ASSESSING NITROGEN UPTAKE OF CORN, WINTER FORAGES AND ALFALFA

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ABSTRACT

Where leaching of nitrate into groundwater is a concern, fertilizer and manure nitrogen applications to silage corn, winter cereal forage and alfalfa must be carefully timed with a goal of having the minimum amount of nitrate present in the soil during leaching or denitrification events where significant nitrogen losses are expected. The main period of nitrogen use by corn is between about knee high and tasselling (2/3 of total N removal), followed by with another less intense period during grain fill (1/3 of final removal). Winter cereals take up nitrogen depending on how much winter growth they make and when the period of maximum uptake occurs, with some varieties taking up the bulk of their nitrogen much earlier than others. Alfalfa has a unique utility in nitrogen budgets because not only can it take up large amounts of nitrogen, if supplied nitrogen is inadequate, it will make its own, thus avoiding any loss in yield. Alfalfa nitrogen uptake is closely related to the amount of top growth.

Key Words: corn, winter forage, cereal forage, N uptake, fertilization, manure, nitrogen, lagoon, dairy, nitrogen budget, nutrient management

INTRODUCTION

Protection of groundwater quality in many locations within the Central Valley of California necessitates that the fertilizer or manure nitrogen applied to a crop exceeds the nitrogen removed by the crop by only a small amount. The current regulations for dairies require that no more than 140% of the nitrogen removed by the crop can be applied in the year 2012 and beyond. Up to 165% may be applied if tissue tests prove a deficiency during the season, but since yield losses will generally already have occurred by the time a deficiency is identified in this way, the 140% target is the practical goal. If nitrate nitrogen in the soil is subject to leaching or loss through denitrification, in order to meet this regulatory target it becomes imperative that the amount of nitrate in the soil be minimal during leaching or denitrification events. Precise timing of nitrogen applications to ensure that the crop needs are met requires a knowledge of when the crop is taking up the nitrogen. When using the information presented in this paper for this purpose, it is critical to consider how the data was developed. Most nitrogen uptake studies are conducted by clipping the above-ground growth of a crop multiple times during a season. The data therefore takes into account only the aerial portion of the crop. During the early part of the season, the developing root system will require additional available nitrogen. In many cases, this nitrogen will come from mineralizing organic nitrogen in crop residues, manure or the pool of organic

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matter in the soil. However, under certain circumstances, such as excessive leaching or very infertile soils, more nitrogen must be applied than is needed to only meet the above ground needs of the crop to ensure enough N for both root and top growth so that yields are not adversely impacted.

The first step in planning nitrogen applications is to assess how much nitrogen will be needed. This is generally considered to be proportional to the total amount of nitrogen removed by the crop. While table values are often used to determine this value when actual data is not available, these values can be inaccurate for specific situations because forage crops, especially winter cereals, are highly variable in both yield and nitrogen content. Actual field data should be used for projections if at all possible.

An easy way to calculate final nitrogen uptake of silage is to multiply tons per acre of 70% moisture silage by the percent protein, then multiply by a conversion factor of .96 to get pounds of nitrogen removed.

Example: A winter forage crop yields 15 tons per acre in mid April and has a protein content of 13%. 15 x 13 x .96 = 187 lbs N/acre removed.

In a situation where there is potential for leaching and subsequent groundwater contamination to occur, nitrogen applications must be timed so that the minimum amount of nitrate possible is present in the soil during times when the leaching events take place.   This requires a good understanding of when crops need the nitrogen. Non-leaching situations allow for much for flexibility in timing of applications and in the use of different kinds of fertilizer and manure materials.

NITROGEN APPLICATION RATES AND TIMINGS FOR SILAGE 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 scheduling applications so that nitrogen availability just meets a crop’s evolving needs. 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.

Approximate amounts of nitrogen taken up by a well-fertilized corn crop are given in table 1. As a grass–type 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 lack of uptake in this table during tasselling. However, it is possible 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.

Table 1. Nitrogen application rates and timings for corn

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

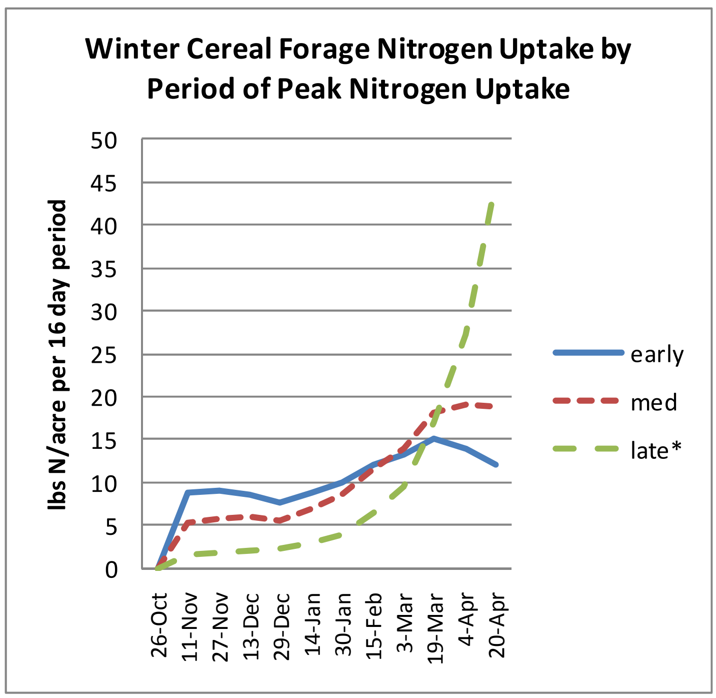
Adapted from Karlen, et.al., Rutgers, N.J. 1985 by M. Campbell Mathews

For 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. Note, however, that denitrification losses will be much greater when the internal drainage of the soils is slow. Denitrification losses, which occur following irrigation and heavy rains, are also usually higher in soils fertilized with organic fertilizers, such as manure, than they in conventionally fertilized soils. Banked nitrogen is therefore most secure in dry periods.

NITROGEN APPLICATION RATES AND TIMINGS FOR SMALL GRAIN FORAGE

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 uptake types, such as Swan oat, Cayuse oat, and Dirkwin wheat, 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 uptake cultivars, such as Ensiler oat, Longhorn wheat, and Trical T2700 triticale, make moderate growth during the fall and winter, then the uptake rate slows 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, such as Bartali Italian rye and Big Daddy annual rye, make less growth during the fall and winter, and then grow rapidly during mid and late spring. These varieties are typically harvested in the vegetative stage, prior to the time that the uptake rate would be expected to level off. Note that early, medium or late in this context is often, but not necessarily the same, as standard early, medium and late maturity designations.



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.

Nitrogen applications should be timed to provide available nitrogen during, or immediately prior to, the period that the crop will utilize them. In most situations, no more than about 120 lbs available nitrogen should be applied at any one time. If more than this is needed, the additional nitrogen should be applied in the spring, nearer to when the nitrogen will be utilized by the crop.

Cold soil temperatures may prevent organic form nitrogen in 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 relatively high rate of available nitrogen 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. This is because the potential for rapid leaching is lower in the early spring rainfall season than during the summer irrigation season, as 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.

Table 2. Modeled above-ground nitrogen accumulation for small grain forage, as percent of harvest removal per half month.
Planted Nov 1, harvest May 16, 200 lbs N/acre total removal
Hanford, CA 30 yr avg temperatures

	each period			cumulative		
	early	med	late*	early	med	late*
1-Nov	0%	0%	0%	0%	0%	0%
16-Nov	6%	4%	1%	6%	4%	1%
1-Dec	6%	4%	1%	12%	7%	2%
16-Dec	5%	3%	1%	17%	11%	3%
1-Jan	5%	3%	1%	22%	14%	4%
16-Jan	6%	4%	1%	28%	18%	5%
1-Feb	8%	6%	2%	35%	24%	7%
14-Feb	8%	7%	3%	44%	31%	10%
1-Mar	10%	9%	4%	54%	40%	15%
16-Mar	12%	13%	8%	66%	53%	22%
1-Apr	13%	15%	14%	78%	68%	36%
16-Apr	11%	16%	22%	90%	84%	58%
1-May	34%	16%	42%	100%	100%	100%

Table 3. Modeled above-ground nitrogen accumulation for small grain forage, as percent of harvest removal per half month.
Planted Nov 1, harvest April 16, 150 lbs N/acre total removal
Merced, CA 30 yr avg temperatures

	each period			cumulative		
	early	med	late*	early	med	late*
1-Nov	0%	0%	0%	0%	0%	0%
16-Nov	7%	4%	1%	7%	4%	1%
1-Dec	7%	4%	2%	14%	9%	3%
16-Dec	6%	4%	2%	20%	13%	5%
1-Jan	6%	5%	2%	26%	17%	7%
16-Jan	7%	5%	2%	33%	23%	9%
1-Feb	9%	8%	4%	42%	30%	13%
14-Feb	10%	9%	5%	52%	39%	18%
1-Mar	11%	11%	8%	63%	51%	26%
16-Mar	13%	15%	13%	75%	65%	39%
1-Apr	13%	17%	23%	89%	83%	62%
16-Apr	11%	17%	38%	100%	100%	100%

Tables 2 and 3 show the percent of nitrogen uptake (top growth) that occurs from a November 1st planting in Merced or Hanford. To use these tables, determine the expected total nitrogen removal expected when the crop is cut for silage. Multiply the total expected removal by the percentage uptake to date. For example, from a Nov 1 planting of a medium uptake pattern cereal forage in Merced with an expected removal of 120 lbs N/acre, the crop would taken up 30%, or 120 x .3 = 36 lbs of N/acre by the beginning of February.

NITROGEN APPLICATION RATES AND TIMINGS FOR ALFALFA

Alfalfa does not require additions of nitrogen because the crop maintains a symbiotic relationship with bacteria that "fix" nitrogen, meaning that they take nitrogen out of the air and turn it into a form that the crop can use. If nitrogen is already present in the soil, the crop will preferentially use the soil nitrogen instead of making its own, while maintaining the capacity to ramp up the nitrogen fixation process when the soil nitrogen runs out. This is advantageous when utilizing organic forms of nitrogen such as manure because, unlike non-legume forages, yields are maintained even if available soil nitrogen is inadequate. In a study comparing alfalfa that was genetically modified to not fix its own nitrogen with a similar variety that did, the alfalfa that fixed nitrogen overall removed the same amount or more nitrogen from a feedlot remediation site than the one that did not because of the stand loss that occurred during periods when soil nitrogen was less available.

Where soil conditions allow, alfalfa will root more deeply than cereal crop roots and can effectively retrieve nitrogen that has moved deeper into the soil. However, the fibrous root systems of corn and grains are better than alfalfa for capturing nitrate. If remediation of excess soil nitrate is a primary goal, consider companion cropping alfalfa with a cereal forage. Applying manure or lagoon nitrogen to alfalfa as part of a nutrient management plan helps the overall nitrogen balance of the dairy because not only is the crop using nitrogen, it is also not contributing additional nitrogen into the system from the atmosphere, as it would if manure were not applied.

The main concerns with additions of manure nitrogen on alfalfa are salt injury, solids smothering crowns, contamination of hay from solids, manure leaving the field in the runoff, and increased weeds from introduction of weed seeds contained the manure and from fertilization of the weeds with the nitrogen, and excessive potassium uptake by the crop which limits its use as a feed for pregnant cows. Each of these challenges can be avoided by proper application practices and stand management.

Even when applied nitrogen is high, 10 to 25% of the nitrogen removed by the alfalfa crop will be fixed by the plant itself. To minimize annual manure N leaching losses, manure application rates should not exceed the equivalent of 75-85% of N removed in harvest. Dry manure should be applied well ahead of planting and incorporated immediately and thoroughly. Large chunks of manure will interfere with alfalfa emergence. Topdressing alfalfa with dry manure is not recommended but if it must be done, it is imperative that the applications be made immediately after cutting before regrowth occurs, and that the manure is not in large chunks.

Applications of nitrogen by injecting targeted amounts of lagoon water nitrogen into the irrigation water offers more flexibility in rates and timings. Only lagoon water that is low in solids should be used for this purpose. If higher solids water must be used, irrigating the first half to three-quarters of each check or set with fresh water only before introducing the lagoon water will help to spread the solids more uniformly over the field.

Application rates of no more than 50 pounds of nitrogen per ton each cutting will minimize the risk of scald from oxygen depletion and also from salt injury. Although there is no yield penalty on alfalfa from not having enough available nitrogen in the soil at all times, it is still necessary to carefully time applications in situations where there is potential for leaching and subsequent groundwater contamination to occur. Applications of manure or lagoon nitrogen must be timed so that the amount of nitrate present in the soil during leaching events is at a minimum so that the maximum amount of nitrogen is take up by the crop and does not adversely impact the groundwater. To do this requires knowledge of when the alfalfa takes up the nitrogen.

The nitrogen uptake pattern for alfalfa is closely correlated with top growth. If the crop is fixing nitrogen, the nitrogen fixation process requires sugars which are manufactured in the leaves. During stand establishment, nitrogen fixation, and corresponding uptake, could be expected to be proportional to the above-ground biomass of the crop. In fall, when the daylength and temperatures are less conducive to sugar production, the nitrogen fixation potential would also be expected to be less.

When nitrogen applications bypass the fixation process, nitrogen applications should be timed according to the amount of expected growth of the alfalfa. First year nitrogen needs will vary depending on when the crop is planted and how much growth will occur prior to the winter season, when growth and uptake is minimal.

One third to one half of the nitrogen needed for regrowth comes from the nitrogen stored in the crowns. On soils prone to leaching, therefore, it may be better to apply the liquid manure nitrogen in the second irrigation if there are two irrigations per cutting and rely on mineralizing organic nitrogen to supply the bulk of the modest needs of the initial regrowth.

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