ESTIMATING NON-FERTILIZER NITROGEN CONTRIBUTIONS

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ABSTRACT

California growers are facing increasing pressure to reduce nitrogen (N) losses in crop production. However, growers also need to maintain high yield levels to remain competitive. This is only possible when N inputs from all sources can be quantified and fertilizer application rates can be adjusted accordingly. The major sources of non-fertilizer N include soil residual nitrate, nitrate in the irrigation water and N mineralized during the growing season from organic material, such as soil organic matter, plant residues and organic amendments.

INTRODUCTION

California is a highly productive agricultural region. Its nutrient intensive production, however, has led to increased groundwater nitrate concentrations with a large proportion of this nitrate likely originating from fertilizer use in agriculture (Harter et al., 2012). California growers are now facing increasing pressure to reduce nitrogen (N) losses in crop production. However, growers also need to maintain high yield levels to remain competitive. This is only possible when N inputs from all sources can be quantified and fertilizer application rates can be adjusted accordingly. The major sources of non-fertilizer N include soil residual nitrate, nitrate in the irrigation water, and N mineralized during the growing season from organic material, such as soil organic matter (SOM), plant residues, manure and compost (Figure 1). In addition, some N is added to fields through atmospheric deposition.

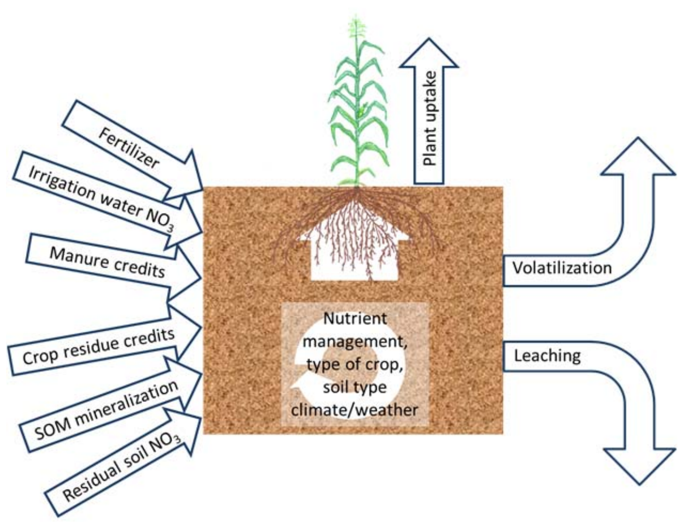

Fig. 1: Overview of the most important site-specific factors affecting crop N availability.

This summary shall provide an overview of the contribution of non-fertilizer N to crop N availability. In my presentation at the meeting I will discuss these sources in more detail with examples from trials from California.

RESIDUAL SOIL NITRATE

Residual nitrate present in the soil profile in spring can be leftover fertilizer N from the previous year or it may have been mineralized from organic material since the harvest of the previous crop. How much these two sources contribute to the residual nitrate measured depends on crop management, soil properties and weather conditions, including precipitation and temperature. For this reason, residual soil nitrate levels are highly variable and samples need to be taken every year.

Soil residual nitrate can be a significant source of crop available N. A nitrate-N concentration of 10 ppm in one foot of the soil profile corresponds to roughly 35-40 lbs N/acre. This conversion of concentration to lbs/acre is based on common soil bulk densities of mineral soils. Soils with high SOM contents, e.g. soils in the Delta or the Tulelake basin, often have a much lower bulk density. In these soils, 10 ppm nitrate-N correspond to 20-30 lbs/acre.

Not all the nitrate present in spring in the top foot or two of the profile may be available for plant uptake. Nitrate is very mobile in the soil and can move with the irrigation water below the root zone when water applications exceed evapotranspiration (ET). Furthermore, crops grown with subsurface drip irrigation may not be able to access the nitrate located near the edge of the bed in the top foot of the profile.

NITRATE IN IRRIGATION WATER

Irrigation water, especially well water, may contain N in the form of nitrate. When irrigation water with a high nitrate concentration is used, agronomically significant amounts of N can be added to a field. With one acre-inch of water with a nitrate-N concentration of 10 ppm, 2.27 lbs N/acre are applied to the field. With one acre-foot of the same water, 27.2 lbs N/acre are applied.

ATMOSPHERIC N DEPOSITION

Nitrogen is also added to fields through atmospheric deposition. In the Central Valley, total annual N deposition may reach 20 lbs/acre or more. However, this source of N depends highly on location and is often not considered for N budget purposes.

NITROGEN MINERALIZATION DURING THE GROWING SEASON

Nitrogen mineralization is a microbial process which strongly depends on soil temperature and moisture. Within the range of soil temperatures found during the growing season in California, N mineralization increases exponentially with increasing temperature. Therefore, mineralization of organic N generally provides much more plant-available N during the summer than during the winter months. The decomposition and mineralization of organic material can provide significant amounts of crop available N in the form of ammonium, which may be further converted to nitrate, both of which are readily plant available forms of N.

Soil organic matter

Although many productive mineral soils contain several thousand pounds of N per acre, most of it is in the form of organic matter and not directly available to crops. It is often assumed that between 1 and 3% of soil organic N is mineralized during the growing season (Bremner, 1965; Gaskell et al., 2006). However, the timing of N mineralization may not coincide with crop

N demand. Many biological and chemical soil tests intended to provide a better estimate of net N mineralization have been proposed, but none of them has found widespread adoption. One weakness of these methods is that they do not take into account soil temperature. California's crop production is highly divers and crops are planted and grown at different times during the year under a wide range of climatic conditions (Figure 2). This makes the development and calibration of soil tests a challenging task.

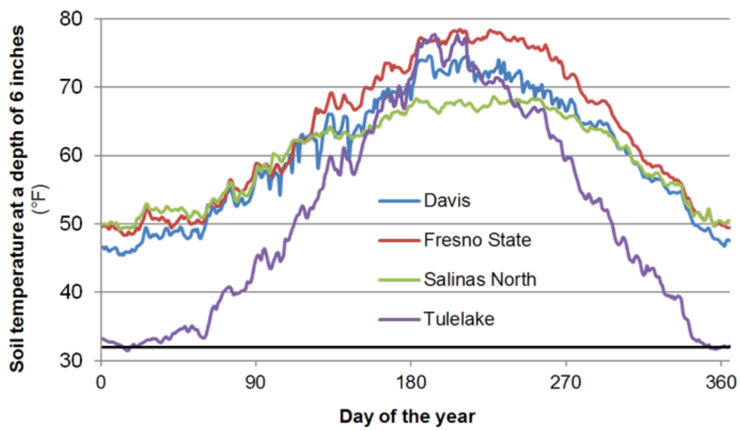

Fig. 2: Changes in soil temperature during the year at selected locations in California at a depth of 6 inches (Data source: http://www.cimis.water.ca.gov/)

Crop residue N credits

The N content of crop residues strongly affects the amount and timing of N released after incorporation. The N content is either expressed in % N in the dry matter or as the carbon (C) to N ratio of the residues. As the C content of most crop residues is between 40 and 45% of the dry mass, a C to N ratio of 20 corresponds roughly to an N content of 2%. Generally, residues with a C to N ratio of 20 or less result in net N mineralization. Examples for residues with a high N content are legume residues and residues from vegetables such as lettuce and broccoli. These residues decompose quickly and the N becomes plant available within weeks. Therefore, depending on the time between incorporation of the residues and planting of the following crop, a considerable part of the N in these residues may have already been mineralized and converted to nitrate when the soil is tested for residual nitrate.

In contrast, straw from small grains and corn stover have a wide C to N ratio and N is released only slowly. When the C to N ratio is wider than approximately 30, residual soil mineral N may initially be immobilized by soil microorganisms, temporarily reducing the amount of N available to crops.

Organic amendments

Nitrogen in organic amendments occurs mainly in organic forms and as ammonium. The ammonium is directly available to plants provided it is not lost to the atmosphere in the form of ammonia. Ammonium contents of organic amendments vary widely depending on the material and its handling. Corral scrapings, composted manure, lagoon sludge and mechanical screen solids from dairies generally contain little ammonium-N, ranging from 0-6% of the total N (Pettygrove, 2009). In poultry manure, ammonium-N may comprise 14-17% of the total N (Gale et al., 2006), while ammonium may account for one to two thirds of the total N in dairy lagoon water (Pettygrove, 2009; Campbell-Mathews et al., 2001).

As is the case with soil organic matter and crop residues, the organic N in amendments is not directly available to plants and must be mineralized by soil microorganisms. When comparing a wide range of organic amendments, the total N concentration has been found to be a good predictor of N availability in organic amendments, with the N mineralization rate increasing with higher N concentrations (Hartz et al., 2000). However, the opposite may be true when comparing a material before and after composting. During composting, microorganisms respire CO_2, resulting in mass loss. Even though ammonia may be lost when N rich substrates are composted, the relative N content (in % of the total mass remaining) generally increases. At the same time readily available material is degraded and more recalcitrant material is left behind. Therefore, composts generally have a favorable C to N ratio, but the N is released at a slow rate.

Only a proportion of the N in manure and compost becomes available to the following crop, with the remainder contributing to increased soil organic matter contents and N mineralization during the following years. When manure is applied continuously for a long time, the soil organic matter content reaches a new equilibrium and the N mineralized from recent and past manure applications may roughly equal the total amount of N added with manure the present year. It has been estimated that in fields with at least 3-7 years of regular manure additions, the manure application rates can be reduced to the point that total manure N applied is approximately equal to projected crop demand (Chang et al., 2007; Crohn, 2006). With composts or composted manures it takes longer to reach equilibrium. However, one challenge is that N mineralization is not limited to the growing season. Some N will be mineralized before planting and after harvest.

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