# ENVIRONMENTAL FACTORS AFFECTING FORAGE QUALITY

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## ABSTRACT

Environmental conditions can have a profound effect on alfalfa forage quality. Factors that reduce growth often result in a fine-stemmed, leafy plant that is high in quality. Examples include cool temperatures, heavy or salty soil, moderate moisture stress, and deficiencies of some nutrients. Conversely, factors that hasten maturity, cause leaf loss or result in thin stands allowing weeds to invade, generally reduce forage quality. These factors include high temperatures, severe moisture stress, and many pests such as nematodes, diseases and insects. Rainfall is an environmental factor that reduces the quality of alfalfa after it has been cut. It causes bleaching of the hay and leaching of soluble nutrients.

**Key Words: seasonal effects, temperature, fertilization, soil type, soil moisture, irrigation, pests, TDN, protein.**

## INTRODUCTION

Management of alfalfa for maximum yield and quality requires an understanding of how environmental and cultural factors influence crop growth and development. These factors include growing conditions, stage of maturity at harvest, weather conditions during cutting, moisture at raking and baling, and storage conditions. The objective of this paper is to discuss the effects of the *environment* on forage quality.

A sequence of cause and effect relationships exists between the environment, plant response, and nutritive value. In general, yield and forage quality are inversely related. Any factor that retards plant development tends to promote the maintenance of forage quality. If a plant is stressed during growth, a shorter, finer-stemmed, leafier alfalfa is often produced. On the other hand, factors that hasten maturity, such as high temperatures, tend to have a negative impact on forage quality.

## SEASONAL EFFECTS ON FORAGE QUALITY

Forage quality is generally highest in spring, declines in summer, and tends to recover under autumn conditions. Alfalfa harvested in spring or fall has a higher leaf and protein content than summer-produced alfalfa at the same maturity, due to the effects of temperature and photoperiod. Cool temperatures and short daylengths in the fall delay maturation and slow the associated decline in forage quality. High summer temperatures increase the rate of plant maturation and cell wall lignification and result

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in lower forage quality due to reduced digestibility. Cool temperatures retard maturity and therefore promote higher quality at a given age. However, inconsistency is to be expected because differences in ambient temperature are seldom independent of other associated variables, such as daylength and moisture conditions.

Seasonal effects on forage quality are evident when comparing data from harvest intervals ranging from 22 to 34 days during the months of May through September (Table 1) Within each month, alfalfa yields were generally greater with longer growing periods. In contrast, average Total Digestible Nutrient (TDN) levels declined steadily from 22 to 34 days. The effect of the environment becomes clearer when we compare cutting intervals across months. The 30 day cutting schedule produced high yields and acceptable quality during May and September. June, July, and August yields were greatest with 34 day cutting intervals, but highest TDN values were obtained at 22 days during those months. Environmental influences on plant development account for most yield and quality differences. The 1/10 bloom stage occurred with the 30-day cutting schedule in June and August, at 26 days in July, and at 34 days in September. In May, plants were still in the bud stage after a 34 day regrowth period.

Table 1. Yield and TDN[1] for various harvest schedules (averages of 2 locations for 2 years)

| Days Between Cuttings | May | | June | | July | | Aug. | | Sept. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Yield | TDN | Yield | TDN | Yield | TDN | Yield | TDN | Yield | TDN |
| | (T/A) | % | (T/A) | % | (T/A) | % | (T/A) | % | (T/A) | |
| 22 | 1.39 | 52.7 | 1.49 | 51.2 | 1.51 | 50.3 | 1.52 | 50.9 | 1.20 | 52.2 |
| 26 | 1.56 | 52.4 | 1.76 | 50.4 | 1.84 | 49.4 | 1.74 | 49.9 | 1.26 | 52.4 |
| 30 | 1.92 | 52.2 | 2.13 | 50.0 | 2.01 | 47.7 | 1.79 | 49.8 | 1.32 | 52.2 |
| 34 | 1.79 | 51.5 | 2.07 | 48.1 | 2.31 | 47.1 | 2.05 | 49.5 | 1.40 | 51.4 |

[1]TDN, Total Digestible Nutrients, reported on a 100% dry matter basis

Increasing daylength and increasing light intensity influence the rate of photosynthesis and result in increased amino acid and non-structural carbohydrate synthesis. The cell wall content, relative to the total dry matter content, decreases. Long days can increase the stem number per plant, diameter of the stem, and/or the internode length thereby reducing the leaf to stem ratio while increasing yield. Marble (1990) reported that the leaf to stem ratio of nondormant alfalfa varieties varied throughout the year. Leaf to stem ratios are high for the first cutting, decline through the summer and then increase again by the fall cuttings. Alfalfa leaf development may be more rapid at long daylengths, but leaf size has not been shown to be affected.

## EFFECTS OF SOIL TYPE ON FORAGE QUALITY

Differences in soil type are difficult to evaluate because they are usually confounded by other environmental factors. Meyer and Jones (1962) reported higher forage quality (lower lignin values and higher crude protein concentrations) in alfalfa produced on heavy clay loams vs. sandy soils. They thought that these patterns were probably

associated with a higher leaf to stem ratio and shorter plants grown on the heavy clays. Soil type per se is probably less important in determining forage quality than its indirect effect through such characteristics as water holding capacity, soil aeration, and nutrient availability. In general, unfavorable soil conditions affect alfalfa production by creating a poor environment for root growth, and limiting water and nutrient uptake. By altering growth patterns, these unfavorable soil conditions then impact forage quality.

## EFFECT OF SOIL FERTILITY ON FORAGE QUALITY

The composition and nutritive value of forages is affected by the availability and uptake of several essential elements. The relationship between soil fertility and forage quality is not clearly defined and depends on the essential nutrient.

**Phosphorus** is the nutrient most often limiting to alfalfa production in most of California. Phosphorus is important in plant energy transfer processes, nitrogen fixation, transport of nutrients, and development of reproductive structures and roots. When phosphorus is limiting, growth is reduced and the plant is stunted with smaller than normal leaves. Higher leaf to stem ratios may occur in plants when growth is restricted by a phosphorus deficiency. The increase in leaf to stem ratio results in greater crude protein concentrations, but reduced growth and stem elongation has a negative impact on yield.

The primary role of **potassium** in plant nutrition is metabolic. It is vital to many plant functions including formation and translocation of sugars and starch, and protein synthesis. The potassium requirement of alfalfa is greater than that for any other nutrient. Potassium has been suggested as a factor in achieving rapid regrowth after cutting and improving overwintering. There is some data to indicate that potassium fertilization has increased nodule number, nodule mass, and N2-fixation rates (Duke et al., 1980). Low levels of potassium have been reported to reduce nitrogen fixation, but this is possibly a secondary response of reduced photosynthesis, when shoot growth is restricted by low potassium levels. Higher leaf to stem ratios may occur in plants when growth is restricted by a potassium deficiency. The increase in leaf to stem ratio results in greater crude protein concentrations, but reduced growth is reflected in lower yields.

For the most part, California soils are not potassium deficient. However, recent research in cotton indicates that, after many years of cultivation, some soils have become deficient in potassium for optimum cotton production, even though traditional soil analysis indicates that there are sufficient levels of potassium in the soil. Research is currently being conducted throughout the state to determine the potential benefit of potassium fertilization on alfalfa yield and quality. The first step in the process is developing information to predict when a potassium application on a specific site would be expected to show a response.

Many crops need **nitrogen** fertilizer, but alfalfa, because it is a legume, does not. Adding nitrogen fertilizer doesn't help alfalfa very much because it can usually make its own, but it does provide a big boost to weeds. Adding fertilizer nitrogen has resulted in no consistent yield or crude protein effects when the alfalfa has been well-nodulated.

## EFFECT OF SOIL MOISTURE STATUS ON FORAGE QUALITY

Too much or too little water can have serious consequences in terms of the performance of alfalfa. When transpiration exceeds water absorption, a stress is imposed on the plant influencing metabolism, development, growth, and ultimately yield. Water stress may retard growth more at one stage of development than at another.

In general, water deficiencies lead to a reduction in vegetative growth (lower yields) and promote early maturity (lower quality) (Table 2). Water stress retards plant development through reductions in photosynthesis. As soil moisture becomes limiting, growth slows. With moderate moisture stress, reductions in both leaf area and yield are noted. Since stem growth is more severely reduced than leaf area, an increase in the proportion of leaves results. This produces a plant with higher protein content and lower fiber levels than a non-stressed plant. Severe water stress causes leaves to fall from the plant lowering the leaf to stem ratio and overall forage quality. If the stress has not been too severe or for an extended period, plant responses are not permanent.

Table 2. Moisture stress effects on alfalfa yield and quality, mean of two years' data (Jensen et al., Nevada, 1987).

| Applied Water[1] | Evapo-Transpiration | Dry Matter Yield | TDN |
|---|---|---|---|
| (in.) | % | T/A | % |
| 27 | 48 | 4.3 | 56a |
| 42 | 75 | 7.9 | 54b |
| 55 | 100 | 8.8 | 54b |
| 70 | 125 | 8.6 | 53b |

[1]Irrigation and rainfall

Drought often leads to a reduction in root density. This limits the uptake of nutrients and water. Moisture levels have been shown to have variable effects on alfalfa crude protein concentrations. Some of the inconsistent crude protein responses to water deficits may be explained by variations in nitrogen fixing capabilities. Soil and plant water deficits depress symbiotic nitrogen fixation. The survival, multiplication, and movement of rhizobia are reduced by soil water deficits. Under extreme moisture stress conditions, nodule shedding may occur.

Under field conditions, moisture stress usually coincides with high temperatures. Both conditions depress plant growth. However, carbohydrate utilization is generally reduced to a greater extent than photosynthesis. Therefore, drought conditions often result in increased soluble carbohydrate concentration in plant tissue. This would suggest that forage quality does not decrease during periods of drought stress until death and deterioration of plant material occur.

Alfalfa does not tolerate wet soil conditions. Too much water negatively affects yield and can lower forage quality. Standing water promotes root rots which can eventually kill the plant. Combined with high temperature, saturated soils result in scalding and plant death within 3 to 4 days. Weak alfalfa is usually replaced by vigorous weeds, reducing quality and lowering the market price of hay.

## EFFECTS OF PESTS ON FORAGE QUALITY

Diseases, insects, nematodes, and weeds can all limit alfalfa production. Although producers may be concerned primarily with yield reductions and survival of the stand, the quality of the forage may also be affected by pests. As with other stresses, pest pressure that delays development will typically result in higher quality forage, but yields will be reduced. On the other hand, conditions that reduce the leaf to stem ratio, increase the fiber concentration, or reduce the protein concentration lower feeding value.

**Diseases** - Many alfalfa diseases reduce yield, quality, and stand life. Foliar diseases occur most often in spring and fall. They reduce the overall energy efficiency of the plant which results in a major loss of yield and quality. Symptoms vary for each disease, but the outcome is similar: infected leaves fall from the plant reducing hay quality. Crown and root diseases weaken root systems and reduce the plants absorptive, nitrogen fixing, storage, and anchoring capabilities. They exhibit their effects on forage quality primarily through retardation of growth and ultimately through stand persistence.

**Insects** - Insects can have either direct or indirect effects on the yield and quality of forage. They can consume leaves, suck plant sap, or feed on roots. Sometimes the consequences of pest pressure are quite obvious as in feeding by the alfalfa weevil, caterpillars, and armyworms. Heavy feeding results in a very low protein, high fiber forage since the majority of the leaf material is removed. Loss of leaves can reduce the feeding value up to 50% and yield up to 35%. Through insect feeding, photosynthesis and productivity are both reduced. Alfalfa weevil, caterpillar, and armyworm feeding are examples of the *direct* effect a pest can have on forage quality. Aphids, on the other hand, influence the quality of the hay *indirectly* in two ways. They suck out plant sugars and often reduce growth and yield. They also deposit honeydew on plant tissue, which contributes to mold growth and reduces feeding value. Insects that feed on roots reduce forage quality indirectly through reductions in stand.

**Nematodes** - Root knot nematode and stem nematode are the most injurious nematodes in alfalfa fields in California. In general, root knot nematodes weaken roots, reduce water and nutrient uptake, and make roots more susceptible to disease. Under severe infestations, development is delayed and the stand declines allowing weeds to invade. Alfalfa infected by stem nematode has enlarged stems and discoloration at the nodes. Internodes are often shortened. The number of stems per crown is reduced and eventually the entire plant dies. The stand thins leaving spaces for invasion by weeds.

**Weeds** - Although weeds do not always reduce forage yields, they almost always reduce forage quality. Protein as low as 9% has been measured in hay containing 80% weeds. Weeds reduce the quality and value of hay because they are often less palatable and less nutritious than alfalfa. Weeds generally contain more fiber than legumes which can potentially lower intake levels. This is important because energy intake is often a limiting factor in high producing and early lactation cows.

Some weeds are comparable to forage species in chemical composition and forage quality, but when they are present in alfalfa fields, they are usually harvested beyond their optimum nutritional stage. The forage quality of weeds declines more rapidly with maturity than does that of alfalfa. Many weeds, even at their optimum nutritional stage are less nutritious than alfalfa. Some weeds are toxic or may cause mechanical injury, in both cases rendering hay unfit for livestock consumption. Weeds that retain moisture can increase curing time and lead to mold, rotting, and spontaneous combustion in stored hay.

## EFFECT OF RAIN ON FORAGE QUALITY

All of the environmental factors discussed thus far affect the quality of the standing crop before it is cut. After cutting, weather conditions continue to impact forage quality. Rainfall has the greatest potential for affecting quality while the hay is curing. It can shatter and destroy leaves, leach soluble nutrients, and prolong respiration. Rain-damaged alfalfa can be brittle after drying, so it is more susceptible to losses during raking or baling. Extra operations may also be necessary to dry the rewetted alfalfa, and these may increase mechanical losses and reduce forage quality.

The effect of rain on alfalfa quality depends on the amount, intensity, and duration of the rain as well as the moisture content of the alfalfa at the time of rainfall. Leaching of soluble nutrients is the primary cause of quality loss, and leaching losses increase as the amount and duration of rainfall increases. As a result, rain damage decreases digestibility and increases fiber concentration. An intense rain for a short time has less of an effect on forage quality than the same amount of rain over a longer duration. Both leaching and leaf loss are greater with drier alfalfa than with that which is freshly cut. Rain early in the drying process causes little loss. The cuticle, or outer coating on the plant surface is largely intact soon after cutting, and is believed to shed water better at that point than when the forage has dried.

## SUMMARY

The nutritive value of a forage is the consequence of the conditions of plant growth. Understanding how environmental conditions and management factors interact to influence forage quality is important in making production decisions. Properly scheduling harvest operations and irrigation, maintaining fertility, and controlling pests can all contribute to produce high quality hay, maintain profitable yields, and productive stands.

## REFERENCES

Hanson, A.A., D.K. Barnes, and R.R. Hill Jr. (eds). 1988. Alfalfa and Alfalfa Improvement. ASA, CSSA, SSSA, Inc. Publishers, Madison, WI.

Heath, M.E., R.F. Barnes, and D.S. Metcalfe (eds.). 1985. Forages - The Science of Grassland Agriculture. 4th edition. Iowa State University Press, Ames, IA.

Marble, V.L. 1990. Factors to optimize alfalfa production in the 1990's. In: Proceedings of the 20th California Alfalfa Symposium. Visalia, CA. pp.4-45.

Meyer, J.H. and L.G. Jones. 1962. Controlling Alfalfa Quality. CA Agr. Exp. Sta. Bull. 784. Univ. of CA, Davis.

Mueller, S.C., C. Frate, and R. Vargas. 1992. Central San Joaquin Valley Alfalfa Establishment and Production. Fresno County Publication. 38 pp.

VanSoest, P.J. 1982. Environment and Forage. In: Nutritional Ecology of the Ruminant. O & B Books, Corvallis, OR. pp. 58-74.

VanSoest, P.J., D.R. Martens, and B. Deinum. 1978. Preharvest Factors Influencing Quality of Conserved Forage. J. Animal Science 47(3): 712-720.