

Environmental Impacts on Forage Quality

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Farmers spend considerable time on crop variety selection in search for high yields but also for high forage quality. And for good reason since genetic advances including brown midrib (BMR) corn hybrids, other BMR summer annuals and, more recently, reduced-lignin alfalfa offer the potential for improved quality. Additionally, the tremendous growth in the availability and range of genetically engineered traits—Bt corn hybrids, glyphosate resistant corn and alfalfa—has greatly increased farmers' pest control alternatives. However, the influence of plant genetics on crop yield and quality is modest when compared to the combined effect of genetics plus environment. For instance, selecting corn hybrids for high silage yield can result in about a 10% yield improvement. But when hybrid selection is combined with the impact of environment—primarily but not exclusively weather conditions—the yield impact triples. Similarly, the combined impact of hybrid plus environment results in much greater differences in corn silage quality (including starch content and digestibility) than does hybrid selection alone.

Plants have several defenses against adverse weather conditions, not all of which promote higher forage quality. Plants accumulate nutrients in various organs to help them survive adverse weather conditions including defoliation from hail or frost, and in the case of alfalfa and other perennial legumes, from the depletion of nutrients following harvest. Plant stress can increase some aspects of forage quality: for example, when subjected to drought stress, corn yields less grain per acre but the stover is usually more digestible. The result is whole-plant silage quality which is often similar to that of corn grown under adequate moisture. Alfalfa grown under limited moisture will be lower in yield but the leaf-to-stem ratio may be higher than when the crop is grown with adequate soil moisture. Another way that plants protect themselves against environmental challenges is by the formation of compounds such as lignin and alkaloids. Increased lignin content in forage crops can decrease dry matter intake by ruminants, while alkaloids are nitrogen-containing compounds that are usually bitter in taste, resulting in decreased palatability. Examples of this include two older varieties of reed canarygrass, “Rise” and “Vantage”, which contain significant amounts of the alkaloid indole. Dairy cattle are particularly affected by these alkaloids; realizing this, in 1985 plant breeders developed and released two reed canarygrass varieties, “Palaton” and “Venture”, that contain about 20% less alkaloid than do the older varieties and are therefore more readily consumed by ruminants.

It ain't the heat...

The two major environmental impacts on forage quality are heat and moisture. High temperatures reduce plant digestibility in several ways: by increased lignification of plant cell walls, higher neutral detergent fiber (NDF), and by decreased metabolic activity resulting in lower protein and soluble carbohydrates. The corn plant will tolerate a wide range in air temperatures, from about 30°F to 110°F. While temperatures above 95°F can negatively affect pollination, this seldom is a problem

provided there's adequate soil moisture. Also, pollen shed usually occurs in the morning before temperatures exceed 95°F. What really affects corn silage quality is the combination of high temperatures and excess soil moisture. Excess heat is harmful; excess soil moisture is harmful; hot and wet is *terrible* for NDF digestibility. To make matters worse, during periods of high precipitation there's often a lot of cloud cover and therefore less sunlight. Cornell University's Peter Van Soest noted that under these conditions the forage quality (primarily of corn silage but of other forages as well) may be even worse than would be predicted by laboratory analyses.

Alfalfa is a cool-season crop but can tolerate temperatures of up to 100°F *if the air is dry*. That's why irrigated alfalfa does much better in Arizona and the arid Southwest than in the Southeastern U.S. "It ain't the heat, it's the humidity."—this is true for alfalfa as well as for humans. What's referred to as the "summer slump" of alfalfa grown in the Southwest usually occurs in July when the dew point peaks for the summer. High temperatures increase the rate of maturity and stem lignin content while plant height and leaf-to-stem ratio decrease. The cumulative effect is lower fiber digestibility. Hot weather can have a long-lasting impact on yield and plant health because when the alfalfa plant is heat-stressed—especially during the "summer slump"—it stores less carbohydrate because of increased respiration.

Summer slump of alfalfa is different than "summer scald", also common in the arid Southwest. Summer scald occurs when the air temperature is over 90°F and water stands for several hours following surface irrigation. The alfalfa roots suffer from lack of oxygen, resulting in reduced growth which in turn leads to lower yield and lower forage quality. Summer scald can also affect bermudagrass and sudangrass, but is most common in irrigated alfalfa.

When managing alfalfa in hot climates, "Fear the night." Hot nights can reduce alfalfa quality, but hot nights preceded by 100°F days are worse. The result is higher crude protein but also higher fiber levels, particularly lignin. Mowing heat-stressed alfalfa at the late bud stage may be too early under these conditions because the alfalfa needs additional time to rebuild root carbohydrates. Although too soon to know for sure, this probably is the case even with reduced-lignin alfalfa varieties.

Summer slump aside, alfalfa is a very good crop for hot environments as long as there's adequate rainfall or irrigation. Alfalfa leaflets have no structural function, so there's almost no change in leaf quality as the plant matures—or as temperatures rise. Stem lignification is at least partly offset by the unchanged leaf quality. The result is a widening of the quality difference between the more and less digestible parts of the alfalfa plant. Therefore, leaf retention during harvest—from mowing through ensiling—is critical for maintaining high alfalfa digestibility. This places additional importance on harvest management—impellers vs. roller conditioners, and no conditioning vs. conditioning. Conditioning may be necessary for dry hay production, but perhaps not for hay crop silage (assuming the use of wide windrows).

If life gives you lemons...

Farmers can't control the weather, but with corn harvested for silage they have some influence over the degree to which the weather impacts forage quality, and hybrid selection is a key. "Hot and wet" reduces fiber digestibility and perhaps grain *yield* but has much less impact on grain *quality*. That's because while corn stalks contain about 65% NDF, corn kernels have only about 8% NDF.

Therefore, kernels are Mother Nature's crop insurance against the impacts of a hot, wet growing season.

Adverse weather conditions can have a large impact on high-fiber, low starch corn hybrids. Over the years there have been a small number of leafy gene hybrids with high forage yield but low grain content, in some cases five or more percentage points lower in starch than normal. (This isn't a general characteristic of leafy hybrids, many of which have normal leaf-to-grain ratios.) When weather conditions are favorable for NDF digestibility a high fiber, low starch hybrid may do well both in the field and in the feedbunk. But during a hot, wet summer the low grain content of these hybrids provides little defense against the impact of adverse weather conditions.

As noted this is not an indictment of leafy hybrids, some of which have performed very well for both yield and quality in university hybrid trials when harvested as whole-plant silage. Some leafy hybrids have a slightly longer "harvest window" since once they reach the generally recommended harvest moisture content there's a slower rate of moisture loss. Leafy hybrids are recommended almost exclusively for silage harvest and have more leaves above the ear. University trials haven't found any consistent differences in yield or forage quality between leafy and conventional hybrids, but there's been little of this testing in weather-stressed environments. The additional leaves in leafy hybrids are all above the ear, where they're most visible—even from the seat of the farmer's pickup truck. But appearances can be deceiving: in one Penn State trial comparing leafy and conventional hybrids, conventional hybrids had 12% leaf content while leafy hybrids were only slightly higher at 13-16% leaf content. Looking at side-by-side rows of leafy and conventional hybrids, most farmers would be very surprised at this small difference. However, there are meaningful differences in starch content within the leafy genotype. In regions where temperatures often exceed 100°F, particularly with surface irrigation that can challenge plant digestibility, farmers should choose corn hybrids (including both leafy and conventional) with a proven record of high grain-to-stover ratio.

Irrigation impacts on forage quality

Most farmers don't have a choice of irrigation method, but it's useful to understand the quality challenges that can be posed by surface (vs. sprinkler) irrigation, both for alfalfa and for corn. Montana research with surface-irrigated alfalfa evaluated the relationship of temperature and how long the field was irrigated. Three weeks after alfalfa was surface irrigated, alfalfa yield was 50% lower when the crop had been flooded for four days at 70°F, but yield was 50% lower when alfalfa had been surface-irrigated for only *two* days when temperatures were 90°F. There was no alfalfa root growth during the time the field was flooded.

The impact of irrigation method on the quality of corn harvested as whole-plant silage can be considerable. Italian researchers, using three U.S. corn hybrids, applied two rates each of sprinkler and surface irrigation to growing corn. When the corn was harvested for silage at 30-32% DM, compared to sprinkler irrigation both high and low rates of surface irrigation resulted in much higher NDF and lignin content, and lower protein, NDF digestibility and rates of digestion. There was much more difference between surface and sprinkler irrigation than between the high and low irrigation rates. Farmers using surface irrigation should pay particular attention to the starch content of the corn they plant for silage, using management strategies (hybrid selection, plant population, fertilization, etc.) that promote high grain content. Over a generation ago Cornell University dairy scientists stated that "The best grain hybrid is the best silage hybrid." With the notable exception of

BMR corn, and particularly in environments where heat and excess soil moisture are frequent challenges, forty years later this statement remains mostly true.

Ash

When deposited in the form of dust or other external contaminants, ash is another environmental factor that can affect forage quality. The ash levels in Western U.S. corn silage are generally higher than in other regions of the U.S. For instance, California corn silage averages about 6% ash while New York and Wisconsin corn silages both average about 3.5% ash. Surface-irrigated corn doesn't get the frequent "wash/rinse" cycles that corn receives from rain or center-pivot irrigation, and additional dust is often deposited by choppers and trucks during harvest, so ash levels in surface-irrigated corn may be even higher than the overall California state average of 6%. (Similar results would be expected in corn silage on farms in other states using surface irrigation.) It should be noted that California corn silage has a slightly higher mineral content than Wisconsin or New York corn silage, some of which is "internal" ash—plant potassium, calcium, etc. But even accounting for differences in the plant's mineral content there's somewhat more "external" ash in Western U.S. corn silage.

Sunlight, light intensity, and when to mow alfalfa—dawn or dusk?

We often underestimate the importance of daylight in discussions of forage quality, mostly because there's so little we can do to change it. Light is the main energy source for forages, influenced by both light intensity and day length. The end process of photosynthesis is glucose, so sunlight promotes the formation of sugars. At the same time there's a decrease in fiber concentration, though much of this is the result of dilution by the increased level of nonstructural carbohydrates and amino acids. Cloud cover reduces the amount of light that plants receive, which decreases forage quality. Fog would be expected to have a similar effect as cloud cover, something that may affect the quality of forage crops grown in California's Central Valley (where ground fog is common) vs. those grown in higher elevation areas.

Plants gain dry matter primarily in the form of sugars during a sunny day and lose these sugars overnight through transpiration. This occurs regardless of whether a forage crop is standing in the field or has just been mowed. Plant sugar content is highest in the late afternoon and lowest right after sunrise. Arizona researchers found 4% higher alfalfa yield when it was harvested at dusk vs. when the same crop was harvested just after dawn. Other research in the Southwestern U.S. found that alfalfa harvested in the late afternoon and preserved as dry hay was higher in digestibility, more palatable to dairy cattle, and resulted in higher milk production.

A challenge in making the diurnal pattern of plant sugar accumulation work for farmers is that much of the sugar accumulated during a sunny day is lost during the night through respiration. Alfalfa mowed in the morning has low sugar content, but when managed in wide windrows can often be mowed and chopped for silage in the same day, thereby avoiding overnight respiration losses. However, alfalfa mowed late in the day (after sugars have accumulated) can seldom be chopped until the following morning so much of the day's gain in sugars is lost overnight. Two years of research at Miner Institute (Chazy, NY) involved mowing replicated blocks of alfalfa between 7:00 and 8:00 AM vs. between 3:00 and 4:00 PM. By the time the alfalfa was chopped for silage—the same day

for that mowed in the AM, the next morning for that mowed in the PM—there was no significant difference in plant sugar content.

So, what should farmers do? For dry hay production mowing in the afternoon may have an advantage since the alfalfa would have to remain in the windrow for at least one night regardless of the time of day that it's mowed. For hay crop silage, the highest quality silage will be that mowed as late in the morning as possible *while still able to be chopped the same day*. However, it's important to keep in mind that harvesting alfalfa at the proper stage of maturity is more important than AM vs. PM decisions.

While we can't change the amount of sunlight, we can manage crops to maximize its impact. Sunlight will penetrate deeper into a canopy of corn when the rows are planted in a north-south direction. More sunlight results in higher yield potential. In a Dupont-Pioneer trial, compared to corn planted in an east-west direction, corn planted north-south and harvested as silage averaged 13% more yield and 11% more milk per acre. There were similar results—12% higher corn grain yield with north-south rows—in an irrigated South Carolina trial. However, not all crops respond similarly to row orientation. In shorter-statured crops including cereal grains, more sunlight penetrating the crop canopy and reaching the soil surface can result in increased weed growth. Researchers in Australia found 44% fewer weeds and 25% higher crop yield with a cereal crop planted in an east-west row orientation.

Soil factors influencing forage quality

Soil is part of the crop's environment, and not just from a soil moisture standpoint. Both total plant-available nutrients as well as the relationship between nutrients impact crop yield, and some of these relationships also affect forage quality. For instance, alfalfa plants need adequate potassium for normal protein production. The higher protein content in alfalfa when soil potassium levels are increased from deficiency to sufficiency is the result of at least two factors: An increased leaf-to-stem ratio and increased nodulation. There are a number of interrelated factors, but the protein content of alfalfa may be reduced when whole plant potassium levels fall below 2.0%.

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