Farm Practices and Nitrogen use Efficiency

Section 5

Integration of N Cycling with Cultural Management

To:
Reduce Nitrogen losses to the atmosphere and leaching
Reduce costs
Reduce environmental impacts

Efficient N Management: Applying the 4 Rs Principle

- Apply the Right Rate
  - Match supply with crop demand (all inputs- fertilizer, organic N, water, soil).
- Apply at the Right Time
  - Apply coincident with crop demand and root uptake.
- Apply In the Right Place
  - Ensure delivery to the active roots.
  - Minimize movement below root zone
- Use the Right Source

The 4 Rs are specific to every individual orchard/field and every year.

Details about each of the 4Rs:

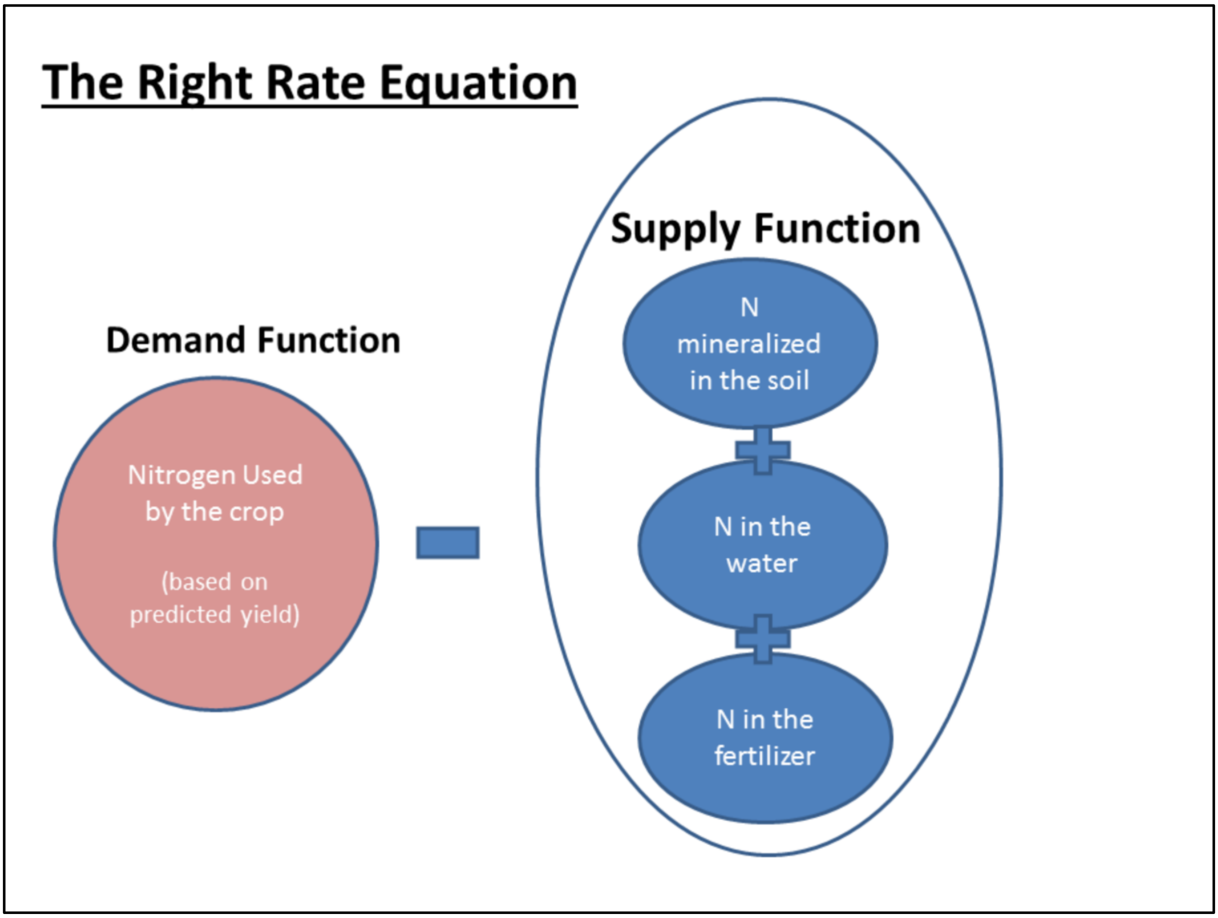
Right Rate:
1. Appropriately assess soil nutrient supply
2. Assess all available indigenous nutrient sources
3. Assess plant demand
4. Predict fertilizer use efficiency

Right Time:
1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply
3. Recognize timing of weather factors
4. Evaluate logistics of operations

Right Place:
1. Recognize root-soil dynamics
2. Manage spatial variability
3. Fit needs of tillage system
4. Limit potential off-field transport

Right Source:.
1. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility

Note: Information on choosing the “Right Source” will be discussed in Section 3



Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Demand is defined as crop use / nitrogen use efficiency (NUE)

Crop Nitrogen Demand

- The amount of nitrogen taken up by the crop
  - N in the harvested crop + crop residues
    - Example Wheat:
      - 60 % N in grain
      - 40% N in straw
        - » Significant N left in the field as crop residues
    - Example : Walnut:
      - N removed in the harvested (removed from field) crop
        - » Includes hulls, sticks, and leaves removed from field
        - » The bulk of the N is removed from the field at harvest
        - » The remainder is cycled each year

Wheat: If only the harvested N were considered demand the crop yield would suffer.
Walnut: The orchard is considered at “steady state” in terms of biomass recycling. The leaves, hulls, and prunings are retained in the field each year

Right Rate: Nutrient Demand in Harvested Crop

Where to get the information

Nutrient removal in harvested portion of crop	Unit	Removal, lb/unit			
		N	P_2O_5	K_2O	S
Corn silage	ton	9.7	3.1	7.3	1.1
Corn grain	ton	23.9	12.5	8.9	2.9
Tomato	ton	2.5	0.92	5.7	
Rice grain	bu	0.57	0.3	0.16	
Wheat grain (winter)	bu	1.16	0.48	0.29	0.1
Potato tuber	cwt	0.32	0.12	0.55	0.03

Yield for Corn silage = 30 t/acre x 9.7 lbs N/ton = 291 lbs N /acre
Yield for Corn grain = 6 t/acre x 23.9 lbs N/ton = 143 lbs N /acre
The difference is the amount of N in the stover

(Modified from: 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, 2012 IPNI)

To look up nutrient demand for the harvested portions of other crops, please visit https://www.ipni.net/app/calculator/home

This slide makes two points.

1. Nutrient removal rates are available
2. The corn example points out that it is removal not the N used

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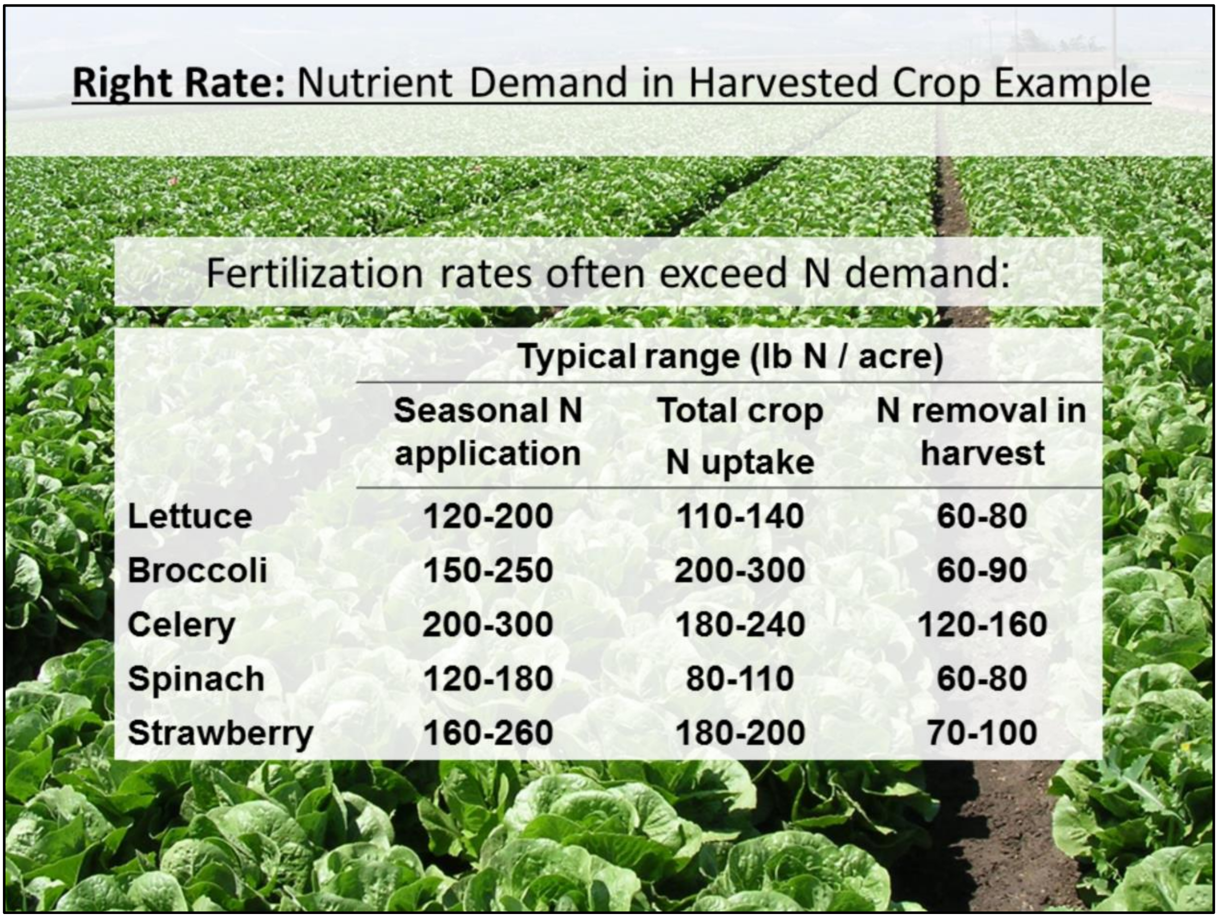


Table: Application rates for vegetable crops tend to exceed N removal through harvest. Though the total crop N uptake quantities more closely match the amount applied, a large portion will be returned to the field after harvest (ex: broccoli stems, etc.). **So, application should be based on the amount taken up through harvest.**

The crop residue N must be considered for the following crop.

Right Rate: Nutrient Demand Examples

ALMOND

Nutrient removal per 1000 lb kernels

Nonpareil
- N removal 68 lb per 1000

Monterey
- N removal 65 lb per 1000

Growth Requirement
- Yield 2,000-4,000 = 0 lb N
- Yield 1,000-2,000 = 20 lb N
- Yield <1,000 = 30 lb N

PISTACHIO

Kerman:
- N removal 28 lb per 1000*

Growth Requirement:
- On-year: 25 lb N
- Off-year=25-40 lb N

*Dry CPC assessed yield

Walnut

- N removal 19 lb per 1000 lb in shell
  8% moisture

Growth Requirement:
- Mature orchard = included in above
- Immature orchard: not as yet available

Examples of amount N removed by harvest for some tree crops.

If yield is unpredictable, begin by using an approximation to determine the first 20% of N needed. Then calculate the remaining fertilization needed after the crop is on the tree, giving a much more accurate estimate of yield for the rest of the season.

Right Rate: Methods for Setting Realistic Yield Goals

- Use experience of the potential of a particular field, and then consider environmental conditions.
  - For annuals, weather at planting can have a major effect.
  - For perennials, the past year's yield plus winter and spring weather can be critical.

- Set **target** of 10% above the field's 3-5 year average, excluding years with unusual negative conditions (pests/disease/drought, etc).

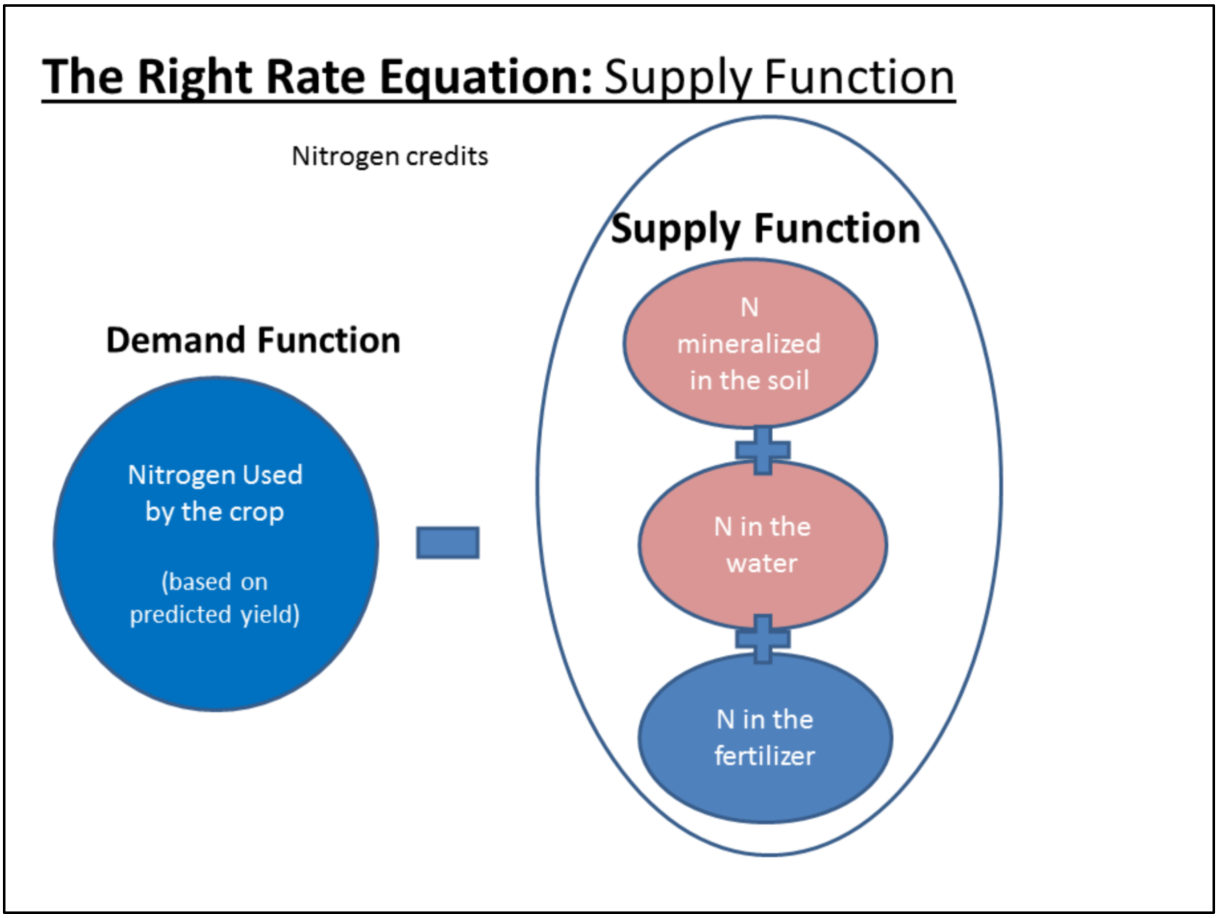
  Estimating too high of a yield can result in early season over application

- Multiple applications combined with in-season tissue and or soil analysis can allow for adjustments

With the more than 100 crops grown in California, it is hard to provide a uniform approach to yield estimation. The best approach is likely to use your own experience to guide you, bearing in mind that getting a yield estimate wrong at the beginning of the year can result in substantial difficulty later in the year.

Calculating Crop N Use

- Nitrogen used per unit of crop yield
- Estimated crop yield
- Example:
- Mature walnuts at 37 lb N per ton
- Yield expected is 3.0 tons/acre
- Result = 111 lb N / acre use



Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Right Rate 'Supply':

Nutrients in Manures and Composts

	Total N	Inorg N	C: Org N
	lb/ton DM	lb/ton DM	
Fresh Manure	50	4	18
Mech Screen Solids	34	4	30
Coral Scrapings	38	2	13
Compost	44	2	14
Anaerobic Dairy Lagoon Sludge	60	10	11

The inroganic N should be available quickly when the C:N ration is <20

The organic N will eventually become available, however the rate of mineralization will depend on:

C: N ratio 20:1 threshold
Temperature
Moisture
Type of organic material

Right Rate 'Supply':

Nitrogen in Manures and Composts and Cover crops

- Consistent application of manure or the growing of a cover crop allows for easy accounting of N available each year.

- Dry lbs manure/cover crop/compost x % N
  - If incorporated the efficiency of decomposition and uptake is probably about 70% over time

Right Rate 'Supply':

Nutrients in Manures and Composts

- A single application of manure or the growing of a cover crop is more difficult
- Dry lbs organic amendment x % N x % decomposition
  - If incorporated the efficiency of decomposition and uptake is probably about 70% **over time**.

First year decomposition	Rates
Cured compost	5-10%
Dried manure	15-30%

About 70% of the organic N will be mineralized over time– the rest is subject to losses.

In the first year mineralization is relatively low.

Availability of N in Crop Residues

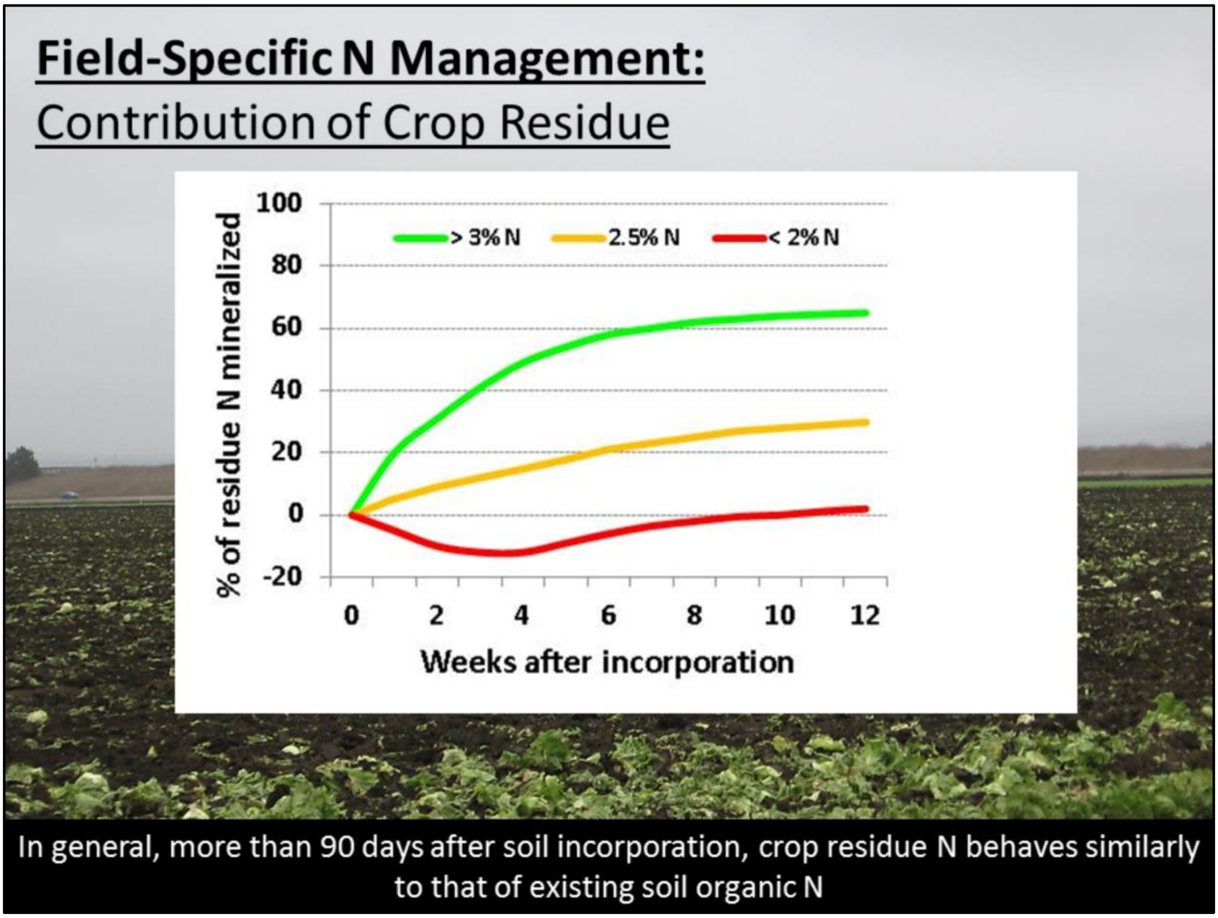
N mineralized during season from crop residues vs. N content of residue. Assumes ideal conditions of moisture and temperature.

Total N in residue (% dry wt.)	% of total N mineralized during in season*
0.5	*Immobilize*
1.0	*Nil*
1.5	14
2.0	25
2.5	34
3.0	41
3.5	47

(drawn from Vigil and Kissel, 1991).

Table: The exact amount of N credit to budget for preceding crops is not well understood. An estimate of available N in crop residues based on residue N content is provided here.

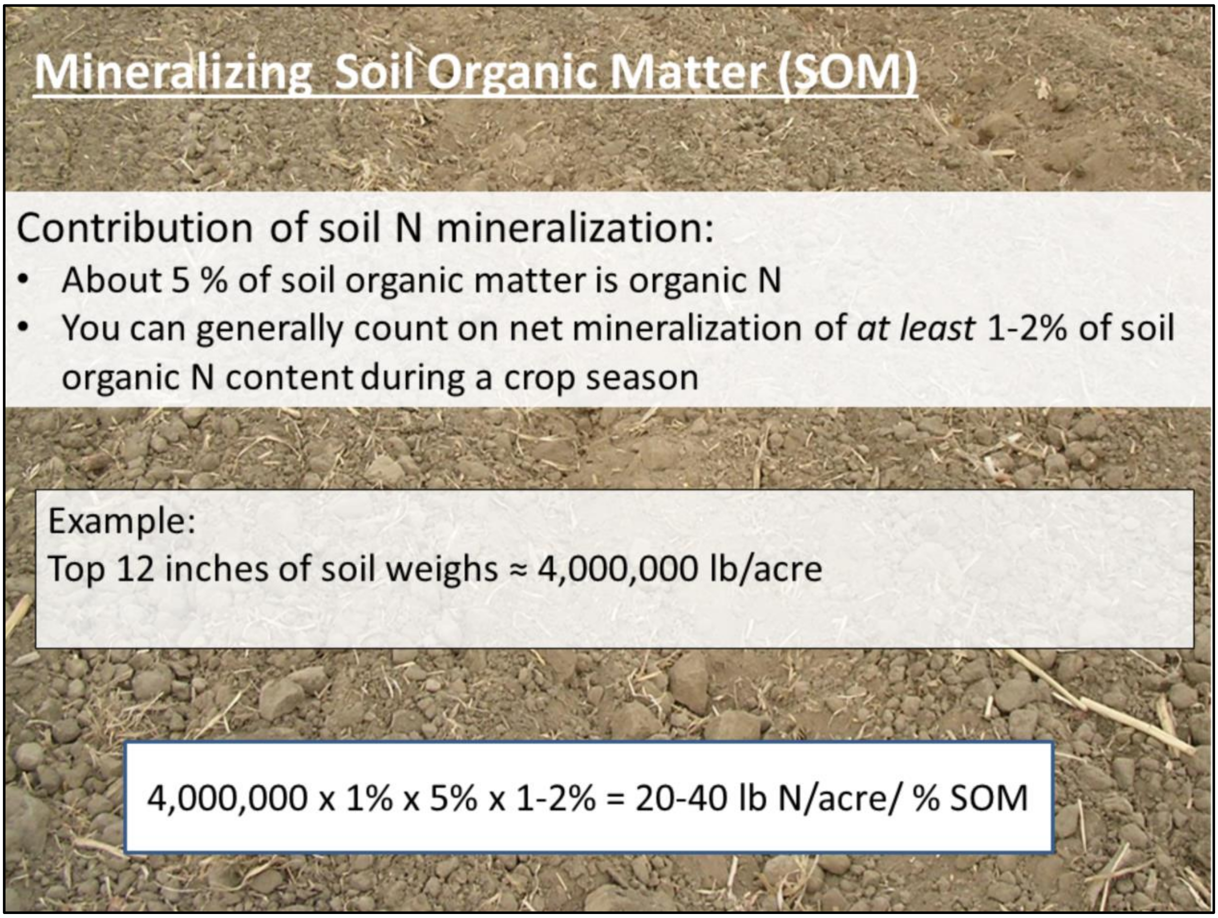
Grasses = 1.5% N
Legumes = 3.5 % N



Crops vary widely both on the amount of nitrogen typically contained in residue, and in the nitrogen concentration of that residue; both factors profoundly influence the nitrogen contribution to the following crop.

Figure:
Green = residue of very high N content
Yellow = residue of intermediate N content
Red = residue of low N content

These examples show the range of N concentrations, with all high enough to expect rapid mineralization once incorporated. When following a high N concentration crop (ex: lettuce), within several weeks more than half of this N will mineralize and be available. For a crop with a medium N content, you can assume that about 1/3 of its N will eventually become crop-available through mineralization. A crop with a very low N content (ex: cereal grain) will not likely contribute mineralized N to the following crop. These residues may even immobilize N, represented by the negative-sloped portion of the red line, necessitating application of additional N before the following crop.



Note: the final amount is multiplied by whatever % organic matter your soil has, perhaps around 1%. The 1-2% net mineralization figure is for a crop season.

The example calculation breaks down as 4,000,000 x 5% x 1% x 1-2% = lb N/acre

Note: in systems where manure and other organic materials are being applied, these portions would be higher. Behavior of N mineralization would also change in a system with very high organic matter content.

Right Rate 'Supply': N in the Soil

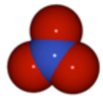
- Especially important for annual crops
- Soil Nitrate Testing at planting or before side-dress is a valuable tool.

Challenges in using these tests:

- Spatial variability – need representative samples
- Turn around time from the lab (there are some quick tests)
- Will the nitrate be there after an irrigation?
- If nitrate is coming from mineralization of an organic source, how much and how quickly will more nitrate be available?

Note: Currently, we do not do soil mineral N tests for perennial crops because the amount of N cycling through from dropped leaves and prunings is such a small percentage of the overall N. This test is much more important for annual crops.

Right Rate 'Supply': N in the Water

- Formula for Nitrate: 

  Nitrate concentration (ppm) x inches irrigation applied x **0.052**

- Formula for Nitrate-N: 

  Nitrate-N concentration (ppm) x inches irrigation applied x **0.23**

Example:

Lab reports 10 ppm Nitrate and you apply 36 inches of water

10 x 36 x 0.052 =

Answer = 19 lb N

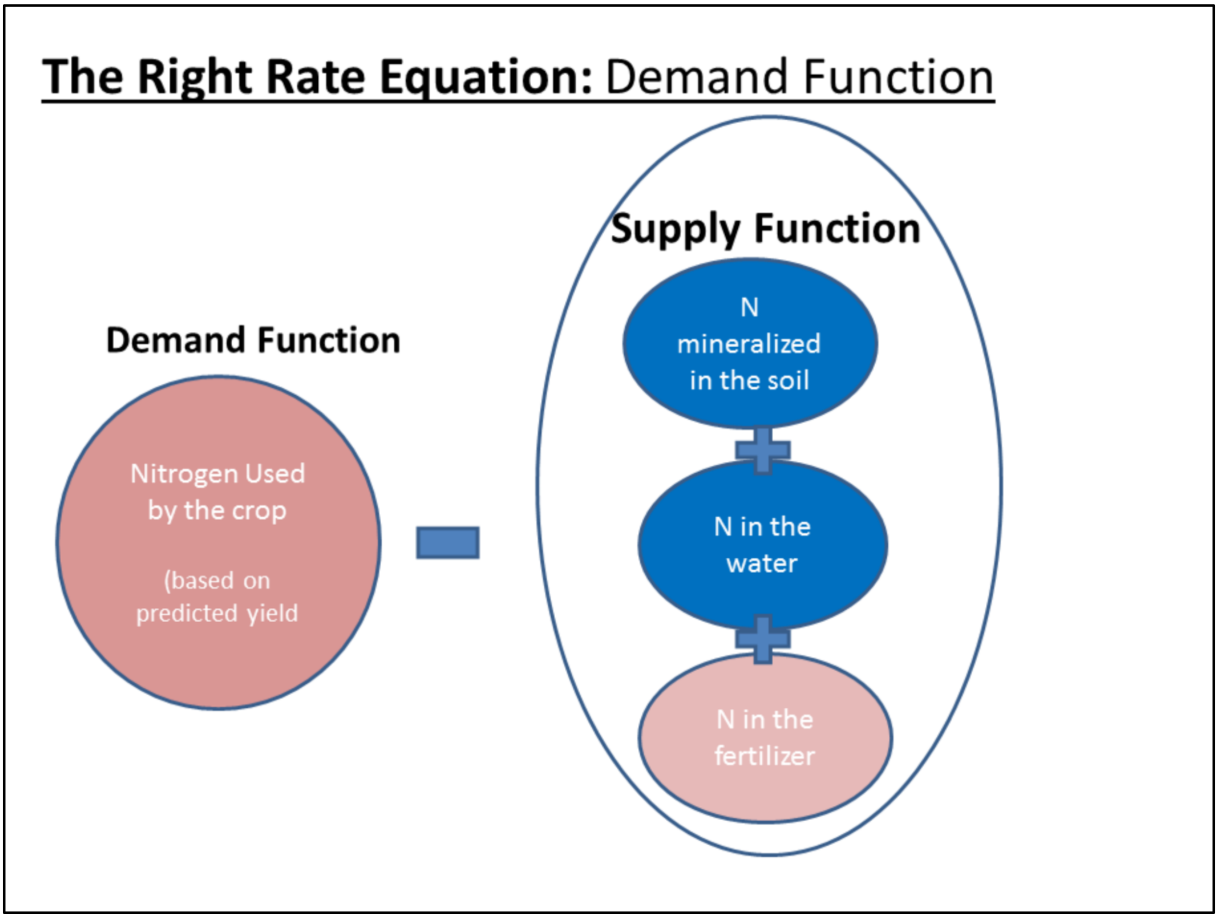
N in water is a free and very readily available nitrogen source.

Note: The conversion factors .052 and 0.23 are constants used to convert from N concentration in ppm to lbs.

When Nitrate concentration is measured in nitrate-N (NO3--N), only the nitrogen is measured.

When Nitrate concentration is measured in nitrate (NO3-), nitrogen and oxygen are both measured.

Note 1 : The two maximum contaminant levels are the same – only difference is the mg/L is the weight on N and O3 versus N .
A factor of about 4.5
62.0049 / 14.0067 = 4.427



Use the right rate equation to avoid excess N, increase nitrogen use efficiency, and increase profitability by accounting for all N inputs.

Nitrogen Use Efficiency

$$\frac{Output}{Input} = Efficiency$$

1. $$\frac{Lbs\ N\ \textbf{exported}\ from\ the\ field\ in\ crop\ products}{Lbs\ N\ all\ sources} = Nitrogen\ Use\ Efficiency$$

2. $$\frac{Lbs\ N\ \textbf{used}\ by\ the\ crop}{Lbs\ N\ all\ sources} = Nitrogen\ Use\ Efficiency$$

Exported in the crop = Just the exported N from field in crop the other N contained in leaves, prunings etc. is cycled in field each year

Used = harvested crop + crop residues = incorporated into soil organic matter

All sources of N– fertilizer, mineralized and water sources

1. Doesn’t include the N used in the crop residues and contribution to SOM. May work with steady state perennials or monoculture.
2. Includes the N used by the crop for harvested and crop residue and contribution to SOM. Works well with annual crop rotations.

Nitrogen Use Efficiency (NUE)

- The highest efficiency is achieved by the best combination of right rate, right time, right place and right source.
  - This requires understanding the dynamics of nitrogen in the soil and the plant

Achievable NUE= 70% (More of a target)

Worldwide NUE = < 50%

Cassman, Kenneth G.; Dobermann, Achim R.; and Walters, Daniel T., "Agroecosystems, Nitrogen-use Efficiency, and Nitrogen Management" (2002). *Agronomy & Horticulture -- Faculty Publications.* Paper 356.
http://digitalcommons.unl.edu/agronomyfacpub/35

Nitrogen Use Efficiency

- Achieving an NUE of 70 % requires:

- Management of croplands to minimize Losses:
  - Volatilization
  - Denitrification
  - Runoff
  - Leaching
- Following the 4R's principles

Estimated N Demand

- Crop N use per Acre x Nitrogen Use Efficiency (NUE)

- Walnut:
  - Crop use = 111 lb N/Acre / 0.70 = 159 lbs N/Acre

Right Rate and Timing 'Demand': Corn Example

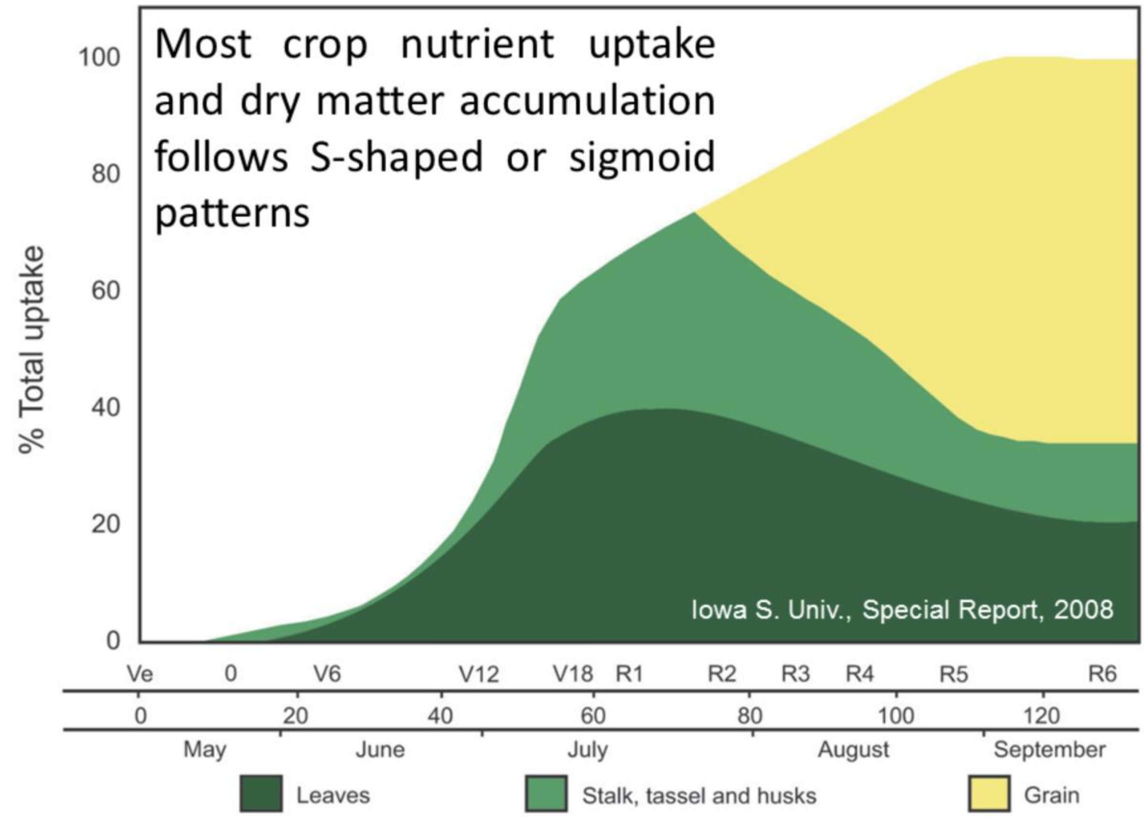
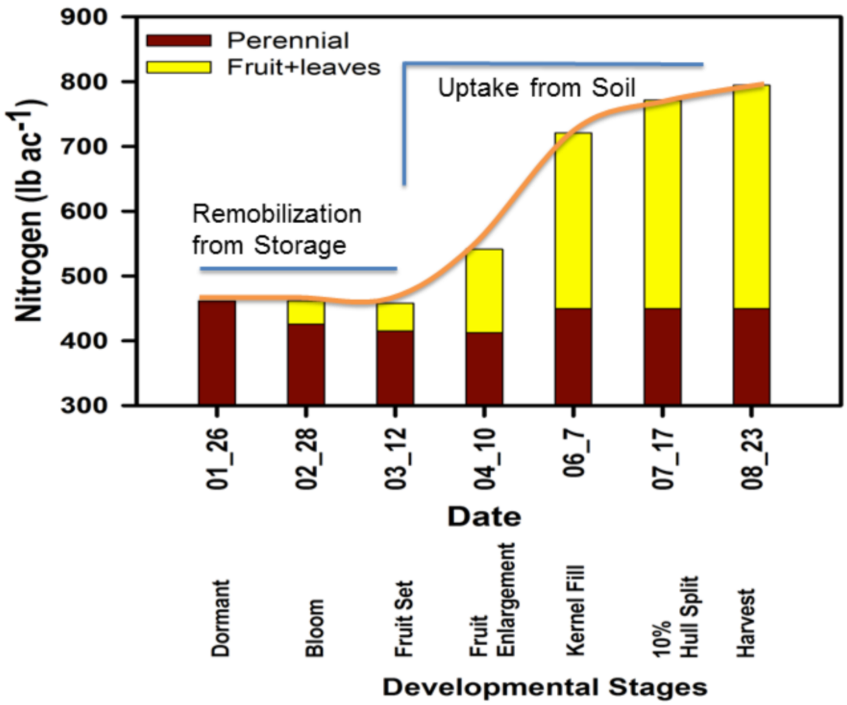


Figure: Cumulative corn N uptake divided by plant organ. Nutrient demand is characterized by slow early uptake, increase to a maximum during the rapid growth phase, and decline as the crop reaches flowering and matures. At flowering, N is remobilized from the flowers back in, rather than taken up.

Demand for N is largely driven by biomass accumulation.

Nutrient demand per time is related to growth rate; fast growth requires a high rate of N uptake and assimilation.

Right Rate and Timing 'Demand': Almond Example



From dormancy to mid-March there is very little N uptake.

Uptake commences at mid-leaf out and is essentially complete by hull split.

<u>Recommended N Split:</u>

20% Leaf Out-Fruit Enlargement

30% Fruit Enlargement
30% Kernel Fill

20% Hull-split through early Post-Harvest

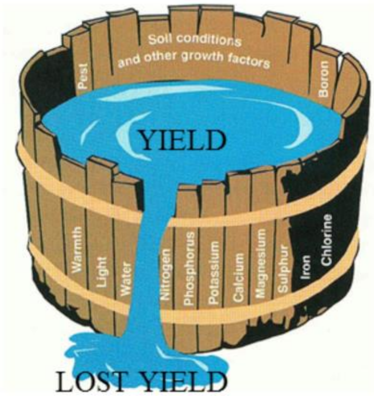
Figure: This curve represents all N in the orchard, including woody perennial tissues, leaves, and fruit.

From January through March, the curve is completely flat. Here, N is being remobilized from perennial tissues into fruit and leaves, rather than taken up. This means that any early season application will not be taken up from soil and has the potential to be lost.

N demand is heavily driven by the amount of nuts on the tree, so rapid uptake from the soil is seen around March and April, with a flattening as the nuts mature.

Right Source: Nutrient Balance

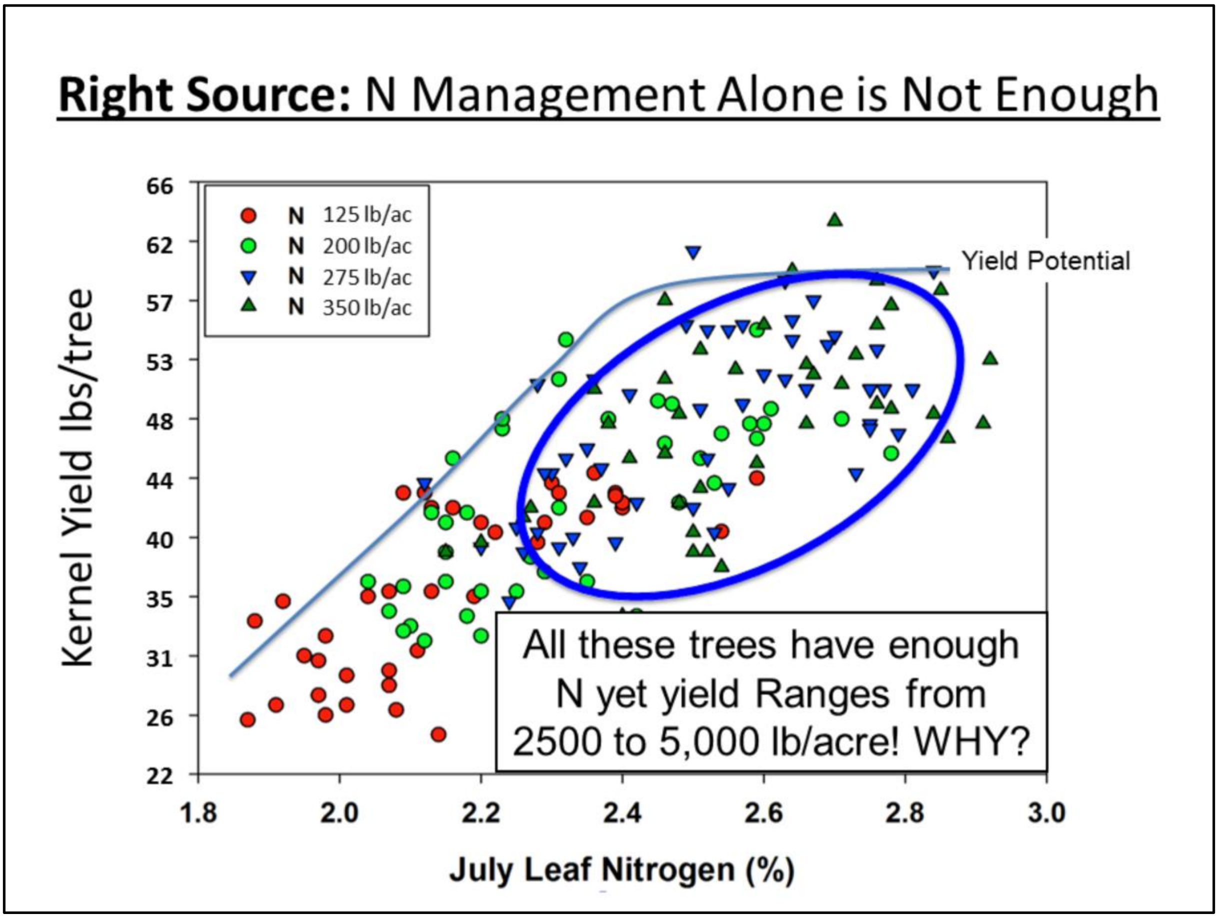
The efficiency of nitrogen will always depend upon the adequacy of all other essential elements and growth conditions.



The Law of Minimum
Justus Von Leibig, 1863

If any nutrient is inadequate - Yield is lost AND a response to other elements cannot occur.

If any nutrient is oversupplied - Money is wasted



It is a fundamental law of plant nutrition that the efficiency of one nutrient cannot be optimized without also optimizing the others.

Figure: All trees in the blue circle were given sufficient N, but why is their yield so variable? Another nutrient must be missing that is preventing efficient use of N. Identifying limiting nutrient can help prevent these inefficiencies.

Right Place: Where are the Roots?

How to manage:

for a crop with a 6-inch rooting depth?

How to manage:

for a crop with a 4-foot rooting depth?

(Photo's Courtesy Tim Hartz and IPNI)

The main goal is to keep N in the root zone. If there are only a few fertigation events per year, each one could be large enough to boost soil N concentration above what the plant could take up at the time of the event. When this is the case, it is crucial to keep the N in the root zone for as long as possible to give the plant a chance to catch up.

Right Place: Where Does N Uptake Occur?

Soil and irrigation practices will influence this greatly:

	Depth of Main Root Zone (inches)
Almond	8-23
Apricot	8-16
Cherry	4-16
Peach	0-32
Plum	10-24
Walnut	0-16

(Adapted from: Atkinson, 1980. The Distribution and Effectiveness of the Roots of Tree Crops. Horticultural Reviews.)

Table: Examples of the root zones of some permanent crops.

References:

Almond 8-23 Dziljanov and Penkov 1964b
Apricot 8-16 Ghena and Tercel 1962
Cherry 4-16 Tamasi 1975
Peach 0-32 Dziljanov and Penkov 1964b
Plum 10-24 Tamasi 1973
Walnut 0-16 Kairov et al. 1977

Fertigation in Pressurized Systems

Goals: Timing of injection during an irrigation event

- Target fertilizer **in the root zone** where crop can use it
- Inject N during the middle to near end of an irrigation event.

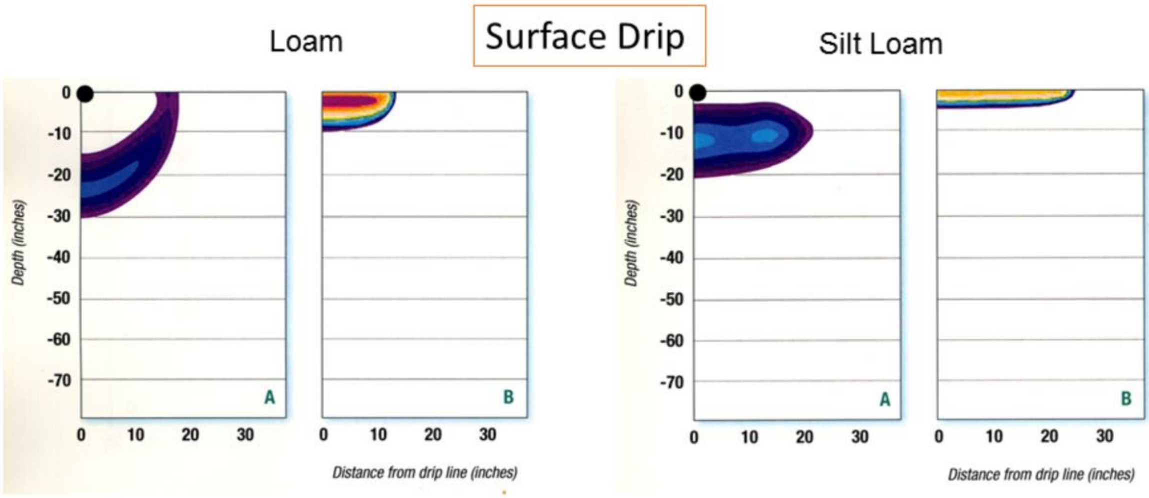
Left: A venturi injector with a small pump used to inject fertilizers into pressurized irrigation systems. This eliminates the requirement that the venturi injector be plumbed across a pressure drop. Right: A differential pressure tank used for fertilizer injection. It is difficult to obtain a constant injection rate using such a tank.

Whatever injection equipment is used, it is important to time the injection so that the injected material stays in the crop's root zone.

Remember that there needs to be a period of clean water irrigation following an injection so that the chemical is applied uniformly and there is not material left in the lateral lines.

Fertigation in Pressurized Systems: Root Zone Targeting Example

When during the irrigation do you inject (for different soil types)?



2 hour injection near start of 27 to 36 hour Irrigation. **N levels elevated at 30 in.**

2 hour injection near end of 27 to 36 hour Irrigation **N confined to top 10 in.**

2 hour injection near start of 27 to 36 hour Irrigation **N levels elevated at 20 in**

2 hour injection near end of 27 to 36 hour Irrigation **N confined to top 6 in.**

(Blaine Hanson, "Fertigation with Microirrigation")

Figures: Distribution of nitrate in soil shortly after application of N fertilizers. Irrigation water and nitrogen fertilizer were applied through surface drip on loam soil (left two figures) and through surface drip on silt loam soil (right two figures). These data sets show that injecting N fertilizers during the latter 1/3 of an irrigation set time yields better placement of N fertilizers and groundwater quality protection. This still leaves adequate time for fertilizer to be distributed uniformly through the system and sufficient time to purge the system of all fertilizer.

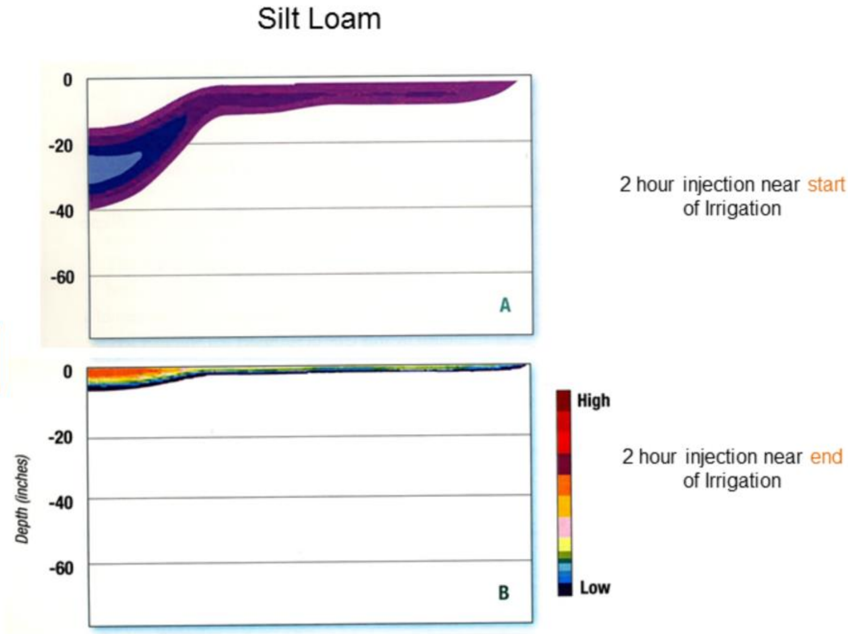
Note: Because of improved abilities to study nitrate movement and heightened scrutiny of nitrogen fertilizer use in CA agriculture, **advice previously given to growers to fertigate toward the middle third of an irrigation event has become outdated**. Research shows this increases the likelihood of nitrate fertilizers percolating below the root zone during subsequent irrigation.

Is it preferable to apply fertilizers at the beginning, middle, or end of the irrigation set?

Fertigation in Pressurized Systems: Root Zone Targeting Example

When during the irrigation do you inject?

Microsprinklers



(Blaine Hanson, "Fertigation with Microirrigation")

Fertilizer injections into **microsprinklers** should occur in the latter 1/3 of total irrigation set time.

Top Figure: Nitrate at 40 in. deep in the soil profile shortly after N fertilizer was injected during the first 2 hours of a longer irrigation set.

Bottom Figure: Nitrate confined to a depth of 6 in. when N fertilizer was injected in 2 hours near the end of a longer irrigation set. This, however, raises the question of whether the fertilizer will penetrate deep enough to supply the crop with sufficient N. But with low volume microsprinklers, irrigations occur frequently, so the fertilizer will be moved deeper into the root zone with subsequent irrigations.

Farm Practices and Nitrogen use Efficiency Summary

The highest nitrogen use efficiency is achieved by: the best combination of right rate, right time, right place and right source.

This requires understanding the dynamics of nitrogen in the soil and the plant and irrigation system performance to reduce nitrogen losses