University of California

Nitrogen Management Training

for Certified Crop Advisers

Nitrogen Management for Permanent Crops

UC Cooperative Extension
University of California
Agriculture and Natural Resources

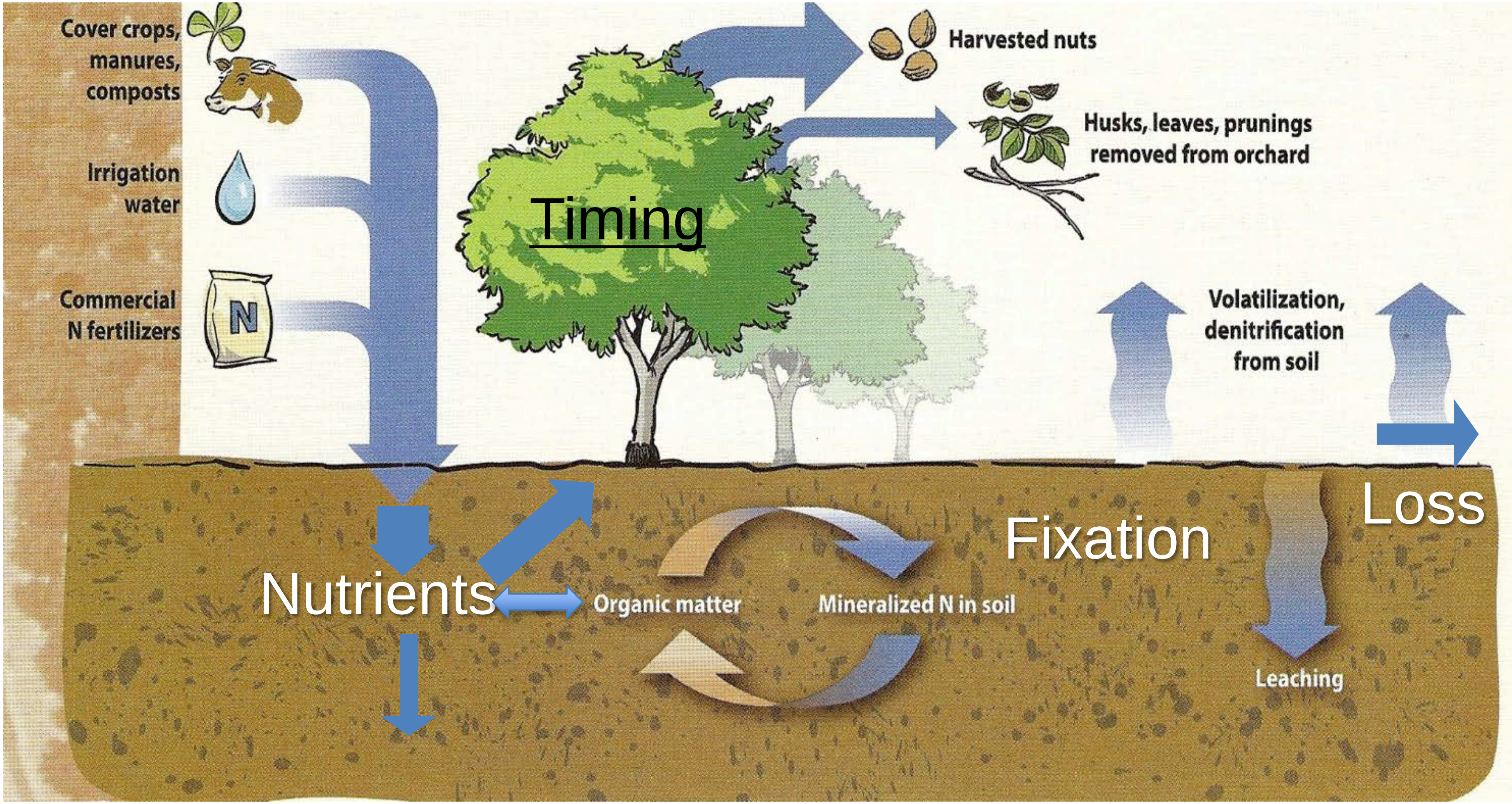
Efficient Nitrogen Management
-the 4 R's-

- Apply the Right Rate
  - Match supply with tree demand (all inputs- fertilizer, organic N, water, soil).
- Apply at the Right Time
  - Apply coincident with tree demand and root uptake.
- Apply in the Right Place
  - Ensure delivery to the active roots.
  - Minimize movement below root zone
- Using the Right Source and Monitoring
  - Maximize uptake, maximize response and minimize loss.

The 4 R's are specific to every orchard each year.

Optimizing N Use in Tree Crops

Supply (Rate) = Demand (Amount and Timing)

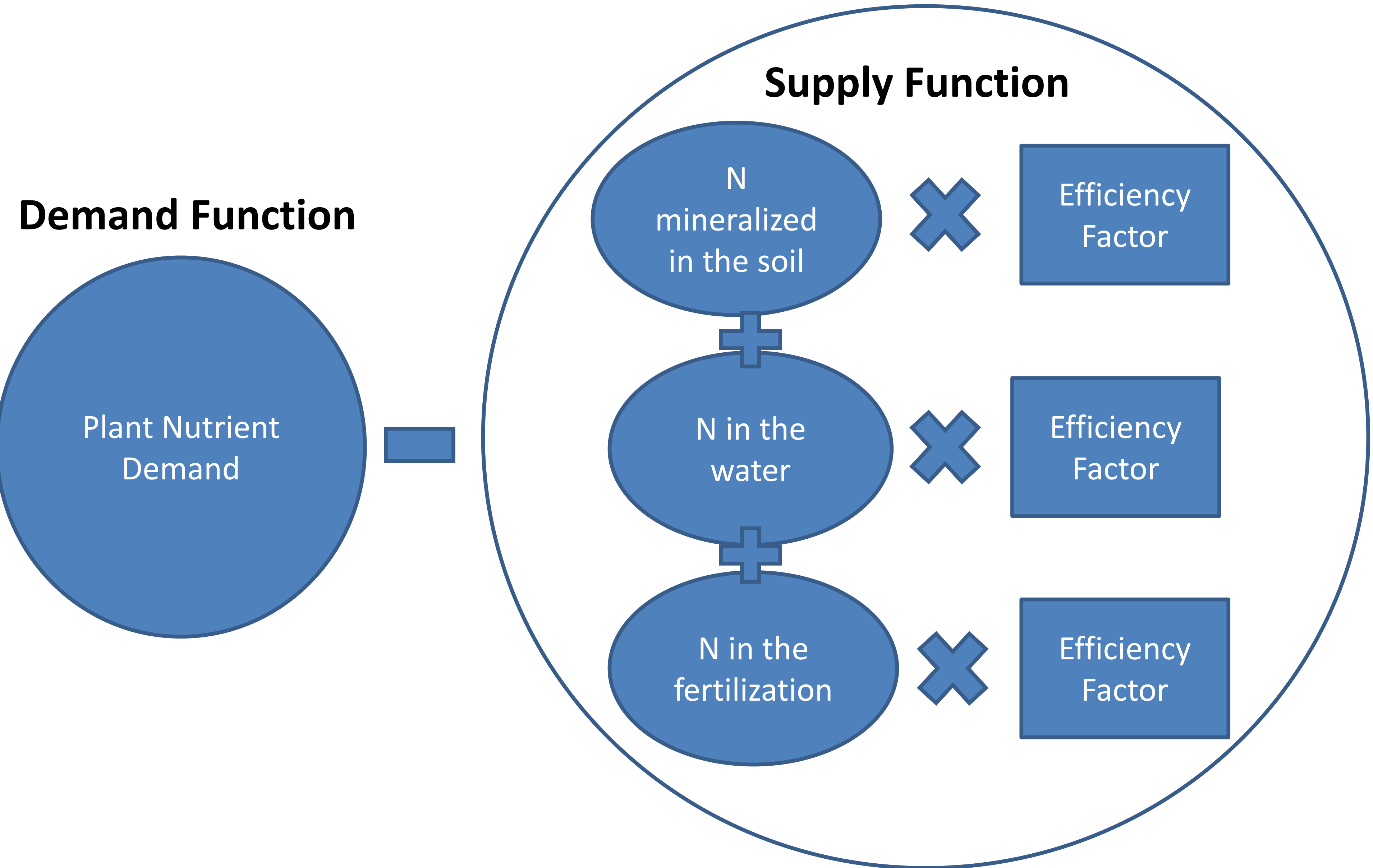


Kathy Kelley-Anderson et al: ANR Pub # 21623

Right Rate

Plant N Demand

The Right Rate Equation: Demand Function



Determining N Demand

- Nutrient Budget Approach
  - What is the total annual tree demand?
  - When during growth and development does uptake occur?

  Experimental Approach:
  - Whole tree excavation, trunk coring, sequential nut collection and analysis, yield measurements- 1000's of individual trees at multiple sites and years

Plant N Demand

Table 2. Total annual nitrogen uptake (lbs/ac) Data obtained from total tree excavations.

Species	Age*	Quantity	Notes	Reference
Apple	6	49	From budbreak to fruit harvest; in 55L pots	Cheng and Raba, 2009
Apple	6	53	Include nutrient increase in tree framework	Scandellari et al., 2010
Cherry	1	8-11.5		Bonomelli et al., 2010
Orange	10	74	Include nutrient increase in above ground tree framework	Roccuzzo et al., 2012
Grape	42	34-53		Pradubsuk and Davenport, 2010
Grape	15	44	Fruits, shoot and leaves	Porro and Dorigatti, 2009
Peach	7	44-118	Excavation and modeling	Rufat and De Jong, 2001
Kiwifruit	mature	178	cv. Hort16A	Boyd et al., 2010

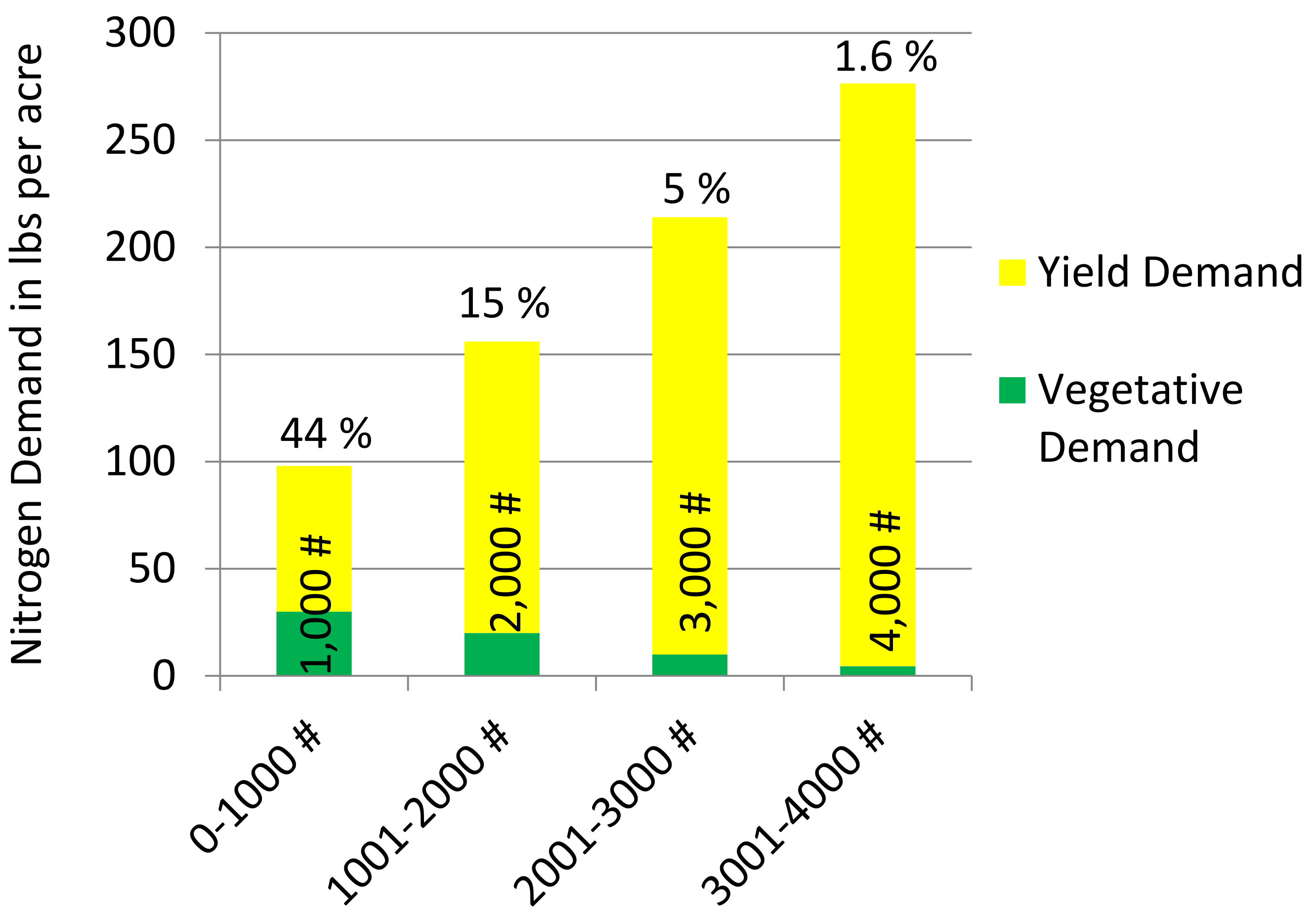
* years.

Modified from: Tagliavini, M. and Scandellari, F. 2013. Methodologies and Concepts in the Study of Nutrient Uptake and Partitioning in Fruit Trees. Acta Hort. (ISHS) 984:47-56

Fruit N Demand

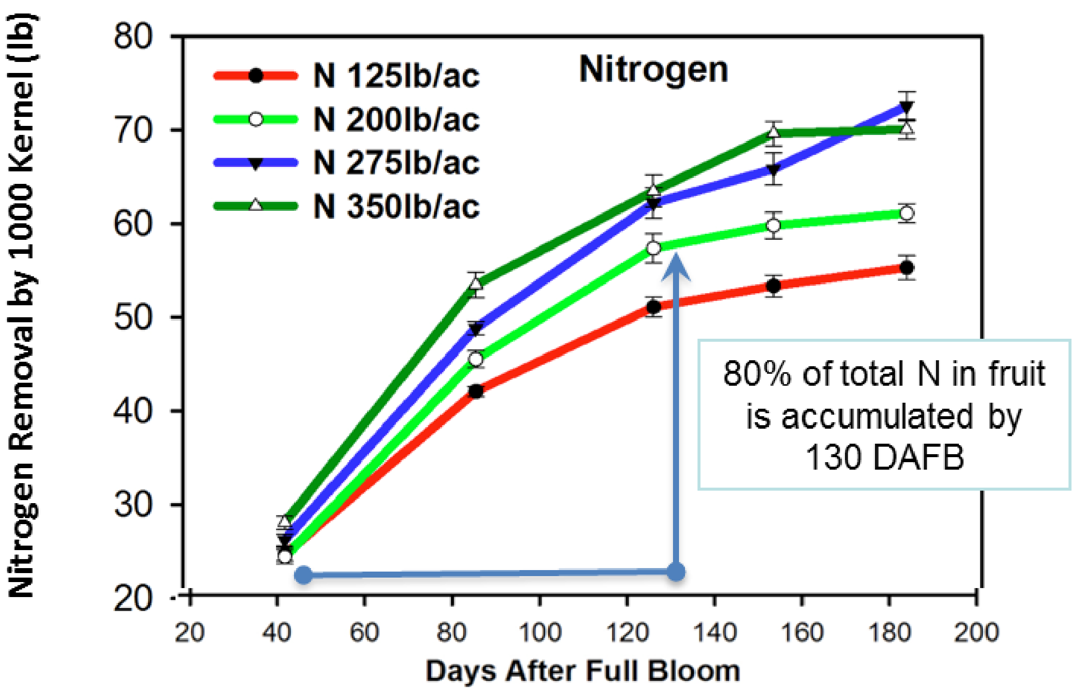
Species	N lbs per 1000 lbs of fruit produced	Source
Apple	0.5-0.6	IFA, 1992;USDA,1963
Citrus	1.1-1.6	Rocuzzo, 2013; Krueger/Arpaia 2010
Cherry (Sweet)	2-2.35	Huguet, 1980
Table Grape	1.3-1.9	Lohnertz, 1991; USDA 1963
Wine Grape	0.8-2	Coombe, 1992; Mullins, 1992
Kiwifruit	1.3-1.8	Smith et al., 1988; Pailly 1992
Walnut (In-shell)	14-20	Weinbaum 1991; Pope 2014
Peach	0.8-1.2	Maragoni and Rombola 1994;USDA 1963
Pistachio	28 (marketable yield)	Siddiqui et al (2013)
French Prune	3 (1000 fresh), 9 (1000 Dry)	Weinbaum, et al., 1994, USDA, 1963
Olives	8	Angelo Rodrigues *et al.,* 2012
Almond	68 (1000 lb kernel), ≈ 16 lb per 1000 lb whole fruit	Muhammad, Saa, Brown et al (2013)

Plant N Demand: Vegetative and Fruit Proportions



Plant Nutrient Demand: Effect of Excessive N Application

- Applying more N than needed does not result in greater N uptake by fruit, but does increase leaching potential.
- There is less vegetative growth when yield is high, even when N is applied in excess.

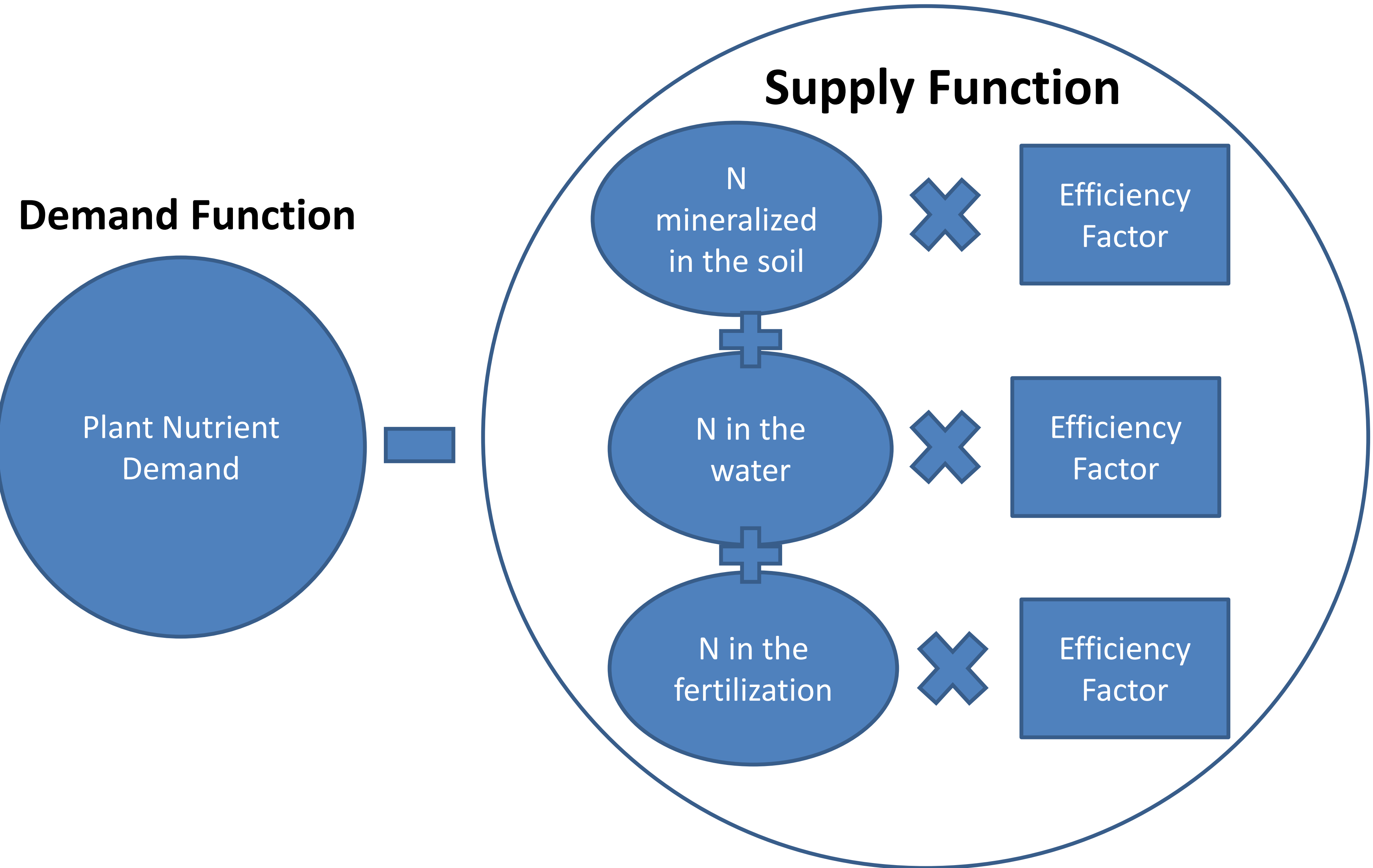


- Increasing N from 275 to 350 lbs N did not increase N removal by fruit.
- In plants receiving adequate N, 68 lbs of N is removed in 1000 lbs kernel yield.
- 80% of crop N is accumulated by 130 days after full bloom.

Right Rate

Sources of N Supply

The Right Rate Equation: Supply Function



Crediting N in Soil: What Controls Decomposition and Mineralization Rates?

Table 11.2
Typical Carbon and Nitrogen Contents and C/N Ratios of Some Organic Materials

Organic material	% C	% N	C/N
Spruce sawdust	50	0.05	600
Newspaper	39	0.3	120
Wheat straw	38	0.5	80
Corn stover	40	0.7	57
Maple leaf litter	48	1.4	34
Rotted barnyard manure	41	2.1	20
Bluegrass from fertilized lawn	42	2.2	20
Broccoli residues	35	1.9	18
Young alfalfa hay	40	3.0	13
Hairy vetch cover crop	40	3.5	11
Digested municipal sewage sludge	31	4.5	7
Soil microorganisms			
Bacteria	50	10.0	5
Fungi	50	5.0	10
Soil organic matter			
Average forest O horizons	50	1.3	45
Average forest A horizons	50	2.8	20
Mollisol Ap horizon	56	4.9	11
Average B horizon	46	5.1	9

Elements of the Nature and Properties of Soils, 3/e by N. Brady and R. Weil

Generally:

- C:N ratio of 20:1 (2% N) is the dividing line between mineralization (immediate release) and immobilization (N binding and later release)
- Most N in added materials becomes available, though it may take several years.
- Long term efficiency of N use from high C:N organic materials in orchards is poorly understood.

Crediting N in Soil: N from Solid Organic Fertilizers

Manure Technical Guide Series
University of California Cooperative Extension

Dairy Manure Nutrient Content and Forms

1. http://manuremanagement.ucdavis.edu/files/134369.pdf

OPTIMIZATION OF ORGANIC FERTILIZER SCHEDULES

Project Leaders:
David M. Crohn and Marsha Campbell Mathews

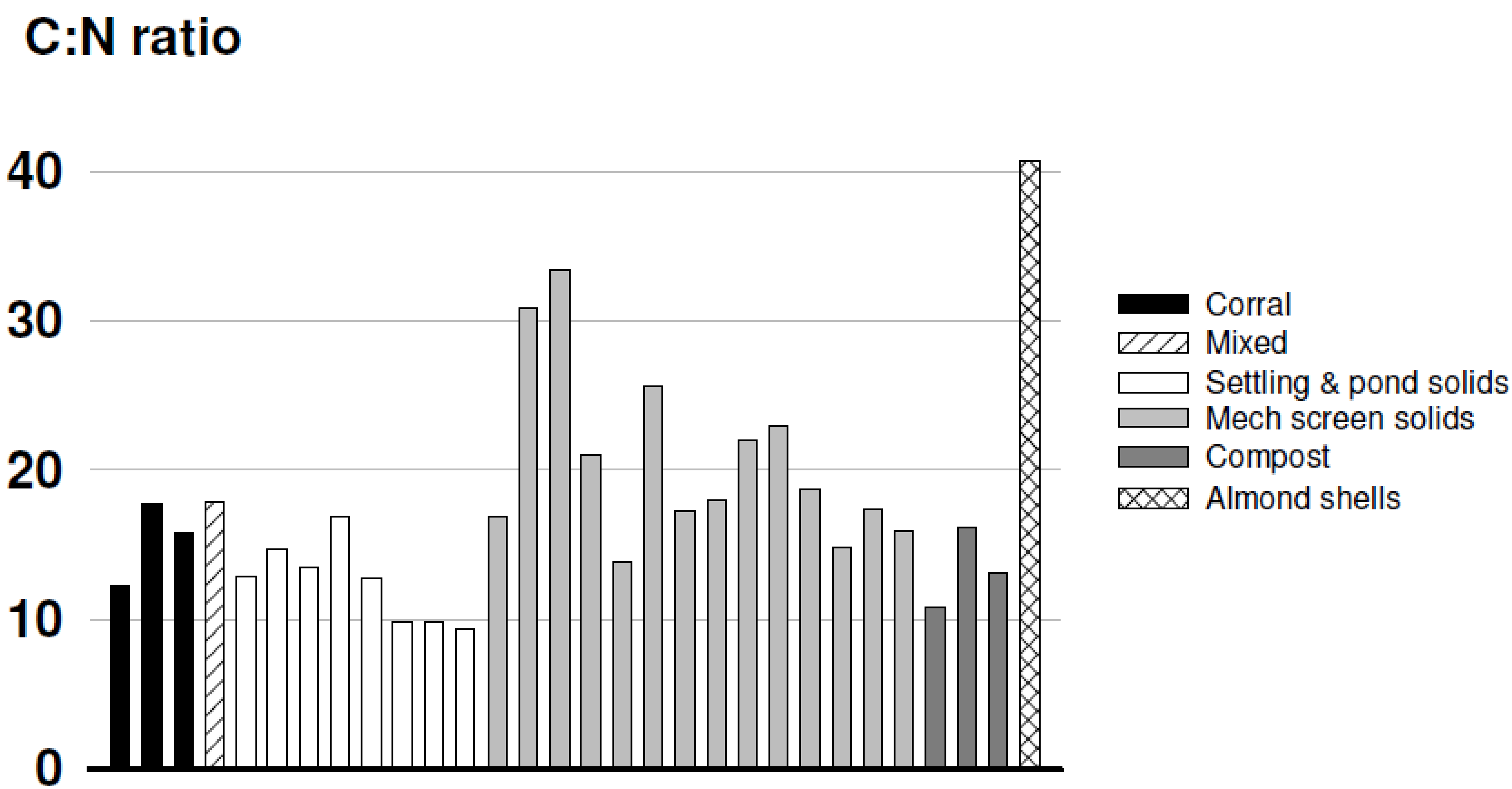
USING DAIRY MANURE AS A NITROGEN FERTILIZER FOR FORAGE CROPS

Marsha Campbell Mathews[1]
David Crohn[2]

2. http://www.cdfa.ca.gov/is/docs/11-0456-SACrohn.pdf

3. http://alfalfa.ucdavis.edu/%2Bsymposium/proceedings/2008/08-159.pdf

Crediting N in Soil: Nutrient Variation in Materials



Steps to Calculate the 'Right Rate'

- Know the tree nitrogen demand based on predicted yield ✓
- Calculate all the N credits ✓
- Calculate the amount of nitrogen still needed ?
- Account for the fertilization efficiency ?

Supply Function: Crediting N in Irrigation 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 or 2.27 ppm Nitrate-N and you apply 48 inches of water

  Answer = 25 lbs N

  But currently we estimate that only 70% of the N in the water will be available, so:

  Answer = 17.5 lbs (25 x 0.7 = 17.5)

Steps to Calculate the 'Right Rate': Example

Example Calculating Remaining N Needed:

- Almond Demand Function: 3,000 kernel produced
  - 3.0 X 68 = 204 lbs N
- Sum of N credits from N in the water = 17 lbs N

Nutrient removal Per 1000 lb Kernels

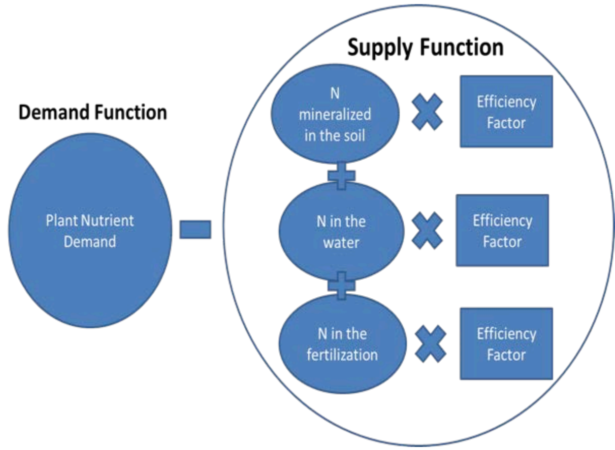
Nonpareil
- N removal 68 lb per 1000

Monterrey
- N removal 65 lb per 1000

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

204 lbs N yield demand
– 17 lbs N supply from irrigation

= 187 lbs N needed by the crop



Nitrogen Use Efficiency

- Regulators will likely set N use efficiency standards at 70%.
  - Feasible in well managed orchards, but easier in some than others.
  - Example: $\boxed{\text{187 lbs N /0.7 = 267 lbs N fertilizer should be applied}}$

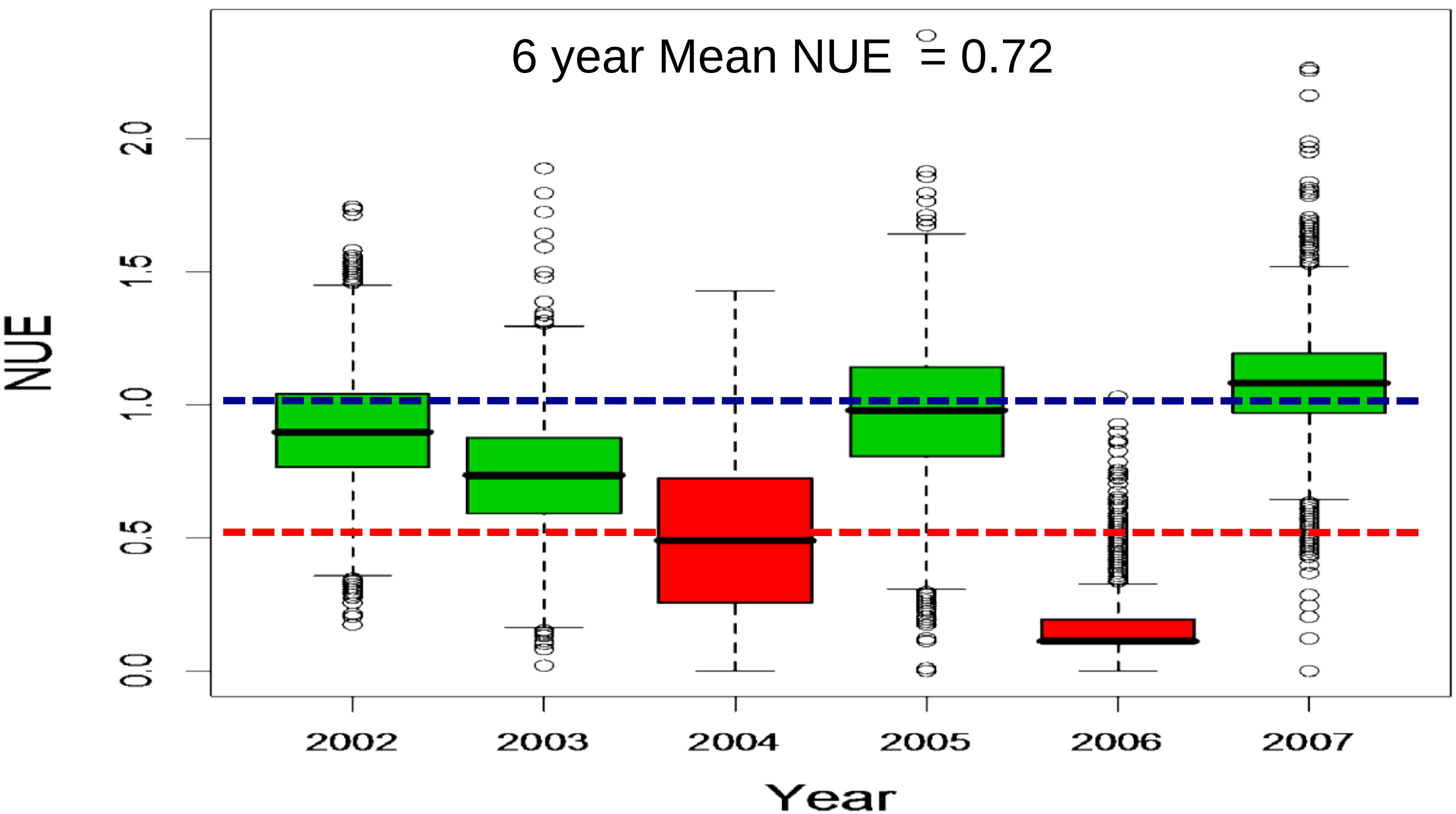
- Efficiency can be reduced by:
  - Poor timing
  - Year to year yield variation (wrong rate)
  - Poor Irrigation uniformity (wrong place)
  - In field or between field variability (wrong rate, wrong place)

Improving Nitrogen Use Efficiency

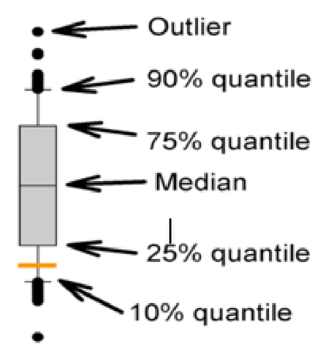
Right Rate

N Use Efficiency: Pistachios

Tree NUE = N removed in harvested fruit / applied N



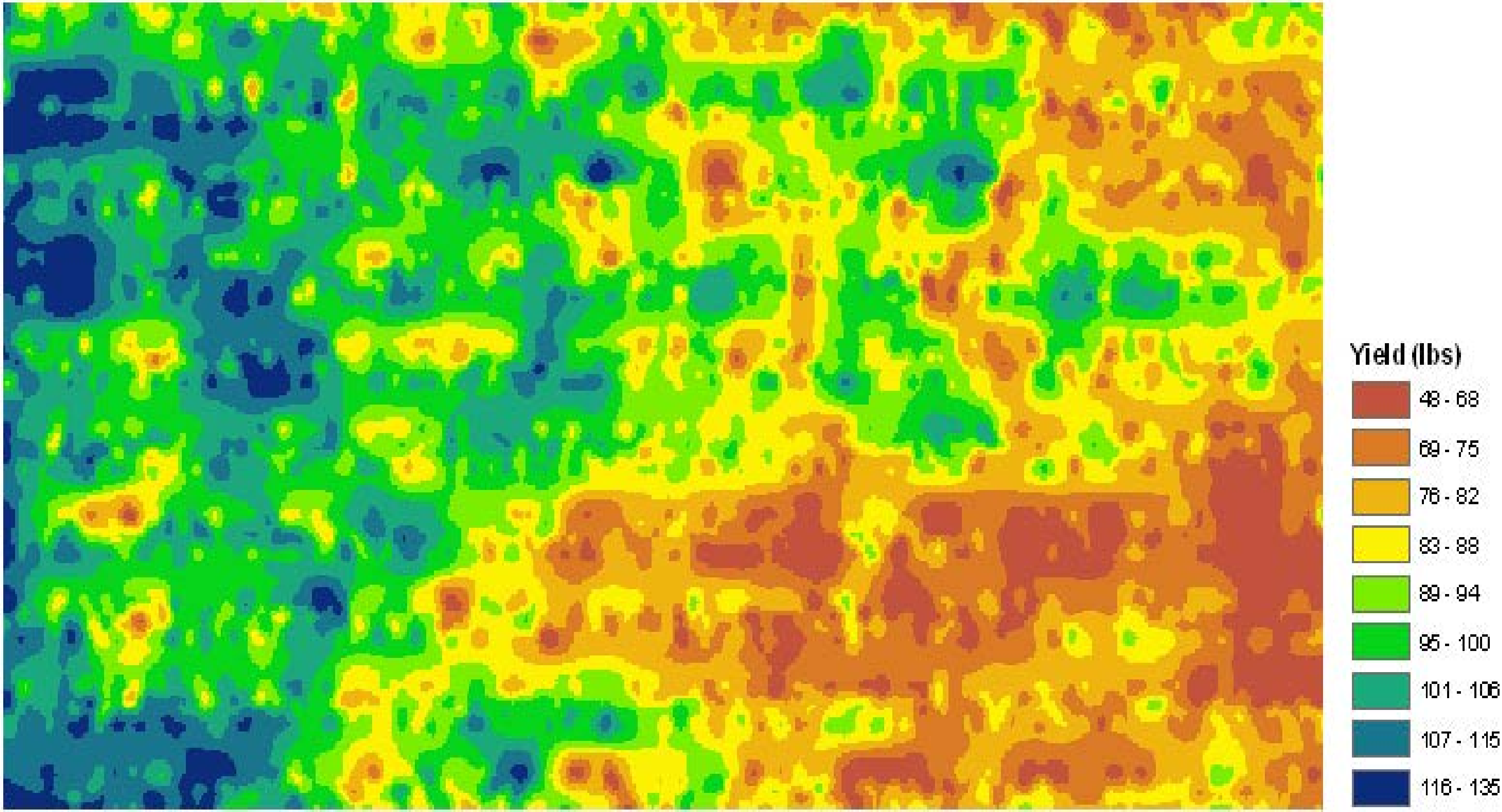
- 42,000 lbs N applied for 6 years to 40 acres
- 26,880 lbs N exported in yield
- 6,000$_{est}$ lbs N pruning, leaves, and growth
- 9,120 lbs N 'lost' 38 lbs N/acre/year



- 24 yo Pistachio, 5 inch rainfall zone, no deep percolation.
- Silt loam, pH 6.7-7.0, OM 0.6%, 2 ppm NO_3N (100cm).
- Fertigated with five in-seasons split apps.
- 10 yr ave yield = 4,000 lb/acre= 112 lb N acre in exported fruit
- Mean N application 175 lb/acre.

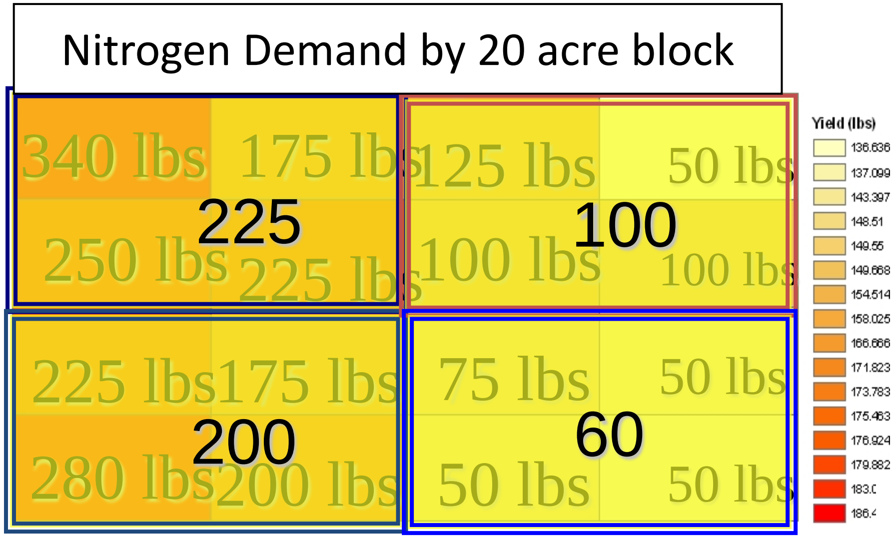
Non-uniform Yield Within Field

Varying yields across 80 acres of Pistachio trees:

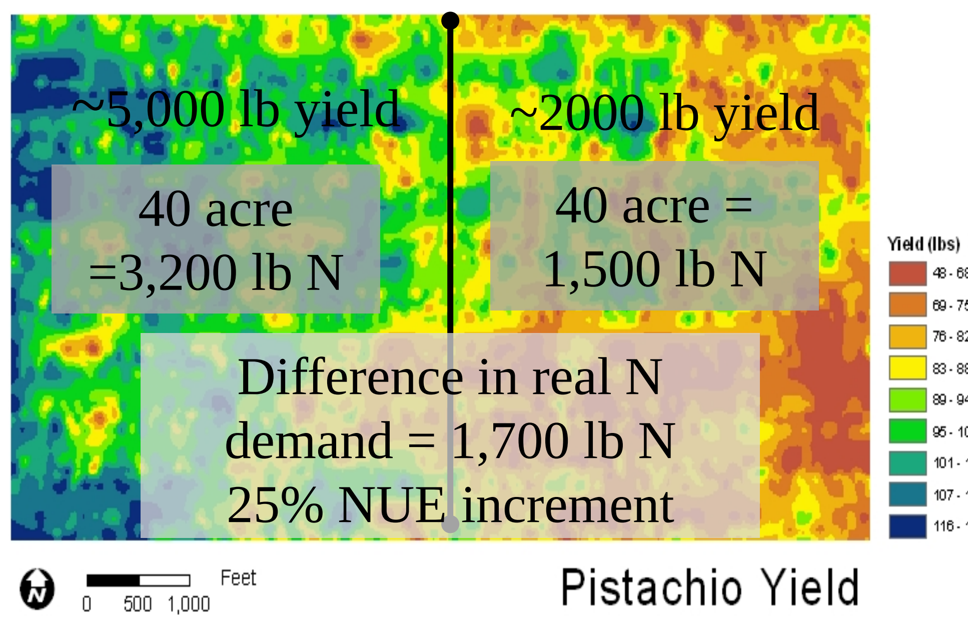


Managed as a single plot, large fields will always be non-uniform and less nutrient-efficient than smaller fields.

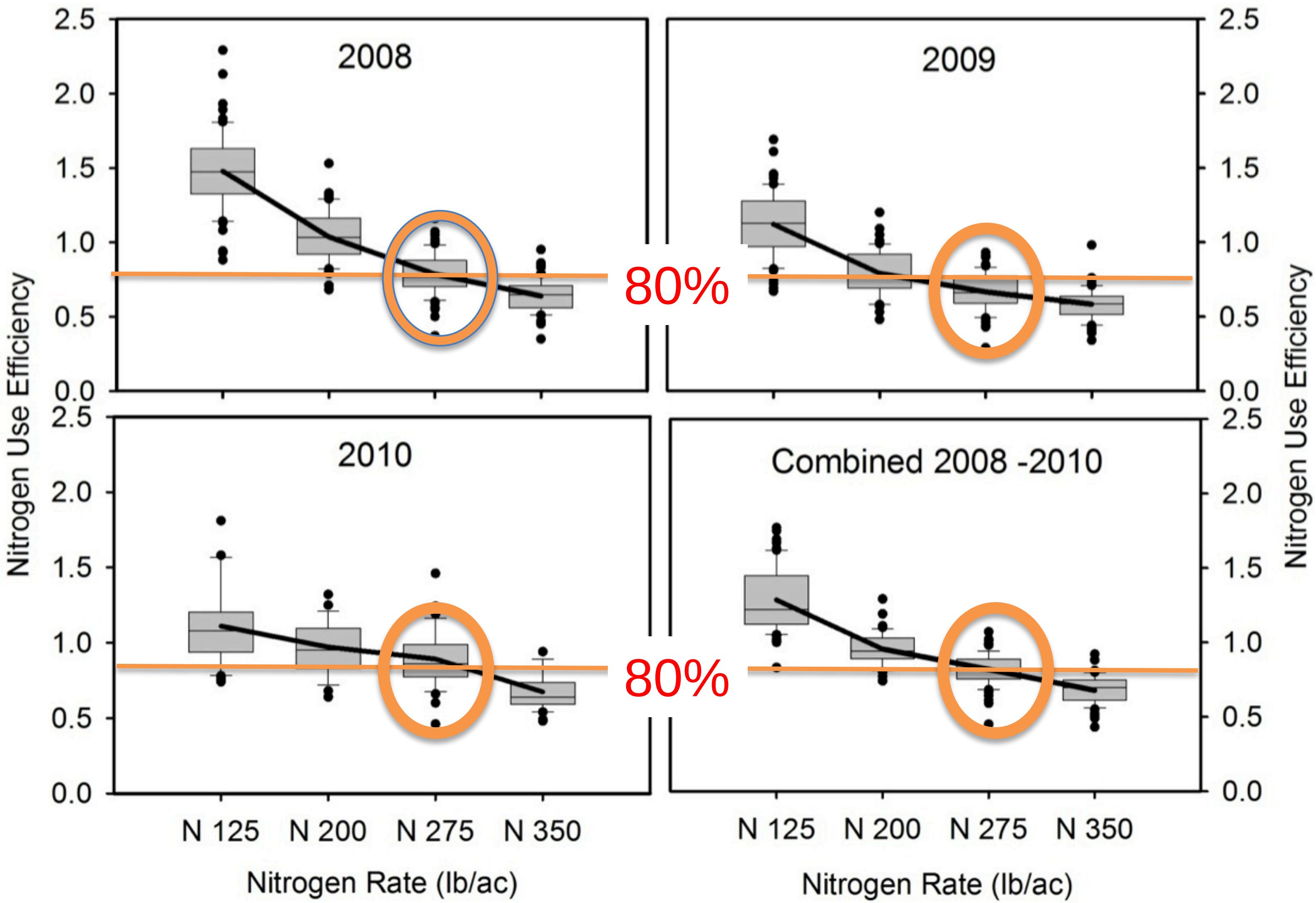
Non-uniform Yield Within Field: Solutions



Whole Field Average N demand = 150 lbs N



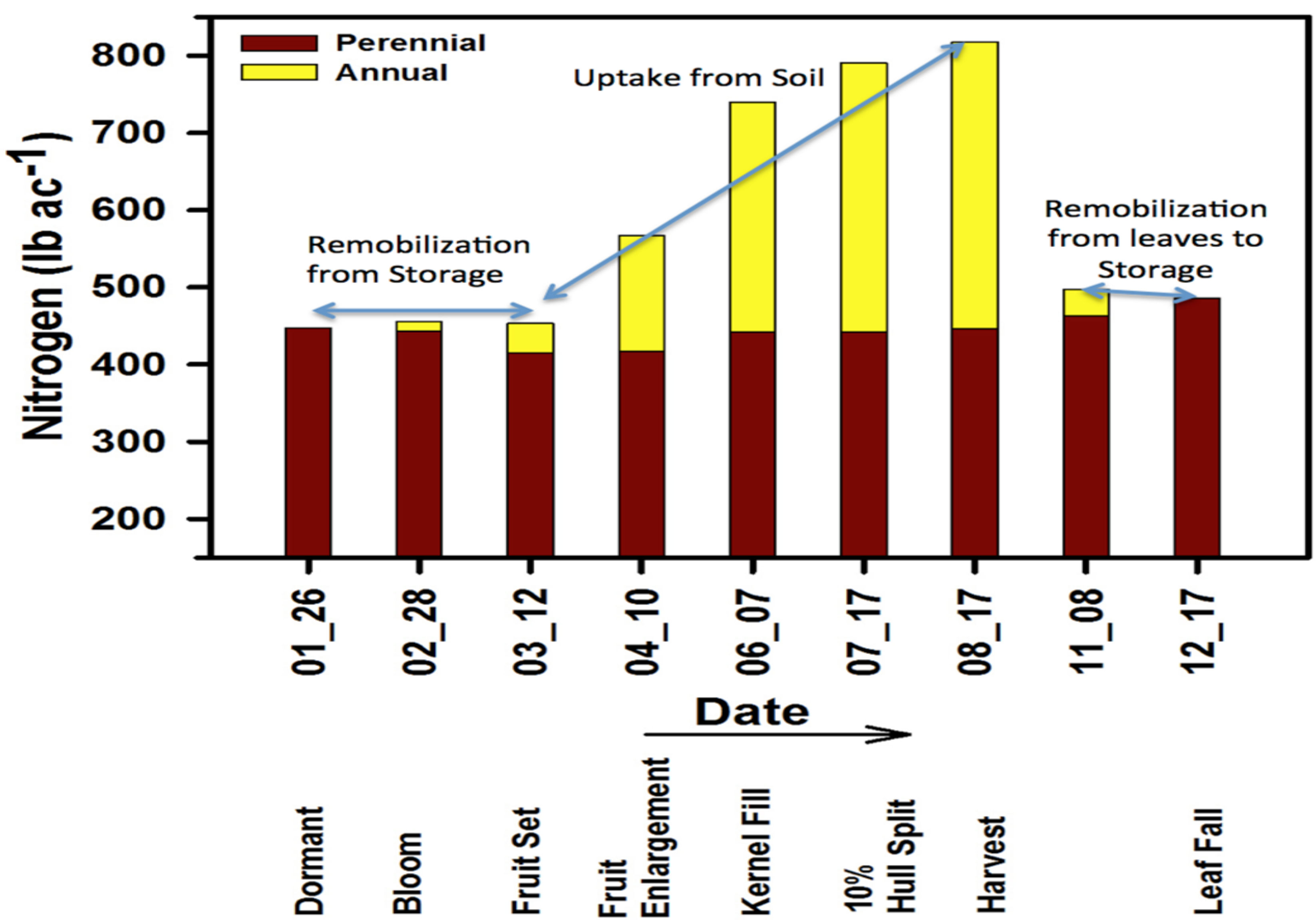
Improved Nitrogen Use Efficiency



NUE = N Export in Fruit/N Applied 70% of 275 = 82: 80% of 275 = 55 or a 40% reduction in lost N

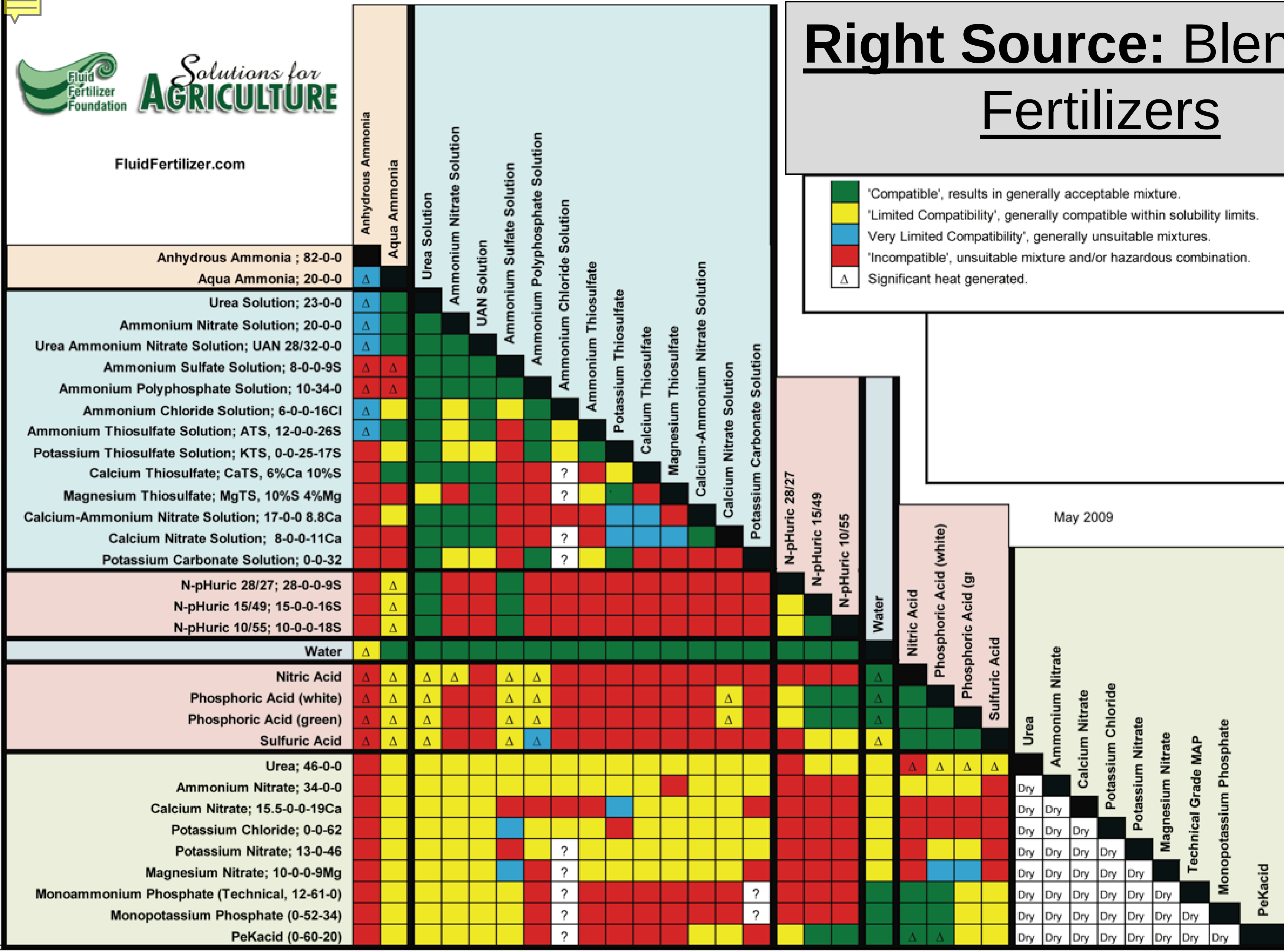
Right Time

Crop N Demand Timing



Right Source

Right Source: Blending Fertilizers



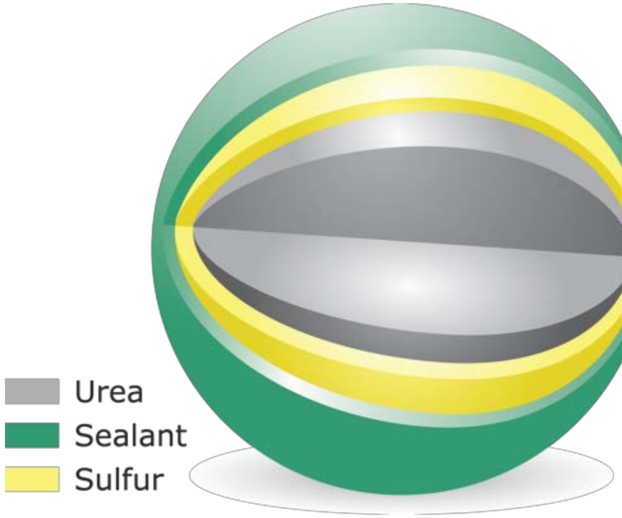
Source: 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, 2012 IPNI

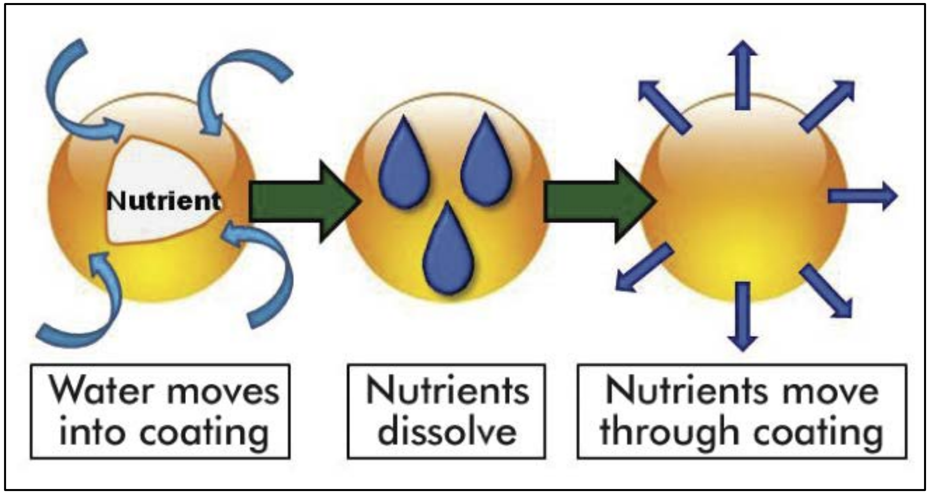
Right Source: Forms of Fertilizer

- New technologies have been developed to improve nutrient stewardship

- Some of the important categories include:

  - Coated fertilizers
  - Slowly soluble fertilizers
  - Inhibitors of biological processes
  - Other nutrient enhancing materials



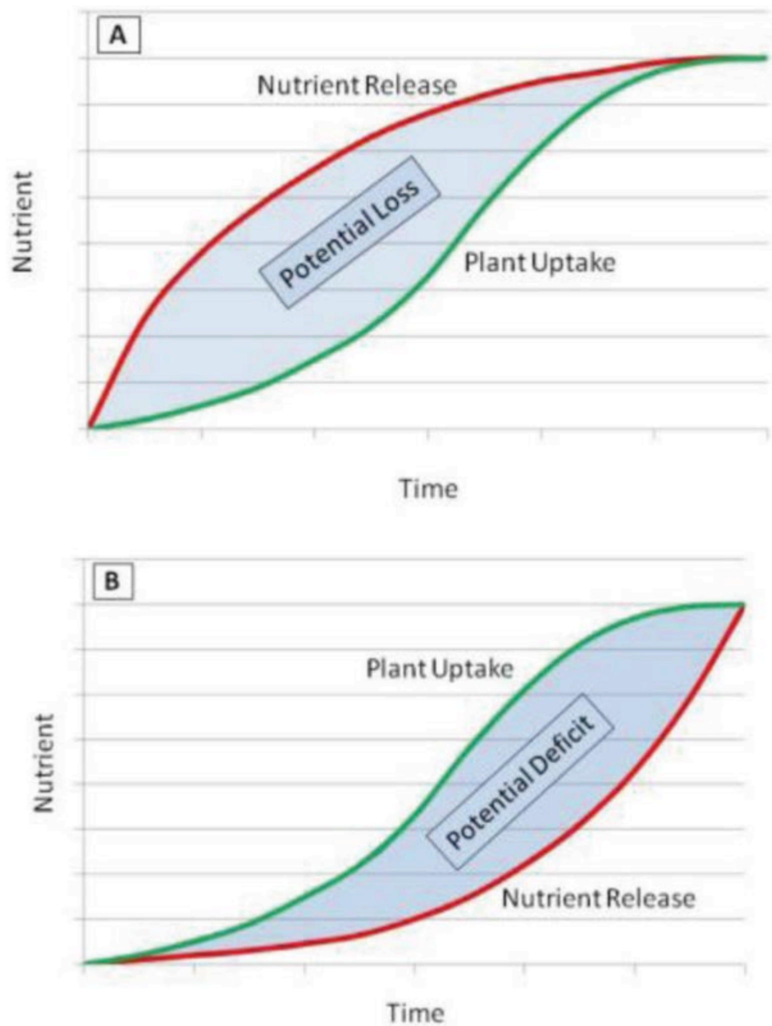


Source: 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, 2012 IPNI

Right Source: Enhanced Efficiency Fertilizer Forms

- Synchronizing nutrient release with plant demand is a challenge with enhanced efficiency fertilizers.

- The same challenge is valid for organic fertilizers.



Source: 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, 2012 IPNI

Right Source: Foliar Fertilizers

BIOLOGICAL RATIONALE:

1) Used to satisfy N needs when demand is extremely high (fruit growth), when application is difficult (wet soils) or risky (rainfall imminent), or when root growth is limited (cold soils, limited transpiration, poor roots post-harvest).

ECONOMIC RATIONALE AND PRACTICAL CONSIDERATIONS:

1) Relative costs and benefits are difficult to assess.
2) Can the need for foliar fertilizers be predicted and the treatment implemented in time?
3) Can a meaningful amount of N be applied?

Right Place

Right Place: Where does N uptake occur?

Crop	Depth of Main Root Feeding Zone (inches)	Reference
Almond	3-18	Olivos et al (2013)
Apricot	3-12	Ghena and Tercel 1962
Cherry	3-15	Tamasi 1975
Peach	0-25	Dziljanov and Penkov 1964b
Plum	1-20	Tamasi 1973
Walnut	0-20	Kairov et al. 1977

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

Leaf Sampling

Leaf Sampling

- July/August leaf sampling is useful to monitor general performance or identify deficiencies but is inadequate as a management strategy
  - Does not provide rate or timing information
  - Too late to respond for current year, too early for next year.
- UCD has developed new Early Leaf Sampling (UCD-ESP) methods for Almond and Pistachio, in Progress for Walnut
  - Useful as a means to determine if leaves will have adequate N for the season
- Several labs have adopted these methods
  - Ask your lab if they use the UCD-ESP program

Leaf Sampling: UCD Early Sampling Protocol

Leaf Collection Method:

- Collect from non-fruiting shoots of 18-28 trees in each mgmt. zone.
- Trees at least 30 yards apart.
- Collect at canopy from at least 20 well exposed leaves/leaflets, 5-7 ft. from the ground.

Timing:

- In April/May, collect samples at 35-45 days after full bloom.
  - Submit to a lab that uses UCD-ESP (almond) or PPM (Pistachio) program
- In July, collect samples using same method as April
  - Use Almond and Pistachio Production manuals to interpret July samples.

Leaf Sampling: UCD Early Sampling Protocol

Fruit Growers Lab: Validation of UCD-Early Season Testing Protocol

Location: Yolo/Colusa County

Collected by: John Edstrom

Sample Number	**Lab Leaf N% 4/11/13**	**Lab Leaf N% 7/10/13**	UCD-ESP PREDICTED **Leaf N in July**	**Difference**
1 (100+105)	3.64	2.55	2.53	-0.02
2 (145 E)	4.41	2.92	2.72	-0.2
3 (145 M)	4.19	2.76	2.66	-0.1
4 (145 W)	4.04	2.82	2.63	-0.19
5 (125)	3.46	2.34	2.48	0.14
6 (710+715)	3.99	2.55	2.61	0.06
7 (720)	3.84	2.67	2.58	-0.09
8 (740)	3.69	2.66	2.54	-0.12
9 (755)	3.99	2.53	2.61	0.08
10 (700+705)	3.96	2.49	2.61	0.12
11 (735)	3.73	2.61	2.55	-0.06
12 (725)	3.8	2.54	2.57	0.03
13 (730)	3.79	2.73	2.56	-0.17
14 (745)	3.97	2.77	2.61	-0.16
15 (750)	4.09	2.43	2.64	0.21

SUMMARY: **UCD-ESP model was within 0.15% in 93% of all samples**
UCD-ESP model was within 0.20% in 100% of all samples

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Contributing Authors:

Patrick Brown, Professor & Pomologist

Sebastian Saa, Postdoctoral Scholar

Daniel Schellenberg, Postdoctoral Scholar

Department of Plant Sciences, UC Davis

University of California

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Course materials available at:

ciwr.ucanr.edu/NitrogenManagement

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