

have already bred alfalfas with very different root systems; some types are strongly taprooted and have very few lateral roots, whereas others are finely branched and have many lateral roots. We expect these root system types may have different tolerances to soil moisture and nutrient contents, but the research on this has just begun.

### **Alfalfa's Challenges**

Even fans of alfalfa must admit to its limitations. Soil pH needs to be near neutral or higher for best alfalfa growth. Its high yields requires high nutrient supply. Its high quality is attractive to pests as well as cows. And, among other things, alfalfa definitely does not like to have 'wet feet.'

#### ***Scald***

When alfalfa is subjected to flooding, especially under high temperatures, it can suffer from what is commonly called 'scald' (Leath et al., 1998). This is a physiological syndrome, in which the shoots turn yellow and wilt within a week or so, and the roots collapse or the vascular tissue dies (Erwin et al., 1959). High soil temperatures increase the damage due to temporary flooding (Thompson and Fick, 1981). Even when alfalfa shows no symptoms of stress after flooding, it is more susceptible to root diseases, such as phytophthora root rot. Older plants appear to be less susceptible than younger plants (Teutsch and Sulc, 1997).

Why is alfalfa damaged by flooding? The main reason is that less oxygen is available to the roots when gas exchange cannot take place among soil voids. Soil is usually both half full and half empty — a shovel-full of soil contains about 50% solids (sand, silt, clay, and organic matter) and 50% voids. Soil voids are filled with gas and water. The more water a soil contains, the smaller the space left for gas, and the fewer pathways remain for gas to move around. Water reduces oxygen movement into soil, because water can carry about 10,000 times less oxygen than the same volume of air. In short, alfalfa roots are suffocated in wet soil. Because warm water can hold less oxygen than cold water, scald is more likely in very warm or hot soils.

How does this relate to surface irrigation of alfalfa with dairy manure pond water in the San Joachin Valley? It may be that even relatively short-term flooding during application of dairy manure pond water causes scald in some cases. This pond water contains manure solids and has a high biological oxygen demand. Solids are likely to plug soil pores and voids,

particularly at the top end of the field, reducing oxygen flow from the atmosphere to the soil. Microorganisms in the soil rapidly decompose the dissolved organic compounds in manure pond water, and use oxygen for this process. This lower oxygen status can last for days, even when the irrigation set was short. The combination of high soil water content, blocked soil pores, and high biological oxygen demand that follows manure pond water application may well induce the scald symptoms reported by some alfalfa growers.

Scald is more likely on fine-textured soils (clays and loams) than sandy soils, because sandy soils retain relatively little water after irrigation and have few small voids that could be blocked by manure pond water solids. On the other hand, the increased frequency of irrigation required on sandy soils may subject alfalfa to more cumulative stress from low oxygen than occasional irrigation on clays and loams.

Alfalfa is more susceptible to scald immediately after harvest than several days later (Rai et al., 1971), which may indicate that harvest stress increases the impact of other stresses (Barta and Schmitthenner, 1986). Delaying irrigation with dairy manure pond water until the plants have recovered from harvest may help prevent scald. Clearly, lowering the content of organic materials, such as suspended solids, should reduce scald occurrence, as should careful traffic management to avoid compaction of fields during harvest, pest control, and fertilizing operations.

I do not know whether alfalfa variety differences exist regarding scald. In cases where scald is a recurring problem that is not alleviated by these management techniques, such as in up-field locations where solids settle out during irrigation, another approach may be to plant these areas with other species, like a palatable grass that can be harvested on the same schedule as alfalfa. Doing so will reduce the acreage of harvested alfalfa, but may help prevent stand decline in the alfalfa that forces re-establishment of the entire field.

### *Salinity*

Alfalfa is moderately sensitive to salinity. The laboratory test for salinity measures how well electricity is conducted through the soil solution when the soil is saturated with water, that is, when no gas remains in the voids. Alfalfa yields generally begin to decline at an electrical conductivity of about 2 dS/m and are zero at about 16 dS/m (Maas and Hoffman, 1977). Stem

elongation is more reduced than leaf growth, resulting in higher leaf:stem ratios under moderate salt stress (Hoffman et al., 1975).

Manure is, unfortunately, a good source of salts. A herd of 1000 high-producing dairy cattle excrete about two tons of salts per day in manure (Meyer et al., 1976). Except for losses during storage, these salts are applied to the soil on most farms.

Growers in the arid regions of California are well acquainted with salinity problems and I will not belabor this topic, except to say that there are public and private efforts to improve salinity tolerance in alfalfa, both in the USA and abroad. For example, groups in Australia are attempting to make alfalfa more tolerant to salinity, so that it can help prevent saline soil development. Dr. Steve Smith has been developing the standard selection procedure for alfalfa breeders to use, which involves exposing plants to low and high (12 dS/m) salt stress and measuring relative plant growth over several harvests. Dr. Lamb and I are working with a visiting Australian scientist, Dr. William Bellotti, to evaluate the procedure and to start selecting plants for tolerance. In other work, we and Dr. Mike Schmitt are selecting alfalfa under heavy manure slurry applications and under saline water irrigation. The ultimate goal is to develop alfalfas that can thrive when exposed to manure or wastewater applications.

There are large differences in tolerance to salinity among alfalfa plants and among varieties. Two notable non-dormant alfalfas with higher salt tolerance are CUF 101 and Salado. With continued public and private efforts, improved salinity tolerance in alfalfa is assured. This will not eliminate the need for good irrigation water and manure pond water management, however, since salts are not easily removed from the soil in many situations.

### *Weeds*

Many growers are concerned about increased weed populations and growth when manure is applied to alfalfa. One-fourth of Minnesota dairy farmers who responded to a survey in 1996 shared this concern (Russelle, 1999). Many weed seeds can pass through the ruminant digestive system and remain viable (Janzen, 1984). Although some plant seeds have lower germination rates afterward (Ocumpaugh et al., 1996), germination rates of others are increased after seeds pass through the ruminant digestive tract.

Dairy manure from Tulare County farms contained seed of several weed species, including barnyardgrass, yellow foxtail, bermudagrass, annual bluegrass, lambsquarters,

pigweed, and mustards (Cudney et al., 1991). Separating solids removes most seed, but liquid manures apparently also can contain significant weed seed contamination. Seed also may enter the liquid manure after it is stored in the manure pond.

Once applied to the field in manure or pond water, these weed seeds can take advantage of the high fertility imparted by the manure and become highly competitive with alfalfa. Whether these weeds reduce the feeding value of the forage depends on the weed species and growth stage. For example, in the Midwest, Marten and Anderson (1975) found that redroot pigweed, common lambsquarters, and common ragweed were similar in quality to alfalfa in June and early July, whereas barnyardgrass, yellow foxtail, Pennsylvania smartweed, and other species had either lower quality or lower digestibility than alfalfa. Of course, some weeds are not palatable, have anti-quality components, or are toxic to livestock.

A healthy alfalfa stand effectively excludes weed seedling establishment by dense shading. Irrigation or frequent rainfall increase weed seed germination, and as alfalfa stands thin due to traffic, disease, and other factors, weeds can become competitive (Peters and Linscott, 1988). But a factor other than addition of weed seed also may be operating in manured fields, because dormancy, hard seededness, and germination of many plant seeds are affected by concentrations of both nitrate and carbon dioxide in the soil.

It has been recognized for decades that soil solution nitrate concentration influences seed germination and dormancy. For example, high nitrate concentration is nearly as effective in breaking dormancy of lambsquarters as is low temperature (Williams, 1962). Part of this is due to osmotic effects; that is, nitrate and other dissolved salts in the soil solution act to dry out seeds that have absorbed water (Bouwmeester and Karssen, 1993). In addition, there is a direct effect of nitrate on seed respiration and as a trigger to begin N assimilation in the seedling (Hilhorst and Karssen, 1989). Effects of high nitrate are magnified by exposure of seeds to light, as occurs during seedbed preparation and after hay harvest. Some plants have a high response to nitrate, whereas others require little for germination (Wamelink et al., 1998).

Clearly, manure application will result in higher nitrate concentrations in soil. This may stimulate germination of seeds that respond to nitrate, such as lambsquarters, barnyardgrass, and others. However, as discussed earlier, manure also reduces oxygen supply in the soil. During aerobic organic matter breakdown, oxygen is used and carbon dioxide is released. A recent report from Japan showed that seed germination of barnyardgrass is enhanced by increased

carbon dioxide concentrations in soil air (Yoshioka et al., 1998). In their work, rainfall alone was enough to promote higher soil carbon dioxide levels; there is good reason to expect that dairy manure pond water applications would do the same.

Growers' concerns about dairy manure and weeds in alfalfa are well founded, not only because manure can add seeds to the field, but also can promote germination of seeds already present and facilitate weed seedling competition with alfalfa. Good weed control practices need to be followed to maintain the stand and optimize forage quality.

### *Excessive forage potassium*

Finally, there are increasing reports of alfalfa forage containing too much in potassium in relation to calcium and magnesium. These reports appear to come mainly dairy farms and appear to be related to the high amounts of potassium recycled onto fields in manure. Magnesium and calcium concentrations are both reduced in alfalfa when soil potassium supply is high. Forages containing more than about 2.75% potassium can present difficult ration balancing problems for the herd, especially dry cows and springing heifers (Howard, 1995). In Wisconsin, tissue potassium exceeded 4.5% in the first harvest under high potassium fertility (Kelling and Schmitt, 1995). Potassium concentrations are usually higher in stems than leaves, so stemmy alfalfa from high potassium fields may be a poor choice for a dry cow or heifer ration.

Alfalfa requires high potassium supply to attain high yields and tolerate stresses. Dairy manure pond water is a good source of this nutrient. However, applications to maximize nitrogen removal by alfalfa will generally increase potassium supply to high levels in the soil. Standard soil tests can diagnose whether potassium supply is adequate or very high; forage tests can tell you whether the ratio of potassium to calcium and magnesium is unfavorable.

Ration balancing is one way to deal with this problem in the short term, but the long term solution requires that potassium application rates be moderated. If past management has resulted in high soil test potassium levels and imbalances of cations in alfalfa, you might try applying a magnesium source, such as dolomitic limestone, and reducing manure application rates so the alfalfa can 'crop down' the potassium.

## Environmental impacts

Drinking water quality is a topic of broad public concern and nitrate toxicity to humans is still a problem in the USA (Kross et al., 1992). Not only can high nitrate cause blue baby syndrome in infants, there is also an apparent link between drinking water nitrate and the form of cancer known as non-Hodgkin's lymphoma (NIH, 1996). And now, it seems that high nitrate in surface water is one factor that regulates development of 'dead zones' in coastal waters (Turner and Rabalais, 1994). It should be clear by now that perennials, like alfalfa, can help prevent migration of nitrate from your field into these waters.

The relative advantage of perennial crops over annual crops in N removal for a given situation is determined by yield and N concentration of the harvested material. Of course, the ability of a crop to absorb a nutrient is limited. On sandy soils, nitrate leaching risk is typically high. Nitrogen (and manure) application rates and timing should be especially well managed on such soils. On finer textured soils, the risk of nitrate leaching is low when N applications match N removal by the crop. When too much nitrate is present in the soil, significant leaching losses may not be avoidable on most soils. It is imperative that manure N be managed responsibly to prevent ground and surface water contamination, so rates and timing should be adjusted according the situation (Bole and Bell, 1978).

We recently analyzed the risk of nitrate leaching loss under perennial forages and corn across Nebraska, Iowa, and Illinois, using a computer model and detailed soils and climate information (Kelley and Russelle, 1999). We assumed the crops were irrigated as needed with water containing 25 ppm nitrate-N. Under dry weather conditions, there was little risk of nitrate leaching except on very shallow, sandy soils. Model output suggested that perennial grasses or alfalfa would reduce the area at risk for significant leaching by 50% in wet years (although significant areas were still at risk) and by several-fold in normal years. In these normal rainfall years, leaching is still a significant risk on most soils in the 3-state region when planted to corn, but most of the area would be protected by perennial plantings. So, when you grow alfalfa right, you're helping protect the environment take credit for it!

To prevent undesirable nitrate leaching, an alfalfa field must be considered as part of a crop rotation. Little or no fertilizer nitrogen is recommended to an annual crop planted after alfalfa in most states. This is due to nitrogen release from decomposing alfalfa tissue and from soil organic matter, especially after tillage. When the field has received large amounts of manure,

the likelihood of excess nitrate production increases. Producers and their consultants need to realize that good management of the alfalfa portion of a crop rotation is not enough. Appropriate nitrogen credits must be given for the previous legume crop and manure applications to prevent nitrate loss.

Perennial crops, like alfalfa, are good places to reuse manure nutrients and can significantly reduce the risk of ground and surface water contamination by nitrate, when the crop and the manure are managed well. Public expectations and pressure are increasing on farmers to be better stewards. Given the reports of high nitrate concentration in ground water in many parts of the USA, including the San Joachin Valley, it is clear that we need to make sure our management of crops, soils, water, livestock, and manure is the very best it can be, all the time. In that way, criticism will not be justified, and regulations will be unnecessary.

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