Managing Nitrogen Efficiently

Patrick Brown

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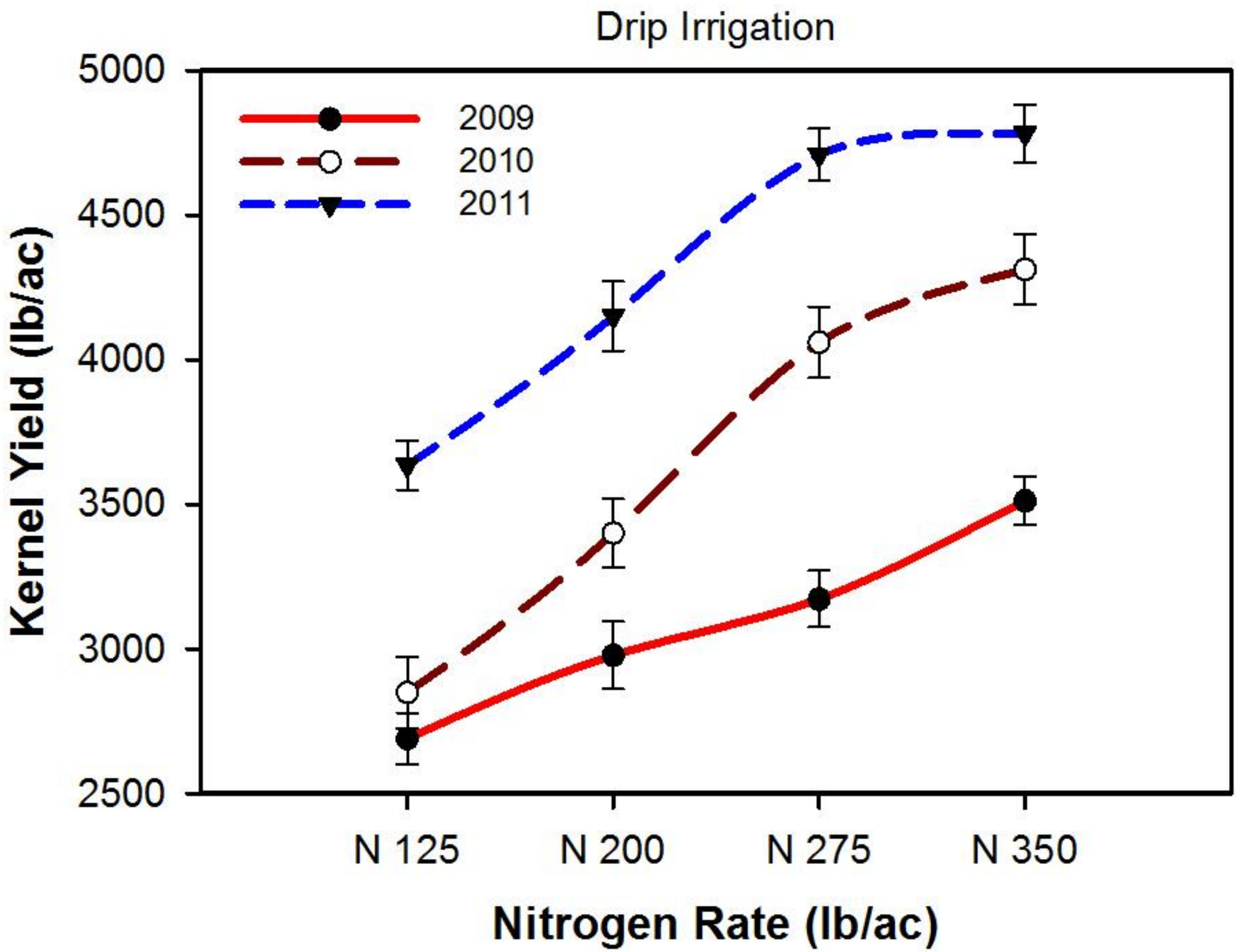
Background

Why the focus on Nitrogen?

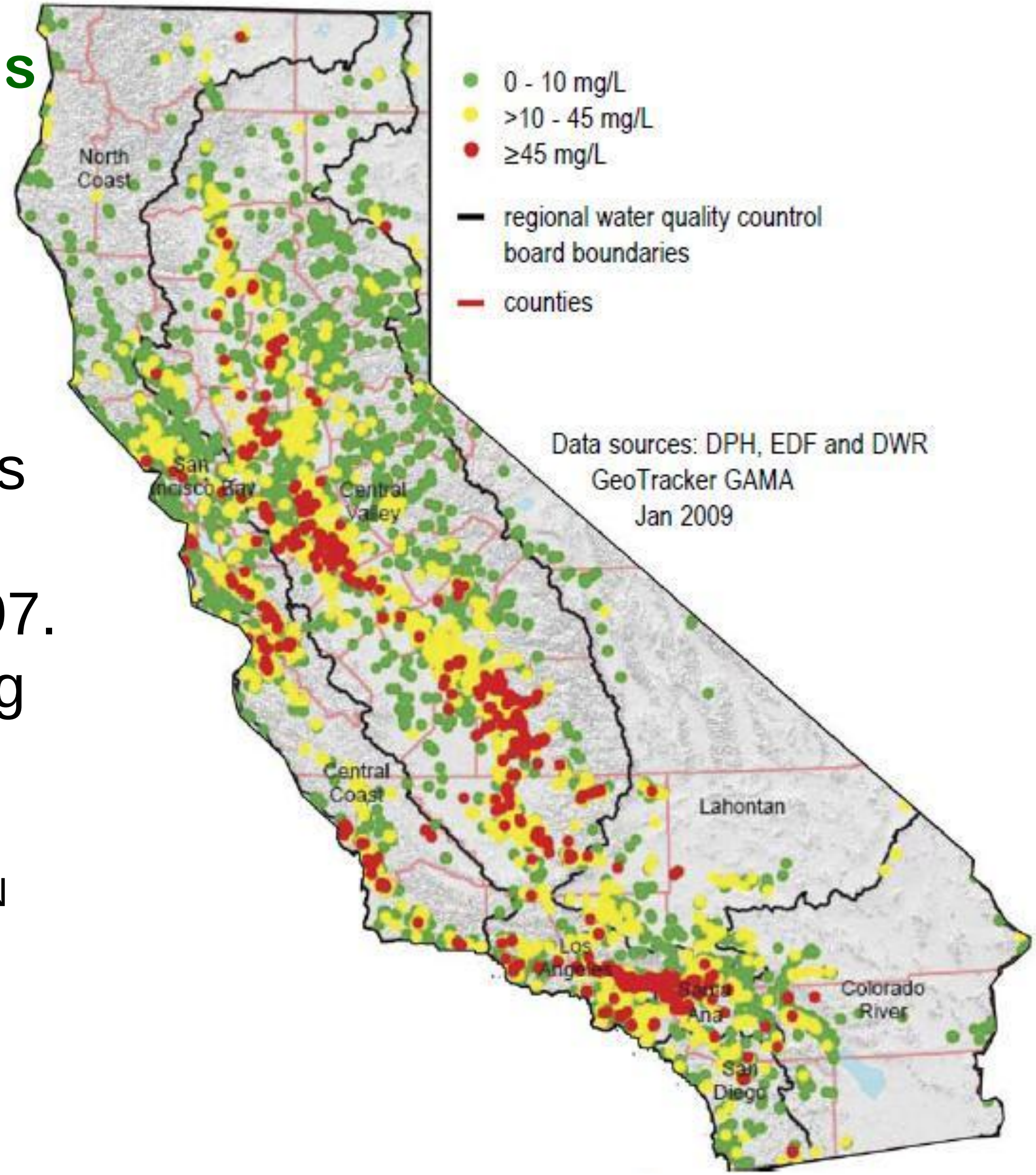
- **Essential for plant growth and critical for crop yield**
  - **N is critical for photosynthesis, protein formation and growth**
  - **Almonds are among the most N and K demanding of any crop.**
- **Nitrogen that escapes the orchard is a pollutant**
  - **Negative impacts of N on Californian water and air resources are well documented.**
  - **Regulatory controls on its use are imminent.**
- **Nitrogen management is complex**
  - **Application of fertilizer N (inorganic and organic) is a major cost**
  - **Current tools for monitoring and management are inadequate**

Satisfy Demand-Prevent Losses-Maximize Efficiency?

Nitrogen is essential for Almond yields



Environmental concerns



Nitrate concentrations in various California wells measured in 2007. Many exceed drinking standards

44 mg/L NO_3 = 10 mg/L NO_3-N

(some from animal manure)

(Ekdahl and others, 2009)

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CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD

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Groundwater Quality Protection Strategy 2-Year Work Plan

RESOURCES

- Email Subscriptions
- Data & Databases
- Business Help
- Public Records Center
- Grants & Loans
- Fees
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- Delta Water Quality
- Enforcement
- Irrigated Lands Regulatory Program
- Salinity (CV-SALTS)
- Storm Water
- Surface Water Ambient Monitoring
- TMDLs and Impaired Water Bodies
- Watershed Management Initiative
- Water Education
- Water Quality Goals
- More...

ANNOUNCEMENTS

- Next Regional Board Meeting - 30 November-1/2 December 2011
- **New!** Regional Board Meeting Dates for 2012
- 12th Meeting of the Groundwater Monitoring Advisory Workgroup, 25 August 2011
- Notice of Public Hearing - Proposed Non-Regulatory Basin Plan amendments
- Central Valley Dairy Representative Monitoring Program, Approval Letter and Response to Comments
- More Announcements...

IMPORTANT INFORMATION...

Regional Water Quality Control Boards' MAPS & WEBSITES | Water Boards' Data Maps | Water Boards' Delta Watermaster | Once-Through Cooling Power Plants | CEDEN California Environmental Data Exchange Network | Water Quality Assessment Integrated Report

IPNI

895 Aerovista Place, Suite 101, San Luis Obispo, California 93401-7906
(805) 549-3147 • Fax (805) 543-0397
http://www.waterboards.ca.gov/centralcoast

Linda S. Adams.
Secretary for Environmental Protection

Arnold Schwarzenegger
Governor

59. The purpose of the nutrient management element of the Farm Plan is to eliminate or minimize nutrient discharges to groundwater and surface water to meet water quality standards using best practicable treatment or control, and to assure compliance with this Order. The nutrient management element of the Farm Plan must be certified by Appropriate professional certification, such as Certified Crop *Advisor to be protective of water quality…*

Example: Regulatory proposal

60. *The nutrient management element of the Farm Plan must include…*

a.Average total crop nutrient demand and method(s) of determination per crop;

b. Average total water demand per crop and total water applied per crop;

c. Monthly record of fertilizer applications per crop, including fertilizer type and quantity applied (including but not limited to fertilizers, compost, manure, and humic acids);

d. Nitrate concentration of irrigation source water;

e. Timing of fertilizer application to maximize crop uptake,

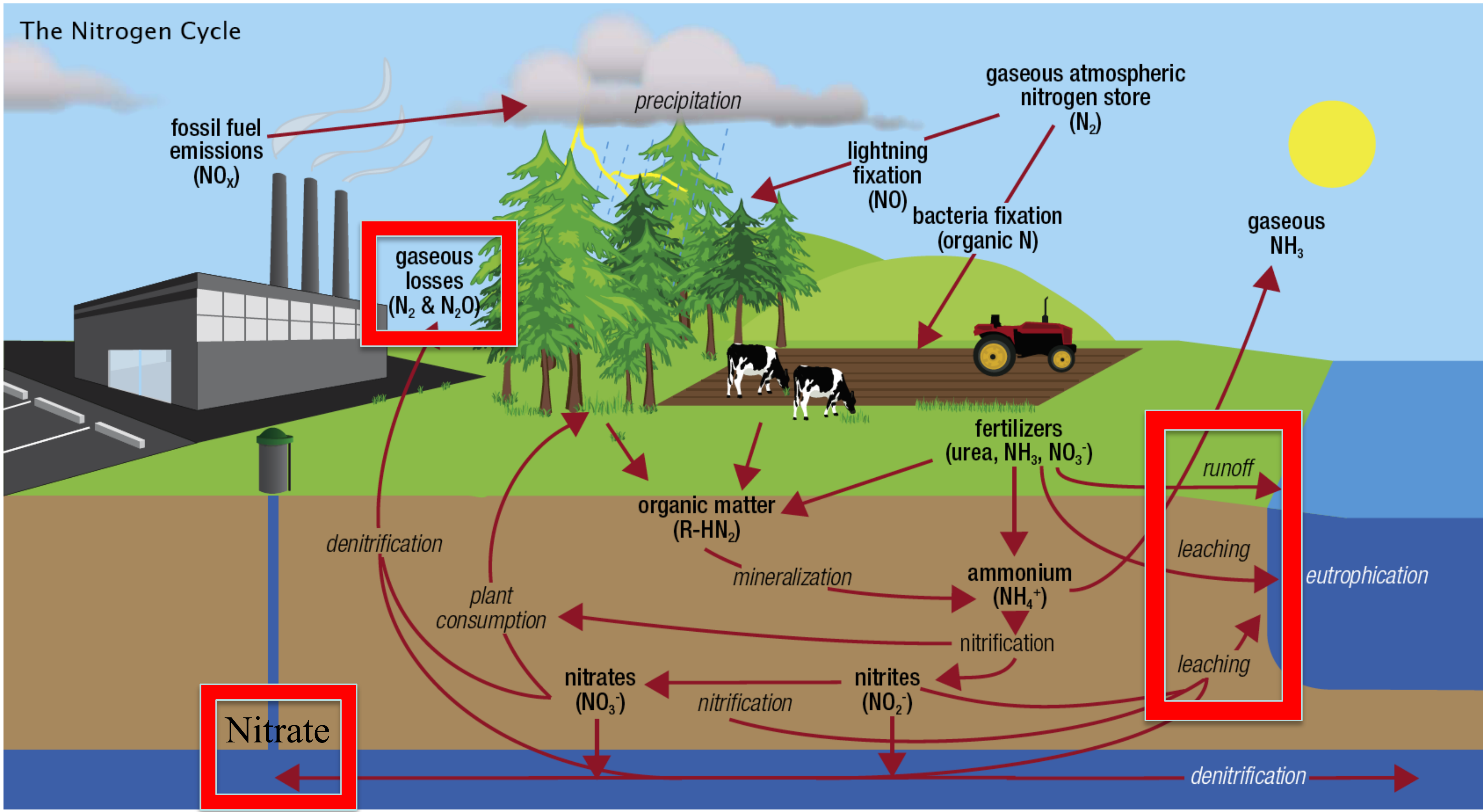
f. Estimation of the amount of fertilizer applied in excess of crop needs,

g. Estimation of excess or residual fertilizer/nutrients in the root zone at the end of the crop growing season;

h. Identification of planned nutrient management practices (such as irrigation efficiency, nutrient budgeting, and nutrient trapping) to eliminate or minimize nutrients in irrigation runoff or percolation to groundwater;

i. Identification of planned management practices related to fertilizer handling, storage, disposal, and mgnt

The Nitrogen Cycle: Nitrogen is essential for all agriculture and all forms of nitrogen (N-fixation, chemical and biological) are subject to loss to varying degrees.



The nitrogen cycle illustrates the various forms and transformations of nitrogen compounds.

(Thomas Harter)

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.

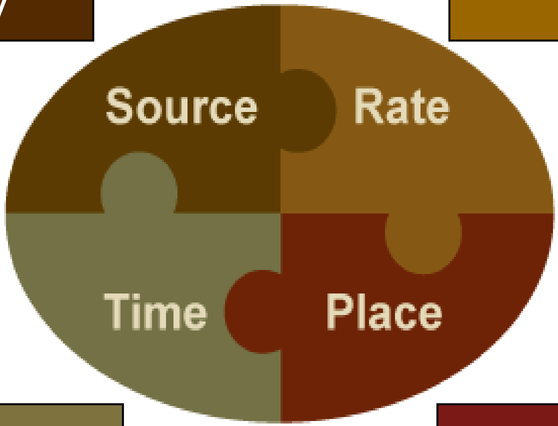
Using the Right Source

- Maximize uptake minimize loss potential.

The basic scientific principles of managing crop nutrients are universal

1. Supply plant available N forms
2. Suitable for the soil properties
3. Considers synergy among elements
4. Is compatibility; user friendly

1. Assess all available nutrient inputs (water, legumes etc)
2. Determine plant demand
3. Optimize fertilizer use efficiency



1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply and movement
3. Incorporate weather factors
4. Evaluate logistics of operations

1. Determine root distribution and dynamics
2. Manage spatial variability
3. Optimize fertigation
4. Limit potential off-field transport

The most relevant scientific principles of managing Almond nutrients are:

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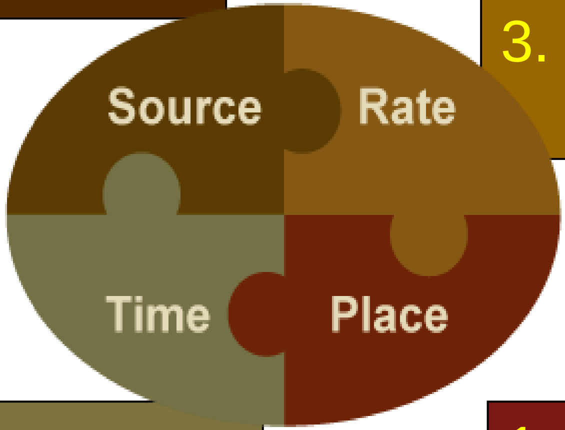
1. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility



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2. Manage spatial variability
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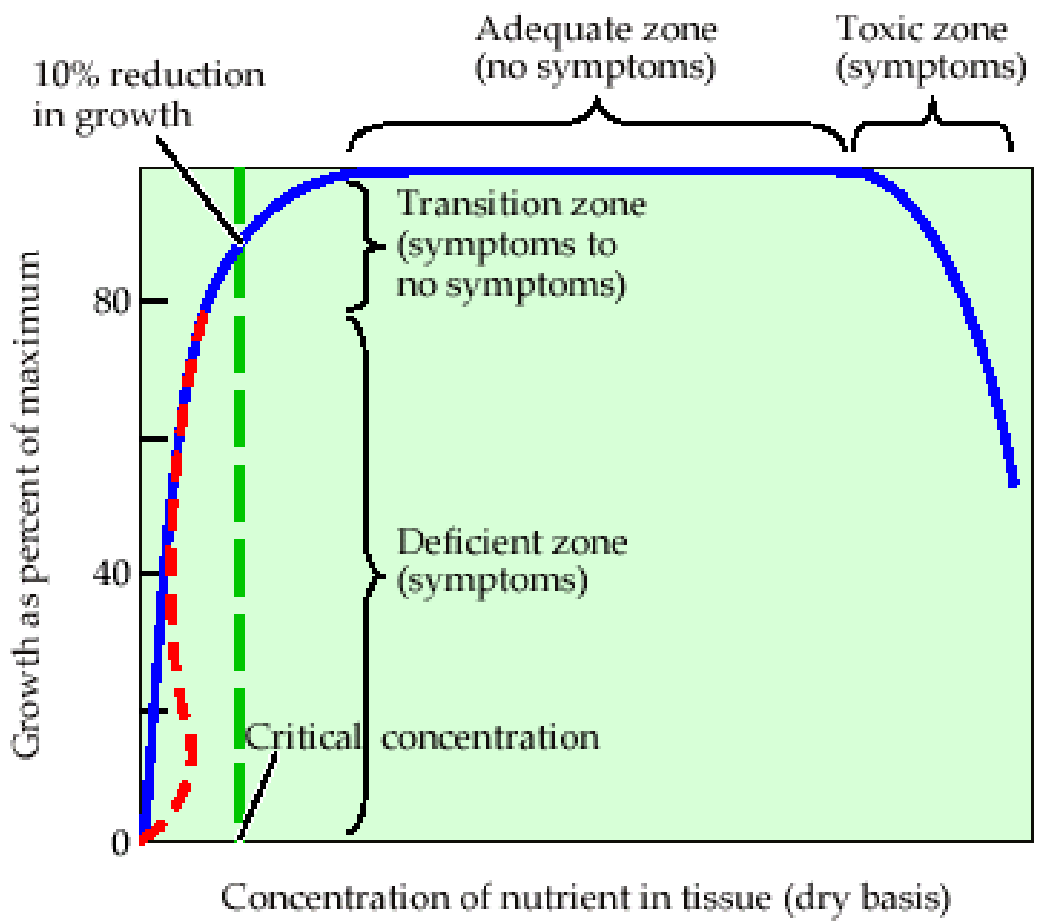
What do we know and how do we manage?
Leaf Sampling and Critical Value Analysis



*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.

:ols are well defined

pur leaves

|uadrant at 6'.

analysis with standard Critical
:d in Almond Production Manual

ıls (N, K, B)

nptoms (P, S, Mg, Ca, Mn, Zn, Fe,

n (Ni, Cl, Mo)

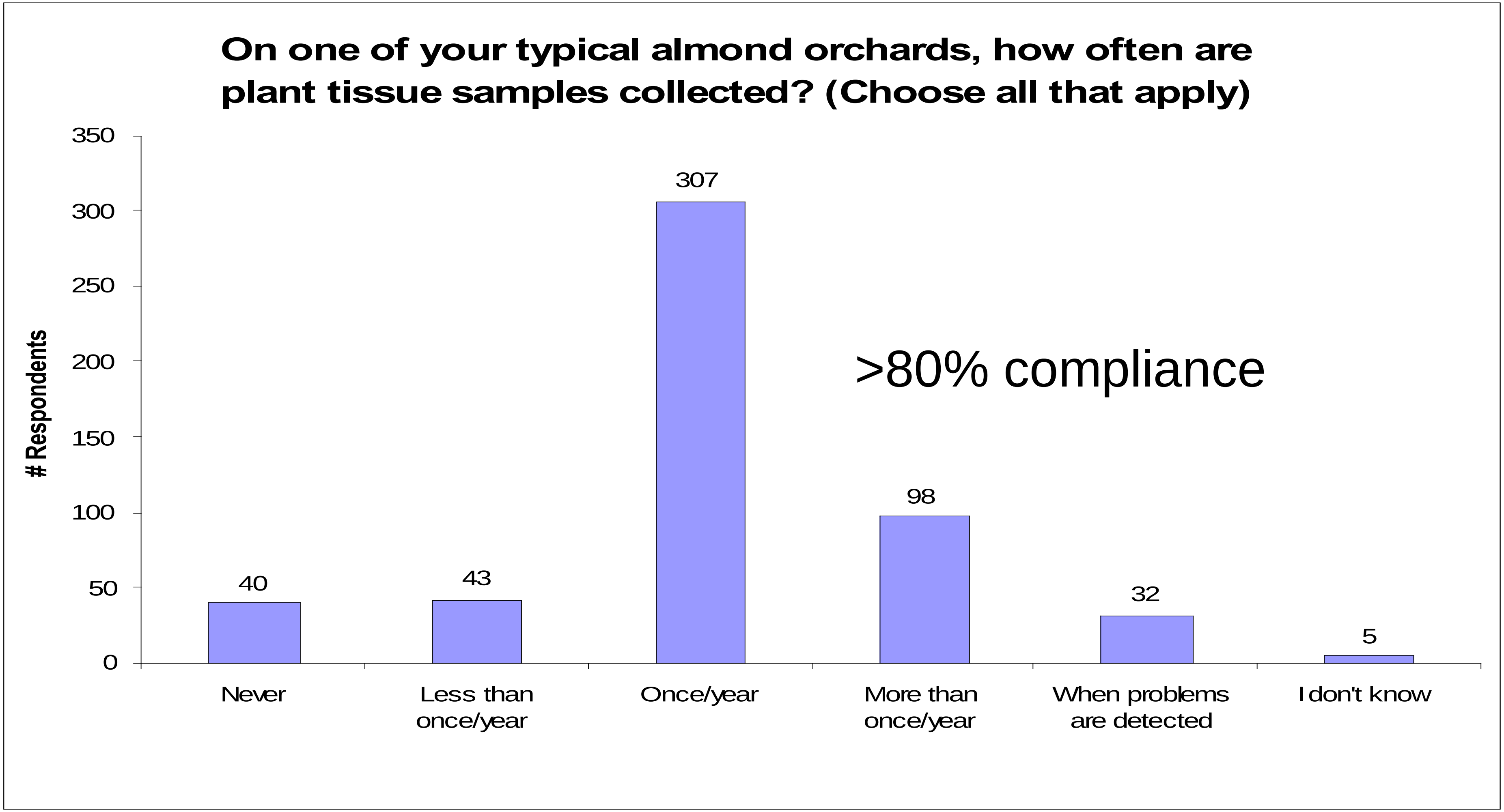
results (NO R'S!)

can indicate a shortage but cannot
espond.

:r decisions are currently based on
l an 'estimate' of fertilizer needs

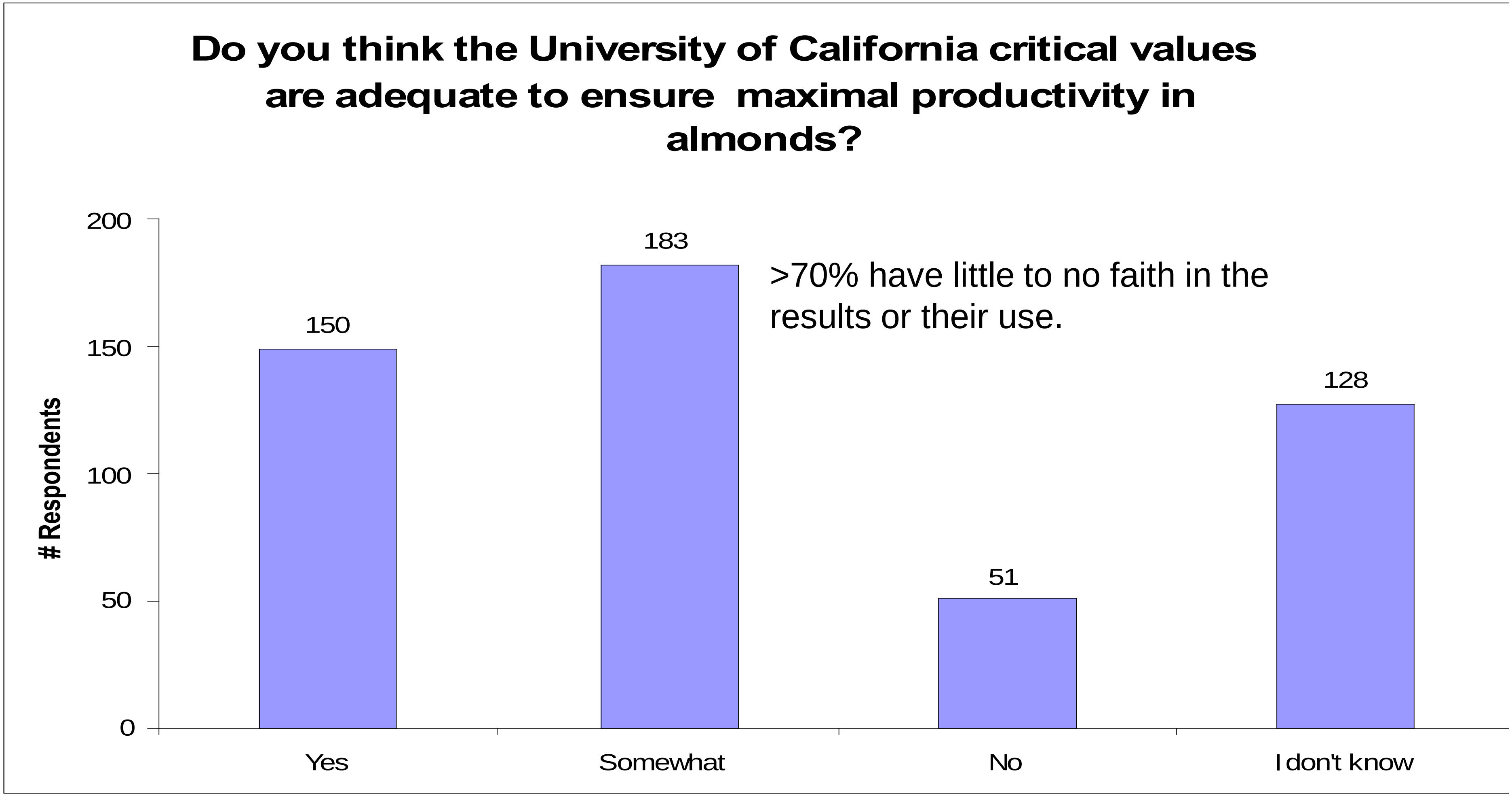
- No guidance on Rate, Timing, Placement or Source

Are tissue samples collected and if so how often?



Brown et al, 2004

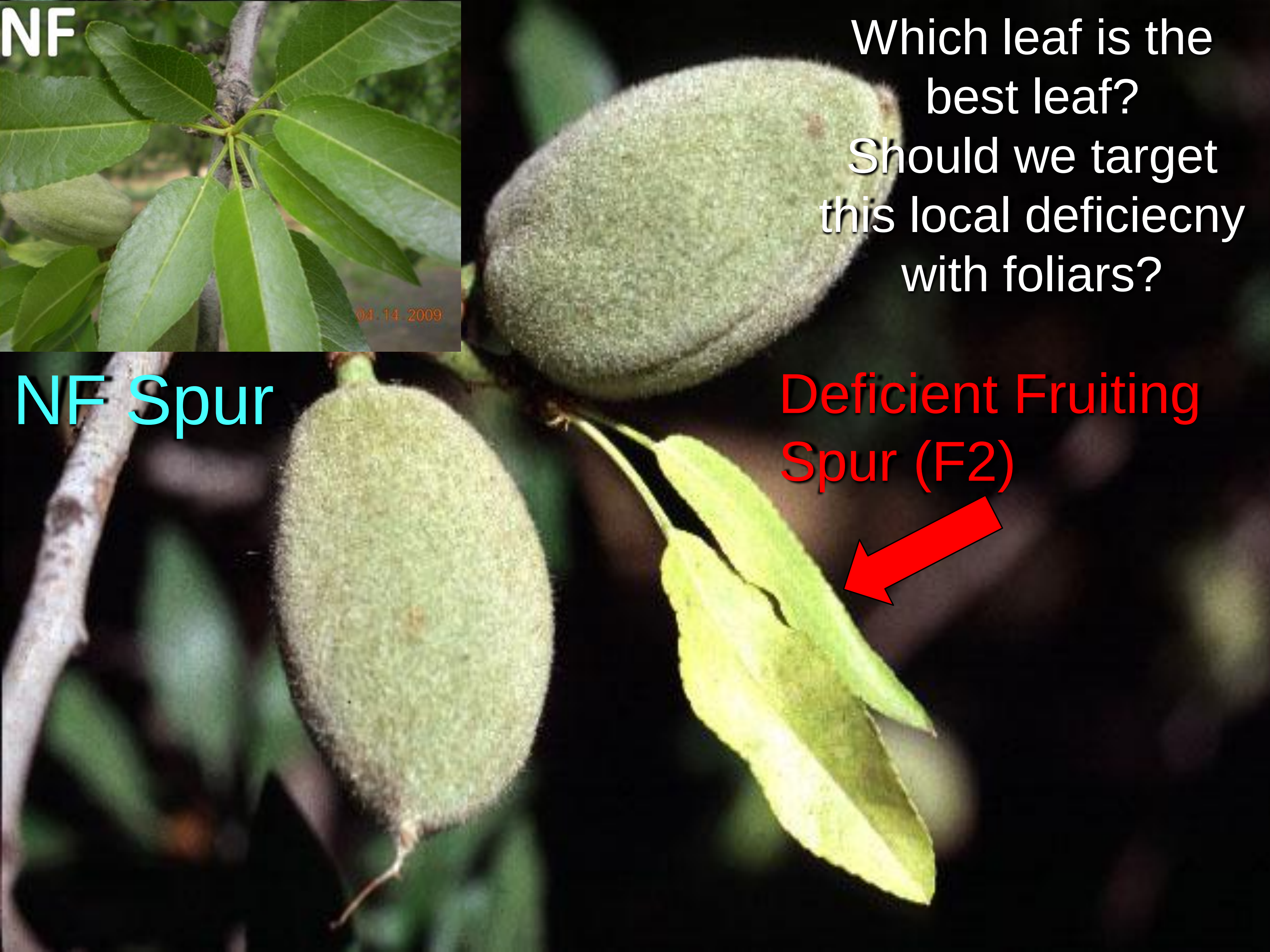
Are tissue samples being used to guide fertilizer management?



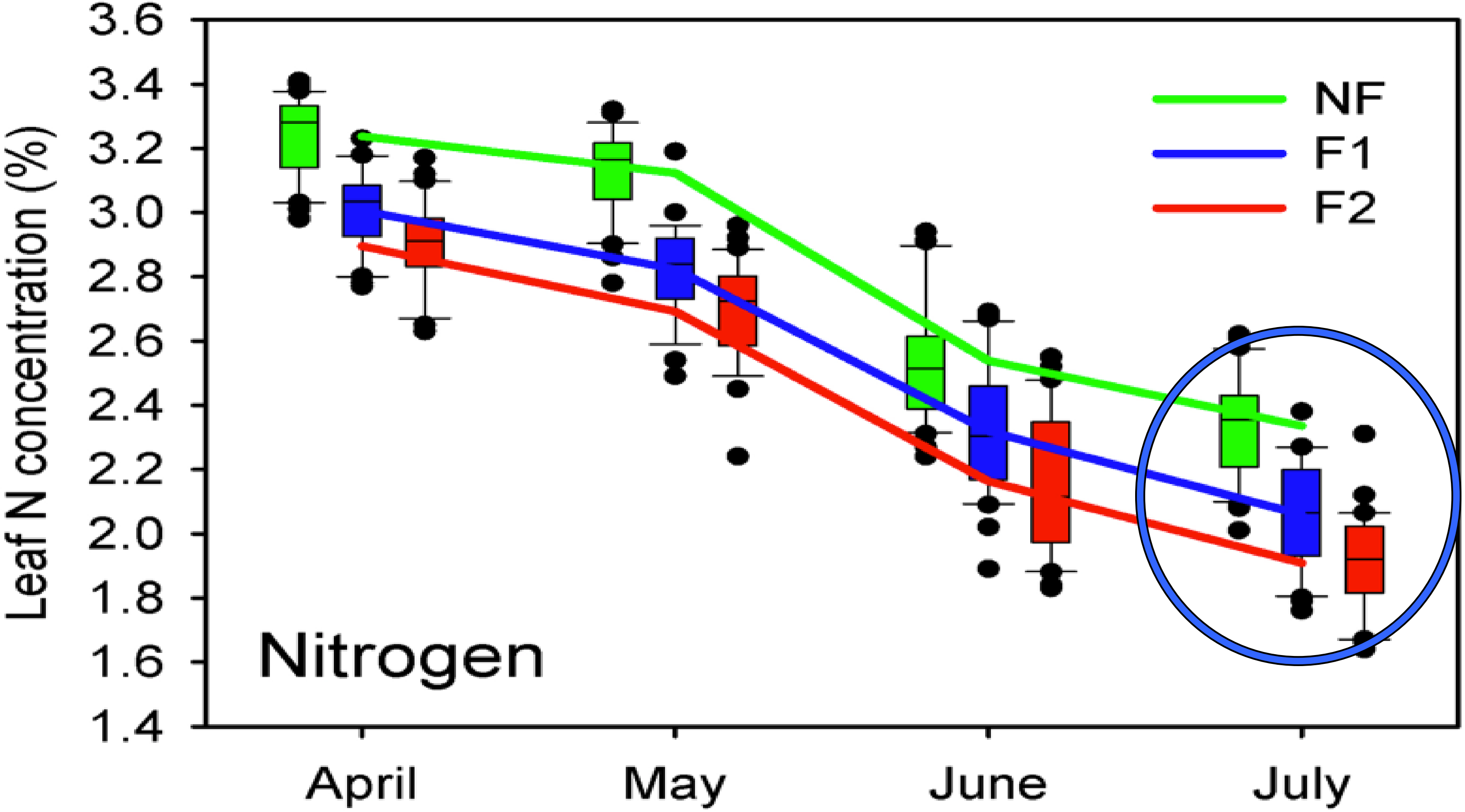
Brown et al, 2004

Apparently tissue sampling is not trusted- Why?

- originally defined as a means to identify when a crop is '..*just deficient..rather than just sufficient.. to define if, but not how much, fertilizer should be added*..'
  - It was designed to detect deficiency.
  - It is not designed to determine how much fertilizer to apply
- the complexity of tissue sampling was recognized, but never adequately optimized for trees.
- limitations of the method and the utility of the approach have been mostly forgotten.


NF
04 14 2009
Which leaf is the best leaf?
Should we target this local deficiecny with foliars?
NF Spur
Deficient Fruiting Spur (F2)

Critical Values are based on July/August sample. Early season CV's have not been validated.



Current Practice: Late summer sample. Too late for current season response. Too early for next season planning (yield potential is defined by winter and spring weather)

Challenge: Develop early season sampling and interpretation methodologies.

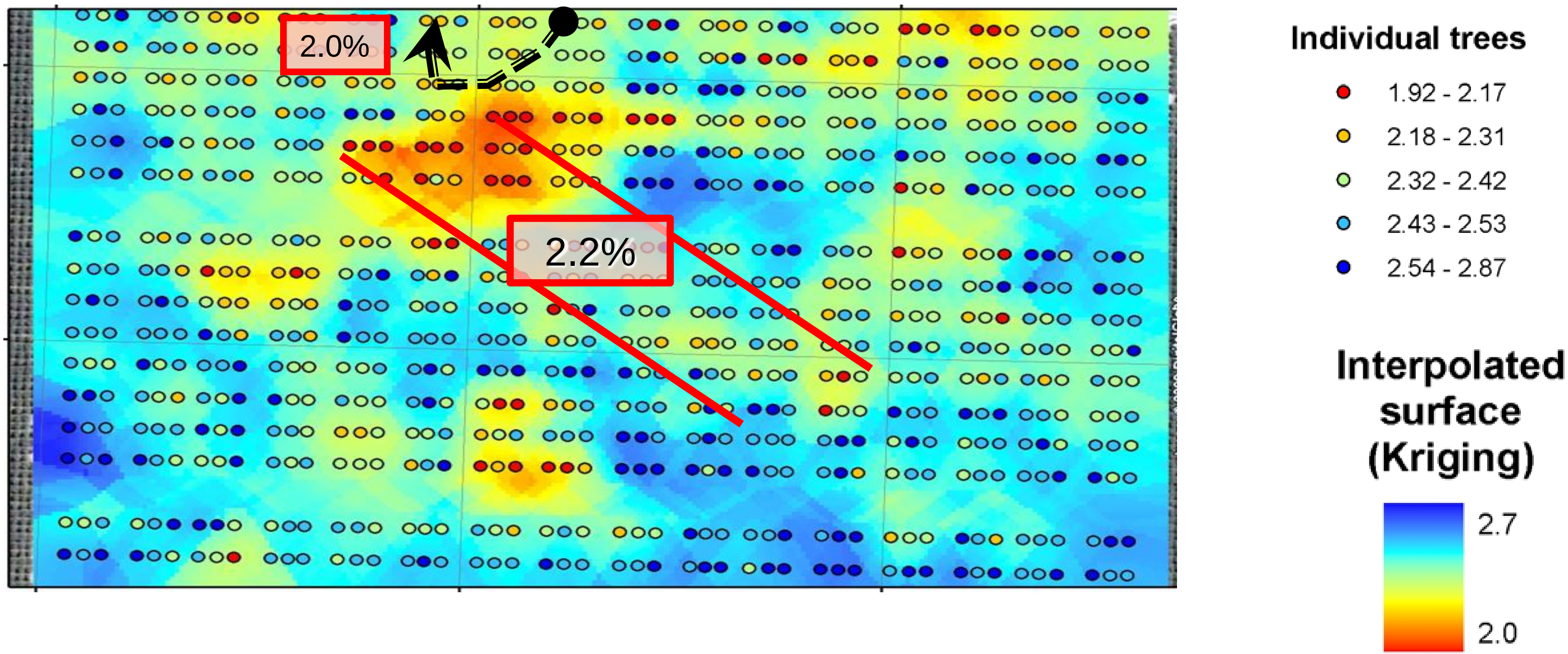
Challenges of Sampling: Field Variability

(768 individual tree samples. High producing 'uniform' orchard)

Typical Sampling: 1 pooled sample per management unit
(Hypothetical) Field Mean 2.2% N (June): Critical Value 2.2% = OK?

No!: *Full productivity can only be achieved when all individuals are above 2.2%*

What is the right target mean? (variability:response:cost:returns:yield)



Challenge: Develop sampling protocols that incorporate variability, have a clear cost:return basis, while remaining cost effective.

Summary: Tissue Testing for Almonds

Problems.

- Difficult to sample properly and hard to interpret. Current practice is a waste of money. Too few samples collected too late.
- Does not inform management practice
- UC critical values are probably correct but do not provide enough information at an orchard level

Solutions

- Develop methodology for early season sampling and interpretation
- Establish statistically valid sampling patterns and interpretation
- Develop improved lower cost (remote sensing, hand held meters etc).
- Integrate sampling with a nutrient budget approach.

Alternatives?

Alternate Approach: Nutrient Budgeting

Efficiently replace the nutrients removed from the field

Estimate current year demand

- Last years yield, this years estimated yield, tree age, “common” sense
- Improved techniques are under development (remote sensing, modeling etc)
- Nutrient content of samples.

Measure and control inputs and losses

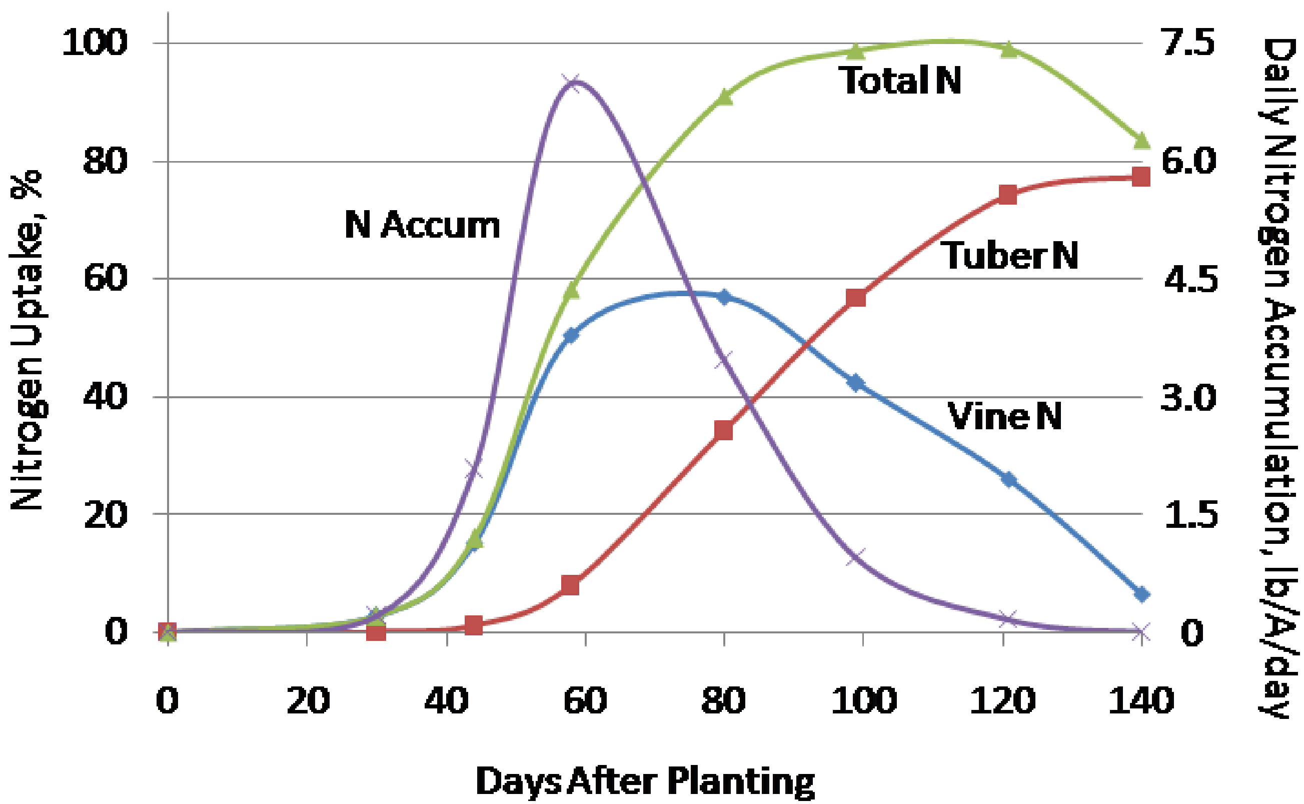
- Soil, fertilizer, irrigation, leaching, volatilization

Manage efficiencies and interactions

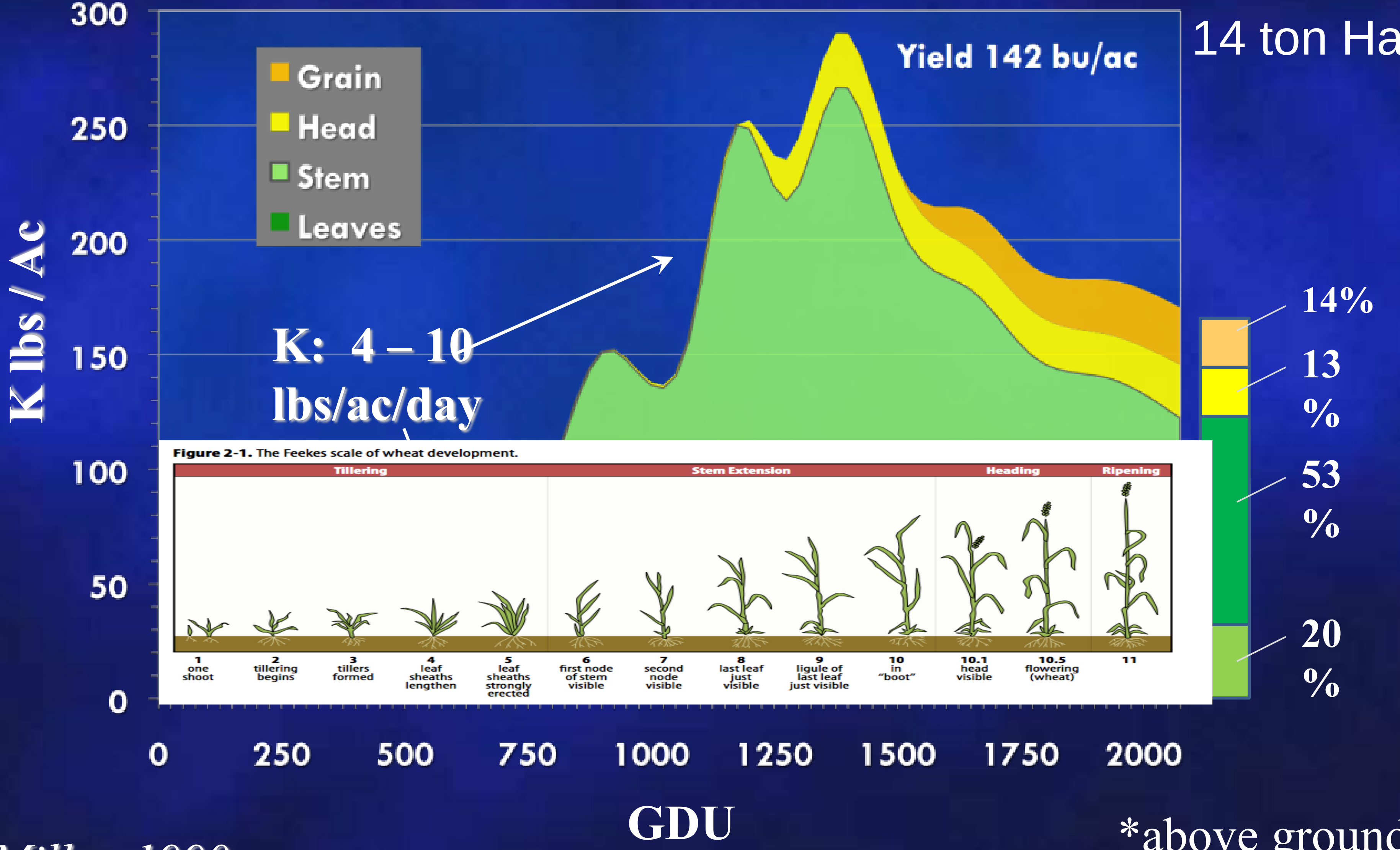
- Synchronization and location of nutrient applications
- Monitoring crop response

How?

Sequential Harvest
Daily accumulation rates and plant parts
(Russet Burbank potatoes, Oregon)



Sequential Harvest: Potassium Aerial Accumulation Wheat - California

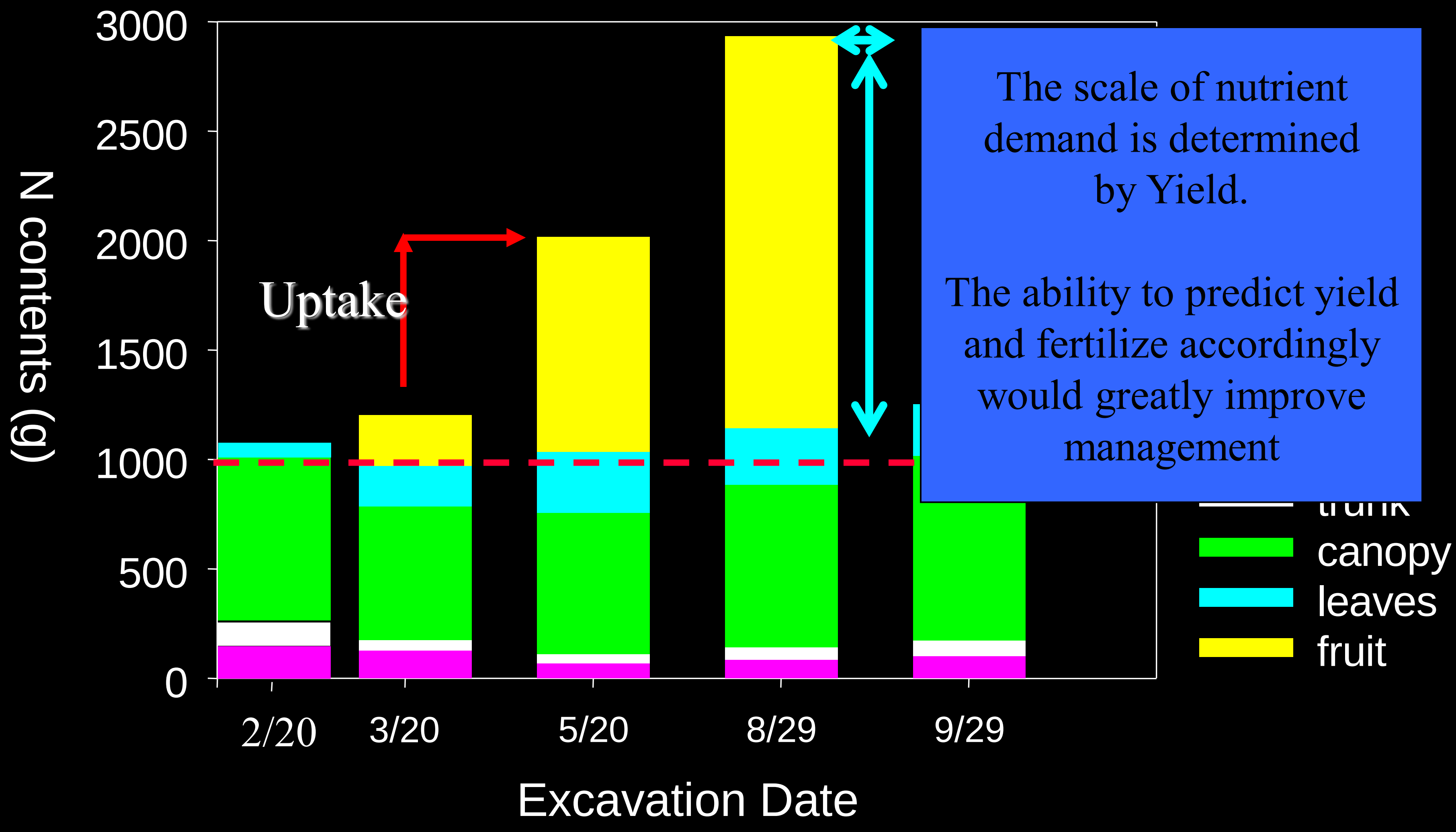


Miller, 1990

Sequential Whole Tree Harvest:

5 mature trees x 5 times in a year

Whole Tree N Contents by Organ in Almond.



The scale of nutrient demand is determined by Yield.

The ability to predict yield and fertilize accordingly would greatly improve management

Efficient Nutrient Management Approach
-the 3 R's-

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Applying the Right Rate

- Match supply with demand (yield estimation)
- Determine nutrient content (leaf sampling)

At Right Time

- In-season fertilizer adjustment (leaf sampling and fruit development)

In the Right Place

- Ensure delivery to the active roots. (Determine root distribution and activity. Determine water and nitrogen movement)

Leaf Sampling And Interpretation Methods For CA Almond Orchards.

Sebastian Saa, UC Davis

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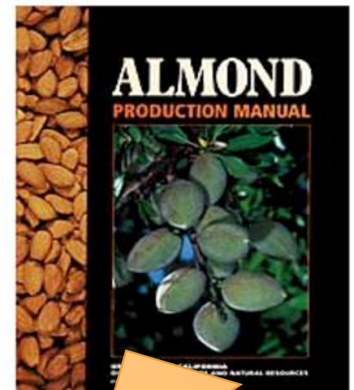
What do we currently do to manage our orchards?

Sample in July

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

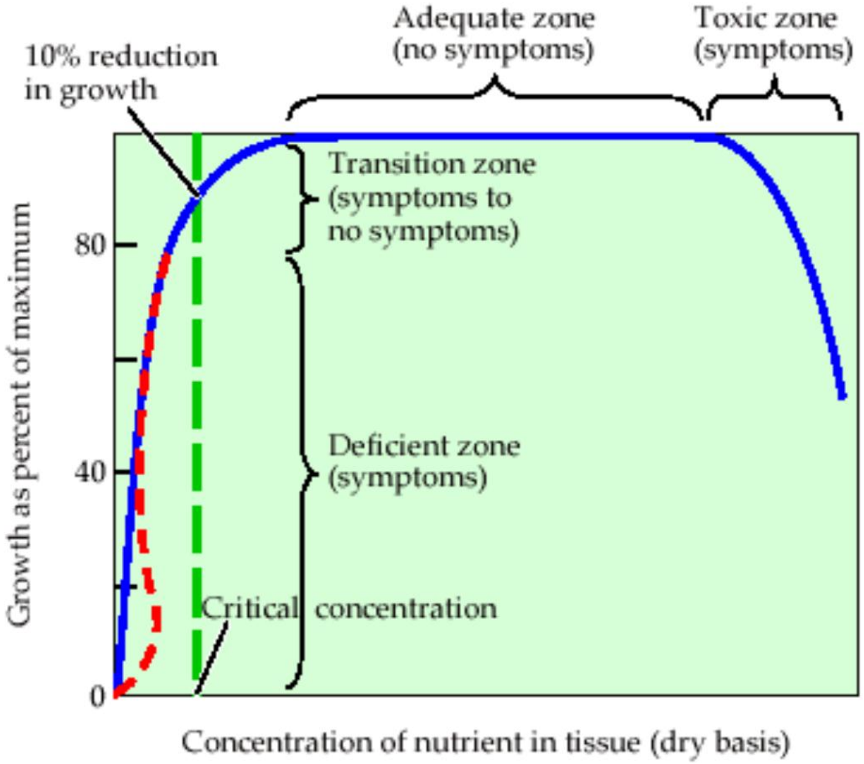
Nitrogen (N)	
Deficient below	2.0%
Adequate	2.2–2.5%
Phosphorus (P)	
Adequate	0.1–0.3%
Potassium (K)	
Deficient below	1.0%
Adequate over	1.4%
Calcium (Ca)	
Adequate over	2.0%
Magnesium (Mg)	
Adequate over	0.25%
Sodium (Na)	
Excessive over	0.25%
Chlorine (Cl)	
Excessive over	0.3%
Boron (B)*	
Deficient 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.

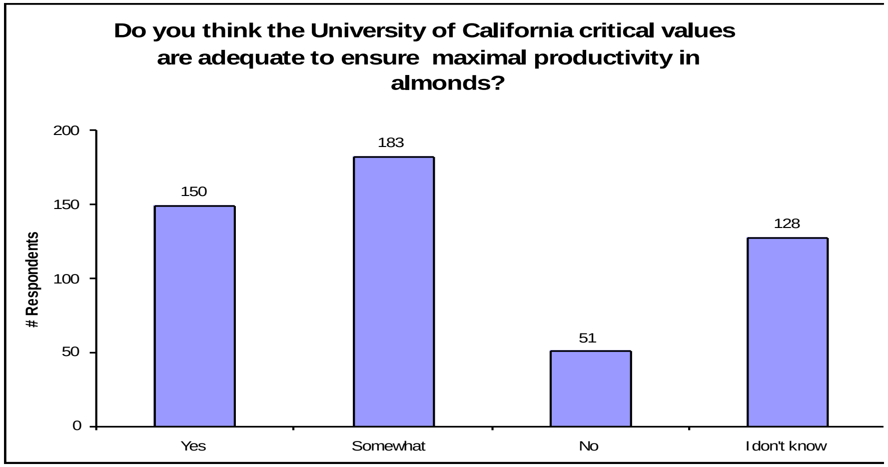


Problem Statement: Critical Values tell us little about management.

Critical Value



Are tissue samples being used to guide fertilizer management?



Possible Reasons for this problem:

- Current Sampling Protocol is too late in year to make in season adjustments.

- Samples collected do not always represent the true nutrient status of the orchard as a whole.

- Our current CV’s may not apply in all cases or may be wrong.

Objectives:

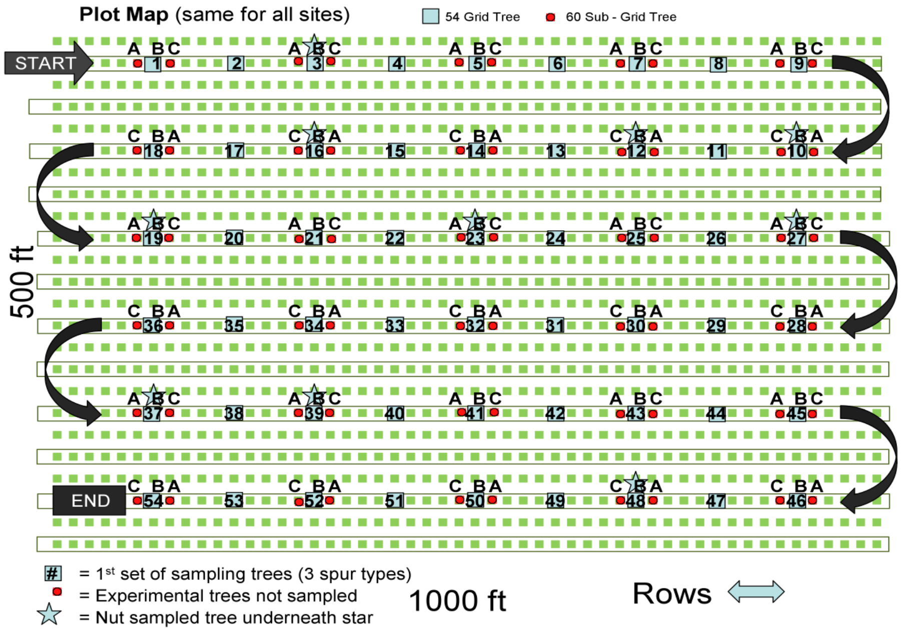
- Develop methods to sample in April and relate that number to July critical value.
- Develop method for grower to sample his field (recognizing that typical practice is only 1 sample per field is generally collected).
- Reevaluate the current CV's.

Experiment:

- Four sites from California's major almond producing regions

Location	Arbuckle	Modesto	Madera	Belridge
Tree Age	1998	1998	2000	1999
Varieties	NP – 50% B – 25% A – 12.5% C – 12.5%	NP – 50% A – 25% WC – 25%	NP - 50% C – 25% M – 25%	NP – 50% M – 50%
Spacing	22' x 18' (110 trees/ac)	21' x 21' (99 trees/ac)	21' x 17' (122 trees/ac)	24' x 21' (86 trees/ac)
Irrigation	Drip	Microsprinkler	Microsprinkler	Microsprinkler

Design and Sampling



- 114 trees x 4 Sites x 3 years.
- Yield.

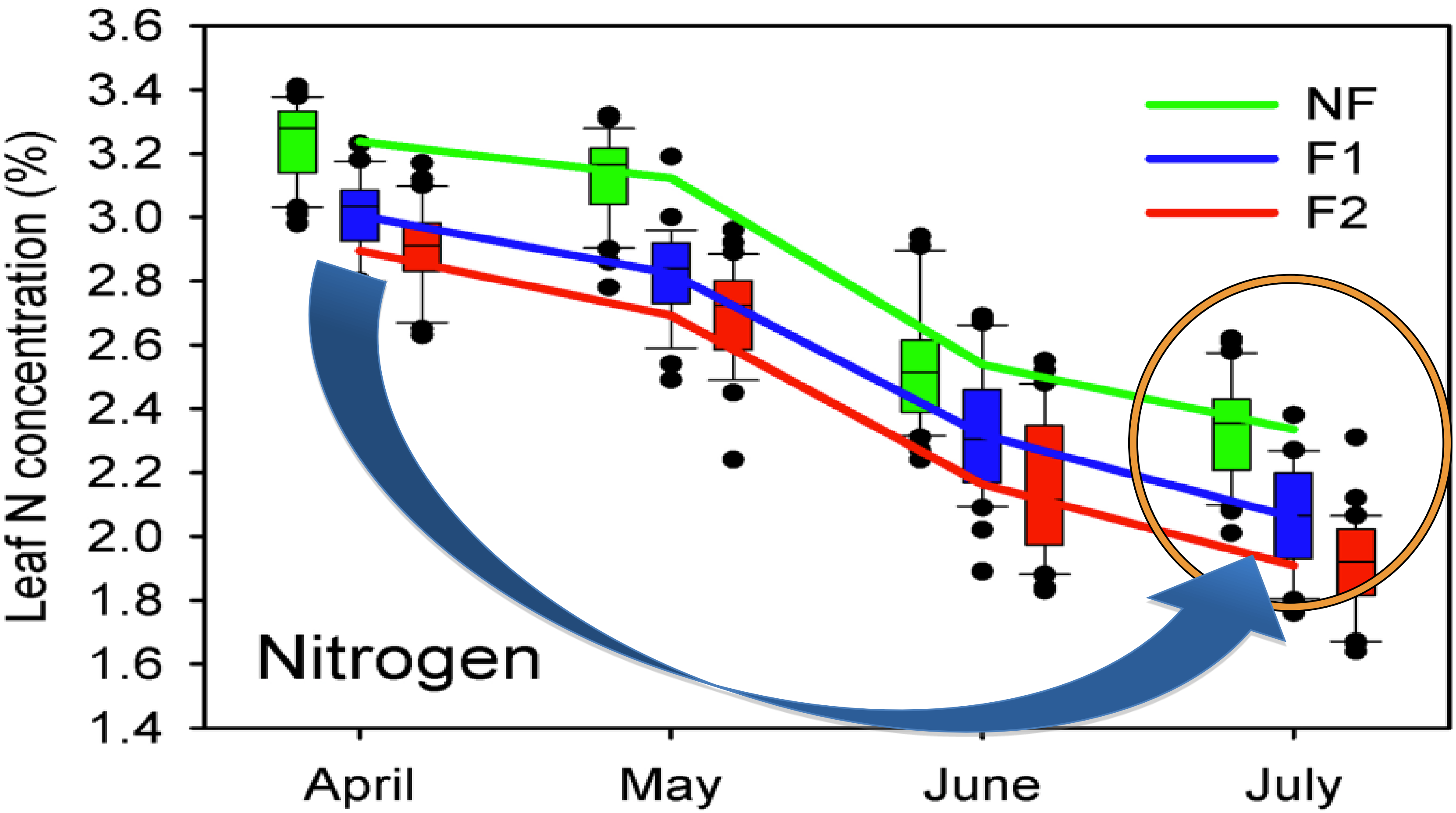
(About 1,130 data points)

- 5 in-season nutrient samples.

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

Time Problem.

Can we sample in April and predict July?



Approach: Multi site, multi year, multi tissue and multi element analysis.

Two Models to answer the same Q.

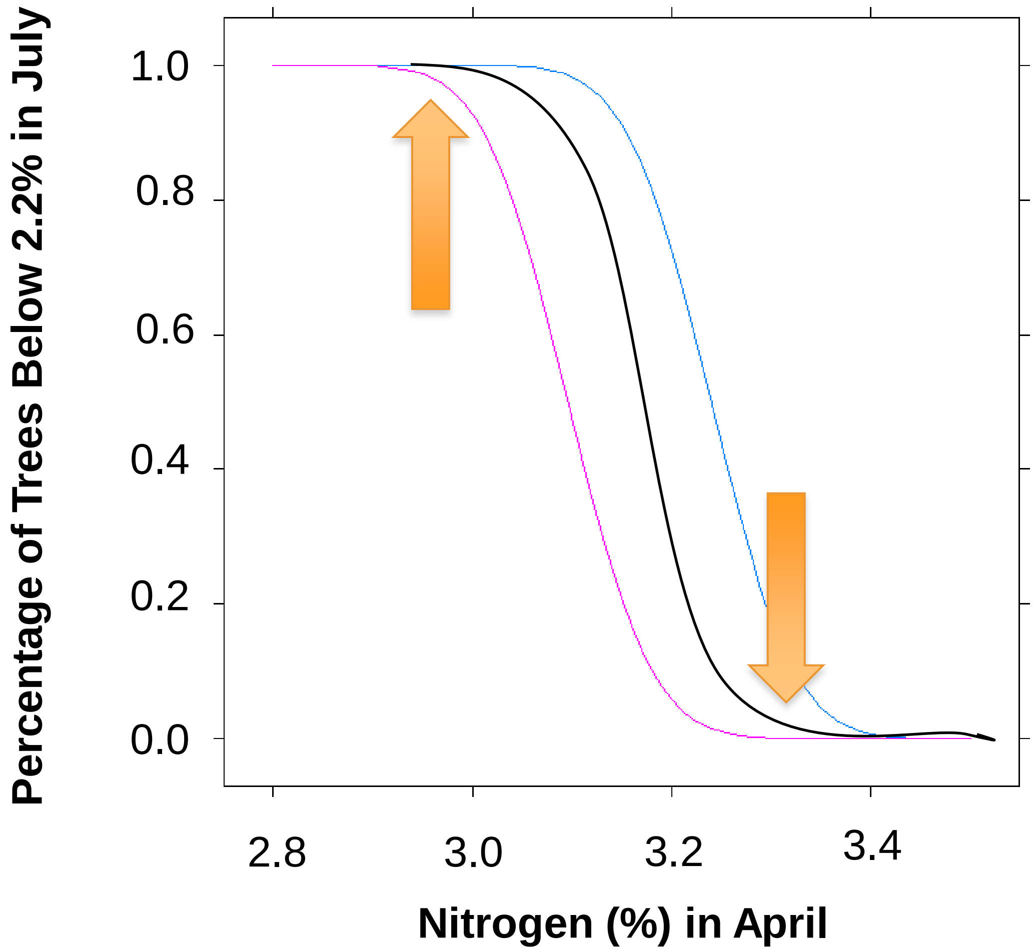
- Model one uses all the April information from F2 spurs to predict the July nitrogen value.
- Model two uses the nitrogen NF information from April to predict the July nitrogen value.
- Both models also predict what percentage of the trees are above or below the current July nitrogen critical value.
- Both models work well but we do not yet know which model is best (validation will be done next year).

Results Cross-Validation Model 1

Site	Year	July Nitrogen Predicted	July Nitrogen Observed
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

Results: Model 2

Expected % of trees below 2.2% in July

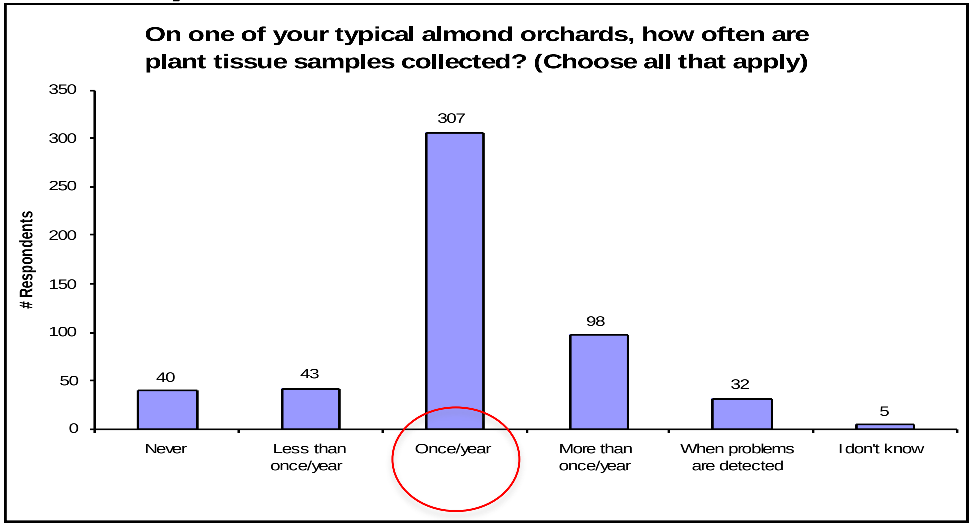


Black Line = predicted
Blue Line = upper CI
Pink Line = Lower CI

Objectives:

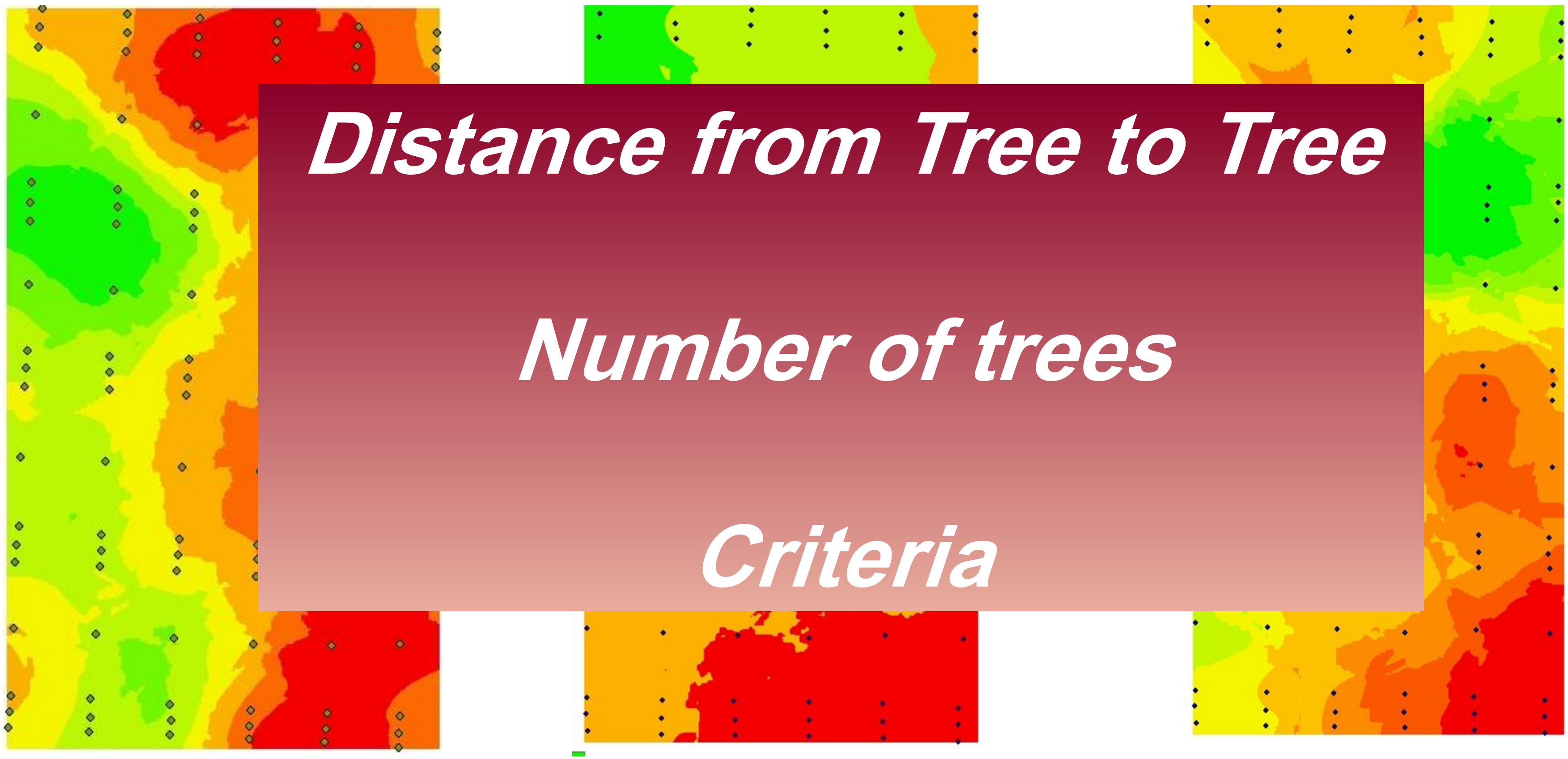
- Develop methods to sample in April and relate that number to July critical value.

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



If you can only collect one sample…

How do you represent the true nutrient status of your orchard as a whole? What is the best way to sample?



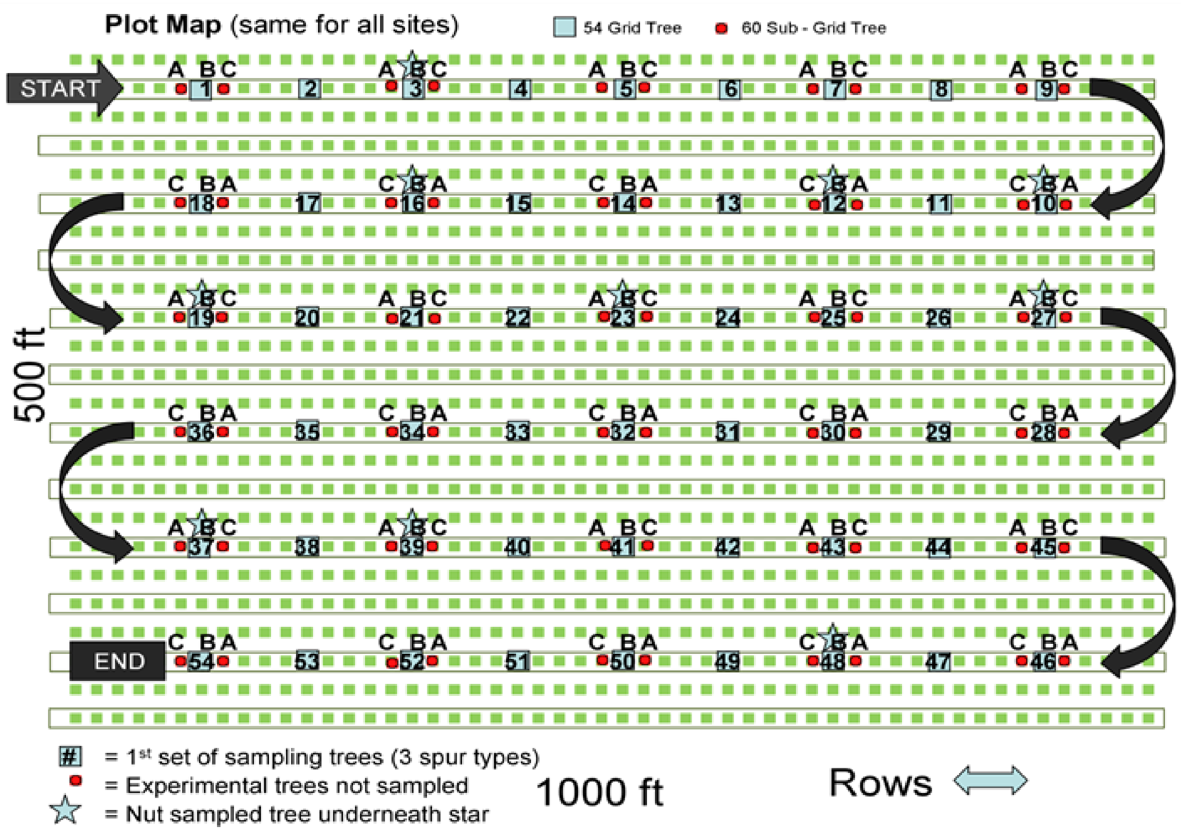
Distance from Tree to Tree

Number of trees

Criteria

Spatial Correlation Concept

→We attempt to test if and when trees are 'communicating'.



Spatial Correlation Conclusions

For the case of nitrogen, we could not detect tree to tree 'communication' in distances farther than 30 yards *(CA almond trees do not talk to each other much).*

However, we do not know if there is 'communication' at shorter distances.

Then, "as conservative protocol" we propose that samples are collected at least 30 yards away.

Number of pooled trees needed in April to estimate the true mean of Nitrogen.

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		

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

Preliminary Sampling Criteria

- Collect leaves from 18 to 28 trees in one bag.
- Each tree sampled at least 30 yards apart.
- In each tree collect leaves around the canopy from at least 8 well exposed spurs located between 5-7 feet from the ground.
- In April, collect samples at 8121 GDH +/- 1403 (43 days after full bloom (DAFB) +/- 6 days).
- if you would like to collect samples in July, then collect samples at 143 DAFB +/- 4 days.

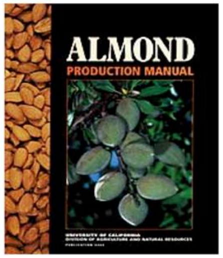
Objectives:

- Develop methods to sample in April and relate that number to July critical value.
- Develop method for grower to sample his field (recognizing that only 1 sample per field is generally collected).
- Reevaluate the current CV's → integrate with nutrient budget approach described in the next talk.

Conclusions: In the past

- **We only had the Almond Fruit Production Manual table.**

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



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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.

Conclusions: In the present

- We have developed two models to predict July Nitrogen concentration using April data.

- Both models measure orchard variability and calculate the percentage of the trees that will be above or below the current July critical value.

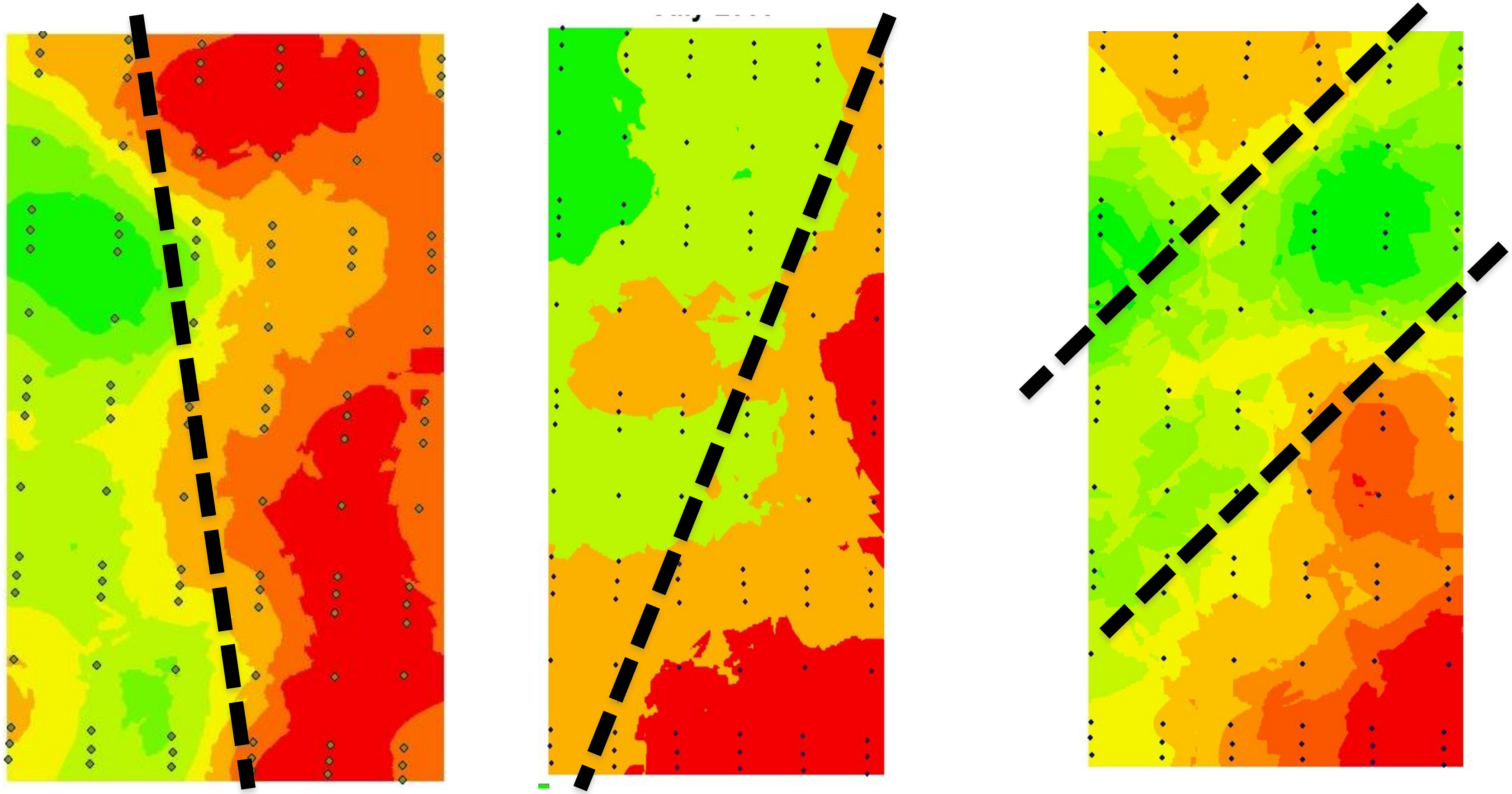
- In other words, both models can provide the information needed to maximize productivity.

Conclusions: In the present

- …However, guaranteeing maximal productivity does not guarantee maximal profitability nor best management.
- We have assumed that field variability exists and cannot be managed – that is not correct.
- To really optimize sustainability, leaf sampling and analysis and subsequent management must also consider economic and environmental factors.

Conclusions: In the future

- **We must not only recognize and interpret orchard variability, we should attempt to control (or reduce) it.**



Thanks!

- Sebastian Saa
- Emilio Laca
- Patrick Brown

Nutrient Budget for Almond

Saiful Muhammad
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.

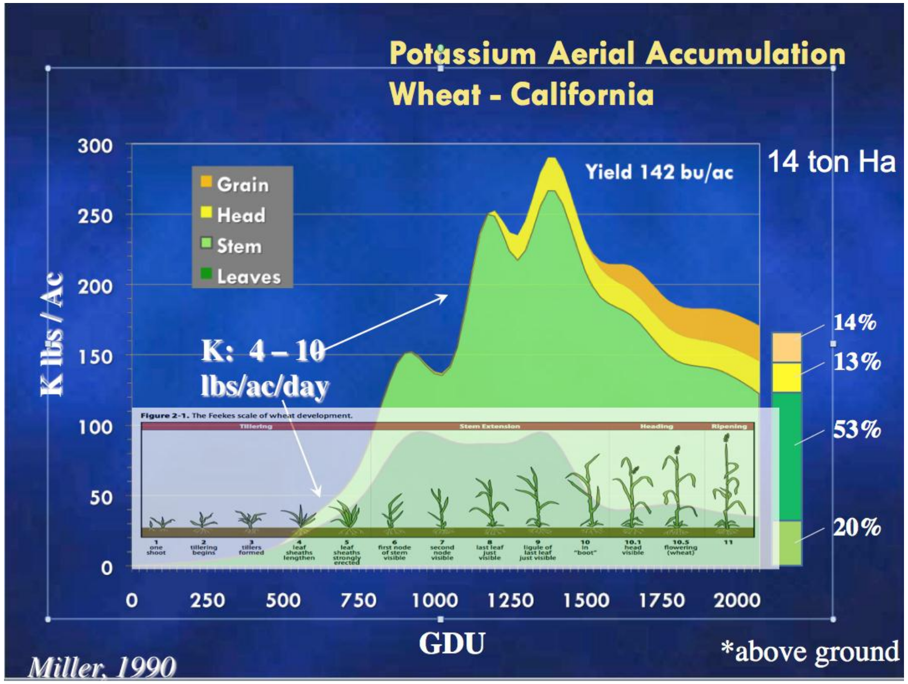
Using the Right Source

- Maximize uptake minimize loss potential.

Determining the Right Rate

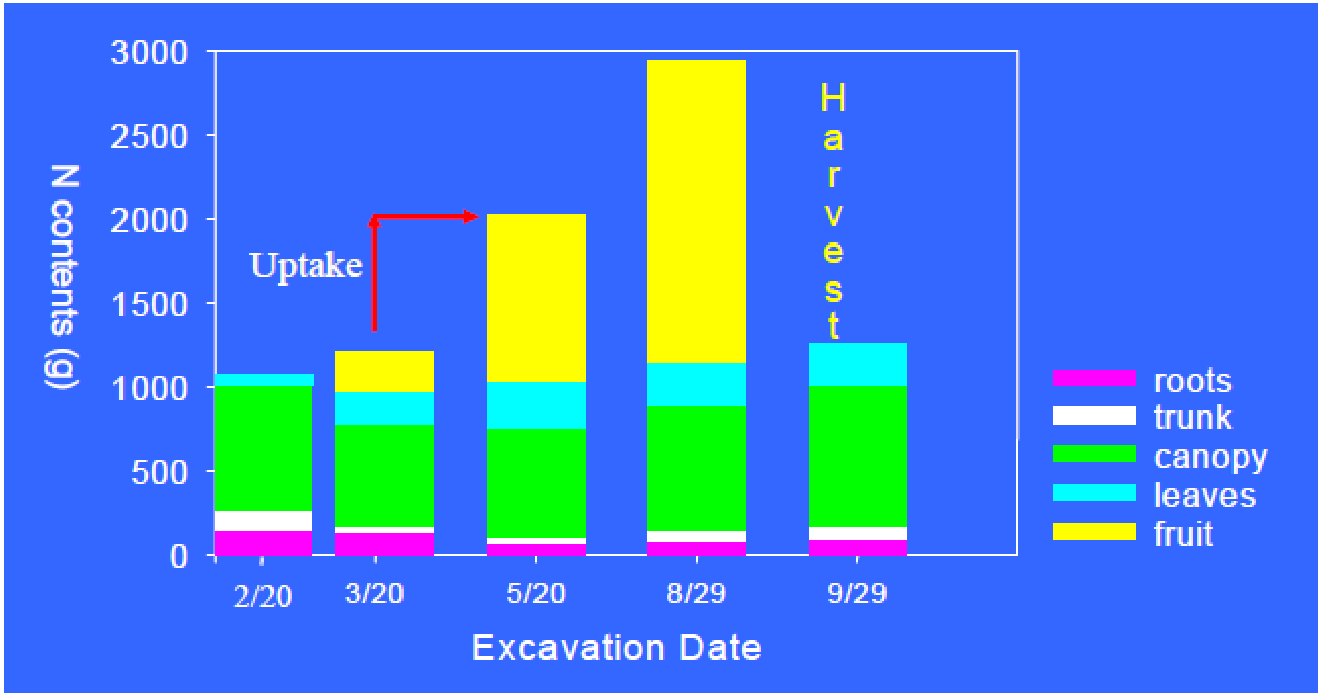
Nutrient Budget Approach

- Provides information on total annual demand
- Develops knowledge of growth and development and derives nutrient demand curves
- Provide information on nutrient uptake rate and timing



Suitability of Almond for Nutrient Budget Management

- Mature almond tree is relatively determinate in growth pattern
- Majority of nutrients are partitioned to fruit
- Irrigation systems and fluid fertilizers have made on-demand fertilizer application easy



Patrick Brown unpublished data

Fertility Experiment

Treatments

- **4 Nitrogen rates – 125, 200, 275 and 350lb/ac**
- **2 Nitrogen Sources- UAN 32 and CAN 17**
- **3 Potassium Source- 100, 200 and 300lb/ac**
- **3 Potassium Sources- SOP, SOP+KTS and KCl @200lb/ac**

Irrigation Types

- **Fan Jet and Drip**

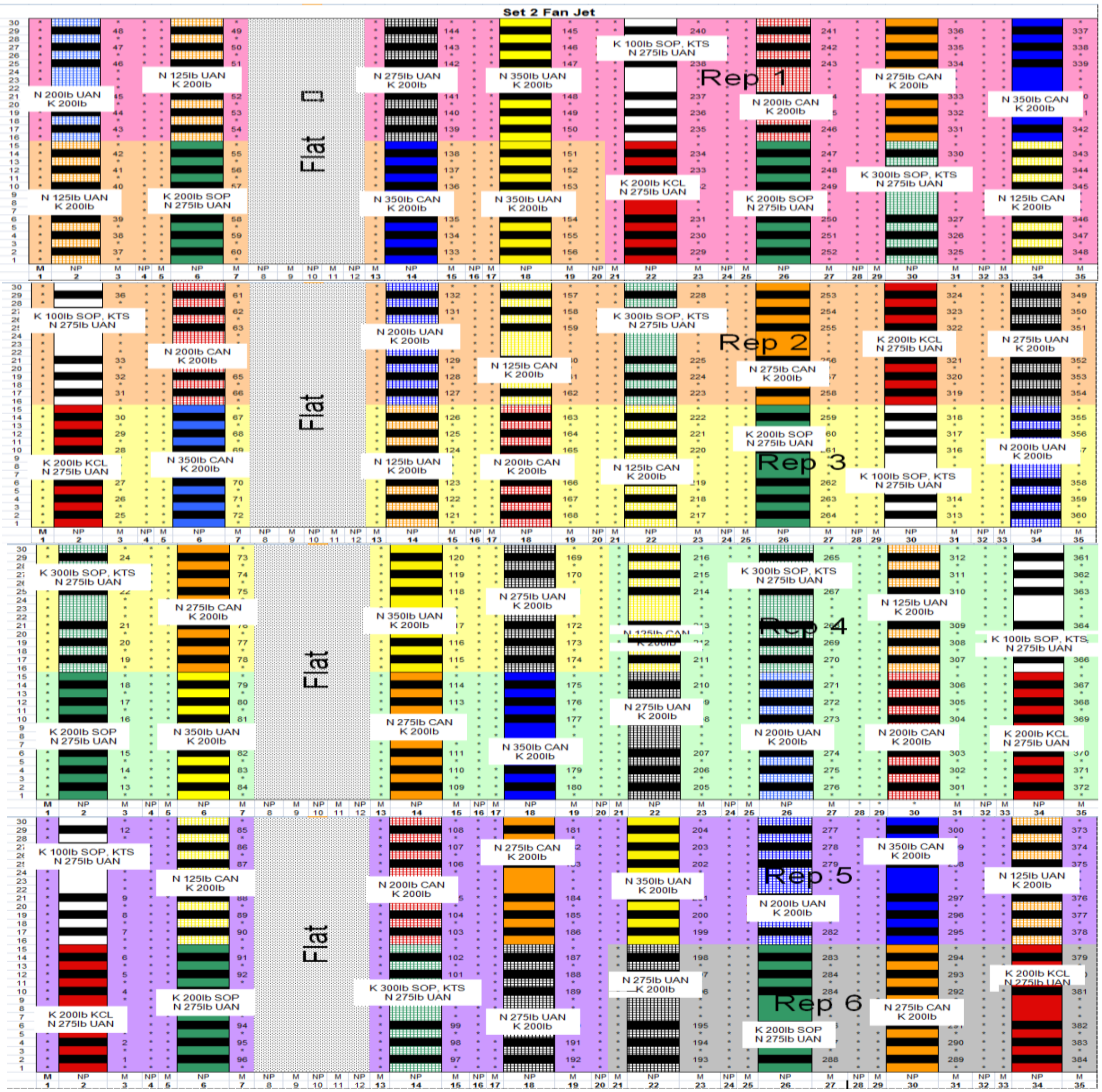
Fertigation

- **4 times during the season**
  - **20, 30, 30 and 20% in February, April, June and October**

Samples Collection

- **Leaf and Nut samples collected from 768 individual trees five time in season**
- **All trees individually harvested**

Experimental Layout



Large experiment covering approximately 100 acres.

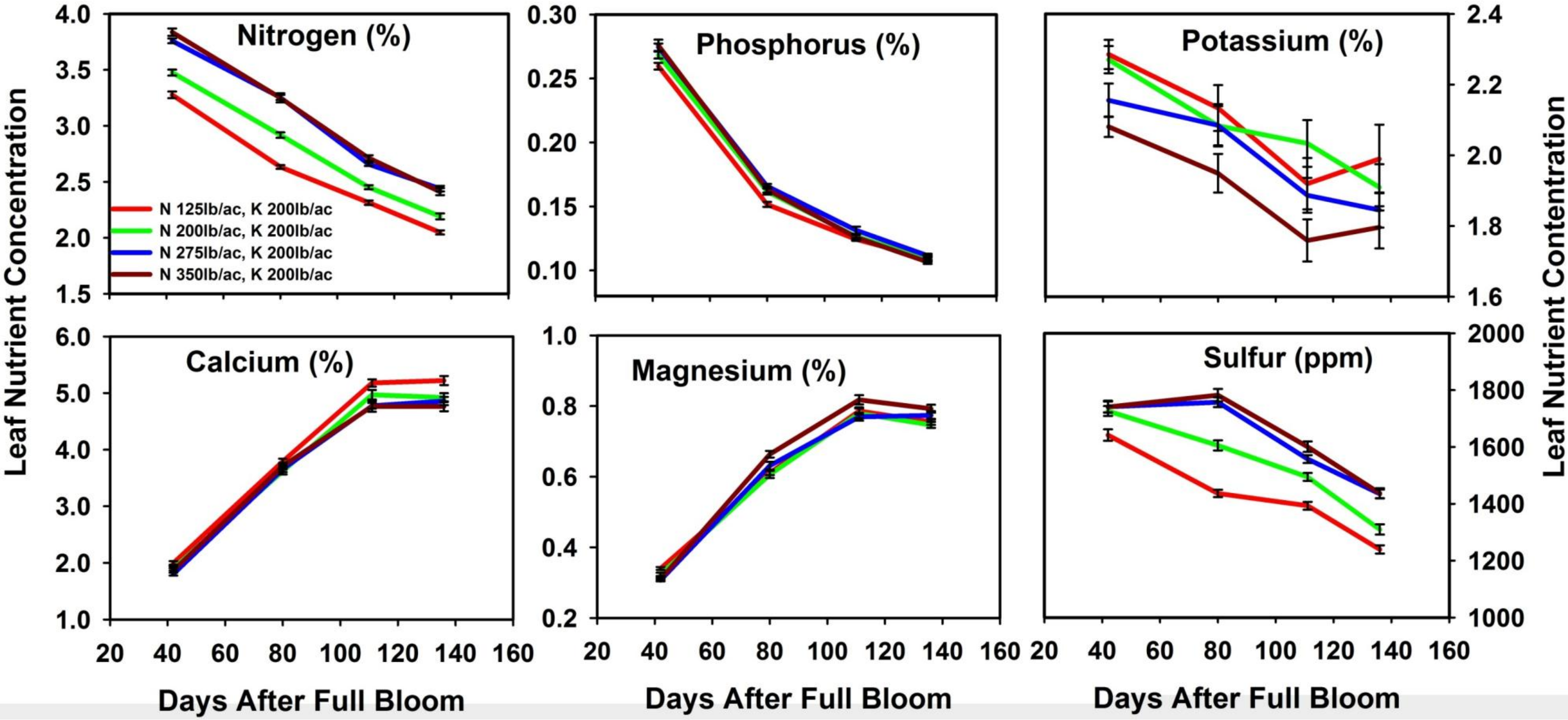
768 trees individually monitored for nutrients, yield, light interception, disease, water.

Trees were 9 leaf in 2008.

Nonpareil - Monterey

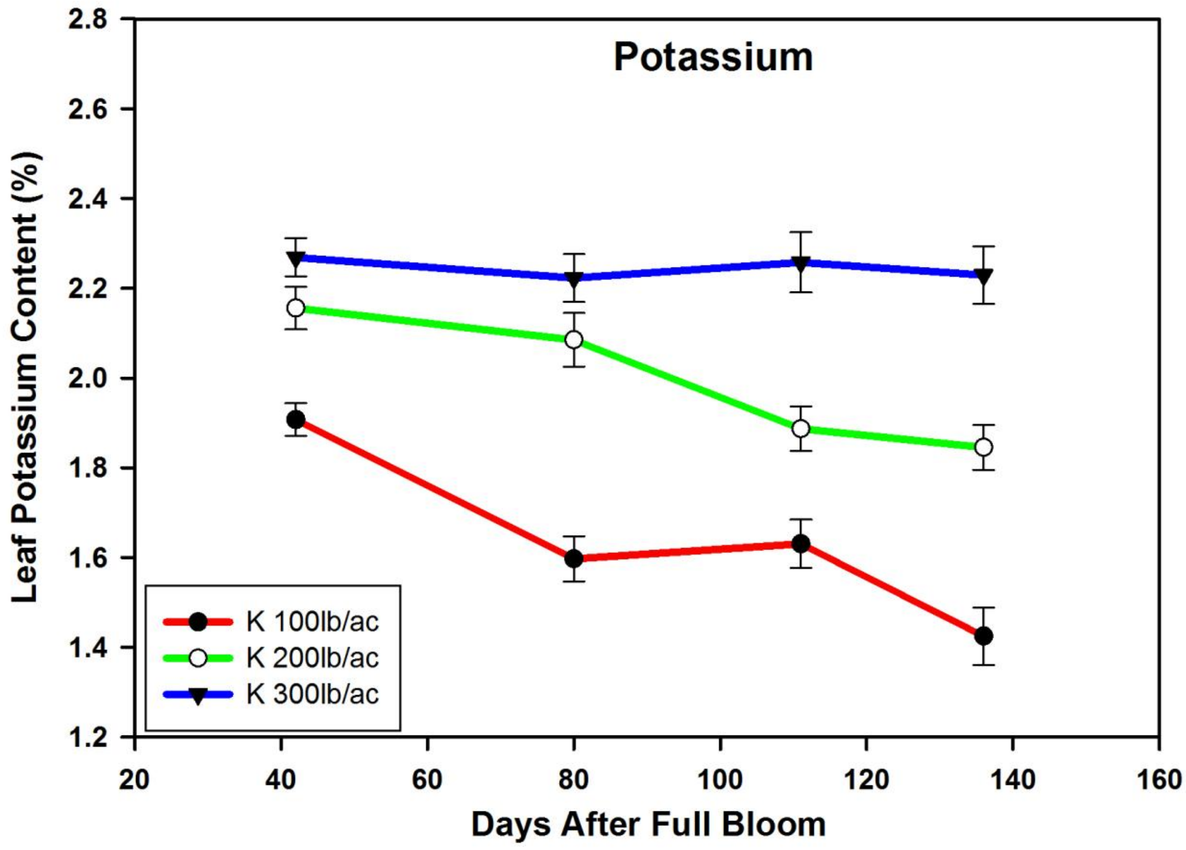
Preliminary Findings

Leaf Nutrient Content 2010



Leaf Potassium Content 2010

No effect of K application rate or tissue K has been observed.



Kernel Yield (lb/ac)

2010

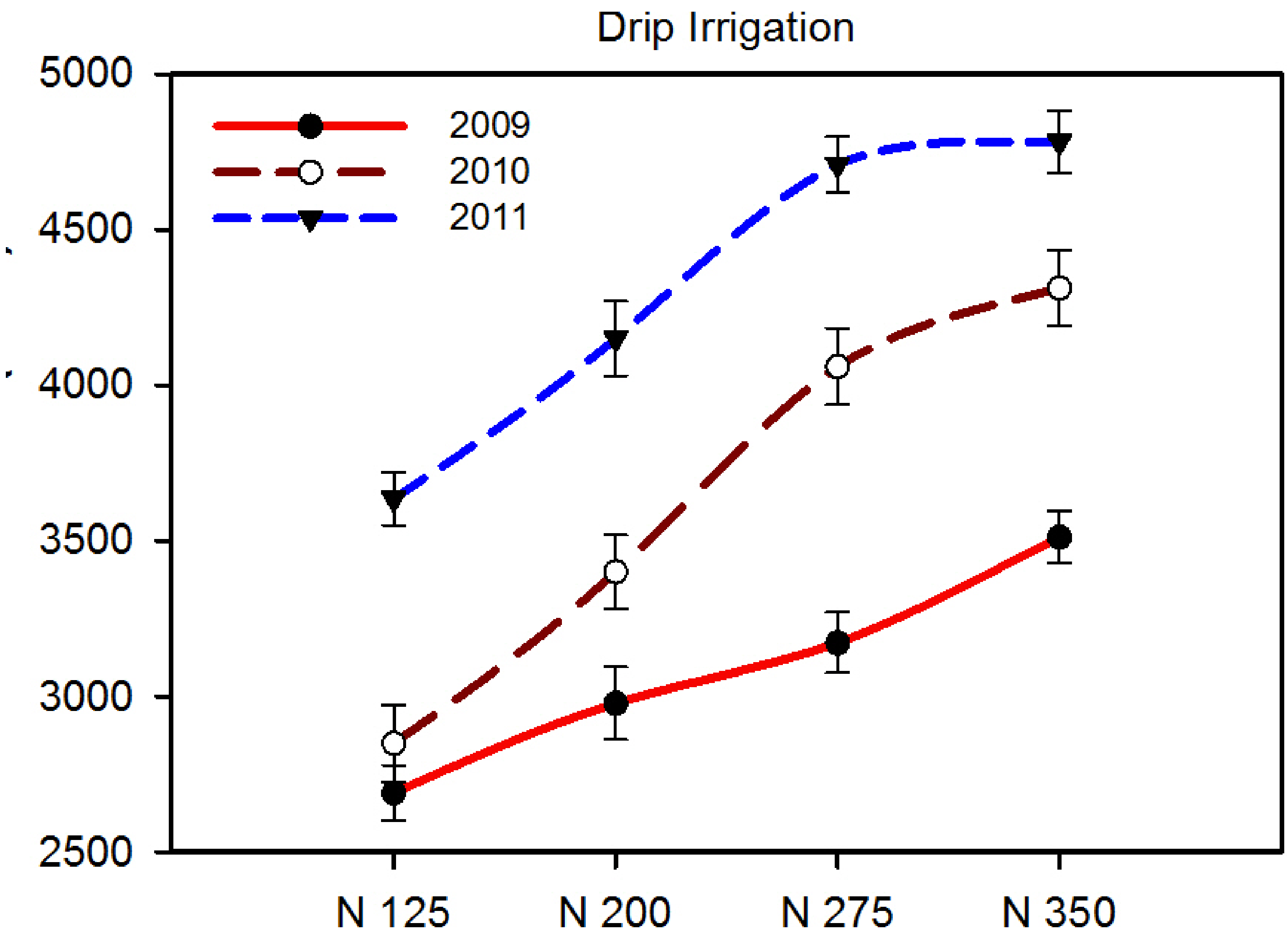
Irrigation	N UAN 32				N CAN 17			
	125	200	275	350	125	200	275	350
Drip	2,865	3,453	3,765	4,064	2,622	3,313	3,960	3,728
	c	b	ab	a	c	bc	ab	a
Fan Jet	2,584	3,109	3,481	3,583	2,730	3,046	3,810	3,530
	c	b	b	a	d	c	a	b

2011

Irrigation	N UAN 32				N CAN 17			
	125	200	275	350	125	200	275	350
Drip	3,732	4,229	4,696	4,775	3,564	4,365	4,833	4,969
	c	b	a	a	c	b	a	a
Fan Jet	3,744	4,048	4,480	4,406	3,746	4,161	4,420	4,361
	c	b	a	a	c	b	a	a

Means not followed by the same letter are significantly different at 10%.
Statistics are only within irrigation type.

Yield Response to Nitrogen



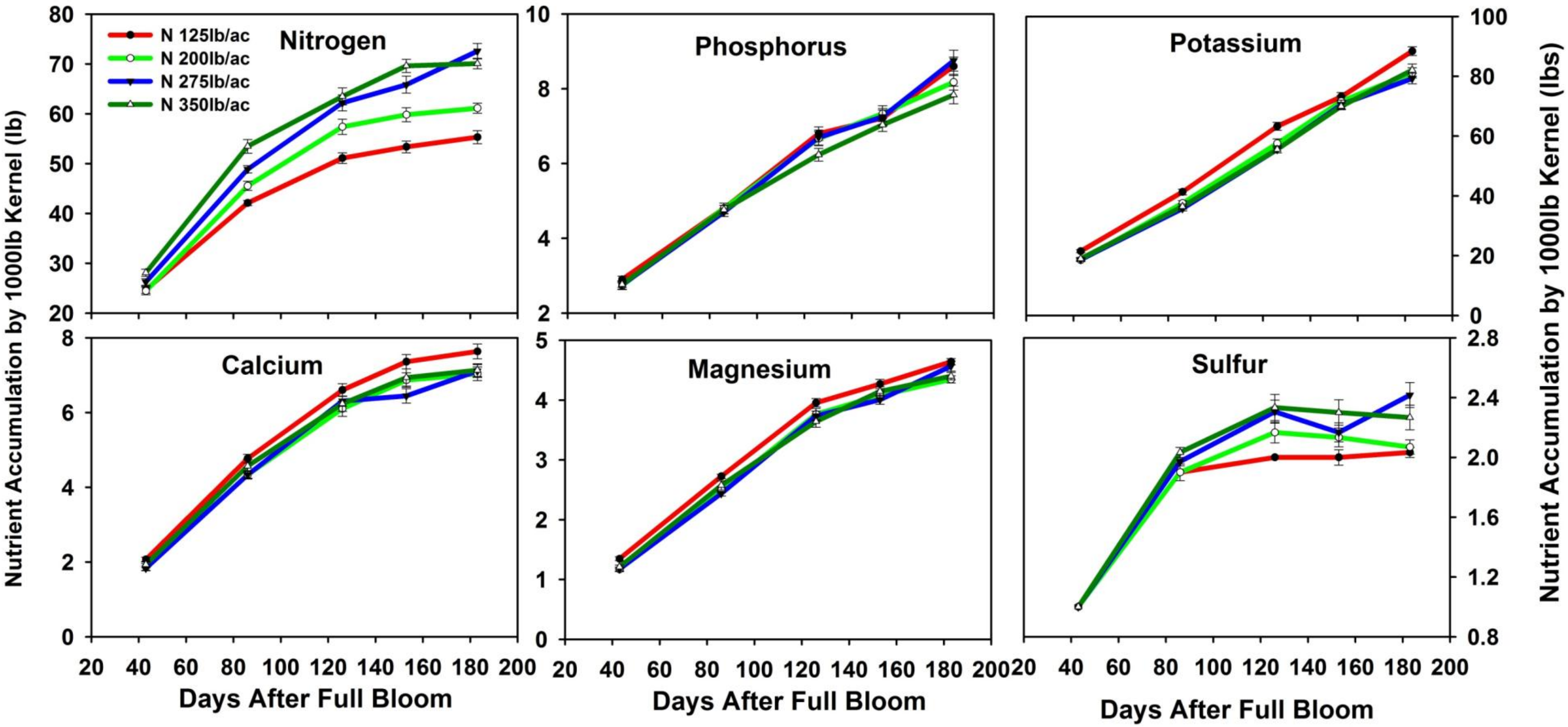
Cumulative Kernel Yield 2009-11

Cumulative Kernel Yield 2009-2011 (lb/ac)

Irrigation	N UAN 32				N CAN 17			
	125	200	275	350	125	200	275	350
Drip	9,328	10,642	11,667	12,356	8,796	10,298	11,844	12,139
	d	c	b	a	c	b	a	a
Fan Jet	9,156	10,245	11,201	11,314	9,563	10,345	11,539	11,109
	c	b	a	a	c	b	a	a

Means not followed by the same letter are significantly different at 10%.
Statistics are only within irrigation type.

Nutrient Export by 1000lb kernel



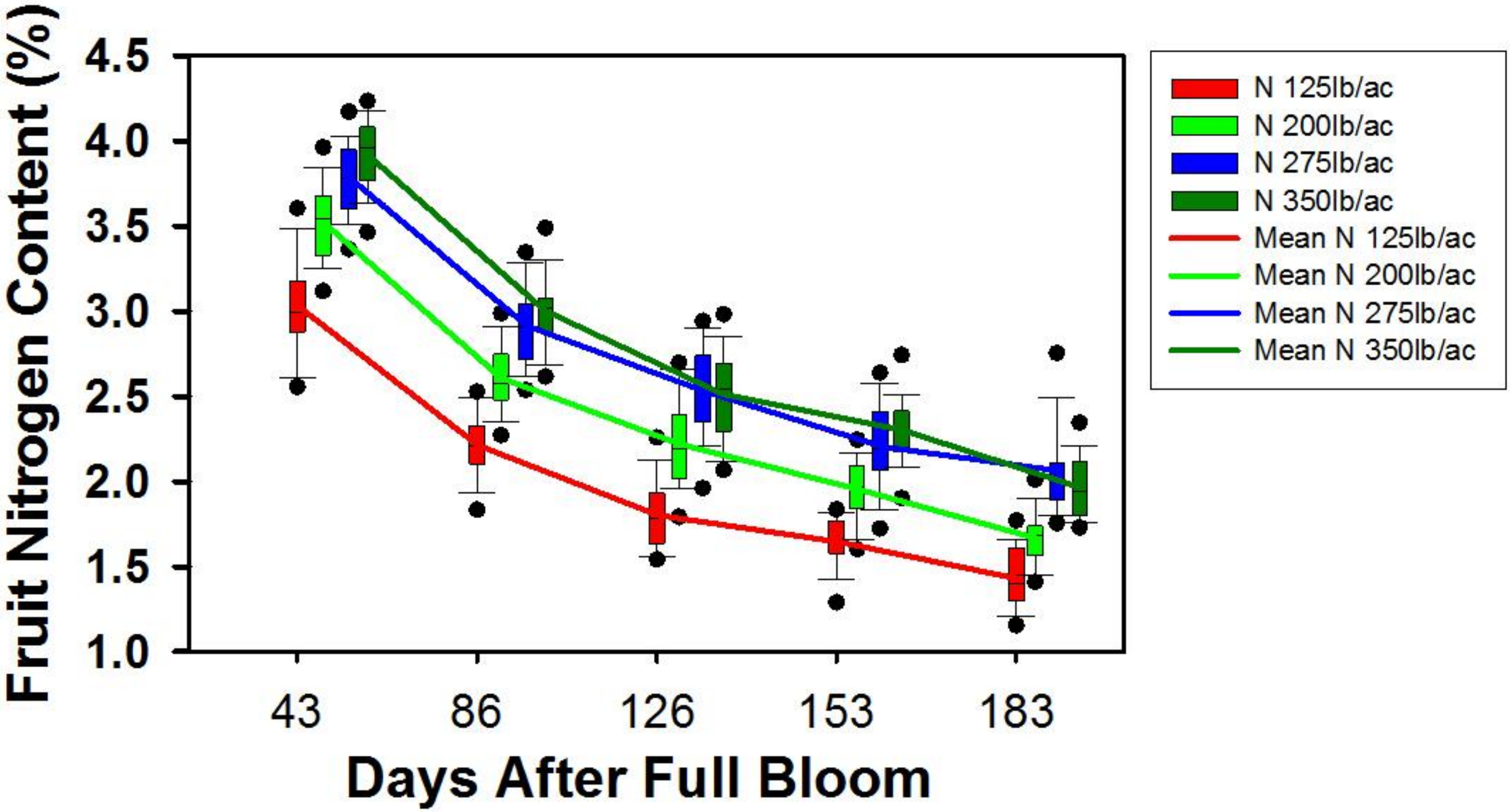
NPK Export by 1000lb Kernel at Harvest 2009-10

NPK Export by 1000lb Kernel in 2009-10 (lb)

Nutrient	2009				2010			
	Nitrogen Rate (lb/ac)				Nitrogen Rate (lb/ac)			
	125	200	275	350	125	200	275	350
N	53	56	58	59	55	61	73	70
	b	ab	a	a	c	b	a	a
P	7.5	7.4	7.2	6.7	8.6	8.2	8.9	7.8
	a	a	ab	b	ab	ab	a	b
K	75	73	73	72	88	81	80	82
					ab	b	b	b

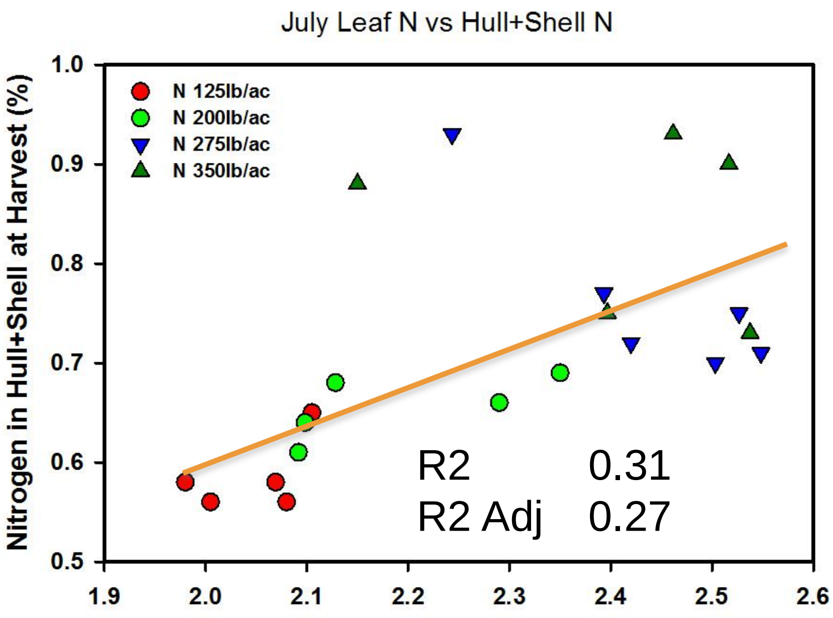
Means not followed by the same letter are significantly different at 10%.

Nitrogen Fertilization and Fruit N Content (2010)



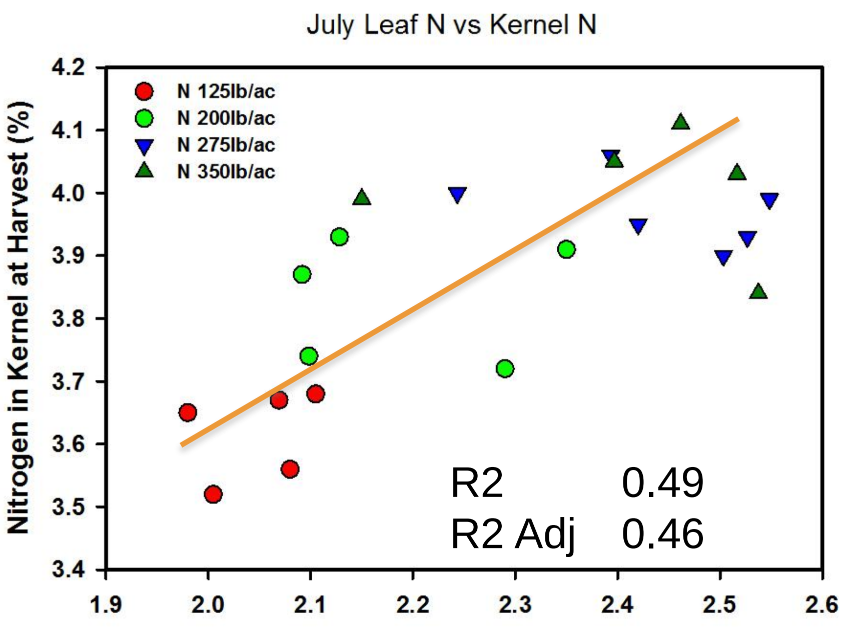
July Leaf N and Hull+Shell and Kernel N at harvest

Hull and Shell



July Leaf N%

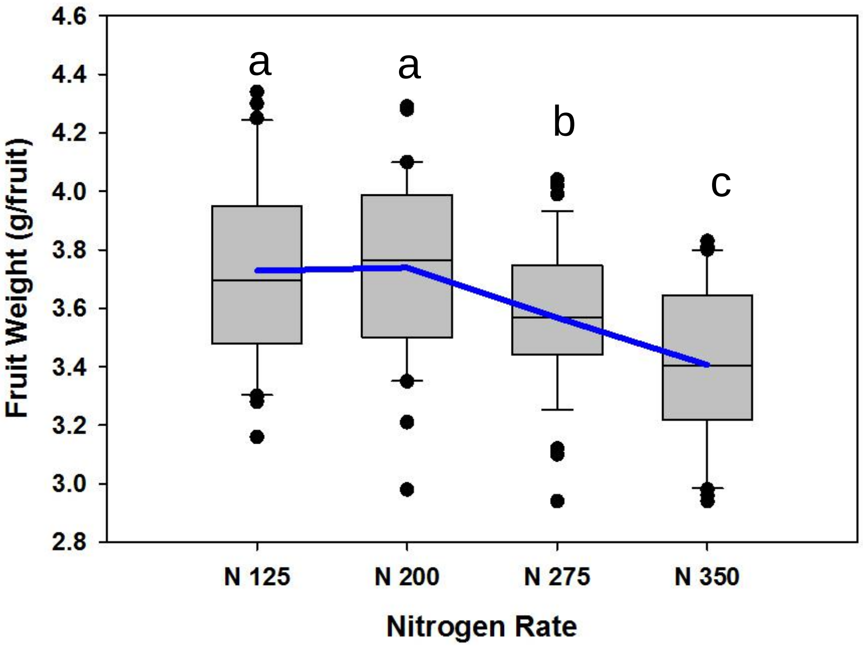
Kernel



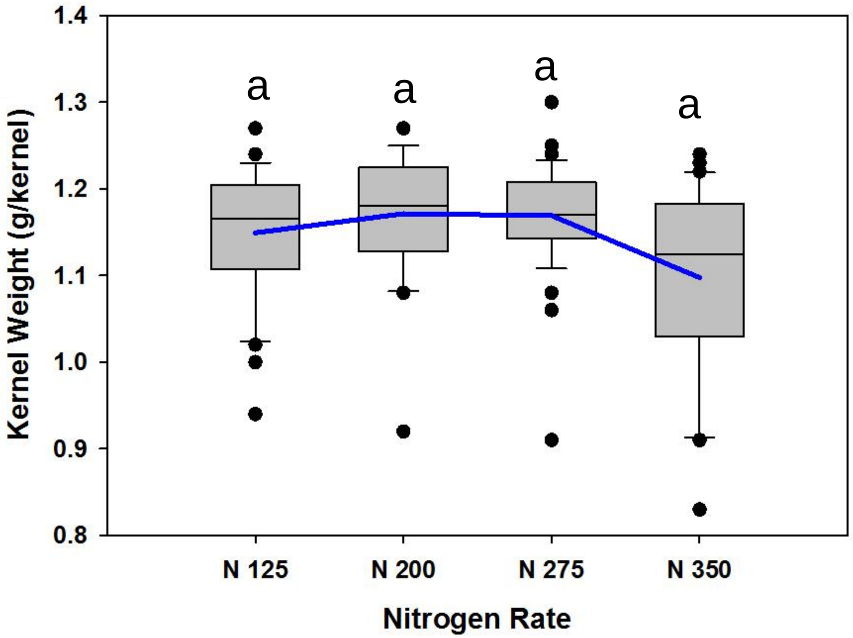
July Leaf N%

Fruit and Kernel weight

Fruit weight (gram/fruit)



Kernel weight (gram/kernel)



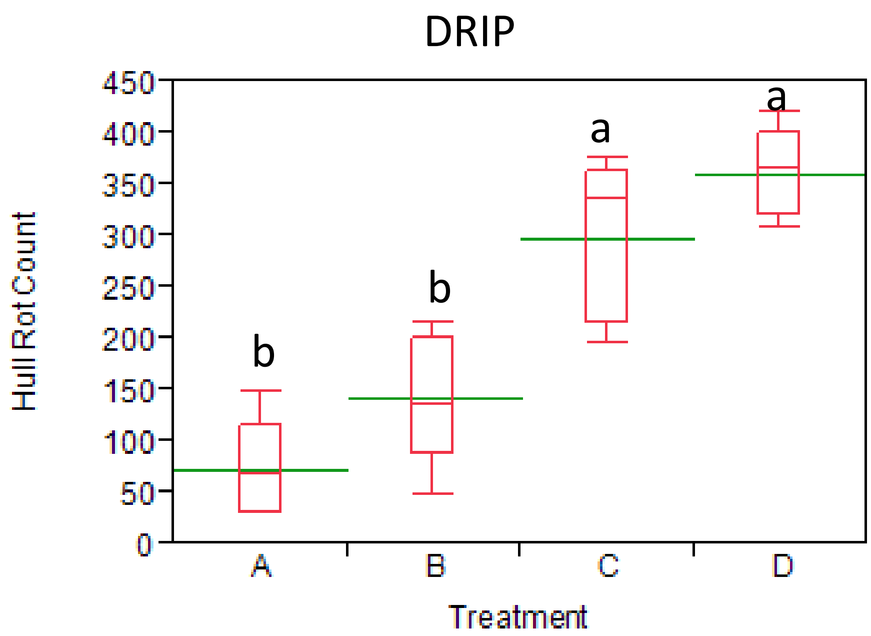
N Fertilization increases Shelling Percentage

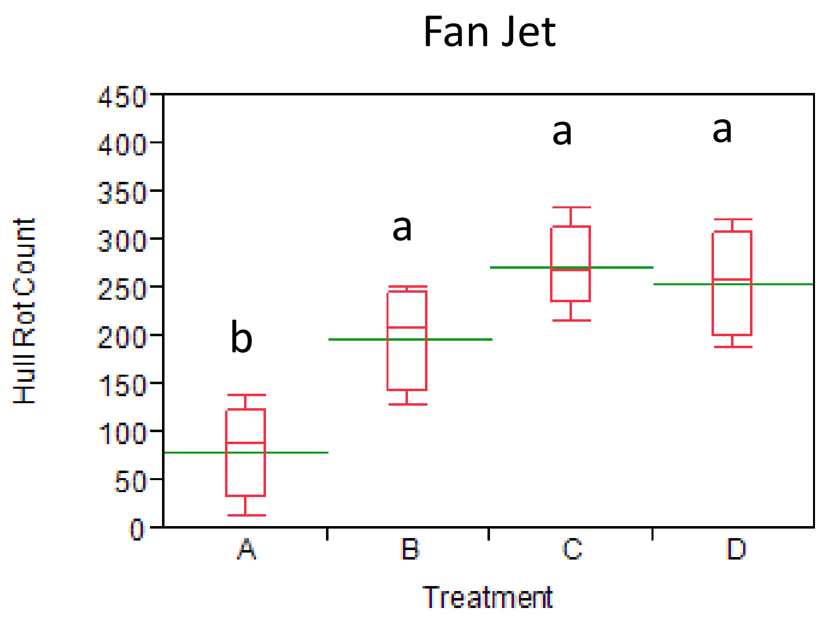
Shelling Percentage (%)

Irrigation	N UAN 32				N CAN 17			
	125	200	275	350	125	200	275	350
Drip	25.8	28.7	28.4	29.8	25.5	27.4	29.9	28.0
	b	a	a	a	c	b	a	b
Fan Jet	26.2	28.0	28.3	28.2	26.6	27.5	30.4	28.0
	b	a	a	a	b	b	a	b

Means not followed by the same letter are significantly different at 10%.
Statistics are only within irrigation type.
Shelling percentage is on the basis of clean 4lb sample

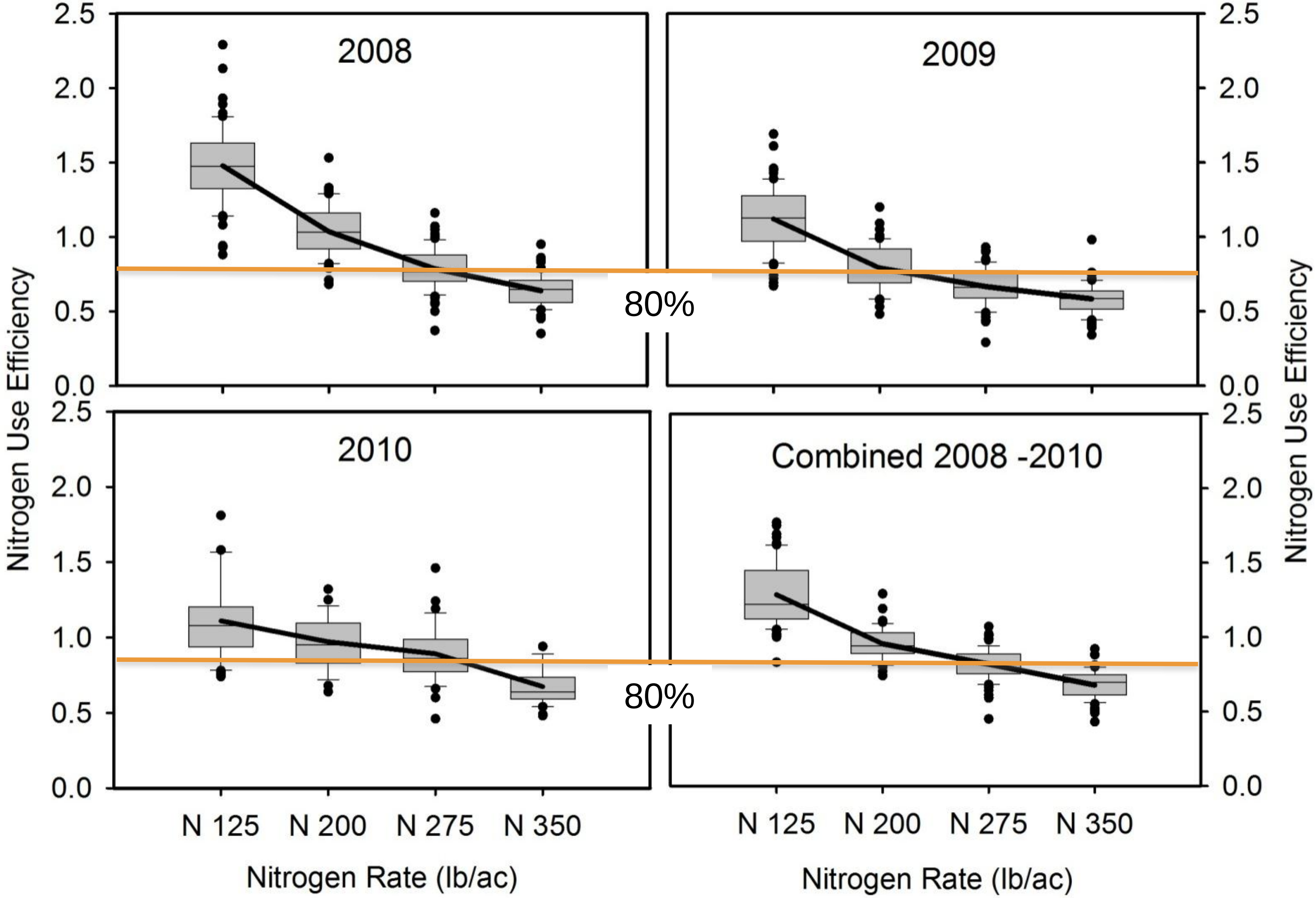
Effect of N fertilization on Hull Rot





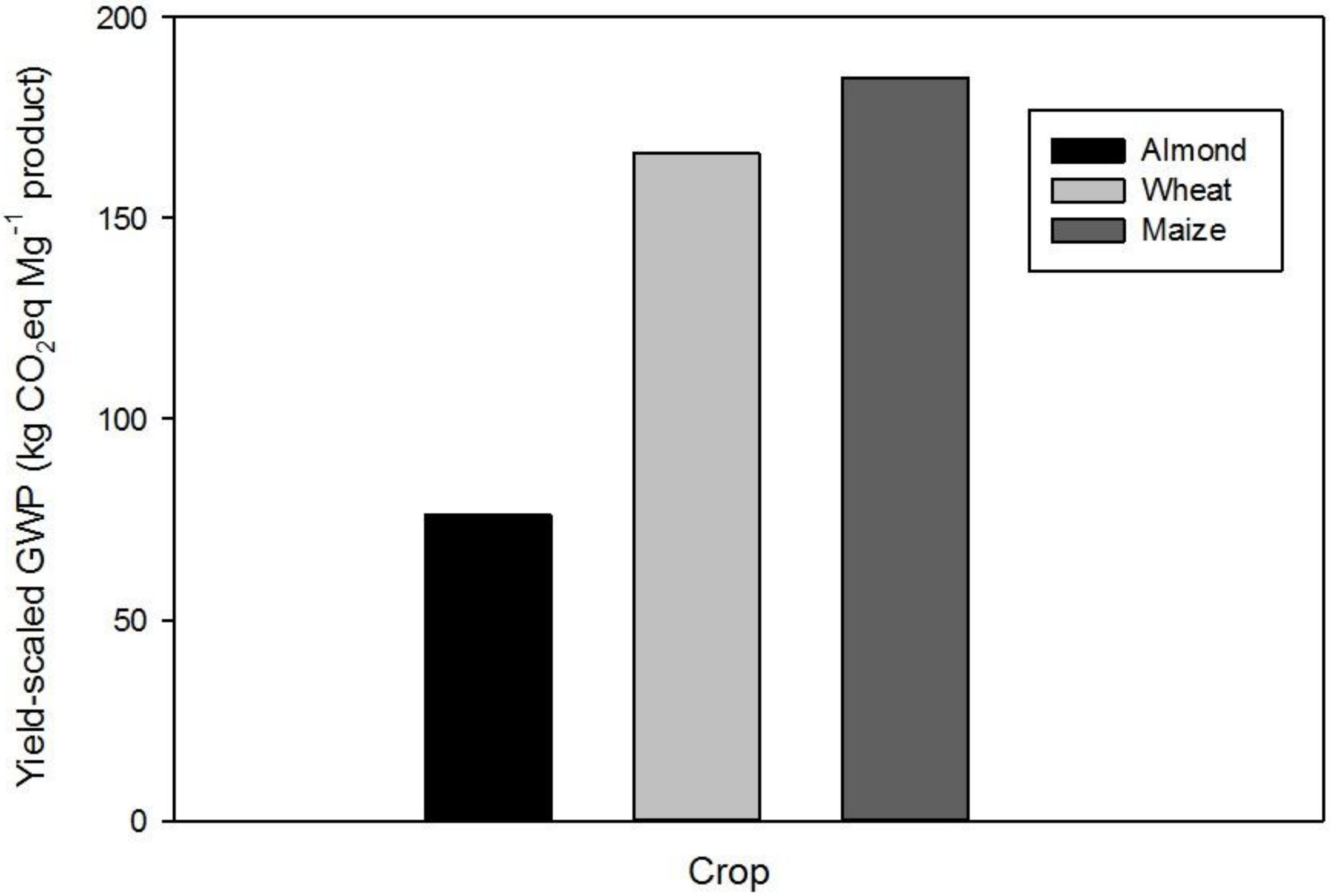
Treatments
A= N 125lb/ac
B= N 200lb/ac
C= N 275lb/ac
D= N 350lb/ac

Nitrogen Use efficiency 2008 - 2010



NUE = N Export in Fruit/N Applied

Relative Greenhouse Gas Generation by Almond, Wheat and Maize



(Schellenberg et al. *Submitted*; Linquist et al. 2011)

Conclusions

- 1000lb kernel removes from 55 (at a leaf N of 2.0% in July) - 70lb N (at a leaf N of 2.4% in July), 8lb P and 80lb K.
- 80% of N, 75% of P and K accumulates in the fruit before 120 DAFB (mid June in 2010).
- In this trial a N rate of 275lb/ac maximized yield (4,700 lb acre) and there was no benefit from N application in excess of this value.
- A Nutrient Use Efficiency (N removed in harvest/N applied) of 75-85% was observed for N rate 275lb/ac rate.
- Although significant differences in leaf K status were observed in 2010; no statistically significant differences in yield have been observed

Conclusions

In this orchard we have attempted to satisfy the 4 R's

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.

An NUE of 65-75% is among the highest ever measured in agriculture – is that good enough?

75% efficiency = 50 lbs N/acre/yr (x 500,000^{+} acres)

= 25,000,000 lbs N/yr

However small changes make a big impact.

- **A 25 lb reduction in N application or 15% increase in efficiency reduces loss by 50%.**

<u>Next Steps</u>:

Adapt fertilization to real yield potential (Site Specific Yield Prediction)

Apply N coincident with tree demand (Determine Root Growth and Uptake Patterns)

Keep fertilizer N in the root zone (Model N and water flow; develop new fertigation technologies; Pulse, Episodic, continuous, differential injection, CRF)

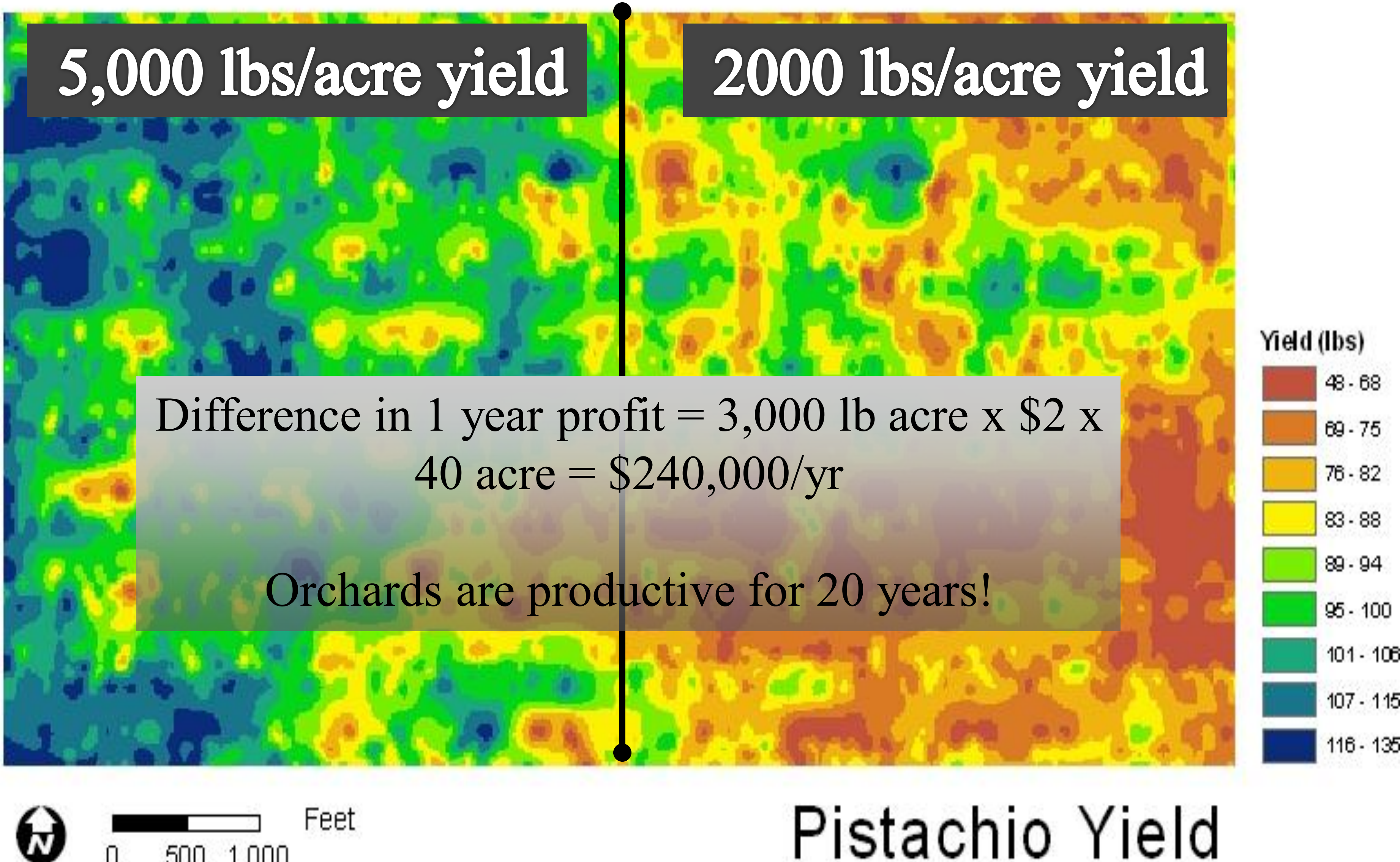
<u>Manage for variability (next step)</u>

Thank You

Now how do we take this to the next level of efficiency?

Managing for Spatial Variability introduces greater complexity in management

Is it worth it?



5,000 lbs/acre yield

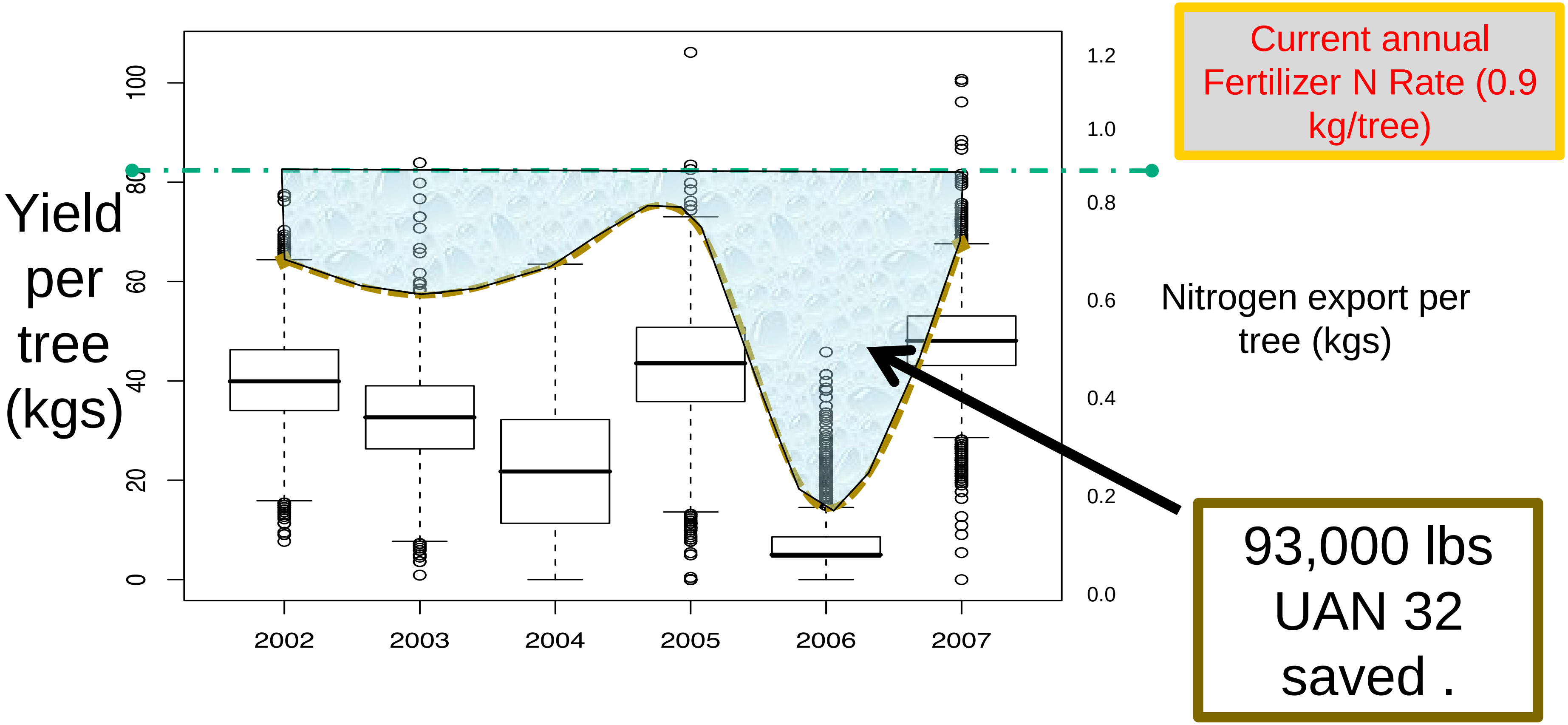
2000 lbs/acre yield

Difference in 1 year profit = 3,000 lb acre x $2 x 40 acre = $240,000/yr

Orchards are productive for 20 years!

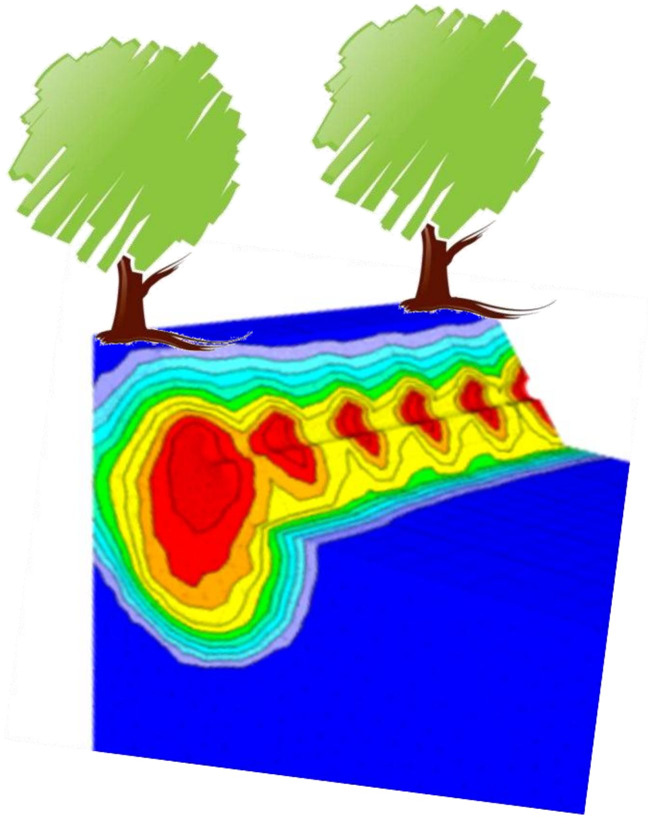
Yield Variability Alters N Demand.

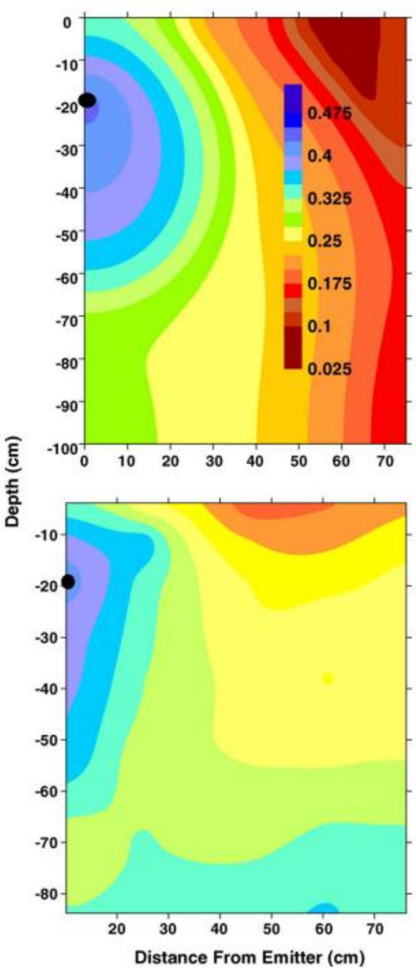
Yield of 10,000 trees for 6 years



Soil Type and Irrigation Practice Alters Nitrate Leaching

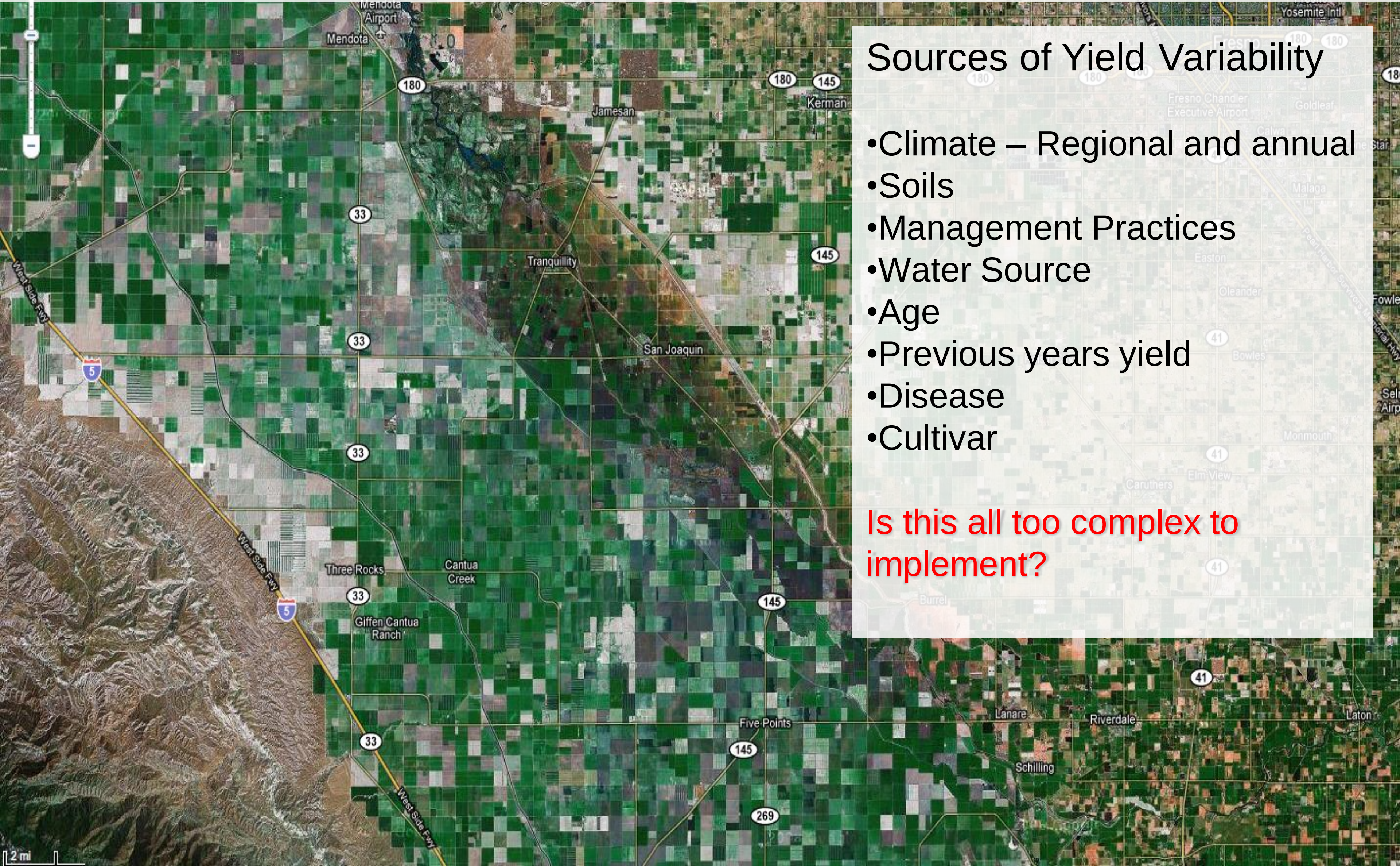
Water and Nitrate Distribution after fertigation event





Large Scale Spatial Variability

Any solution must offer scalability and specificity



Sources of Yield Variability

- Climate – Regional and annual
- Soils
- Management Practices
- Water Source
- Age
- Previous years yield
- Disease
- Cultivar

Is this all too complex to implement?

New University: Almond Board: Industry Collaborative Project

growing ADVANTAGE
The Almond Conference

Managing Variability to Optimize Sustainability

High intensity mapping to establish Zonal Irrigation/fertigation System. (ZIFS)

Contrast Irrigation/fertigation Control Systems
- Soil Sensing (Conductivity, Matric etc Models etc)
- Plant Sensing (Stem Water, Nutrition, Psychrometer etc)
- Above Canopy sensing (tower mounted or aerial imagery)
- Climate and modeling based.

Measurements:
- Yield, nutrient flux, root growth, nutrient status, N and Gas loss

Industry Partners Needed!

Fertigation, irrigation, consulting, fertilizer, sensing and control, farm management.

Goal:

A fully scalable (field –farm- county – state) Irrigation and Fertigation Protocol