USING DAIRY MANURE AS A NITROGEN FERTILIZER FOR FORAGE CROPS

Marsha Campbell Mathews[1]
David Crohn[2]

ABSTRACT

Recent regulations in the Central Valley of California limit the application of all forms of nitrogen to 140% of crop nutrient removal on cropland associated with dairies. This is a difficult target to attain because so much of the nitrogen is in the organic form and must be mineralized prior to crop use. Successful management strategies require an understanding of nitrogen chemistry in the soil, crop uptake patterns and rates of mineralization of organic forms of nitrogen. Nitrogen budgets must be developed only after assessing the potential to leach nitrate from the soil during irrigations. This determines whether nitrogen can be applied in fewer, larger applications or if it is necessary to apply multiple smaller doses in the water. This in turn, determines the type of infrastructure that a dairy must install in order to achieve these application rates.

Key Words: manure, nitrogen, lagoon, dairy, nitrogen budget, nutrient management

INTRODUCTION

Recent regulations in the Central Valley of California limit the application of all forms of nitrogen to 140% of crop nitrogen removal on cropland associated with dairies. This is a difficult target to attain because much of the nitrogen is in the organic form and must be mineralized prior to crop use. Careful management is necessary to effectively utilize these nutrients. Misused, these nutrients can kill or damage crops, contaminate ground and surface waters, and result in forage that is toxic to animals consuming it. It is critical to understand the forms and concentrations of nutrients, how these forms behave in the soil, and to have the ability to apply the appropriate amount of nutrients so that the crop will best be able to utilize them.

FORMS OF NITROGEN IN MANURE AND SOIL

Liquid manure contains two main forms of nitrogen, ammonium and organic. The ammonium form behaves in generally the same way as other ammonium-containing fertilizers. The ammonium form of nitrogen is positively charged and adheres to soil particles, which are mostly negatively charged. When liquid manure is first applied, most of the nitrogen remains in the upper foot of the soil because the ammonium nitrogen adheres to the soil.

As long as the ammonium nitrogen is in the ammonium form, it is resistant to leaching. Ammonium form nitrogen applied on warm soils in summer or early fall will convert to nitrate within days of application through a microbial process called nitrification. Nitrate form nitrogen

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[1] UCCE Farm Advisor, Stanislaus County, 3800 Cornucopia Way, Suite A, Modesto, CA 95358; Email: mcmathews@ucdavis.edu. [1] UCCE Biological Systems Engineer, Environmental Sciences Dept, UCR Riverside, CA 92501 crohn@ucrac1.ucr.edu , **In**: Proceedings, California Alfalfa and Forage Symposium, 4-5 December, 2008, San Diego, CA, UC Cooperative Extension, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu).

is negatively charged and can leach readily, especially during irrigation or heavy winter rainfall. Therefore, when liquid manure is initially applied, nearly all the nitrogen stays in the upper foot or so of the soil. It is not until the next leaching event after the nitrogen has converted to nitrate and is subject to losses from leaching and denitrification.

Well over half of the nitrogen excreted by cows, however, is in the organic form. This nitrogen is bound up in particles and must be broken down by microorganisms in a process called mineralization before it becomes available to the crop in the form of ammonium or nitrate, referred to as crop available nitrogen. The rate of breakdown depends on many factors, including soil moisture content, soil temperature and the resistance of the material to decay. The presence of organic nitrogen complicates the use of liquid and solid manure on crops because if a crop does not take up this nitrogen as it is released, it may become a source of groundwater contamination under leaching conditions. In determining rates of nitrogen application, the release of available nitrogen from current and past applications of liquid and dry manure needs to be taken into account and applications of available form nitrogen reduced accordingly.

The organic form nitrogen in liquid manure also remains in the upper foot of soil because the size of the particles usually prevent movement through the soil. If the liquid manure has high solids, the largest particles may remain on the soil surface as a crust until incorporated by tillage.

LEACHING RISK AS A BASIS FOR NITROGEN BUDGETING

The timing of applications and forms of manure nitrogen that can be beneficially applied is largely determined by the potential for nitrogen to be leached from or denitrified by the soil. The potential to leach nitrogen is mostly a function of how much water moves through the soil. Nitrate moves though the soil with the water. In light soils, there are relatively few binding sites to hold nitrate during periods of water movement. In heavy soils, rapid movement of nitrate can occur when water moves though cracks or old root channels. Large amounts of nitrate can and do move past the root zone even in heavy soils.

The amount of leaching that will occur is determined by how much water is applied in relation to how much water can be retained by the soil. In a typical surface irrigation system (flood or furrow), application rates are often determined by the amount of water necessary to move water from one end of the field to the other rather than how much is needed to refill the soil profile. Applying less water in a given irrigation is not usually a practical option, although all efforts should be made to do this if possible. Pre and first irrigations are usually the most inefficient. Since these irrigations occur during the period when there is the least amount of crop uptake, and often follow long periods of time where mineralization has been occurring in the absence of a crop, there is potential to leach nitrate if large amounts are present in the soil at this time.

If leaching conditions do not exist because irrigation water application rates are appropriate and rainfall rates are not excessive, it is feasible to apply nitrogen well in advance of crop utilization. If leaching conditions do exist and cannot be remedied, careful management will be necessary to minimize the movement of nitrate to groundwater. Application rates of available nitrogen should not exceed the amount of uptake expected between the time of application and the next anticipated heavy rainfall or irrigation that exceeds the amount needed to refill the soil profile.

In addition, the amount of nitrogen mineralizing from organic form nitrogen during that period also needs to be considered and subtracted from the amount applied.

NITROGEN APPLICATION RATES AND TIMINGS FOR CORN

Under conditions where most or all irrigations have the potential to leach nitrate, movement of nitrate to the groundwater can be minimized if large quantities of nitrate are not present in the soil during irrigation events where deep percolation is occurring. This is accomplished by splitting the application of available nitrogen into several smaller applications that are timed to coincide with crop need. In this synchronized-rate nutrient application system, typically about 50 pounds nitrogen per acre, but no more than 65 pounds nitrogen per acre, is applied in each of five to six corn irrigations. The irrigations in which the nitrogen is applied are selected to coincide with periods of peak nitrogen uptake by the corn crop. If dairy liquid manure is used, this equates to a dilution with fresh water that varies but is commonly around ten to one (fresh water to nutrient water). At these dilutions, crop growth inhibition from excess salts would not be expected to occur unless the dilution water itself was of poor quality. Also, because the concentration of ammonium in the irrigation water is relatively low at these application rates, volatilization of ammonia to the atmosphere during irrigation is expected to be minimal. Lower amounts of nitrogen, around 30 pounds of available nitrogen per acre, may be necessary if the water is to be applied to very young corn (less than 15 inches high) in order to avoid ammonia toxicity to the leaves and/or to avoid salt damage.

Table 1. Nitrogen Uptake by Corn Grown for Silage (above ground only, 8.5% protein at harvest)

				25 tons/acre		30 tons/acre		35 tons/acre		40 tons/acre	
stage	GDU		% total N uptake per period	lbs N/acre used each stage	lbs N/acre before and after tasselling	lbs N/acre used each stage	lbs N/acre before and after tasselling	lbs N/acre used each stage	lbs N/acre before and after tasselling	lbs N/acre used each stage	lbs N/acre before and after tasselling
V4	305	4 leaves fully emerged	3%	7		9		10		12	
V8	422	8 leaves fully emerged	5%	11		14		16		18	
V12	571	12 leaves fully emerged	14%	30		36		43		49	
VT	753	tassel fully emerged	40%	85	134	102	161	119	187	136	214
R1	909	silks emerging	-5%	-10		-12		-14		-16	
R2	1140	blister stage	5%	11		13		15		17	
R5	1490	early dent	32%	69		83		96		110	
R6	1598	physiological maturity	0.2%	0.5	80	1	96	1	112	1	128
		total	100%	213		256		299		341	

Yields are in tons/acre corrected to 70% moisture

Adapted from Karlen, et.al., Rutgers, N.J. 1985 by M. Campbell Mathews

Table 1. gives approximate amounts of nitrogen taken up by a well-fertilized corn crop. As a cereal plant goes from a vegetative to a reproductive phase of its life cycle, nitrogen stored in leaves and stalks may be remobilized for use in the rapidly growing reproductive parts of the

crop. There may be nitrogen losses to the atmosphere during this process. Also, nitrogen is lost from pollen being shed during pollination. This accounts for the negative values in this chart during tasselling. However, there is evidence that the crop does not actually stop taking up nitrogen during this time, but rather the crop's losses exceed the rate of uptake. In general, for silage corn, roughly 2/3 of the nitrogen is taken up before tasselling, and 1/3 during grain fill.

On soils that are not prone to leaching once cultivation has ceased, a large single application of liquid manure nitrogen in the second or third irrigation that provides over half of the total available nitrogen needed for the crop has given reasonable yields at acceptable application to uptake ratios. This can be an advantageous strategy in situations where it can be difficult to apply small amounts of liquid manure through existing infrastructure. These situations also make it easier to utilize more dry manure in the nitrogen budget, as the mineralizing nitrogen can be "banked" in the soil for later use during portions of the year.

NITROGEN APPLICATION RATES AND TIMINGS FOR WINTER CEREAL FORAGES

Winter forages planted during November in the Central Valley will typically take up less than 50 pounds of nitrogen per acre in the aerial portion of the crop prior to mid-January. Uptake will be higher under conditions of increased growth, such as earlier planting or sustained unseasonably warm temperatures. A light pre-plant irrigation with liquid manure in early fall may supply the crop with enough available nitrogen to carry the crop until mid January, but may not be adequate to meet the demands of spring-growth, especially in years with heavy winter rains which may leach or denitrify the nitrogen. The bulk of lagoon nutrients should be applied in late January to early February, with only light applications in the fall pre-plant irrigation. If the field has an application history that includes dry manure or lagoon water containing significant organic form nitrogen, in many cases mineralizing organic nitrogen will supply all the nitrogen the crop needs until the early spring. Exact timing and amounts will vary according to the season, the planting and harvest dates, maturity type and total expected nitrogen removal.

Winter small grain forages will take up nitrogen differently depending on their growth pattern. Early maturing types will make more growth in the warm fall months, grow more during the winter, flower and begin to fill grain early in the spring. Their daily nitrogen uptake peaks then declines as the grain matures. Medium maturing cultivars make moderate growth during the fall and winter, then the uptake levels off during flowering, when they are often harvested. Under normal circumstances, both early and medium maturing winter forages begin to take up more significant amounts of nitrogen starting in late January to early February. The rate of nitrogen uptake peaks in March and April but uptake continues until harvest. Late maturing varieties make little growth during the fall and winter, then grow rapidly during mid and late spring. These varieties are typically harvested in the vegetative stage and uptake rate does not level off prior to being cut.

Nitrogen applications should be timed to provide available nitrogen during, or immediately prior to, the period that the crop will utilize them. No more than about 120 lbs available nitrogen should be applied at any one time. If more than this is needed, a second spring application may be necessary.

Cold soil temperatures may prevent organic form nitrogen from fall applied dry manure from mineralizing fast enough to supply the needs of winter cereals during the February to early March growing period. It may be possible to apply a higher nitrogen rate on the winter crop if nutrients are applied in the late winter-early spring, just prior to the period of rapid uptake for the crop. A higher rate can be applied during this period than in the summer because the conversion of ammonium (which sticks to the soil) to nitrate (which leaches readily) occurs more slowly in cold soils than in warm ones. More importantly, the potential for rapid leaching is lower in the spring than during the summer irrigation season because it is unlikely that the amount of water going onto the field during a spring rainfall event in the Central Valley would exceed the amount of water applied in a single typical summer irrigation.

These factors, combined with the rapid uptake that typically occurs in the spring, provide some assurance that a single application of between 100 and 150 pounds of nitrogen per acre, depending on expected crop uptake, can be applied with minimal negative impact on groundwater just prior to jointing of the winter cereal crop. If more nitrogen is needed, it should be split into two spring applications. In planning to apply nutrients in a winter irrigation, it is assumed that the irrigation can be done without water leaving the field or without damage to the crop by waterlogging. Lighter textured soils with good internal drainage are most conducive to winter applications. Heavier textured soils may require planting on raised beds to provide drainage. If a winter irrigation with liquid manure cannot be made, and nitrogen applied in the fall has been lost through leaching or denitrification, the crop will likely need commercial nitrogen to be applied during the winter. If commercial fertilizer is applied, then additional cropland and additional storage capacity will be needed to hold the lagoon nutrients until they can be applied in modest amounts to finish off the spring crop and supply the summer crop.

INFRASTRUCTURE CHANGES NEEDED TO ACCOMMODATE TARGETED NITROGEN APPLICATIONS

Liquid manure must be blended with fresh water in most cases. This can be done by installing a flow meter and throttling valve on the lagoon pump output and using this to mix the correct amount of lagoon water into the irrigation water. The amount of liquid manure to apply is calculated based on the flow rate of the water, the duration of the irrigation, and the nutrient concentration, and the throttling valve is adjusted to until the flow rate is displayed on the meter readout matches the flow rate calculated to provide the desired nitrogen application rate.

Pipelines must be correctly sized to insure that plugging from solids does not occur when reducing the flow rate of liquid manure. In addition to installing a flow meter system, it may be necessary to increase lagoon capacity, install additional pipeline, or make other modifications. Separators, settling basins, and other technology that minimizes solid buildup in the pond are also important components of the lagoon nutrient management system. Changes to the irrigation system itself may also be necessary because if the irrigation is not uniform, all parts of the field may not get the same amount of nutrients, resulting in excesses in some areas of the field (usually the head) and not enough in others.

These changes can represent significant capital outlays on a dairy and it is critical that an appropriate nitrogen budget, based on risk of nitrogen losses from leaching and/or denitrification, be determined prior to making infrastructure investments. Changes to one part of the manure handling system invariably affect all other components, so much thought needs to be put into how the system will ultimately function and into the order in which the system components should be installed over time.

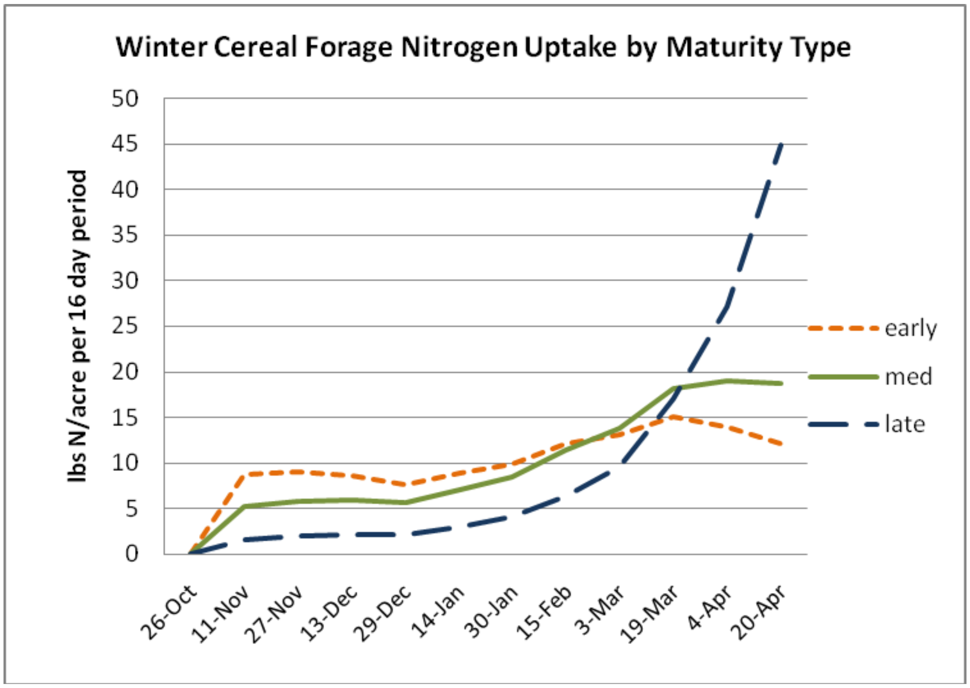

Figure 1. Nitrogen uptake by winter cereal forage in the Northern San Joaquin Valley by maturity type. Based on a planting date of October 26, a harvest date of April 20, and a total nitrogen uptake of 120 lbs nitrogen per acre. Weather data is a 15 year average from Denair, CA. The tables below provide the modeled nitrogen uptake rates based on the same parameters.

Above-ground Nitrogen Accumulation for Small Grain Forage
planted October 26   harvest April 20

Lbs/acre Nitrogen Uptake per 16 day Period

	early	med	late
26-Oct	0	0	0
11-Nov	9	5	2
27-Nov	9	6	2
13-Dec	9	6	2
29-Dec	8	6	2
14-Jan	9	7	3
30-Jan	10	9	4
15-Feb	12	12	6
3-Mar	13	14	10
19-Mar	15	18	17
4-Apr	14	19	27
20-Apr	12	19	45

Cumulative lbs/acre Nitrogen Uptake by Maturity Type

	early	med	late
26-Oct	0	0	0
11-Nov	9	5	2
27-Nov	18	11	4
13-Dec	26	17	6
29-Dec	34	23	8
14-Jan	43	30	11
30-Jan	53	38	15
15-Feb	65	50	21
3-Mar	78	64	31
19-Mar	93	82	48
4-Apr	107	101	75
20-Apr	119	120	120