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Balancing the Nitrogen Budget

Bill Peacock

Sources of nitrogen in the soil/water system other than fertilizer should be considered when developing a fertilization program. This includes nitrogen from soil humus, crop/animal residues, symbiotic fixation from legumes, irrigation water, and residual nitrate in the soil.

For crops with a low nitrogen requirement, such as grapes or early season fresh-shipping fruits, these sources of nitrogen may be more than adequate and no additional nitrogen fertilizer is required. For other crops with higher nitrogen demands, sources of nitrogen within the system can substantially reduce the amount of fertilizer needed. The following nitrogen budget, Table 1, illustrates the sources and losses of plant available nitrogen.

Table 1. Nitrogen Budget

Sources	Losses
Mineralization of soil organic matter	Crop removal
Decomposition of plant/animal residue	Leaching
Symbiotic fixation from legumes	Denitrification
Residual nitrogen in soil water	Volatilization
Nitrogen in irrigation water	
Nitrogen fertilizer	

Sources of Nitrogen

Soil Humus: Soil organic matter is a loosely defined term used to cover organic materials in all stages of decomposition. In general, soil organic matter can be placed in two categories. The first is humus, a relatively stable material that is fairly resistant to further rapid decomposition. The second includes those organic materials that are subject to rapid decomposition such as fresh crop residues and organic material in the process of decomposing and becoming humus.

Humus is stable, dark-colored organic material that accumulates as a by-product of decomposition of plant and animal residues added to soil. The humus content of soils in the southern San Joaquin Valley ranges from 0.25% to 2.5%. One acre-foot of soil weighs approximately 4 million pounds; therefore, an acre of surface soil a foot deep contains about 5 to 50 tons of humus. The nitrogen content of this humus is about 5.0 to 5.5%. Thus, Tulare County soils have 500 to 5000 pounds of nitrogen in the surface foot of soil - soil humus content decreases dramatically with depth.

Even though the soil has a large pool of N stored in soil humus, this nitrogen is mostly insoluble andnot available for plant uptake. It must first be mineralized to inorganic forms by soil microbes before plant uptake can occur, and humus is very stable and slow to mineralize. From this large pool of organic nitrogen trapped in humus, about 10 to 65 pounds per acre are mineralized in any given year (see Table 2). This is in addition to nitrogen released during the rapid decomposition of crop residue and animal or green manures.

Table 2. Mineralized Nitrogen from Humus in Three San Joaquin Valley Soils[1]

Soil Type	Humus (%)	Mineralized Nitrogen (lbs N/yr)
Delhi Loamy Sand	0.3	10 to 15
San Joaquin Loam	0.6	20 to 25
Chino Fine Sandy Loam	1.5	50 to 65

[1]Represents average in surface two feet of soil.

Crop Residue: A live plant is 90 to 95 percent water; the rest is nearly all carbon, hydrogen, oxygen, and nitrogen in the form of organic compounds. Most crops during the course of a season will assimilate 50 to 250 pounds of N per acre in their tissue. Some of this is removed from the field when the crop is harvested; the rest is returned to the soil and recycled.

Crop residue must be decayed by soil microbes before the nitrogen and other nutrients are mineralized (released) and available for plant uptake. Nitrogen in organic matter is mineralized to the inorganic forms of ammonium (NH_4) and nitrate (NO_3) which plants are capable of utilizing.

Plant and animal residues differ in composition and rate of decomposition depending on the plant species, plant age, and especially plant parts: roots, woody stems and twigs, leaves and fruit. Some tissue is decomposed releasing minerals within a few months while other tissue takes years to decompose. In general the lower the carbon to nitrogen ratio the faster decay occurs, but the content of carbonaceous tissue dramatically affects decomposition as well. The following table gives typical nitrogen concentrations of various organic materials along with carbon to nitrogen rations (C/N). Organic materials with a C/N ratio greater than 20 decompose slowly unless nitrogen is added to the system to feed the soil microbes (Table 3).

Table 3. Nitrogen Concentrations and C/N Ratios in Organic Materials

	% N	C/N
Plant Tissues - Trees		
Evergreen leaf (pine)	0.5-0.8	60-70
Tree roots (fine)	0.5-1.0	60-90
Bark (oak)	0.5	80
Wood (oak)	0.1-0.3	130-400
Plant Tissues - Herbaceous		
Clover or bean leaf	2.5-5.0	8-16
Grass shoots (young)	3-4	12-15
Grass shoots (mature, yellow)	0.5-2.0	20-80
Animal and Microbe		
Insects, mammals	6-12	5-10
Fungi (grown on leaf)	3-4	11-16
Bacteria	4-12	5-14
Dung (horse, cow, chicken, etc.)	1-2.5	25-60

Source of data: Swift, heal, and Anderson 1979, Tisdale, Nelson, and Beaton 1985

Atmosphere: Nitrogen (N) is an abundant element and occurs principally as N_2 gas in the atmosphere (78 percent by volume of the atmosphere is nitrogen gas). It is estimated that over every acre of land there are about 35,000 tons of inert N_2 gas.

This large pool of N_2 gas is useless to higher plants. It first must be converted to usable forms primarily by microorganisms either associated with the roots of legumes or free living in the soil. Some nitrogen is also converted by lightning and rainfall (about 5 pounds per acre per year) and by the manufacture of nitrogen fertilizers.

Legumes: Most of our legume crops (alfalfa, beans, peas) generally do not require nitrogen fertilization because bacteria, *Rhizobium*, living on their roots have the ability to take nitrogen from the air and convert it to forms that plants can use. Alfalfa is extremely efficient in this regard. Many others are not; thus, legume crops such as beans often respond to nitrogen fertilization. Legumes provide some or all the nitrogen for their own growth, and they often build up a supply that can be used by crops that follow. Accounting for this nitrogen helps to reduce the fertilizer bill for the following crop.

Green Manure: Green manure plants are grown to be cultivated into soil to improve soil fertility and soil structure. Legume cover crops grown in vineyards and orchards serve as a green manure and help with nitrogen fertility. Legume cover crops can fix 50 to 150 pounds of N per acre depending on the variety, the presence of the correct bacteria, and the growth of the covercrop. An experiment in a Tulare

County table grape vineyard showed that a Lanna vetch cover crop grown for two winters and incorporated into the soil increased the nitrogen status of the vines to high levels. It was estimated that the Lanna vetch green manure grown in six foot strips was providing between 75 to 100 pounds of nitrogen per year. Much of this nitrogen can be lost as volatile ammonia, perhaps 25 to as much as 75%, if the covercrop is not incorporated into the soil.

Nitrogen in Irrigation Water: Water can also contain nitrogen, mostly in the inorganic nitrate form. The nitrate-nitrogen (NO_3-N) concentration in irrigation water in the San Joaquin Valley varies from 0 to 50 pounds of N per acre-foot of water (1 ppm of NO_3-N = 2.7 lbs N per acre-foot).

Residual nitrogen is also present in the soil-water. Concentration varies with cropping and fertilizer history, and levels are continually changing in response to farming, biological, and physical processes. Residual nitrogen in soil-water can contribute significant amounts of available nitrogen to the plant and should be considered when developing a fertilizer program, particularly for annual crops.

Both nitrogen in irrigation water and residual nitrogen in soil-water can be determined by a laboratory.

Add It Up: When you add up these sources of nitrogen they can be quite significant. Even so, most crops (but not all) still require additional fertilizer nitrogen to maximize yields. Nitrogen fertilizer can be applied in a variety of forms, the crop has no preference, it's the farmers choice. Forms of N fertilizer can include synthetic fertilizers, a variety of animal manures and composts, and a variety of leguminous covercrops and green manures.

Harvesting Nitrogen by Crop Removal

Each crop has a unique nitrogen requirement necessary to optimize yield and quality. The amount of nitrogen removed from the field by harvesting and removing the crop is an indicator of the nitrogen demand of the crop. The approximate total nitrogen removed by the crop and typical fertilizer N rates are shown in Table 4.

Closing Remarks

Nitrogen cycles among several large pools representing different forms of the element in the ecosystem. Nitrogen is lost from the farm by crop removal, volatilization of nitrogen gases back to the atmosphere, and leaching of nitrogen below the root system. Good nitrogen management limits the losses while maximizing the efficiency of nitrogen uptake by the crop.

Table 4

Crop	Yield (tons/acre)	N Harvested in Crop[1] (lbs/acre)	Optimum Fertilizer Nitrogen Rates (lbs/acre)
Fruits and Nuts			
Grapes (fruit)	7-15	14-30	0-50
Peaches/Nectarines (fruit)	7-25	20-80	0-175
Walnuts (nuts)	2-3	80-120	70-175
Almonds (nuts)	.75-1.2	75-120	75-200
Oranges (fruit)	7-15	35-80	75-135
Agronomic Crops			
Cotton (lint/seed)	1-1.5	72-110	120-200
Wheat (grain)	2-4	90-180	150-210
Barley (grain)	1.5-3	65-135	100-150

[1]Nitrogen removed from field by harvesting the crop.