METHODS TO ASSESS ALFALFA FORAGE QUALITY IN THE FIELD

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ABSTRACT

A rapid, reliable, and accurate method to predict alfalfa forage quality prior to harvest would assist growers with harvest decisions. Most quality prediction methods are based on weather data or morphological characters. Growing degree day (GDD) models use temperature data to predict alfalfa forage quality. These models have been found to adequately predict alfalfa forage quality in some studies. However, the diversity of environments in California would require that numerous studies be conducted to develop site-specific relationships between forage quality and GDD. It would be more practical to use a method based on morphological characters. Studies were conducted in four diverse alfalfa-production areas of California to test methods based on morphological characters. The predictive equations for alfalfa quality (PEAQ) system, based on the height of the longest stem and the stage of the most mature stem, was easy to perform and more accurate than the mean stage by count method (MSC). The PEAQ method predicted ADF well in the intermountain location, however more research is needed before this method can be recommended for the Sacramento Valley, San Joaquin Valley, and the Low Desert Region. The data also indicated that development of regional equations could improve quality predictions.

Key words: Quality prediction, harvest timing, nutritive value, ADF, mean stage, PEAQ

INTRODUCTION

In contrast to most other alfalfa-production regions of the country, alfalfa produced in the West is typically sold to a livestock operation off the ranch; the forage and livestock enterprises are distinct. The primary market for alfalfa hay is the dairy industry, but hay is also sold to beef producers and horse owners. As with any farm enterprise, maximizing profits is a primary objective of the grower. Employing production practices that lead to top yields has historically been the principal means of accomplishing this goal. However, in recent years, forage quality has emerged as a major concern. The dairy industry recognizes the importance of high-quality alfalfa hay for peak milk production and now have higher forage quality expectations than ever before.

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The price of alfalfa hay in California is commonly based on the total digestible nutrient (TDN) concentration of the forage. TDN is calculated from the acid detergent fiber (ADF) value. Neutral detergent fiber (NDF) and crude protein (CP) are currently rarely used in price-setting negotiations. Hence, ADF determination is the primary basis for deciding alfalfa price in California and much of the West and is the focus of this paper. The value of hay classified as premium (greater than 54% TDN on a 90% dry matter basis) has been calculated to be about $30 per ton greater than fair hay (less than 52% TDN) in California markets (Putnam, 1994). This indicates that a large importance is placed on a relatively small change in forage quality.

Alfalfa quality is normally determined by sampling bales after alfalfa is cut, raked, baled, and stacked. Unfortunately, by this time there is virtually nothing a grower can do to compensate for cutting over-mature alfalfa. A method to accurately assess forage quality of the standing alfalfa crop is clearly needed so that growers can effectively maximize alfalfa yield while at the same time produce hay that meets the quality standards of the dairy industry.

**IMPORTANCE OF GROWTH STAGE**

It is well known that harvest timing, or more precisely alfalfa maturity at the time of harvest, is the single most important factor influencing alfalfa forage quality. In general, as alfalfa matures forage quality declines. Although progress has been made toward improving forage quality through plant breeding, harvest timing is likely to remain the overriding determinant. This is due to the physiological changes that occur as alfalfa matures. Alfalfa in the late vegetative growth stage has approximately equal proportions of leaves and stems (Figure 1). However, as alfalfa grows beyond the vegetative stage, the amount of leaf material remains relatively unchanged. Therefore, much of the yield increase with advancing maturity is attributed to increased stem weight, not increased leaf weight. Not only does the proportion of stem material increase, but the quality of stems decreases; they become higher in fiber and lignin and are less digestible. Plant fiber is only partially digestible by livestock. Consequently, digestibility, and alfalfa forage quality in general, are very closely linked with plant maturity.

**DETERMINING FORAGE QUALITY IN THE FIELD**

Presently, most producers schedule alfalfa harvests on a calendar basis and/or with visual field inspections. The primary problem with harvesting on a calendar basis is that weather will cause plant maturity on a given date to vary. Visual field inspections to estimate alfalfa maturity are imprecise. Bloom is the most easily recognizable maturity characteristic, but by the time appreciable bloom is present, alfalfa is often too mature to meet the quality standards imposed by the dairy industry. Feeling stem tips for the presence of buds is more useful, but is still an inadequate means to accurately assess alfalfa maturity in a field. Since individual stems vary considerably in morphological stage, it is difficult to assess an entire field accurately.

Another method of determining alfalfa forage quality in the field is to sample alfalfa forage prior to harvest and submit the sample for chemical analysis using either wet chemistry analysis or
near infrared reflectance spectroscopy (NIRS). However, this approach is impractical due to time delays, cost, and changes in alfalfa quality that occur daily.

Researchers throughout the United States have worked to develop a more precise method to predict the forage quality of the standing crop. Efforts have focused on three areas: growing degree day models, plant morphology (stage), and predictive equations based on both plant height and alfalfa stage. For any method to be widely accepted by alfalfa producers and consultants, it must be rapid, relatively easy to perform, and reasonably accurate.

**GROWING DEGREE DAY MODELS**

Temperature obviously influences the rate of alfalfa development. The growing degree day (GDD) concept uses temperature (average daily temperature minus a base temperature) to predict alfalfa growth and forage quality. The base temperature normally used is 41°F (5°C). The starting date for GDD accumulation is an important consideration and has varied between studies. March 1 was used in some studies (Lewis and Balliette, 1991; Cherney, 1995), while in other studies GDD were accumulated after air temperature during the day remained above 41°F for five consecutive days (Allen and Beck, 1996). Studies in the Midwest indicated that alfalfa was near 40% NDF after 700 GDD were accumulated in the spring. Although NDF is a different fiber measurement than ADF, 40% NDF is comparable to the 54% TDN standard set in California for dairy quality alfalfa.

While the GDD method has been used in some areas with reasonable accuracy, there are several limitations that have prevented wide-spread adoption of the GDD system by western growers. First, the GDD approach has not been widely tested in the West. Tests in other areas, however, have demonstrated that the GDD method is not widely applicable across environments (Cherney, 1995). The diversity of environments found in California alone, would require that numerous studies be conducted to develop site-specific relationships between forage quality and GDD. However, even within some production regions in California, there are significant environmental differences due to changes in elevation, topography, and specific weather patterns. Similarly, both fall dormancy and harvest management the preceding fall influence alfalfa growth rate and cause field-to-field variation in alfalfa development in the spring. All these factors limit the usefulness of the GDD approach to predict alfalfa forage quality in much of the West, particularly in California. Also, the GDD method appears to be inadequate for predicting alfalfa quality across cuttings (Fick and Onstad, 1988, Sanderson, 1992); and is, therefore, only used for the first cutting. This is a severe limitation to the use of GGD in much of California where alfalfa is cut at least six times per season.

**THE STAGING METHOD**

Systems using alfalfa stage of development have generally been found to be more accurate over a wide range of environments than methods based solely on weather data. The 10 stage scoring system (Table 1) developed by Kalu and Fick has been used successfully to describe alfalfa development and to predict forage quality. A weighted average, based on the weight of stems present in each category is used to predict forage quality. This approach is referred to as
mean stage by weight or MSW. This method is too time consuming to be used by most producers as a harvest management tool. However, research indicated that mean stage by count (MSC), based on the number rather than weight of stems in each category, could be substituted for MSW without a significant reduction in accuracy (Mueller and Fick, 1989).

Recent studies have been conducted in several western states including California, Oregon, Washington, Idaho, and Montana to test the validity of this system. Most studies demonstrate that MSC is correlated with forage quality, but the predictive ability of this system is open to question. With the MSC method, stems over 12 inches long are categorized based on the presence of reproductive features (i.e., bud, bloom, or seed pod). However, weather conditions, stress and insect pressure can influence the appearance of reproductive structures. For example, a very tall sample without reproductive structures grown in a cool environment may actually be higher in fiber than a shorter sample that has reproductive structures grown in a warmer environment (Figure 2). Although much quicker and easier to perform than MSW, an additional drawback to the MSC method is that it is perhaps still too laborious for adaptation by growers.

THE PEAQ METHOD

Other morphological characteristics that change as alfalfa matures may be better indicators of forage quality than the presence of reproductive features. Heintz and Albrecht (1991) evaluated 15 morphological traits of alfalfa in Wisconsin to determine which factor or group of factors is most useful for developing equations for routine forage quality predictions. They found that height of the tallest stem and maturity stage of the most mature stem represented the best compromise between ease of use and prediction accuracy for fiber determinations. The method developed using these characteristics is called the PEAQ method, predictive equations for alfalfa quality (Owens et al., 1995). Studies (Owens et al., 1995; Vodraska and Seyedbagheri, 1996) have confirmed the usefulness of this approach.

A nationwide effort lead by Mark Sulc and Ken Albrecht is currently underway to validate the PEAQ method across states. States involved in the project are Ohio, Iowa, New York, Pennsylvania, South Dakota, Wisconsin, and California. Samples collected from these states were analyzed for forage quality and simple measurements were made, height of longest stem and stage of most mature stem. The longest stem and stage of most mature stem data were used to predict ADF and NDF of the sample, using the equation developed by Hintz and Albrecht (1991). Initial results from 1994 and 1995 showed a strong relationship \( r^2 = 0.64; \text{RMSE} = 2:12 \) between the height of the longest stem and the ADF value of the sample (M. Sulc, personal communication, 1996). The PEAQ predictions appeared to be more accurate in some states than others, but more data is needed to confirm this observation. It was also noted that the PEAQ method did not perform well for samples less than 30 cm (12 inches) or greater than 100 cm (39 inches). This is not a serious limitation to the PEAQ method, as the height of most field samples will fall well within these limits.

Studies are underway in California to determine how robust or widely applicable these equations are to evaluate forage quality. California probably has greater diversity in production regions than any other state in the United States. A total of over 400 samples were collected.
during spring and summer from producer fields in the intermountain area (3-4 cut area), the Sacramento Valley (6-7 cut area), the San Joaquin Valley (7-8 cut area), and the Low Desert Region (8-11 cut area). In 1995 the height of the tallest stem, stage of the most mature stem, number of nodes on the tallest stem, and the MSC were determined for forage samples collected from the Intermountain Region and the Sacramento Valley. Samples were obtained from all four locations in 1996.

The 1995 results from the intermountain area and the Sacramento Valley indicated that the PEAQ method is a better predictor of forage quality than the MSC method. When data from both years and all four locations were combined, a relationship existed between height of the longest stem and stage of the most mature stem and ADF (Figure 3), but there was considerable variability and relatively high prediction error ($R^2 = 0.52$; RMSE = 3.02). When location was included as a variable in the regression, an additional 5 percent of the variation was explained ($R^2=0.57$; RMSE=2.89). This demonstrates that accuracy may be improved by development of regional equations, in agreement with Sanderson (1992) and Cherney (1995).

Further analysis of the larger 2-year data set for the Intermountain Region (n=246) showed that the equation developed with intermountain data better predicted ADF for that area ($R^2=0.83$ RMSE=1.63) than the prediction equation with all of the California locations (Figure 4). Previously-developed regression equations from Wisconsin, Hintz and Albrecht (1991), and Idaho, Vodraska and Seyedbagheri (1996), were used to predict the ADF value for the intermountain data set. Both equations appeared to adequately predict the actual ADF data, but they were slightly biased (Figure 5). The Idaho equation appeared to predict better than the Wisconsin equation at ADF values below 30 percent. (Hay suited for lactating dairy cows is generally considered to be below 30% ADF.) Interestingly, the intermountain equation appeared superior to Idaho and Wisconsin equations for predicting ADF using data from the Sacramento Valley, San Joaquin Valley and the low desert of California (Figure 6).

**PRACTICAL CONSIDERATIONS**

A method to predict alfalfa forage quality may be most useful in short-season areas where alfalfa growth is comparatively slow and there is a long interval between harvests. In regions with a longer growing season, such as the Central Valley and Low Desert of California, use of these prediction methods might be less practical, especially in mid-summer. At this time of year alfalfa is cut very frequently, every 26 - 30 days. Harvest date is largely dictated by other factors such as equipment constraints, labor availability and irrigation schedules. However, in these areas a method to predict alfalfa forage quality could be very useful in the spring, and to a lesser degree in the fall. At these times of year, alfalfa quality does not decline as rapidly as in mid-summer.

An advantage of the PEAQ method is that an estimate of forage quality can be obtained quickly, 1 to 5 minutes per sample (Owens et al.; 1995). An alfalfa producer can sample several areas of a field in a relatively short time period. Sulc (1996) recommends that at least five samples be taken per field. Each sample is taken from about a 2 square foot area ($1 \times 2$ ft.), providing about 100 stems per sample. A sample is cut leaving a 1.5 inch stubble height. Forage quality is calculated for each sample using the appropriate equation and the results from the five
samples are then averaged. Adoption of the PEAQ method by growers can be facilitated by the
development of simple tables, like those used in southern Idaho (Table 2).

It may be adequate to measure height alone as a rough estimate of forage quality. Height
alone at all California locations was nearly as accurate as height and stage for predicting ADF. In
the intermountain area height alone (Figure 7) compares very closely to the prediction equation
that includes both height and stage. Various mathematical transformations of height improve the
prediction, but only very slightly. The elimination of stage data collection may be a practical
consideration. Although both factors are correlated to ADF content, height is much more
important than stage of the longest stem.

CONCLUSIONS

The PEAQ method, measurement of the height of the longest stem and stage of the most
mature stem, appears to be both accurate and useful in areas with a short growing season and
long intervals between cuttings. The usefulness of the PEAQ method in the Central Valley and
low desert of California is still unknown. Limited data from these areas indicates that the height
of the longest stem is related to the ADF content of the forage. However, this relationship does
not fully explain the variability in ADF content. More data is needed to fully evaluate the
usefulness of the PEAQ method under the diverse environmental conditions in the West.

The PEAQ method satisfies the criteria for acceptance by alfalfa producers; it is rapid,
relatively easy to perform, and reasonably accurate. The PEAQ system is not a substitute for
standard laboratory analysis and, therefore, should not be used to formulate rations or as a basis
for marketing decisions. Losses that occur through the harvest and curing process in production
fields are avoided when hand clipping. Therefore, the PEAQ method does not predict forage
quality after mechanical field harvesting, but it is a valuable tool to estimate the quality of standing
alfalfa to assist growers with harvesting decisions.

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assistance with the statistical analysis.

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**Table 1.** Morphological stages of development for individual stems. Maturity stage is used to calculate mean stage by weight (MSW), mean stage by count (MSC) and stage of the most mature stem for predictive equations for alfalfa quality (PEAQ).

Adapted from Kalu and Fick, 1983.

<table>
<thead>
<tr>
<th>Maturity Stage</th>
<th>Stage Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Stem length &lt; 6 inches, no buds or flowers</td>
</tr>
<tr>
<td>1</td>
<td>Stem length from 6 to 12 inches, no buds or flowers</td>
</tr>
<tr>
<td>2</td>
<td>Stem length &gt; 12 inches, no buds or flowers</td>
</tr>
<tr>
<td>3</td>
<td>1 to 2 nodes with visible buds, no open flowers</td>
</tr>
<tr>
<td>4</td>
<td>More than 2 nodes with visible buds, no open flowers</td>
</tr>
<tr>
<td>5</td>
<td>1 node with at least one open flower</td>
</tr>
<tr>
<td>6</td>
<td>2 or more nodes with an open flower</td>
</tr>
<tr>
<td>7</td>
<td>1-3 nodes with green seed pods</td>
</tr>
<tr>
<td>8</td>
<td>More than 3 nodes with green seed pods</td>
</tr>
<tr>
<td>9</td>
<td>Nodes with mostly mature brown seed pods</td>
</tr>
</tbody>
</table>
Table 2. Table developed for growers in southern Idaho using Idaho PEAQ equation to estimate percent acid detergent fiber (ADF) in first-cutting irrigated alfalfa. Source: Vodraska and Seyedbagheri 1996

<table>
<thead>
<tr>
<th>Stem Length in inches</th>
<th>Growth stage of most mature stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>25.2 25.7</td>
</tr>
<tr>
<td>22</td>
<td>25 26.5 27.1</td>
</tr>
<tr>
<td>24</td>
<td>26.8 27.3 27.9</td>
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<tr>
<td>26</td>
<td>27.6 28.1 28.7</td>
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<tr>
<td>28</td>
<td>26.9 29.5 30</td>
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<td>28.7 30.3 30.8</td>
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<tr>
<td>32</td>
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<td>34</td>
<td>31.3 31.9 32.4</td>
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<tr>
<td>36</td>
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</tr>
<tr>
<td>38</td>
<td>33.5 34 34.5</td>
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<tr>
<td>40</td>
<td>34.3 34.8 35.3</td>
</tr>
<tr>
<td>42</td>
<td>35.1 35.6 36.1</td>
</tr>
</tbody>
</table>

Figure 1. Forage yield relative to quality at different alfalfa growth stages
Figure 2. The distribution of stems in alfalfa stage categories for samples collected from the Intermountain Region and the Low Desert Region. Both samples were collected in mid-summer. ADF concentration for both samples was 30%. Height of the longest stem for the intermountain and low desert samples were 24 and 14.5 inches, respectively.

Figure 3. Comparison of actual ADF to PEAQ prediction of ADF for alfalfa samples collected from the Intermountain Region, Sacramento Valley, San Joaquin Valley, and Low Desert Region of California in 1995 and 1996.

ADF = acid detergent fiber,
MAXHT = height of longest stem
MAX = stage of most mature stem
Figure 4. Comparison of actual ADF to PEAQ prediction of ADF for samples collected from the Intermountain Region of California in 1995 and 1996.

ADF = acid detergent fiber; MAXHT = height of longest stem; MAX = stage of most mature stem

ADF = 18.02 + 0.43(MAXHT) + 0.39(MAX) (R² = 0.63)

Figure 5. Predicting the ADF of alfalfa from the Intermountain Region of California using equations derived from Wisconsin, Hintz and Albrecht (1991), and Idaho, Vodraska and Seyedbagheri (1996) data bases.

ADF_{Idaho} = 16.2 + 0.41(MAXHT) + 0.52(MAX)

ADF_{Wis} = 11.57 + 0.53(MAXHT) + 0.79(MAX)
Figure 6. Predicting ADF of alfalfa from the Sacramento Valley, San Joaquin Valley, and Low Desert Region of California using the equation derived from the California Intermountain data base.

Figure 7. Relationship between ADF and the height of the longest stem for alfalfa samples collected from the Intermountain Region in 1995 and 1996.

ADF = acid detergent fiber; MAXHT = height of longest stem; MAX = stage of most mature stem.