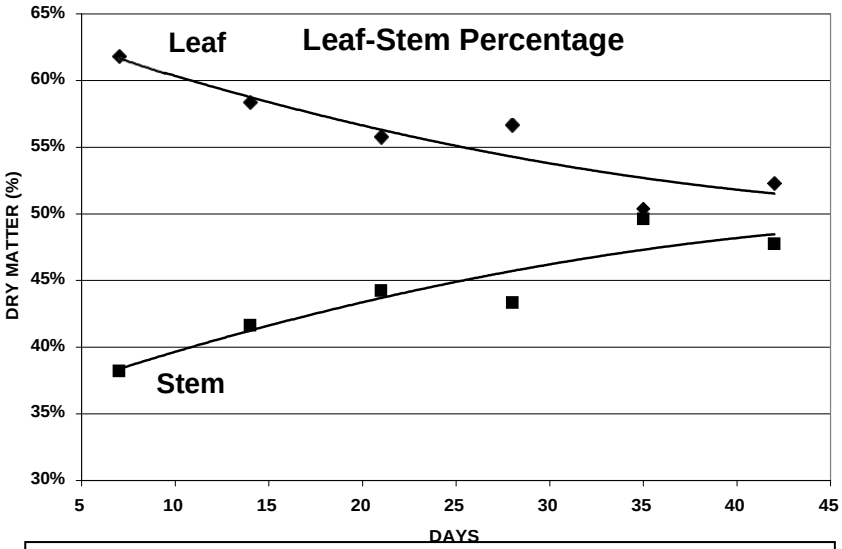


**Figure 1.** Changes in leaf and stem percentage over a single summer growth period, Davis CA.

plant continues to grow. The ADF and NDF concentrations goes up (Figure 2), whereas CP and NDF digestibility goes down, particularly in the stem component (Figure 3). Note that the fiber and protein content of the leaf doesn't change very much (Figures 2 and 3). This increase in NDF and ADF (as well as NDF digestibility) is due to what is happening at the cellular level; the young, tender primary cell wall in the stem is strengthened by highly lignified secondary cell wall. The rate of growth of the stem (weight increase per day), and the rate of lignification of the stem (increase in lignin percentage or NDF/ADF percentage) is also highly influenced by time of year, temperature, and other factors, such as variety.

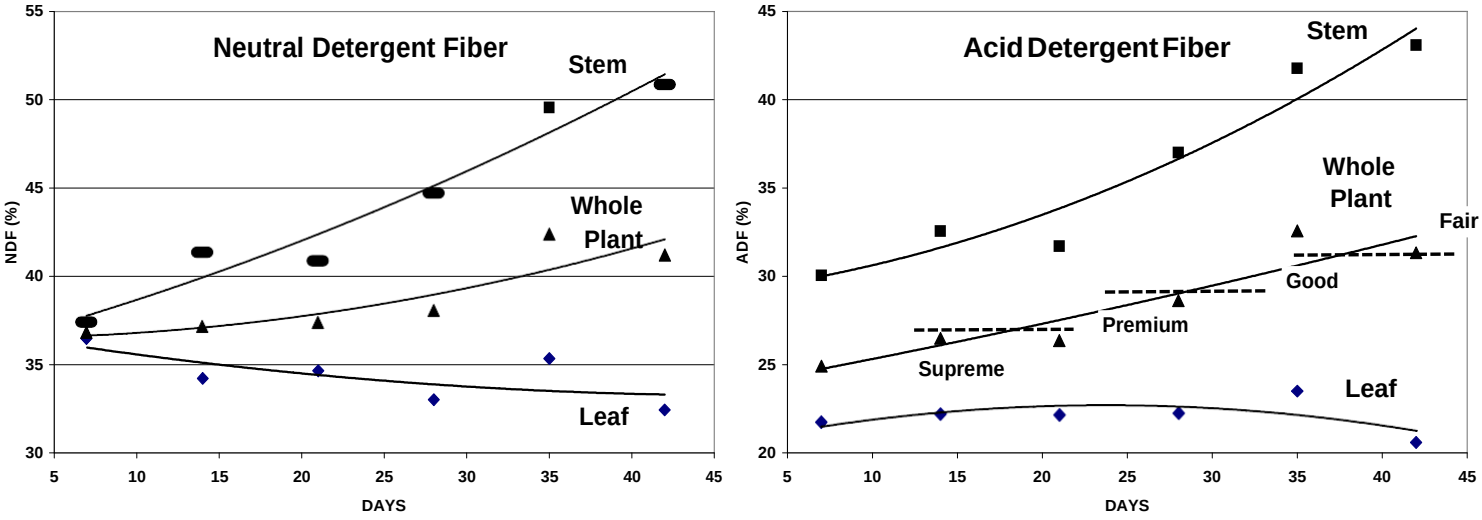


Figure 2. Changes in concentration of NDF and ADF over a single growth period, Davis, CA

***Leaf Percentage.*** The leaf percentage of hay is a major determinant of quality. Leaves can have two to three times the CP content of stems and sometimes half the fiber concentration (Figures 2-3). In some forages, leaves consist of two-thirds of the feeding value, although they may be less than 50 percent of the DM. The decline in forage quality is mainly due to stems, which decline about 0.5 percentage points in digestibility (IVDDM) per day, and increase dramatically in NDF and ADF, whereas leaves decline only very slightly over time.

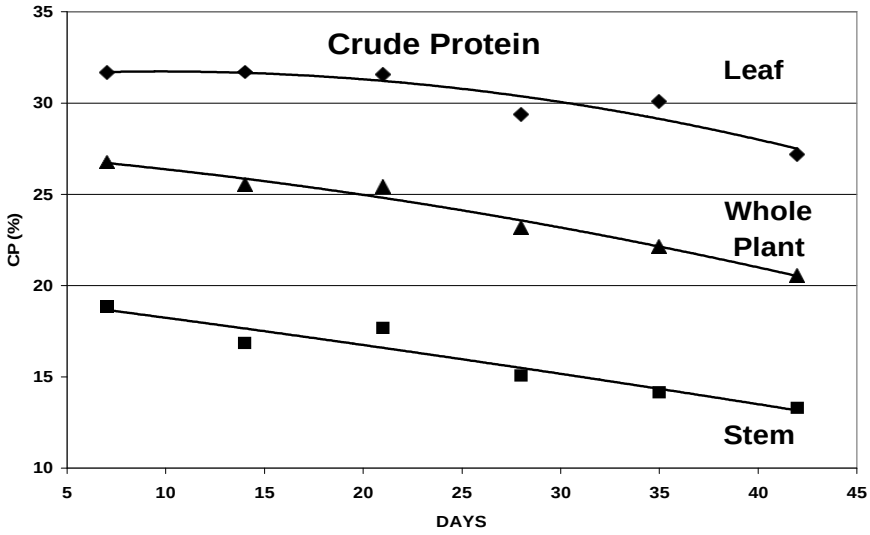


Figure 3. Changes in Crude Protein concentration of leaf, stem and whole plant during a single summer growth period, Davis, CA

Although plant maturity has a dramatic effect, there are also many other factors that influence leaf percentage. These include insect and disease damage, variety, irrigation, rain damage, harvest and

curing impacts, as well as environment. Thus, any agronomic practice that impacts leaf–stem ratio or plant maturity at harvest will affect forage quality

***Yield–Quality Tradeoff.*** Although forage quality is dramatically improved by short cutting schedules (e.g., 24 day intervals), but yield is also dramatically reduced, as is stand life, allowing for increases in weed infestation. The tradeoff between yield, quality, weeds, and stand life is a major and complex issue for forage producers and is of tremendous economic importance. This is amply illustrated in Figure 4, data from the early 1970s, which shows the profound influence of harvest schedule on yield (which increases 53% with late cuts vs. earliest), and quality (which declines from 'Supreme' to 'Fair' with late cuts).

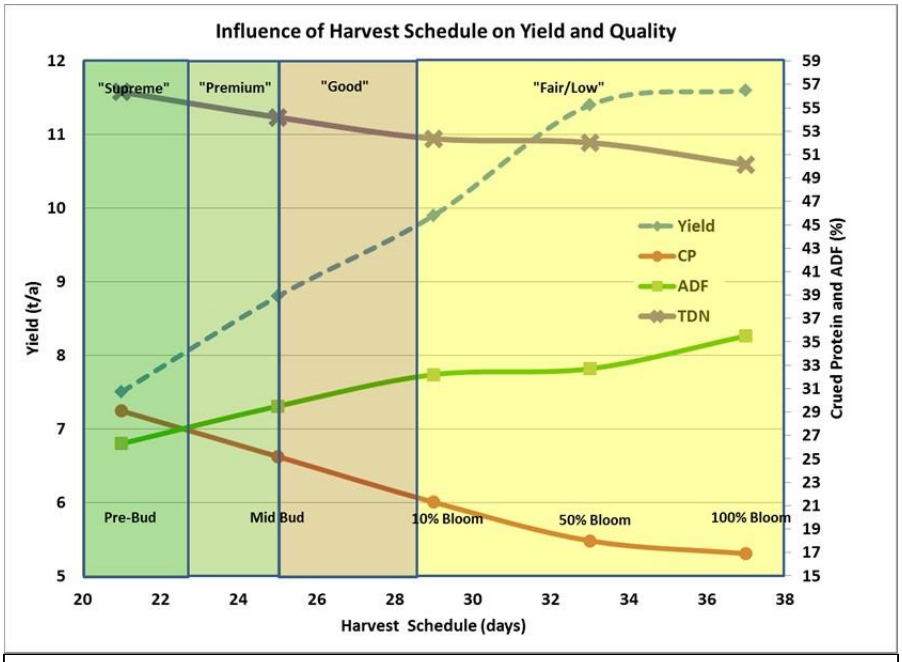


**Figure 4.** Effect of harvest scheduling on yield and quality (Data from Marble, 1974, Davis, CA). Classifications are as per USDA-Hay Market Guidelines (2016). Note that most nutritionist desire additional analyses to predict quality, particularly fiber digestibility estimates.

***Cutting Schedule.*** Cutting schedule is, overwhelmingly, the most powerful method under a grower's control to manipulate forage quality, since both maturity and leaf percentage are impacted. Growers have generally gravitated toward early- to late-bud harvests to attain high forage quality, but at great expense of yield (Figure 4 and 5). If yield, stand persistence, and weeds were not important, the earliest possible cutting dates (e.g. 21-24 days) would typically provide the highest quality forage, but these cutting intervals would rarely provide optimum economic returns.

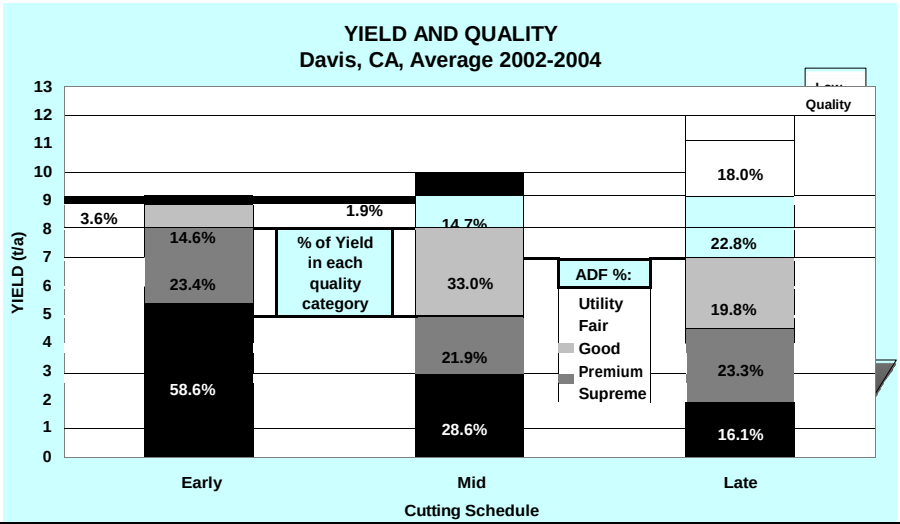


**Figure 5**. Influence of harvests schedules (approximately 24 days (early, 8 cut system), 28 days (Mid, 7 cut system), and 35 days (late, 5 cut system) on yield of alfalfa hay which fit into various quality categories based upon ADF%.

The vigorous cutting schedules commonly practiced to attain high quality may ultimately work against high-quality production since stands may thin and weeds may invade. Clearly, a more integrated approach balancing yield, quality, persistence, and economics is required. We

generally recommend a 'staggered' approach to harvest schedules so that a quantity of higher quality hay can be obtained, along with maintaining higher yields and stand persistence. Basically, don't use a single set cutting interval for the entire season. Vary the interval and give fields a "rest" at different times during the summer when producing top dairy quality is difficult to accomplish due to the heat. This is tied in with irrigation schedule: several cuttings a year should be fully irrigated (perhaps 2-4 times depending upon system) and allowed to 'go long'.

***Persistence.*** Although not covered extensively here, stand persistence is greatly affected by cutting schedule. Thus, the tradeoff between yield and quality also includes a significant tradeoff with stand persistence. Harvesting early nearly always leads to early stand decline, thus cutting early every single harvest is not recommended. Since weeds are a frequent consequence of stand decline, this must be considered – long-term persistence is an important factor affecting future quality.

***Environment and Temperature.*** Alfalfa forage quality is generally highest in spring (i.e., first and second cuttings) and late fall, and lowest in summer, but forage quality also changes due to temporary weather patterns. Data collected over 3 years using eight to ten mostly non-dormant varieties in Fresno County, California, show large differences over the season and among years (Figure 6). Seasonal and environmental differences were far greater than the differences among varieties. Seasonal and yearly variations have their effect primarily through temperature, but day length and light intensity are also important. The high temperatures of summer increase growth rate (primarily stem growth), hasten plant maturity, and increase lignification of the cell wall. High temperatures also hasten respiration rates, which in turn reduce the quantity of soluble carbohydrates in the stems and leaves. Respiration turns sugars and starches into carbon dioxide and produces energy to produce other compounds in the plant, such as cell wall material or protein. Thus, high rates of respiration have the dual effect of lowering the highly digestible "sugar pools" in the plant and hastening growth and maturity.

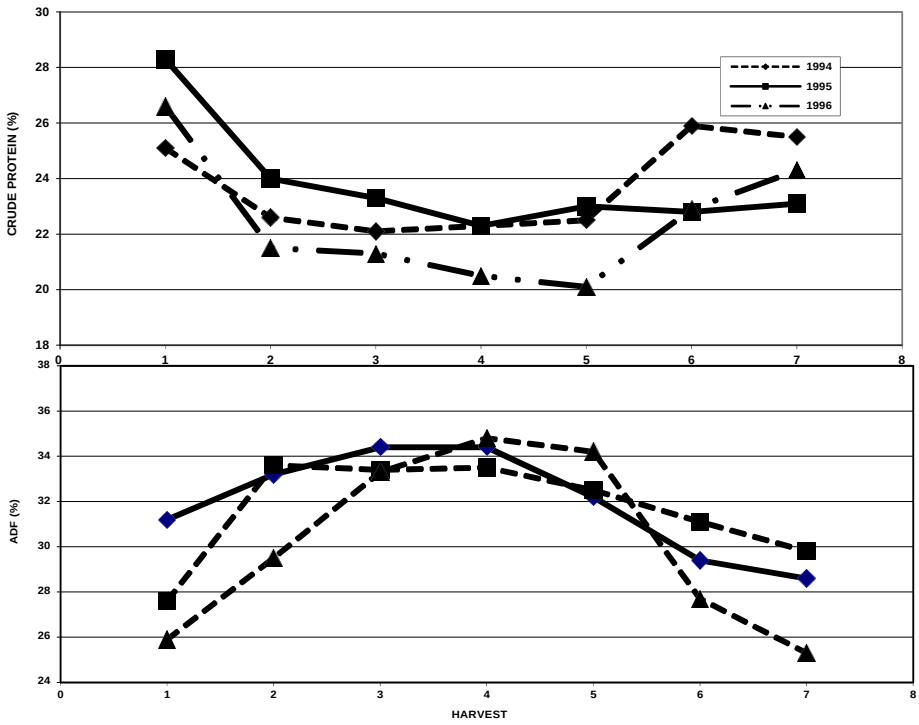


**Figure 6.** Seasonal influences on crude protein (top) and acid detergent fiber (bottom) values. Data average of ten non-dormant varieties, 1994–1996, Kearney Ag. Center, Fresno Co., CA

***Weeds and Species Mixtures.*** Although weeds can theoretically have neutral, positive, or negative

effects on alfalfa forage quality, the overwhelming effect is negative. Most weeds, especially grassy weeds, increase the NDF concentration (fiber) and lower intake and reduce NDFD, decrease protein and digestibility. Conversely, many weeds can increase yields of sparse alfalfa stands, since they "fill in" bare areas, but this yield increase rarely compensates for the lower quality of the forage. In the "Fair" quality hays in Table 1, many are classified that way due to weeds.

The primarily characteristics of weeds that influence quality are the species of weed and maturity at harvest. Some weeds, such as pigweed (*Amaranthus retroflexus* L.), lambsquarters (*Chenopodium album* L.), and volunteer cool-season grasses, may provide good forage quality if harvested early but can also contain high nitrate levels, contributing a significant risk to animal health. Some weeds, like common groundsel (*Senecio vulgaris* L.) and fiddleneck (*Amsinckia menziesii* [Lehm.] Nelson & J. F. Macbr.), are toxic to animals and thus substantially lower the feeding value, even if the energy or protein are not affected. Green and yellow foxtail (*Setaria viridis* [L.] Beauv. and *Setaria pumila* [Poiret] Roemer & Schultes), foxtail barley (*Hordeum murinum* L.), yellow starthistle (*Centaurea solstitialis* L.), and Russian thistle (*Salsola tragus* L.) can all contribute to lowered palatability and lower animal acceptance, sometimes causing pain and injuring the mouths of the animals. Even in cases where weeds do not reduce the lab feeding value, they may reduce the marketability of the hay due to buyer perception. In practice, inability to control weeds is one of the most common causes of low forage quality of alfalfa.

***Harvest Effects***. The process of drying, raking, handling, and baling hay has long been known to affect forage quality. Alfalfa leaves dry much faster than stems. Since growers must wait until stem moisture is sufficiently low for bailing, hay is often harvested at a point where leaves are too dry for handling. Leaf shatter is a significant hazard in western states and can reduce forage quality by reducing leaf–stem ratio. Any method, be it mechanical or chemical conditioning, wider swath width, or skillful raking that speeds the drying process of stems, can improve forage quality.

The greatest risk for leaf shatter is during raking process and baling, although any field operation may increase leaf shatter, depending on conditions. Field operations (such as intensive conditioning or wide windrows) that hasten drying of stems help preserve forage quality. Some hay preservatives may enable growers to bale under more moist conditions, thereby conserving leaf material. Where extremely dry baling conditions prevail, re-wetting windrows or using steam to soften leaves just before baling can be beneficial. Dew can provide much-needed softness and leaf retention, and therefore nearly all growers in the West bale at night or in early morning during summer months to maximize leaf retention. Applying good harvesting skills to maintain forage quality remains a major challenge to growers.

***Conditioning, Windrow Width, Respiration and Drying Effects***. Traditional conditioners, if well adjusted, can have a significant effect on quality since they hasten stem drying. Stem drying can also be greatly hastened by increasing windrow width. This allows growers to more closely match the drying rate of leaves and stems and to retain leaf material. Conditioning also slows respiration of carbohydrates, reducing quality loss. Wide windrows can be of great assistance in hastening curing. At the 2015 Alfalfa Symposium, Dan Undersander presented the economic costs of 2%, 4%, and 8% dry matter losses, not only for the value of the dry matter yields of the hay itself (up to $19/ton), but the losses from a decline in quality since sugars and

starches are the main components that decline during excess respiration during the curing process (Table 4-Undersander, 2015). We should recall that sugars and starches are major components of the energy yield of forage crops, thus any method which hastens drying rates so that respiration ceases quickly can improve quality.

***Time of Day*.** Observations from the 1940's have shown changes in soluble carbohydrate levels in alfalfa due to time of day. More recent data from Idaho, California, Utah, and other states have pointed to the advantage of harvesting alfalfa in the late afternoon, which takes advantage of the temporary accumulation of soluble carbohydrates associated with photosynthesis during the day. Accumulation of sugars (and other soluble components) in the cells may lower the apparent fiber and the crude protein concentration due simply to the greater quantity of accumulated cell solubles. As the alfalfa plant rapidly photosynthesizes in the late morning, sugars and starches may accumulate in plant tissue. At night, these compounds are respired and utilized by the plant, increasing the fiber concentration. If hay is cut in the afternoon, and respiration in windrows is minimal, then the higher concentration of soluble carbohydrates may contribute up to 1 to 1.5 percent to the energy (ME, DE, or TDN) of the forage. There is evidence that animals prefer afternoon-harvested forage as either grazed forage or hay. The advantages of afternoon harvest would likely be greatest under cool, bright-sunshine conditions, and under conditions where the forage is highly conditioned to increase drying rates and minimize respiration in the windrow after harvest. Afternoon harvests are not necessarily appropriate in circumstances where rain damage is the more important concern, and every hour of drying time is important. In addition, most growers have so many fields to harvest that it would not be possible to cut them all in the late afternoon only.

**Table 4.** Losses Due to Respiration and their potential impact on yield and quality (D. Undersander, 2015 Western Alfalfa & Forage Symposium)

| Dry Matter Loss | 2% | 4% | 8% |
|---|---|---|---|
| | Economic Loss ($/t) | | |
| Hay value $239/t | $4.78 | $9.56 | $19.12 |
| Forage Quality Loss from 4% sugar/starch loss | | | |
| ADF, % | NDF, % | RFQ | Value, $/t |
| 30.0 | 40.0 | 153 | $239.00 |
| --Forage quality if lose 4% dry matter of starch/sugars-- | | | |
| 33.0 | 43.4 | 134 | $125.00 |
| Prices from Midwest Hay Market Report, Nov 6, 2015 | | | |

**TERMINOLOGY:**

CP = Crude Protein
ADF = Acid Detergent Fiber
NDF = Neutral Detergent Fiber
NDFD = NDF digestibility
IVDDM = In Vitro Digestible Dry Matter
EE = Ether Extract
ADIN = Acid Detergent Insoluble Nitrogen
DE = Digestible Energy
ME = Metabolizable Energy
NE = Net Energy
$NE_l$ = Net Energy of Lactation,
$NE_g$ = Net Energy of Gain
TDN = Total Digestible Nutrients
TTNDFD= Total Track NDFD
DCAD= Dietary Cation-Anion Difference

***Rain Damage during Harvest***. Rain reduces the level of available carbohydrates or available energy by leaching soluble components from the plant. It also decreases forage quality by causing greater leaf loss. Since soluble components are typically 100 percent digestible, leaching decreases the energy value significantly, as well as protein content and dry matter. The extent of leaching is influenced by stage of maturity, forage moisture at the time of the rain, amount and intensity of rain, and condition of the hay during the rain event. Rain can increase dry matter losses caused by leaching and leaf shatter from 10 to over 50 percent, depending on the amount of rainfall.

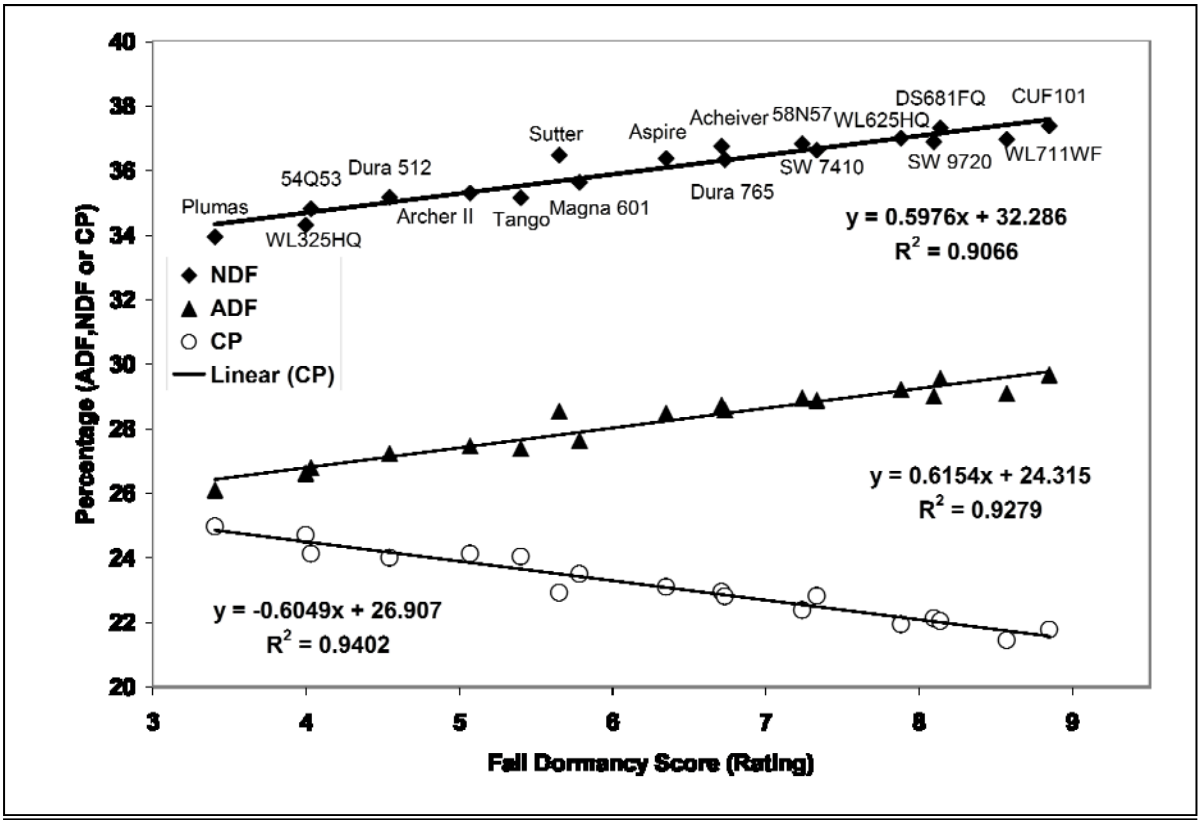


**Figure 7.** Effect of fall dormancy ratings on forage quality (ADF, NDF, and CP) of 18 varieties grown at Davis, California. Data points represent an average of 3 years, three cutting schedules, all harvests, about seven harvests per year (2002–2004). Lower fall dormancy of alfalfa varieties tends to reduce ADF and NDF, and increases protein on the average, but this should be evaluated against the generally inferior yields of these varieties under Mediterranean and desert conditions.

***Variety***. Research from a number of locations has shown differences in quality among some, but not all, varieties under the same cutting schedule. Varieties differ primarily due to changes in leaf percentage, or because of slower growth rates, which are often a function of fall dormancy (FD), or due to subtle changes in cell wall structure, such as lower lignin or higher rates of cell wall degradation in the rumen. Multifoliolate varieties (varieties that produce more than three leaflets per leaf) can, in some cases, result in higher quality forage, but this is not always so. The key issue is leaf percentage and stem quality, not number of leaves, but leaf mass. Some standard trifoliolate varieties have also been developed to have a superior forage quality without increasing the number of leaflets.

***Fall dormancy*** has a powerful effect on quality of varieties in a Mediterranean environment (Figure 7). In a three-year study at UC Davis, non-dormant varieties were significantly lower in quality than dormant varieties. There was an approximately 0.6 percent increase in either ADF or NDF and a 0.6 percent decrease in CP per unit increase in Fall Dormancy (FD) from FD rating 3 through 9 (the higher the number, the more non-dormant the variety). Growers have found that planting more dormant cultivars has become an important strategy for improving quality. However, the growth rates of more dormant varieties may be significantly lower those of other adapted varieties in a region. Under most circumstances, growers must be prepared to accept lower yields with these varieties. Yield is still the predominant economic factor for alfalfa growers, but under some economic conditions, such as low price years, growers have been willing to sacrifice some yield for higher forage quality.

***Biotechnology*.** Biotechnology (the insertion of genes or the changing of genetic structure through biotechnology methods) has already had an impact on quality and may do so more in the future. The Roundup-Ready trait (RR alfalfa), commercialized in 2005, offers growers a new tool to produce nearly weed-free hay, and a number of growers have taken advantage of this technology to improve quality by improving control of difficult-to-control weeds. These may include dodder, dandelion, nutsedge, groundsel and others. However, it should be pointed out that any practice which effectively improves weed management is likely to have the same result.

A second technology, HarXtra is a trait that results in lower lignin content of the forage, was de-regulated in 2014 and is continuing to be commercialized in 2016-17 in western states. This is being marketed by Forage Genetics International. Several other presentations at this symposium will review this technology. These are important developments to watch. Data from UC Davis from experimental lines controls (both at FD 4) over two years indicated significant differences in NDFD and lignin, especially at late cutting schedules (35 day). Alforex has also released non-GE reduced lignin lines. These varieties have not been widely tested in California or other western states – and so development of data on the relative performance of these lines (FGI's HarXtra and Alforex' HiGest) is important to understand their potential impacts, especially as they interact with harvest schedules. Please see M. Sulc, Charlie Brummer, Mark McCaslin, Don Miller, and Heidi Rossow's presentations this symposium.

Table 5. Late schedule (35 day) forage quality of 4 experimental LL varieties and 4 released varieties, 5 harvests/year Davis, CA, average of 2 years

| Variety | ADF | Ash | CP | ADL | IVTDM | IVdOM | NDF | NDFD | TDN1 | RFQ | NFC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 54R01 (control) | 26.2 | 6.6 | 23.4 | 5.0 | 84.4 | 77.4 | 30.8 | 48.8 | 70 | 233 | 39 |
| Ameristand 405TRR (control) | 27.9 | 6.6 | 22.8 | 5.3 | 82.9 | 76.3 | 32.6 | 47.3 | 68 | 218 | 37 |
| Liberator (control) | 26.8 | 6.7 | 23.0 | 5.1 | 83.9 | 76.9 | 31.5 | 48.3 | 69 | 230 | 38 |
| WL 355RR (control) | 27.5 | 6.7 | 22.8 | 5.3 | 83.1 | 76.4 | 32.2 | 47.4 | 69 | 220 | 38 |
| 12RRL-1 (Lot RRL-1281-F) | 25.6 | 6.8 | 22.9 | 4.5 | 85.6 | 79.0 | 30.1 | 51.3 | 71 | 246 | 40 |
| 12RRL-2 (Lot RRL-1284-F) | 26.3 | 6.8 | 23.0 | 4.5 | 85.2 | 78.7 | 31.2 | 51.3 | 70 | 236 | 39 |
| 12RRL-3 (Lot RRL-1290-F) | 25.4 | 6.8 | 23.2 | 4.4 | 85.8 | 78.9 | 30.3 | 51.8 | 71 | 247 | 39 |
| 12RRL-4 (Lot-1291-F) | 26.0 | 6.8 | 22.9 | 4.6 | 85.2 | 78.5 | 31.0 | 51.1 | 70 | 238 | 39 |
| Mean | **26.5** | **6.7** | **23.0** | **4.8** | **84.5** | **77.8** | **31.2** | **49.7** | **69.8** | **233.4** | **38.6** |
| variety | *** | ns | ns | *** | *** | *** | ** | *** | *** | ** | ** |
| cut | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| variety*cut | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

***Stand Density***. Leaf percentage, CP, ADF, and lignin are not largely affected by stand density per se. Evidence from studies in Wisconsin, Idaho, Oregon, and Wyoming have shown that leaf percentage, CP, ADF, and lignin were not affected by initial seeding rates. This is because at

higher plant densities, the numbers of stems per crown is greatly reduced; thus the number of stems per unit area does not differ significantly between very high and moderately low densities. However, stem thickness may be slightly greater under low densities. Counteracting this effect, however, is the possibility that light penetration into the lower sections of the alfalfa canopy may improve leaf retention compared with thick stands.

However, a more important factor is the effect of stand density on weed infestations. When stand densities fall below a certain number (between four and six plants per square foot, or 30-40 stems/$ft^2$, depending on the age of the stand), open spaces become available for the growth of weeds. The weeds, in turn, can have a substantial impact upon forage quality. This is likely the most important consideration of alfalfa stand density in relationship to forage quality. Maintaining a high stand density is desirable for high yields, weed management, and high quality.

***Soil Type***. It has long been known that alfalfa produced on certain soils, primarily heavy clay or salty soils, produces higher quality alfalfa than that produced on sandy or loamy soils. This has been attributed to greater plant stress on those soil types, and slower growth rates, perhaps due to lack of oxygen in the root zone or salt effects. Because stress often reduces growth rates, this primarily reduces stem growth, not leaf growth. The stress seems to produce a shorter, finer-stemmed, leafier alfalfa than alfalfa harvested at the same harvest interval on sandy or loamy soil. It should be noted, however, that climatic influence might be a more important factor than soil type in comparing regions.

***Fertilizers*.** As a general rule, fertilizers are likely to have either no effect, or decrease the quality of alfalfa. Most fertilizers improve yields of alfalfa when the elements contained in the fertilizer are in short supply in the soil. Thus, if P, K, S, or micronutrients are low in soil or tissue tests, yields of alfalfa will improve with application of those fertilizers. In most cases, however, the improvement in yield that results from application of fertilizers will result in more rapid growth rates, which is more likely to decrease, not increase, forage quality as a result of increased stem growth.

Research in California, Wisconsin, and Oregon has clearly shown that there is either no difference, or a decline in alfalfa quality, when K fertilizers were used on K-deficient sites. These results are not surprising, considering the importance of K in improving alfalfa growth and yield. Similar results have been seen with P and S. These studies indicate the importance of fertilizing for maximum yield. Additionally, a well-fertilized crop will be better able to sustain the short cutting schedules necessary for producing high-quality forage. However, fertilizers generally do not improve quality per se.

Another important factor is the potential negative effect of specific plant nutrients on quality. Dairy nutritionists emphasize the importance of minimizing the amount of K contained in hay fed to close-up cows (pregnant cows nearing birth), to prevent problems with calcium nutrition and milk fever. With excess K in the soil, “luxury consumption” occurs and concentrations of K exceeding 3% of DM can be observed. This is generally not a problem with most classes of animals, but pregnant and newly-calved bovines may be affected. Alfalfa is well known for luxury consumption of K, where the K concentration of the forage increases without an increase

in yield. This is clearly not desirable, either from the grower's point of view (waste of fertilizer with no return), or from the nutritionists' point of view, due to the danger of excess K in the forage.

Some growers feel that nitrogen (N) fertilizers may improve the quality of alfalfa. However, there is little evidence to support this practice for either yield or quality. Nitrogen fertilizers are unlikely to improve ME, NE, or TDN, or reduce fiber. There are some instances of N fertilizers causing slight improvements in CP concentration, but an equal or greater number of field trials show no effect of N fertilizers on CP. Nitrogen fertilizers are likely to contribute to the nonprotein N fraction in the plant (these may show up as protein but are not), which is mostly metabolized and excreted by the animal. This has a metabolic cost and may contribute to environmental problems caused by the increased N in the animal waste. Additionally, N fertilizers encourage grassy weeds more than alfalfa, which may lower quality. Although applications of N fertilizers may make the plants look greener, it is not recommended to apply N fertilizers to alfalfa in attempts to improve forage quality or yield.

***Irrigation Management.*** Irrigation management is probably the most important yield-limiting factor in western states. Over-applications of water, too little water, or lack of drainage are major problems with alfalfa production. However, water stress sometime can *improve* forage quality, since the leaf–stem ratio can be improved due to lack of growth of the stem component. Conversely, well-watered alfalfa may cause the plant to retain more leaf fraction, and improve carbohydrate concentration in the leaves of non-stressed plants. However, since yields are linearly related to water availability and are dramatically reduced by water stress, it is not recommended to stress alfalfa in favor of quality. The loss in alfalfa yield is too great to justify allowing water stress as a means of improving quality.

**FACTORS AND PRINCIPLES THAT INFLUENCE ALFALFA QUALITY:**

***PRIMARY MECHANISMS***

- Plant Maturity at Harvest
- Leaf Percentage
- Mixture with Weeds
- Environmental Effects

***AGRONOMIC FACTORS***

- Cutting Schedules
- Rain Damage
- Time of Day for Harvest
- Harvesting Effects
- Variety
- Stand Density
- Soil Type and Fertility
- Irrigation
- Pest Interactions

***Insects and Diseases***. Insect and disease pests can have a positive or a negative effect on forage quality, but the effect is typically negative since their feeding habits include consuming leaves, thereby decreasing the leaf percentage or sucking juices. Sucking insects, such as aphids, may reduce soluble carbohydrates, thereby reducing forage quality. Insects that intensively suck plant sap, such as the silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) in the Imperial Valley and cowpea aphid (*Aphis craccivora* Koch) in the Central Valley, cause widespread stickiness (honeydew) on the plant surface; this in turn encourages fungi (sooty molds) to develop, which

lowers palatability and consumer acceptance. Generally, insects must be controlled to maintain high-quality alfalfa and prevent leaf loss.

## SUMMARY

Attaining high-quality alfalfa forage is a critical aspect of profitability for alfalfa and animal productivity. Attributes of quality include digestible energy, voluntary intake, protein, ruminally effective fiber, and minerals. The biological attributes that drive forage quality must be considered (Figure 8) that include leaf-stem percentage and cellular factors such as soluble carbohydrates and cell wall liginification. Forage quality has many attributes and should be evaluated through both laboratory measurements and subjective observations (odor, mold, weed content, etc.). Measurements of plant cell wall (NDF) and its degradability (NDFD), crude protein (CP), and ash are likely to be the most useful measurements for routine analysis, with additional analyses required for specific purposes. Cutting schedules, weed management, and harvest management are the most powerful methods for improving quality under the control of growers, but seasonal effects (spring, summer, fall) can be major determinants of forage quality. Variety, time of day of harvest, insect management, and water stress can influence quality but are usually less important than cutting schedules, harvest management, time of year, or climate. Watch for innovations in biotechnology which may impact quality. Fertilizers generally do not improve quality, but quality can differ somewhat by soil type due to other factors. Alfalfa growers who invest the time in understanding quality factors for animal performance benefit by their improved ability to successfully market their hay.

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