Principles of Nutrient Management in Orchards

Mae Culumber

UCCE Nut Crop Advisor – Fresno County

Young Orchard Irrigation and Nutrient Management Workshop 2025

UC CE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

Nutrient Management Planning

- Increase yields
- Reduce production costs
- Prevent surface and groundwater contamination

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources | Cooperative Extension

14 Essential Elements for tree crops

Macronutrients

- Nitrogen
- Potassium
- Phosphorous
- Magnesium
- Calcium
- Sulfur

Micronutrients

- Zinc
- Boron
- Iron
- Manganese
- Copper
- Chloride
- Nickel
- Molybdenum

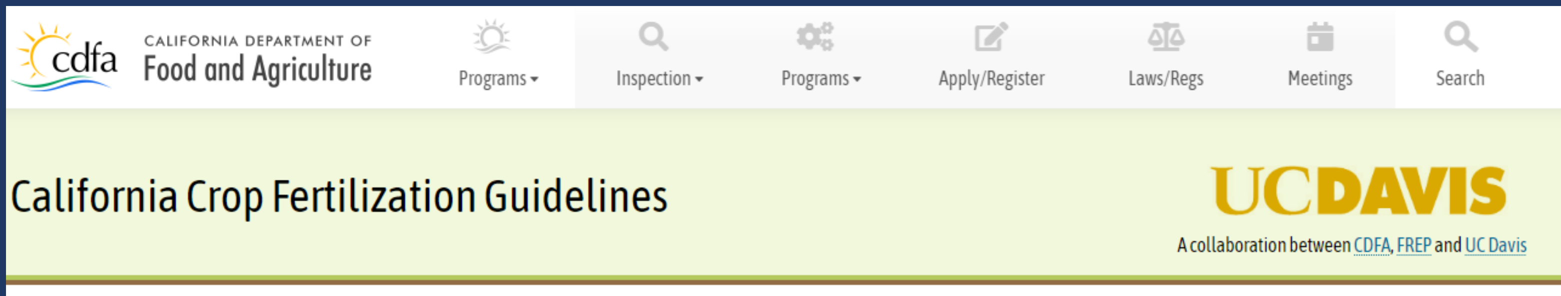
Factors influencing nutrient availability to orchard crops:

- Soil texture and mineral composition
- Nutrient interactions
- Soil organic matter
- Soil pH
- Irrigation water chemistry (nitrates, salts, etc.)
- Fertilizer form and application method
- Irrigation management

Successful nutrient management requires knowledge of :

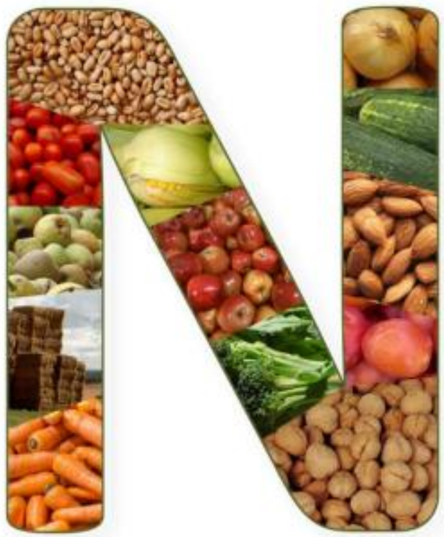
- **Crop requirements**
- Crop uptake patterns
- Nutrient budgeting
- Soil and tissue nutrient analyses
- Proper irrigation management

N,P,K demand per 1000 lbs of crop:



	N	P_2O_5	K_2O
Almonds (kernels)	68	18-20	85-95
Pistachio	28	7	29
Walnut	15	5	7.5
Manzanillo Olive	4	2	8
Peach and Nectarine	1-1.5	0.5	2-2.5

Nitrogen concentrations in harvested plant parts – Update 02/2024



Includes updated values for

- Cotton – Acala
- Cotton – Pima
- Kiwi
- Lemons
- Mandarins
- Nectarines
- Oranges – Navel
- Oranges – Valencia
- Sorghum – Grain
- Perennial parts of cherry and citrus trees

Daniel Geisseler

February 28, 2024

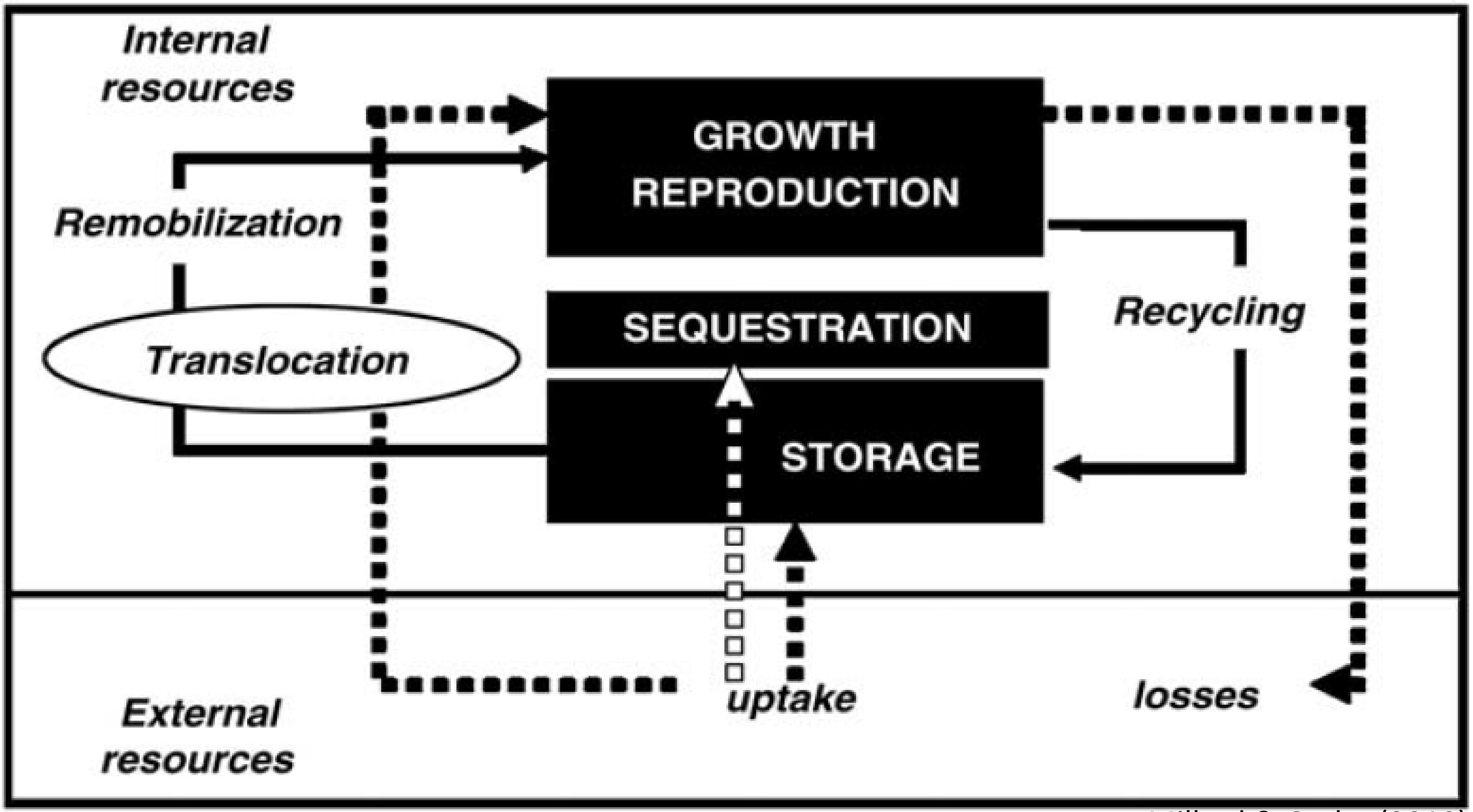
Average N concentrations and observed variability from scientific research and on farm reporting

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Variety: Nonpareil					
Brown et al., 2012; Brown, 2013	California	1	2008	1	4
Brown et al., 2012; Brown, 2013	California	4	2009	1	7
Brown et al., 2012; Brown, 2013	California	5	2010	1	8
Brown et al., 2012; Brown, 2013	California	1	2011	1	4
Brown et al., 2012; Brown, 2013	California	1	2012	1	4
Variety: Monterey					
Brown et al., 2012	California	1	2011	1	4
Overall		**5**		**5**	**31**

http://geisseler.ucdavis.edu/Geisseler_Report_U2_2024_02_28.pdf

Nitrogen accumulation in permanent tissues of trees



Millard & Grelet (2010)

- Deciduous trees cycle nitrogen (N) and other nutrients by **remobilizing** them from the senescing leaves into woody tissue and by **storing** a portion of accumulated nutrients in perennial organs
- ~10-40 lbs/ac each year

N needs for vegetative growth

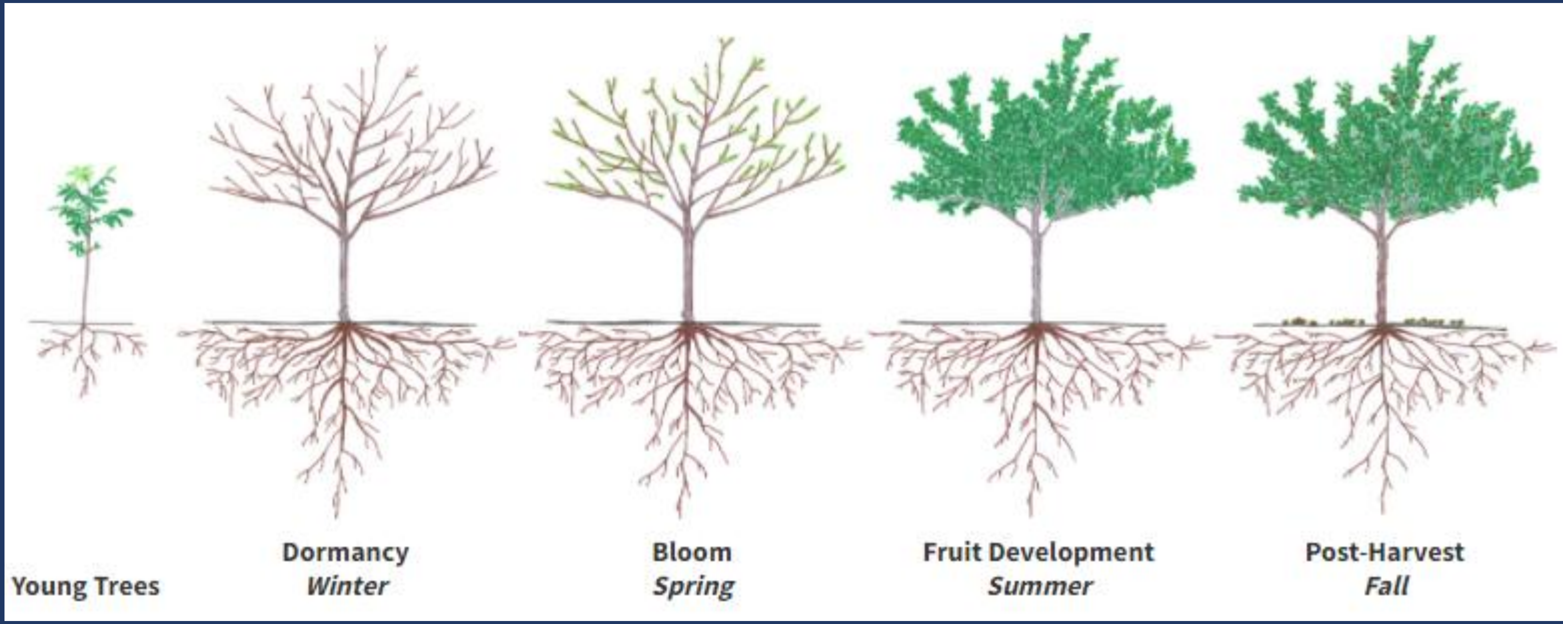
For 2nd leaf or older:

- N needs around 25-30 pounds for vegetative growth
- Needs to be added to crop requirements if yielding under 2000 lbs/acre

Successful nutrient management requires knowledge of :

- Crop requirements
- **Crop uptake patterns**
- Nutrient budgeting
- Soil and tissue nutrient analyses
- Proper irrigation management

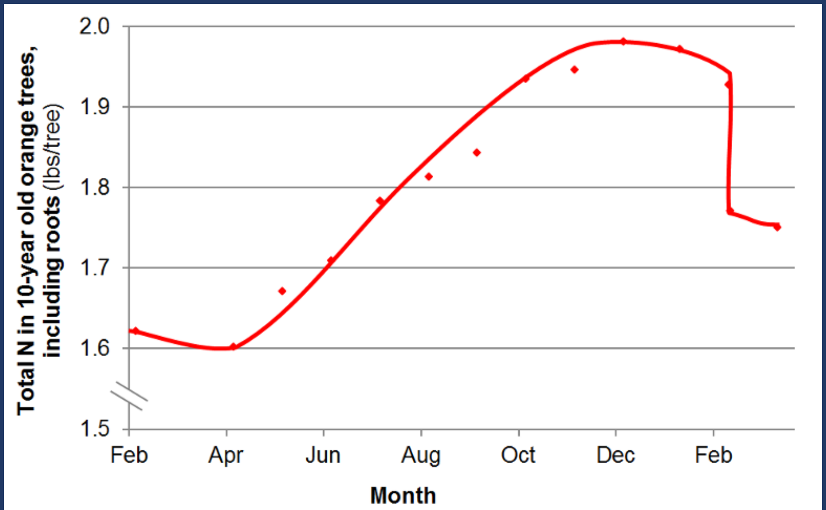
When are nutrients needed?



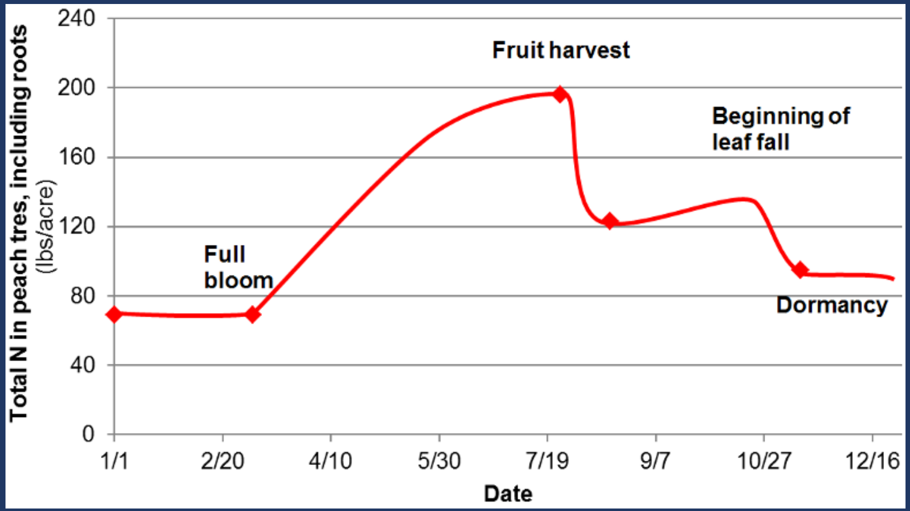
- Deciduous trees store nutrient in canopy branches, trunk, and roots over winter and redistribute during growth in the spring
- Uptake only occurs during active growth beginning after leaf out, highest from onset of shoot growth to late stages of fruit development
- Nutrients are best applied when the trees can use it

Crop Nitrogen Uptake and Partitioning

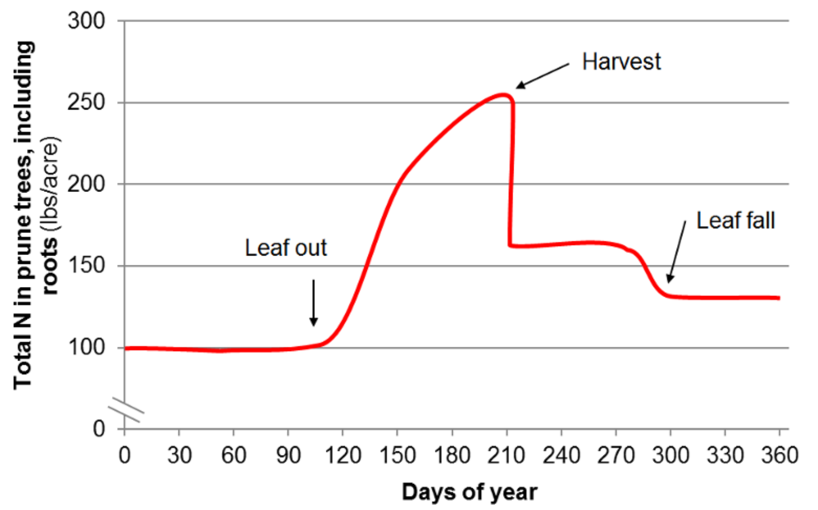
CDFA
CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE



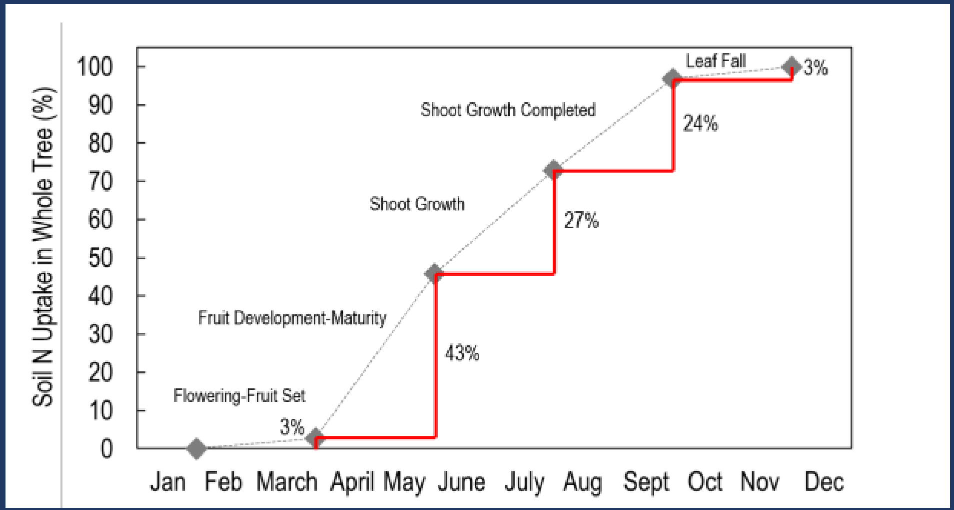
- Citrus (Roccuzzo et al. 2012)



- Peach (Saenz et al. 1997)

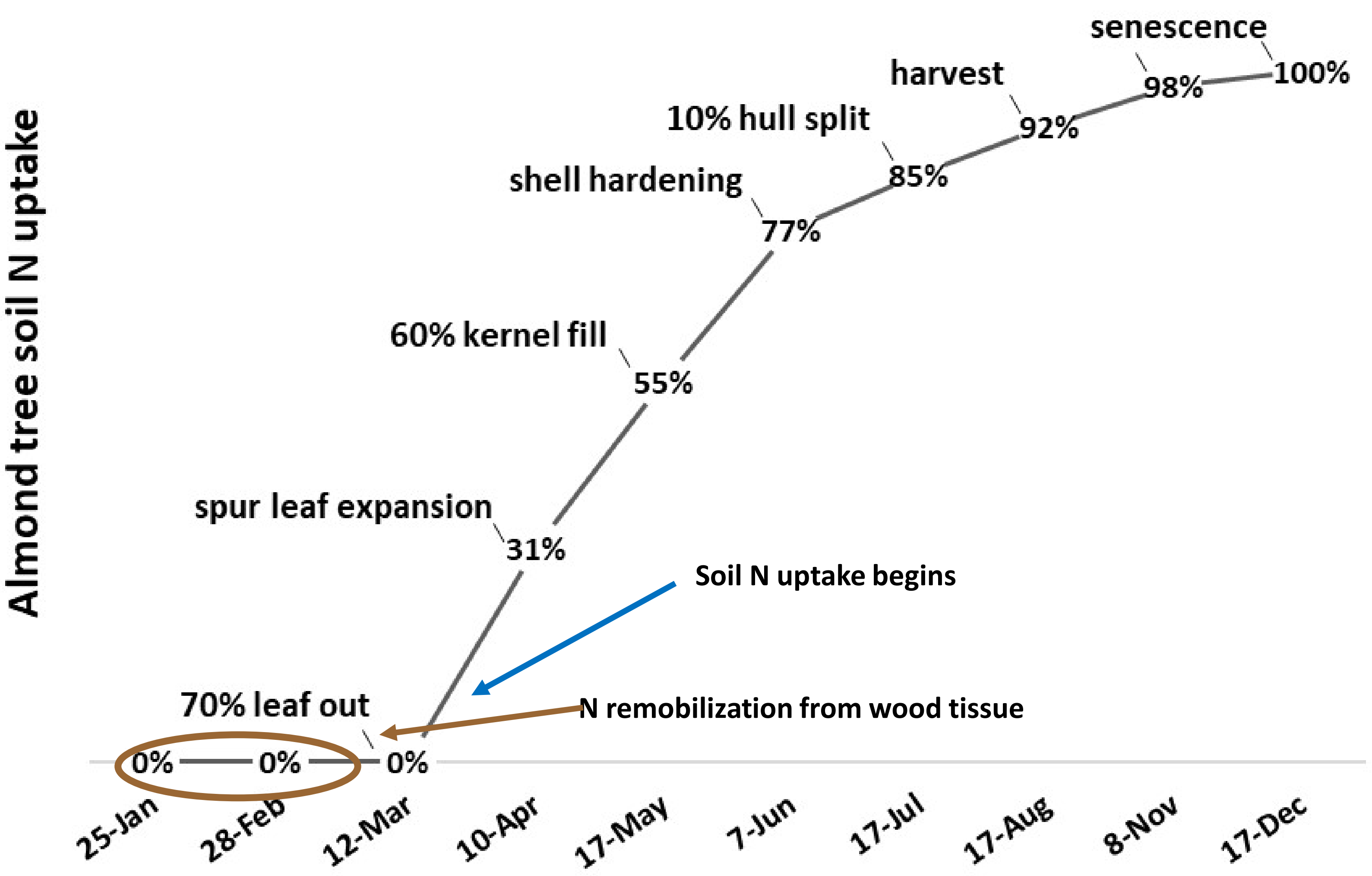


- Prune and Plum (Weinbaum et al. 1994)



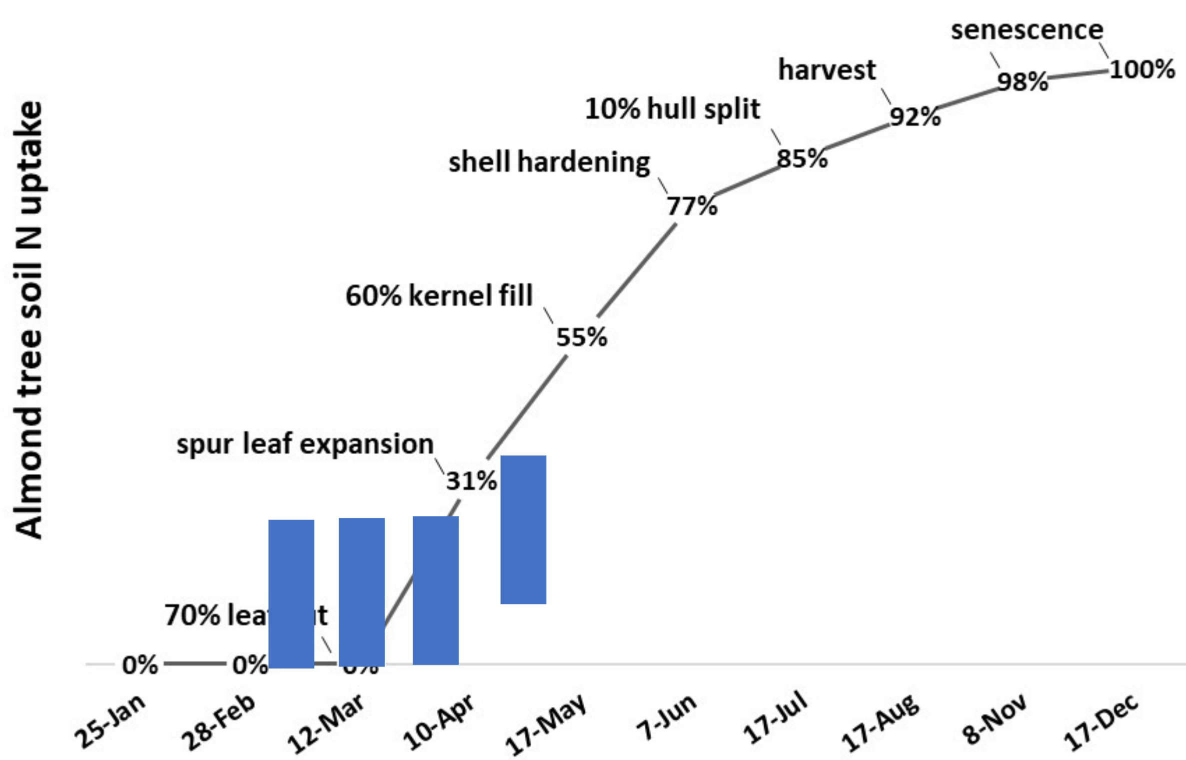
- Sweet Cherries (Brown et al. 2023)

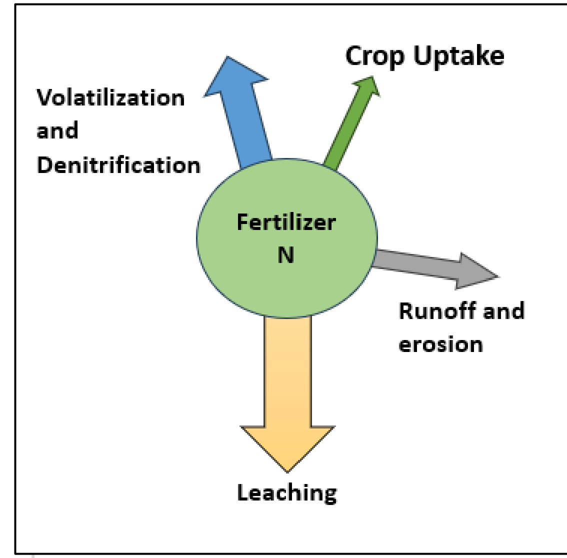
Almond N uptake through the season



Adapted from Muhammad et al. 2020

Common Fertigation Approach



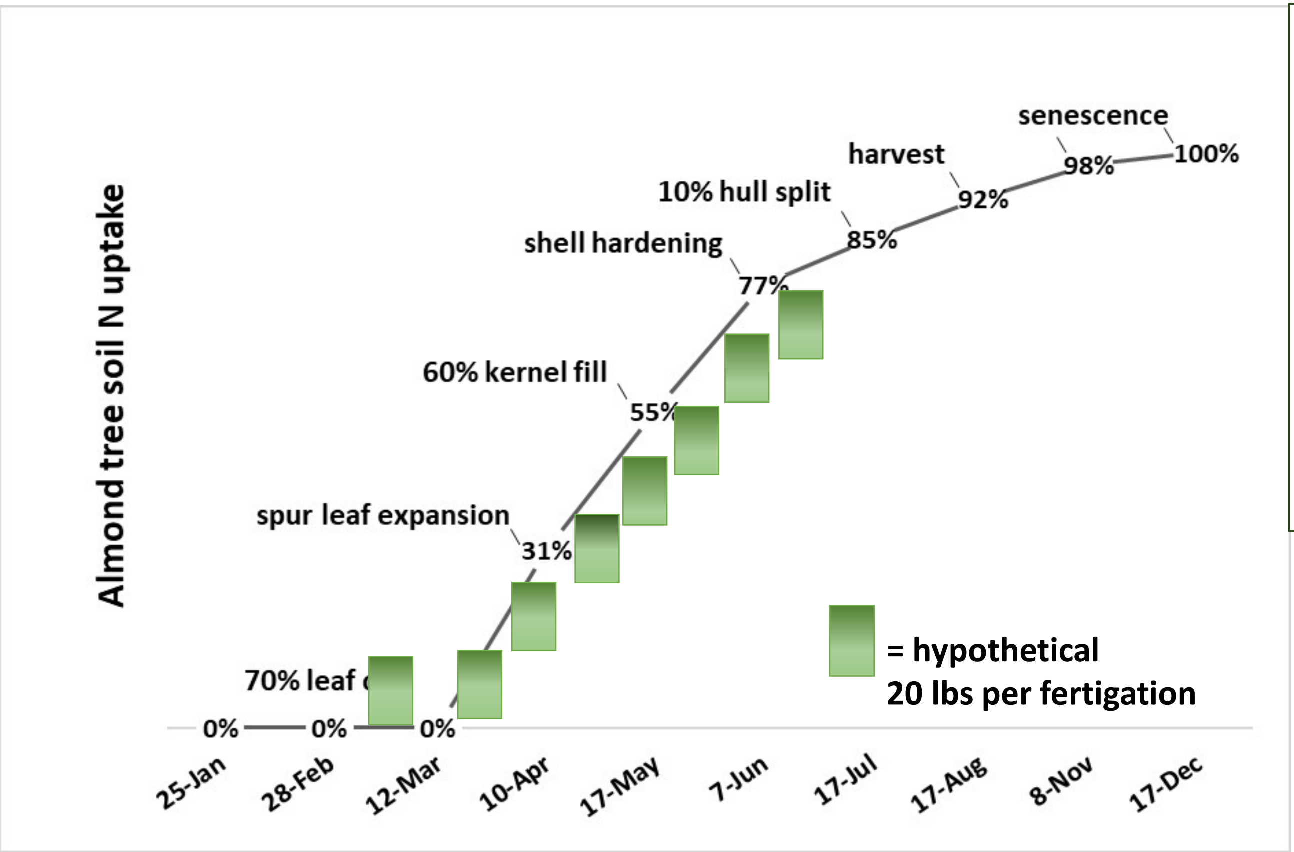


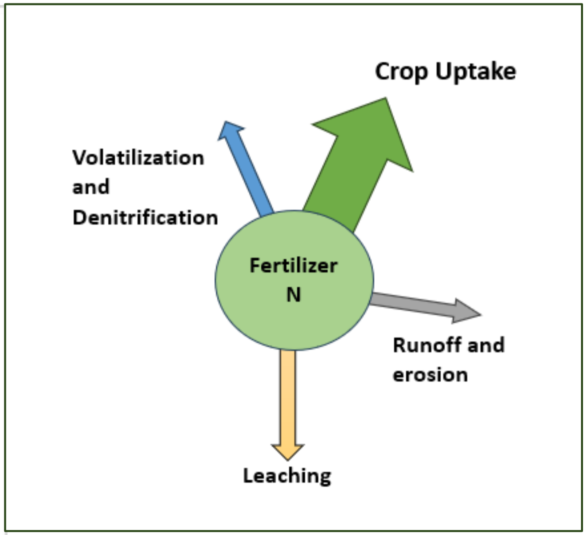
high concentrations exceed what can be absorbed by tree roots

= hypothetical 50 lbs per fertigation

Too early and too much in a single set increases leaching potential

Match N applications with tree uptake





High frequency low concentration (HFLC) fertigation increases nitrogen use efficiency (Baram et al. 2016)

By 101–126 DAFB, kernels have gained 60–70% of their total weight, then rate of fruit N accumulation decreases (Muhammad et al. 2020)

Successful nutrient management requires knowledge of :

- Crop requirements
- Crop uptake patterns
- **Nutrient budgeting**
- Soil and tissue nutrient analyses
- Proper irrigation management

Initial N budget and adjustment

- Estimate demand:
  - Last year’s yield, this year’s estimated yield, tree age
  - account for N inputs (fertilizer, water, soil, amendments, cover crops)

  Adjustments:
  - Revised yield estimate and leaf sampling

Source of N in irrigation water

Nitrate-nitrogen (NO^3-N) in the water:

N (lbs/acre inch) = NO^3-N concentration (ppm) *0.23

Acre inches applied	3 PPM	5 PPM	10 PPM	15 PPM
1	0.7	1.15	2.3	3.45
6	4.1	6.9	13.8	20.7
12	8.3	13.8	27.6	41.4
24	16.6	27.6	55.6	82.8
48	33.2	55.2	112	166

Example: 36 inches of 10 ppm water applied through the season = 82.8 lbs/season, @80% efficiency 66 lbs/season

Example N budget for Almond

N source	N budget for 2500 lb Cropload
Crop N removed	2.5*68=**170**
Vegetative growth N	**30**
Total N requirement	**200**
N credits: 66 lbs N irrigation water @ 80% NUE	-66
Net Crop N requirement after credits	134
Total fertilizer N for the season to apply (80% NUE)	**(147/0.80) =168**

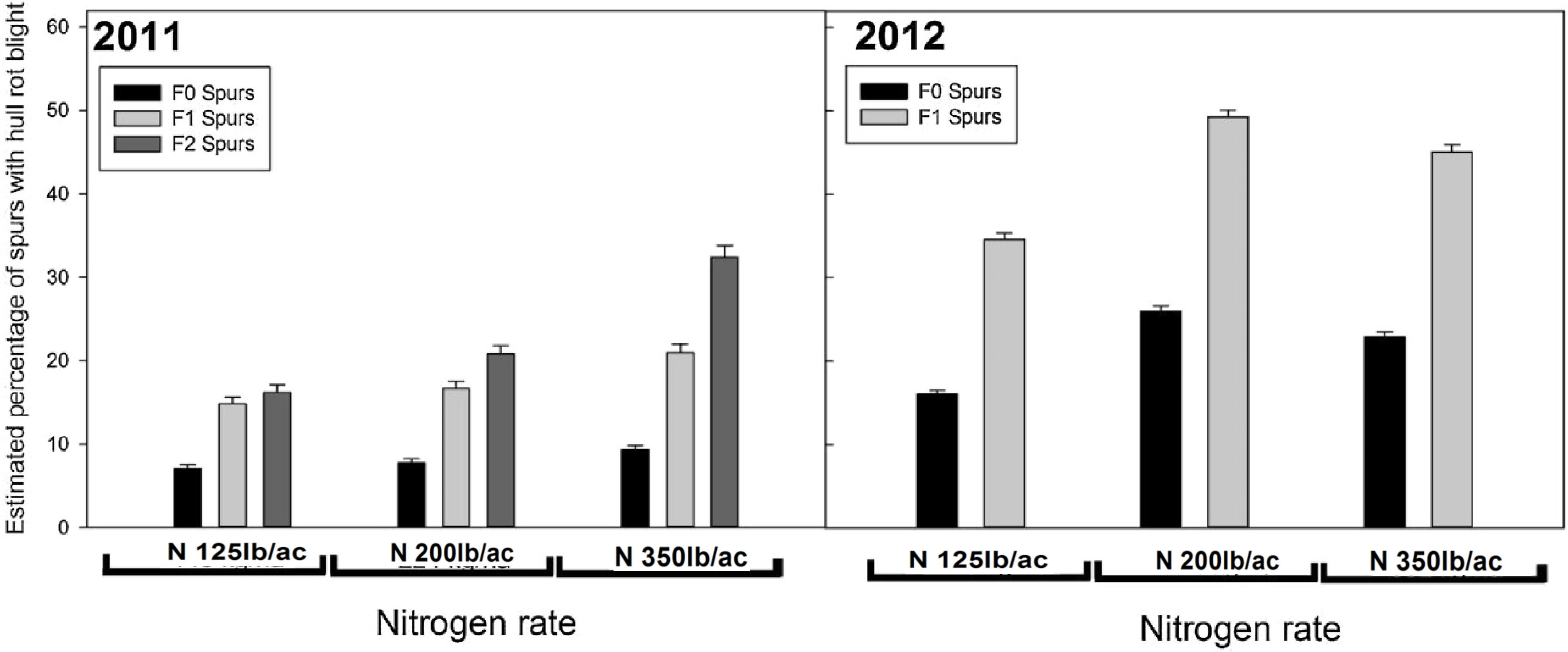
Partition 195 lb/ac rate N fertigation through growth stages

Crop development stage	~days after full bloom (DAFB)	~month in growing season	% of season N applied	# fertig.	Lbs per fertigat ion
Stage 1: (70% leaf expansion through fruit enlargement)	30-55	Mid-March to Late-April	30%	4	15
Stage 2: (Shell hardening and kernel fill)	55-110	Late-April to Mid- June	55%	5	21
Stage 3: (Initiation of hull split to 3 weeks post-harvest)	110-190	Mid-June to late-September	15%	2	15

BE CONSERVATIVE: Many little feeds are better than slugs
Prevents over fertilizing trees and reduces leaching potential

Problems with excess N

Almond hull rot incidence with increased N:



F0, F1, F2 = Zero, Single, and Double Fruited Spurs. (Saa et al. 2016)

- Concentrations above adequate levels may not increase yield, but can increase fertilizer costs and hull rot

Potential Consequences of Large Applications

- 50 lbs N /ac shanked into soil followed by flood mid-April, scorched mature almond canopy
- Too much in a single shot can burn tree roots and leaves, and cause nut drop

Nutrient mobility in soil

Mobile	Intermediate	Immobile
N, S, B, Mn, Cl	K, Ca, Mo, Ni	P, Mg, Cu, Fe, Zn

- Zn, Cu, and Fe have restricted solubility and movement
- Soils that limit root growth can cause Zn, Fe, Cu deficiencies
- Nutrients and roots must be in the same place
- Root exploration and ‘soil health’ is critical

Soil fertility guidelines for potassium (K^+)

Fertility Level	Extractable K (ppm)
Very Low	< 75
Low	75 -150
Medium	150 – 250
High	250 -800
Very High	> 800

- K can undergo exchange reactions with other nutrients, be fixed to clay minerals, or leached with irrigation water
- Ammonium acetate test considered best indication of available K^+
- Levels below 150 ppm are considered low and trees are likely to respond to fertilization

K fertilization through almond growth stages

Partition 200 lb K_2O/ac rate

Crop development stage	month in growing season	% of season N applied	lbs per acre (K_2O)
Stage 1: (70% leaf expansion through fruit enlargement)	Mid-March to Late-April	20%	40 (KNO_3, KTS, K_2SO_4 through drip)
Stage 2: (Shell hardening and kernel fill)	Late-April to Mid- June	30%	60 (through drip or applied as foliar, 5-10 lb/application)
Post Harvest/dormancy	Mid-June to February	50%	100 (banded SOP needs rainfall or irrigation)

Sandy soils with lower exchange capacities need multiple smaller applications throughout the year

Foliar applications

- overcome soil chemical or physical conditions that prevent nutrient uptake
- provide targeted nutrients to prevent short term deficiencies during reproductive growth, or periods of peak demand
- Commonly used for N, K^+, Zn+, Fe+ and other micronutrients

Zinc and Boron

- Both absorbed through leaves, stored overwinter, and moved to the buds for use at almond bloom
- Apply 1-2 lbs. solubor/ac in 100 gallons and 5 lbs zinc sulfate in 100 gallons in October
- Foliar zinc also effective at early leaf out and boron pre-bloom
- To correct a very B deficient orchard, a combination of foliar, drip, and soil applied B fertilizer may be needed.
- Tank mixes of Zn and B: Acidify the spray solution* to pH 5 before adding zinc then B

Online Tools:

- CropManage https://cropmanage.ucanr.edu/
- CDFA FREP website for orchard crops https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/
- UC Davis Fruits and Nuts website https://fruitsandnuts.ucdavis.edu/

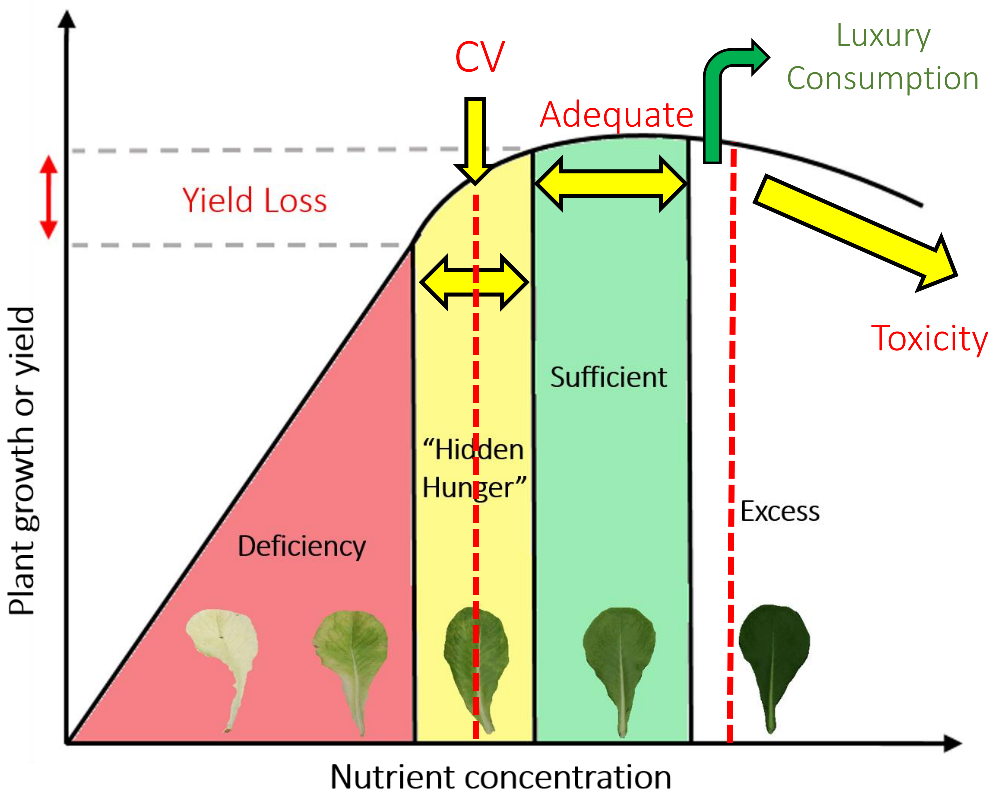
Successful nutrient management requires knowledge of :

- Crop requirements
- Crop uptake patterns
- Nutrient budgeting
- **Soil and tissue nutrient analyses**
- Proper irrigation management

Tissue analyses: show hidden toxicities and deficiencies when visible symptoms are not present

WARNING

Element	Critical value	Adequate range
nitrogen (N)	1.8%	2.2–2.5%
phosphorus (P)	0.14%	0.14–0.17%
potassium (K)	1.6%	1.8–2.2%
calcium (Ca)	2.0%	2.1–4.0%
magnesium (Mg)	0.45%	0.5–1.2%
sodium (Na)	—	—
chlorine (Cl)	—	0.1–0.3%
manganese (Mn)	30 ppm	30–80 ppm
boron (B)	90 ppm	150–250 ppm
zinc (Zn)	7 ppm	10–15 ppm
copper (Cu)	4 ppm	6–10 ppm



Slide: Doug Amaral

A collaboration between:

cdfa FREP UC DAVIS UNIVERSITY OF CALIFORNIA

Plant Tissue Sampling in Orchards and Vineyards

Patricia Lazicki and Daniel Geisseler

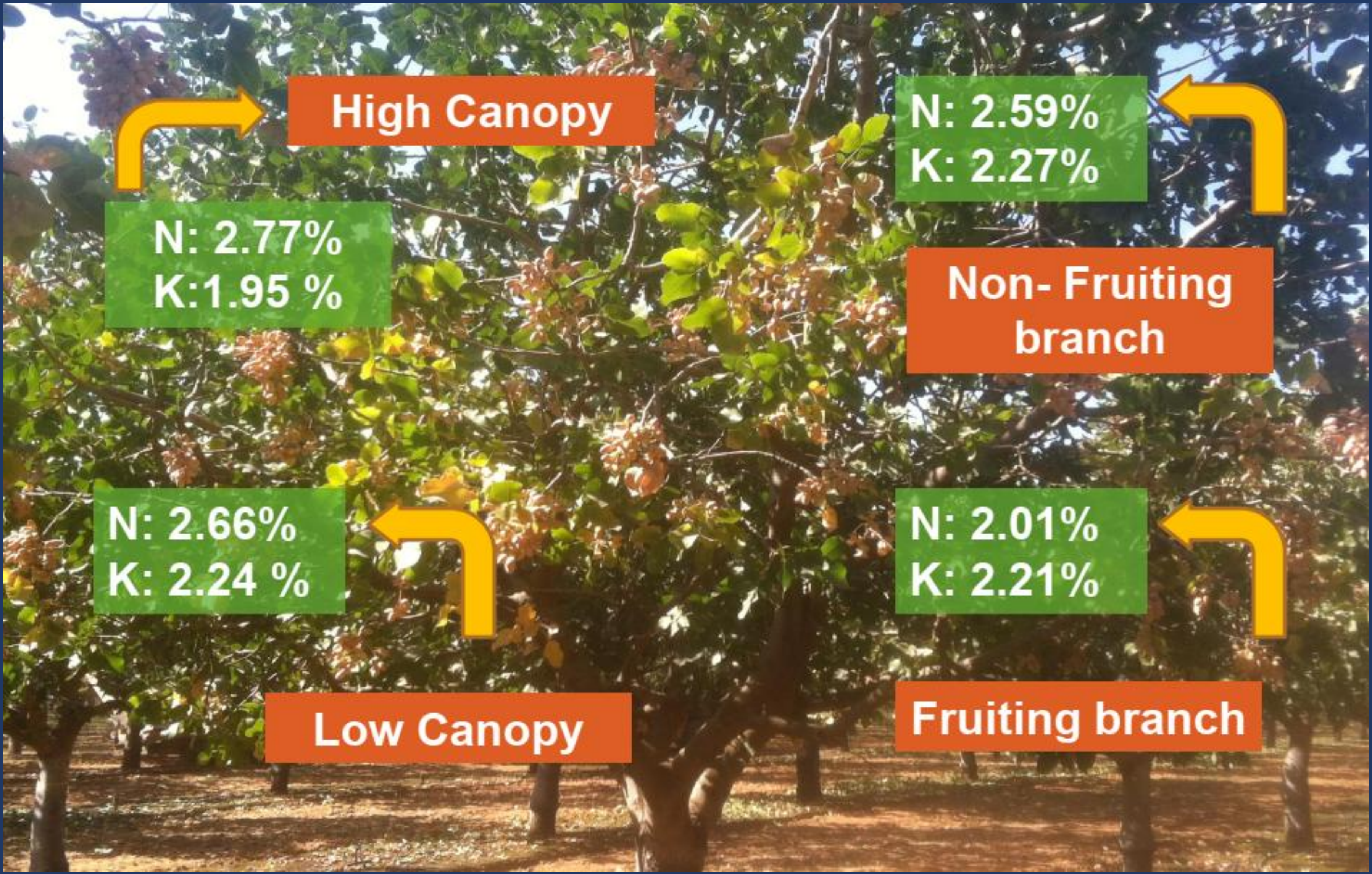
Table 1: Sampling procedure for California orchard and vineyard crops

Plant	Sampling date	Plant part	Plants to sample	Total parts needed	Notes
Almond (spring)	36-48 days after full bloom	Leaves from non-fruiting, well-exposed spurs 5-7 feet above the ground	18-28 trees (>30 yards apart)	Leaves from 5-8 spurs per tree	Tested with Nonpareil almonds. Predicts all nutrients in July leaves (traditional method uses the same sampling protocol). Boron status better correlated with hulls of mature almonds at harvest.
Avocado	Aug-Oct	Terminal leaves from non-flushing, non-fruiting spring flush shoots (5-7 months old), 3-5 feet above the ground	>10 trees per block	4 leaves per tree (one from each quadrant)	Avocado leaf testing methods adapted from citrus. Currently not very reliable. Combine with tree vigor observations.
Citrus	Sept-Oct	Terminal leaves from non-flushing, non-fruiting spring flush shoots (5-7 months old), 3-5 feet above the ground	>10 trees per block	4 leaves per tree (one from each quadrant)	Recommended block size 5-10 acres
Grapevine	Full bloom	Petioles of leaves opposite flower clusters	25-50 vines	One or two petioles per vine	Petiole nitrate varies widely between rootstocks and varieties. Analyses are best used in combination with observations of tree vigor.
Olive	July	Mature mid-shoot leaves from non-fruiting, current-season shoots	30-40 trees	80-100 leaves	Deficiencies uncommon; N may not need to be tested annually if normally sufficient
Peach and Nectarine	Jun-Jul	Mid-shoot leaves from moderately vigorous current-season shoots	30-50 trees	60-100 leaves	
Pistachio (spring)	30-45 days after full bloom	Leaves from non-fruiting, exposed branches 6-7 feet from the ground	At least 18 trees, (>25 yards apart)	10 leaves per tree	Used to predict summer N and K levels. Pistachios are susceptible to K deficiency; samples may need to be taken every year.
Pistachio (summer)	Jul-Aug	Fully expanded sub-terminal leaflets from non-fruiting branches, ~6 feet from the ground	10- 20 trees	4-10 leaves per tree	Traditional sampling time for all nutrients. Spring analyses can predict summer N and K.
Prune and plum	July	Fully expanded leaves from non-fruiting spurs 5-7 feet above the ground	>25 trees per block	One or two leaves per tree	Recommended maximum block size 40 acres. Prunes are susceptible to K deficiency; samples may need to be taken every year.
Walnut	Jun-Jul	Terminal leaflets from fully expanded spur leaves, 5-8 feet above the ground, from around the tree	5-10 trees	50 leaves	

Sources: Almond [7,13], avocado [3,8], citrus [8], grapevine [8], olive [9], peach and nectarine [9], pistachio [2], prune and plum [11], walnut [1].

- Crop
- Sampling date
- Plant part to sample
- Quantity needed

https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/pdf/Orchard_Tissue_Sampling.pdf


High Canopy
N: 2.77%
K:1.95 %
N: 2.59%
K: 2.27%
Non- Fruiting branch
N: 2.66%
K: 2.24 %
N: 2.01%
K: 2.21%
Low Canopy
Fruiting branch

Leaf Sample Critical Values - Mature Almond

	N %	P %	K %	Boron (Hull) ppm	Zn ppm
Adequate	2.2 – 2.7	0.10 – 0.3	>1.4	80-150	>15
Excessive	>2.7		>1.6 - 1.8	>200	

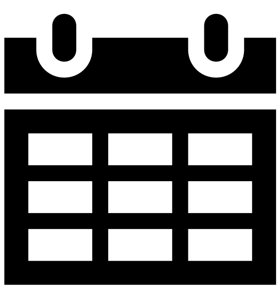
- Early season (43 days post full bloom) 3.5% N
- Mid-summer analysis important to make determinations about end of season fertility management, and next seasons nutrient management plan
- Can also help determine if foliar applications are necessary to rapidly correct deficiencies

Soil Analyses for Nutrient Management Planning

- Determine what portion of the nutrient pool is plant-available, but don't generally measure the quantity of nutrients available to a crop
- Important to use a combination of both soil, tissue, and water analyses to estimate fertility needs

Sample timing

- Soils should be analyzed often enough to recognize potential nutrient management issues before they adversely impact plant growth
- Nitrogen management: annual in spring or every 3 years minimum
- Salinity reclamation: annual in fall



Soil Analytical Report

Sample ID: 33598 - 1 | Date Received: 8/8/2024 | Report Date: 8/13/2024

Field: North Fancher Dead | Depth: 0-12 | Crop: Almonds

Analyte	Result	Desirable	Flags
Salinity (Water Extraction)			
pH (Sat Paste)	7.38	6.5-7.5	
EC (dS/m)	1.49	< 2	-
Ca(meq/L)	10.20		
Mg (meq/L)	6.96		
Na (meq/L)	1.89		
Cl (meq/L)	0.47	< 10	-
HCO3 (meq/L)	2.63		
K_Sol (meq/L)			
SO4 (meq/L)	17.50		
SAR	0.65	< 5	-
B (mg/L)	0.01	< 1	-
Sat %	24.4		
Exchangeable Cations (Ammonium Acetate)			
TEC (meq/100g)	8.46		
Calcium (ppm)	1240		
Magnesium (ppm)	187		
Potassium (ppm)	100		
Sodium (ppm)	24		
Base Saturation (%)			
Calcium (%)	73.1	65-75%	
Magnesium (%)	18.2	10-15%	+
Potassium (%)	3.0	2-5%	
Sodium (%)	1.2	0-2%	
Hydrogen (%)	0.0		
Other Bases (%)	4.0		
Nutrients (ppm)			
Sulfate-S (ppm)	68.4	6 - 12	+ +
Nitrate-N (ppm)	7.8	10 - 15	-
Phosphate-P(ppm)	9.4	7 - 25	
Zinc (ppm)	5.3	2 - 4	+
Iron (ppm)	14.0	10 - 20	
Copper (ppm)	2.5	0.8 - 1.6	+
Manganese (ppm)	8.6	12 - 24	-
Organic Matter (%)	1.0	1 - 3	-
Limestone	0.15	(%)	
Total Nitrogen		(ppm)	
Gypsum Req.	0.00	(tons/acre)	

Flags: NA = Not Analyzed - - = Very Low - = Low + = High + + = Very High ="BDL = Below Detectable Limits

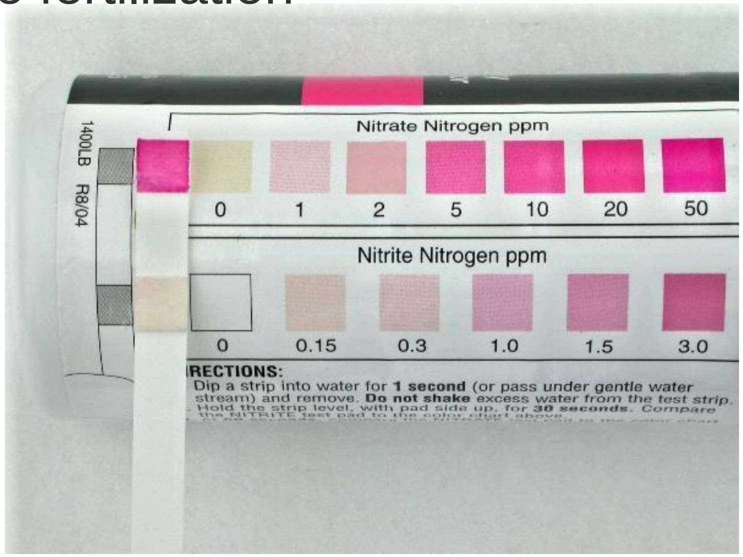
R105GRAPH Page 1 of 2

- Submit soil and water samples to a certified ag lab
- Different labs have different formats. Use one lab with consistent, quality results and a format you understand

UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

Nitrate test strips

- Soil nitrate levels always in flux due to inputs from fertilizers, mineralization of soil organic matter and crop residues, and irrigation water
- Soil nitrate quick test provides estimate of soil nitrate availability to guide decisions just prior to fertilization



https://blogs.cdfa.ca.gov/FREP/index.php/nitrate-quick-test/

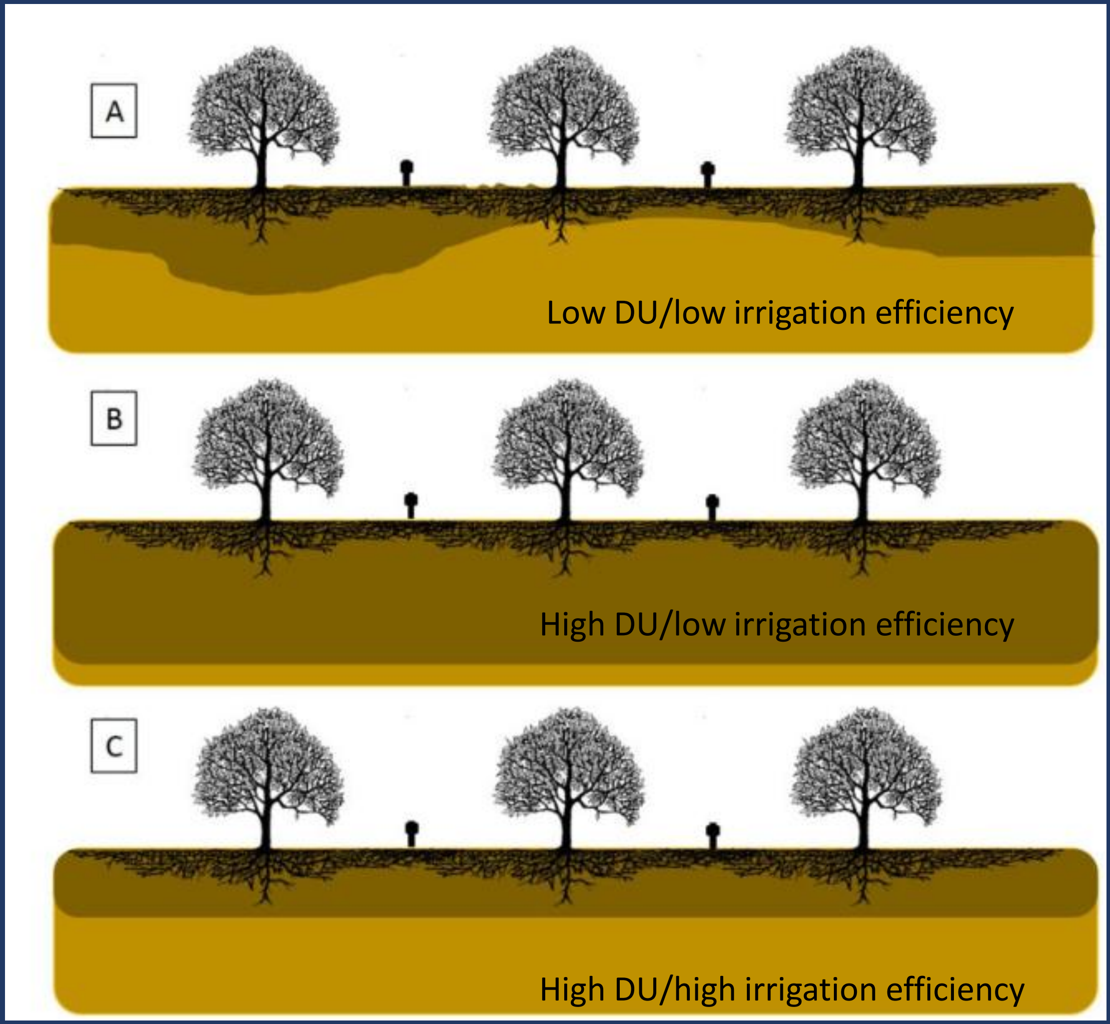
UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources Cooperative Extension

Successful nutrient management requires knowledge of :

- Crop requirements
- Crop uptake patterns
- Nutrient budgeting
- Soil and tissue nutrient analyses
- **Proper irrigation management**

Distribution Uniformity & Efficiency

- A. areas that receive more or less water, receive more or less fertilizer
- B. Good system DU with over irrigation will lead to nutrient leaching across the field
- C. Good DU with good irrigation scheduling = even nutrient application and retention in the rootzone



Lightle, D. 2019

Fresno County - Early Spring

- Increased water availability in the early spring months following a wet winter often coincides with N application
- Increases loss of nutrients from the rootzone

Take home messages

- Effective nutrient management requires accurate accounting for crop and growth demand
- Treat each orchard separately each season: consider historical yield performance, previous season's tissue analysis, and overall canopy conditions
- Overapplying N will not increase yield, but can increase fertilizer costs and hull rot in almonds

Take home messages

- Re-estimate your N budget based on current season's leaf tissue analysis and changing yield estimates
- Foliar applications can help overcome deficiencies identified by leaf tissue analyses
  - Follow recommended rates, application method for the time of year, soil type etc.
- Efficient nutrient management requires proper irrigation scheduling with a well-maintained irrigation system

Thank you!

Mae Culumber
cmculumber@ucanr.edu
559-259-1053