MANAGEMENT OF NITROGEN AND MANURE IN CORN AND SMALL GRAIN FORAGES

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ABSTRACT

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 inject multiple smaller doses into the irrigation water. Since there are so many variables to consider when developing a nitrogen application strategy, a tool which simultaneously calculates these processes may be useful in projecting how well proposed nitrogen applications will meet crop demands while minimizing nitrogen loss to groundwater.

Key Words: manure, nitrogen, cereal forage, corn, fertilization, nitrogen budget, nutrient management

Introduction

Regulations in the Central Valley of California limit the application of all forms of nitrogen to essentially 140% of crop nutrient removal on cropland associated with dairies. This is a difficult target to attain because much of the nitrogen is in on organic form that must be mineralized prior to the crop being able to use it. Careful management is necessary to effectively utilize these nutrients. It is critical to understand the forms and concentrations of nutrients, how they 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. Management of these systems to protect both groundwater quality and yields is challenging, especially using surface irrigation due to the large amounts of data that much be tracked and complexity of the soil nitrogen systems.

Forms of Nitrogen in Manure and Soil

There are three major forms of nitrogen that are found in soils and fertilizers. Nitrate and ammonia are both readily available for crops to take up while organic forms that comprise manures and crop residues must first be broken down by microorganisms. 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.

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Ammonium form nitrogen does not stay in this form, however. If applied on warm soils in summer or early fall it will convert to nitrate within days of application through a microbial process called nitrification. Nitrate form nitrogen is negatively charged and can leach readily during irrigation or heavy winter rainfall because it does not adhere to soil particles which are mostly negatively charged. When liquid manure is initially applied, therefore, nearly all the nitrogen stays in the upper foot or so of the soil.   It is not until the next leaching event, after the ammonium is converted into nitrate, that the nitrogen subject to subject to losses from leaching and denitrification.

Well over half of the nitrogen excreted by cows, 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 up 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.

Like ammonium, the organic form nitrogen also remains mainly in the upper foot of soil because, depending on the porosity of the soil, the size of the particles hinders downward movement. 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 application strategies

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 depends 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 get 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 efforts should be made to do this if possible. Pre- and first irrigations are usually the most inefficient because the water travels slowly over loose soil. 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 of nitrate are present in the soil at this time.

Nitrogen uptake by corn

Nitrogen needs while the crop is small are modest. If large amounts of nitrate nitrogen are present in the soil during the first irrigation this period they may be subject to leaching losses and much of the nitrate that was there is lost. If a very early "rescue" irrigation is necessary on small corn, 10 – 30 lbs/A of nitrogen injected into that irrigation may prevent severe nitrogen deficiency if there is a possibility that much of the existing available soil nitrogen with be leached away from small roots.

Starting when the corn reaches about the 8 leaf stage (2 ½ to 3 feet) the nitrogen needs of the crop increase dramatically. A corn crop that will ultimately yield 30 tons will need up 6 to 10 lbs of nitrogen per day during the 10 day period from 12 leaves to tassel. This period accounts for about 40% of the nitrogen uptake for the entire season. A nitrogen fertilization plan needs to be designed to ensure that sufficient nitrogen is supplied during this time.

While the plant is tasseling and pollinating, nitrogen uptake essentially stops. Nitrogen uptake is a metabolically expensive process for the plant, and nitrogen is not taken up when it is not needed. Net loss of nitrogen has been measured during this period however, possibly from pollen shed or losses to the atmosphere from ineffiencies in the process of remobilization of nitrogen stored in leaves and stalks.

Nitrogen uptake resumes during grain fill. About a third of the nitrogen that is removed in the grain is from nitrogen remobilized from stalks and leaves, the remainder needs to be supplied from the soil during grain fill. In general, for silage corn, roughly 2/3 of the nitrogen is taken up before tasselling and 1/3 during grain fill.

Table 1. gives approximate amounts of nitrogen taken up by a well-fertilized corn crop.

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

Nitrogen application rates and timings for corn

In situations where leaching conditions are minimal 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. However, if leaching conditions do exist and cannot be remedied, careful management will be necessary to minimize the movement of nitrate to groundwater.

When 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 multiple split application system, typically about 50 pounds nitrogen per acre, but no more than 65 pounds ammonium form nitrogen per acre, is applied in each of five to six corn irrigations. The amount of nitrogen applied in each of these irrigations is selected to coincide with the nitrogen demands of the crop. Either commercial water-run ammonia-type or liquid dairy manure (lagoon water) can be injected into the irrigation water at the targeted rate. If lagoon water is used, this equates to a dilution with fresh water that varies greatly 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.   No more than 30 pounds of available nitrogen per acre should be applied in the water if the corn is very small (less than 15 inches high) in order to avoid ammonia toxicity to the leaves and/or to avoid salt damage.

On soils that are not prone to leaching except in the pre and first irrigations, a large single application of liquid manure nitrogen in the second or third irrigation providing over half of the 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 uptake by 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 will 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 typically are harvested in the vegetative stage and do not level off in their uptake prior to being cut.

Nitrogen application rates and timings for winter cereal forages

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 temperature 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 it 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, provides 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 into 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 nutrient water cannot be made, the crop will still likely need commercial nitrogen to be applied during the winter if nitrogen applied in the fall has been lost through leaching or denitrification. 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. Yields and nitrogen needs of winter cereals harvest in the soft dough stage are often much higher than when cut in the boot or flower stage. These rates will need to be adjusted accordingly, also additional nitrogen will be need to be provided during grain fill.

Special considerations for using manures as a fertilizer source

To use lagoon water appropriately, it is essential to know and be able to adjust the amount of lagoon nitrogen that is being applied. The amount of liquid manure to apply can be calculated based on the flow rate of the water, the duration of the irrigation, and the nutrient concentration.

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. The flow rate of the lagoon water is adjusted so that the correct amount of lagoon water is injected into the irrigation water. 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.

Dry manure, and the organic portion of liquid manure, are challenging to use in nitrogen budgets because the nitrogen is released over time through a microbial process called mineralization. Release rates are not well understood and can take years, especially for dry manure. It is easiest to use dry manure efficiently in either a cropping situation where leaching can be controlled, or where it comprises only a modest portion of the total amount of nitrogen applied. Since there are so many variables to consider when developing a nitrogen application strategy using dry manure and the organic portion of liquid manure, the UCCE N Ledger, and Excel-based program is being developed which will allow the user to visualize the outcomes of proposed manure applications. This program simultaneously calculates mineralization from multiple manure applications, projects leaching based on soil type and irrigation amounts, and compares the soil nitrogen each day to anticipated crop needs. This calculator should prove useful in projecting how well proposed nitrogen applications will meet crop demands while minimizing nitrogen loss to groundwater.

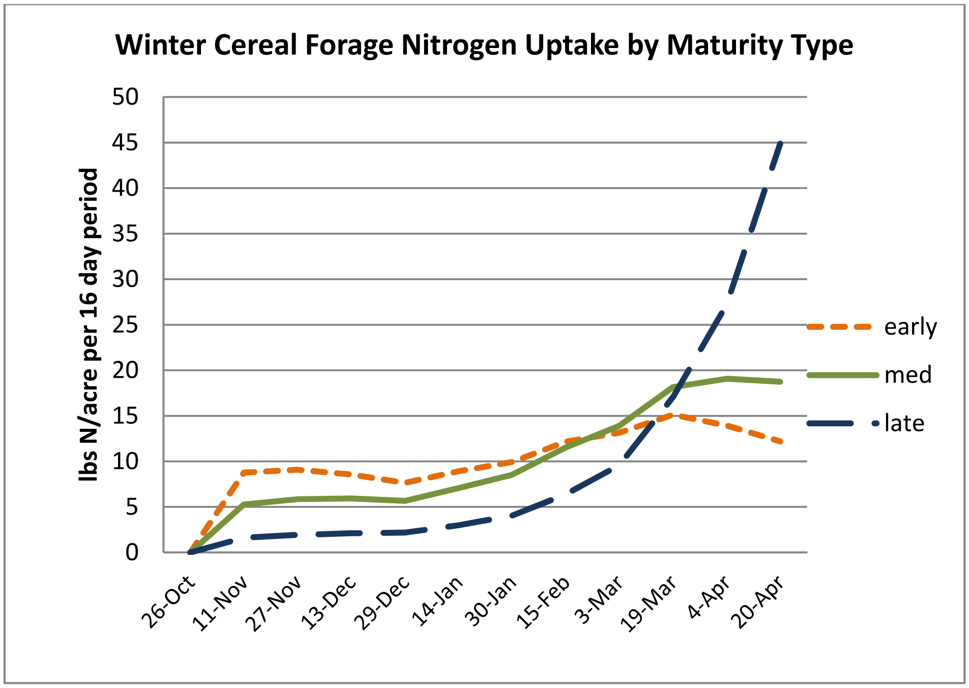

Figure 1. Nitrogen uptake by winter cereal forage in the Northern San Joaquin Valley by maturity type, harvested at late boot or flower stage prior to grain fill.
Based on a planting date of October 26, a harvest date of April 20, and a total nitrogen uptake of 120 lbs nitrogen per acre.

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