

NUTRIENT MANAGEMENT IN ALFALFA-CORN SILAGE ROTATIONS

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There are increasing questions about the sustainability of annual row crop systems, in particular the soybean-corn rotation. These questions arise primarily from increased soil erosion and nutrient runoff during and after the soybean phase and nitrate leaching during both phases (Randall, 2003).

The American public is increasingly concerned about how farming affects the environment. According to a Gallup Organization poll in 2001, over 80% are concerned about water and air pollution and the loss of wildlife habitat. A poll in 1999 by the Pew Research Center for the People and the Press showed that over 80% of the American public agreed with the statement: 'There need to be stricter laws and regulations to protect the environment.' Nearly 90% of Midwest respondents in a survey conducted by American Farmland Trust in 2001 said they would favor additional incentives for farms that put management practices in place to protect water quality, enhance wildlife habitat and protect ground water recharge systems. The Conservation Security Program in the current Farm Bill is evidence of this public willingness to help farmers achieve these goals.

Growing perennial forages, like alfalfa, especially in strategically selected places on the landscape, can go a long way toward satisfying the public's demand for responsible farming, and in keeping dairy farmers in business. This paper will concentrate on the benefits of including alfalfa in the rotation, but will touch on aspects of nutrient cycling with corn silage.

Whole-farm P and N balances

Whole-farm nutrient balances are problematic for many dairy farmers. Many import more P than they export in milk or culled animals (Anderson and Magdoff, 2000). The largest inputs are in purchased feed and minerals, and the second most important source is fertilizer. Between 40 and 80% of P imports are retained on the farm (Klausner, 1993). The typical result of this imbalance is increasing soil test P levels on fields that receive more manure P than is removed in crop harvest. There are currently no counties in Wisconsin where the average soil test P level is not below 30 ppm (1995-99), whereas 24 counties were below 30 ppm in 1974-77 (Combs and Peters, 2000). High soil test P is a critical factor that determines whether runoff water will threaten surface water quality. Soil test P levels consequently are a component of nutrient management plans and the P risk index. Unlike the situation with N and K, crop P removal does not increase at very high soil test P levels (Russelle et al., 2001b), which means that draw-down of many high-testing soils will require many years, if not decades, without P additions in fertilizer or manure (Randall et al., 1997). Reducing dietary P and appropriate use of manure to supply crop P are two feasible alternatives to address this problem (Ebeling et al., 2002).

Dairy farms also tend to import too much N, but because of N loss by volatilization, leaching, runoff, and denitrification, we do not see an N build-up in the soil. Incorporating more

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alfalfa in your crop rotation may help you solve the excess N problem on your farm. When effective soil bacteria, called rhizobia, are present in root nodules, alfalfa can obtain most of its N from the atmosphere by symbiotic fixation. This means that part of the N in alfalfa is actually newly 'imported' N on the farm – beneficial for those who need 'free' N, but less welcome on farms rich in N. Fortunately, alfalfa and other legumes also absorb inorganic N from the soil, and reduce symbiotic fixation by an equal amount. For example, on an abandoned barnyard site in central Wisconsin, we found that first cut alfalfa fixed nearly all its N from the atmosphere where soil and manure N uptake was only 10 lb/acre, but fixed little N from the air where inorganic N uptake was 130 lb/acre (Russelle et al., 2002, unpublished data).

Alfalfa's high protein yield per acre makes it a valuable crop for removing excess N. Most N absorbed by plants is converted to protein. We used alfalfa at the site of a derailment in North Dakota to remove excess nitrate from the soil and ground water (Russelle et al., 2001a). The contaminated ground water was irrigated on the alfalfa and annual crops of corn and wheat. Total N removal in alfalfa was 870 lb/acre over the 3 years, whereas the annual crops removed only 330 lb/acre. In the last year of the cleanup, corn silage produced the same dry matter yield as alfalfa, but removed only one-half as much N, because of corn's lower protein content.

Estimated nutrient removal by harvested crops can be used to calculate the amount of nutrients that may be replaced by fertilizer or manure. A typical corn silage crop will remove about 10 to 15 lb N, 2 to 4 lb P, and 10 to 15 lb K per dry ton. Alfalfa will contain 50 to 60 lb N and remove about 4 to 7 lb P and 25 to 60 lb K/dry ton. Plants often will accumulate N and K in luxury amounts when soil levels are high. The concept of N removal by alfalfa is complicated because part of its N is newly fixed from the atmosphere.

According to the National Agricultural Statistics Service census for 1997, yields in Illinois, Iowa, Minnesota, and Wisconsin averaged about 15 tons/acre for corn silage and about 3.5 tons/acre for alfalfa hay (plus estimated haylage). These represent dry matter yields of about 9.7 and 3.0 tons/acre, respectively. In other work, we have estimated average crude protein concentration in alfalfa to be 17.5%, based on reports from forage testing laboratories (Russelle and Birr, 2002, unpublished data). Thus, corn silage removed an average of 120 lb N, 29 lb P, and 120 lb K/acre, whereas alfalfa contained about 170 lb N/acre and removed 16 lb P and 130 lb K/acre. Clearly, these figures should not be used indiscriminately to estimate removals on individual farms, but they indicate the likely magnitude of nutrient removals.

Manure applications

Corn grown for silage provides at least two windows of opportunity for manure application, preplant and after harvest. There is an increased risk of N loss after corn silage harvest, because of the relatively long time during which N mineralization and nitrification can occur in autumn. Cover cropping is a possible and occasionally effective way to reduce N leaching losses after corn silage, but seeding needs to occur immediately after silage harvest to allow sufficient nutrient demand to build up in the cover crop (Stute, 2000). On soils that have optimum soil test P levels, manure applications should be limited to P removal. For an average dairy manure slurry that contains 18 lb P₂O₅/1000 gal, only 3600 gal/acre should be spread per year for corn silage that will yield 15 tons/acre. Solid dairy manure could be spread at the rate of 16 tons/acre, assuming it contains 4 lb P₂O₅/ton. If the manure is incorporated, the farmer should give credit for the available N, and reduce the fertilizer N application accordingly. Several states

recommend that second-year N credits be given for manure, because there is good evidence for continued N release from organic compounds in manure over time (Cusick et al., 2002).

Alfalfa may benefit from preplant manure, even when soil test levels of P and K appear to be adequate (Schmitt et al., 1993), perhaps due to N and micronutrients in the manure or to soil conditioning factors. Alfalfa stands may suffer, however, when application equipment causes soil compaction. Preplant manure rates should be limited to the P or K needs of the crop for establishment and 2 to 3 years of production, except on sandy soils where these manure rates could result in large nitrate leaching losses. For unmixed manure lagoons, application rates should be reduced to prevent excessive N applications, because lagoon water contains low P and K concentrations. Soil testing is the only way a producer can know how much P or K to apply to alleviate deficiencies. In cases of optimum (not excessive) soil test levels, applying rates equal to actual removal should prevent or slow the accumulation of P and K in the soil.

Preplant manure should be mixed well into the soil to avoid seed contact with manure. Germinating seeds are often killed by the high salt concentrations in manure. Lodging of companion crops is a common problem on manured soils; therefore, preplant manure is best used for sole-seeded alfalfa.

Topdressing manure on established alfalfa works well for many farmers, but this practice can reduce stands because of crown damage in wheel tracks, smothering, salt damage, increased competition from grasses, and introduction of weed seeds. Best results occur when manure is applied within a few days of mowing (Lory et al., 2000; Wiederholt et al., 2002).

Farmers have mixed opinions about applying manure to alfalfa. About one-half of Indiana farmers reported yield improvements and the other half reported stand damage after topdressing manure on alfalfa (Joern and Volenec, 1996). Minnesota dairy farmers reported several reasons they topdressed manure on established alfalfa and other perennial forages, but also listed a number of reasons for not doing this (Russelle, 1999). The most frequently given reasons for not topdressing alfalfa with manure include lack of time, lack of uniformity in spreading, increased weed problems, and manure is used on other crops.

Providing that traffic does not compact the soil and that alfalfa regrowth is limited, several researchers have concluded that low rates of manure applied to established alfalfa either do not damage the stand or increase yield (Daliparthi et al., 1994; Barnhart, 2000; Fuchs, 2002). Higher rates and spreading slurry on growing forage may cause leaf dessication ('burn') by high salt or ammonia concentration, or reduce plant survival by smothering (Wiederholt et al., 2002). Private and public plant breeders are developing alfalfa for greater tolerance to these stresses, since a selection and evaluation methodology has been developed (Lamb and Russelle, 2002, unpublished data). Solid manures must be well pulverized to avoid smothering.

If soil test levels of K are low, the high ammonium content of manure may reduce K uptake further, resulting in decreased alfalfa persistence over winter (Joern and Volenec, 1996). Alfalfa requires at least as much K for optimum winterhardiness as it does for optimum yield. We found that moderately winterhardy alfalfas that are stressed by frequent harvests required more K for winterhardiness than for yield (Sheaffer et al., 1986). However, dairy farmers must be cognizant about dry cow health problems associated with excessive K in the ration (Howard, 1995).

Manure typically has been broadcast on established alfalfa stands, but options exist that may improve manure nutrient use and reduce adverse effects on the stand when used under the right conditions. On low fertility soils, shallow injection of slurry into alfalfa improved yields,

even though some stand damage occurred from the single disk openers or an aerator/tillage tool (Anonymous, 2001; Fuchs, 2002). On high fertility soils, yield was decreased at low manure rates (3,000 gal/acre), but not at higher rates.

Topdressed manure slurry on alfalfa may reduce the numbers of beneficial lactic acid bacteria on the forage. When slurry was applied to alfalfa vegetation in a Wisconsin study, silage fermentation declined (Wiederholt et al., 2002), and these researchers suggested farmers use silage inoculants on alfalfa that has received topdressed manure. There are conflicting reports of palatability problems for manured alfalfa hay and silage.

There are additional concerns that topdressing manure on forage crops may promote transmission of diseases, such as *Johnes* and *Listeria* (Pell, 1997; Stabel, 1998). There is some disagreement about whether hay or silage that are contaminated with infested manure actually transmit the disease, however (M.T. Collins, personal communication, 2/10/2003), and more research is needed on this topic.

The WORST time to apply manure to alfalfa can be just before terminating the stand. Although this is convenient in terms of soil trafficability and logistics, doing so will increase the risk of nitrate leaching losses during the following 18 months if a fair to good stand of alfalfa is being terminated. Corn demand for N is low during spring, so N mineralized from manure, alfalfa residue, and soil organic matter is likely to leach into the soil. Deep nitrate, even within the corn root zone, is not used as efficiently as nitrate in the topsoil. Furthermore, the first corn crop after alfalfa usually does not need extra N. Off-site impacts occur if this nitrate leaches to ground water or drains to surface water.

Protection of water quality

Many of the perennial forages grown in the Upper Midwest have deep root systems. Alfalfa's roots grow about 4 to 6 feet deeper each year the stand persists, if soil conditions allow. Deep root systems help prevent nitrate leaching, because the crop has more time to absorb nitrate from the soil solution before it escapes the root zone. Nitrate removal from the subsoil at depths below those of many annual crops helps prevent N loss from the farm (Blumenthal and Russelle, 1996). At the same time, when alfalfa absorbs this nitrate, it fixes less N from the atmosphere.

Nitrate leaching occurs mainly in spring in the four-state region of Illinois, Iowa, Minnesota, and Wisconsin. Crop water use in late fall and early spring helps dry the soil, thereby slowing the movement and loss of nitrate. Water use is closely related to crop biomass yield. Cool-season perennial forages like alfalfa produce 1.5 to 2.5 tons of dry matter by the time corn begins rapid growth in early June, and alfalfa uses several inches of water during this time. In addition to active uptake of soil nitrate, this helps reduce nitrate flow through the soil.

Over the past few years, there have been numerous reports on the 'Dead Zone' in the Gulf of Mexico. This area of water has been as large as 7000 mi² and contains extremely low oxygen levels and has shifted the shrimp fisheries of Louisiana to Texas (Turner and Rabalais, 1994). The size of the 'Dead Zone' depends, in part, on how much nutrient load the Mississippi River delivers to the Gulf. Much of the nitrate in the Mississippi River apparently comes from agricultural fields on tile-drained soils in the North Central Region (Antweiler et al., 1996). Research in several states has shown that nitrate losses in tile drainage effluent under corn and soybean are very high – often in the range of 20 to 80 lb N/acre annually. This nitrate is delivered to ditches, which eventually drain into the river system. Denitrification, the conversion of nitrate to N gases, occurs along the way, but significant loading of the Mississippi still occurs.

How does alfalfa help protect the Gulf of Mexico? It is very clear that perennial forages like alfalfa reduce nitrate losses to very low values in tile-drained land. Research in several locations has shown that nitrate losses are lower under alfalfa and other perennial forages than under corn or soybeans, and that this benefit continues for a year or more following rotation to corn (Kanwar et al., 1995; Randall et al., 1997; Watts et al., 1997).

Reduced fertilizer needs for corn after alfalfa

Alfalfa provides a considerable amount of N to the next season's crop, and the fertilizer replacement value ranges between 0 and 190 lb N/acre, depending on the density of the alfalfa stand at termination (Table 1). Definitions of a 'good' alfalfa stand vary from more than 3 to more than 5 plants/ft² among some states. Wisconsin is the only one of these states to include the amount of alfalfa regrowth in the estimation of fertilizer N credit. This approach is well supported by the literature. For example, we found that N uptake and yield of corn increased with the amount of topgrowth incorporated in the soil (Sheaffer et al., 1991).

Table 1. First-year fertilizer N credit given for alfalfa when rotating to corn on medium- to fine-textured soils.

State	Regrowth	Alfalfa stand at termination		
		Good	Fair	Poor
		----- lb N/acre -----		
Illinois		100	50	0
Iowa		----- 150-180 -----		
Minnesota		150	75	40
Missouri		120-140	40-60	0-20
Nebraska		150	120	90
South Dakota		150	50-100	0
Tri-state (MI, IN, OH)		140	100	40
Wisconsin	Less than 8"	150	120	90
	More than 8"	190	160	130

Note the range in fertilizer N credits for a poor stand of alfalfa, which vary from 0 to 150 lb N/acre. Plant-available N is released from soil organic matter when sod crops are tilled. Why would some states suggest full fertilizer N rates to corn following poor alfalfa stands? Although it is reasonable to reduce the fertilizer N credit for poor stands of alfalfa, the majority of experiments have shown that even poor stands provide measurable N for the subsequent crop. Some states recommend that farmers accept a second year N credit from alfalfa. These credits range up to 75 lb N/acre.

Generally speaking, the fertilizer N credit for a good stand of alfalfa equals the recommended N rate on corn following corn, which means that ***farmers should not apply fertilizer N to corn following a good stand of alfalfa***. Unfortunately, many farmers and crop consultants do not accept this potential economic benefit of growing perennial legumes. Surveys show that farmers do not account for that fertilizer N credit, and usually apply the same amount of N to corn after alfalfa as to corn after soybean (Padgitt, 1995; Russelle, 1997). This will rarely

improve corn yield, but will almost always result in excessive N supply to the corn, with the increased risk of leaching (Lory et al., 1995). However, if best management practices are followed in the rotation, the beneficial effect of the legume of reducing nitrate loss may continue for a year after stand termination (Huggins et al., 2001).

Use of the presidedress N test (PSNT) is recommended in many states as a means to verify N supply for corn. Soil samples from the upper 1 to 2 feet of soil (depending on the state) taken when corn is 6 to 12 inches tall are analyzed for nitrate-N. The test can be misleading if N fertilizer has been applied to the field, but has not been converted to nitrate (e.g., an ammonium-based fertilizer applied with a nitrification inhibitor before planting the current crop). The PSNT is most cost-effective for fields that have been manured or rotated from a legume forage crop.

Concluding remarks

Increasing attention to controlling agricultural sources of environmental contaminants makes it imperative that farmers stay informed of regulations and that they comply with these regulations. Nitrogen management was the biggest issue farmers faced for several years, and now P management is in the spotlight. It appears that air quality is next on the horizon. Whole farm nutrient plans, TMDLs, P risk indexes – all will affect how, and whether, you will do business. By increasing alfalfa acreage, and by managing it and your annual crops better, you will help reduce the need for increased regulation.

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