Managing Nutrients Efficiently

Patrick Brown

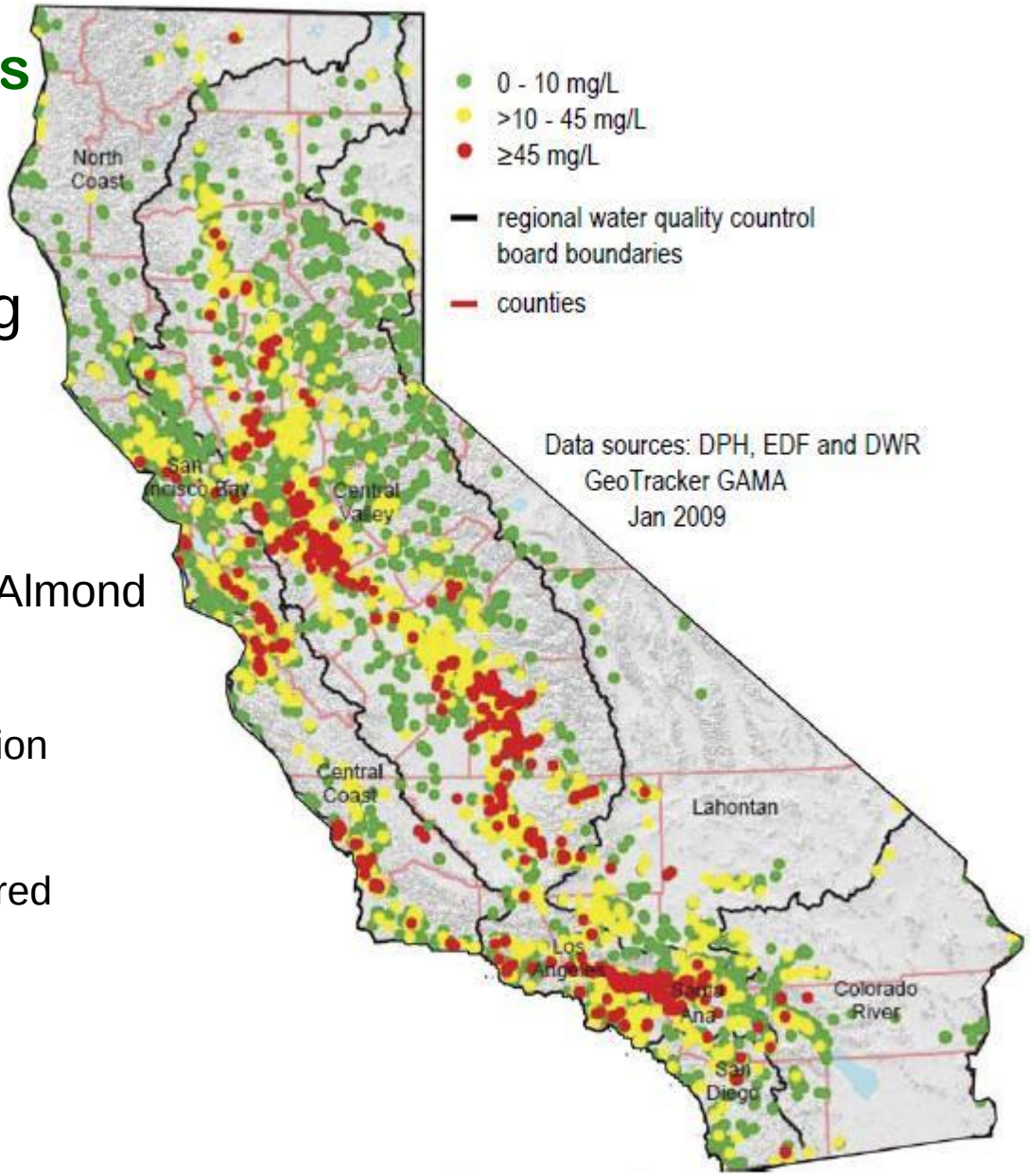
Recent Research on Plant Nutrition in Californian Almond: (2008-13)

Goals:

- **Maximize Productivity AND Minimize Loss of N and P to the Environment**
  - **Prepare for new legislative regulation of N and P.**
- **Improve efficiency of fertilizer use through fertigation**
  - **Optimize rates, timings and integration with irrigation.**
- **Provide easy to use tools and accurate and sensitive guidelines**
  - **Current tools for monitoring and management practices are inadequate**
  - **Develop new tools (Sampling and nutrient budgeting)**

Environmental concerns

Nitrate concentrations in many California wells exceed EPA drinking standards.



New Requirements for N use in Almond (in negotiation):

- Growers will receive an N allocation based on historic yields + X%
- Monitoring practices will be required (wells, soil sampling, accounting)
- In highest risk environments management practices (timing, fertigation etc) may be required

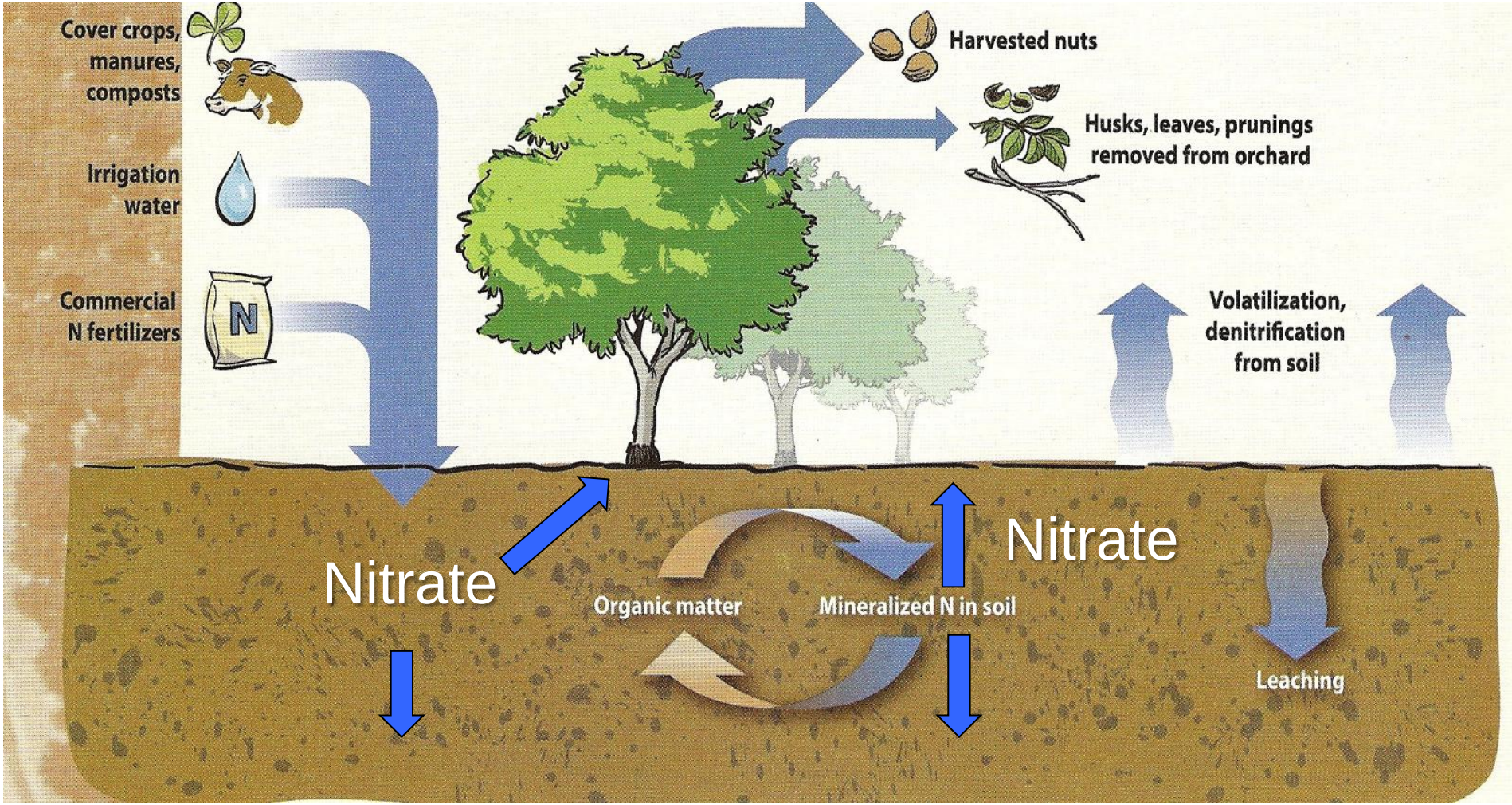
(Ekdahl and others, 2009; Harter Report, 2012)

How are nutrients obtained?

Soil Science and Plant Nutrient Uptake

- Nutrients are taken up in water only by active roots.
  - Active root growth is required.
  - Water, oxygen, suitable temperatures are required for uptake
  - Leaves are required for nutrient uptake by roots
  - Uptake is proportional to demand – NOT THE OTHER WAY AROUND!
- N, S, Mg, Ca, B are mobile in most soils
  - Water movement delivers these nutrients to roots
  - Water moving past the root zone can carry N with it.
- Mn, Zn, Cu, Ni, Fe have restricted solubility and movement in soils.
- K is mobile in some soils but not others
  - Soil tests to determine K-fixation are essential to K management.

The Nitrogen Cycle: A balancing act.



Kathy Kelley-Anderson et al: ANR Pub # 21623

Efficient Nutrient Management Approach
-the 4 R's-

Applying the Right Rate

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

At Right Time

- Apply coincident with root uptake.

In the Right Place

- Ensure delivery to the active roots.

Using the Right Source

- Maximize uptake minimize loss potential.

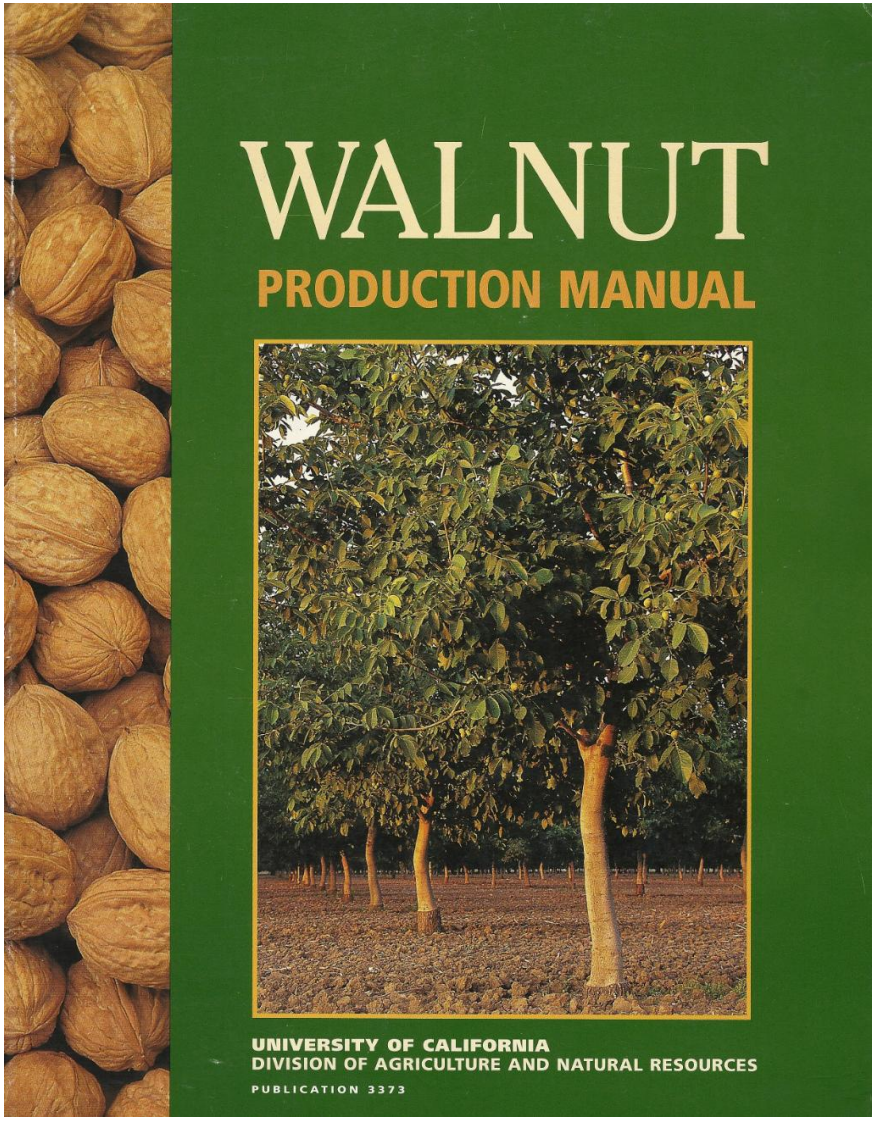
Use Effective Monitoring and Prediction Tools

What do we know and how do we manage?
Leaf Sampling and Critical Value Analysis

Table 24.2 Critical nutrient levels (on a dry weight basis) of walnut leaves in July.

Element	Concentration
Nitrogen (N)	
Deficient below	2.1%
Adequate	2.2 to 3.2%
Phosphorous (P)	
Adequate	0.1 to 0.3%
Potassium (K)	
Deficient below	0.9%
Adequate over	1.2%
Calcium (Ca)	
Adequate over	1.0%
Magnesium (Mg)	
Adequate over	0.3%
Sodium (Na)	
Excess over	0.1%
Chlorine (Cl)	
Excess over	0.3%
Boron (B)	
Deficient below	20 ppm
Adequate	36 to 200 ppm
Excess over	300 ppm
Copper (Cu)	
Adequate over	4 ppm
Manganese (Mn)	
Adequate over	20 ppm
Zinc (Zn)	
Deficient below	18 ppm

Source: Beutel, Uriu, and Lilleland (1983).



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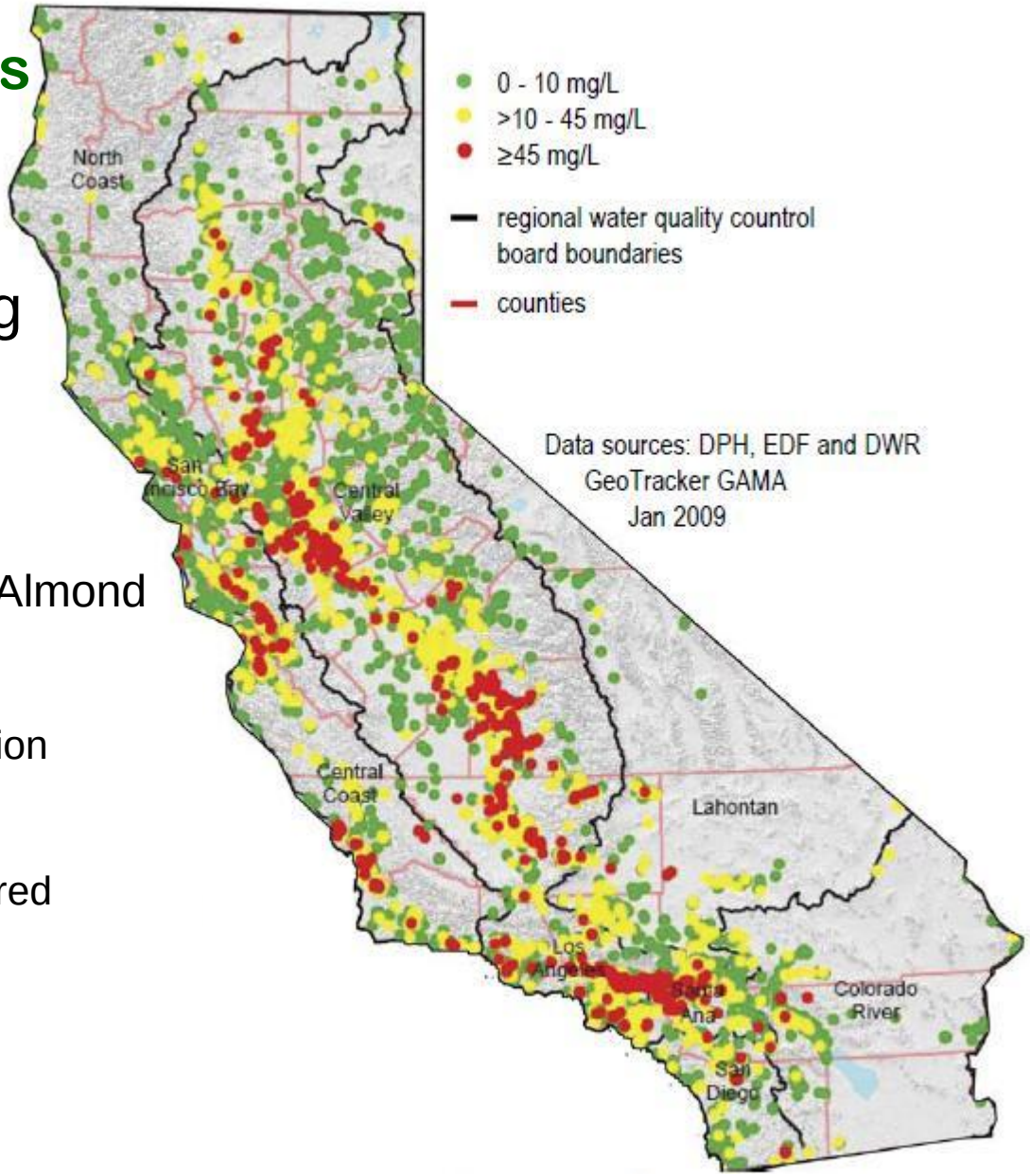

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- Growers will receive an N allocation based on historic yields + X%
- Monitoring practices will be required (wells, soil sampling, accounting)
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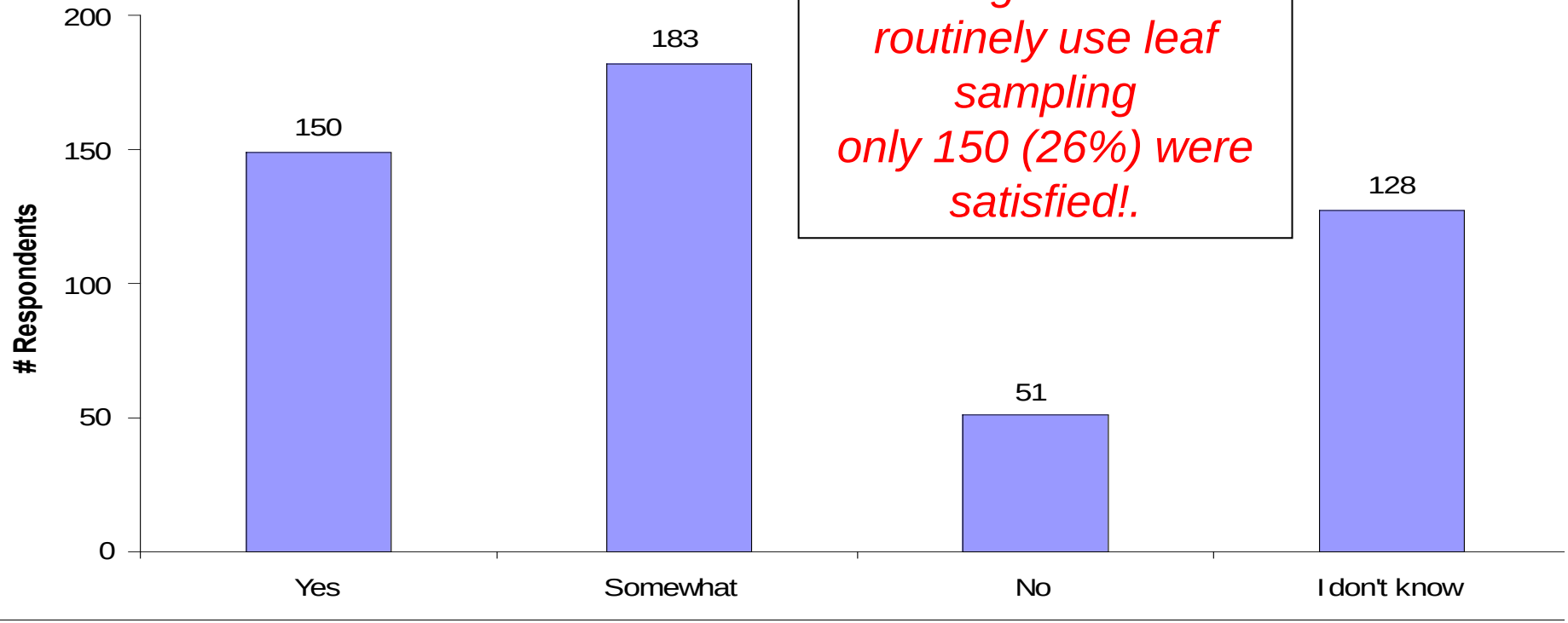
(Ekdahl and others, 2009; Harter Report, 2012)

Is Leaf Sampling and Analysis Trusted?

Are the Current Guidelines for Leaf Testing Adequate to make Fertilization Decisions?



Of 680 growers who routinely use leaf sampling only 150 (26%) were satisfied!.

Brown et al, 2004

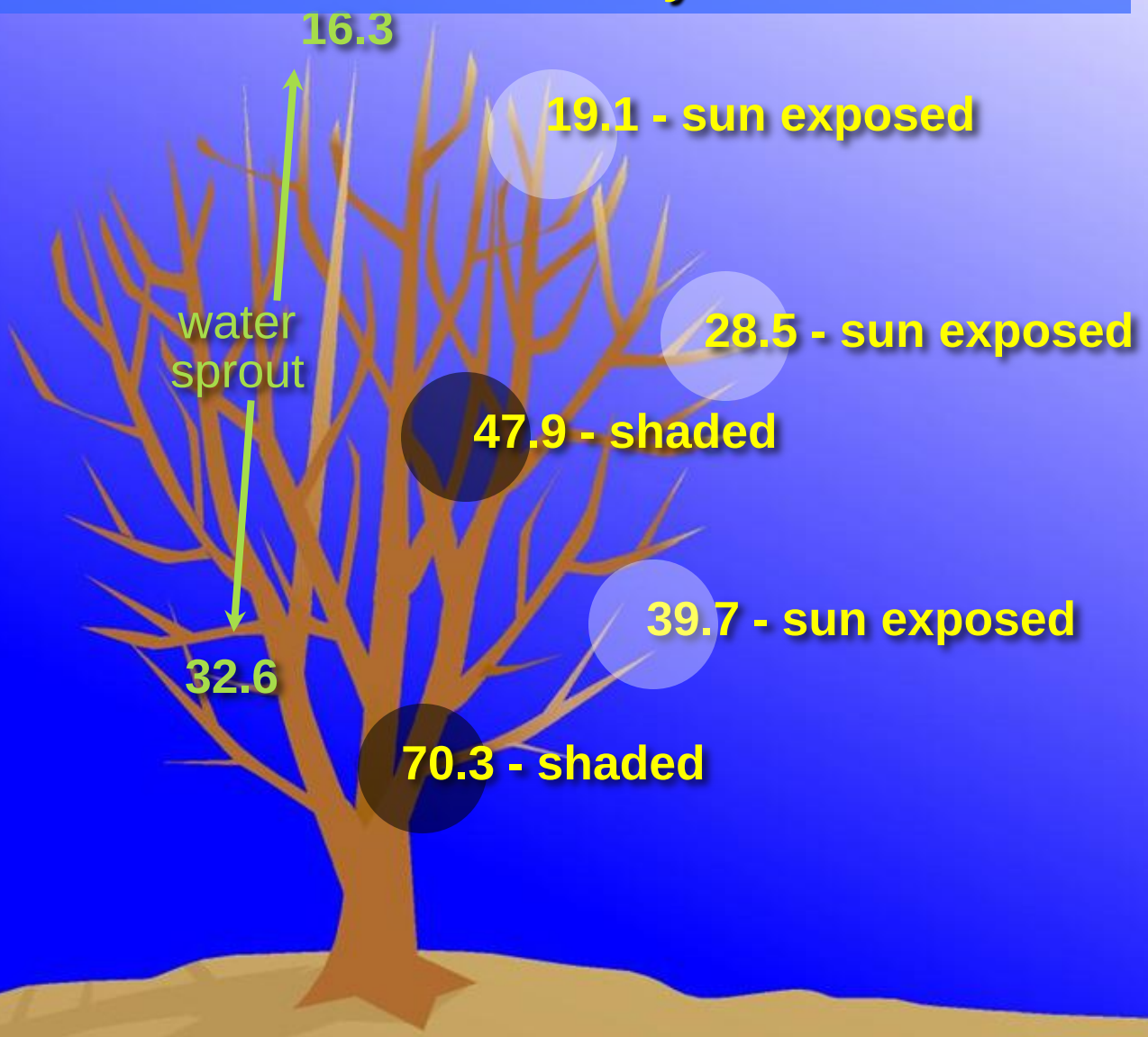
Reasons for low satisfaction:

- **Samples collected do not always represent the true nutrient status of the tree, or the orchard as a whole.**
- **Late summer sampling is too late in year to make in-season adjustments.**
- **Our current CV's may not apply in all cases or may be wrong.**
  Walnut values were developed on Hartley cultivar 20 years ago.
- **A leaf analysis does not provide enough information to make management decisions.**

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)**

Problem 1: Too Much Variability in a Tree.



Shoot Zn Distribution Through A Dormant Peach Tree (ppm)

Standard Sample: Fully Exposed non-fruiting leaves in late summer

Problem 2: Sampling is too late to adjust fertilizer for current crop load.

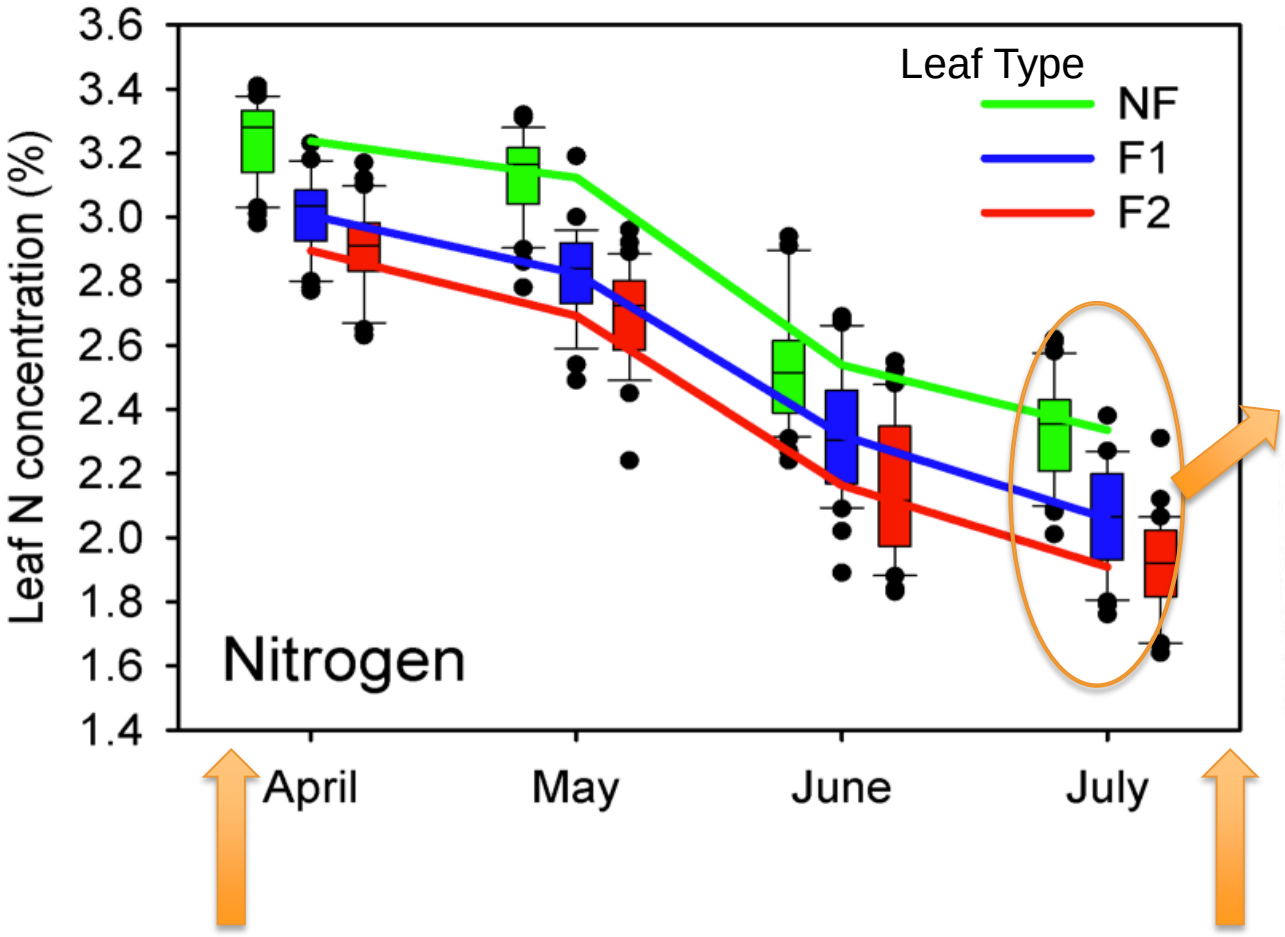
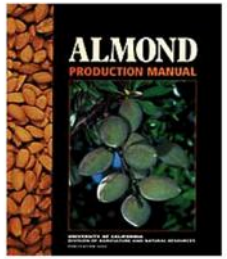


Table 26.2 Critical nutrient levels (dry-weight basis) in almond leaves sampled in July.

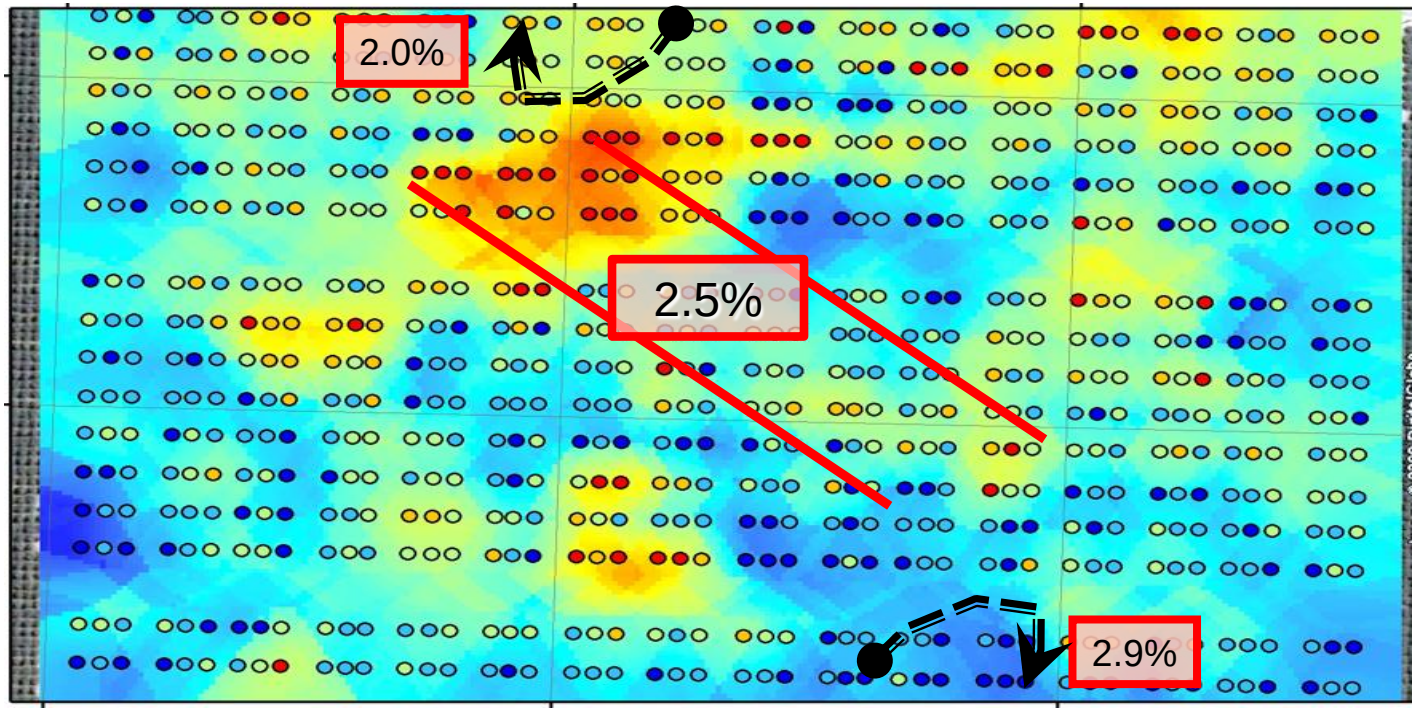


Nitrogen (N)	
Deficient below	2.0%
Adequate	2.2–2.5%
Phosphorus (P)	
Adequate	0.1–0.3%
Potassium (K)	
Deficient below	1.0%
Adequate over	1.4%
Calcium (Ca)	
Adequate over	2.0%
Magnesium (Mg)	
Adequate over	0.25%
Sodium (Na)	
Excessive over	0.25%
Chlorine (Cl)	
Excessive over	0.3%
Boron (B)*	
Deficient below	30 ppm
Adequate	30–65 ppm
Excessive over	300 ppm
Copper (Cu)	
Adequate over	4 ppm
Manganese (Mn)	
Adequate over	20 ppm
Zinc (Zn)	
Deficient below	15 ppm

*Critical values for boron deficiency and toxicity are currently being revised. Hull boron >300 ppm is excessive. Leaf sampling is not effective to determine excess boron.

Problem 3: Field Variability

Common Sampling Practices are Inadequate:



% N

Individual trees

- 1.92 - 2.17
- 2.18 - 2.31
- 2.32 - 2.42
- 2.43 - 2.53
- 2.54 - 2.87

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

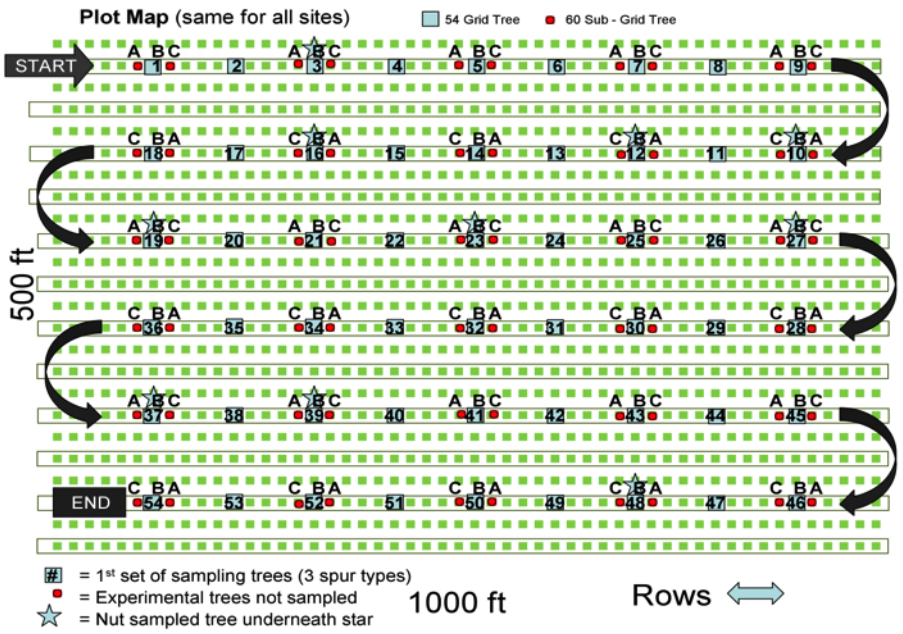
Leaf Sampling And Interpretation Methods For CA Almond Orchards.

Sebastian Saa, Patrick Brown. UC Davis

Improved Tissue Sampling and Interpretation:

- Develop methods to sample in spring and relate that number to summer critical value.
- Develop sampling methods that accurately predict average field nutrient concentration AND variability.
- Provide an integrated grower friendly method:
  - recognizing that typical practice is to collect only 1 sample per field.

Leaf Sampling: Experimental Design



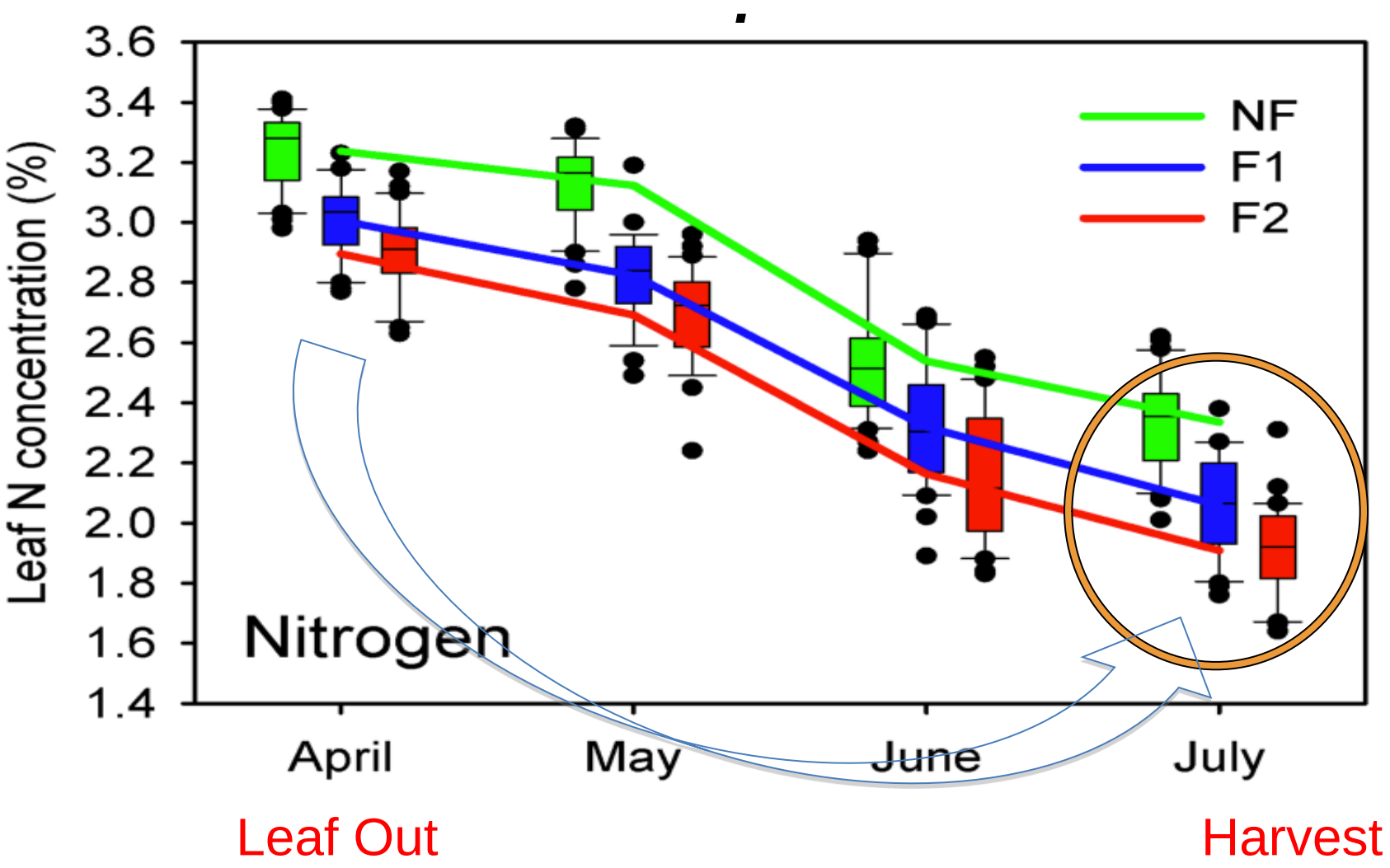
- 100 acre x 4 Sites x 4 years.
- Leaves collected at multiple dates. Yield recorded

(About 1,130 data points)

- Model Developed in 2011
- Validated at 6 sites in 2012.

(8,500 x 11 = 93,500 data points)

Can we predict late summer N with spring leaf sample? Which leaf type should be used?



YES: Spring samples can effectively predict summer tissue values:

Collect leaf samples as early as 40 days after bloom from non fruiting spurs.
- **self correcting for sample date/season.**

Utilizes tissue P, S, B, Mn, Cu, N, K, Ca, Mg and applies series of formula.

Validated in 2012 in California, needs to be validated in Australia.

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

Objectives:

- Develop methods to sample in spring and relate that number to late summer critical va

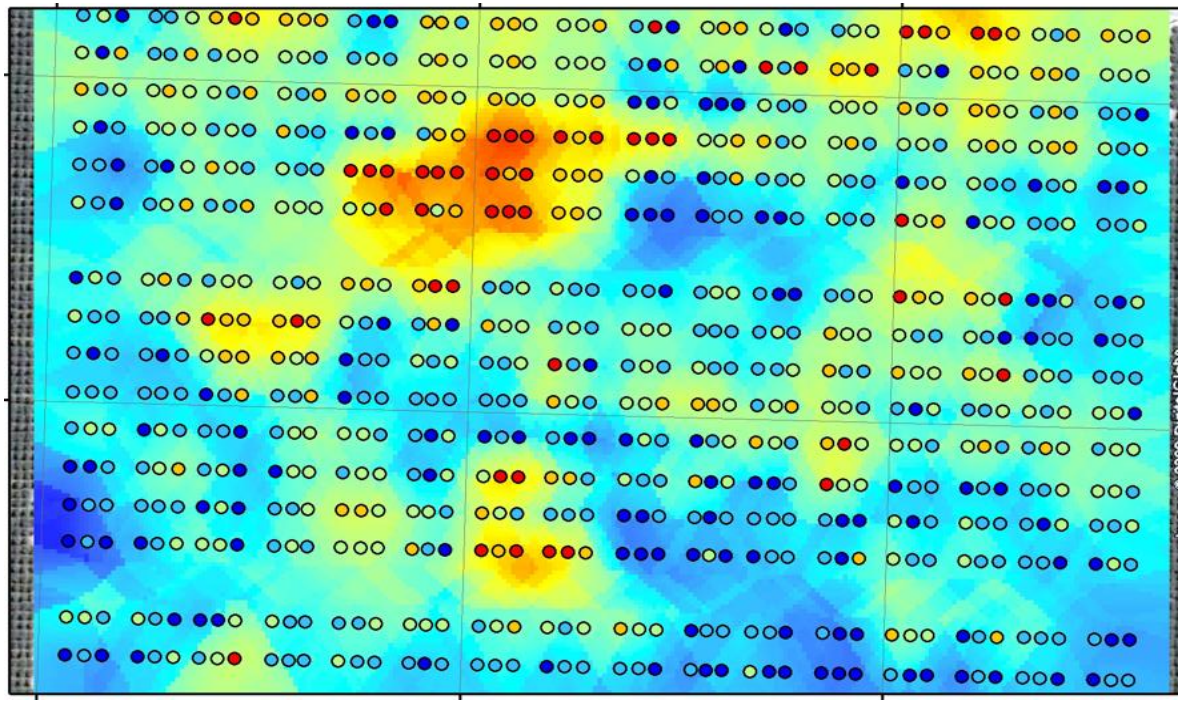
- **Develop a protocol for growers to sample their fields properly (recognizing that only 1 sample per field is generally collected).**

Field Variability:

How many trees should be sampled?

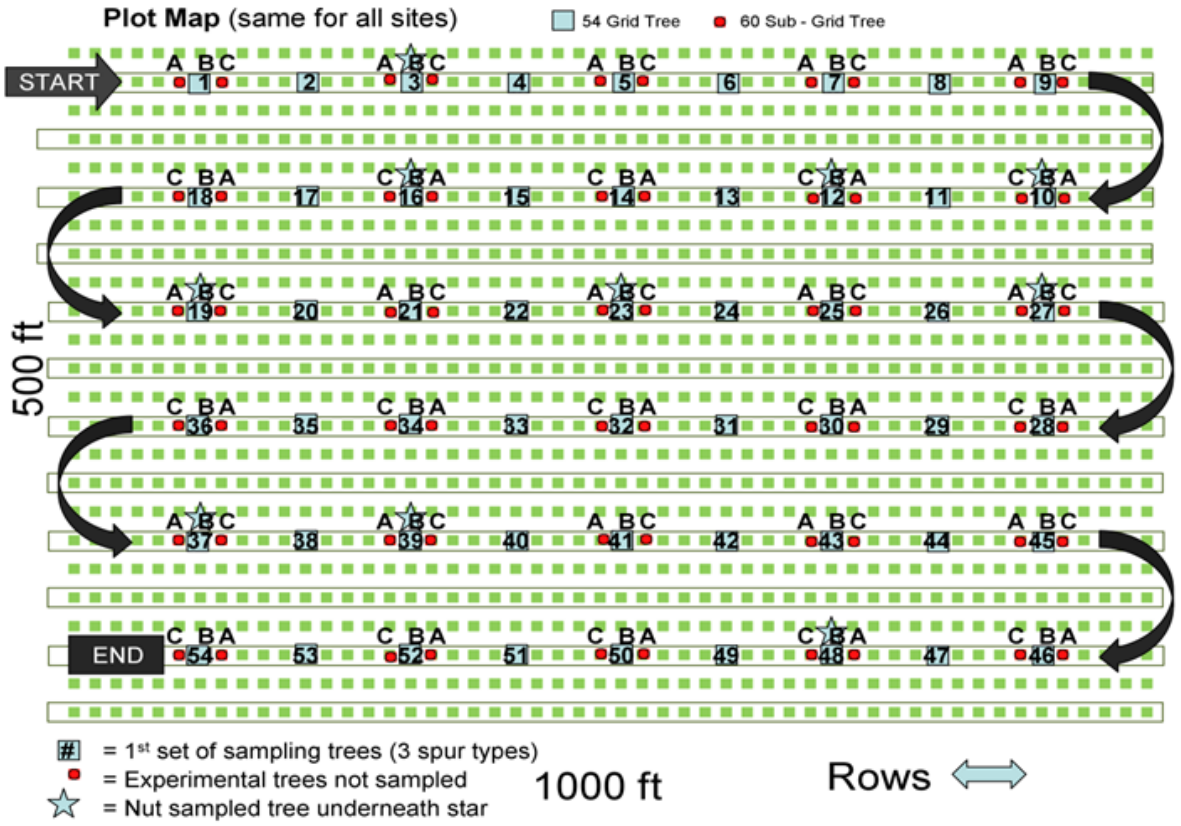
How far apart?

Which leaf type?



Spatial Correlation and Statistical Modelling

➔4 orchards of 100 acres. Multiple tissue sampling. 4 years. Extensive statistical analysis



Number of trees needed (spring or summer) to estimate the field N.

Each sampled tree must be 30 yards apart

Number of Acres	Trees needed at 95% Confidence	Trees needed at 90% Confidence
2	25	18
5	27	19
10	28	19
50	28	20
100	28	20
Note: 1 acre is assumed to be 100 trees		

Number of trees from which leaves must be collected and pooled into a single bag for a single nutrient analysis

Recommended Sampling Criteria: Almond

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

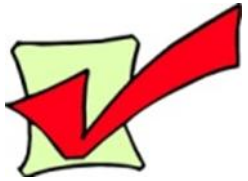
- **Collect leaves from 18 trees in one bag.**
- **Each tree sampled at least 30 yardsapart.**
- **In each tree collect leaves around the canopy from at least 8 well exposed spurs located between 5-7 feet from the ground.**
- **In spring, collect samples soon after full leaf expansion (approx. 30-50 days after full bloom (DAFB). In summer, collect at traditional sampling date.**
- **Have lab analyze for P, S, B, Mn, Cu, N, K, Ca, Mg and apply UCD-ESP model to predict July nutrient status.**

Non-Uniform Orchard:

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

Objectives:

- Develop methods to sample in Spring and relate that number to Summer critical value.



- Develop method for grower to sample his field (recognizing that only 1 sample per field is generally collected).

- Even if you sample well and predict from April to July it is still not good enough since it does not provide quantified management guidelines.

ALTERNATIVE APPROACH

Nutrient Budget for Almond

Saiful Muhammad, Patrick Brown
UC Davis

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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.

Determining the Right Rate and Timing

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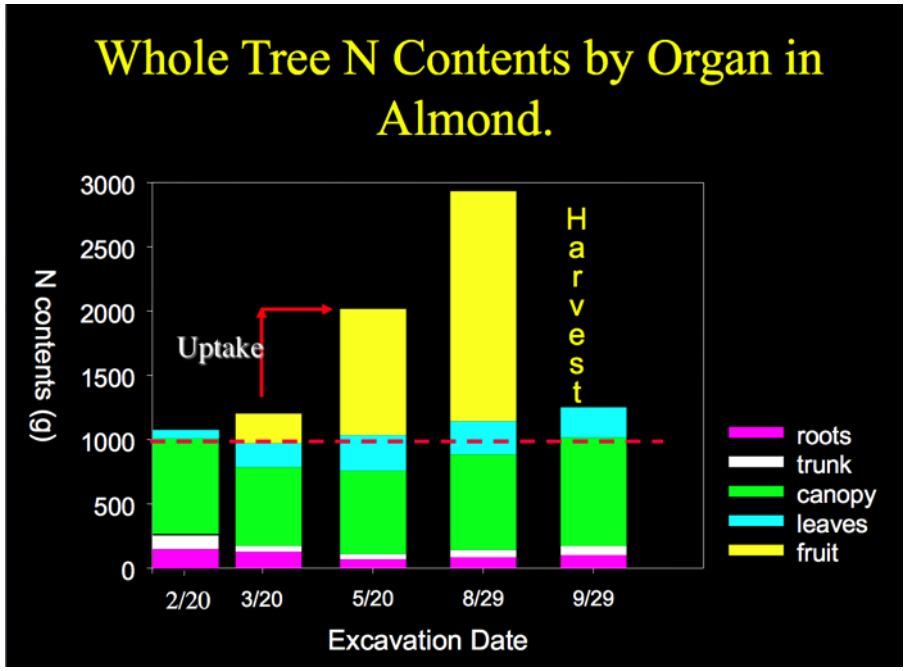
Nutrient Budget Approach

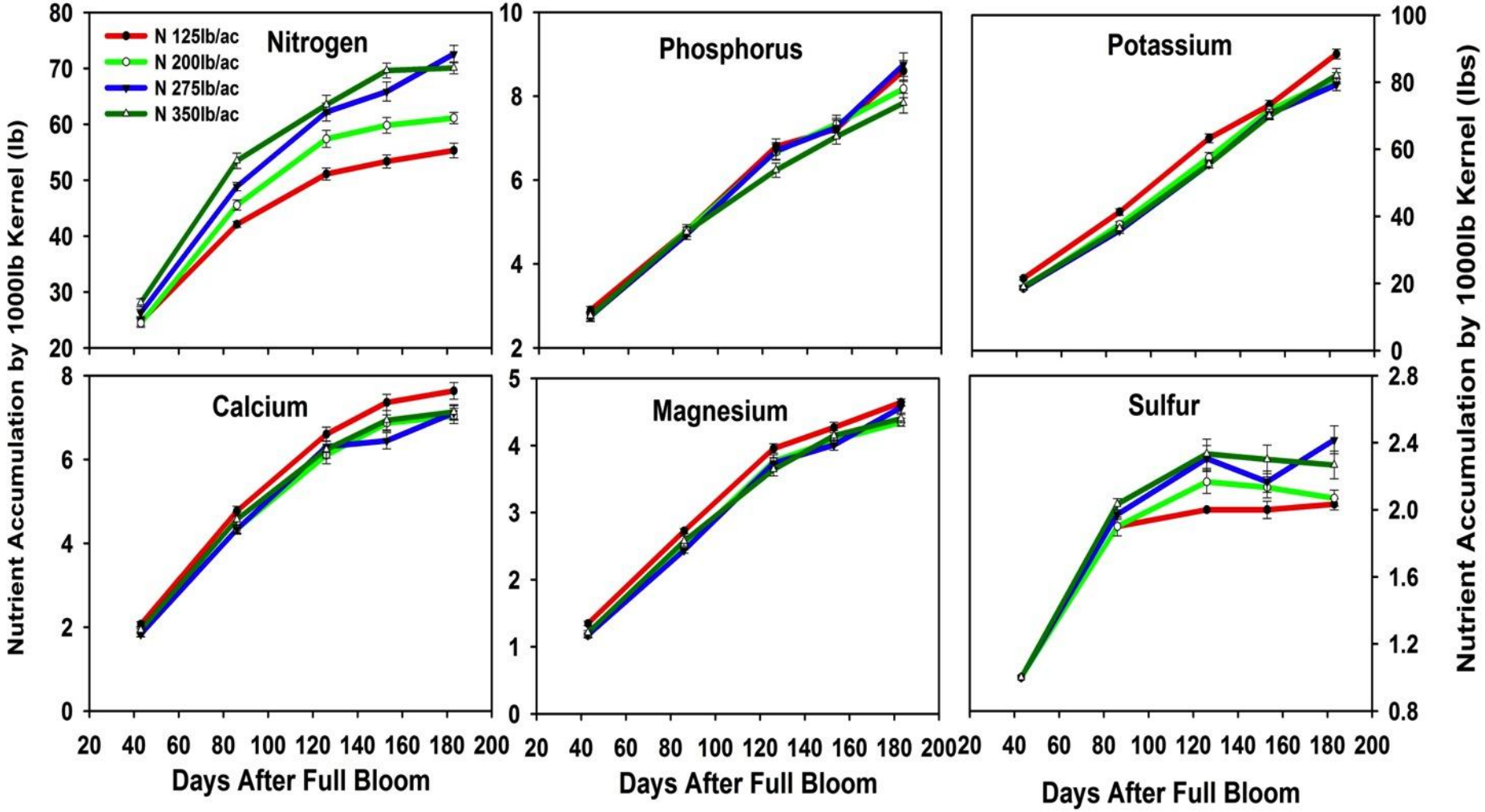
- What is tree total annual demand
- When during growth and development does uptake occur.

Approach:

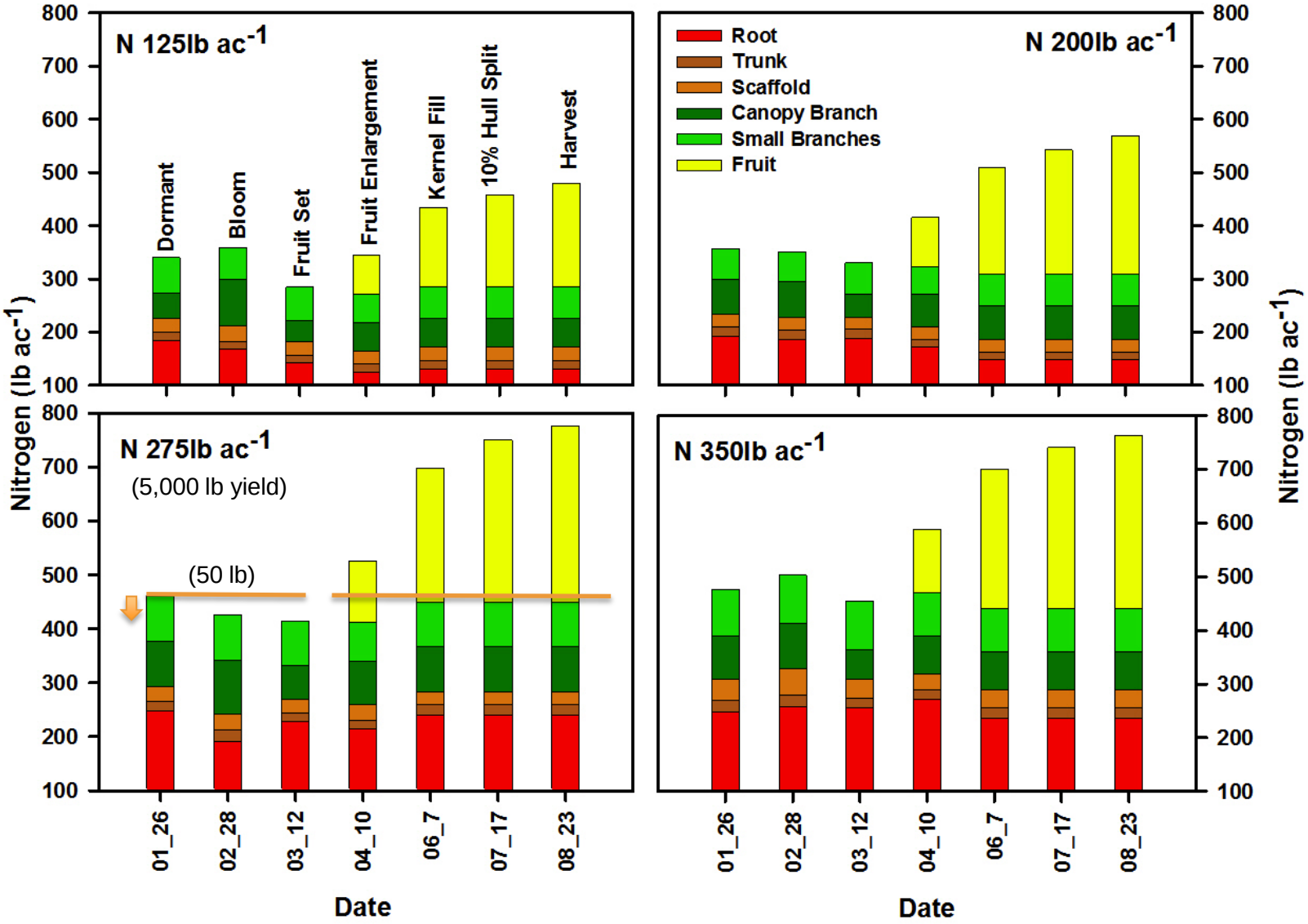
- Whole tree excavation, trunk coring, sequential nut collection and analysis, yield modeling- 1000's of individual trees



Nutrient Accumulation during Growing Season (per 1000 lb kernel)



Annual Change in Nutrient Content: Almond



Nutrient Demand

Nutrient removal Per 1000 lb
(Almond =Kernel equivalent, Walnut = Kernel plus Shell)

Nonpareil

- N removal 68 lb per 1000
- K removal 80 lb per 1000
- P removal 8 lb per 1000

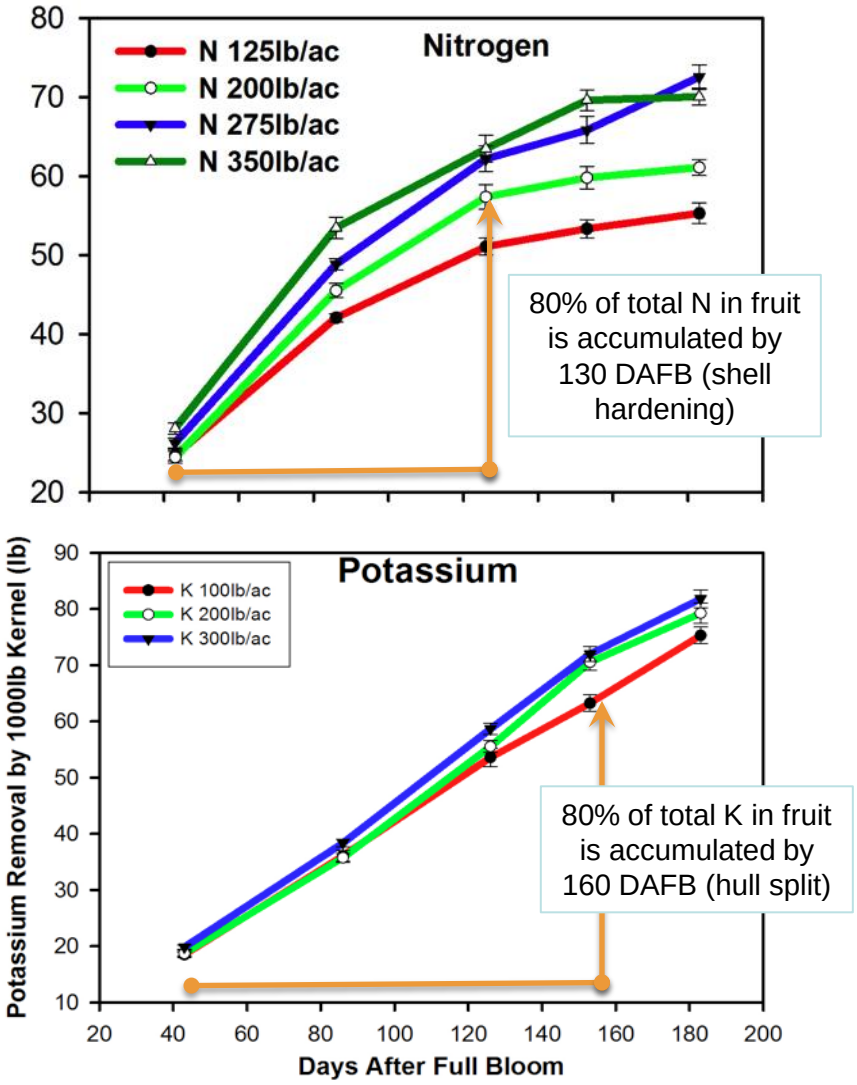
Monterrey

- N removal 62 lb per 1000
- K removal 71 lb per 1000
- P removal 7 lb per 1000

Walnut Hartley, (K Kelley Anderson et al 2006)

- N removal 40 lb per 1000

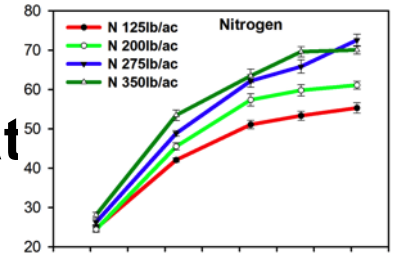
2011



Conclusions: Managing Nitrogen in Almond

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

- **Make an preseason fertilizer plan based on expected yield.**
  - **1000lb kernel removes from 68lb N, 8lb P and 80lb K.**
- **Conduct leaf analysis following full leaf out.**
- **Using leaf analysis and updated yield estimat fertilization for remainder of season.**
  - **Time application to demand**
    - **80% N –full leaf out to kernel fill**
  - **Apply up to 20% immediately post harvest, corrected for actual yield - but only if trees are healthy. Use foliars if N loss**



Conclusions: Managing Nitrogen

Leaf analysis is useful to monitor orchards but it is NOT adequate to make fertilizer decisions.

Follow the sampling rules!

- **18 trees/one bag/each 30 yards apart. You can sample in spring to estimate summer. (working with ABC to validate)**
- **Use leaf analysis in conjunction with yield estimate to adjust in-season fertilization.**
- **Keep good records and sample consistently and correctly over the years.**

How efficient can we be?

Experiment initiated in 2008 – 2013 utilizing best practices based on 4 R's and detailed monitoring:

Applying the Right Rate

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

At Right Time

- Fertigate coincident with demand.

In the Right Place

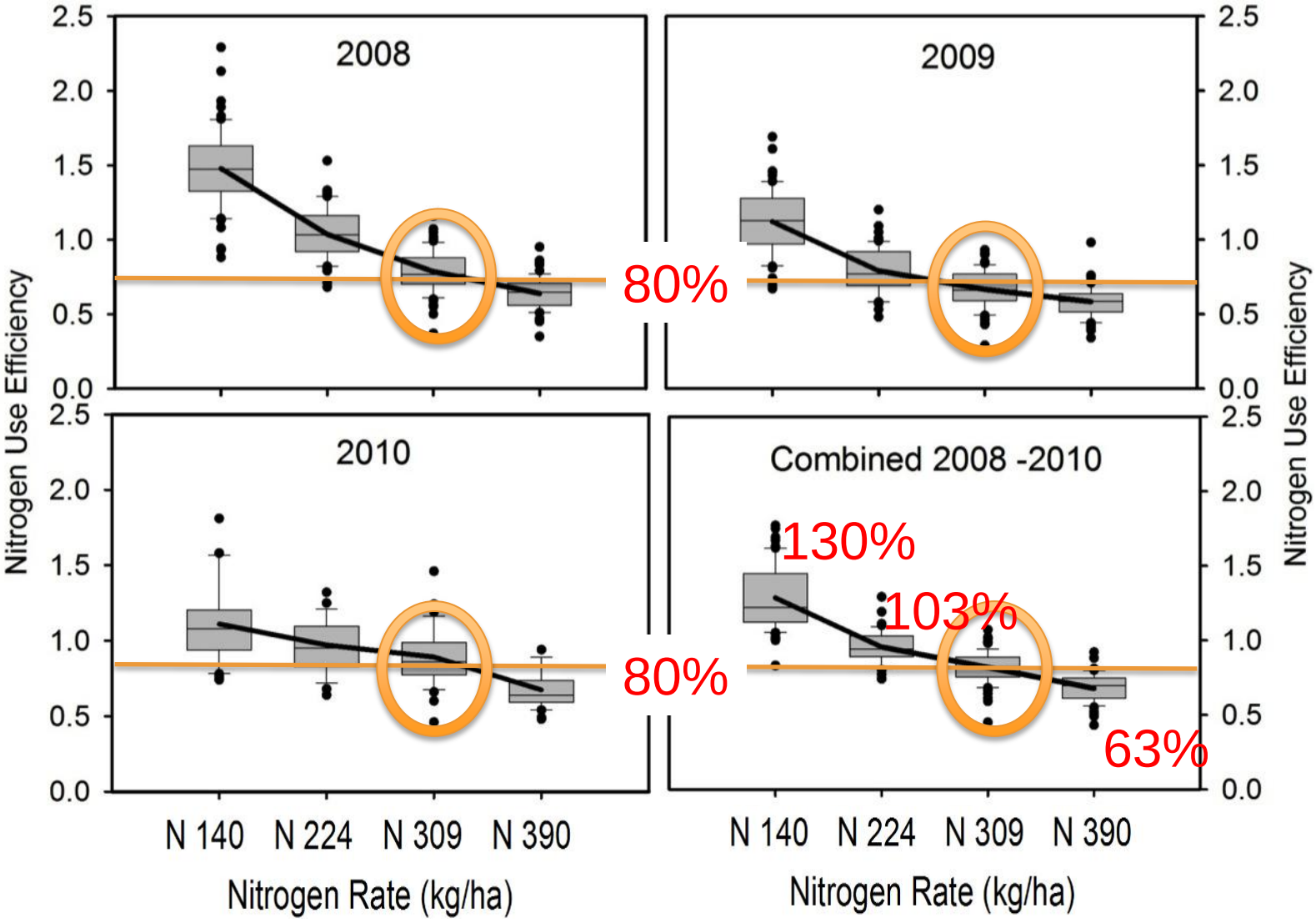
- Ensure delivery to the active roots.

Using the Right Source

- Soluble, compatible and balanced.

New Sampling Methods

Nitrogen Use efficiency 2008 – 2010 under optimum treatment (N 275) was >80%



NUE = N Export in Fruit/N Applied

Why bother? $$, wastage, balance, sustainability.

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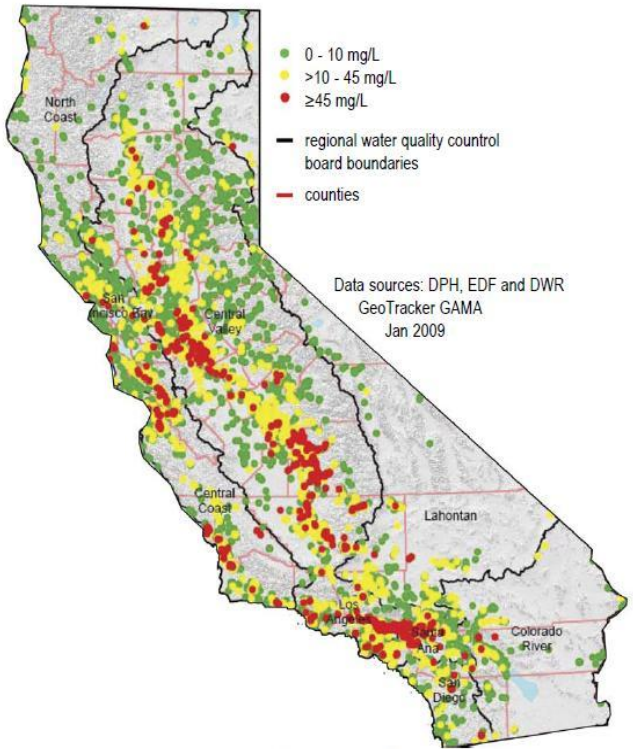
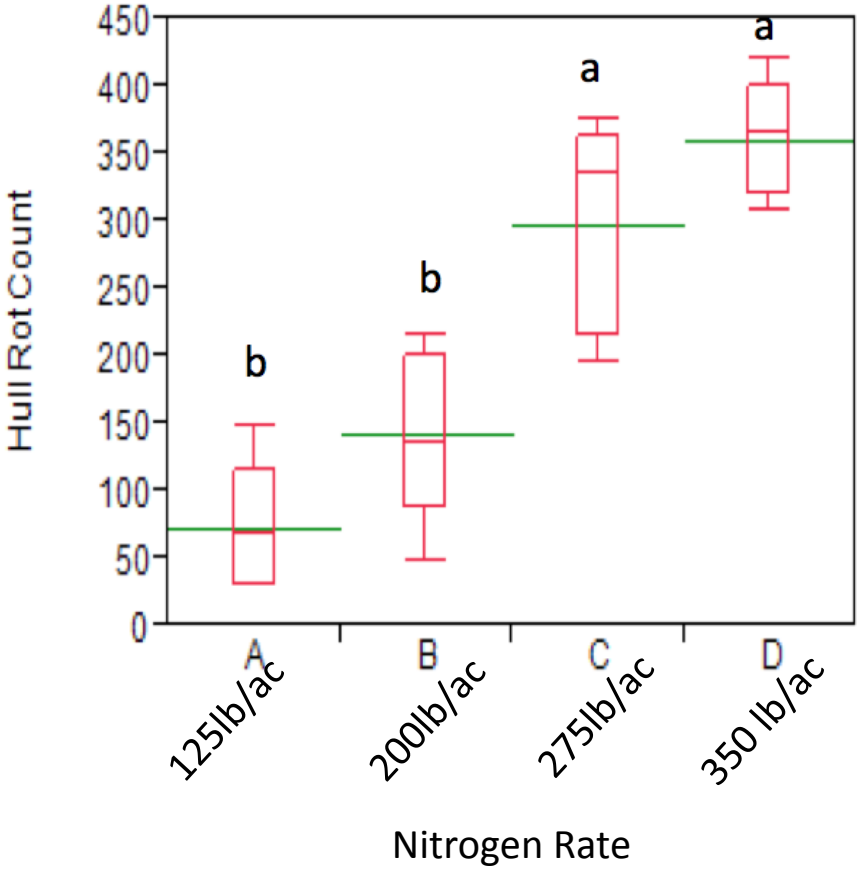
Water Quality



Disease Interactions



Thank you!

- Sebastian Saa
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- Paramount Farming
- Almond Board of California
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