Application of dairy manure to alfalfa Issues and techniques

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ABSTRACT

Alfalfa is an excellent crop for manure applications. This long-lived perennial forage can form a very deep root system, has high water demand, and produces high yields of protein per acre, so it can recover more nitrogen from the manure than most other crops. Unlike nonlegumes, alfalfa yields are not reduced when manure nitrogen availability is lower than expected. However, alfalfa suffers from several limitations, including limited salinity tolerance, poor ability to withstand flooding, and excessive potassium accumulation, and forage quality usually suffers from weed competition, which often is increased by manure application. Stand decline and poor quality feed are the obvious results, but environmental impacts may also be serious. Some of these limitations can be overcome by proper crop and manure management, others by improved varieties. It is crucial that producers manage manure rates and timing to limit unintended economic and environmental impacts.

Key Words: manure, nitrogen, potassium, scald, salinity, weeds, nitrate leaching

INTRODUCTION

Alfalfa is the most important forage legume in the USA and is grown on over 20 million acres from coast to coast. This audience knows it as a premier fiber and protein source for livestock, but it is also the source of many other products, such as xanthophyll, a yellow pigment important in poultry and egg production, and food grade protein that has helped malnourished children overcome protein deficiency. This under appreciated crop is the feedstock of a French cooperative, which is marketing about 30 products from alfalfa. But in the USA, alfalfa mainly yields milk, meat, and fast horses.

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Alfalfa is recognized by producers for it's deep rooting ability, large yield potential, and high protein concentration, but also for it's attractiveness to insect pests, diseases, and gophers, large phosphorus and potassium need, high water demand, and low tolerance to flooding, salinity, and traffic damage. Alfalfa is expensive to establish, so longevity is valued by many producers. The quality of the product usually affects its value in the market, so top producers work hard to keep the stand free of weeds and grasses.

It is alfalfa's high water and nutrient demand that make it a good crop to fertilize with manure, while its sensitivities to flooding, salt, traffic, and weed invasion often thwart producers' effective use of manure on their alfalfa. At least one previous presentation at this symposium, the paper by Drs. Kelling and Schmitt ('Applications of manure to alfalfa: Crop production and environmental implications'), has dealt with use of slurry and solid manure on alfalfa. I also address some of alfalfa's strengths and weaknesses when it is faced with manure application, but focus on the use of dairy manure pond water in the San Joachin Valley.

Alfalfa's Strengths

Nitrogen uptake

Cool season perennial crops, like alfalfa, begin growth earlier than annual summer crops, such as corn, and continue growth longer into the autumn. Greater water and nutrient uptake of perennial forages make them ideal candidates for preventing soil and water contamination by nitrate (Bergstrom, 1989; Campbell et al., 1994). Absorbed nitrate is removed from the site in harvested forage, which reduces the potential for nitrogen release as plant residues decompose. Well-managed legumes like alfalfa can be highly profitable, while simultaneously improving soil quality, reducing soil erosion, reducing weather-, price-, and management-related risks, minimizing pests in succeeding annual crops, and decreasing outlays for commercial N fertilizer (Peterson and Russelle, 1991).

It sometimes comes as a surprise to learn that alfalfa is effective at removing nitrate from the soil (Blumenthal and Russelle, 1996), even though its symbiosis with a bacterium, now called *Sinorhizobium meliloti*, can provide prodigious amounts of nitrogen from the atmosphere to the plant (Peoples and Craswell, 1992). One piece of evidence that alfalfa is a good nitrogen scavenger is that soil nitrate concentrations usually remain very small in well-managed alfalfa fields. This is true for fields that do not receive nitrogen fertilizer or manure applications and for those where agronomically appropriate rates of nitrogen are made (Lory, 1993). Because it is a legume and can obtain all its nitrogen from the atmosphere, it does not suffer yield losses when manure nitrogen availability is lower than expected. In addition, even at high nitrogen application rates that cause nitrate leaching losses, alfalfa typically will not contain toxic concentrations of nitrate, whereas grasses may (Russelle et al., 1996).

Because alfalfa uses both water and nitrate, it can be as effective in reducing nitrate leaching as perennial grasses under many situations (Kelley and Russelle, 1999). Both alfalfa and Conservation Reserve Program stands allowed very little nitrate leaching to subsurface tile drains on an artificially drained soil, but annual losses were 20-80 lb nitrate-N/acre under well-managed continuous corn and corn-soybean rotations (Randall et al., 1997). The main problem limiting better nitrate retention under corn and soybean crops appeared to be the lack of water and nitrate uptake in fall and spring. During these times, both the alfalfa and the Conservation Reserve Program stands were actively growing.

In other recent research, we used alfalfa to remove excess inorganic nitrogen at a railroad derailment site in North Dakota (Russelle et al., 1998). We compared two types of alfalfa, standard cultivars that fix nitrogen gas from the atmosphere and one that cannot. Alfalfa was irrigated with N-impacted ground water. Nitrogen removal by the non-N-fixing alfalfa was 870 lb N/acre over 3 years, compared to only 330 lb N/acre for a rotation of corn silage-spring wheat-corn silage. Even though a corn silage crop yielded as much dry matter in one year as the non-fixing alfalfa (5.9 tons of dry matter), the corn removed only one-half as much soil nitrogen (160 lb N/acre in corn vs. 370 lb N/acre in alfalfa). The difference? Alfalfa has much higher protein concentration than corn, and what really regulates nitrogen harvested from a field is the yield of protein, not simply dry matter. Although we do not know how much N was taken up by the N-fixing alfalfas, they reduced soil solution nitrate concentrations to the same low, stable levels as the non-fixing alfalfa.

This ability of alfalfa to strip nitrate from soil solution may provide a way to clean up nitrogen-laden water as soil solution moves through the root zone. A few years ago, Dr. Todd Peterson tried the idea of phytofiltration with alfalfa on a sandy soil in Nebraska (personal communication). He irrigated the crop with water containing about 30 ppm nitrate-N, but measured only 2 ppm nitrate-N escaping the root zone. Vocasek and Zupancic (1995) reported that soil nitrate concentrations typically declined under alfalfa even with high rates (270-400 lb ammonium-N/acre annually) of treated effluent from a beef processing facility in Texas. The harvested alfalfa in their experiment contained about 350 lb N/acre. What proportion of this nitrogen was uptake of effluent and soil nitrate? These authors could not tell for sure, but our work (Lamb et al., 1995) with isotopically-labeled fertilizer showed that alfalfa continued to fix about 20% of its nitrogen from the air, even at very high fertilizer nitrogen rates.

These and other findings confirm that alfalfa actively removes nitrate from the soil. How much nitrogen is it capable of removing? When calculating nitrogen budgets for manure and wastewater applications, it probably is important to account for nitrogen the crop continues to fix. For example, if a farmer expects an 8-ton hay yield with 20% protein, this is equivalent to about 460 lb N/acre harvested. If we assume that this hay contains 20% nitrogen from the fixation, then the 'removal capacity' of the crop for nitrogen from manure, wastewater, and soil is about 370 lb N/acre.

Although it is not easy to measure nitrogen fixation rates on your farm, you can tell whether alfalfa root nodules are active or not under your conditions by digging plants in several areas of the field and looking for the telltale pink color in the nodules. This color indicates that a compound like hemoglobin, which gives our blood its red color, is active in the nodule. Plants with pink nodules are getting at least some of their nitrogen from the atmosphere. On the other hand, if the nodules are all greenish or gray, or are soft or watery, then those plants are most likely depending entirely on soil nitrogen for growth.

Dairy manure pond water is used to provide both water and nutrients to alfalfa. Because nearly all the inorganic nitrogen is in ammonium form, it will not move very rapidly through the soil. However, under warm soil conditions (above 50 F), conversion of ammonium to nitrate by soil microorganisms is rapid, and most ammonium will be converted to nitrate within a few weeks. If nitrate supply exceeds alfalfa nitrogen demand, then most of it stays in solution. Water leaching through the soil will carry nitrate with it.

Although nitrogen demand by alfalfa is large, it varies with time. Generally speaking, the faster a crop is growing, the higher the nitrogen demand. Low nitrogen demand by alfalfa occurs during the week or two following harvest and during dormant periods. Avoid water leaching during these periods.

There are large differences in nitrate uptake capacity among alfalfa plants. Research at the University of California and by the USDA-ARS group at St. Paul, MN, has clearly shown that alfalfa can be selected for high or low nitrate uptake. Unfortunately, plant selections made in both cases were done under controlled environment conditions, and they failed to perform differently in the field. Working with a student and a postdoctoral assistant, Dr. JoAnn Lamb and I have now developed a technique that can be used to select alfalfa under field conditions for higher or lower nitrate uptake. She has begun plant selection and we expect to produce the first new alfalfa types within a couple of years. Improving alfalfa's ability to remove excess nitrate should allow higher manure application rates, while also improving alfalfa competitiveness with grasses and other weeds in non-fertilized fields.

Rooting depth

Another advantage of alfalfa is that it can be very deeply rooted, penetrating 4 to 6 feet per year in deep soils. Deeply rooted species increase the probability that mobile nutrients, like nitrate, will be absorbed before leaving the root zone with percolating water.

And alfalfa can be remarkably deep-rooted. There are anecdotal accounts of roots extending more than 100 feet through soil and fractured rock, but rooting depth depends on water supply, soil compaction, soil fertility, variety, and other factors. Over eighty years ago, Packard (1917) presented interesting results from the Imperial Valley that are valid today. With infrequent, heavy irrigation on a sandy loam soil, alfalfa roots were plentiful in the upper 6 feet of soil and penetrated to the water table at 15 feet. Under more typical conditions, roots are most abundant in the upper 2 feet of soil.

On average, alfalfa taproots elongate at about one-half inch per day, with a wide range among individual plants (Jodari-Karimi et al., 1983; Meyers et al., 1996). Deep roots are able to absorb water and nutrients quite effectively, if conditions are right (Lipps and Fox, 1964; Mathers et al., 1975). In contrast, little water and nutrient absorption occur from deep roots if the topsoil is kept moist. Thus, the most effective removal of nitrate will be with light, frequent irrigation that restricts water infiltration to the upper part of the soil, or with heavier, infrequent irrigation, so that deeper roots are called into action as the topsoil dries.

In some situations, such as areas where rainfall or irrigation are inadequate, having very deep roots is beneficial. In other situations, such as regions with high water tables, shallow root systems are more efficient, and may be the only way alfalfa can survive. Dr. Lamb and I are working to develop alfalfas that have either fast or slow root growth. She and her colleagues