Managing Pistachio Nutrition : Macronutrients

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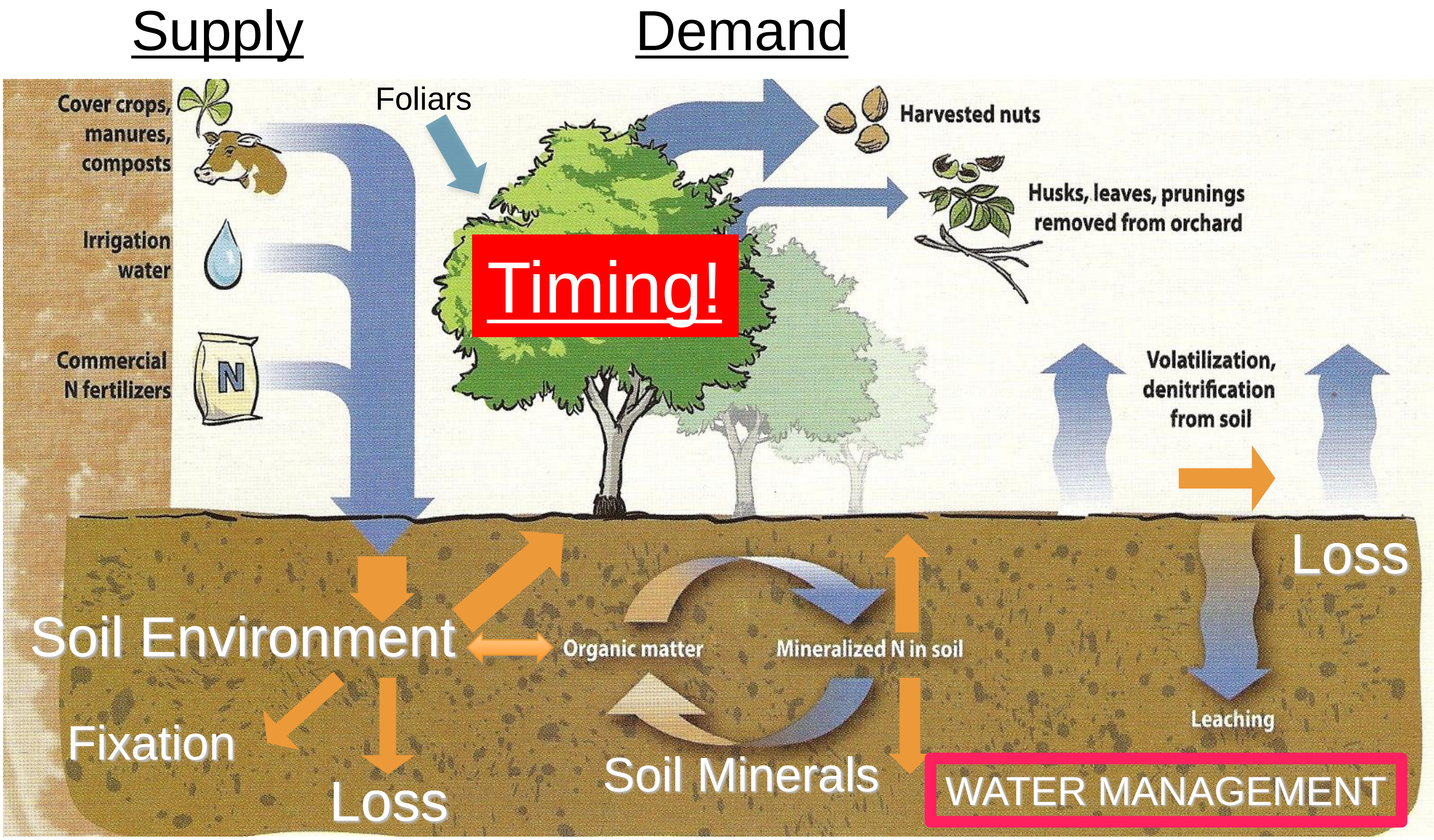
The Nutrient Cycle: A balancing act.

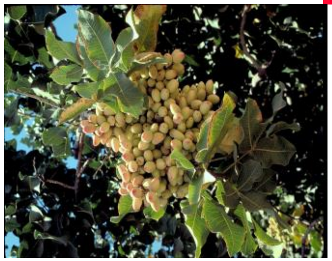


Kathy Kelley-Anderson et al: ANR Pub # 21623

How, Why, When, Where and What of Tree Nutrition

Principles and Practices:

- How are nutrients acquired by plants
- Why are they needed, what is their function and how do they move in the plant.
- How to sample orchards, detect deficiencies and predict fertilizer demand.
- How much, when and where are they required.

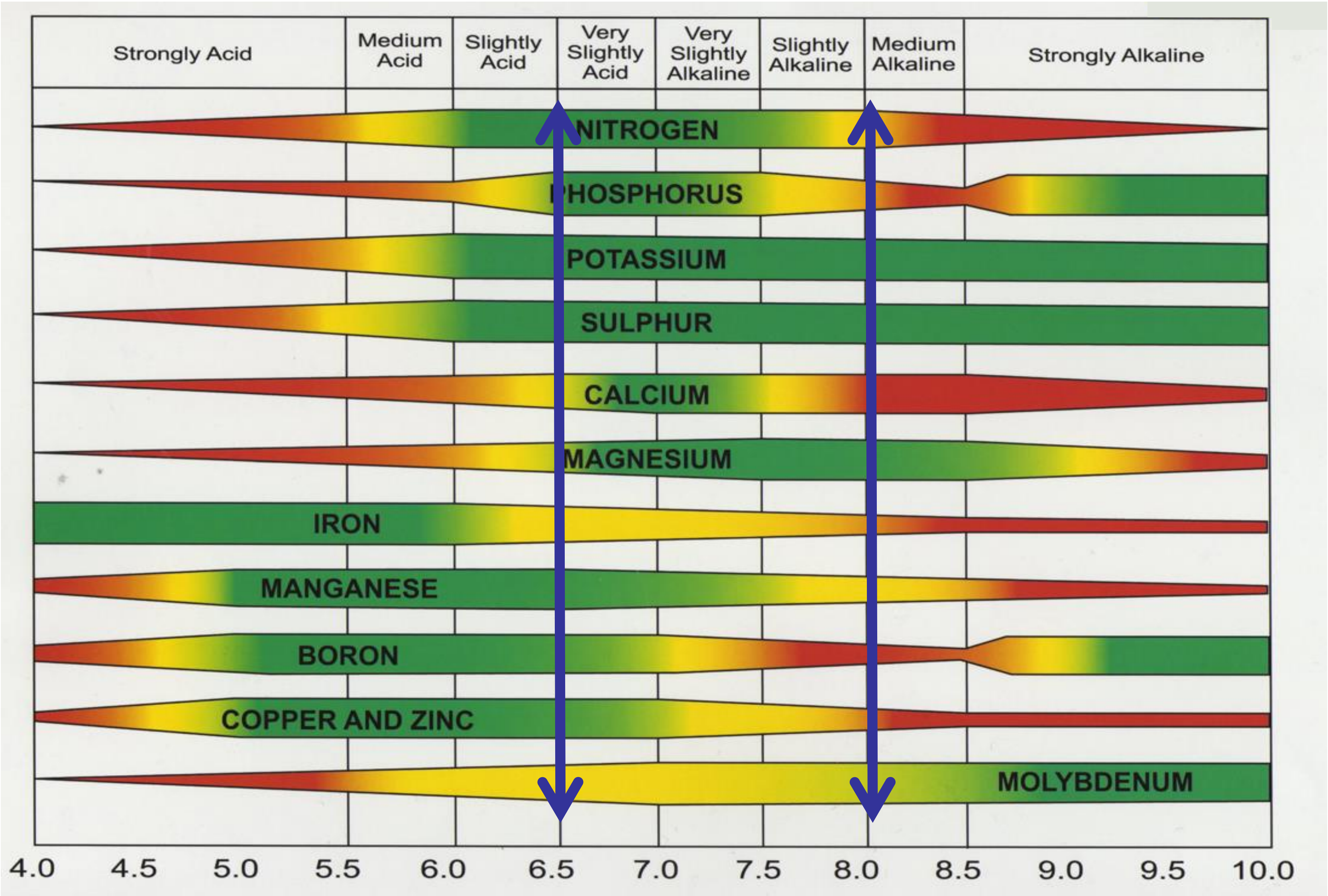


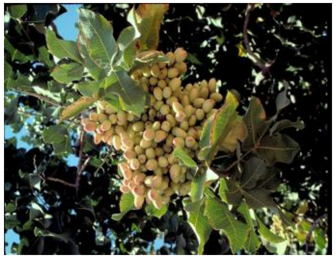
Soil Supply Processes

- Nutrients move to the root in soil moisture
- Nutrient supply from a soil depends on:
  - The size of the nutrient ‘pool’ (bank balance),
  - The ‘solubility’ of nutrients in the ‘pool’ (ATM limit)
- Solubility is determined by soil minerals, pH, CEC, lime, organic matter content.
- Soils must allow root penetration, provide adequate water and oxygen for root growth.

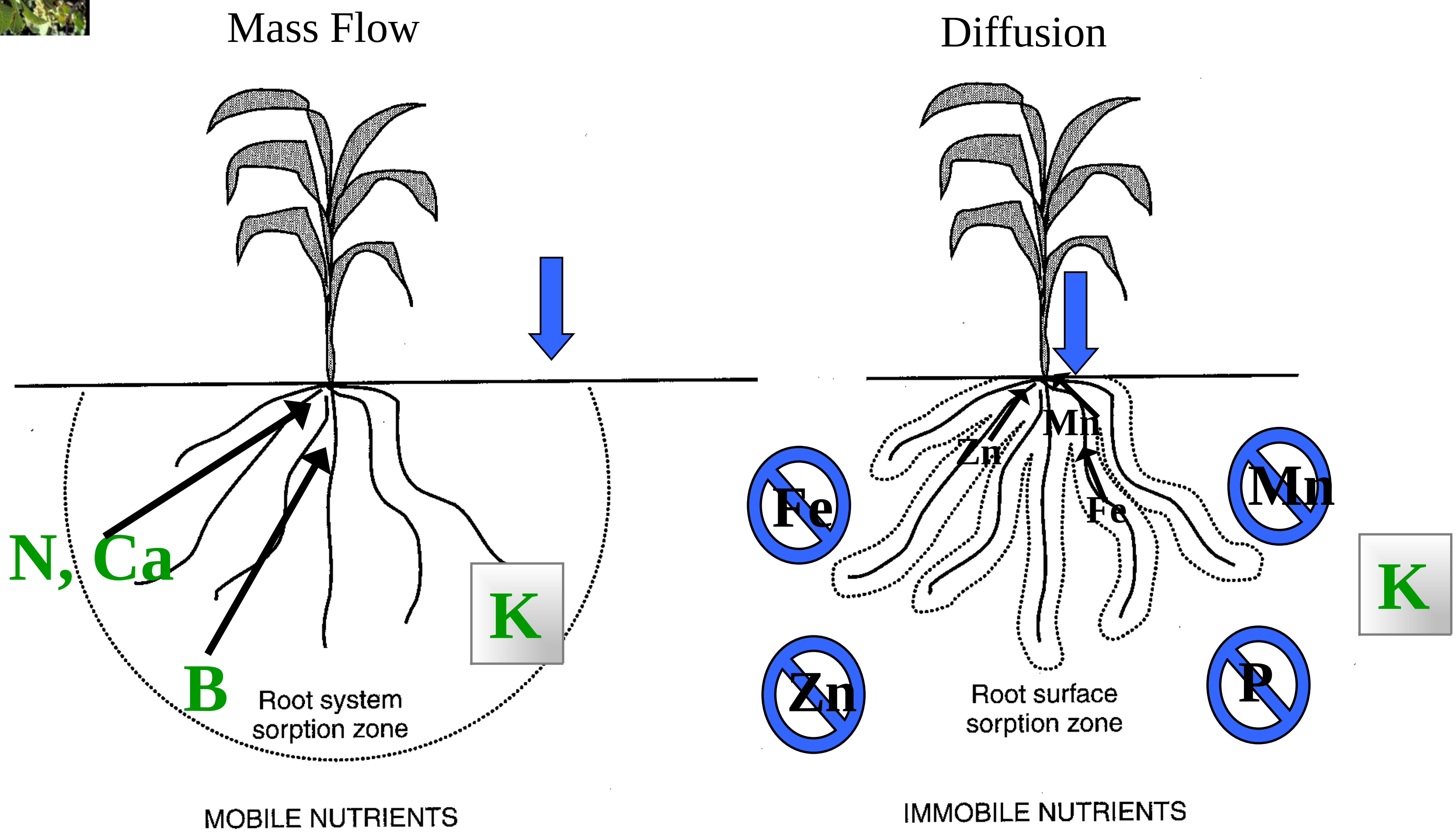
Soil pH and Minerology determines Nutrient Solubility

(knowledge of solubility characteristics of your soils is important.)





Mass Flow (soluble nutrients) versus Dissolution/Diffusion (insoluble elements)



Micronutrients (excluding B and Cl) are immobile in the soil and can only be obtained from soil in close proximity to the root surface. Root growth and root patterns (fineness, depth etc) influence uptake.

Key Principles: Soil Science and Plant Nutrient Uptake

Nutrients are taken up in water only by active roots on trees with leaves.

- Active root growth is required.
- Water and oxygen are required for uptake
- Leaves are required for nutrient uptake by roots

N, S, Mg, Ca, B are mobile and soluble in most soils

- Water movement delivers these nutrients to roots
- Nutrients can be leached or displaced.

Soil Science and Plant Nutrient Uptake

Mn, Zn, Cu, Ni, Fe, P have restricted solubility and movement in soils, hence:

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

K is mobile/available in some soils but not others

- Soil tests to determine K-fixation are essential to K management.
- K, Mg and Ca can interact hence you must know the ratios of these ions to predict their behaviour.

Factors that Affect Nutrient Uptake

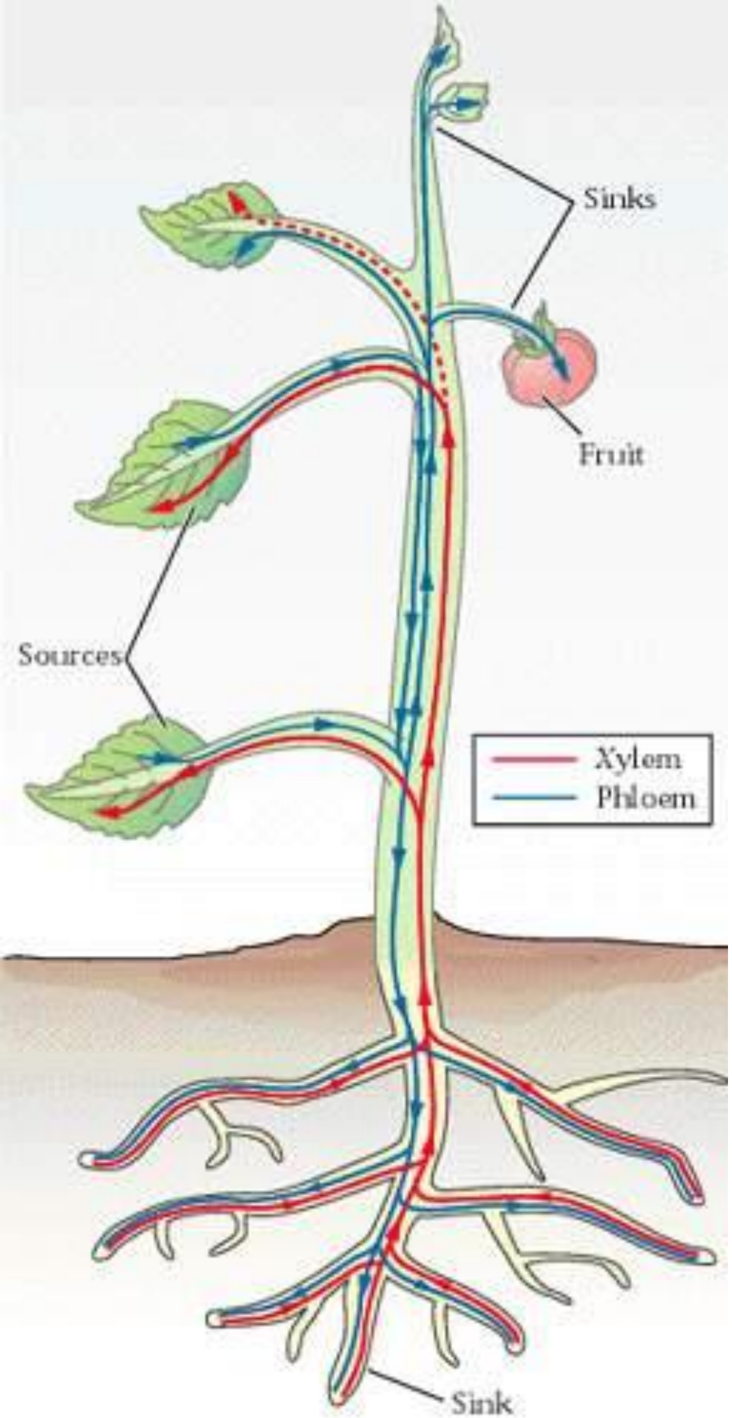
- Poor irrigation system design and scheduling
- Drought or flooded soils
- Weed competition
- Poor root growth: presence of hardpans, poor water infiltration, perched water tables, alkali spots
- Salinity (soil or water), pH, nutrient fixation
- Low soil temperature (microbial activity, root activity)
- Weather/climate, limitations of tree uptake and transport
- Nutrient imbalance and toxic elements
- Low or high native soil fertility for one or more nutrients
- Root disease (i.e. Verticillium wilt affects K uptake)

Environment Interacts with Nutrition.

Nutrient Mobility in Plant Affects Fertilization

Freely Mobile **(nutrient moves from mature leaves to all plant parts)**	**Low Mobility** **(a very small amount of nutrient moves from mature leaves to other plant parts)**	**Immobile** **(No movement.)**
Nitrogen	Zinc	Manganese
Potassium	Molybdenum	Iron
Sulphur	Copper	Calcium
Magnesium	Nickel	Boron
Chlorine, Molybdenum		

- The mobility of an element determines how fertilizers should be managed, where and when symptoms of deficiency and toxicity will appear.
- Boron is the only element that varies in mobility between species. B is highly mobile in Almond, Apricot, Olive, Apple, Pear (and related species) and immobile in all others (Pistachio, Walnut, Citrus etc)



Mobile Elements (N, P, K, Mg, S) move in both the Xylem (one way) and Phloem (two way).

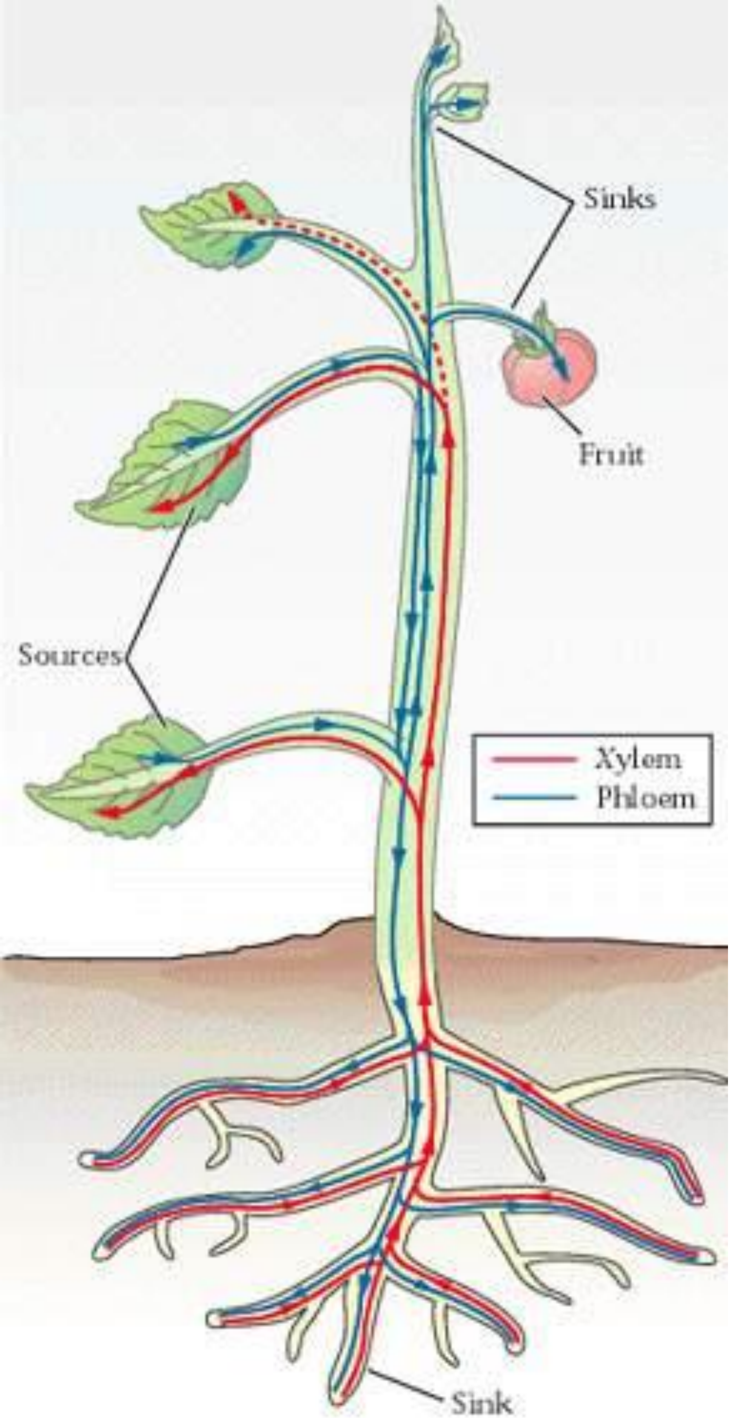
Movement is driven by demand for growth.

Fertilization can have longer term benefits and nutrients can be stored.

Foliar fertilizers can effectively supply current and developing tissues.

Older plant parts develop deficiencies first.

Photosynthesis and growth drives uptake and movement.



Immobile or Poorly mobile Elements (Ca, Zn, Mn, Fe, B) move exclusively or mostly in the Xylem.

Delivered by one-way flow of water in xylem.

Driving force is the transport of water

- limitation in water flow can cause deficiencies
- tissues that don't lose water are most likely to get deficient.

Management Implications:

- Supply required throughout all stages of growth and reproduction.
- Fertilizers have limited long term effectiveness.
- Foliar fertilizers benefit only the tissues sprayed and cannot benefit tissues developed after application.

Nutrients cannot be 'stored' for later use.

Zinc foliar applications have only a local effect on sprayed leaves

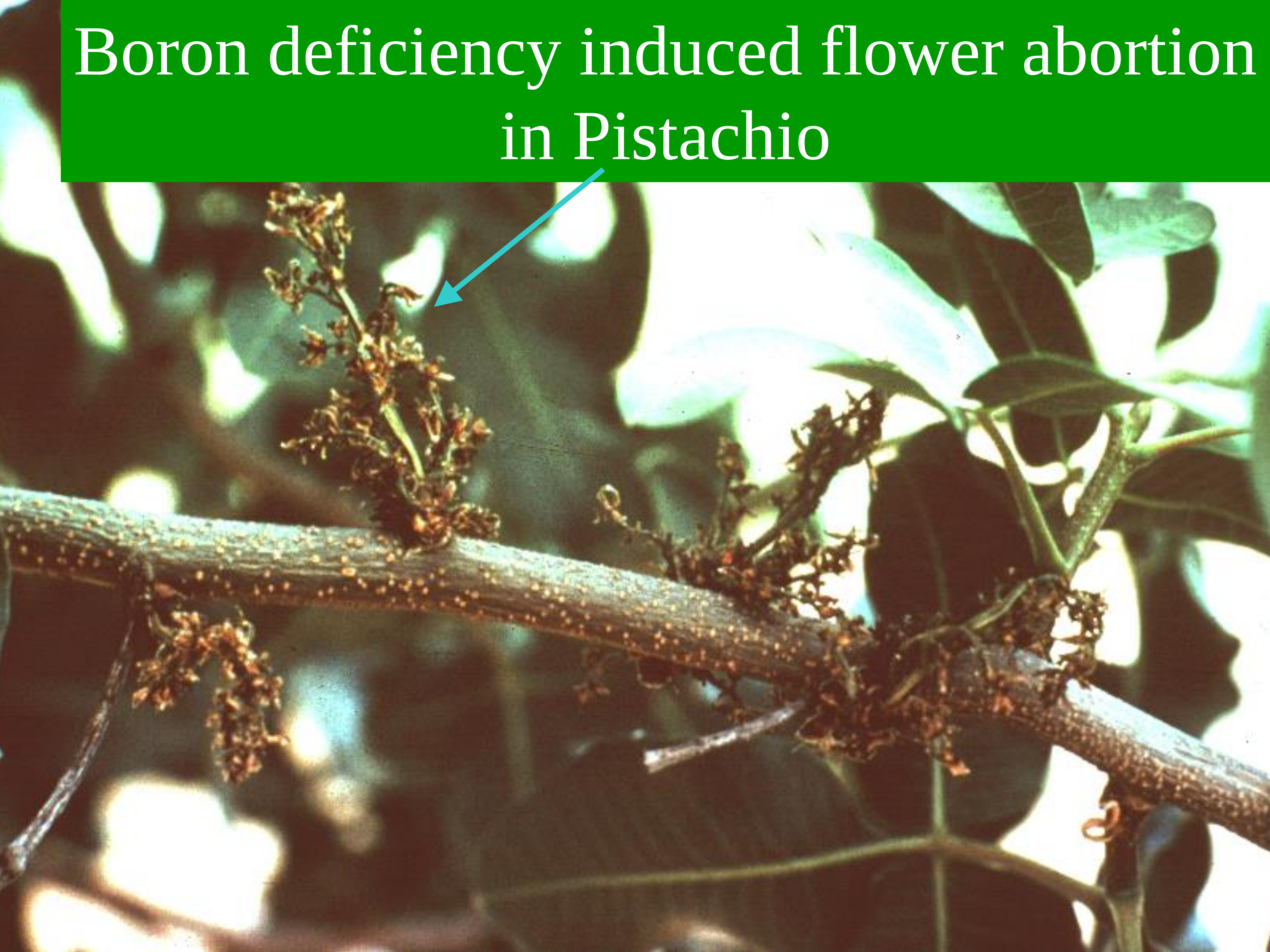
Immobile nutrients can be deficient even when most of the plant has sufficient nutrient.

Tobacco grown in zero B hydroponics with foliar B applied to oldest leaves

Boron deficient flowers

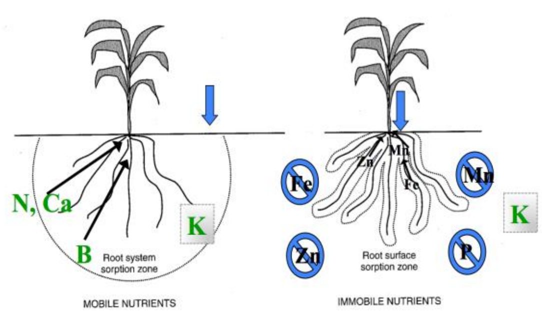
Boron sufficient leaves

Boron deficiency induced flower abortion in Pistachio

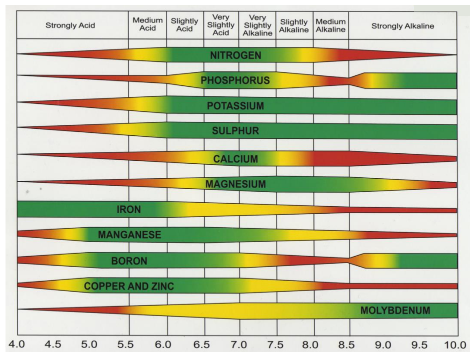


Plant Nutrient Uptake and Crop Response to Fertilizer

Movement in Soil influences Fertilization



Soil pH and chemistry determines Nutrient Solubility
(knowledge of solubility characteristics of your soils is important.)



Nutrient Mobility Defines Response to Soil and Foliar Fertilizers

Freely Mobile (nutrient moves from mature leaves to all plant parts)	Low Mobility (a very small amount of nutrient moves from mature leaves to other plant parts)	Immobile (No movement.)
Nitrogen	Zinc	Manganese
Potassium	Molybdenum	Iron
Sulphur	Copper	Calcium
Magnesium	Nickel	Boron
Chlorine, Molybdenum		

- Roots, water and growth are required for nutrient uptake.
- Nutrient Mobility/Solubility in Soil
  - N, Mg, Ca, S, B are soluble and mobile in most soils
    - Generally predictable response to fertilization, formulations are less relevant
  - Mn, Zn, Cu, Fe, P are not soluble and mobile in many soils.
    - Less predictable response, greater dependence on source.
- Nutrient Mobility in Plant
  - Mobility influences response to fertilizers.
  - N, P, K, S, Mg, Cl are mobile and have more predictable and long lasting response to soil and foliar fertilization
  - Zn, Mn, Fe, Cu, B are immobile, nutrients cannot be stored and fertilizer response is shorter and less predictable.

How Should I Fertilize?
Focus on N, K

- What tools (leaf, soil, water) should I be using, and how?
  - All of them, plus a little bit of plant nutrition understanding, and:
  - Fertilize according to yield potential of CURRENT year
- What are the critical values, how do I sample and how do I recognize plant symptoms?
  - Leaf sampling must be done properly to be useful
  - You cannot manage nutrition based on leaf analysis alone.
- How do I use this information to meet new N management guidelines?

Efficient Nutrient Management
The 4 R's + 1.

Nutrients are used most efficiently when you:

Apply the Right Rate
- Match tree demand with fertilizer supply.

At Right Time
- Apply nutrients when root uptake is most active.

In the Right Place
- Ensure delivery of nutrients to the active roots and not past the root zone.

Using the Right Source
- Choose fertilizers sources that maximize uptake and minimize loss.

Management can be fine tuned by using:

- Soil testing (pH, salts, soil physical conditions, problem elements)
- Leaf analysis (critical values and orchard sampling)
- Nutrient Budgeting

What do we know and how do we manage?

Leaf Sampling and Critical Value Analysis

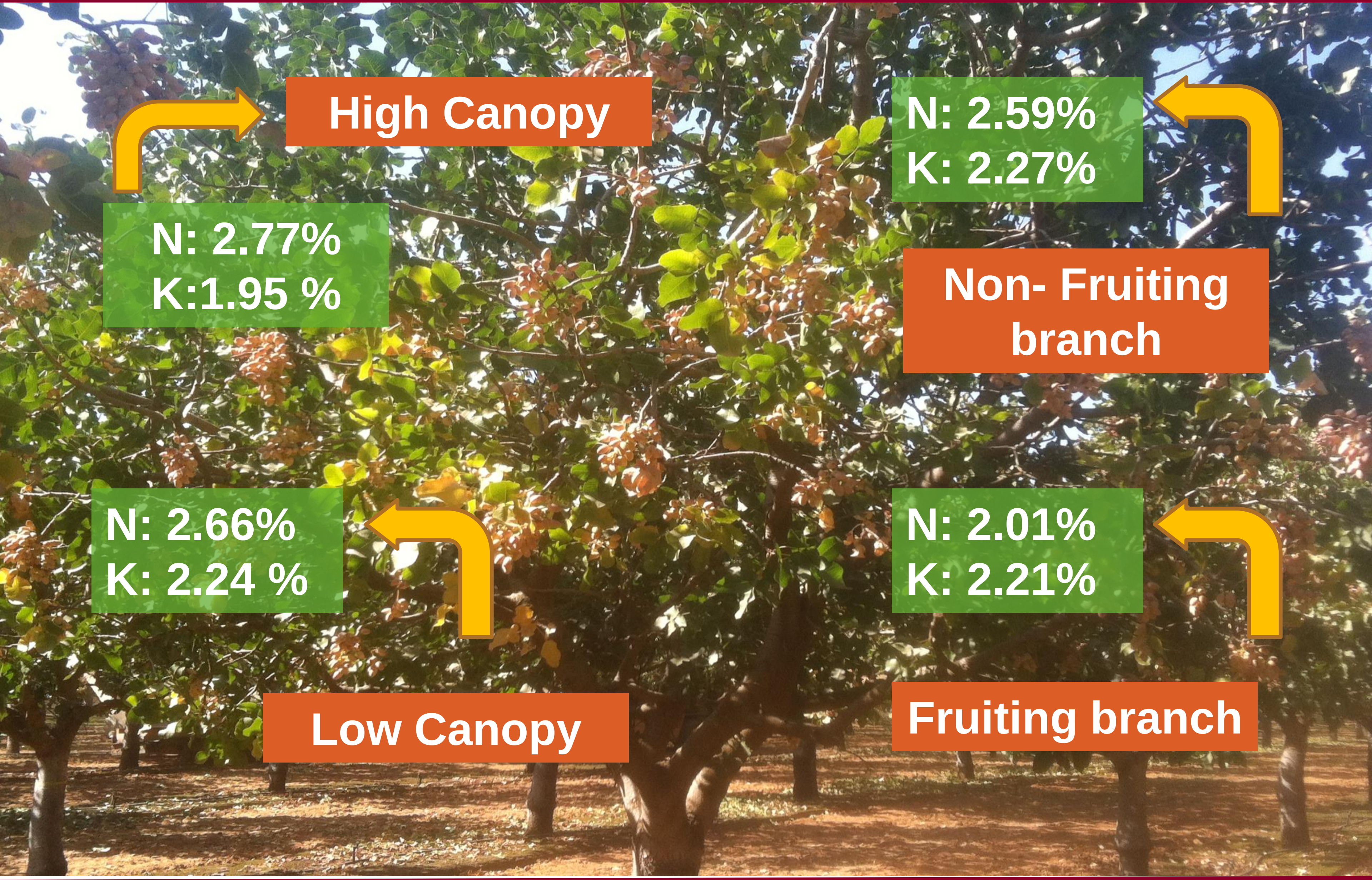
WARNING

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

Problems and Limitations with Leaf Sampling and Critical Value Analysis

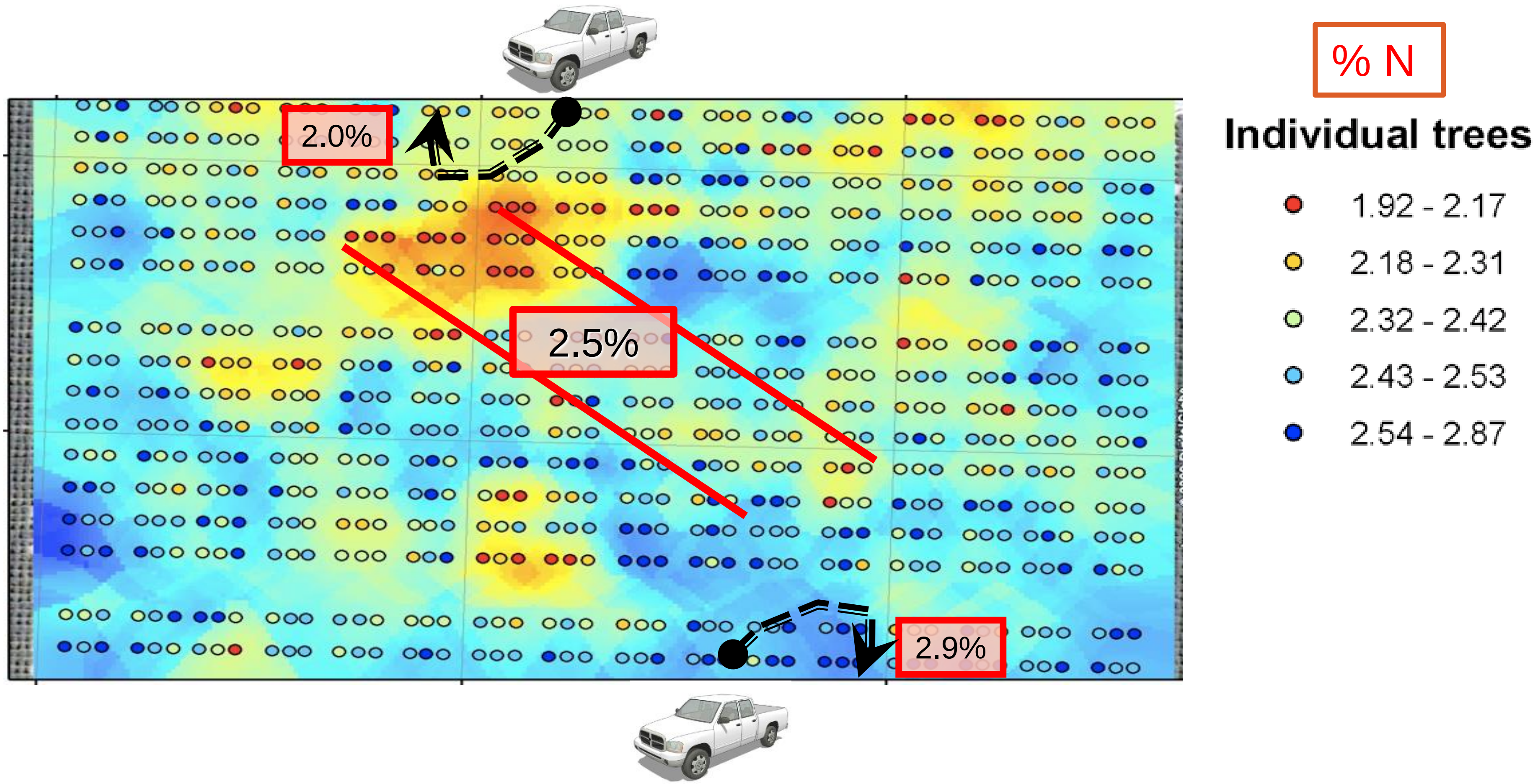
- The experimental basis for these numbers is not strong
  - Small Scale yield trials (N, K, B)
  - Leaf symptoms (P, S, Mn, Zn, Fe, Cu)
  - Unknown (Mg, Ca, Ni, Cl, Mo)
- Leaf sampling provides no guideline on how to fertilize!
  - Leaf analysis can indicate a shortage but cannot define how to respond.
  - No guidance on Rate, Timing, Placement or Source (NO R's)
  - Fields are variable – how do you optimize your investments?
- Leaf sampling is useful as a monitoring tool but is NOT an adequate management tool.

Problem 1: Challenges of leaf sampling-Canopy variability



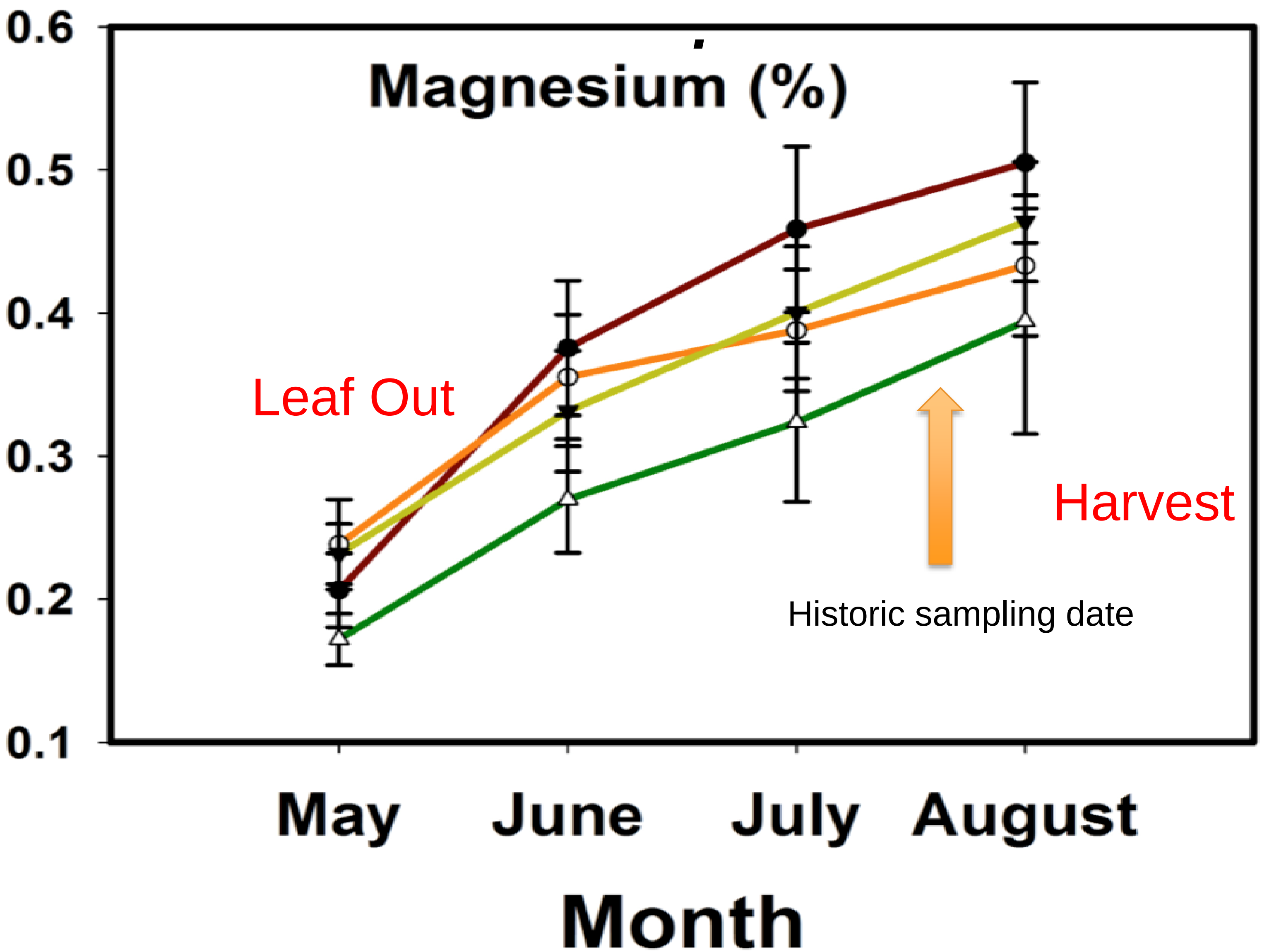
Problem 2: Field Variability

Common Sampling Practices are Inadequate:



What is the average nutrient concentration and how much variability is there?.

Problem 3: Samples collected in July are too late in the season to influence management



Leaf Sampling And Interpretation Methods For CA Orchards.

Ismail Siddiqui, Sebastian Saa, Patrick Brown. UC Davis

Recommended Sampling Criteria

Average Orchard (10-200 acre block. Spring or Summer Sampling)

- **Collect sub terminal leaves from non-fruiting branches.**
- **Minimum of 13 trees each tree sampled at least 25-30 yards apart.**
- **In each tree collect 10 leaves around the canopy from well exposed branches located between 5-7 feet from the ground.**
  - **If cost is a constraint, samples can be pooled into a single sample for analysis to guide an individual orchards management**
  - **Analyze for the N, P, K, S, Ca, Mg, Cu, Zn, Fe, B**
- **In spring, collect samples soon after full leaf expansion (approx. 30-50 days after full bloom (DAFB), for standard sample collect in late July.**

Non-Uniform Orchard:

- **Repeat this process in each orchard zone of similar performance.**

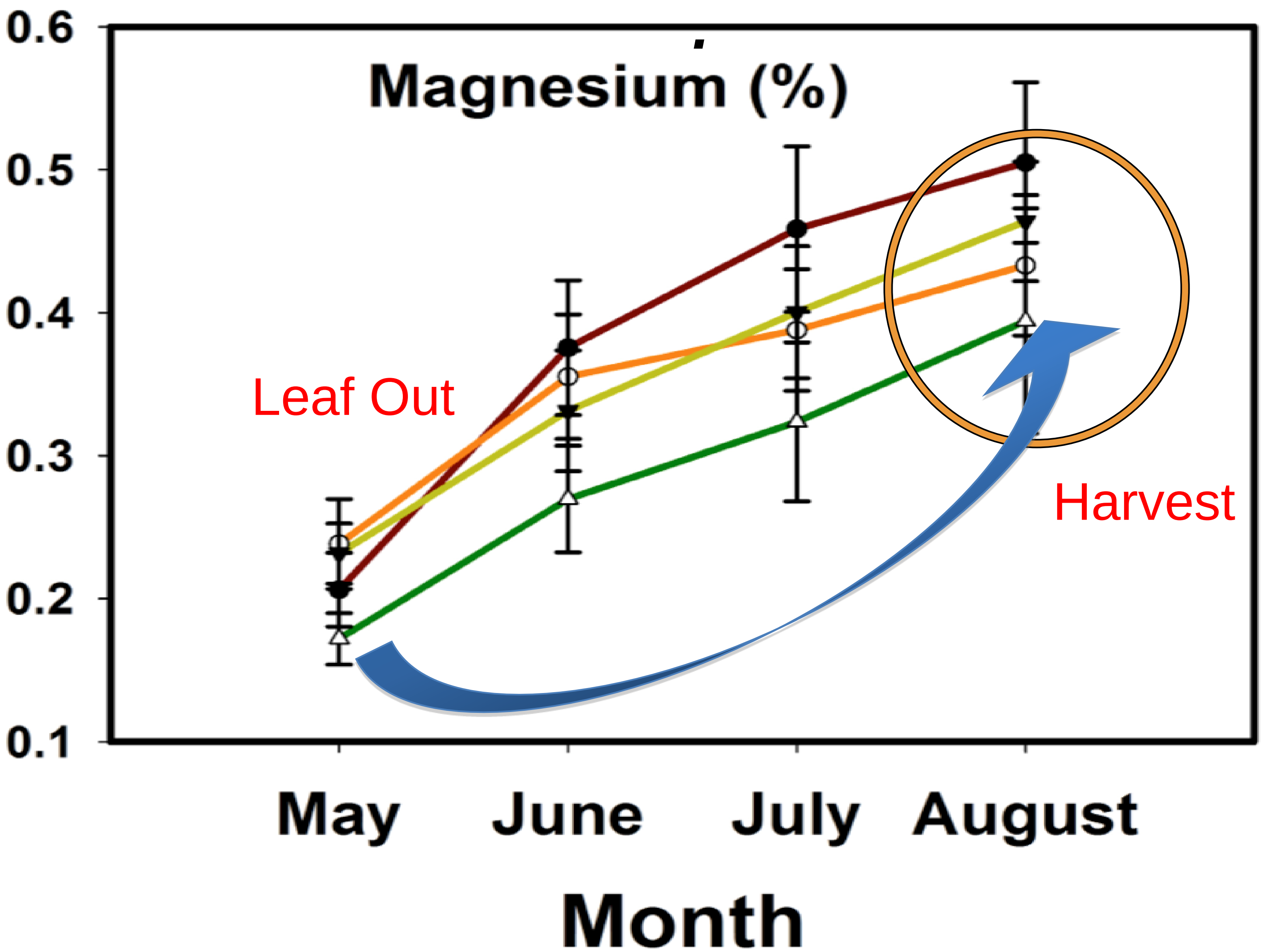
Recommended Sampling Criteria

Sub-terminal Leaf on non-fruiting branch.

13 trees at least 30 yards apart. 10 leaves per tree. Pooled

In non-uniform orchards, sample each soil or productivity zone separately.

Can we predict late summer nutrient status with spring leaf sample?



YES: Spring samples can effectively predict summer tissue values: UCD-PPM program

Site	Year	Summer predicted leaf N from spring sample	Summer measured leaf N.
Arbuckle	8	2.4	2.3
Belridge	8	2.4	2.4
Madera	8	2.5	2.4
Modesto	8	2.4	2.4
Arbuckle	9	2.4	2.6
Belridge	9	2.4	2.4
Madera	9	2.6	2.4
Modesto	9	2.6	2.7
Arbuckle	10	2.4	2.5
Belridge	10	2.3	2.7
Madera	10	2.3	2.3
Modesto	10	2.4	2.5

UCD-PPM

Model for interpreting Spring Analysis can be found at:

Google: FNRIC Pistachio early leaf sampling

Or:

Fruit Growers Lab currently uses the program.

http://fruitsandnuts.ucdavis.edu/Weather_Services/Nitrogen_Prediction_Models_for_Almond_and_Pistachio/
Or Google “UCD PPM Pistachio”

Collect samples properly approximately 40 days after bloom, submit to lab and request UCD-PPM

Nitrogen Management for Pistachio

Ismail Siddiqui, Patrick Brown
UC Davis

Mandated Nitrogen Management Planning (ILRP)

- **Application rates will be based upon field specific crop N budget estimations, accounting for all applied N.**
- **Certified Crop Advisor or 'self certified' grower sign off required.**
  - Training/testing Requirement
- **Post season verification and reporting.**
  - Collated and Managed by Local Water Coalitions
- **In the short term growers can choose how to respond.**
  - Regulations are however still being developed and litigated.

To achieve optimal productivity with restricted nitrogen will REQUIRE enhanced efficiency of N use.

Efficient Nutrient Management Approach
-the 4 R's-

Applying the Right Rate

- Match demand with supply (all inputs- fertilizer, organic N, water, soil).

At Right Time

- Maximize uptake minimize loss potential.

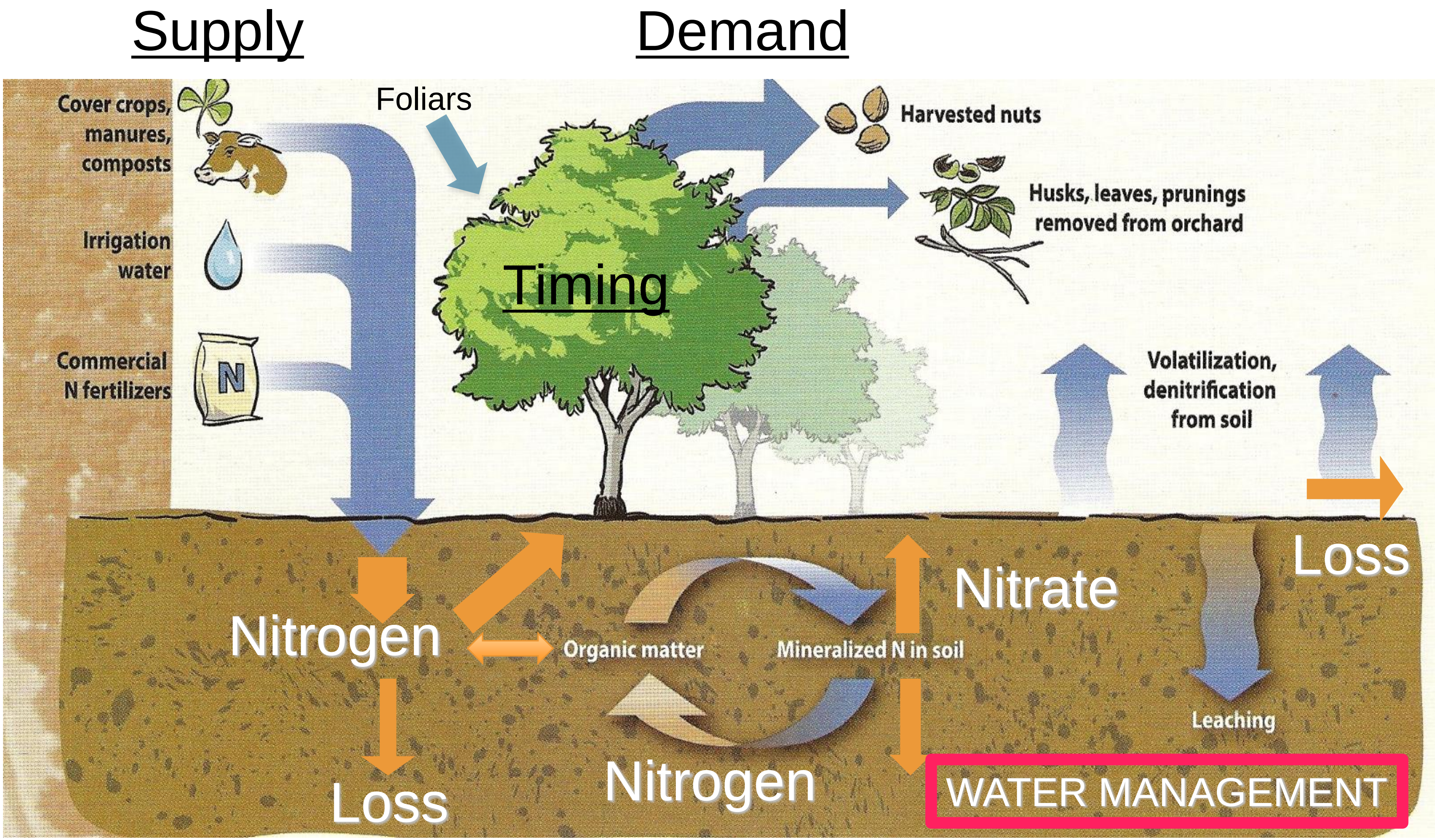
In the Right Place

- Ensure delivery to the active roots.

Using the Right Source

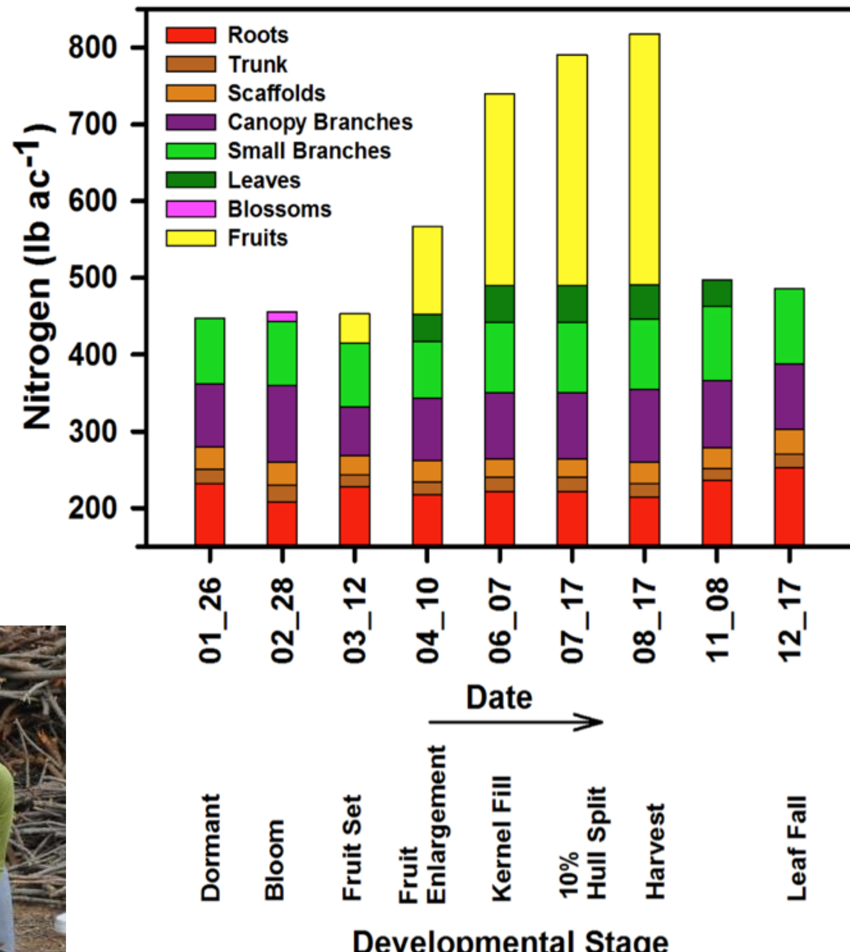
- Maximize uptake minimize loss potential.

The Nitrogen Cycle: A balancing act.

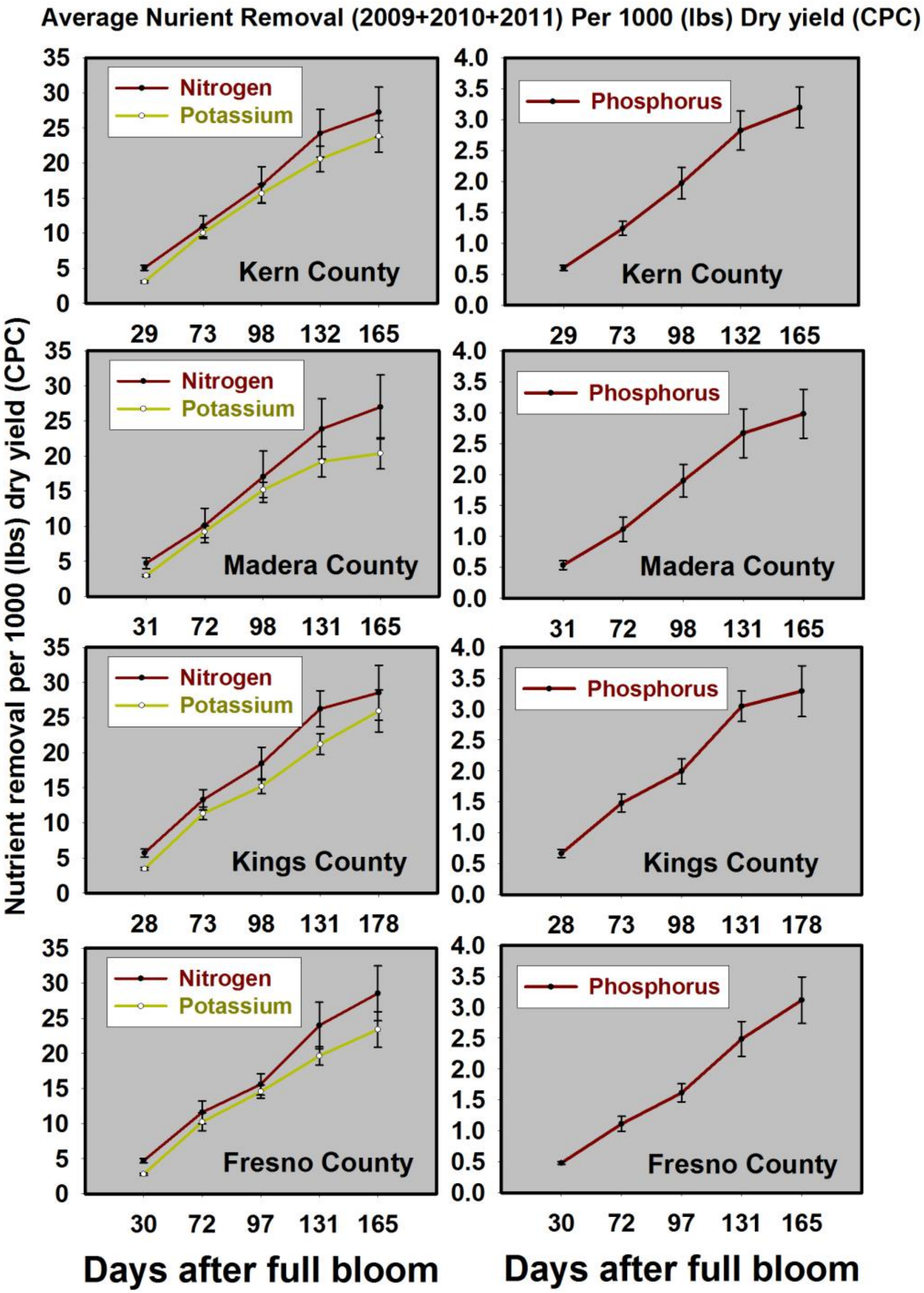


Kathy Kelley-Anderson et al: ANR Pub # 21623

Right Rate: Plant Nutrient Demand



Muhammad, PhD Dissertation. 2013



Nutrient removal Per 1000 lb

(CPC Yield)

- Nutrients removed in all fruit components and accounts for losses in non-marketable fruit.
  - N removal 28 lb per 1000
  - K removal 25 lb per 1000
  - P removal 3 lb per 1000
  - Mg, S, Ca are abundant in most soils and not removed in large quantities.
- 25 lb N per acre, per year is required for tree growth (averaged over 20 years – Rosecrance et al 1998)
- 4000 CPC lb yield 'removes'
  - 116 lb N (+25 for growth)
  - 100 lb K (+22 for growth)
  - 12 lb P

Choosing the Right Rate Requires Setting a Realistic Yield Goal

- Use your experience of the potential for the particular orchard and then consider the prevalent environmental conditions.
  - Previous years yield, winter chilling and spring flowering weather can be critical.

- Look at the trees in April and after fruit set. Estimates are fine since they will always be superior to using the same N regime every year.

- Make in-season adjustments to account for greater or lower than expected yields.

Google Pistachio Nitrogen Prediction to find an interactive Nitrogen Management Spreadsheet

http://ucanr.edu/p/41860

Pistachio Prediction Model (PPM)

May nutrients	Insert May values here	Nutrients	Prediction (July)
*DAFB	35	July N (%)	2.62
N (%)	3.0	July K (%)	2.02
P (%)	0.23		
Ca (%)	1.3		
Cu (ppm)	10		
Mg (%)	0.25		
K (%)	1.3		
DAFB:	Days after full bloom		

In-season Nitrogen and Potassium Fertilization plan for commercial pistachio orchards

Year:		
Field section:		
Block:		
Nitrogen (N)	Based on:	Based on:
	Pre-season estimated yield and Nitrogen/potassium budget and application schedule	Revised estimated yield and Nitrogen/potassium budget and in-season application schedule
Crop forecast (lbs CPC yield)	5000	4000
Estimated Nitrogen (N) in leaves in July (%)		2.62
Nitrate-N concentration in irrigation water (PPM)	10	
Irrigation containing N03 (Acre feet)	1	
N from other sources (lbs)	10	
N required for tree growth (lbs/ac)	25	
Total nitrogen demand	236	196
Required nitrogen application (lbs)	183	143
Recommended Nitrogen distribution, based on 4 applications		
Budget (Apr/May) = 20% of total	37	37
Budget(June) = 30% of total	55	40
Budget (July) = 30% of total	55	40
Budget(Aug) = 20% of total	37	27
Potassium (K)		
Estimated Potassium (K) in leaves in July (%)		2.02
K requird for tree growth (lbs/ac)	22	
Total potassium demand	203	169
Required potassium application (lbs)	185	153
Recommended Potassium distribution, based on 4 applications		
Budget (Apr/May) = 20% of total	37	37
Budget(June) = 30% of total	55	44
Budget (July) = 30% of total	55	44
Budget(Aug) = 20% of total	37	29

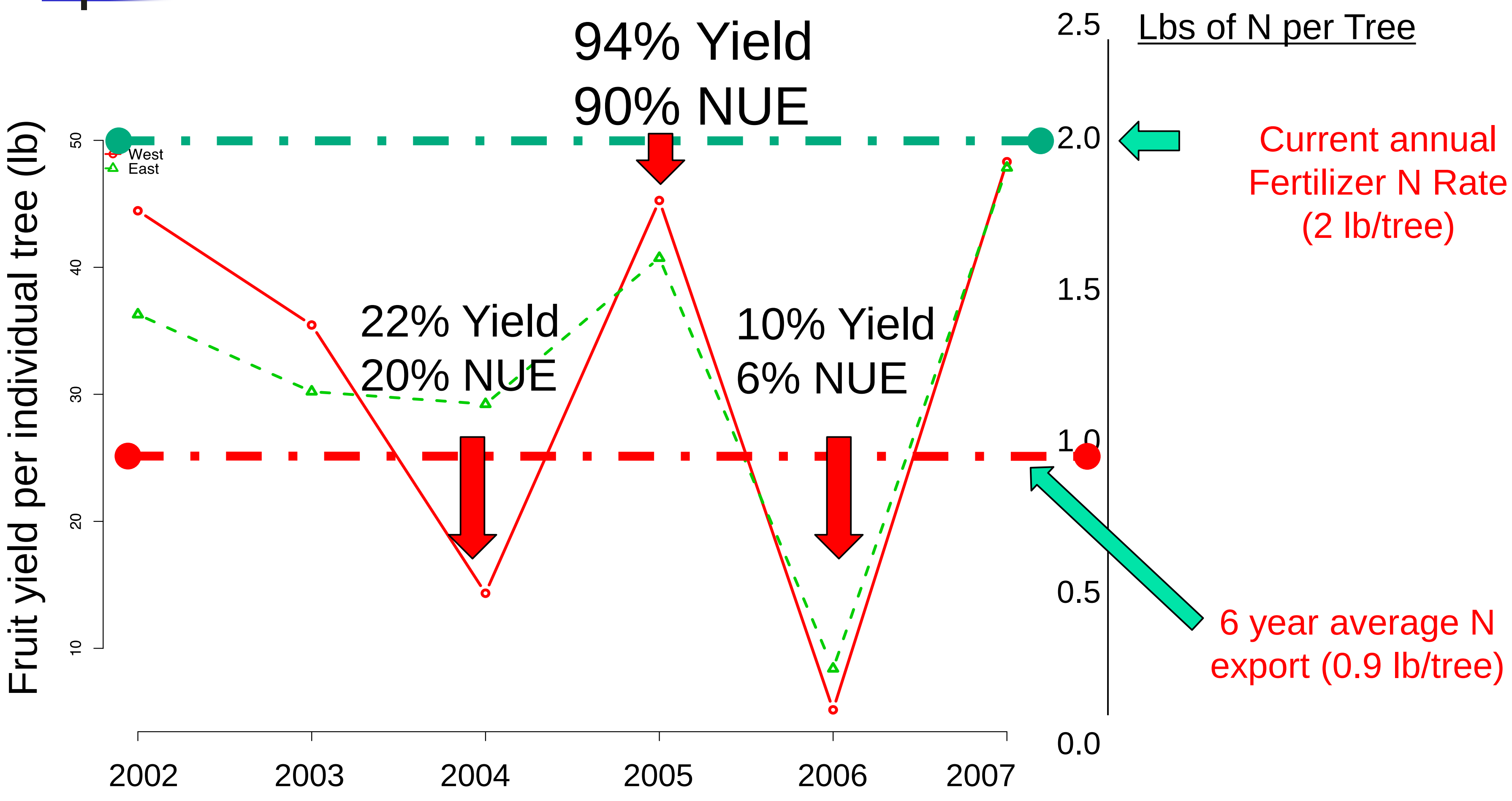
Note:
1) If leaf N% is close to the 2.5% threshold then the entire adjustment may not be necessary.
2) Budget for N requirement is based on estimated crop size and application schedule is calculated to satisfy that requirement.
3) Required nitrogen application is total demand minus nitrogen from other sources.
4) For Nitrogen concentrations in lbs/AcFt, N (ppm) = lbs-AcFt/2.7.
5) Soil test for K fixation is critical as K availability in the soil depends on soil mineralogy.
6) Every field is unique- site specific management is recommended.

Google: FNRIC Pistachio early leaf sampling

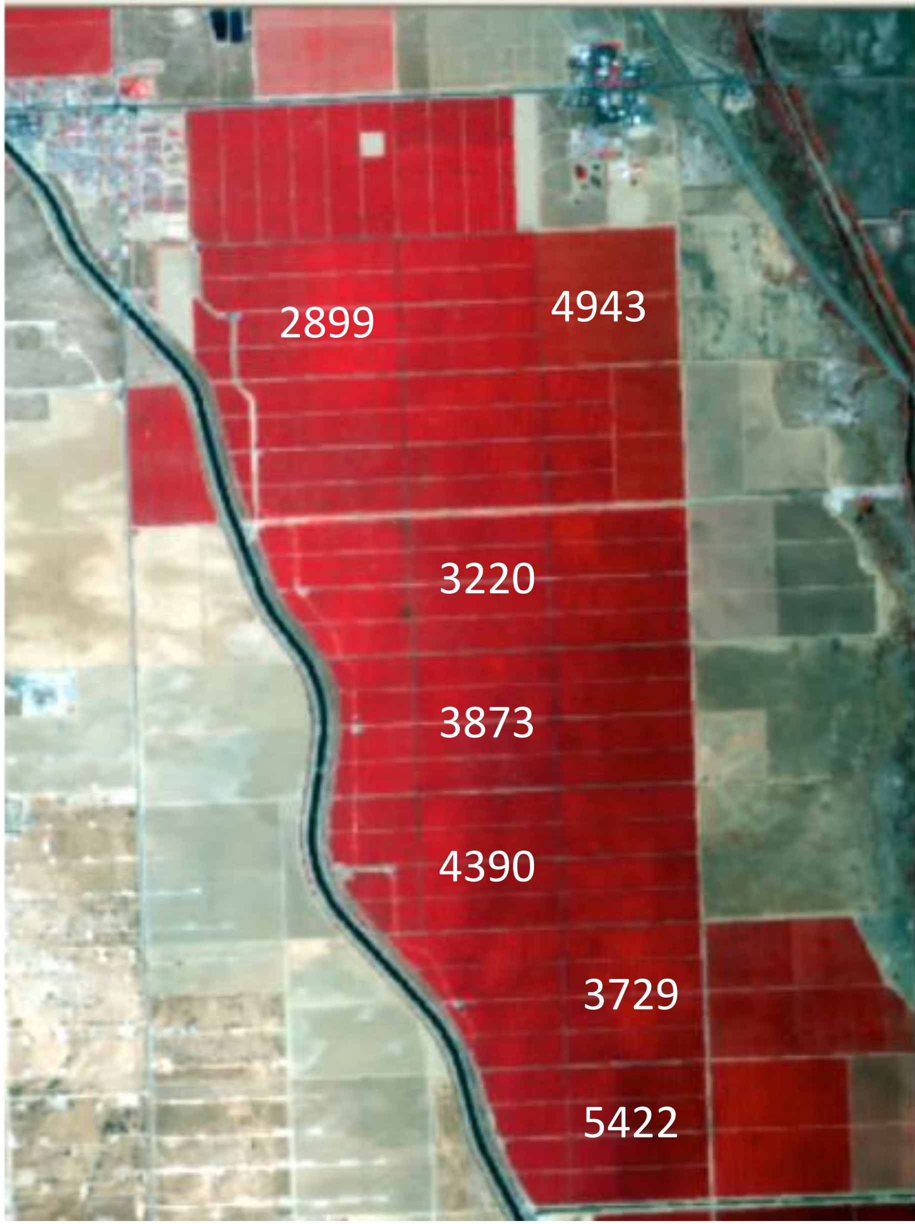
http://ucanr.edu/p/41860

Variation in Yield and NUE over Time

Overall Nitrogen Use Efficiency (NUE) = 44%



Yield and Final Nutrient Use Efficiency: 275 Lbs N Applied



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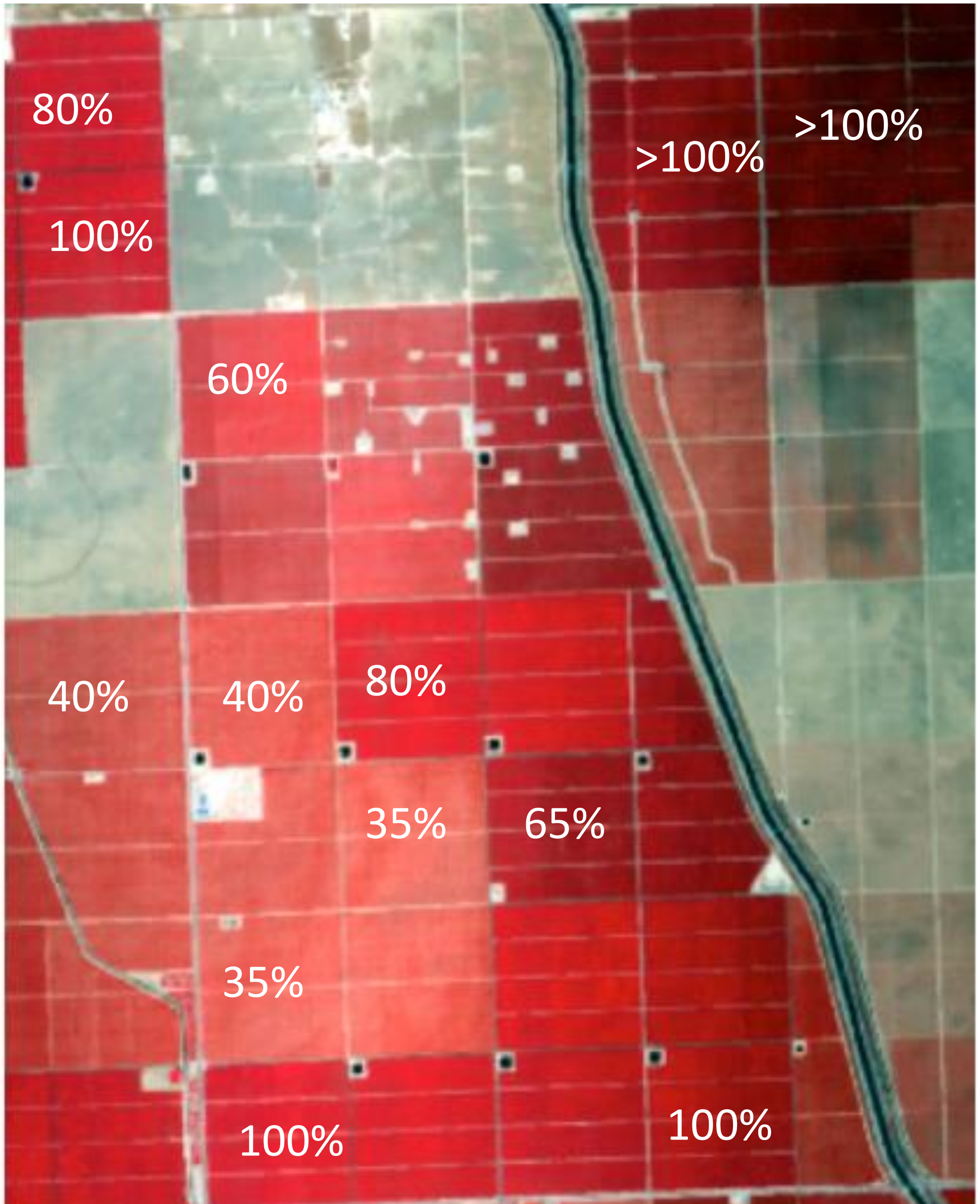
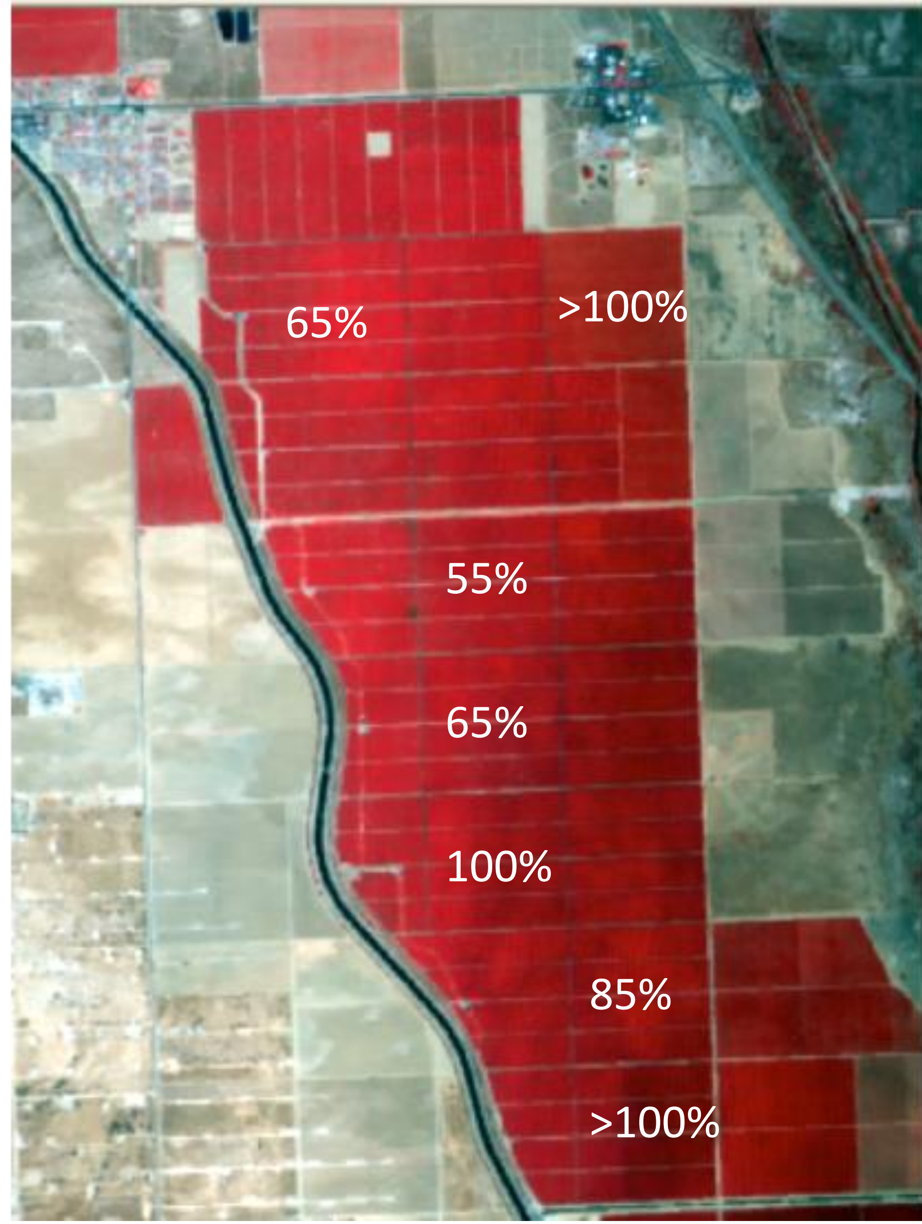
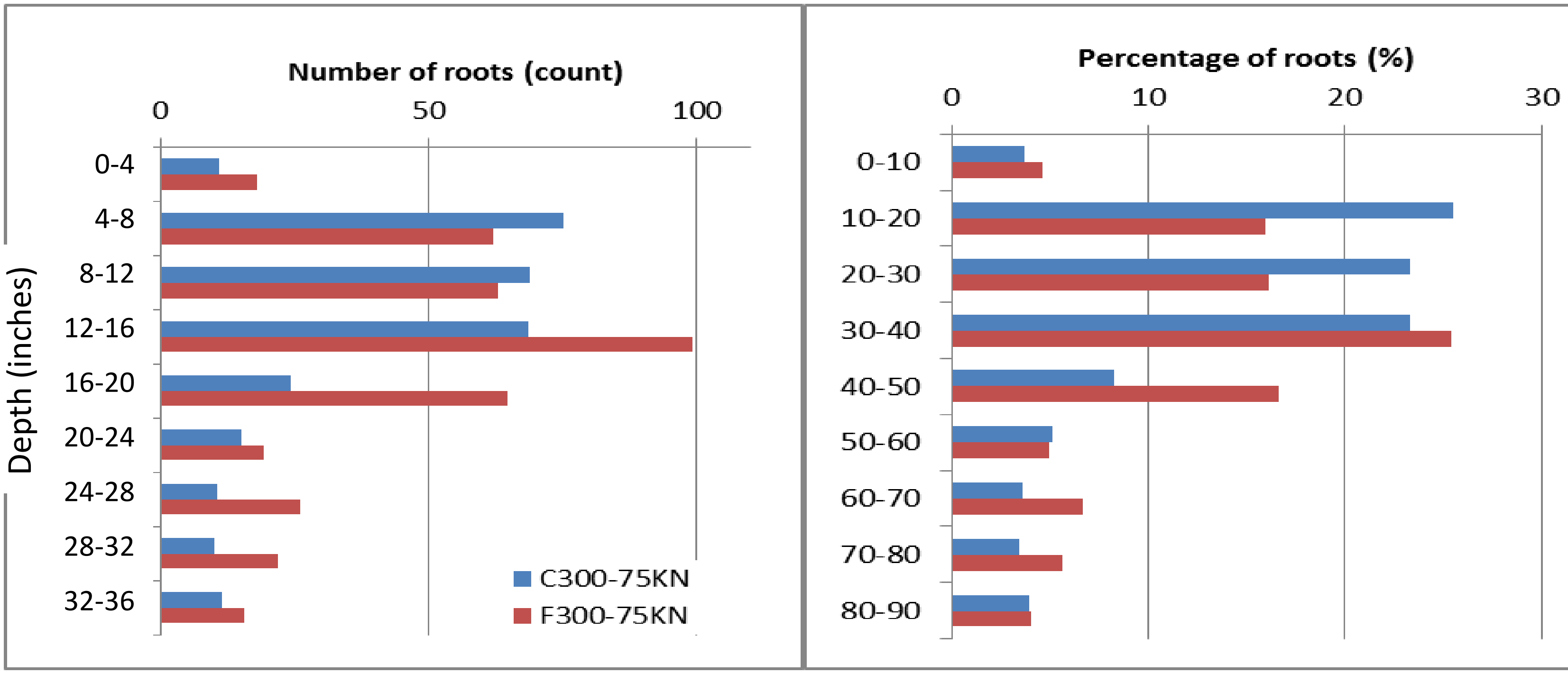




Right Place: Where does N uptake occur?



➔In Almonds, and probably pistachio the majority of the roots are in the first 18 inches of soil.

Olivos, Unpublished

Right Time: When roots are active and when trees are hungry.

Root Growth Patterns in Almond

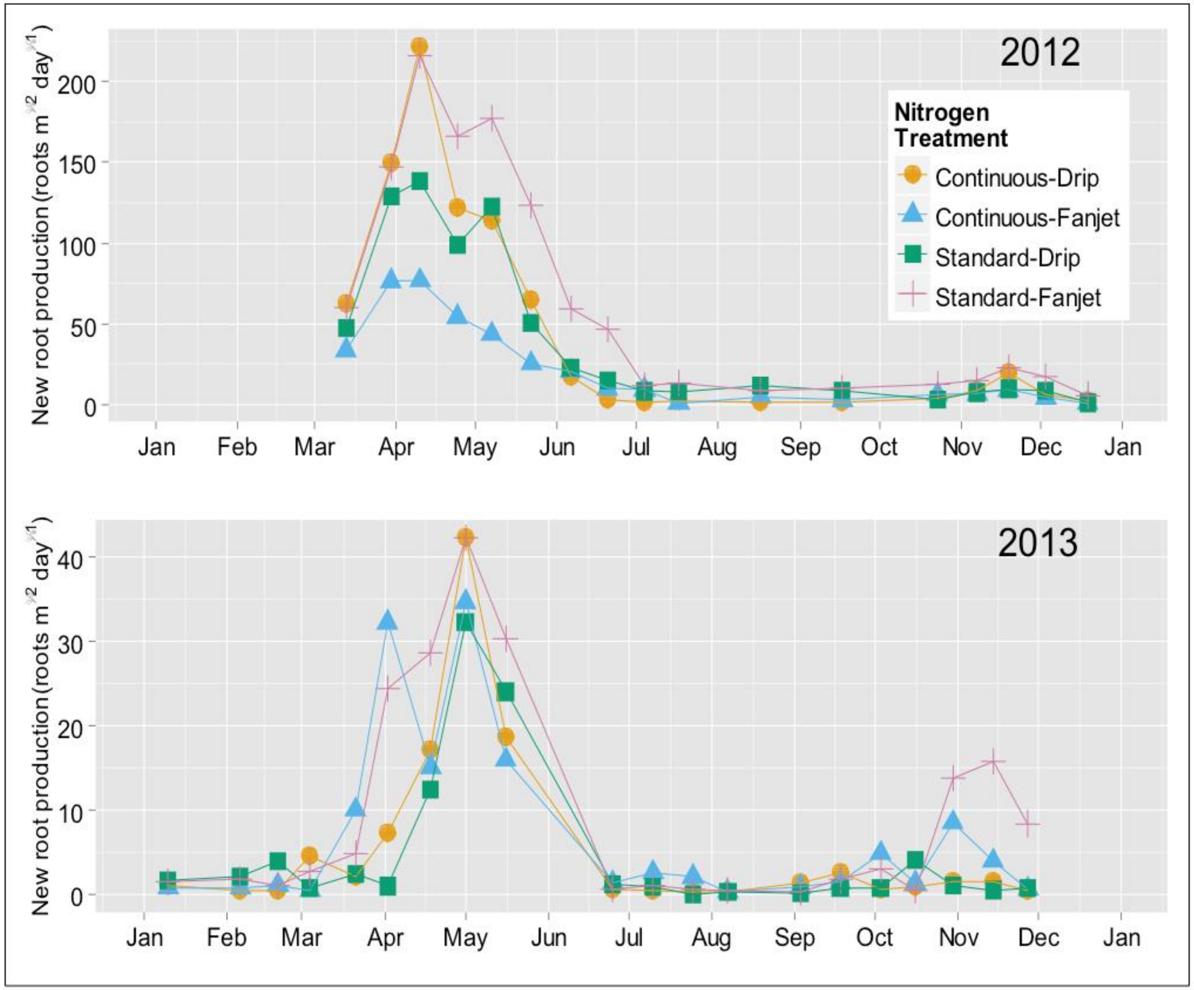
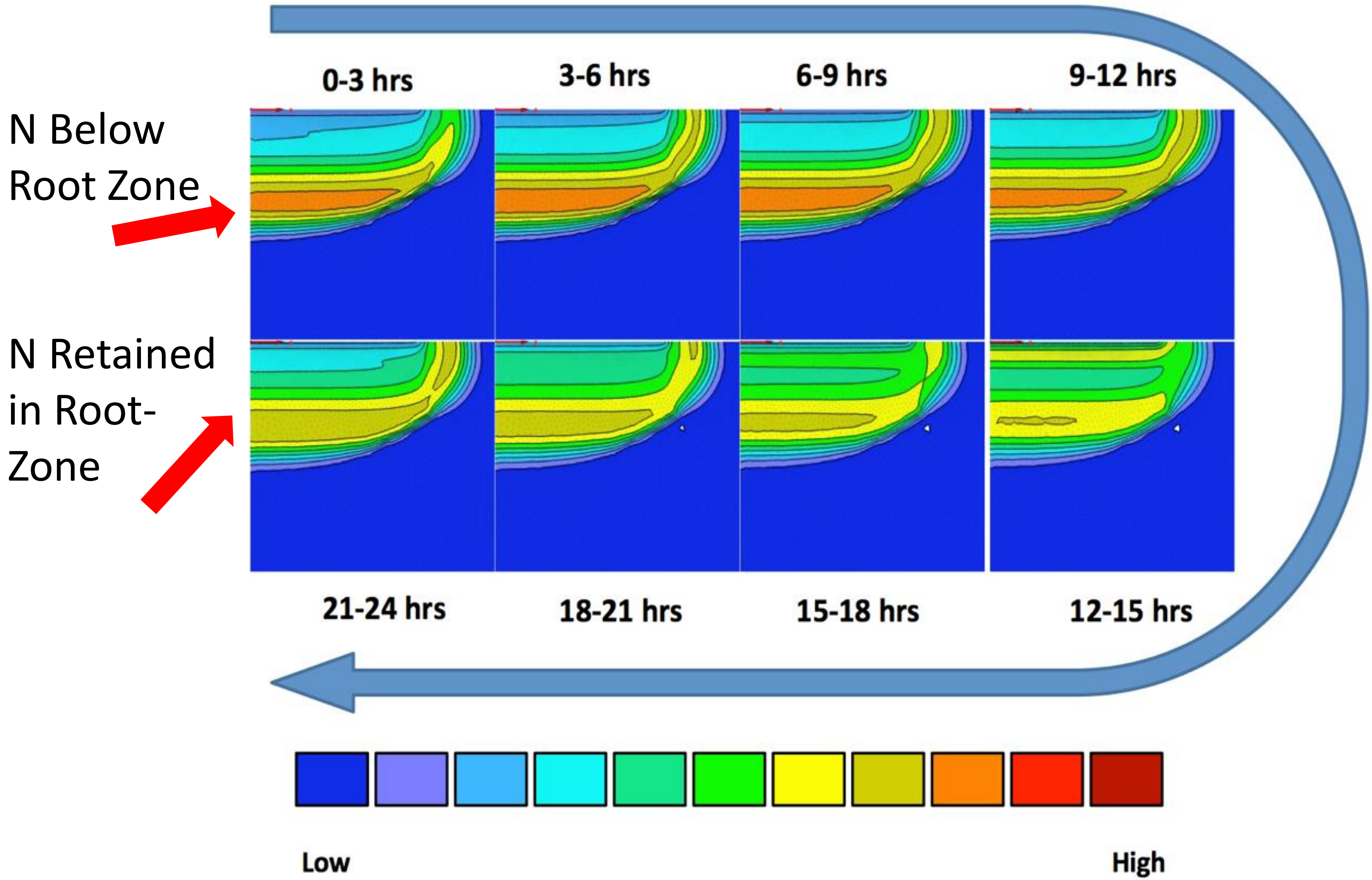


Figure 3 Number of new roots produced during the growing season in Experiment 2: Nitrogen Fertigation experiment.

Fertigation and Nitrogen Managment

- Nitrogen is highly mobile in soils and can be leached easily by irrigation water.
- Nitrogen moved to bottom of root zone is subject to loss upon next irrigation.
- The margins of the irrigated root zone are frequently high in salinity, root growth and N uptake are restricted
- Apply Nitrogen toward end of irrigation cycle to avoid deep movement
- Apply in as many small doses in a year as possible

Fertigated N Should be Applied Toward End of Irrigation Event



Nitrogen Application Timing

1) Conduct preseason yield prediction (28lb per 1,000 + 25lb for growth)
2) Calculate Demand less N in all sources (irrigation water N, soil residual N)
3) Apply fertilizer to meet difference.

Date	% of Annual N Demand	Comments
April	12.5%	Apply when leaves have just emerged
May	25%	Adjust according to leaf analysis and updated yield estimate
June	25%	Adjust according to updated yield estimate
July	37.5%	Greatest period of crop demand

Post harvest application should only occur if trees are healthy and N application was too low.

Nitrogen

- **Leaf Levels:**
  - % N indicates status of tree
  - 1.8% is critical value.
    - Each individual tree needs to attain this value to maximize productivity
  - 2.2 – 2.5% is a common field range…but be aware, tissue analysis is NOT suitable to make fertilizer decisions.

Conclusions: Managing Nitrogen

Base your fertilization rate on realistic, orchard specific yield and adjust in response to spring nutrient and yield estimates.

- Make a preseason fertilizer plan based on expected yield.
  - Pistachio 1000 lb CPC yield removes 28 lb N, 25 lb K and 3 lb P.
- Conduct leaf analysis following full leaf out.
- Using leaf analysis and updated yield estimate, adjust fertilization for remainder of season.
  - Uptake of N, K, P occurs uniformly from leaf out to harvest.
  - Apply up to 20% immediately post harvest, corrected for actual yield - but only if trees are healthy.
- Every field and every year is a unique decision, adjust fertilization accordingly.

Nitrogen

- <u>**Deficiency Symptoms**</u>
  - Mobile: new leaves mobilize N at expense of old leaves
  - New leaves pale
  - Old leaves yellow and drop
  - Reduced shoot growth; shorter and thinner
  - Reddish bark if severe

If you see yellowing you have already caused yield damage!

Potassium

- **Leaf Levels:**
  - % K indicates tree status
  - 1.6% is critical value
  - 1.8 – 2.2% is optimal range

Potassium

- <u>Leaf Symptoms:</u>
  - Symptoms appear early to mid summer
  - Small leaves without chlorosis but with scorched margins
  - Worst on older leaves of current shoots
  - Sparse foliage with pronounced dieback
  - Yields decline as K declines

If you see symptoms you have already caused yield damage!

Phosphorus

- **Leaf Levels:**
  - % P in leaf dry matter
  - 0.14% is critical value
  - 0.14-0.17% is typical range

Phosphorus

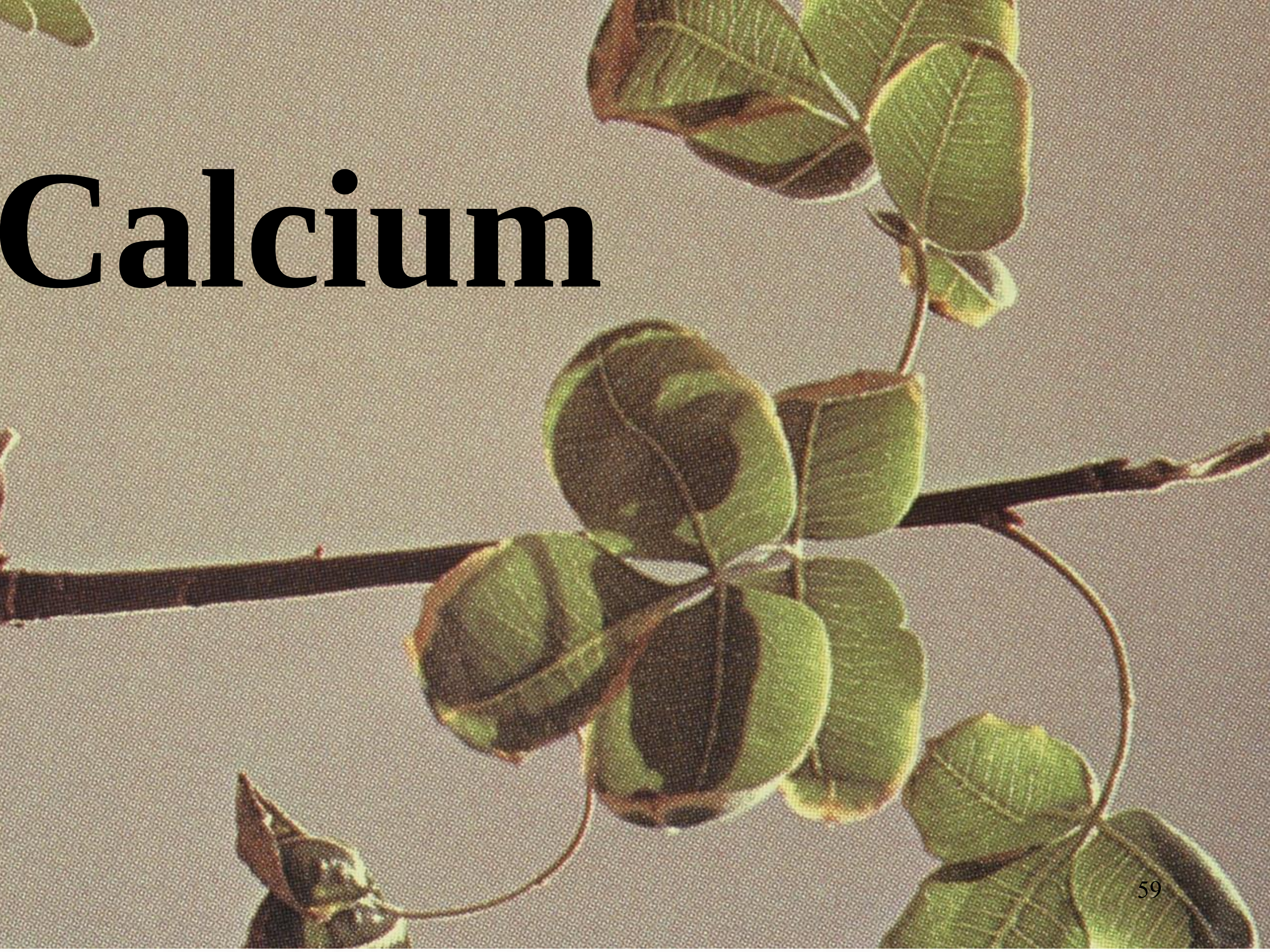
- **<u>Leaf Symptoms:</u>**
  - **initially interveinal chlorosis then leaves became bright yellow, dessicated and drop**
  - **first on leaves next to clusters**

Not commonly seen in California.

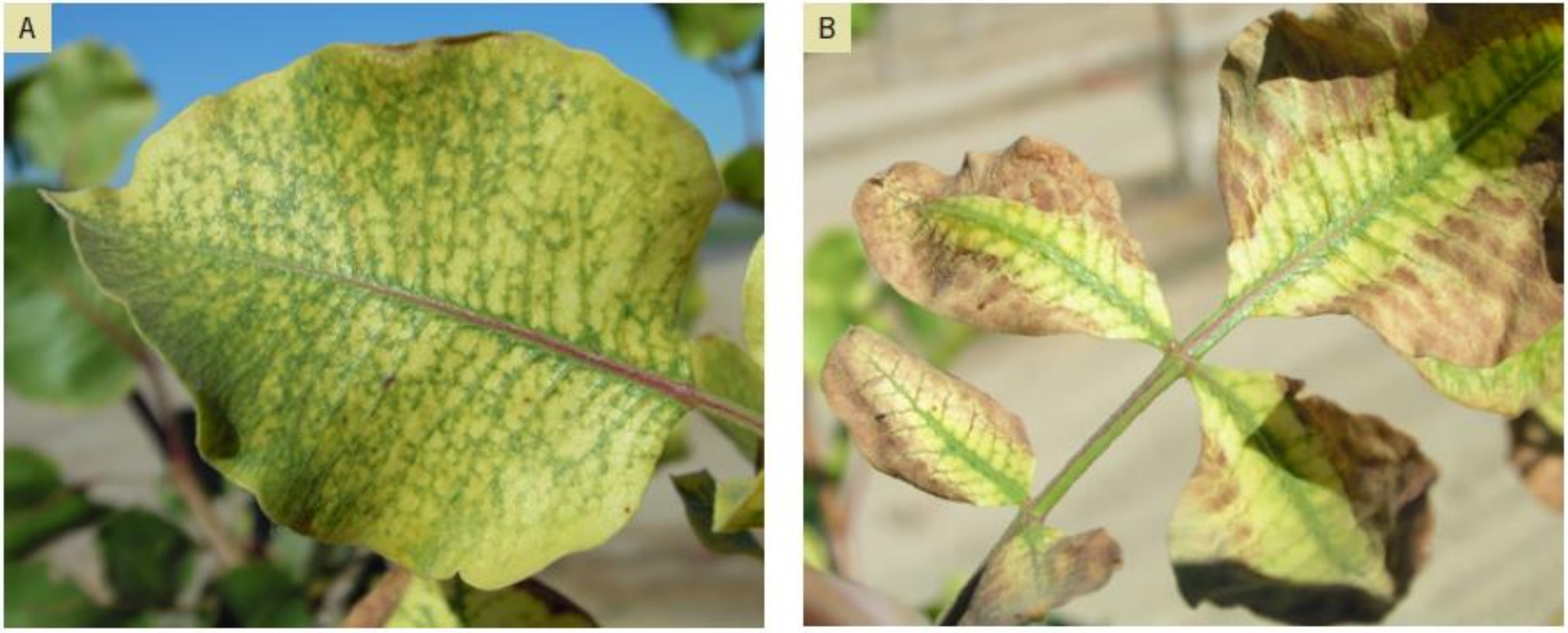
Critical Leaf Values
Calcium and Magnesium

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

Calcium



Magnesium



Summary:

Apply the Right Rate

- Match demand with supply (all inputs- fertilizer, organic N, water, soil).
- Nutrient demand changes as Yield changes. Fertilizer rates should vary, year to year and field to field.
- Conduct Tissue Sampling to monitor your progress, but do it right!

At Right Time

- Time fertilizations with demand.
- Uptake occurs only when healthy leaves are on the tree.

In the Right Place

- Ensure delivery to the active roots.
- Minimize movement of nutrients beyond the root zone
- Pay attention to variability within a field and between fields