Plant Nutrition Management in an Age of Expenses and Regulations (Part 1)

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Plant Nutrition Management in an Age of Expenses and Regulations (Part 1)

Moderator: Bob Curtis, ABC

Presenters:

Patrick Brown, UC Davis

Gabriele Ludwig, ABC

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Saiful Muhammad (Patrick Brown), UC Davis

Managing Nitrogen Efficiently

Patrick Brown

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Background

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Why the focus on Nitrogen?

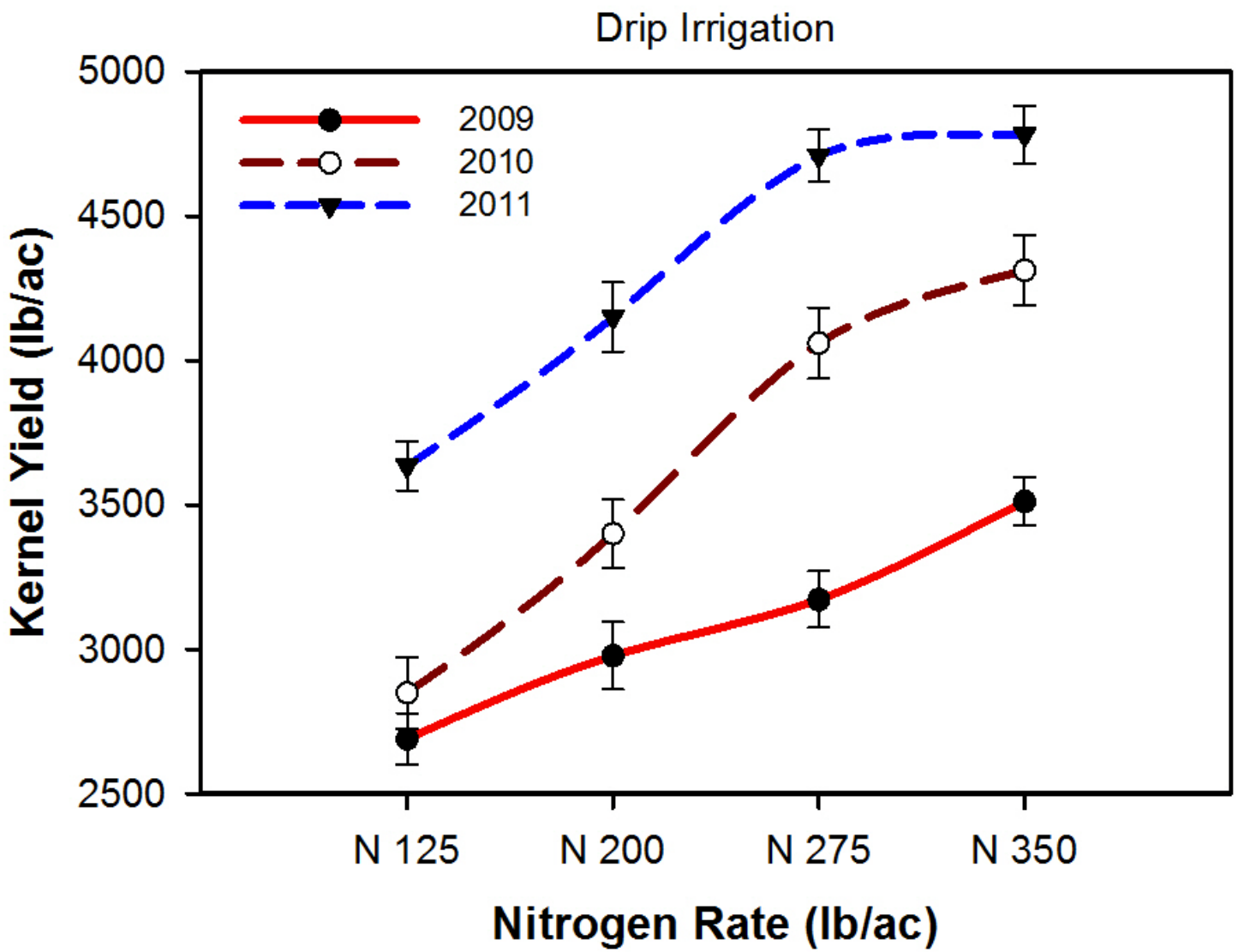
- Essential for plant growth and critical for crop yield
  - N is critical for photosynthesis, protein formation and growth
  - Almonds are among the most N demanding of any crop.

- 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)
  - Current tools for monitoring and management are inadequate

Satisfy Demand-Prevent Losses-Maximize Efficiency?

Nitrogen is Essential for Almond Yields

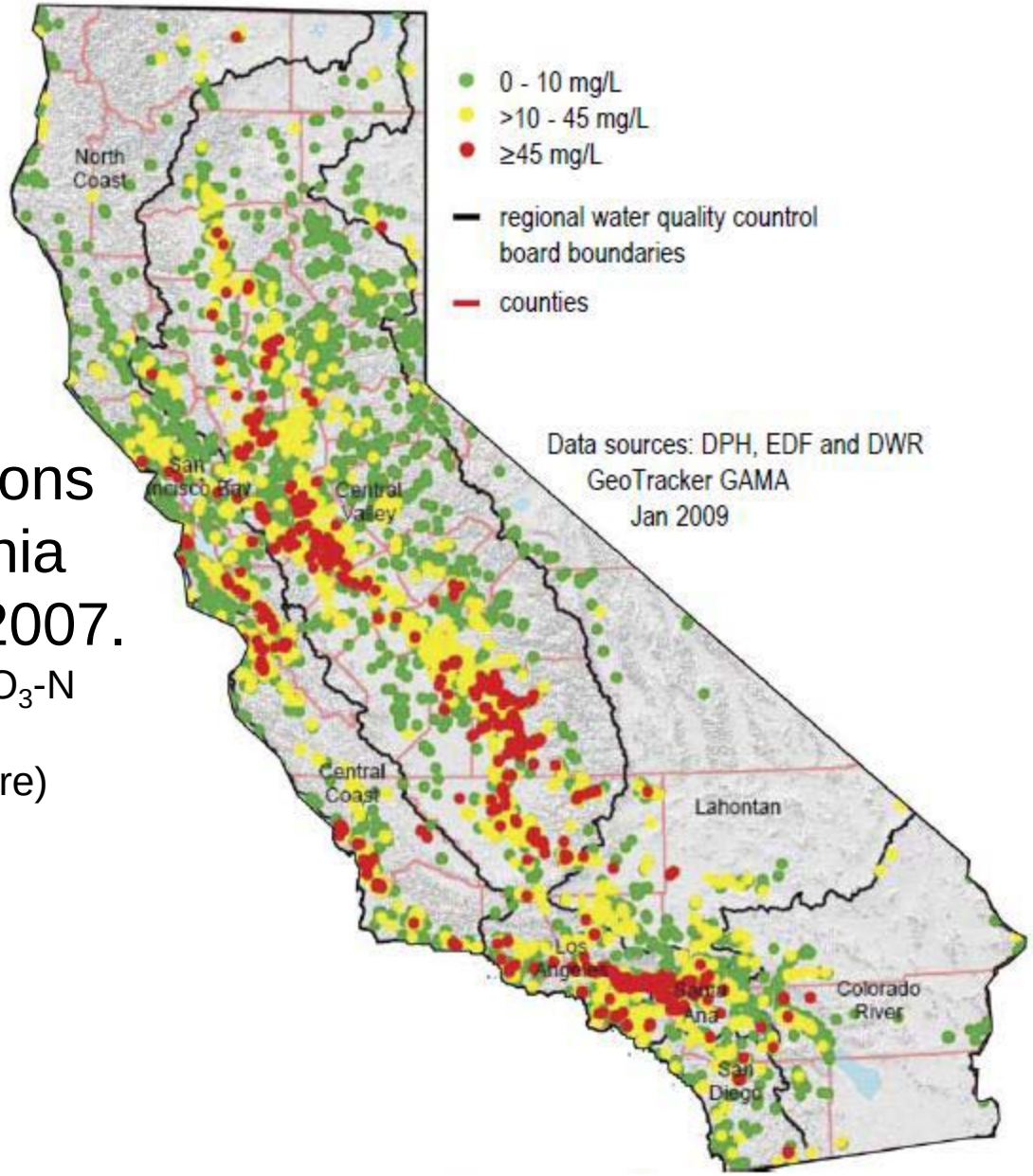


Environmental concerns

Nitrate concentrations in various California wells measured in 2007.

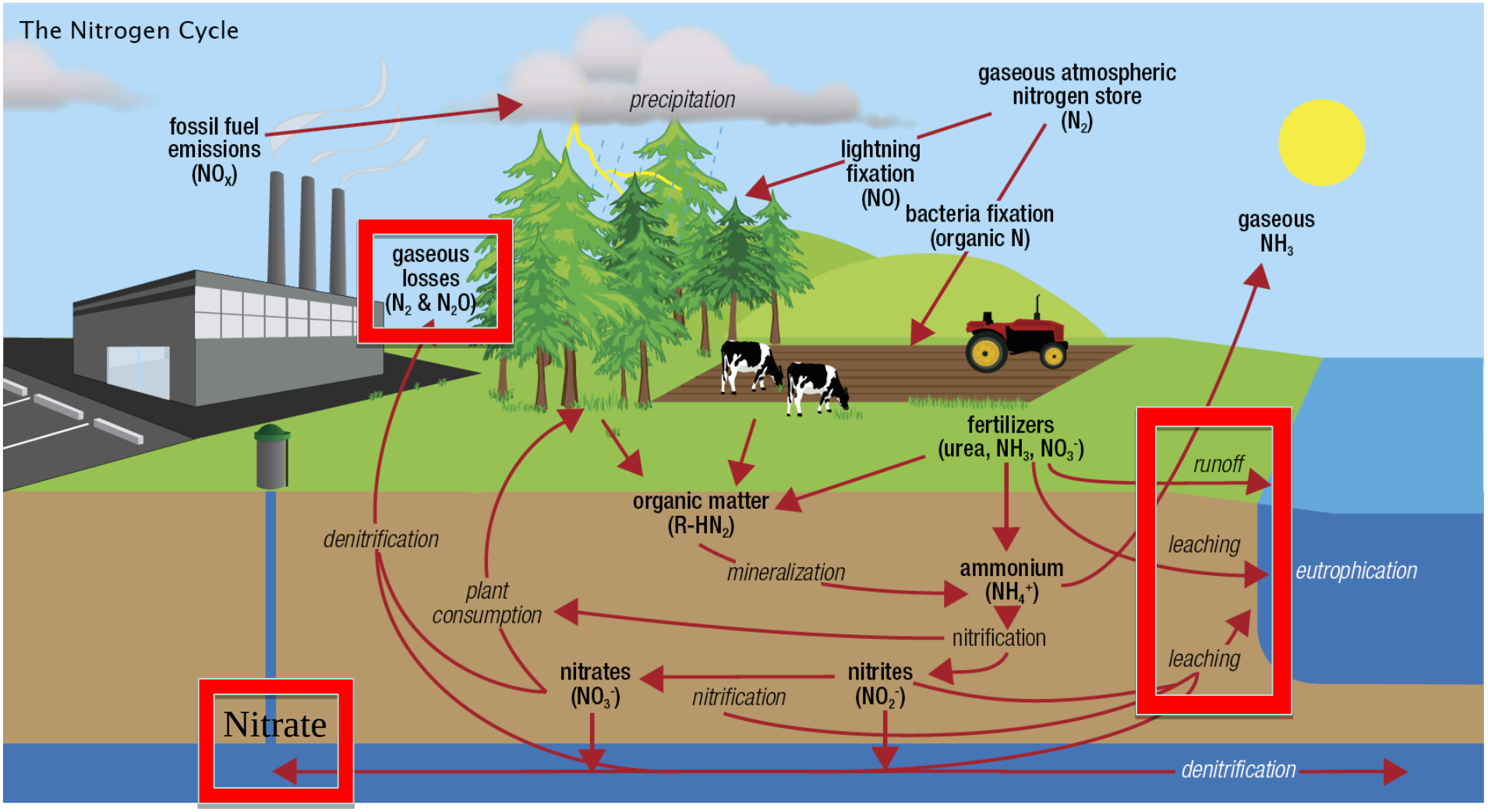
44 mg/L NO_3 = 10 mg/L NO_3-N

(some from animal manure)



(Ekdahl and others, 2009)

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.

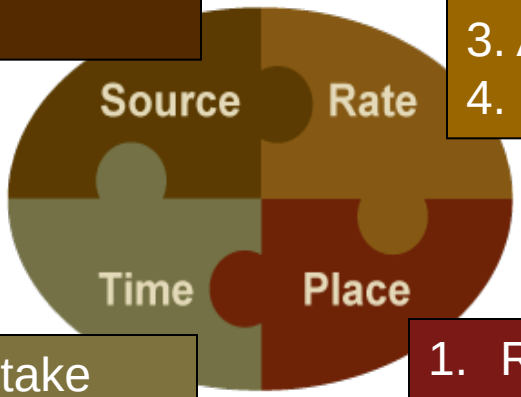
Using the Right Source

- Maximize uptake minimize loss potential.

The Basic Scientific Principles of Managing Crop Nutrients are Universal

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

1. Appropriately assess soil nutrient supply
2. Assess all available indigenous nutrient sources
3. Assess plant demand
4. Predict fertilizer use efficiency



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

1. Recognize root-soil dynamics
2. Manage spatial variability
3. Fit needs of tillage system
4. Limit potential off-field transport

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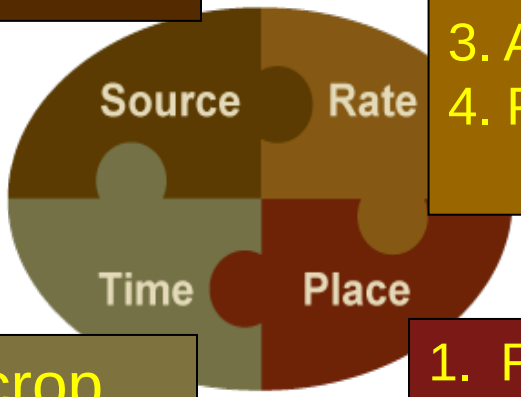

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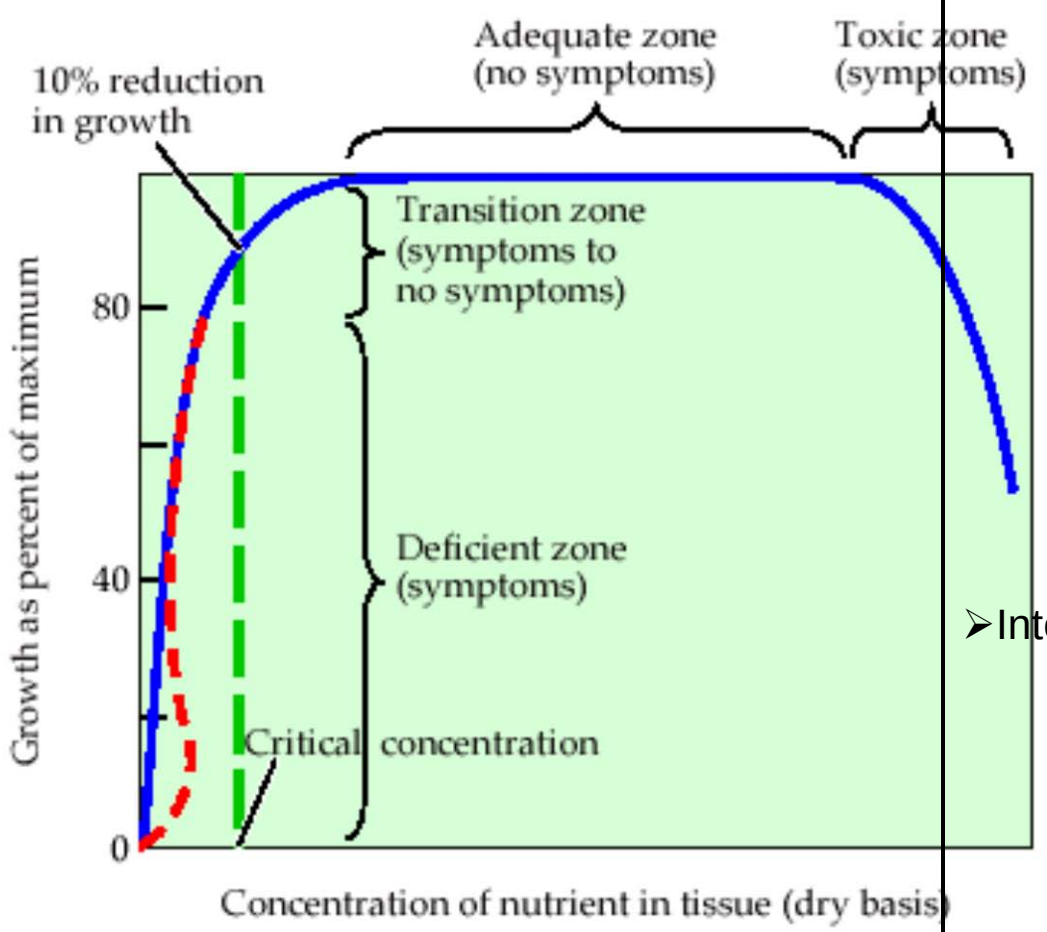
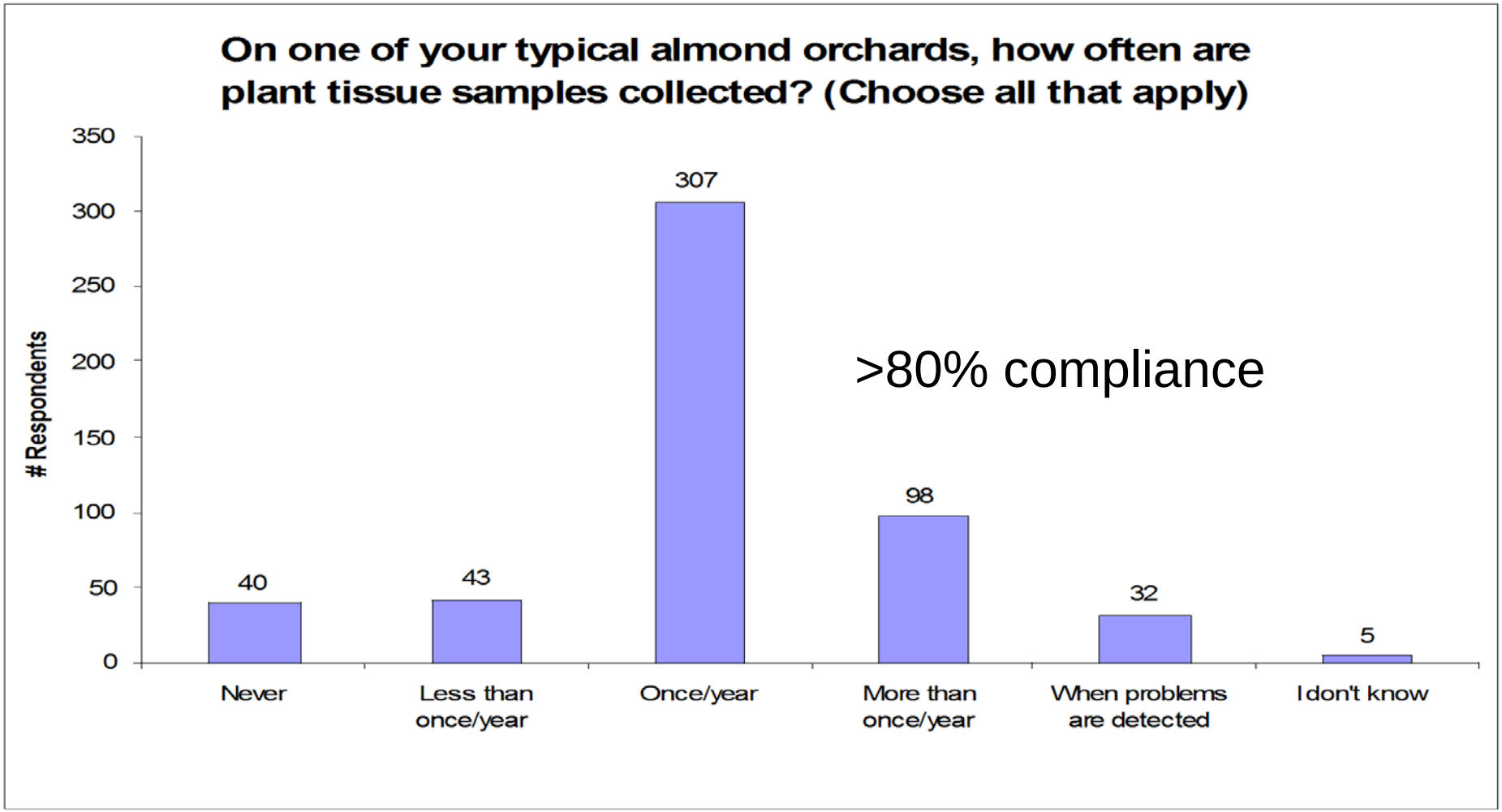
What Do We Know and How Do We Manage?
Leaf Sampling and Critical Value Analysis

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



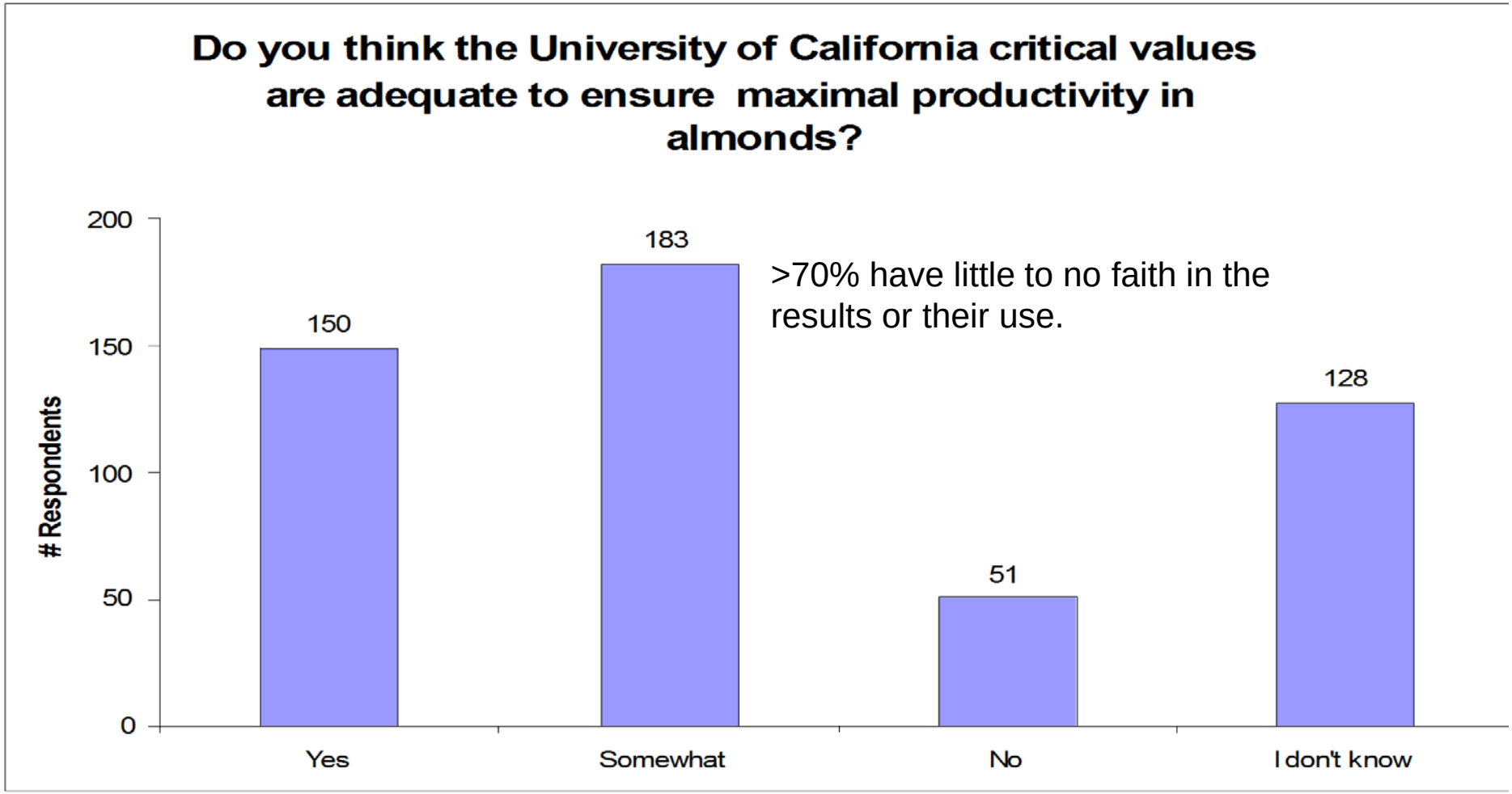
- Sampling protocols are well defined
  - Non fruiting spur leaves
  - July/August
  - South West quadrant at 6'.
  - Contrast leaf analysis with standard Critical Values published in Almond Production Manual
    - Yield trials (N, K, B)
    - Leaf symptoms (P, S, Mg, Ca, Mn, Zn, Fe, Cu)
    - Unknown (Ni, Cl, Mo)
- Interpretation of results (NO R'S!)
  - Leaf analysis can indicate a shortage but cannot define how to respond.
  - Thus: Fertilizer decisions are currently based on experience and 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?



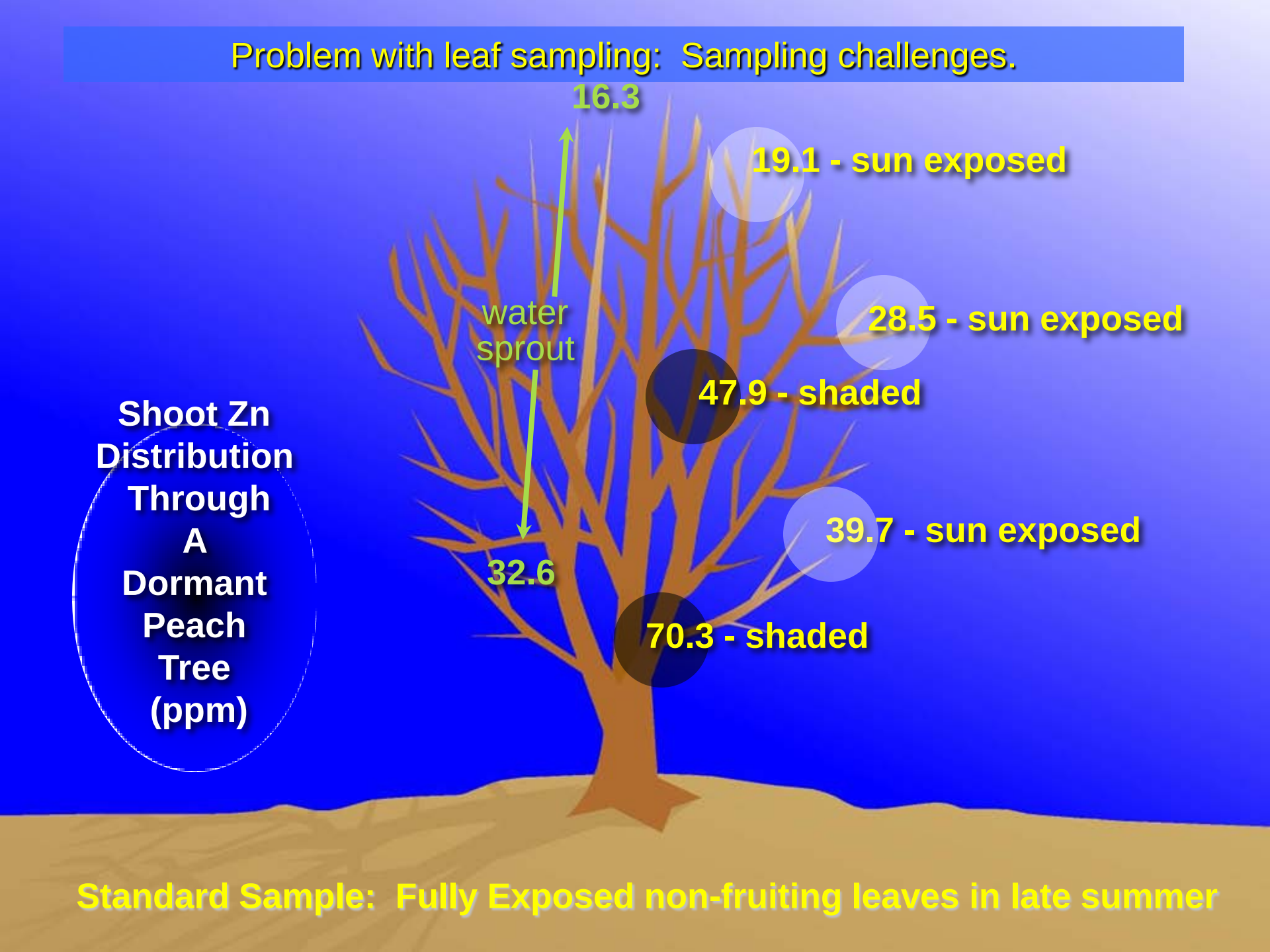
>70% have little to no faith in the results or their use.

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.

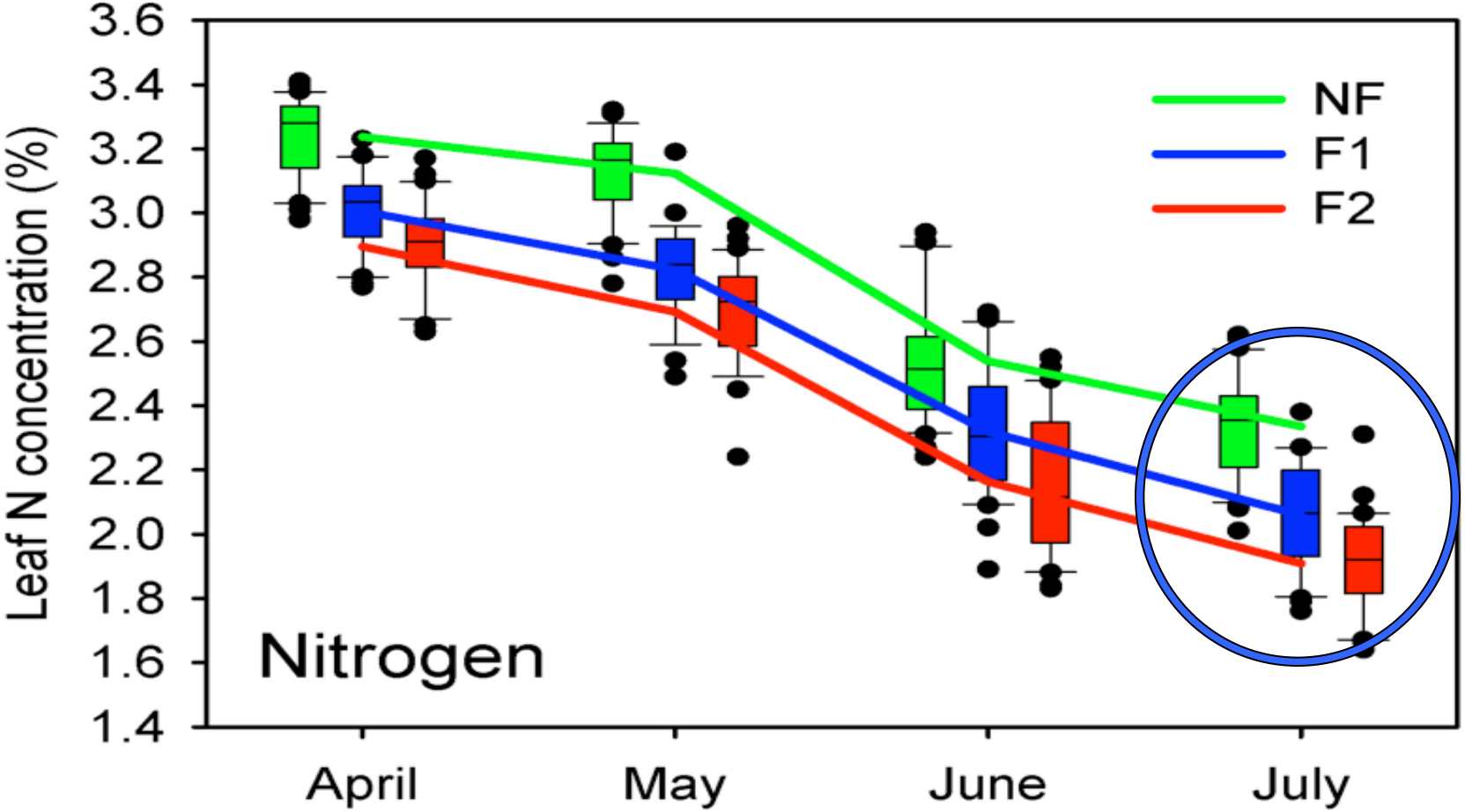
Problem with leaf sampling: Sampling challenges.



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


Which leaf is the best leaf?
Not Deficient
Deficient

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.

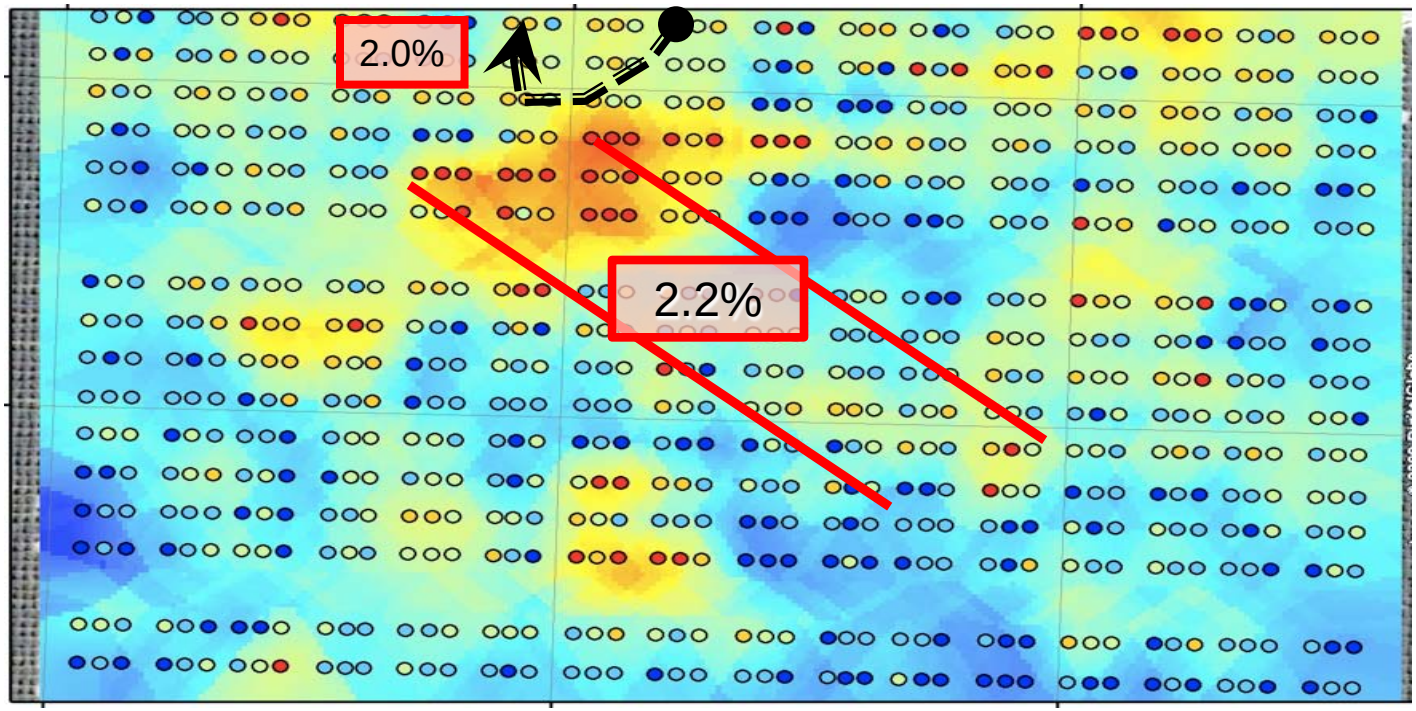
Challenges of Sampling: Field Variability

(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%*

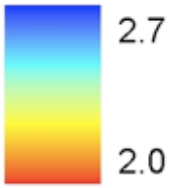
What is the right target mean? (variability:response:cost:returns:yield)



Individual trees

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

Interpolated surface (Kriging)



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. Sampling in the way most people currently do it, is a waste of money.
- Does not inform management practice
- UC critical values are probably correct at a tree level but a single ‘pooled’ sample does 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 and an understanding of the processes.

Alternatives?

Alternate Approaches to Nutrient Management

Nutrient Budgeting:

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Efficiently replacing nutrients removed from the field

Essential Components and Challenges:

Estimate current year demand (Last years yield, this years estimated yield, tree age, common sense)

- Improved techniques are under development (remote sensing, modeling etc)
- Yield monitoring

Measure and control inputs and losses (soil, fertilizer, irrigation, leaching, volatilization)

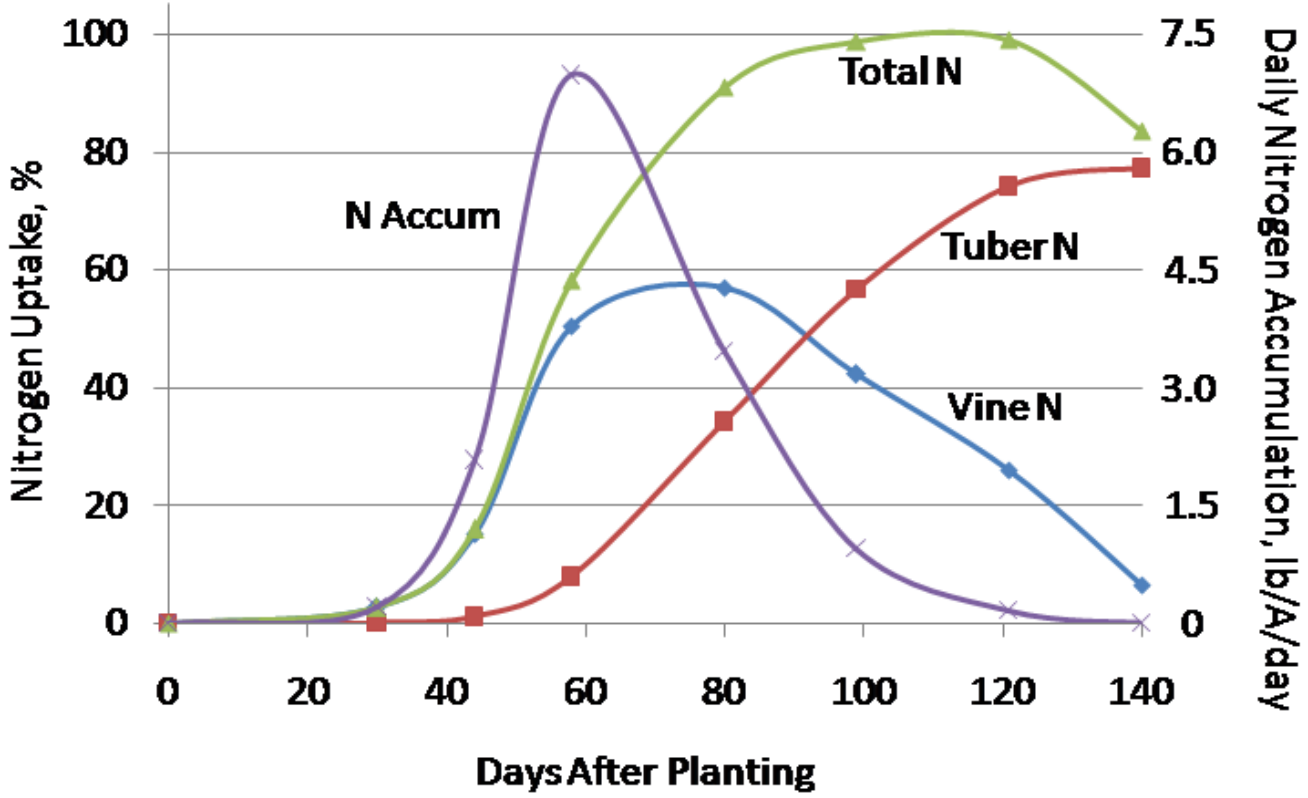
Manage efficiencies and interactions

- Synchronization and location of nutrient applications
- Monitoring crop response

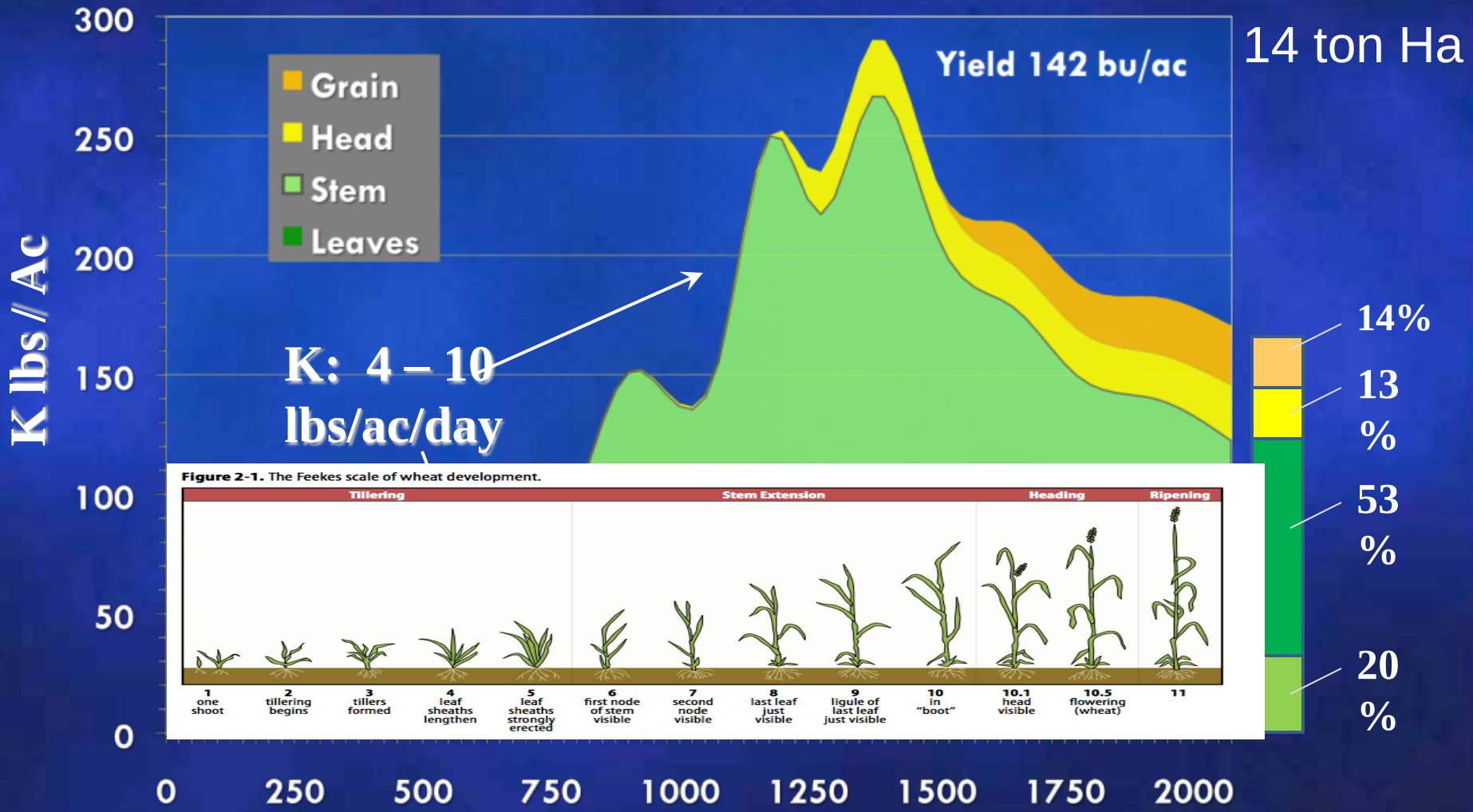
How?

Daily accumulation rates and plant parts

(Russet Burbank potatoes, Oregon)



Potassium Aerial Accumulation
Wheat - California

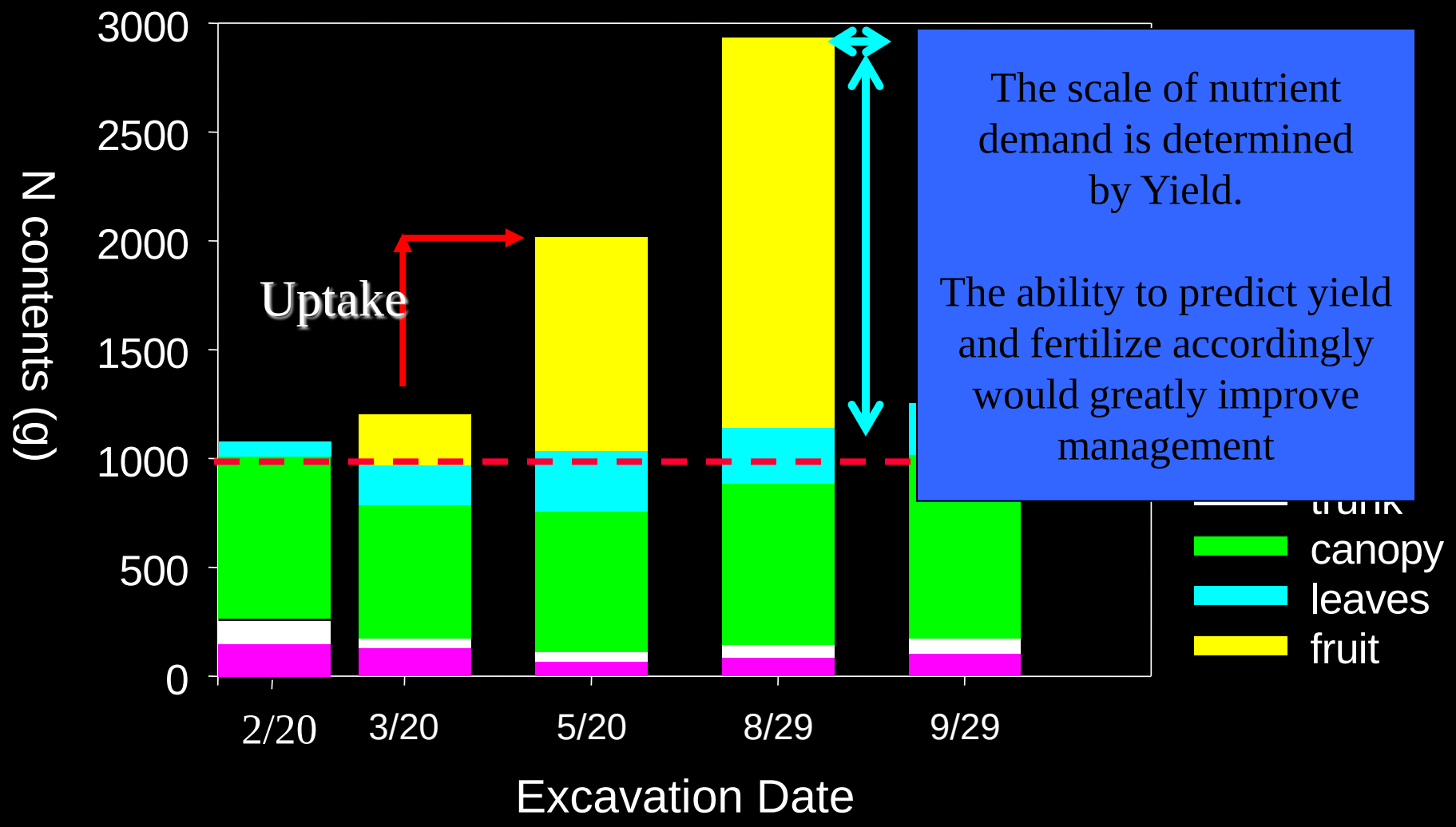


*above ground

Miller, 1990

Nutrient Demand: Whole tree Harvesting:
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 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.

Thank You

Fertilizers: The Expenses and Regulations

Gabriele Ludwig, Almond Board of California

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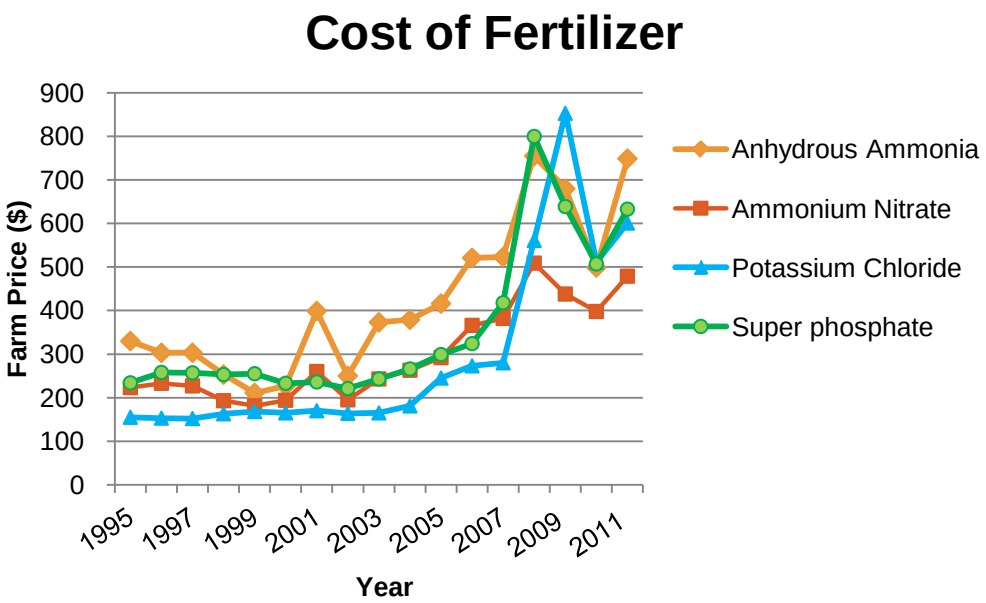
Fertilizers: The Expenses and Regulations

Fertilizer prices have been increasing

Regulations on fertilizer use are increasing

- Water quality
- Air Quality

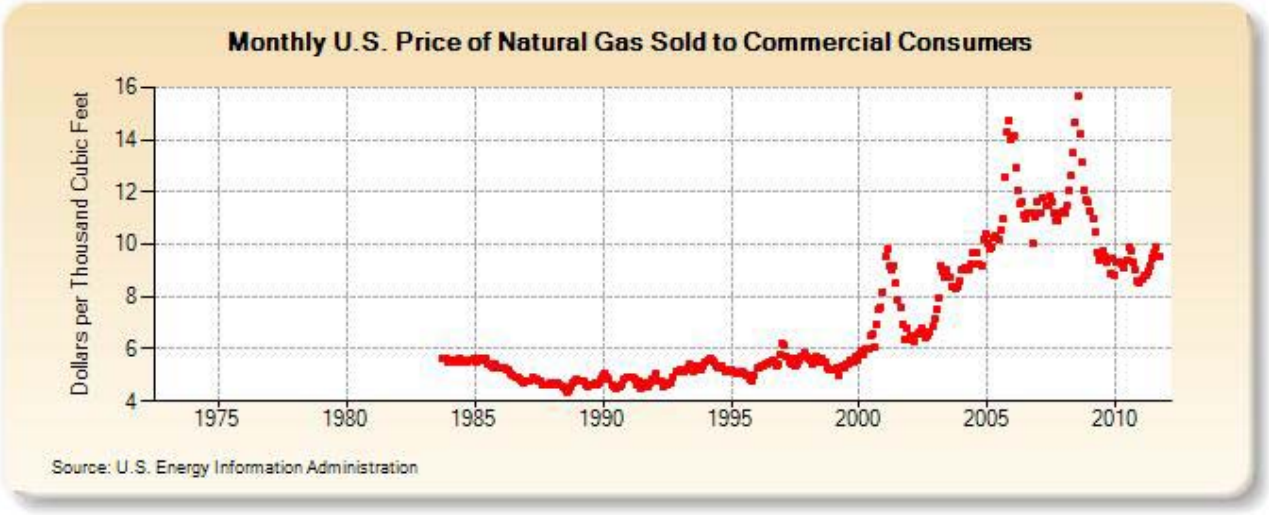
Trends in Fertilizer Costs



Source: http://www.ers.usda.gov/Data/FertilizerUse/

N,P,K fertilizer costs have more than doubled the last 10 years.

- N cost directly tied to natural gas prices
  - Natural gas US supply predicted to be stable but more costly to extract/produce
- P & K prices tied to international market demand

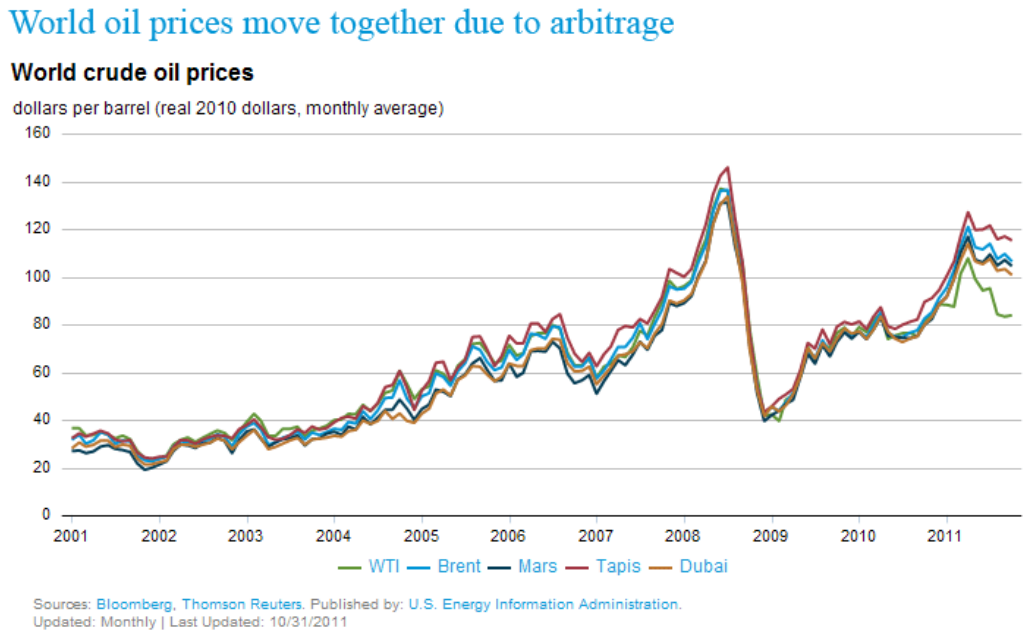


Trends in Fertilizer Costs

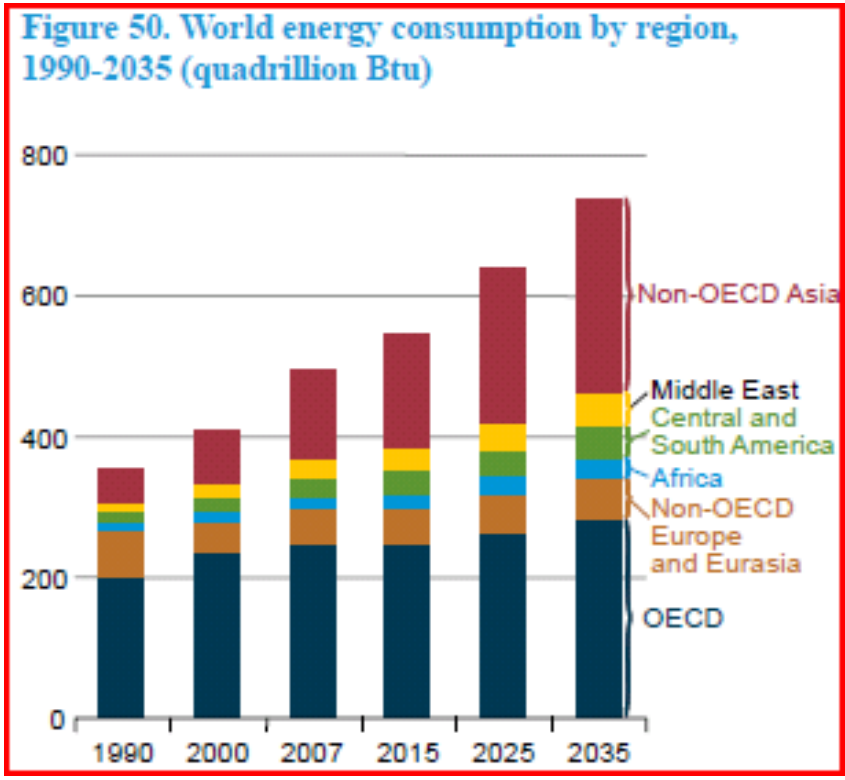
Prices also tied to oil prices

(for extraction, formulation, transportation, etc.)

- Increasing energy use by Asia



Many types of crude oil are produced around the world. Variations in quality and location result in price differentials, but because oil markets are integrated globally, prices tend to move together.



Source: U.S. Energy Information Administration: Annual Energy Outlook 2011

Nitrogen Impacts the Environment

"Reactive Nitrogen" is every form of nitrogen other than N_2

EPA and CA agencies are regulating reactive nitrogen.

Forms of "reactive nitrogen":

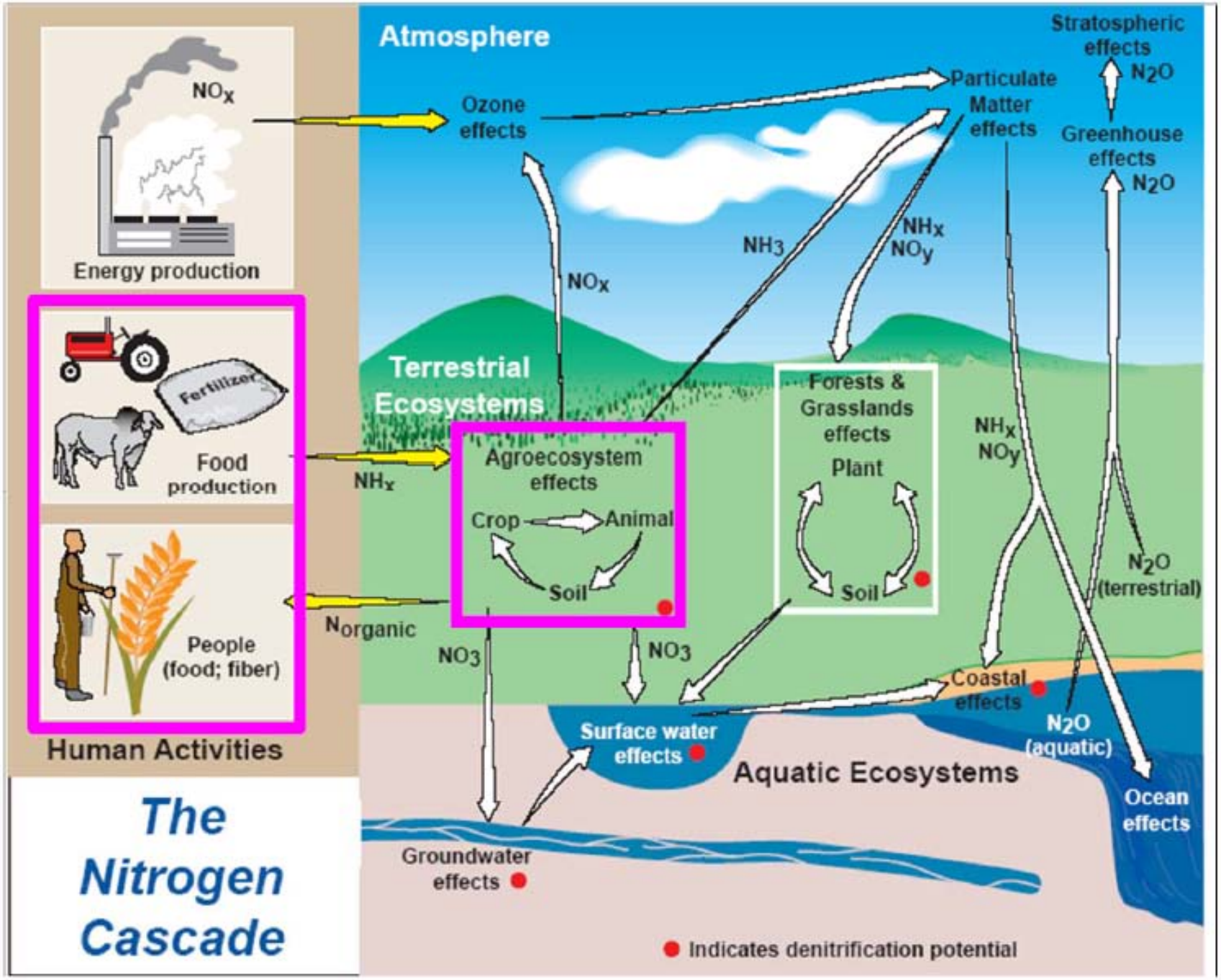
NH_3^-;NH_4^+ (Ammonia) ➔ $PM_{2.5}$, Water, N deposition

N_2O (Nitrous Oxide) ➔ Greenhouse gas

NOx (NO, NO_2 or Nitrogen Oxides ➔ Ozone (Smog)

NO_2^-, NO_3^- (Nitrite, Nitrate) ➔ Ground and Surface Water

Organic-N (N in organic matter) ➔ surface water



The Nitrogen Cascade

Galloway & Cowling, 2002; UNEP, 2003

Media on N Environmental Effects

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Tainted water flows from taps of rural Valley homes

By Mark Grossi / The Fresno Bee

Saturday, Oct. 01, 2011 | 11:00 PM

E-MAIL PRINT TEXT SIZE: Tweet

27 Comments

TOOLEVILLE -- From her living room window, Vale
where pristine snowmelt flows to farm fields.

She loves walking along the canal, knowing the spa

Pure water turns toxic in nitrate-laced Valley soil

By Mark Grossi / The Fresno Bee

Sunday, Oct. 02, 2011 | 11:00 PM

E-MAIL PRINT TEXT SIZE: Tweet Share +1

10 Comments

But with nearly 1 million acres of farming in Tulare County, fertilizers still are considered a prime suspect.

A group of UC Davis professors, led by hydrologist Harter, will try to figure out the extent of nitrat

g to get worse?

pplied decades ago may
s only now may be invading

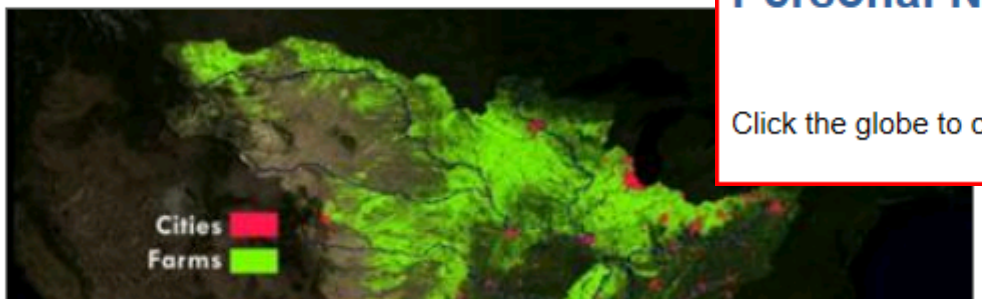
Jun 15, 2011

Record 'dead zone' predicted in Gulf of Mexico

Comment 220 Recommend 225 Tweet 310

By Doyle Rice, USA TODAY

Updated 2011-06-17 3:52 PM



culator | Change Your N Footprint | N-PRINT Project

Personal N Footprint Calculator

Click the globe to calculate your personal nitrogen footprin

Ground Water: Irrigated Lands Program

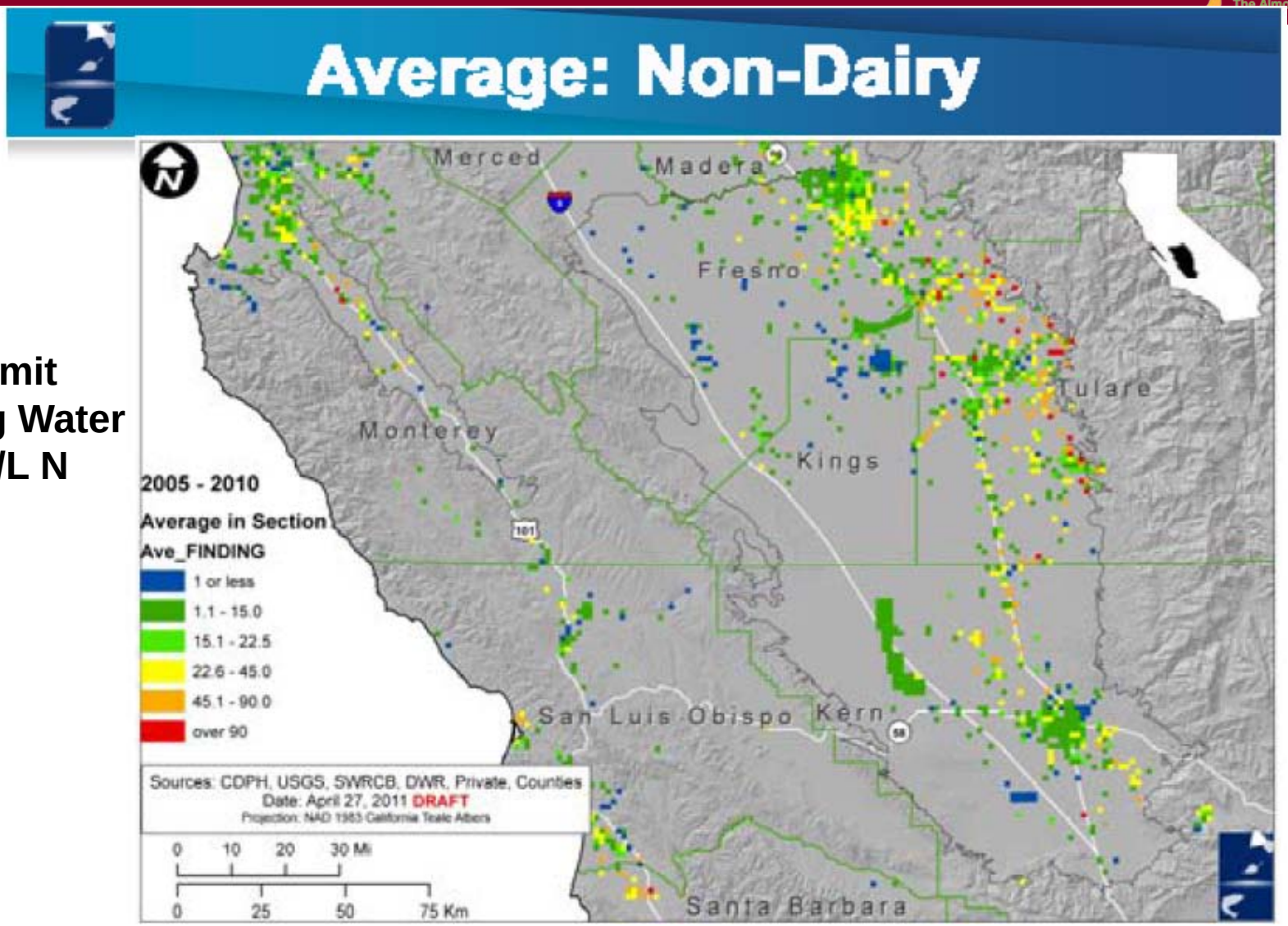
Permitting Program of the Central Valley Regional Water Board for agricultural discharges into surface waters

- Ground Water now added to the permit

- Main concern is nitrate and salt leaching into ground water
  - Nitrates exceed drinking water limits in some locations of the Central Valley (e.g. Tulare Basin)
  - Report to the Legislature due early 2012 on Nitrate in Ground Water
    - UCD is assessing levels, sources, trends for Tulare and Salinas Basins
    - Discuss possible mitigation measures.

Ground Water: Nitrate Levels in Tulare Basin

N max limit Drinking Water = 10 mg/L N



Data from Draft Report on Nitrate in Ground Water to Legislature (SBX2-1) by UC-Davis, May 3, 2011

Requirements of Expanded Irrigated Lands Program

1) Any grower with irrigated lands in the Central Valley will need to join a coalition
2) Each coalition will be responsible for finding mechanisms to reduce potential leaching/run off concerns
   - Will need documentation from growers of changed practices
3) Each grower expected to review their fertilizer practices and develop measures to reduce potential impacts from fertilizer inputs.
4) Where nitrates in ground water are a known issue, growers expected to develop and follow a Nutrient Management Plan.

Fees increasing as part of budget agreement

Air Quality: Greenhouse Gases

Nitrous Oxide (N_2O) is 300x more potent GHG than CO_2.

- Formed by bacteria in the soil.
- ARB had planned to regulate fertilizers

ARB now looking for off-set protocols for voluntary reductions in ag N_2O emissions.

- Off-sets: voluntary reductions in greenhouse gases that can be bought by entities to meet mandated reductions

Role of Research

Current ABC funded research is critical for ensuring almond growers can continue to produce a high protein, highly nutritious food.

- Seeking refinements to increase N use efficiency.
- Seeking better tools to help assess when and how much N is needed by the trees.
- Developing data on actual N_2O emissions and possible carbon off-sets
- Nutrient Management Sustainability Module

Pollination Update

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?

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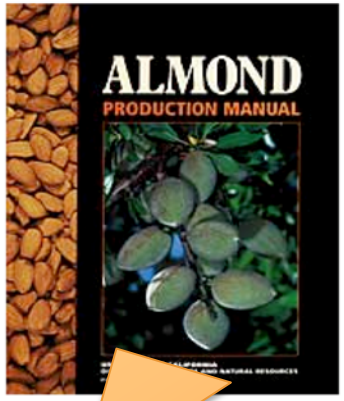
Sample in July

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

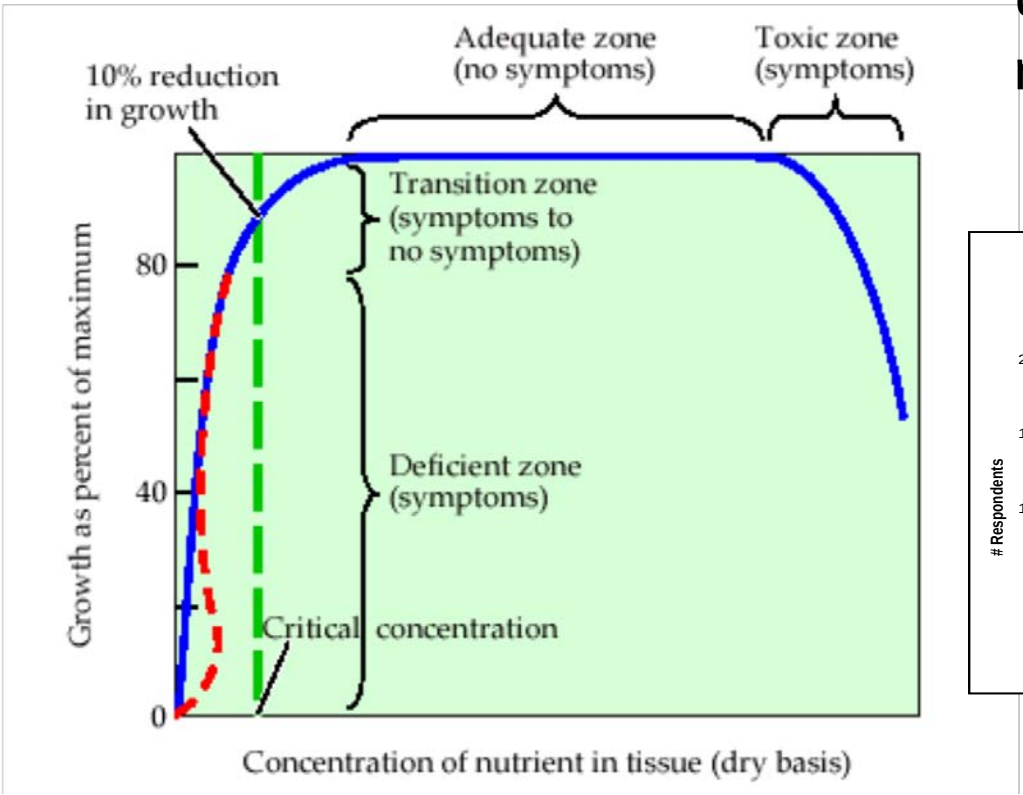
Nitrogen (N)	
Deficient below	2.0%
Adequate	2.2–2.5%
Phosphorus (P)	
Adequate	0.1–0.3%
Potassium (K)	
Deficient below	1.0%
Adequate over	1.4%
Calcium (Ca)	
Adequate over	2.0%
Magnesium (Mg)	
Adequate over	0.25%
Sodium (Na)	
Excessive over	0.25%
Chlorine (Cl)	
Excessive over	0.3%
Boron (B)*	
Deficient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



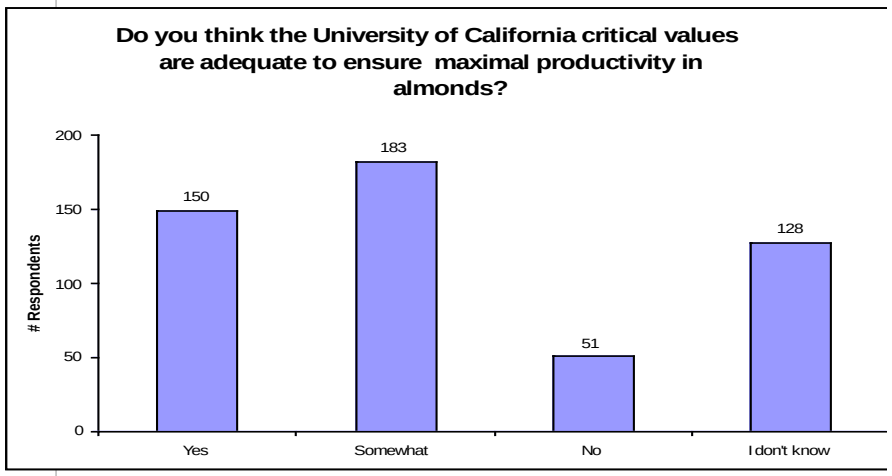
*Critical values for boron deficiency and toxicity are currently being revised. Hull boron >300 ppm is excessive. Leaf sampling is not effective to determine excess boron.

Problem Statement: Recall to Dr. Brown's Lecture

Critical Value



Are tissue samples being used to guide fertilizer management?



Possible Reasons To 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:

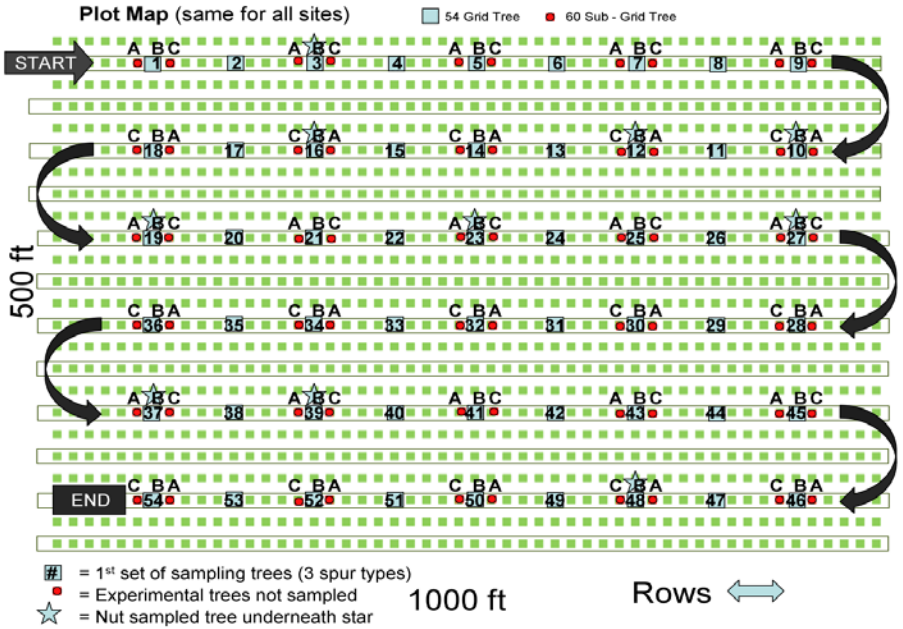
- Develop methods to sample in April and relate that number to July critical value.
- Develop method for grower to sample his field (recognizing that typical practice is only 1 sample per field is generally collected).
- Reevaluate the current CV's.

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.

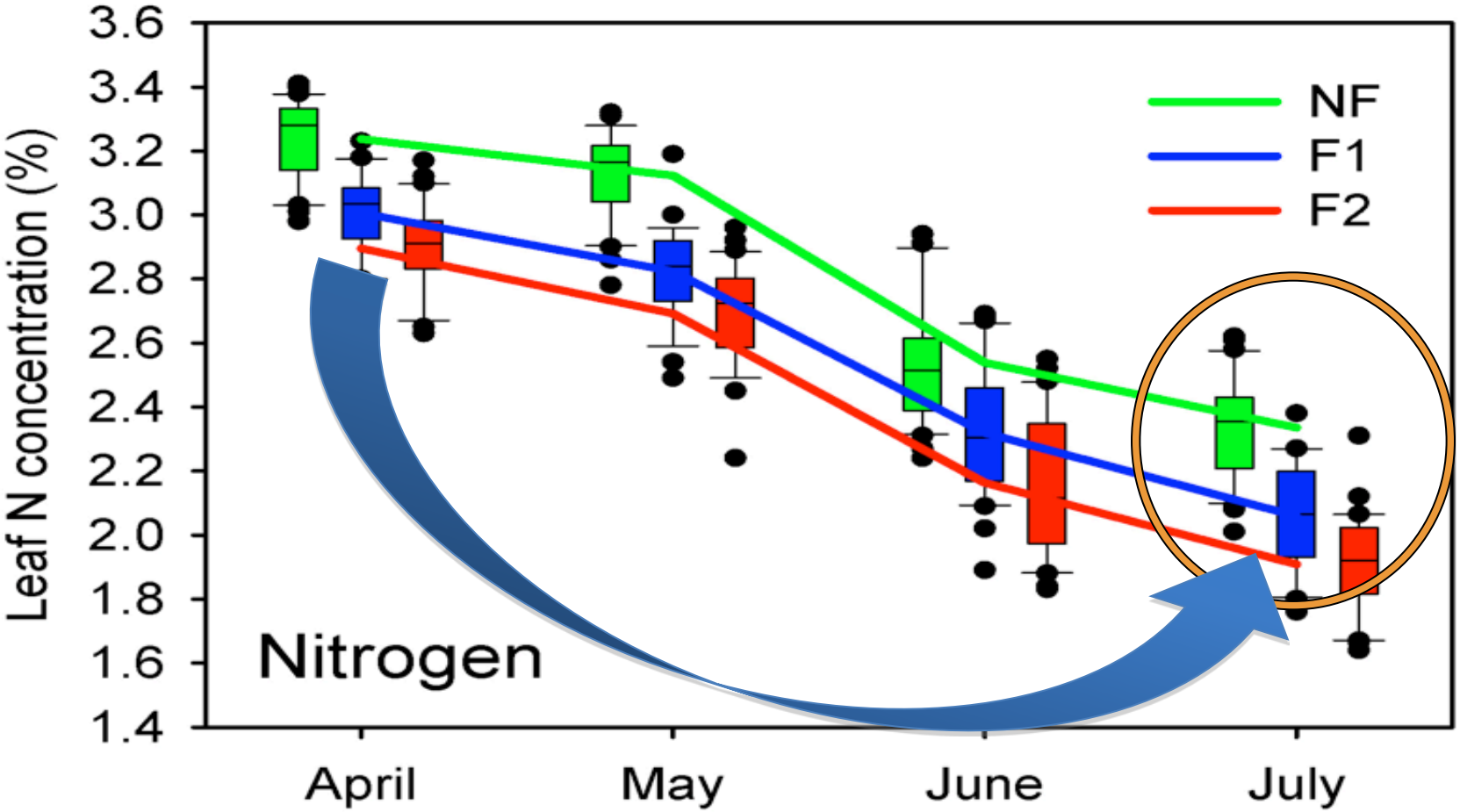
(About 1,130 data points)

- 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 Question

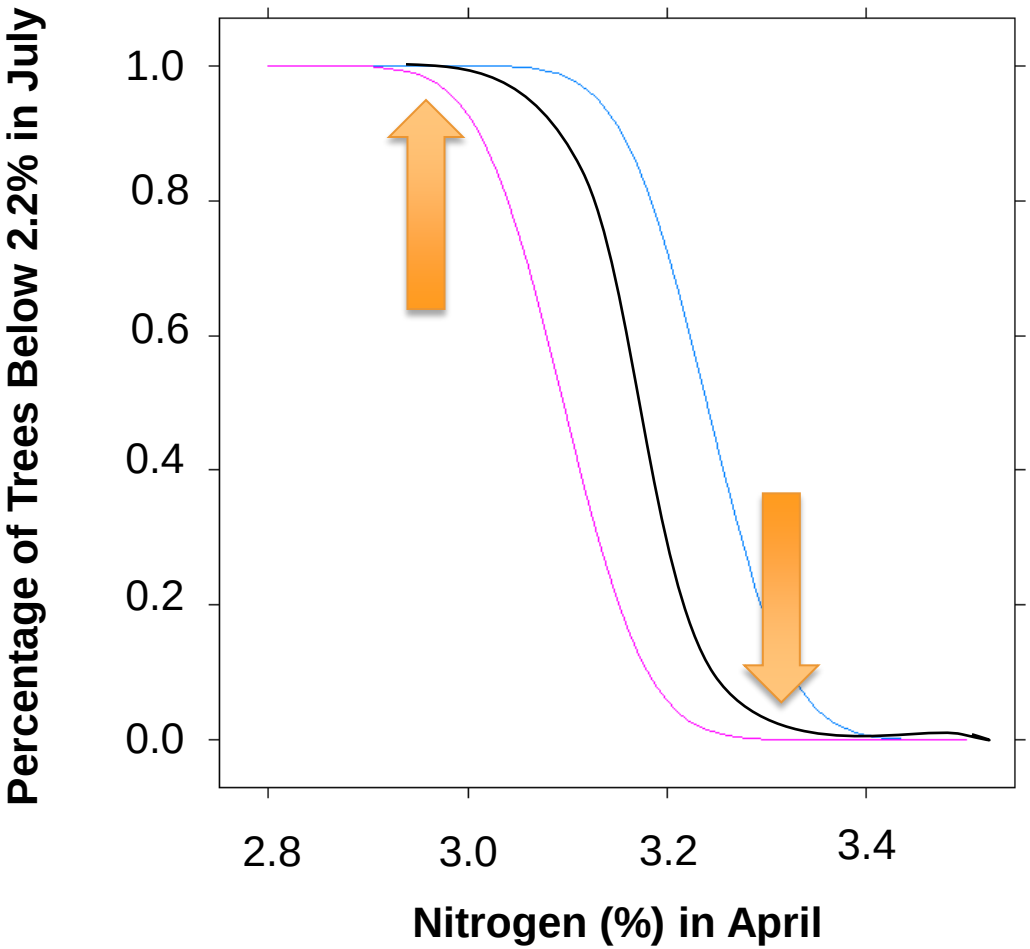
- Model one uses all the April information from F2 spurs to predict the July nitrogen value.
- Model two uses the nitrogen NF information from April to predict the July nitrogen value.
- Both models also predict what percentage of the trees are above or below the current July nitrogen critical value.
- 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

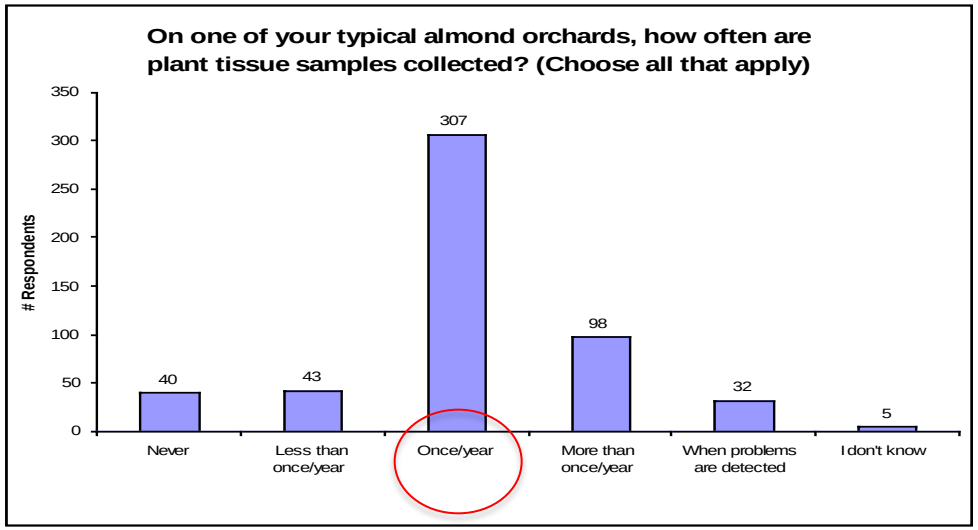


Black Line = predicted
Blue Line = upper CI
Pink Line = Lower CI

Objectives

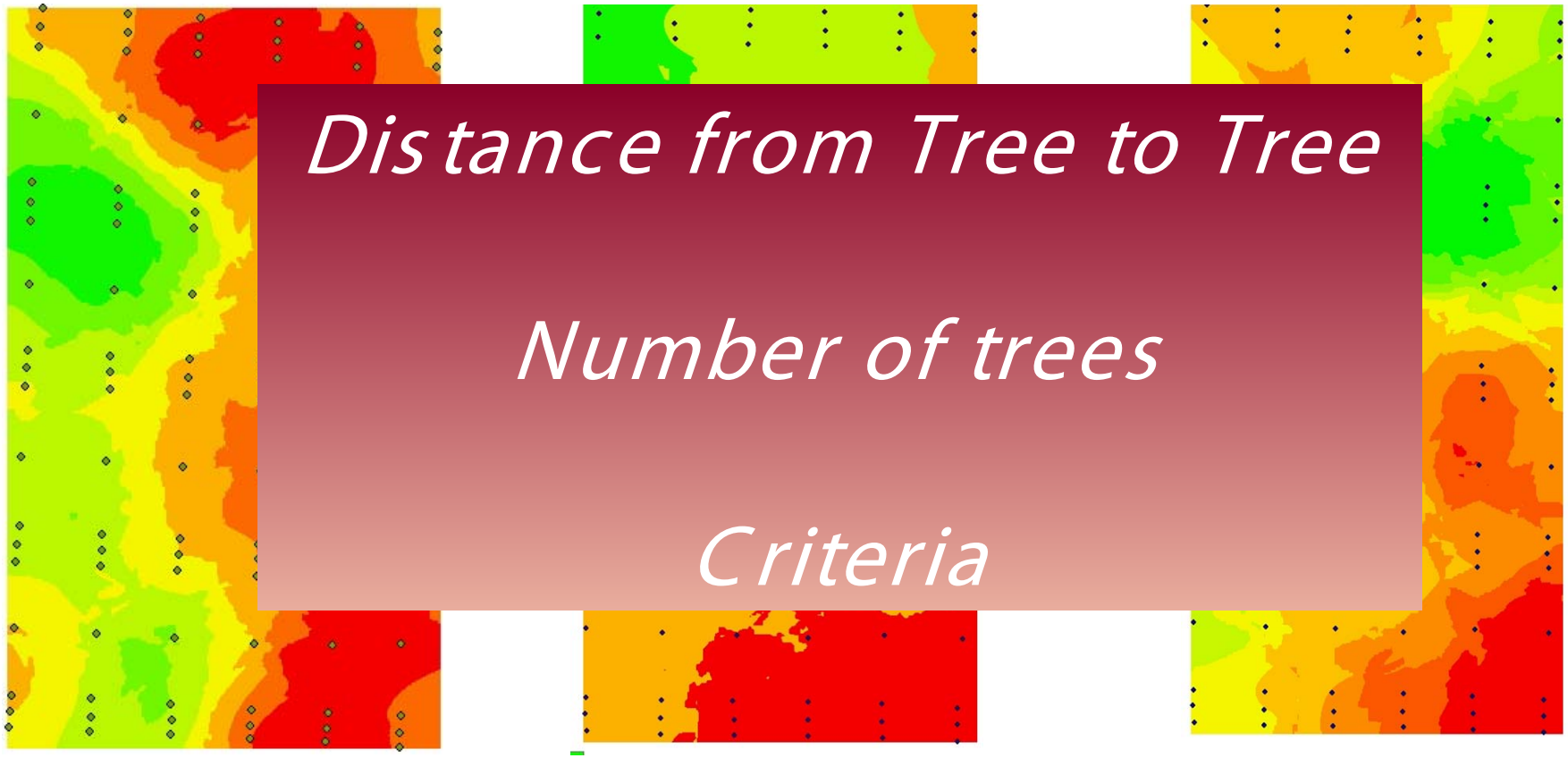
- Develop methods to sample in April and relate that number to July critical value.

- 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?



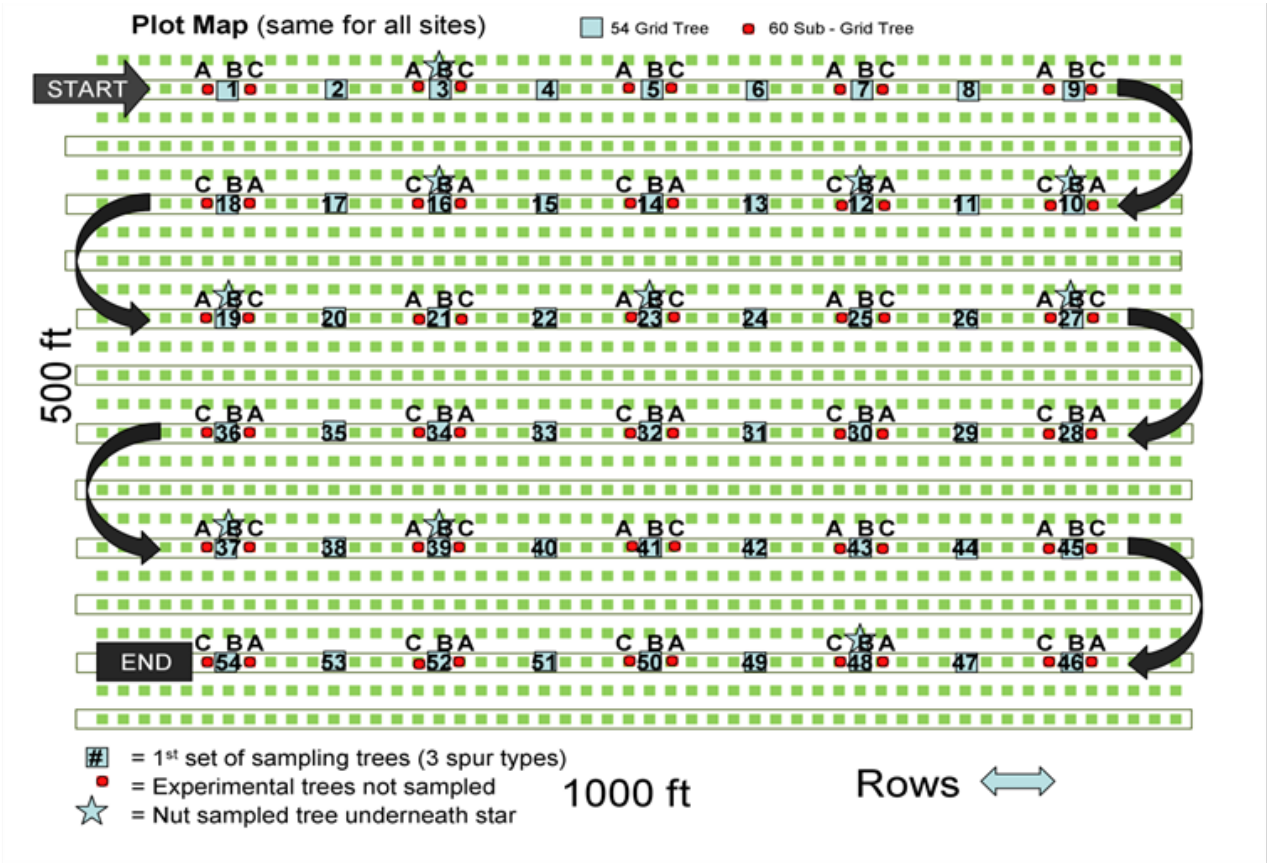
Distance from Tree to Tree

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		

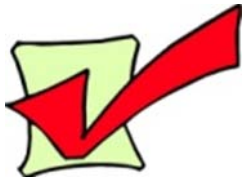
Pooled trees = Number of trees from which leaves must be collected and pooled into a single bag for a single nutrient analysis

Preliminary Sampling Criteria

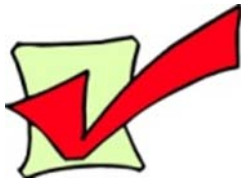
- Collect leaves from 18 to 28 trees in one bag.
- Each tree sampled at least 30 yards apart.
- In each tree collect leaves around the canopy from at least 8 well exposed spurs located between 5-7 feet from the ground.
- In April, collect samples at 8121 GDH +/- 1403 (43 days after full bloom (DAFB)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



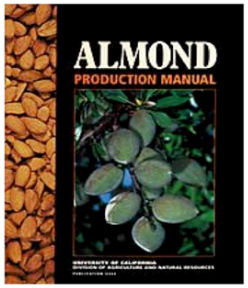
- Reevaluate the current CV's ➔ integrate with nutrient budget approach described in the next talk.

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.

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.

Conclusions: In The Present

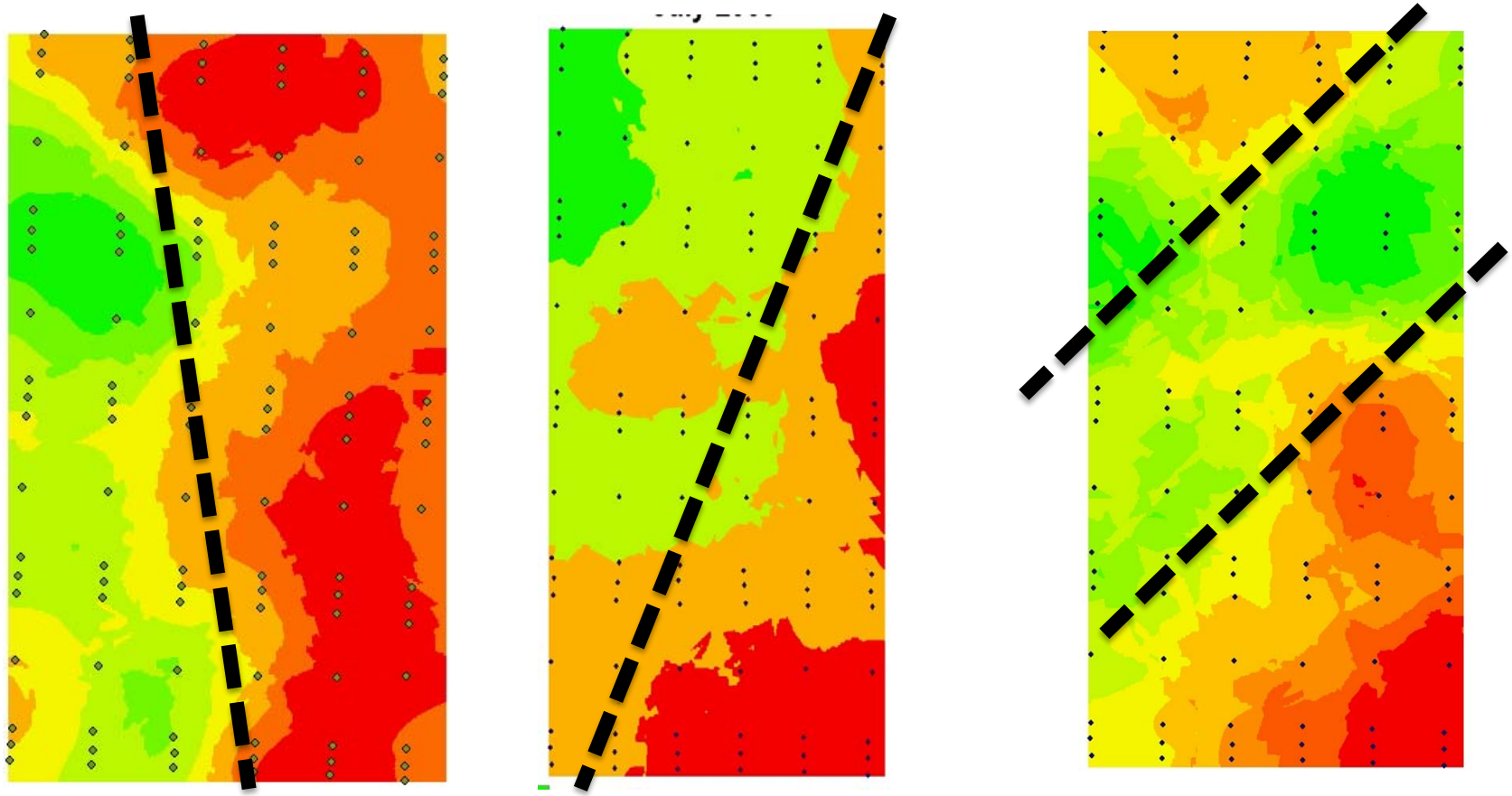
- We have developed two models to predict July Nitrogen concentration using April data.
- Both models measure orchard variability and calculate the percentage of the trees that will be above or below the current July critical value.
- In other words, both models can provide the information needed to 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 (Patrick Brown), UC Davis

growing ADVANTAGE
The Almond Conference

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.

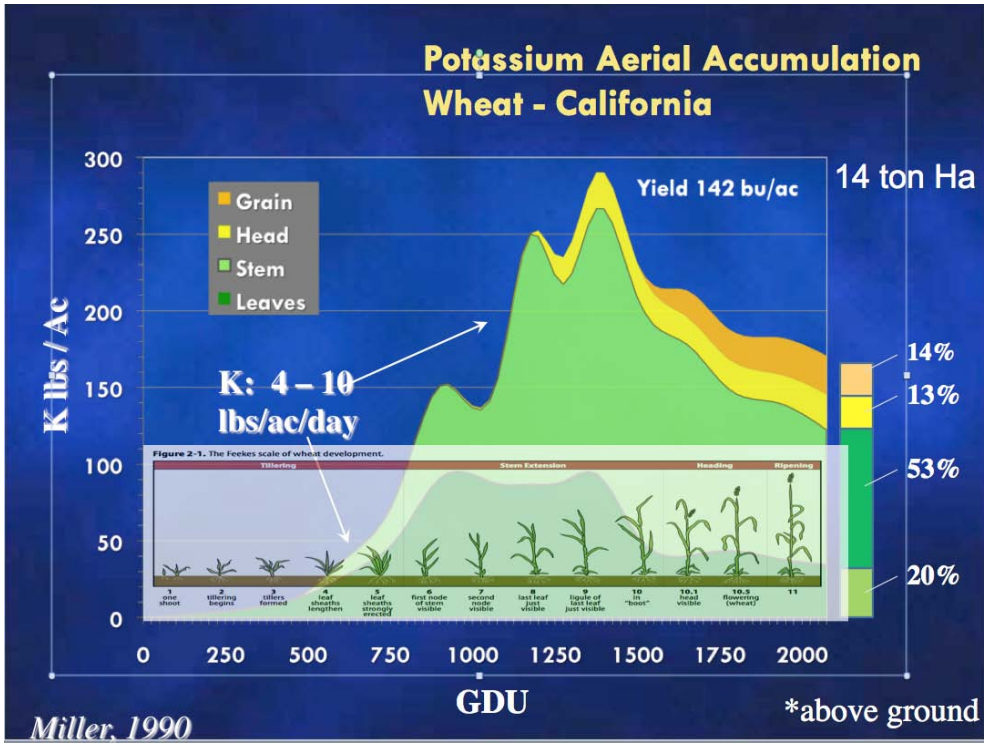
Using the Right Source

- Maximize uptake minimize loss potential.

Determining the Right Rate

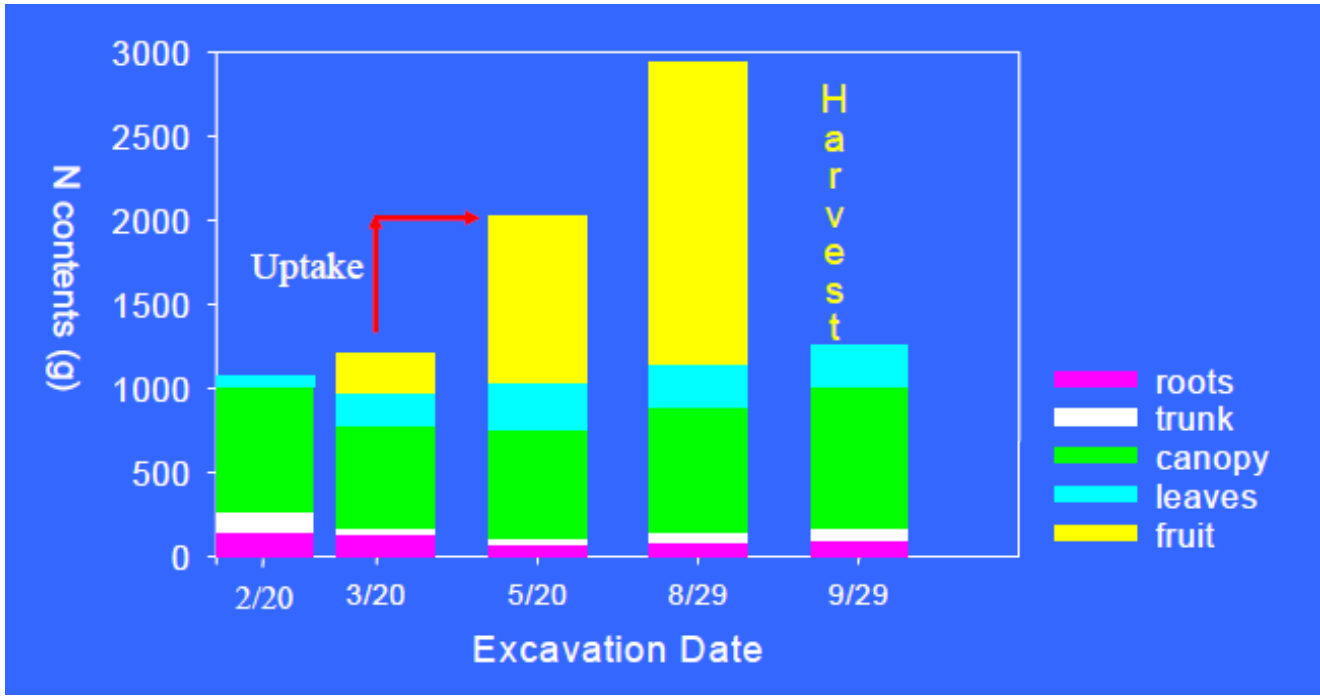
Nutrient Budget Approach

- Knowledge of growth and development to develop nutrient demand curves
- Knowledge of nutrient 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

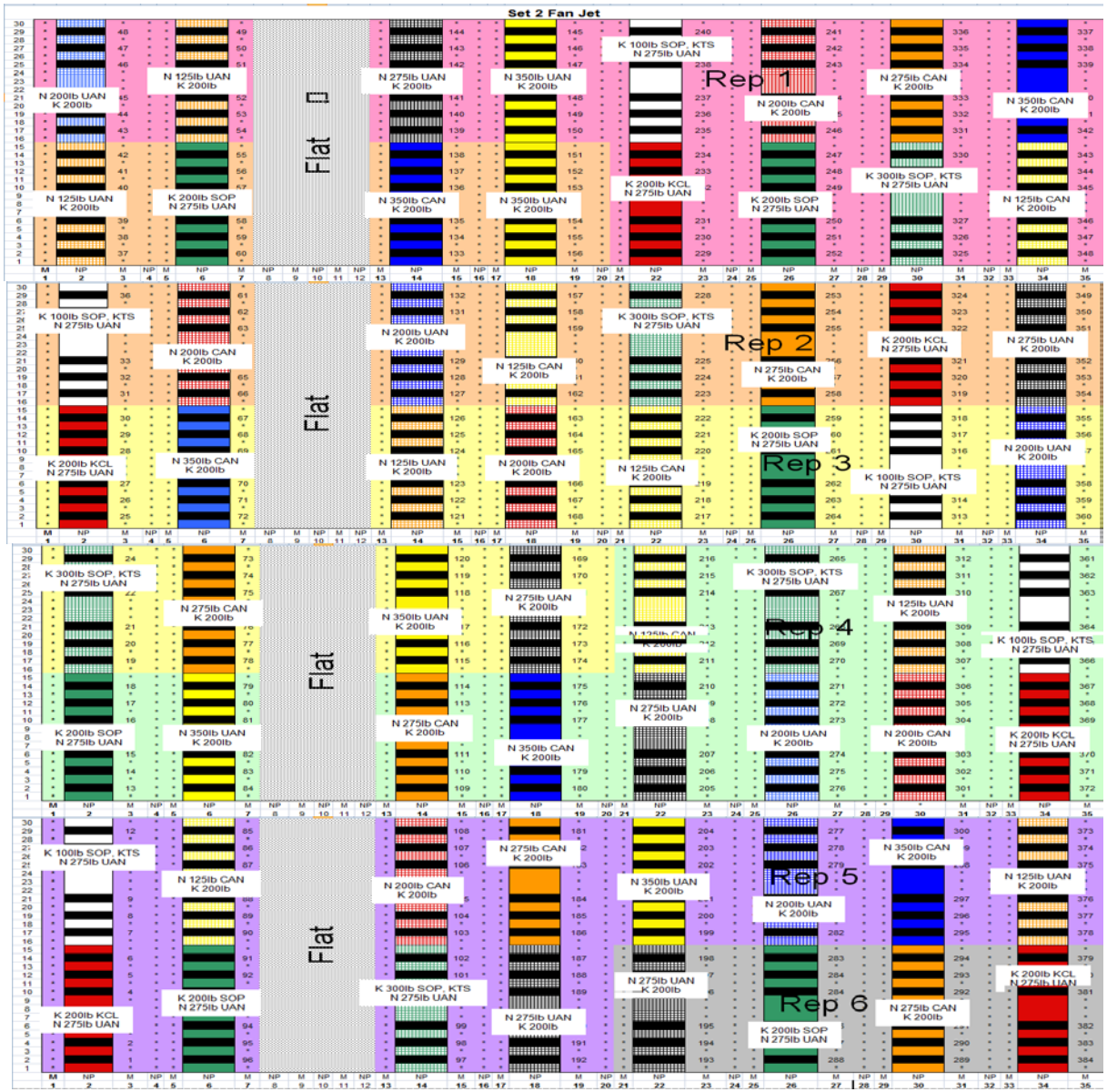
Fertigation

- 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.

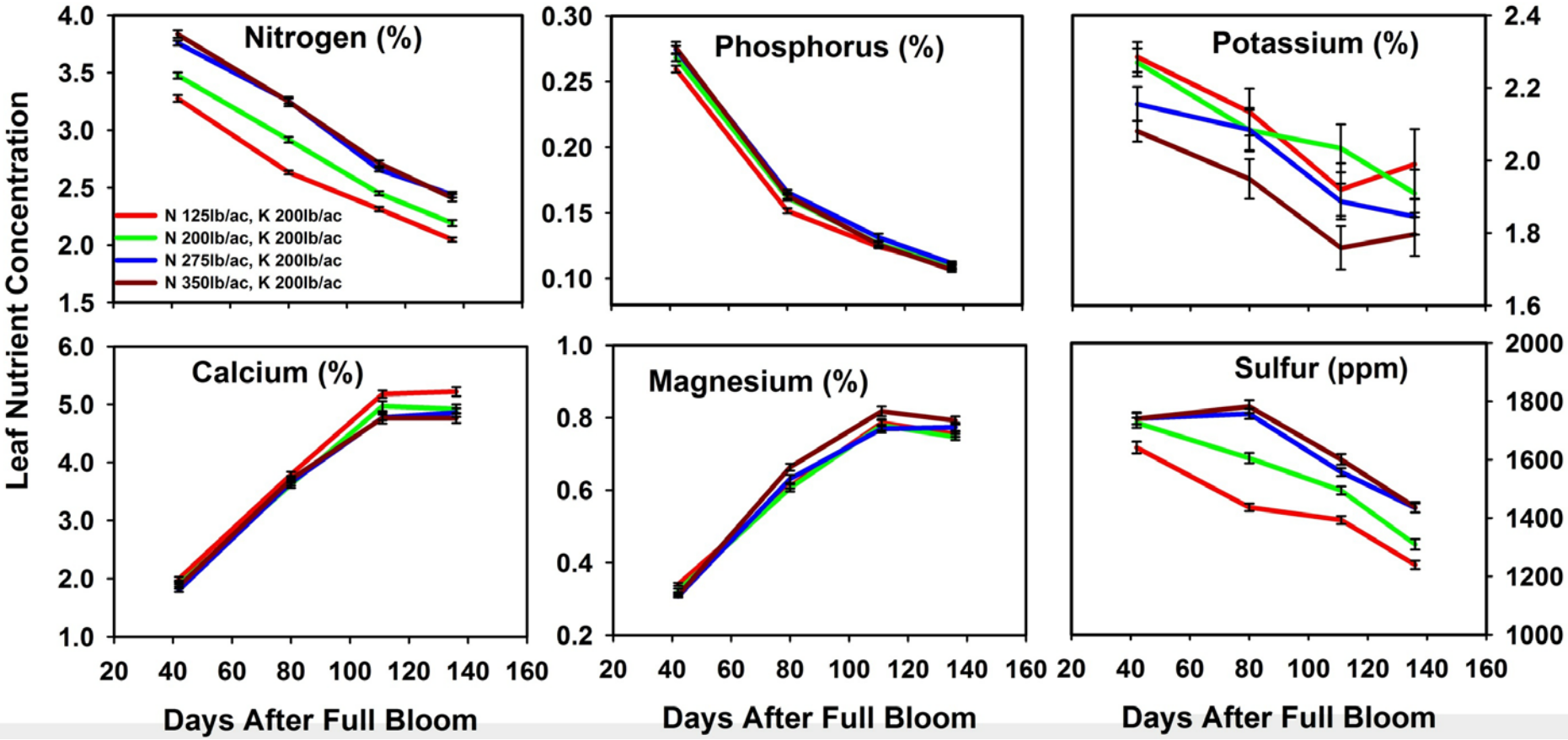
768 trees individually monitored for nutrients, yield, light interception, disease, water.

Trees were 9 leaf in 2008.

Nonpareil - Monterey

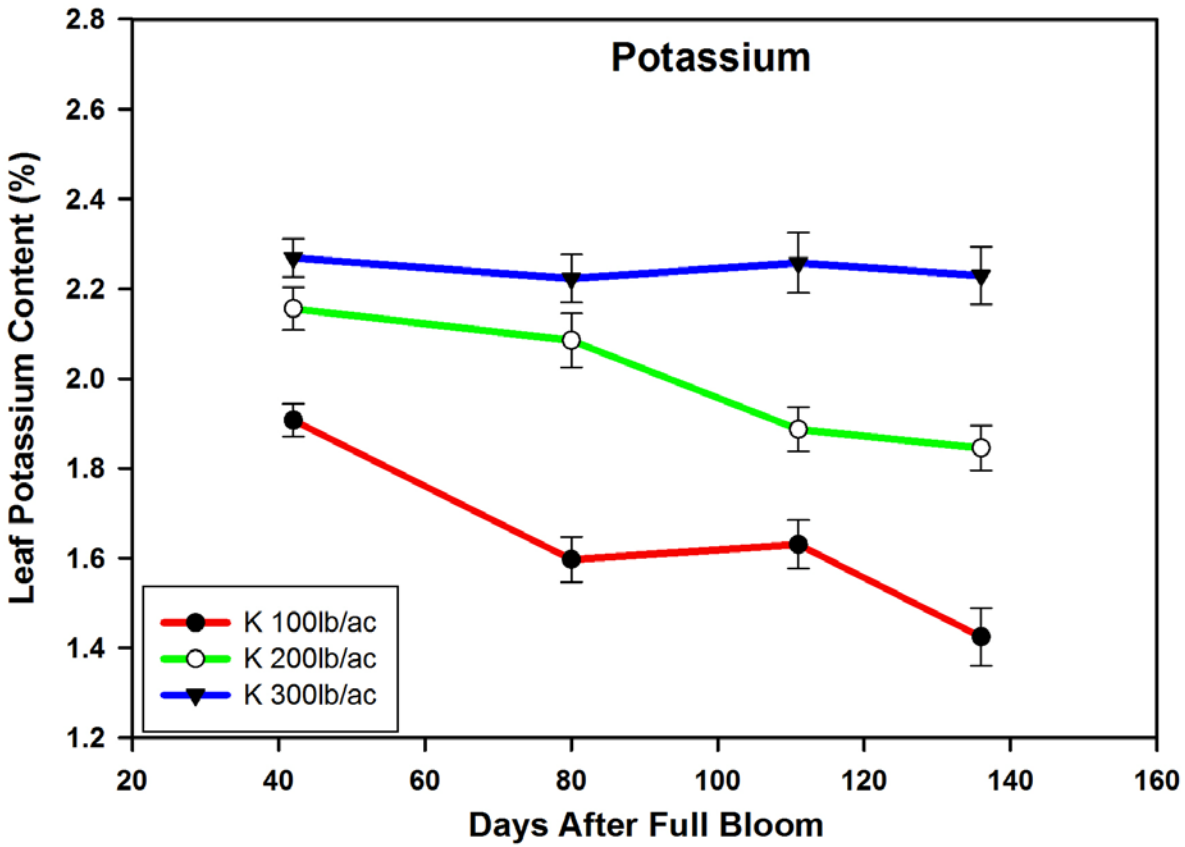
Preliminary Findings

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

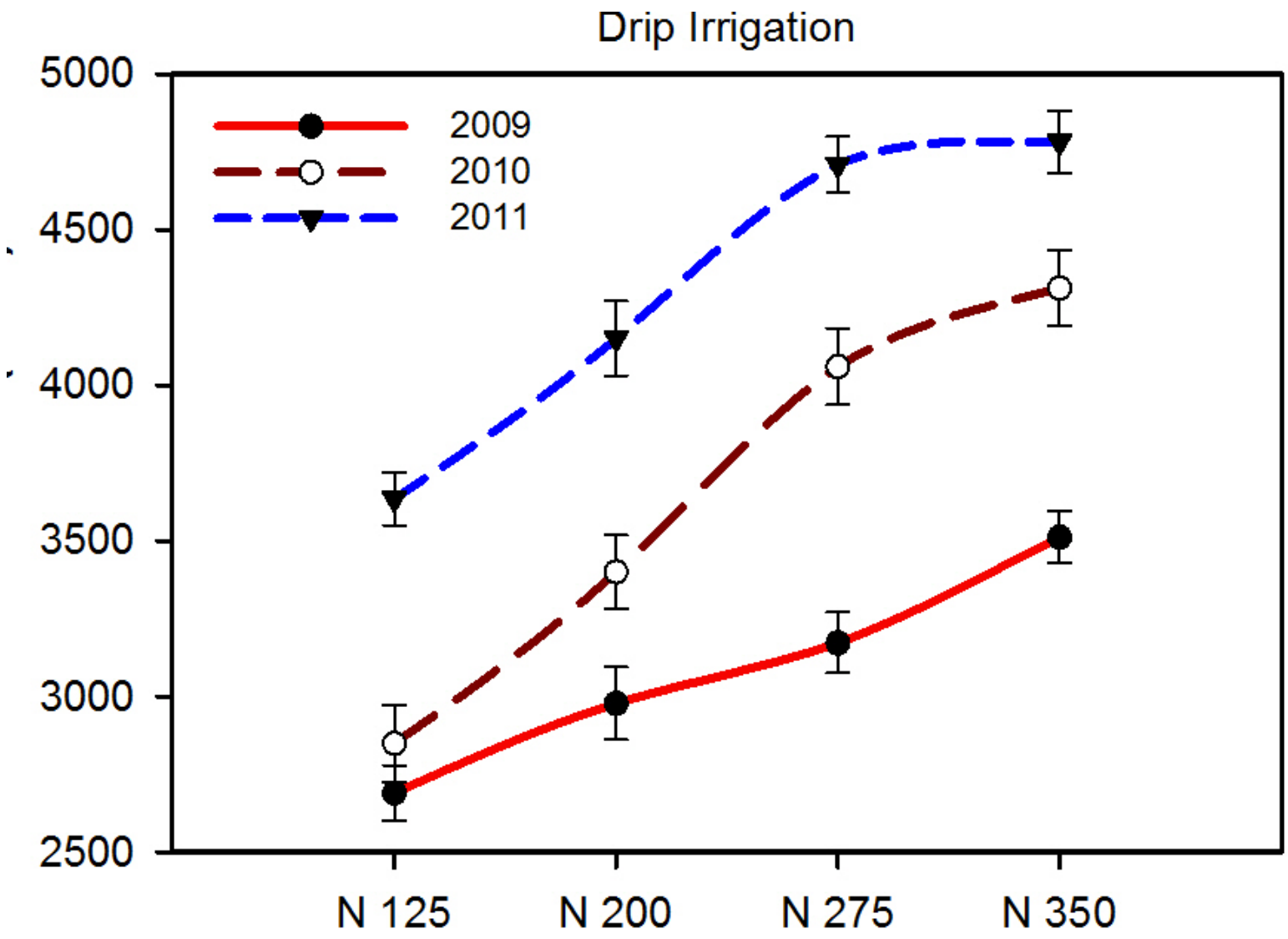
Irrigation	N UAN 32				N CAN 17			
	125	200	275	350	125	200	275	350
Drip	2,865	3,453	3,765	4,064	2,622	3,313	3,960	3,728
	c	b	ab	a	c	bc	ab	a
Fan Jet	2,584	3,109	3,481	3,583	2,730	3,046	3,810	3,530
	c	b	b	a	d	c	a	b

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



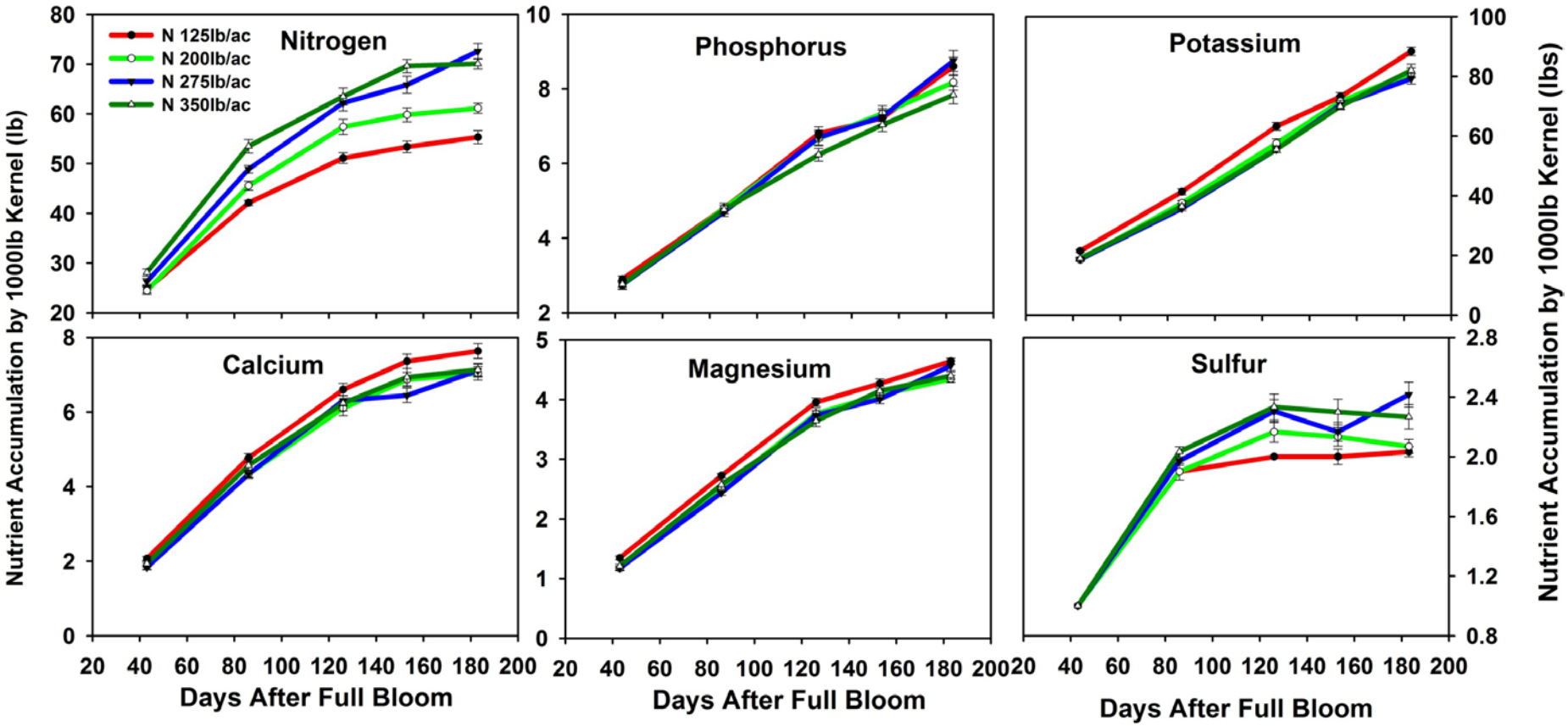
Cumulative Kernel Yield 2009-11

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



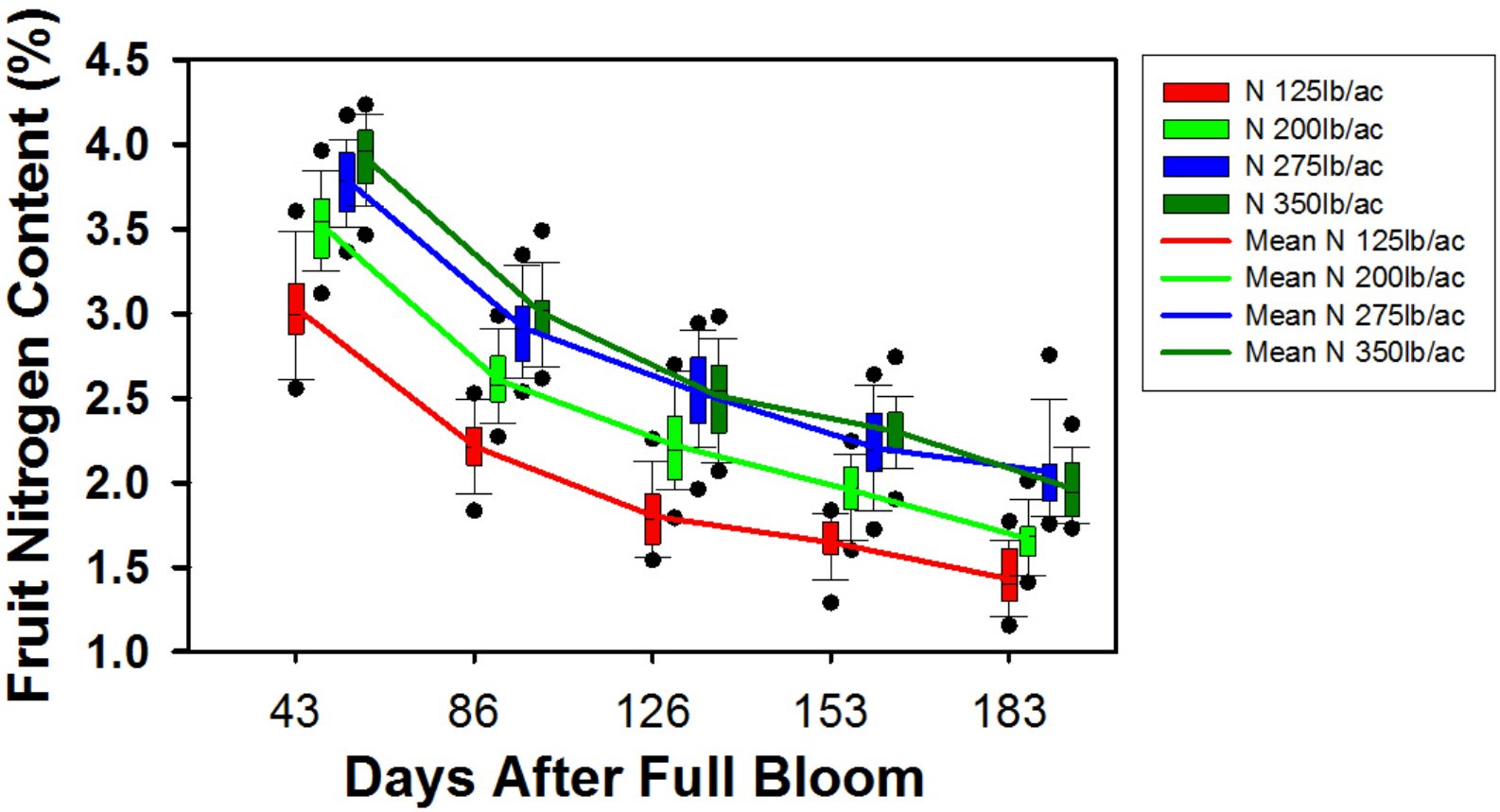
NPK Export By 1000lb Kernel At Harvest 2009-10

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

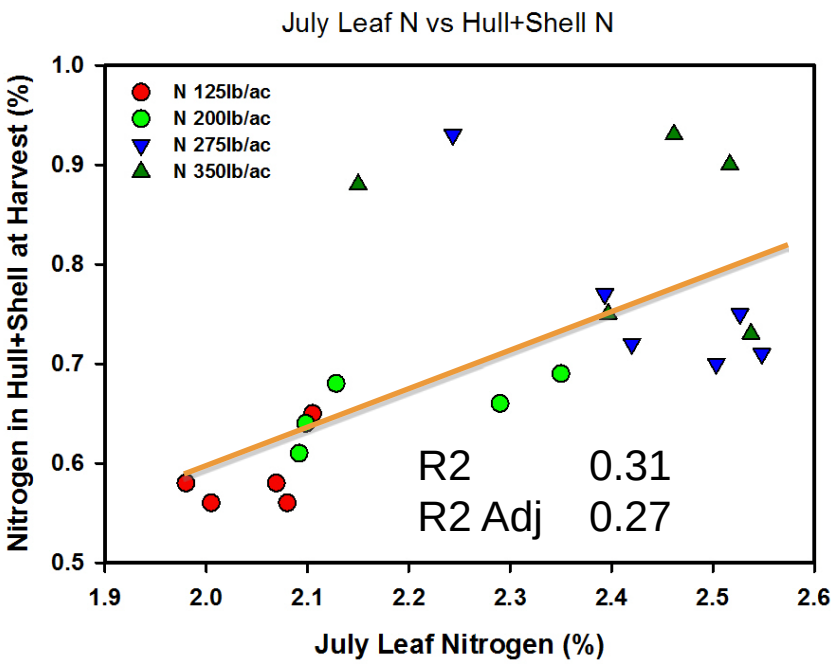
Nutrient	2009				2010			
	Nitrogen Rate (lb/ac)				Nitrogen Rate (lb/ac)			
	125	200	275	350	125	200	275	350
N	53	56	58	59	55	61	73	70
	b	ab	a	a	c	b	a	a
P	7.5	7.4	7.2	6.7	8.6	8.2	8.9	7.8
	a	a	ab	b	ab	ab	a	b
K	75	73	73	72	88	81	80	82
					ab	b	b	b

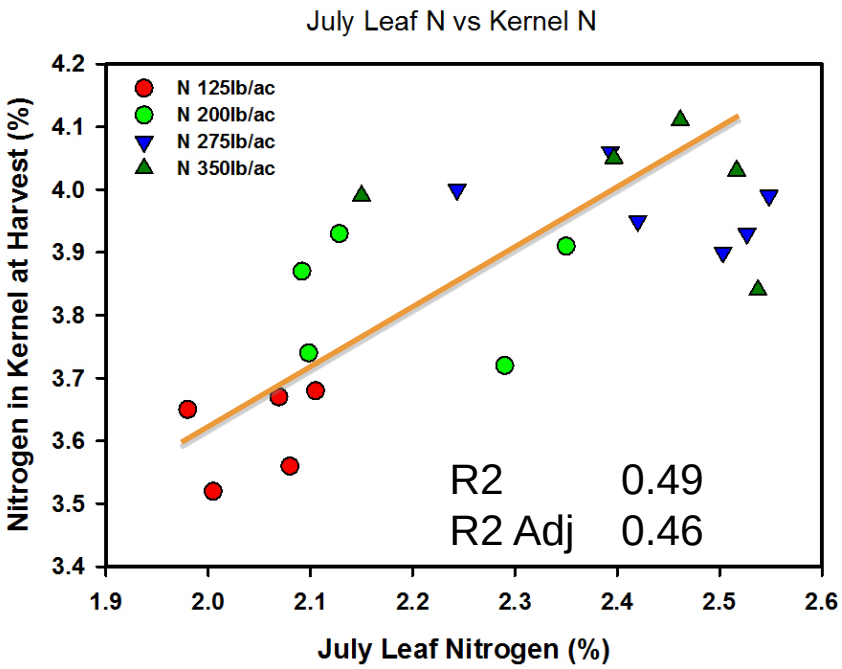
Means not followed by the same letter are significantly different at 10%.

Nitrogen Fertilization And Fruit N Content (2010)



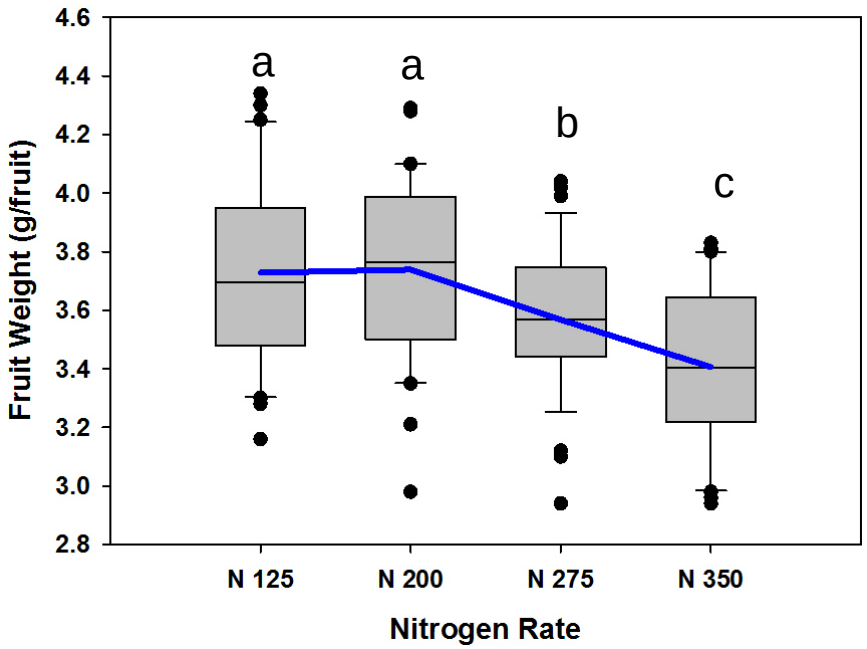
July Leaf N And Hull+Shell And Kernel N at harvest



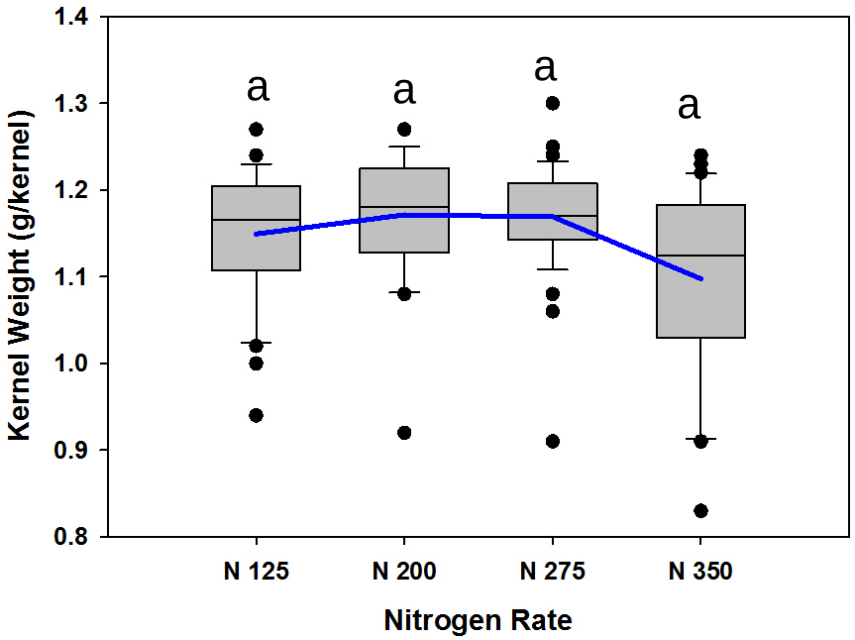


Fruit and Kernel weight

Fruit weight (gram/fruit)



Kernel weight (gram/kernel)



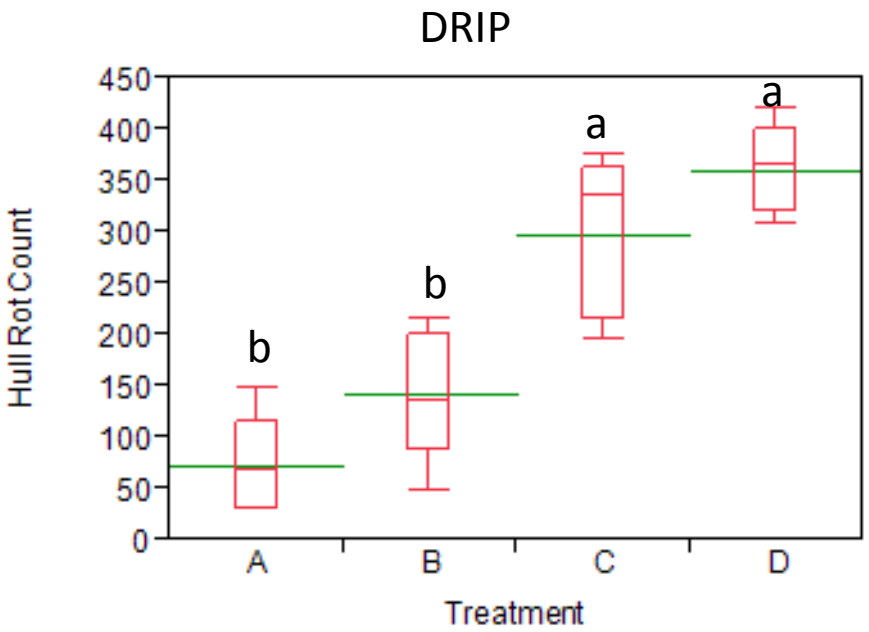
N Fertilization increases Shelling Percentage

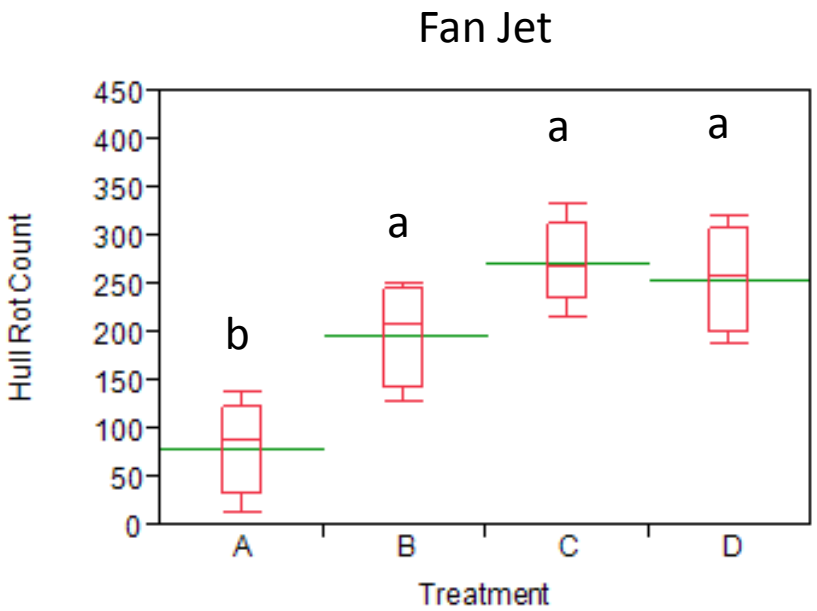
Shelling Percentage (%)

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

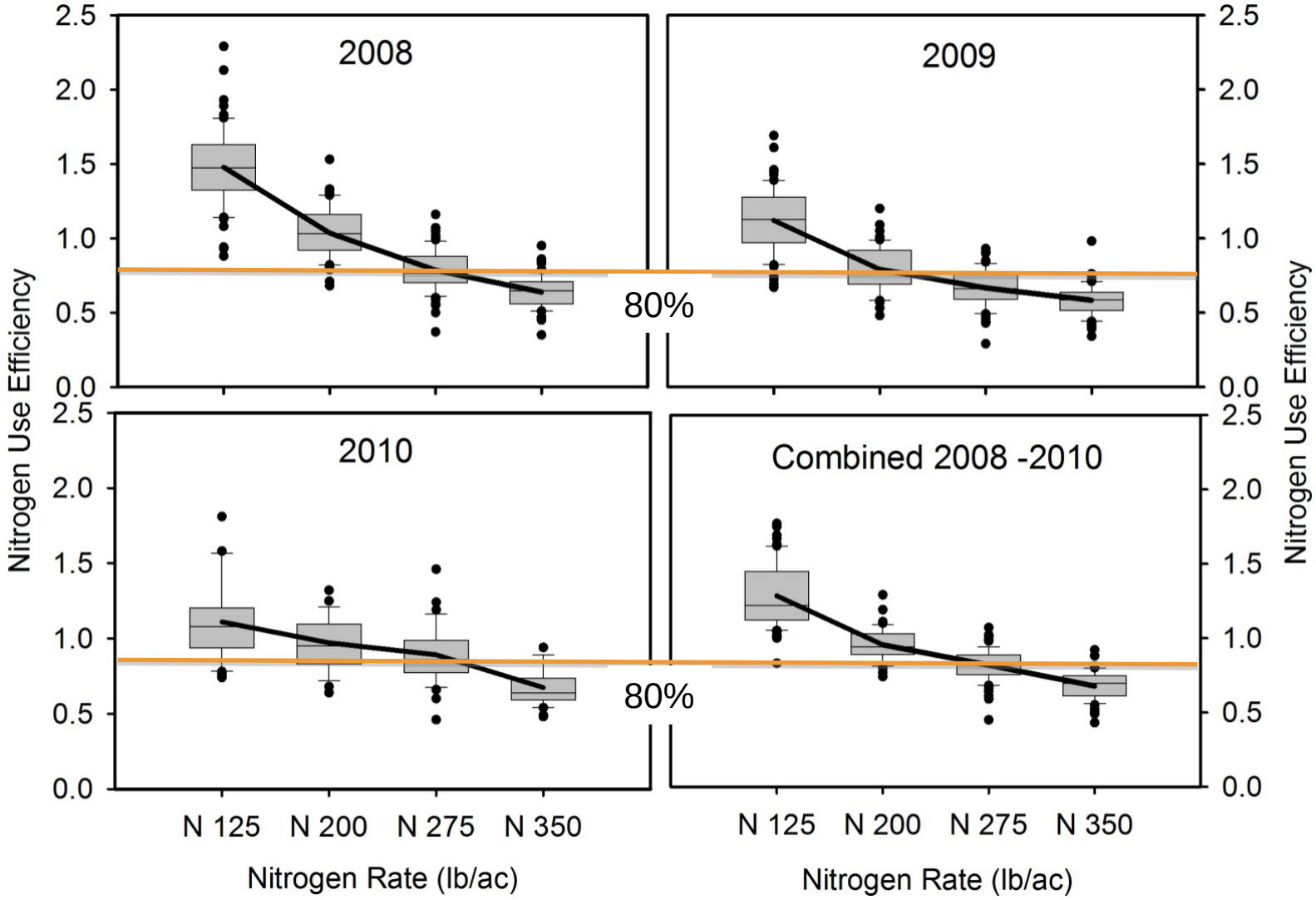
Effect Of N Fertilization On Hull Rot





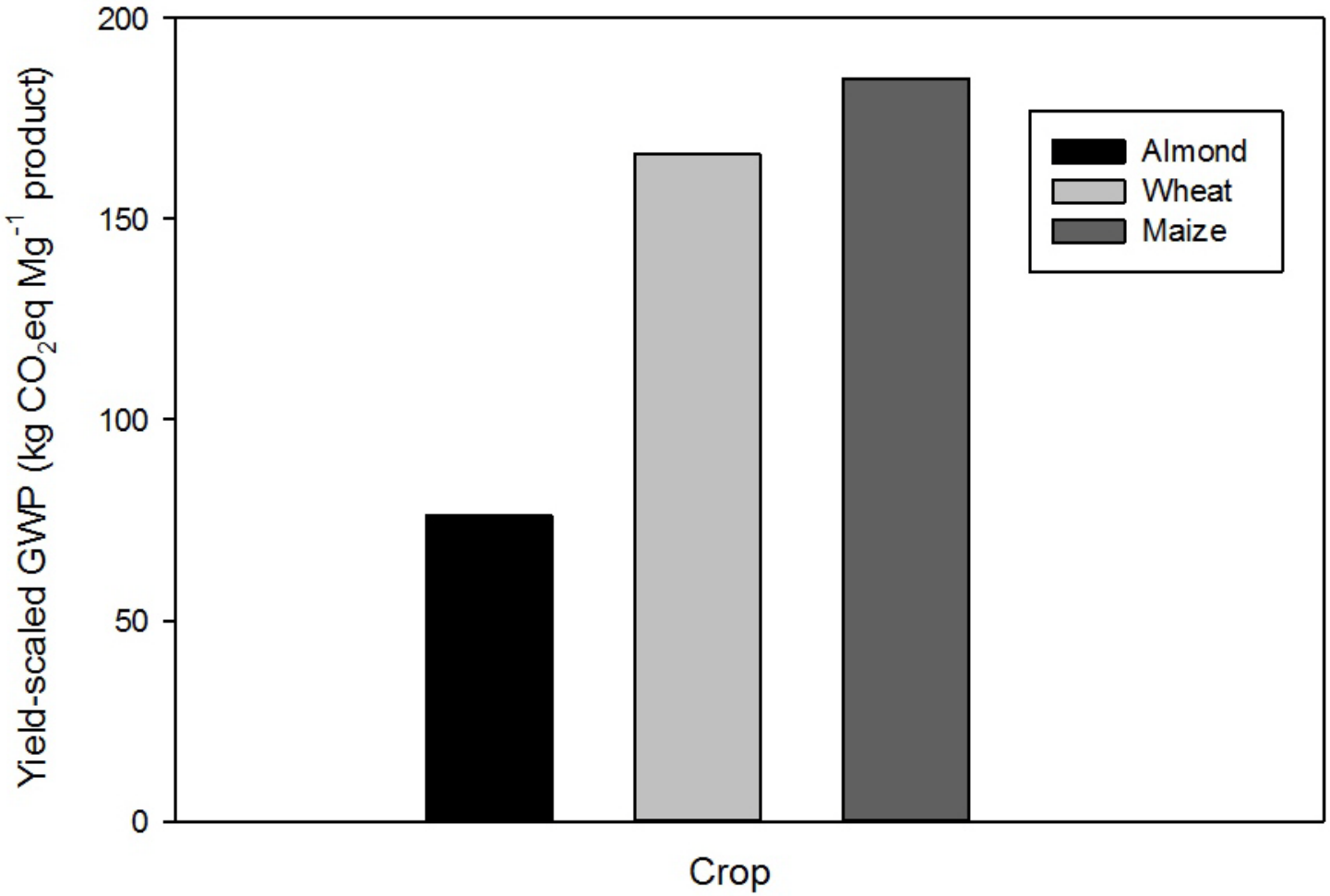
Treatments
A= N 125lb/ac
B= N 200lb/ac
C= N 275lb/ac
D= N 350lb/ac

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, however; no statistically significant differences in yield have been observed

Conclusions

In this orchard we have approached 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 (next step)

Apply N coincident with tree demand (see Brown and Hopmans posters)

Keep fertilizer N in the root zone (see Sanden, Brown and Hopmans posters)

Manage variability (next step)

Monitor for soil and plant accumulation (see Brown poster)

Thank You

Poster Session 2 and Coffee Break: Dedicated Trade Show

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Plant Nutrition Management in an Age of Expenses and Regulations (Part 2)

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Plant Nutrition Management in an Age of Expenses and Regulations (Part 2)

Moderator: Bob Curtis, ABC
Gabriele Ludwig, ABC

Presenters:

Blake Sanden, UC Cooperative Extension

Jan Hopmans, UC Davis

Will Horwath, UC Davis

Almond Irrigation: Strategies & Alternatives

Blake Sanden – Irrigation Advisor, Kern County
http://cekern.ucdavis.edu/Irrigation_Management/

ESSENTIAL Water/Fertigation for Almonds

1 : something basic <the essentials of astronomy>

2 : something necessary, indispensable, or unavoidable (Merriam-Websters Dictionary)

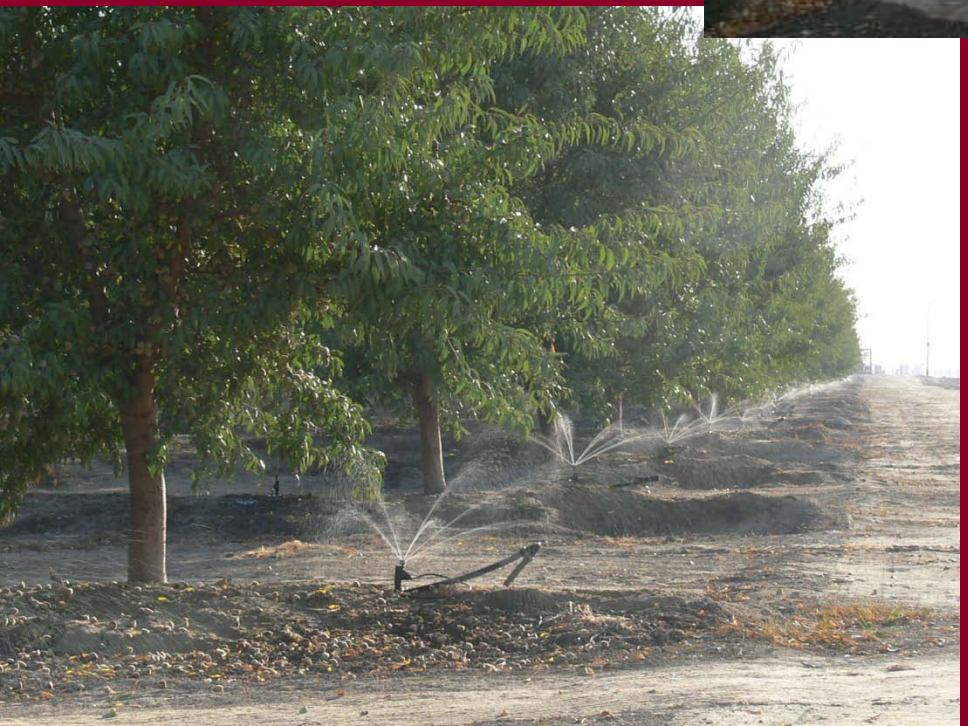
3 : making 4,000 lb/ac nut meats!

(Westside almond growers)


"Essential" is just the basics, right? So can flood irrigation with 8 inch alfalfa valves @ 200 gpm be optimal?


What about 18 inch valves
@ 2000 gpm?

Micro-irrigation system capable of injecting fertilizer and applying 0.6 to 1.5 inches/day




... or do you need this kind of
system ...

… and this much technology?

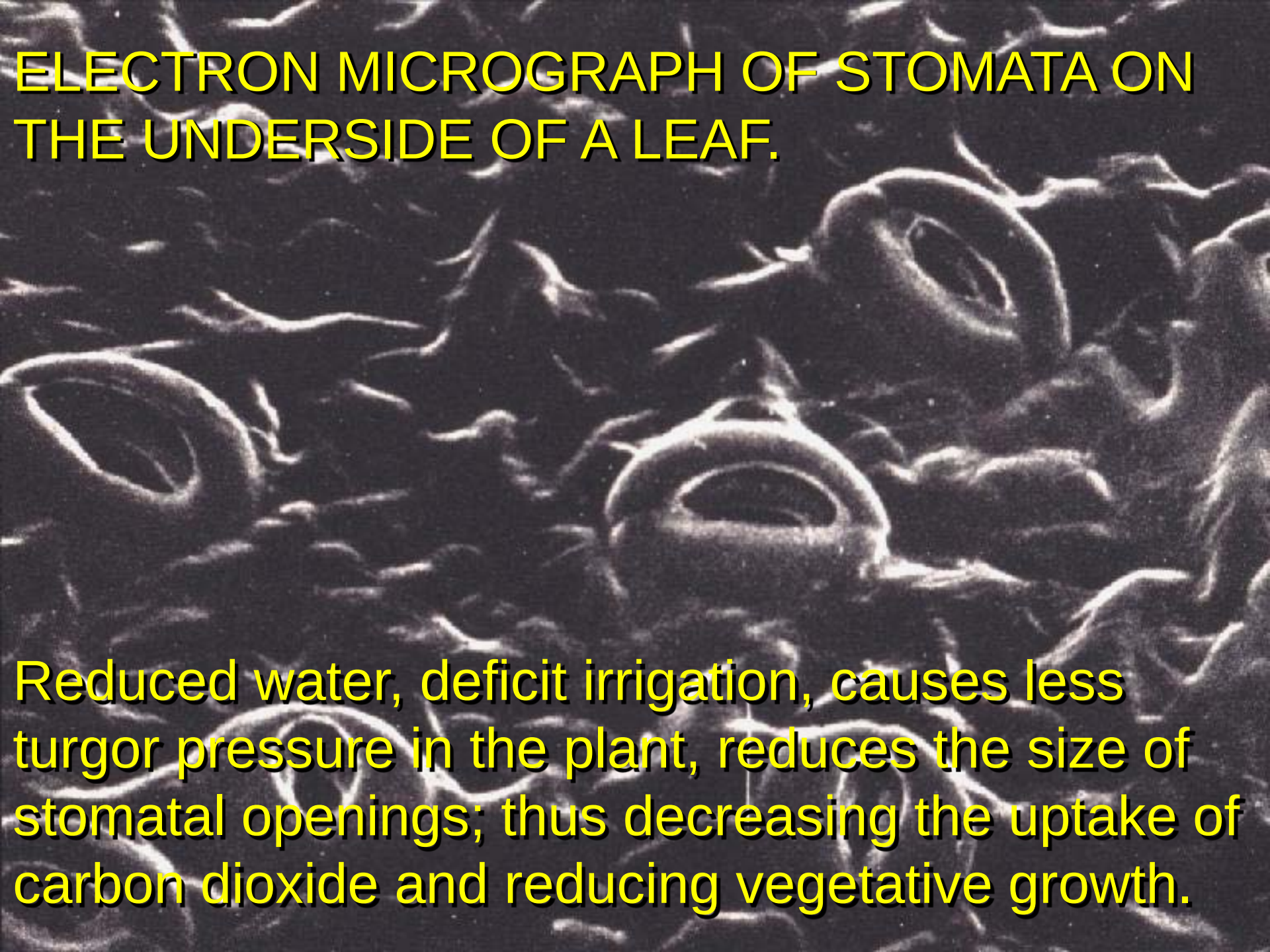
YES ...

NO ...

DEPENDS.

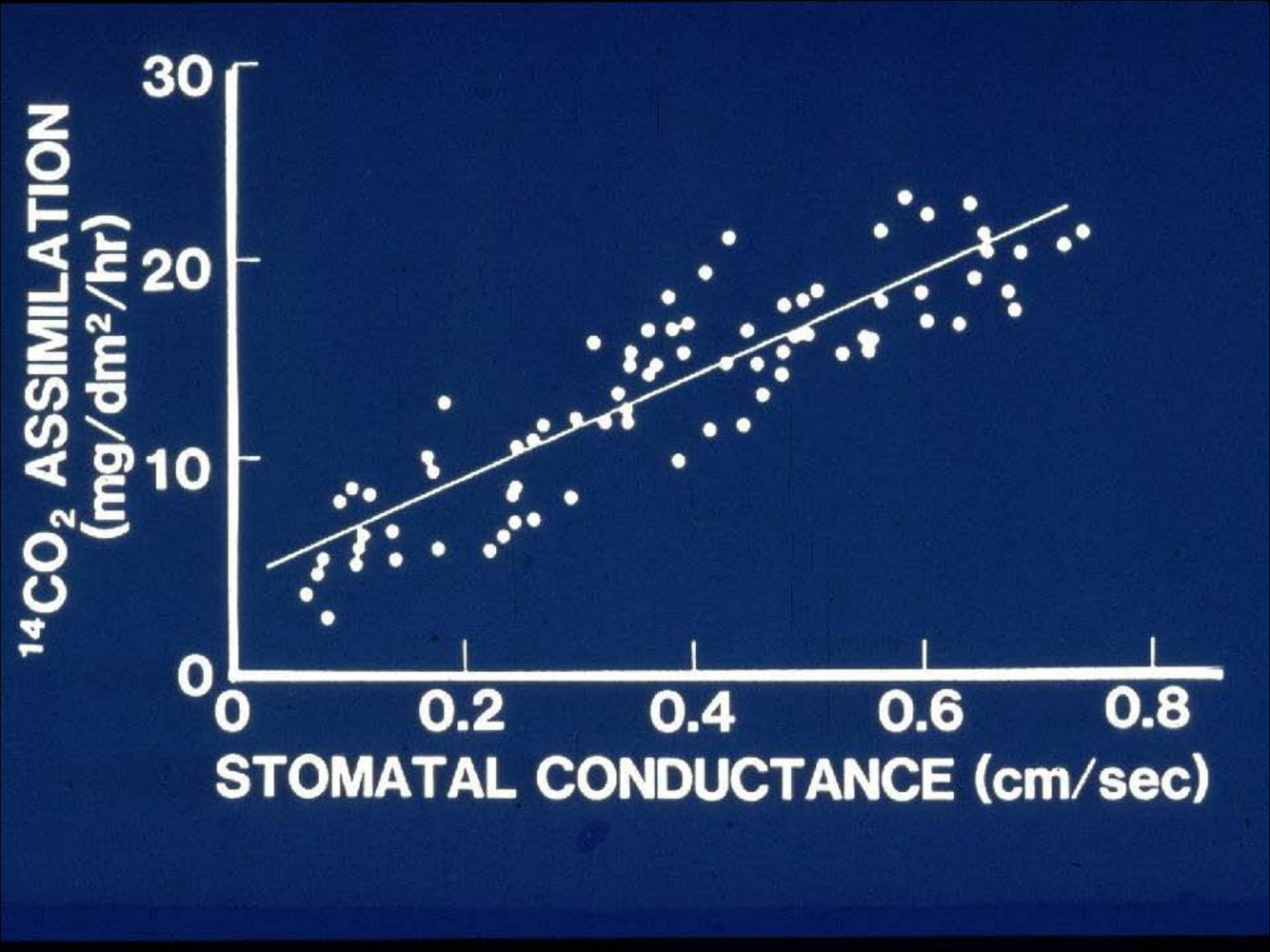
What’s the critical process that keeps the crop growing?

- Optimal photosynthesis
- Maximum carbon dioxide uptake



ELECTRON MICROGRAPH OF STOMATA ON THE UNDERSIDE OF A LEAF.

Reduced water, deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing the uptake of carbon dioxide and reducing vegetative growth.

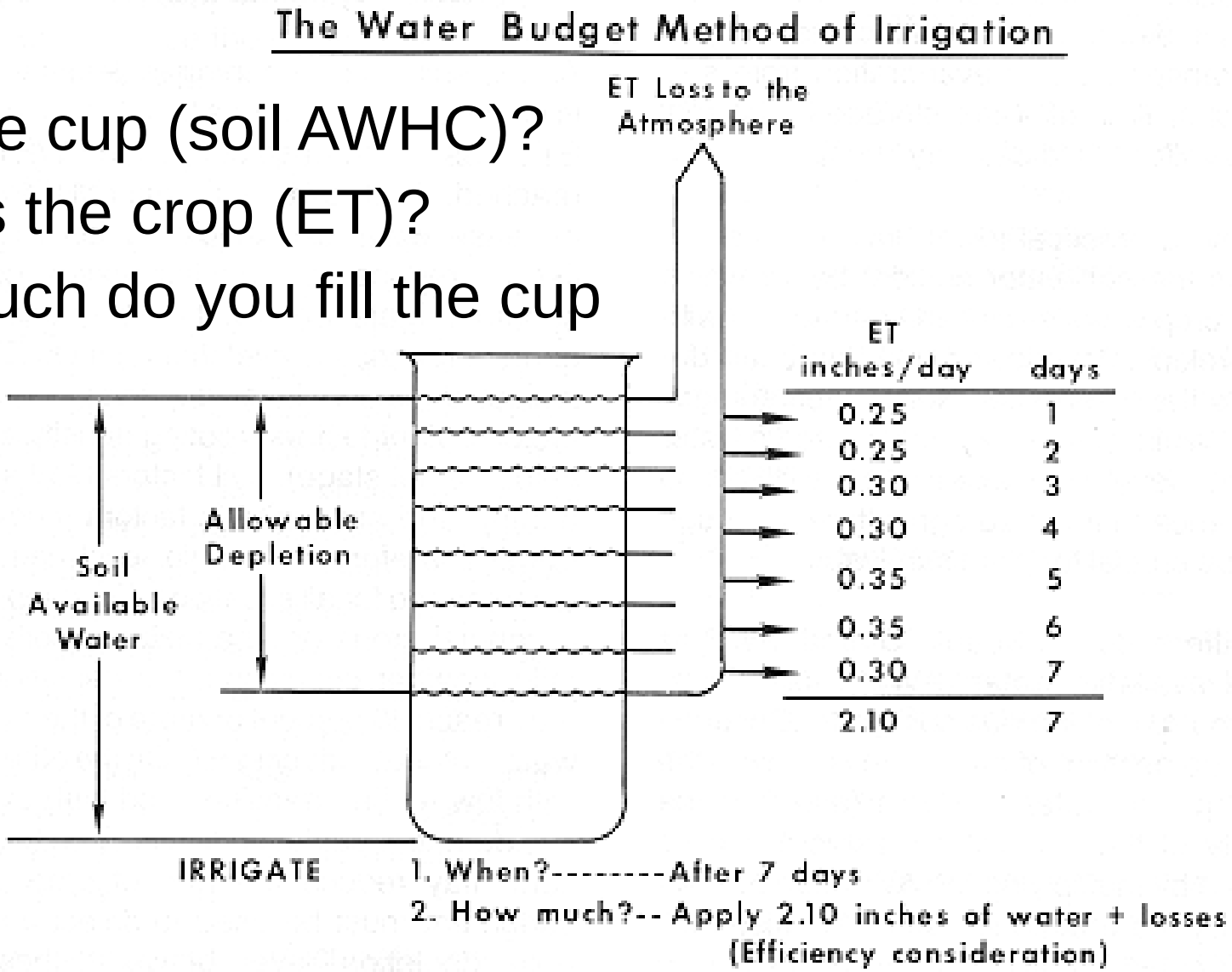

$^{14}CO_2$ ASSIMILATION
(mg/dm²/hr)
30
20
10
0
0
0.2
0.4
0.6
0.8
STOMATAL CONDUCTANCE (cm/sec)

~~4~~ 3-point sermon:

- Understanding soil water holding characteristics, irrigation system characteristics & monitoring
- Crop water requirements (ET), CIMIS
- ~~Fertigation options (just a teaser)~~
- Irrigation & crop salinity tolerance

Creating The Efficient Field Water Balance – Your Soil Moisture Checking Account!

- How big is the cup (soil AWHC)?
- How thirsty is the crop (ET)?
- How often/much do you fill the cup (Scheduling)?



The “dirt” is the thing. Know your soil!

IDEAL: deep, well drained, non-alkali sandy to sandy clay loam

Soil Texture Determines Available Water Holding Capacity

SOIL TEXTURE
"FEEL METHOD"

$$\text{AWHC} = \%\text{Volume} = \frac{\text{inch depth of water}}{\text{1 foot depth of soil}}$$

The Soil & Irrigation System Are The "ESSENTIAL" Integrating Factors For Creating An Optimal Water Balance.

California crops sit most firmly on a chair with 4 legs!

Crop

LIFE CYCLE & WATER USE (ET)
ROOTING CHARACTERISTICS
DESIRED STRUCTURE / SPACING
HARVEST REQUIREMENTS
FIELD TRAFFIC

Water

SOURCE / SUPPLY
SALTS / QUALITY
REQUIRED AMENDMENTS
COST

System

IRRIGATION METHOD
DISTRIBUTION PATTERN
IRRIGATION FREQUENCY
MONITORING
MAINTENANCE / REPAIR
OPERATING COST
CAPITAL COST

Soil

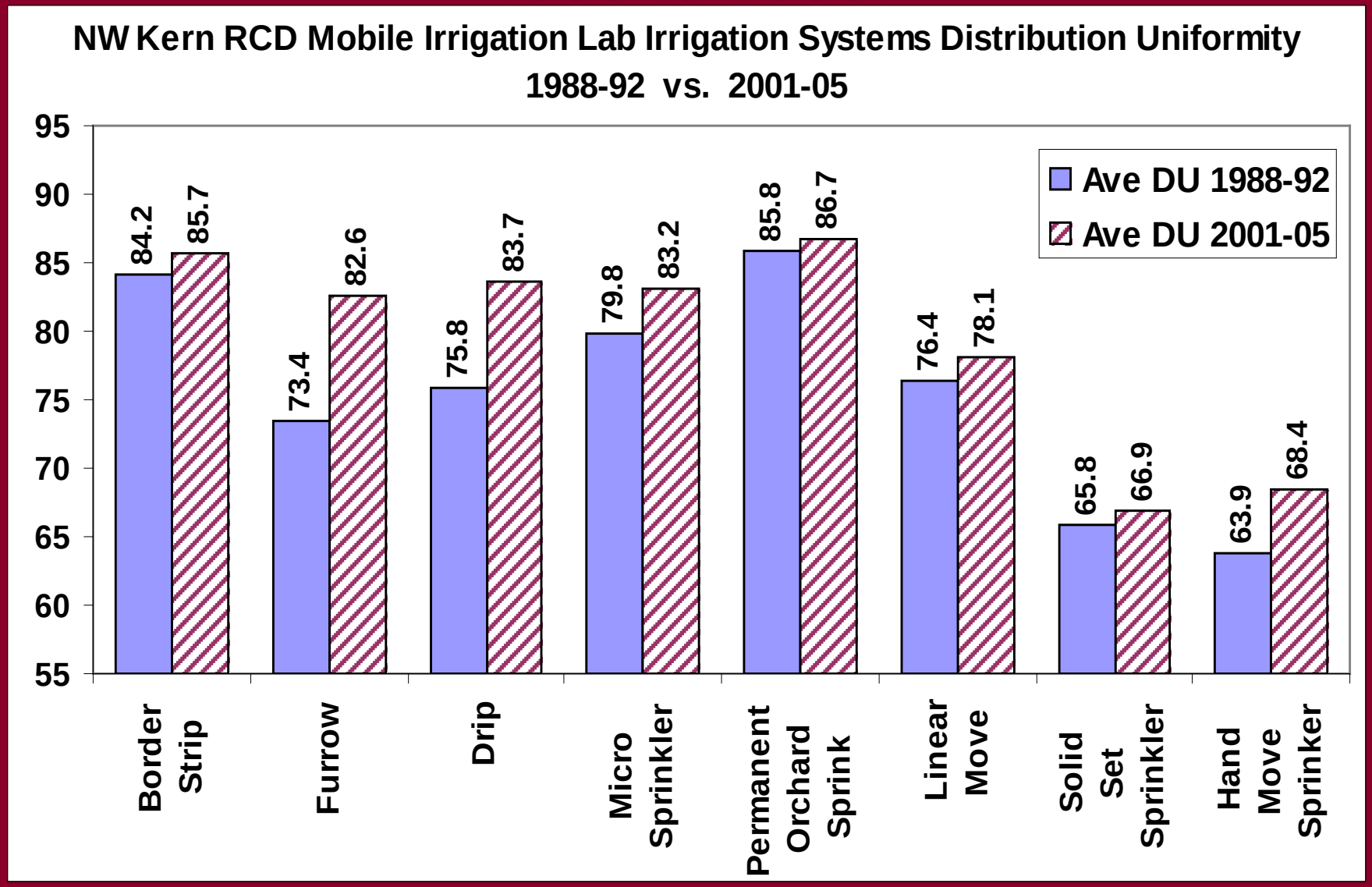
TOPOGRAPHY
TEXTURE
INFILTRATION RATE
DRAINAGE
SALTS / QUALITY
AMENDMENTS / COST

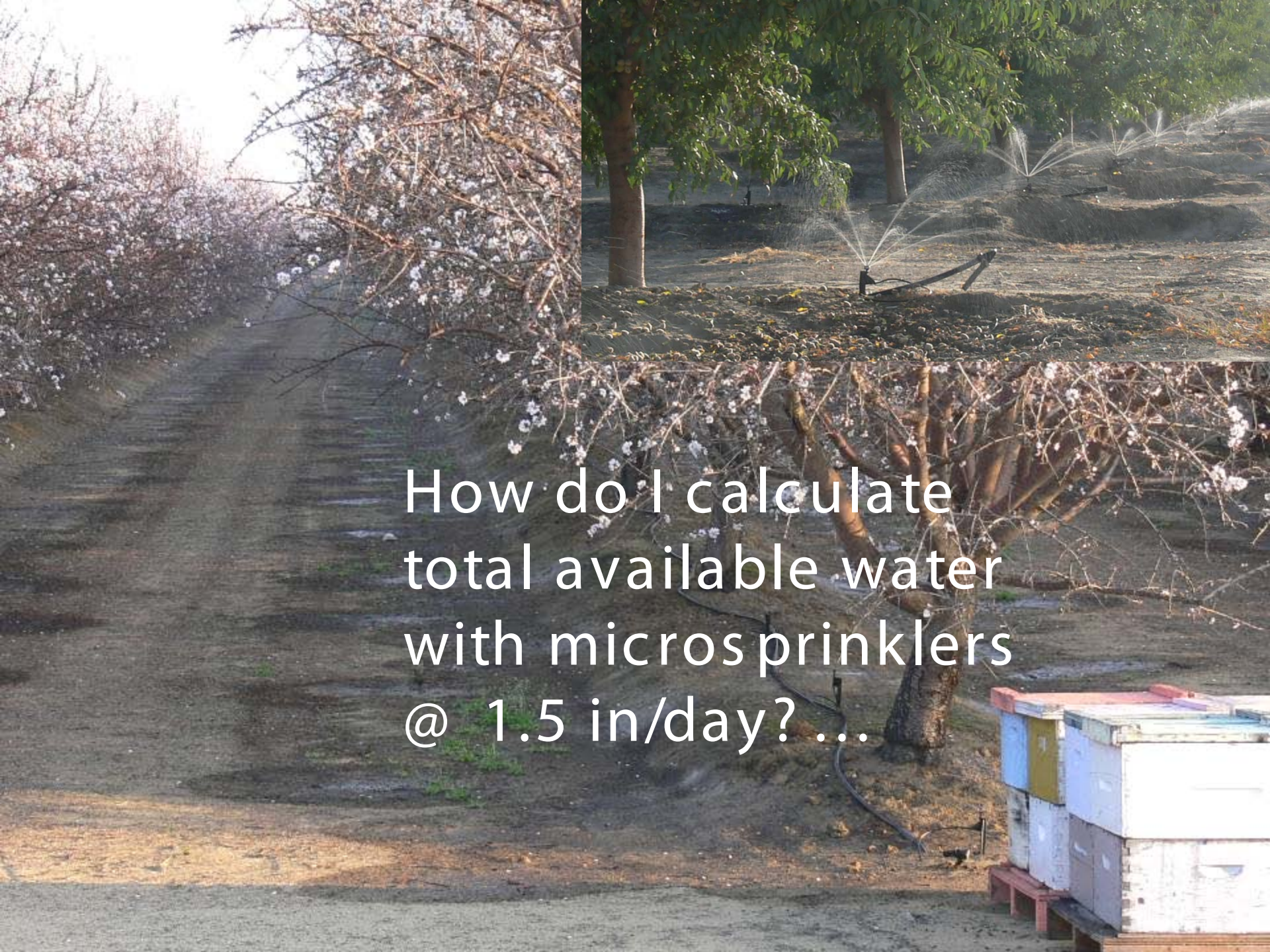
<u>So Point 1:</u> If I understand my soil water hold-ing capacity and schedule accordingly, then can flood irrigation be as "effective" as micro/drip?

(1st leaf almonds needing to grow as much vegetative matter as possible)

Irrigation non-uniformity can have severe impacts on water use and yields

Field measured DU for 1,351 irrigation systems on 152,721 acres in Kern County, 1988 to 2005.





How do I calculate total available water with microsprinklers @ 1.5 in/day? …

Summed 0-6 ft water content 6/24/09 after 24 hour irrigation


... or account for "subbing" in
a double-line drip?

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

growing ADVANTAGE The Almond Conference

Refill Times for Different Soil Textures and Micro Systems

[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available

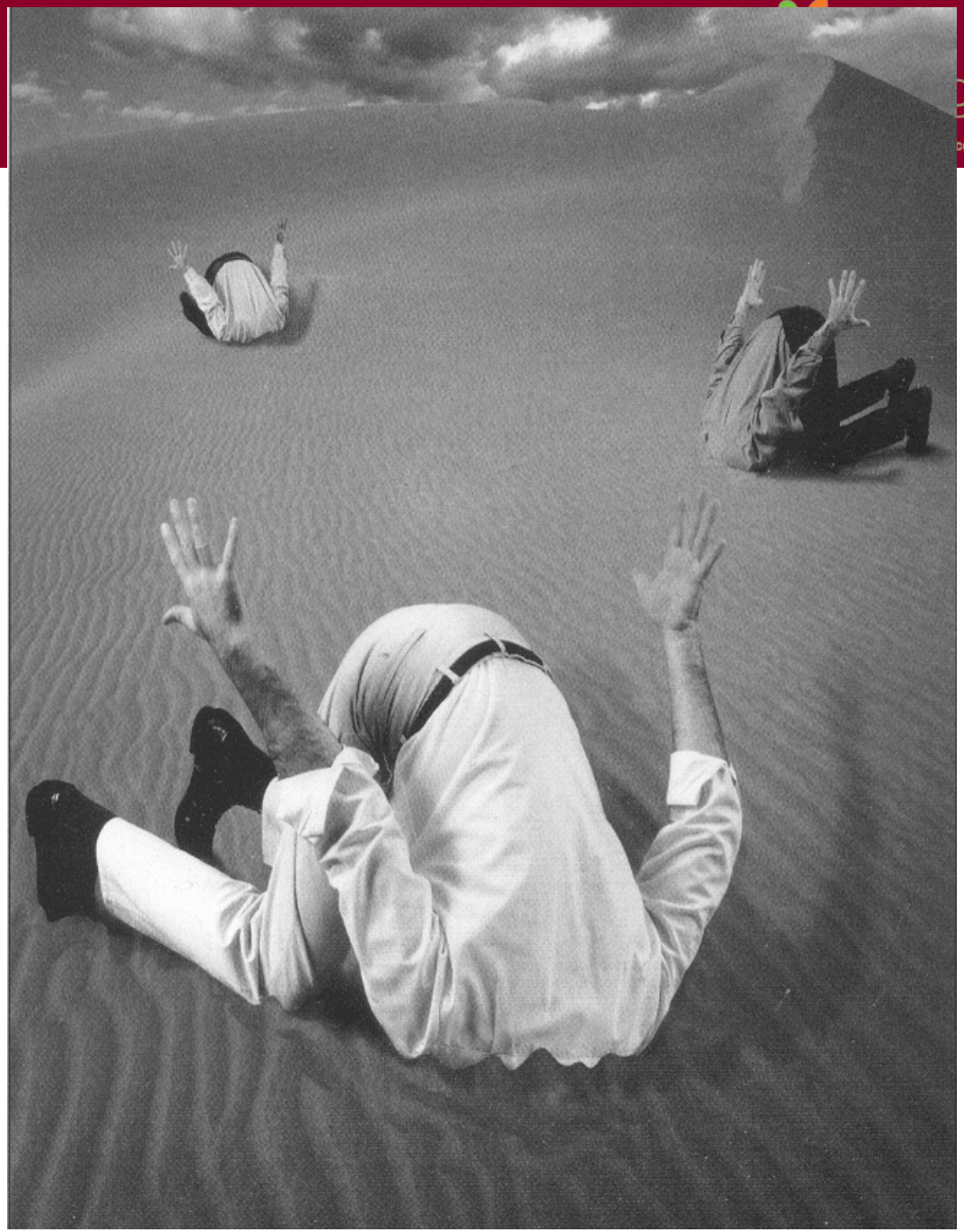
ALMONDS 0.28 inch/day ET

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	Dble-Line Drip 1-gph, 10 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	10 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	14 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)
Sand	0.7	2	2.2	0.3	11.6	1.6	12.5	2.4
Loamy Sand	1.1	3	7.8	1.0	19.6	2.7	20.9	4.0
Sandy Loam	1.4	4	17.5	2.4	26.9	3.6	28.3	5.4
Loam	1.8	5	35.9	4.9	37.1	5.0	38.6	7.3
Silt Loam	1.8	6	43.1	5.8	39.7	5.4	40.8	7.7
Sandy Clay Loam	1.3	6	31.1	4.2	28.6	3.9	29.5	5.6
Sandy Clay	1.6	7	44.7	6.0	37.6	5.1	38.3	7.2
Clay Loam	1.7	8	54.3	7.3	42.6	5.8	42.9	8.1
Silty Clay Loam	1.9	9	68.2	9.2	50.6	6.8	50.5	9.6
Silty Clay	2.4	9	86.2	11.6	64.0	8.6	63.8	12.1
Clay	2.2	10	87.8	11.9	62.3	8.4	61.5	11.6

[1]Based on a tree spacing of 20 x 22'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter.

Note: Peak water use @ 0.28"/day and 20 x 22' spacing = 74 gallons/day/tree. 0.20"/day = 55 gallons/day/tree.

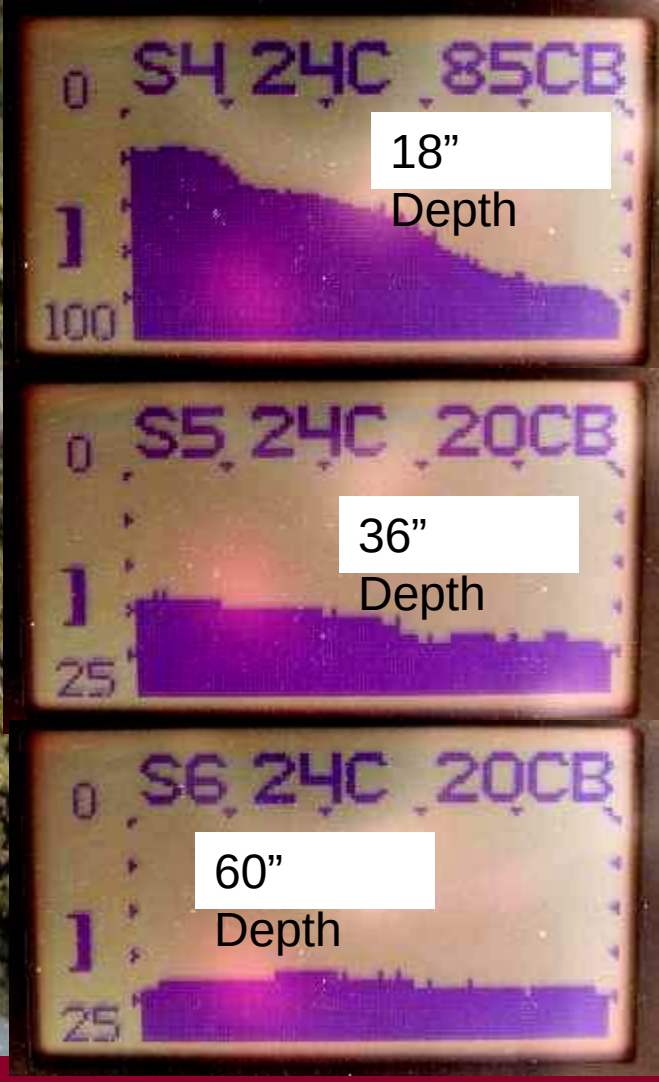
Table takes into account merging water patterns below soil surface for drip irrigation.



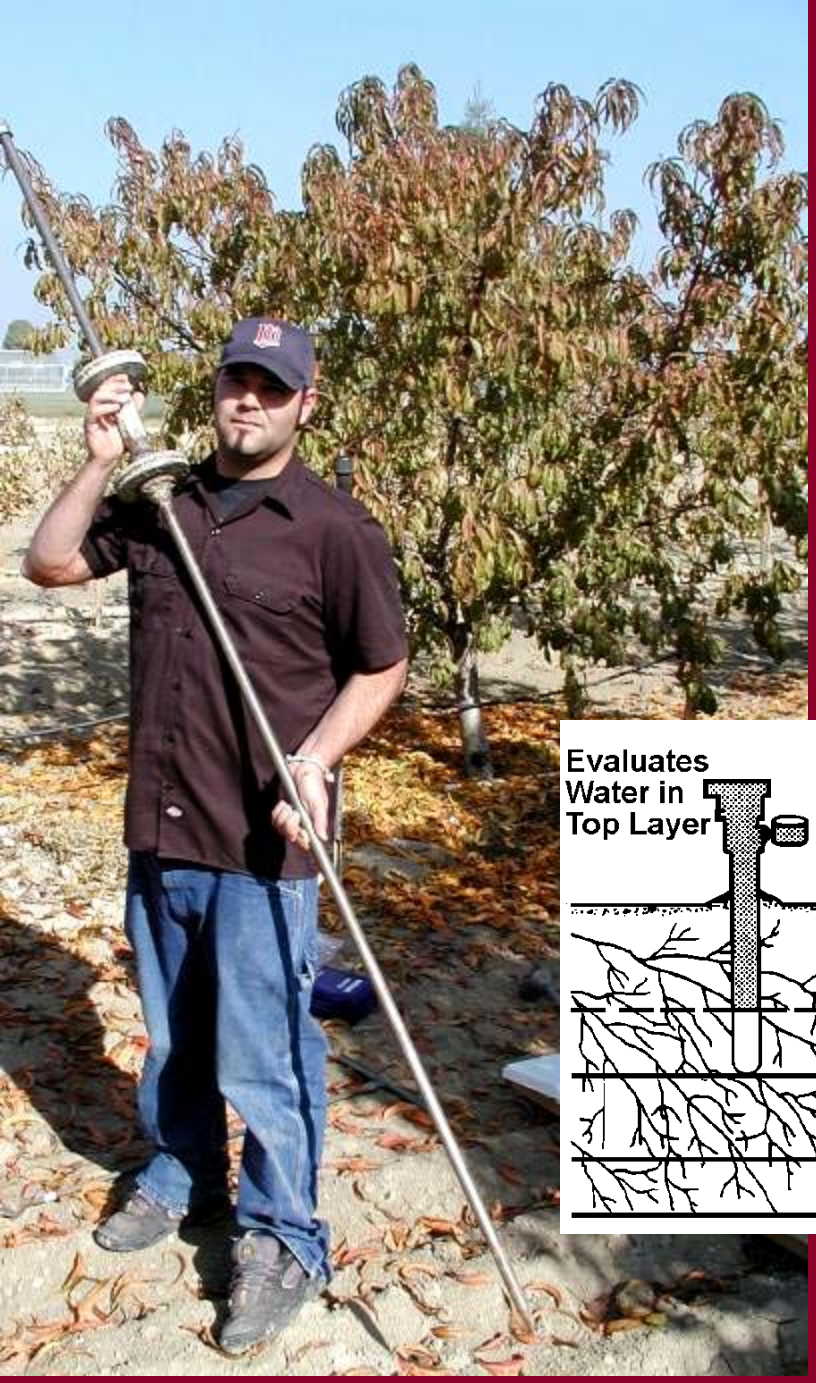
Hand-powered twist augers

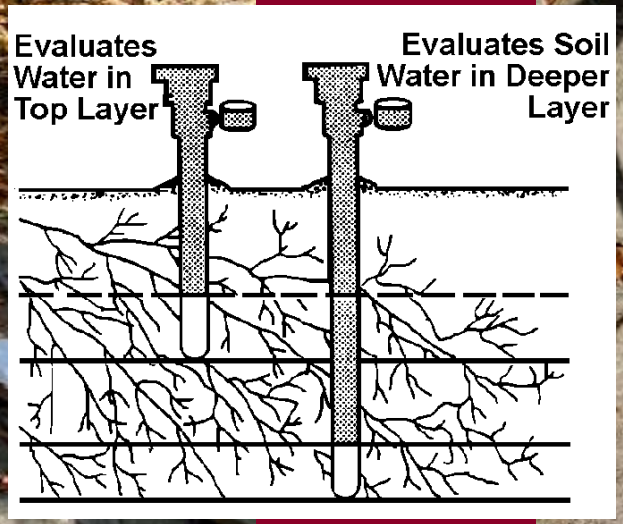
3 foot push or slide hammer-type probe

A device using low levels of radiation, the neutron probe, was developed in the 1960's for checking soil moisture. Used mostly by researchers and irrigation consultants, it is often the standard check for the accuracy of other instruments -- largest sample "volume" to estimate moisture



Checking reliability of dry readings on tensiometers with a soil core obtained with a 3 foot hammer probe



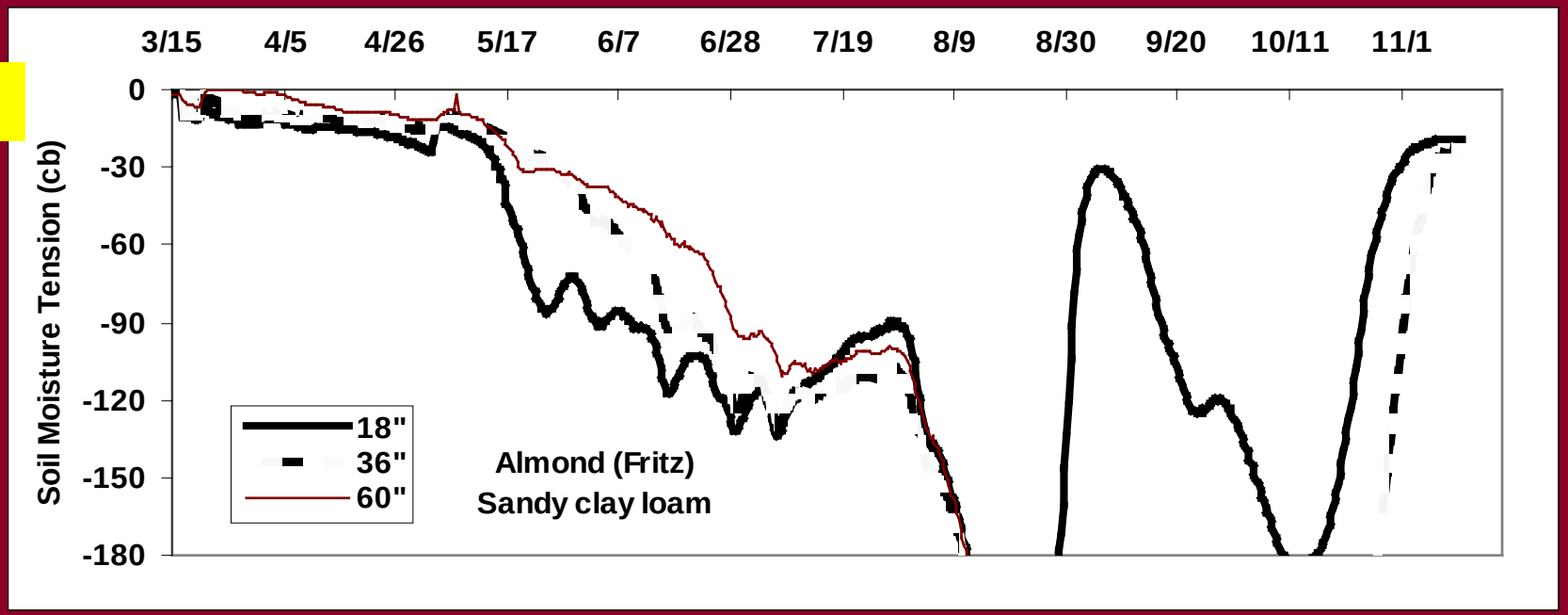


Tensiometers, Watermarks for Soil Moisture Tension (matric potential)

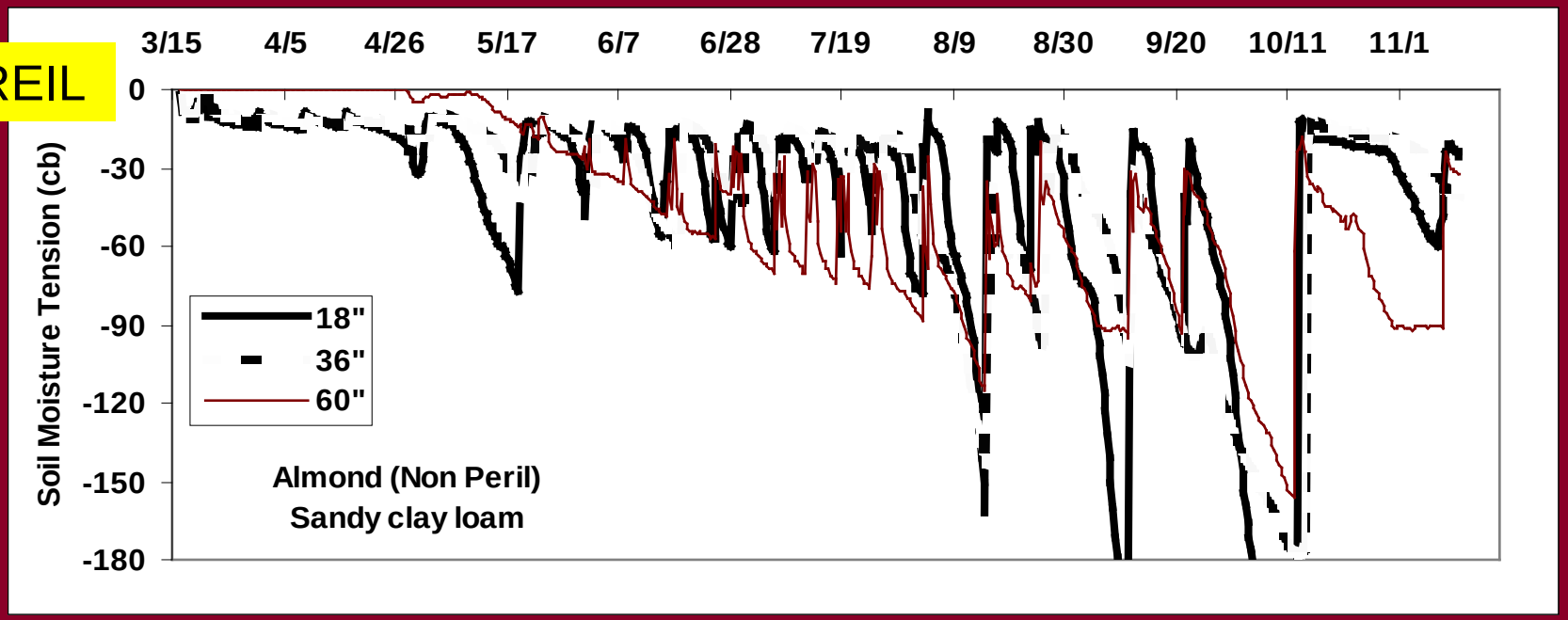
A variety of loggers can be used for various sensors: Costs from $100 (Hobo) to $5,000 (Campbell)

Watermark Readings from AM400 logger, reading 3x/day

FRITZ



NONPAREIL



Electronics, data loggers, weather stations and multi-stage sensors can increase the cost rapidly up to $5,000 to $10,000. Does this degree of sophistication

PureSense Comprehensive Soil Moisture & Irrigation Summary for Almonds

Irrigation Forecaster - PureSense Irrigation Manager

File Help

Site Info

Site: UC Fertility Fanjets SMP

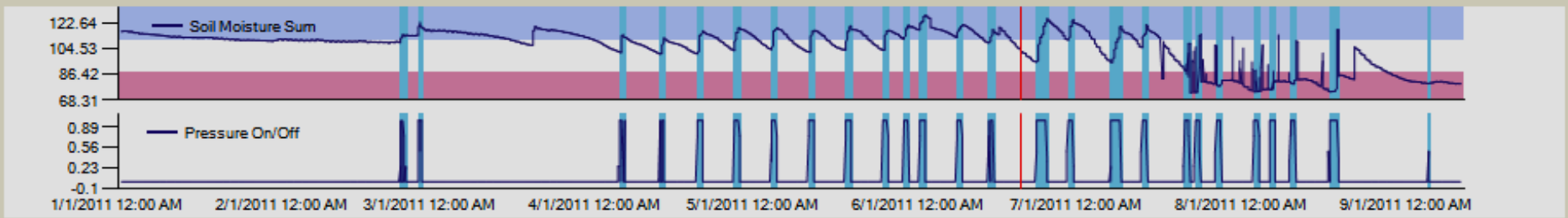
Soil Mois

Irriga

Chart Date Range

From: 1/ 1/2011 To: 9/12/2011 Update Chart

Use Bounds System Bounds Upper 110 Lower 88 Save Bounds



Double click on Chart to run calculations for that point in time

Hover Value 6/20/2011 8:00:00 AM 104.33 %

Value used for Calculations 6/20/2011 8:00:00 AM 104.33 %

Site Meta Data

Number of Sensors 5 Probe Length (meters) 1.5 Manufacturer Sentek

Irrigation Event Details

Water Bank

Total moisture capacity	13.47	in
Current moisture holding level	12.78	in
Minimum moisture capacity	10.78	in
Bounds Calculation Type	UserSet	

Time to Irrigate

Hours since last irrigation event end	110.9	hrs
Volume of water depleted	1.65	in
Average rate of water bank depletion	0.01	in/hr
Esitmated hours remaining until irrigation	137.0	hrs

5 Days 17 Hours

Irrigation Application Rate

Average infiltration rate	.0342	in/hr
Volume needed to reach total capacity	0.69	in
Estimated irrigation duration	20.3	hrs

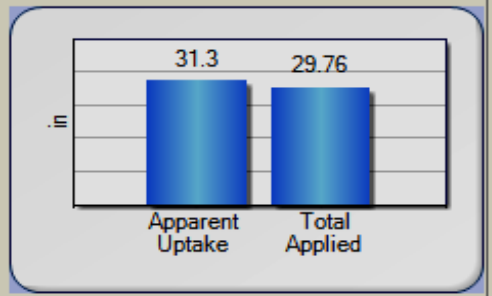
Irrigation Water Balance

Start 1/ 1/2011 Update

End 6/20/2011

Apparent Root Water Uptake 31.3 in

Total Applied Water 29.76 in



Equipment for checking soil Moisture

- Seat of the pants still most common method

~~4~~ 3-point sermon:

- Understanding & monitoring soil water holding characteristics
- Crop water requirements (ET), CIMIS
- Fertigation options (just a teaser)
- ~~Irrigation & crop salinity tolerance~~

Crop water use is made up of EVAPORATION (E) From The Wet Soil And Leaves And TRANSPIRATION (T), hence ET

Calculating ET for crops:

$$ET_{crop} = ET_o * K_c * E_f$$

ET_o = reference crop (tall grass) ET

K_c = crop coefficient for a given stage of growth as a ratio of grass water use. May be 0 to 1.3, standard values are good starting point.

E_f = an "environmental factor" that can account for immature permanent crops and/or impact of salinity. May be 0.1 to 1.1, determined by site.

CIMIS – CA Irrigation Management Information Service

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

The whole Central Valley covers Zones 12 to 16: for an "normal year" ETo of 53.3 to 62.5 in/yr, with most area @ 53 to 58 inches.

Do almonds really need as much water as alfalfa – 52 to 56 inches?

The old recommendation was 42-45 inches?

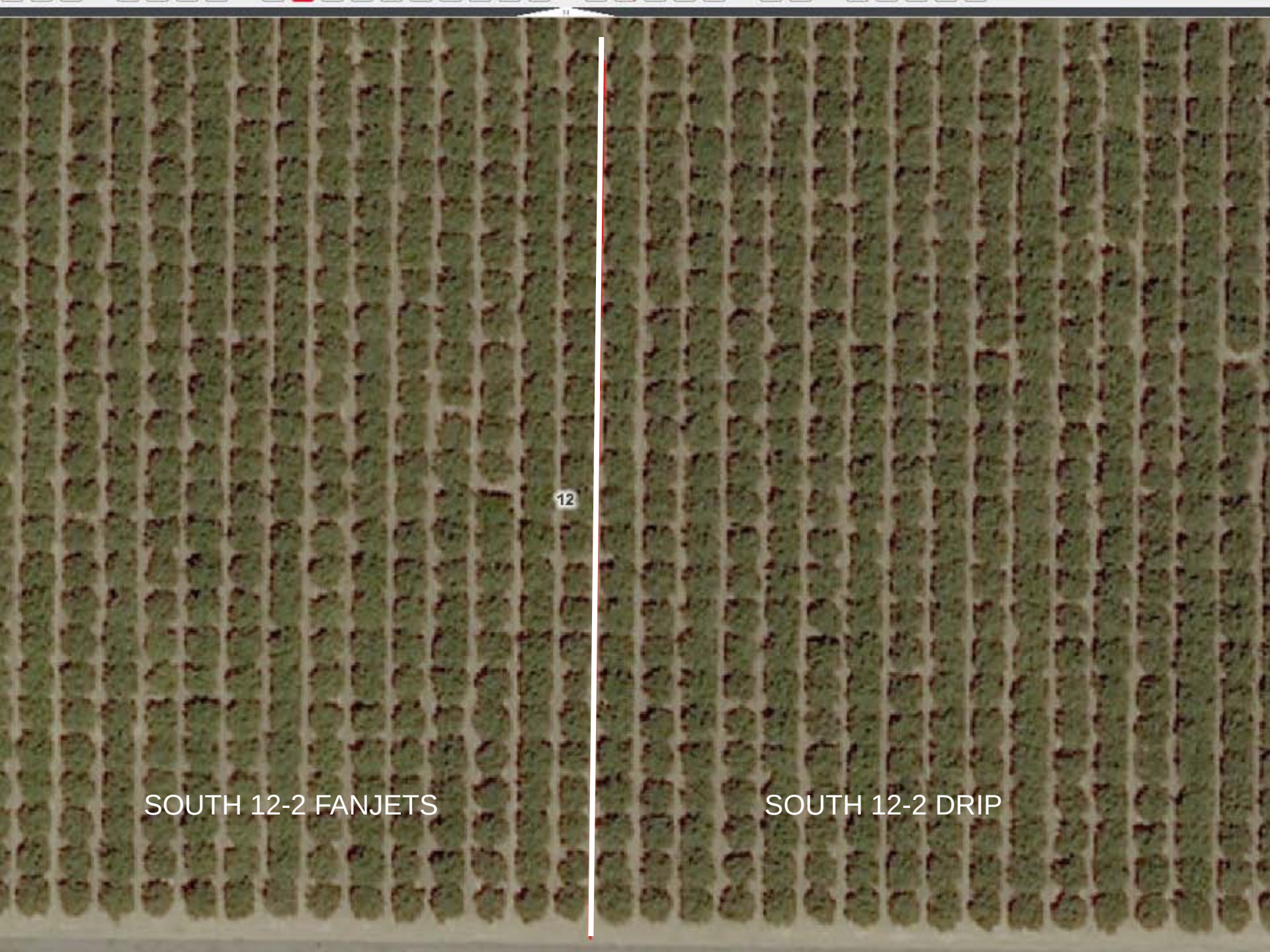
What's the right ET?

UNIVERSITY of CALIFORNIA
COOPERATIVE EXTENSION

Fertigation: Case study of interaction of water and nutrient management in almonds: 2008-2012

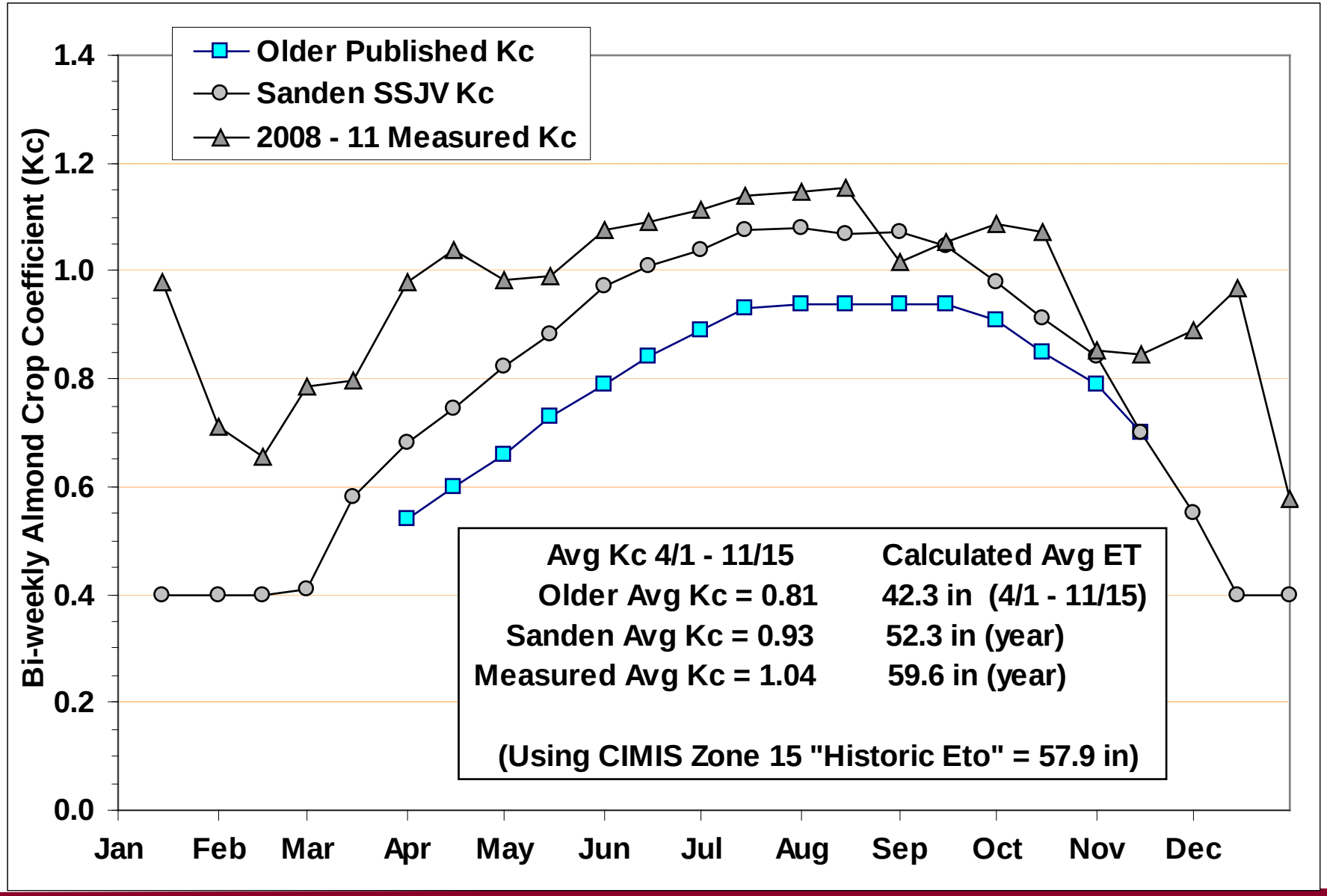
Blake Sanden – Irrigation & Agronomy, Kern County

Collaborative USDA Specialty Crops and California Almond Board Project

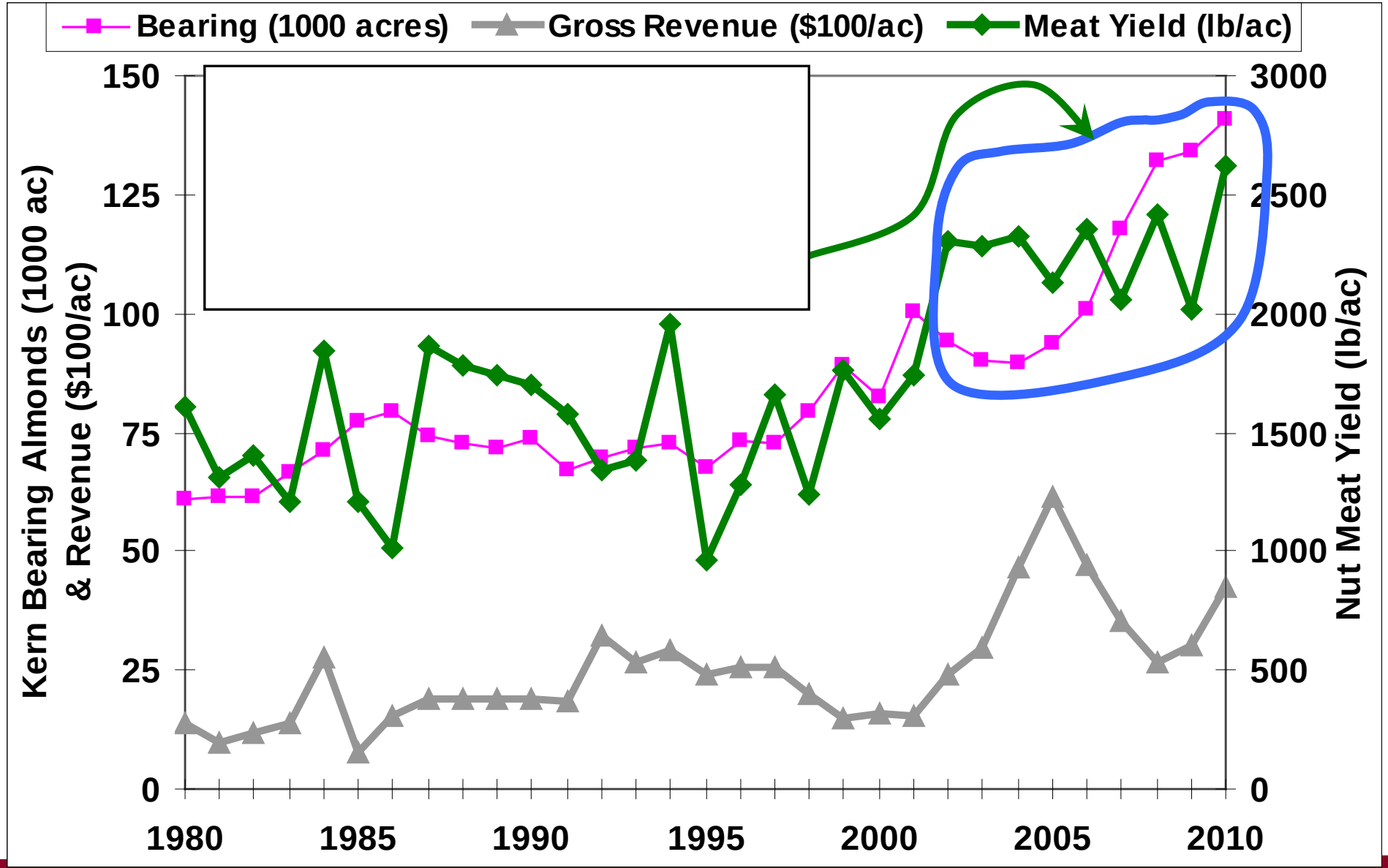

12
SOUTH 12-2 FANJETS
SOUTH 12-2 DRIP

Measuring nutrient and irrigation response under …

What are Optimal Almond Kc's And crop ET?

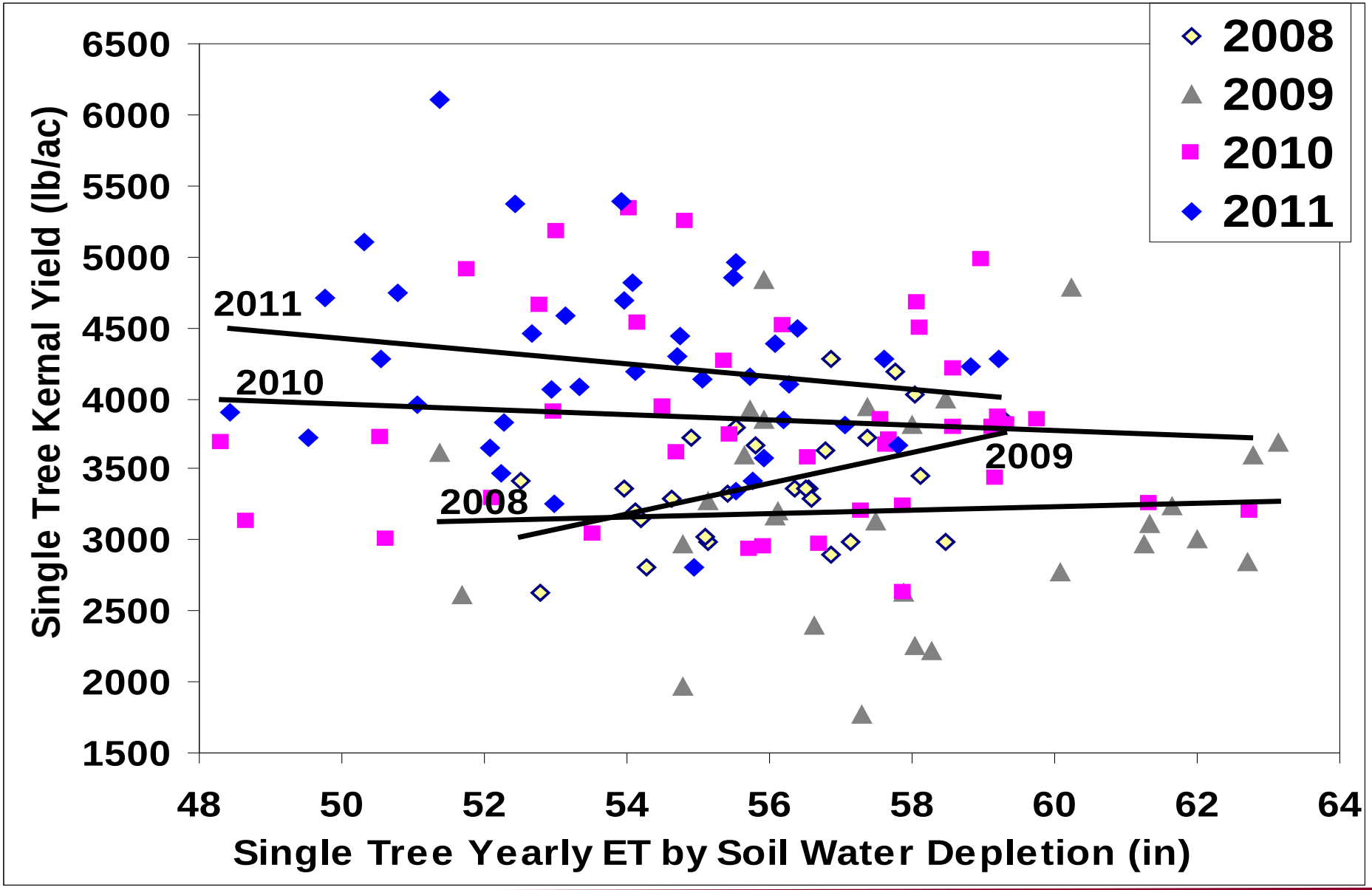


Changes in Kern County Almond Yield And Acreage From 1980-2010



So, if I give the tree 60 inches of water do I get more yield?

Single Tree Yield By Tree Neutron Probe Depletion + Applied Irrigation ET



~~A~~ 3-point sermon:

- Understanding & monitoring soil water holding characteristics
- Crop water requirements (ET), CIMIS
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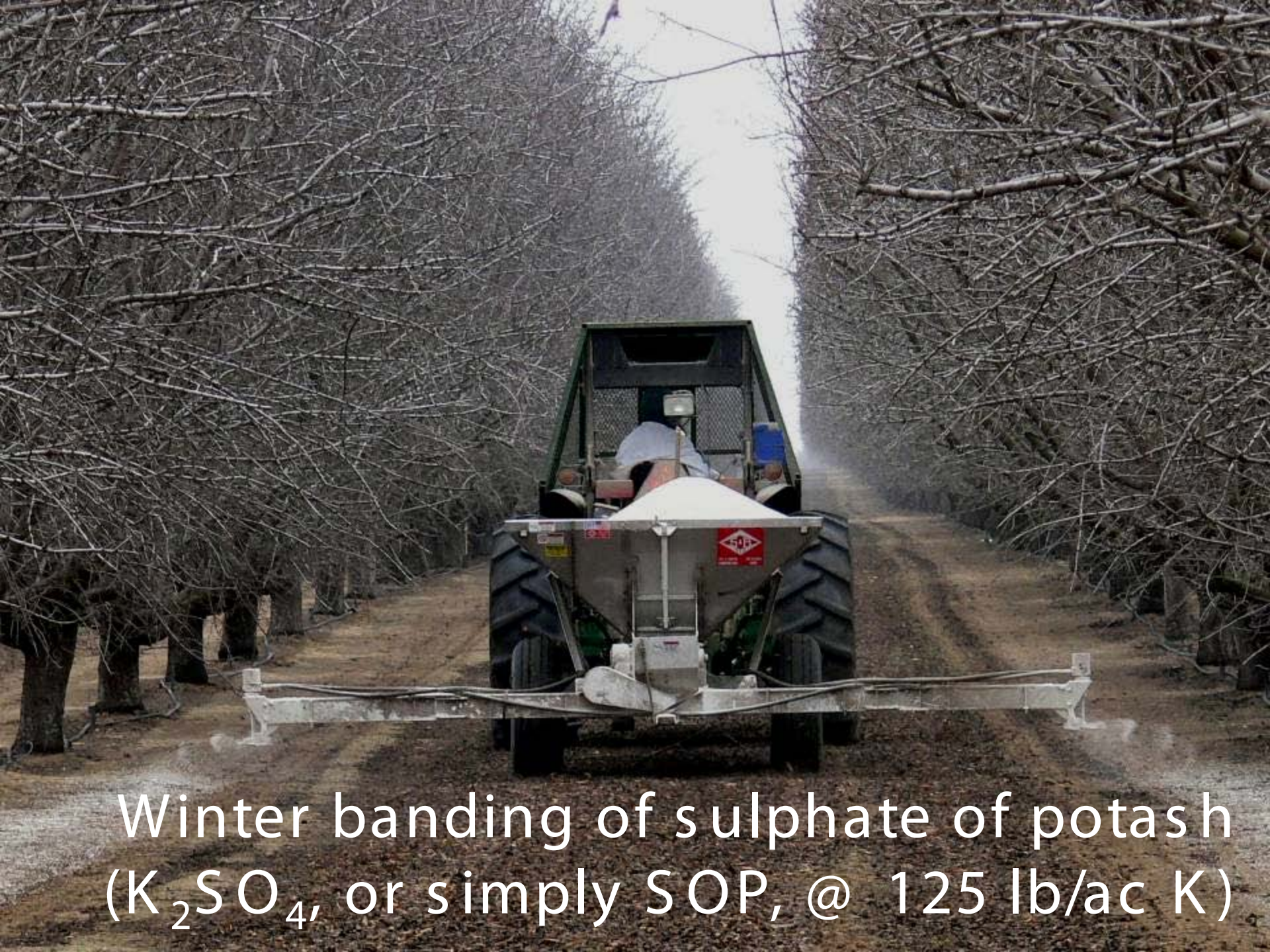
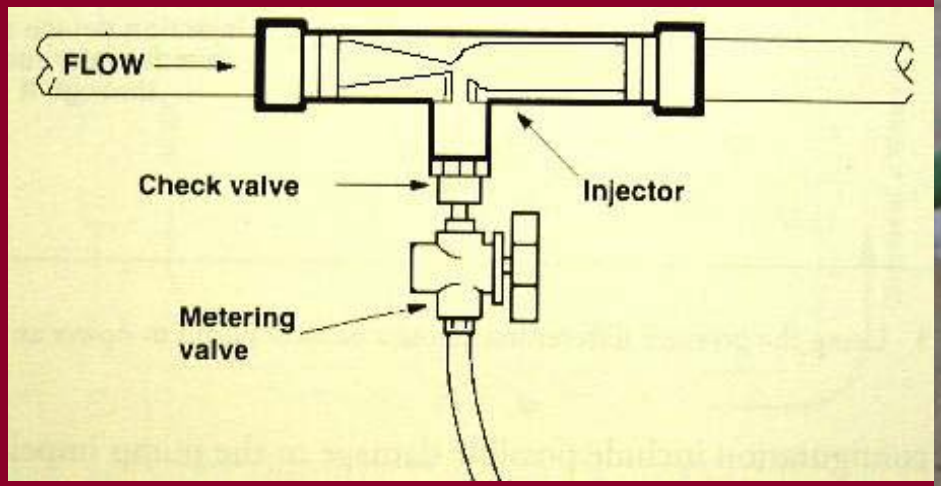
- Irrigation & crop salinity tolerance



Winter banding of sulphate of potash (K_2SO_4, or simply SOP, @ 125 lb/ac K)

Chemigation: Getting It In

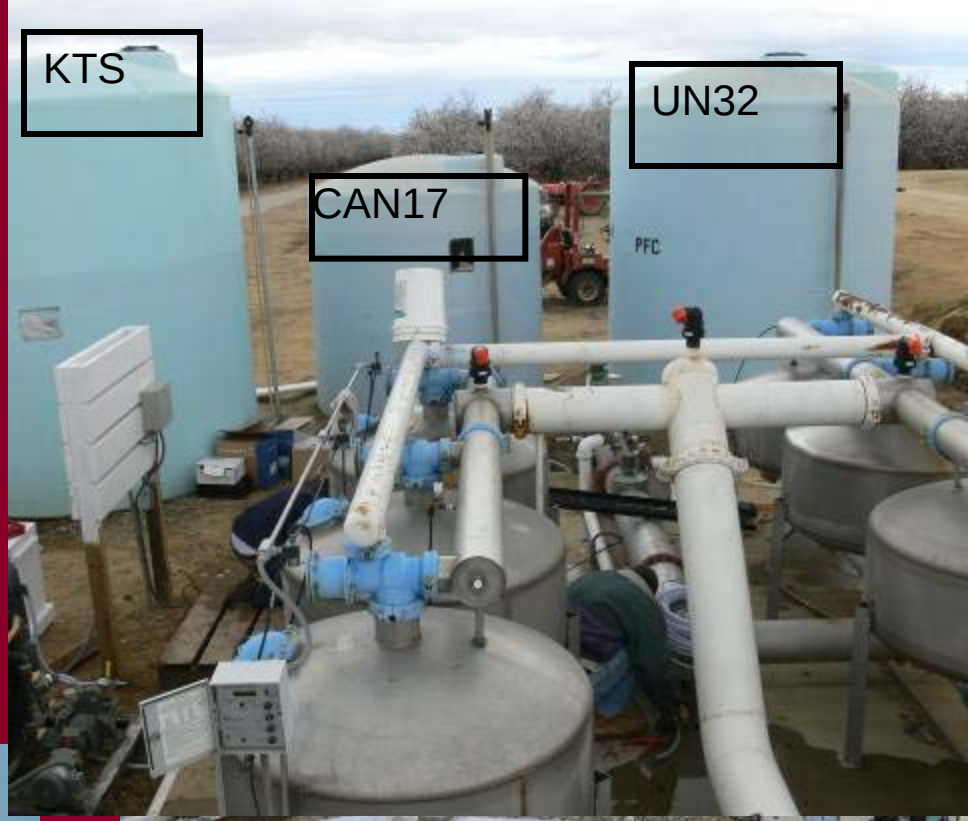
- Venturi (Mazzei): chemical injected into vacumn created by pressure differential, usually fertilizer, but injection rate easily adjusted for small volume



Main fertility trial:

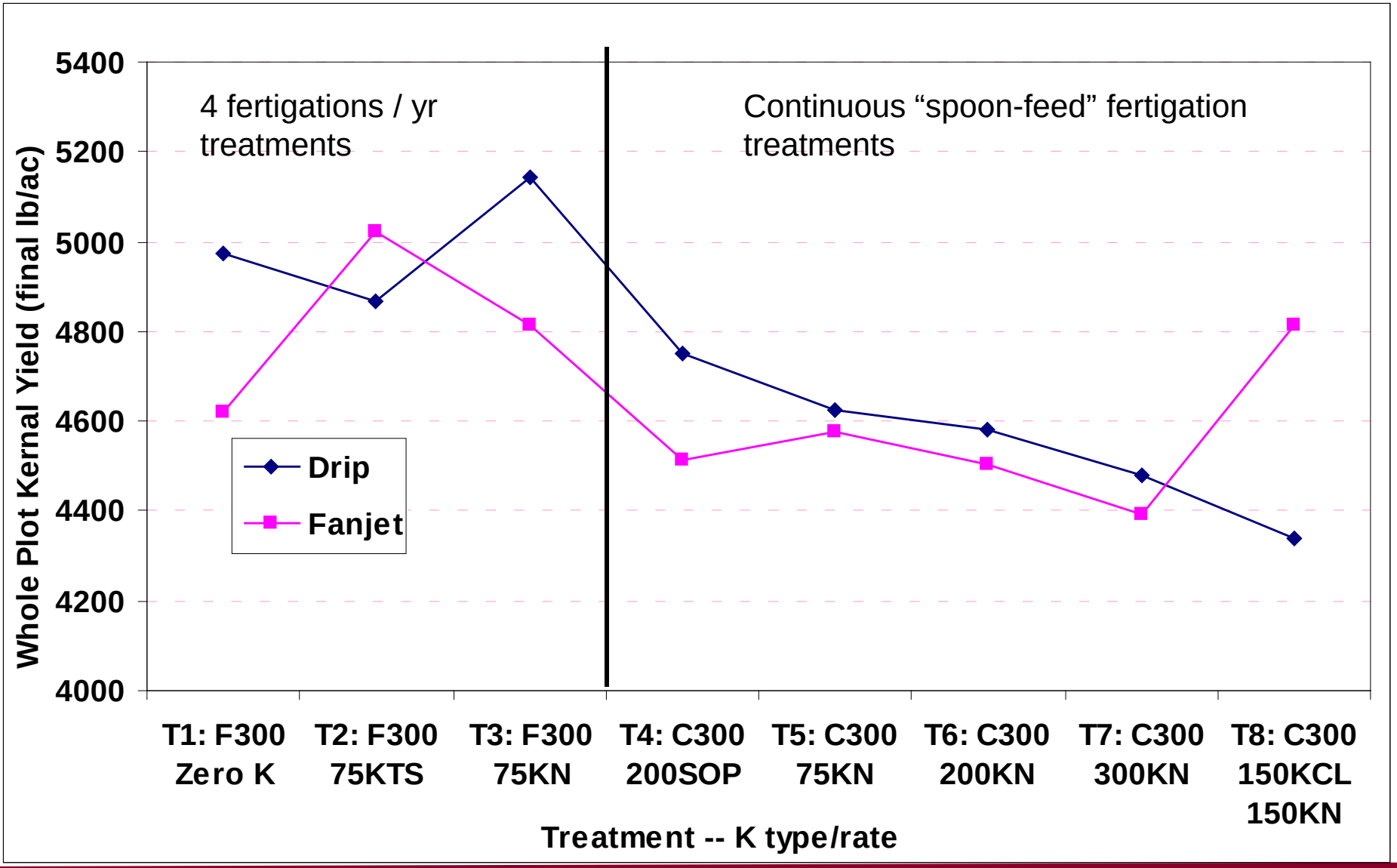
Direct injection 4x/year

Bloom	20%
April	30%
June	30%
Post Harvest	20%



2011 installation of 5 Grundfos dosing pumps for "spoon-feed" fertigation trial

2011 Nonpareil Yields for Episodic vs. Continuous Fertigation

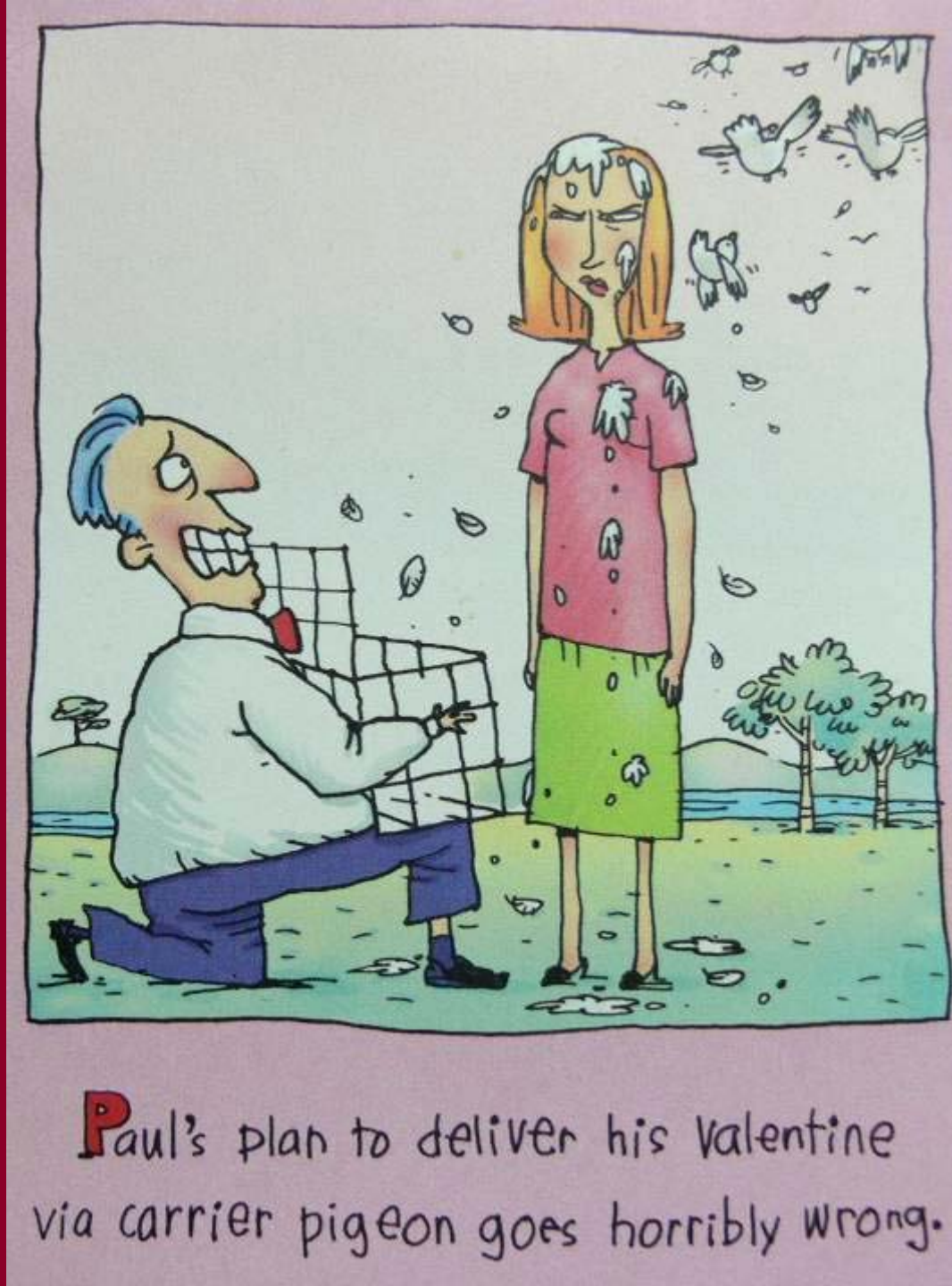


Conclusions

- Know soil AWHC and volumetric storage
- Know net infiltration and/or system application capacity to avoid stress and fertilizer leaching
- Organize system & ET data for records
- Plan irrigations using "normal year" ET and CIMIS – update with real-time soil and tree water status monitoring to maximize yield & efficiency
- Have reasonable estimate of crop nutrient demand given realistic field yield expectations
- Know fertilizer injection rates and match to tree nutrient uptake – most in by July


Technology is helpful, but the most valuable thing you can put in the field is your shadow …

…because pigeons happen despite our best plans!!



Optimizing Root Uptake

Jan Hopmans, UC Davis

growing ADVANTAGE
The Almond Conference

Subsurface is Highly Complex System

- **Spatially variable soils (texture & layering), root distribution, irrigation water application;**

  Leaching Fraction concept revisited – Local leaching

  <u>General background + Paramount Farms results</u>

- **Mechanisms of root water and nitrate uptake are not well understood:**

  a) Is water stress in one part of root system compensated for by additional uptake in non-stressed part of the root system?

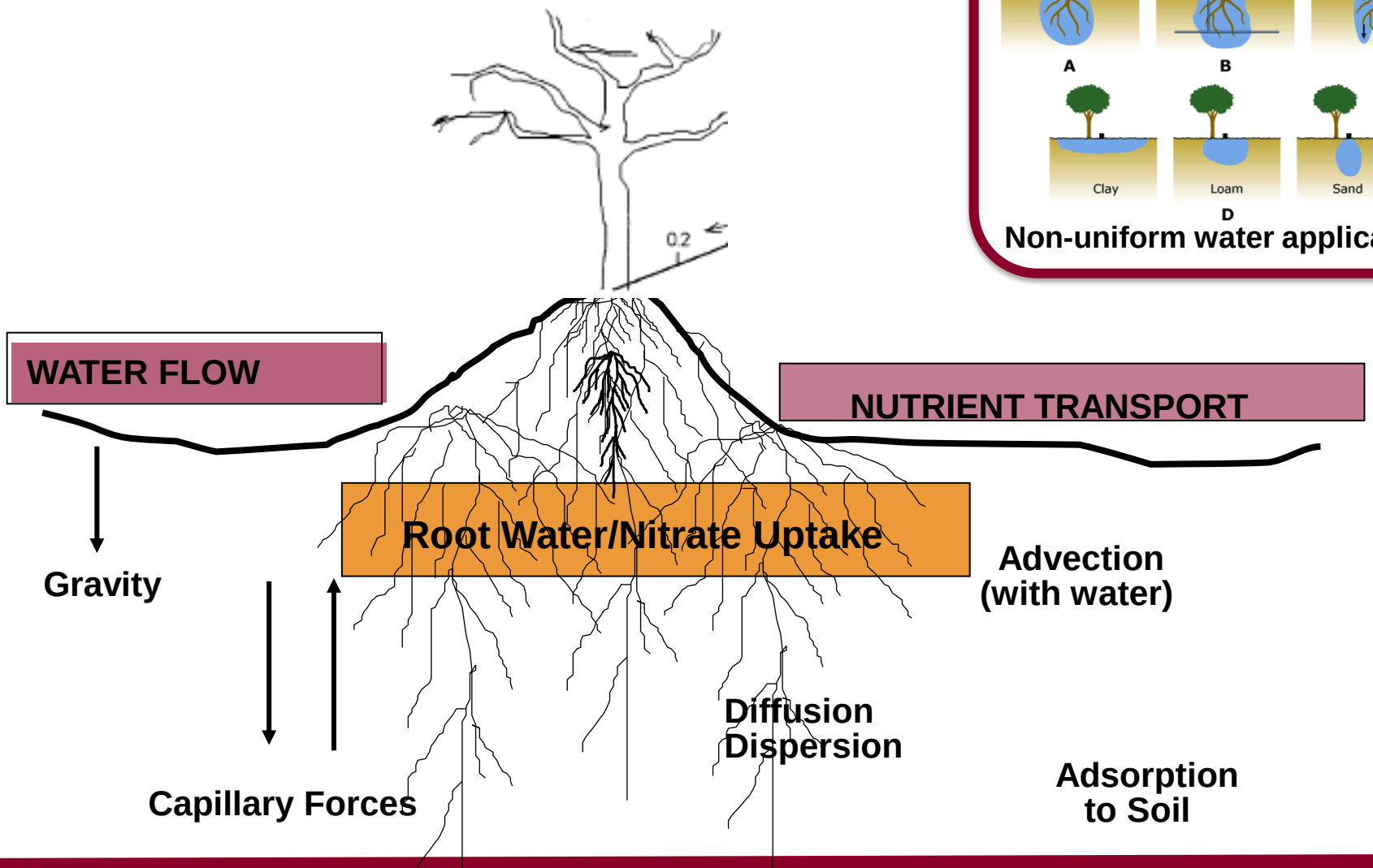
  b) Is root water uptake directly coupled with nitrate uptake?

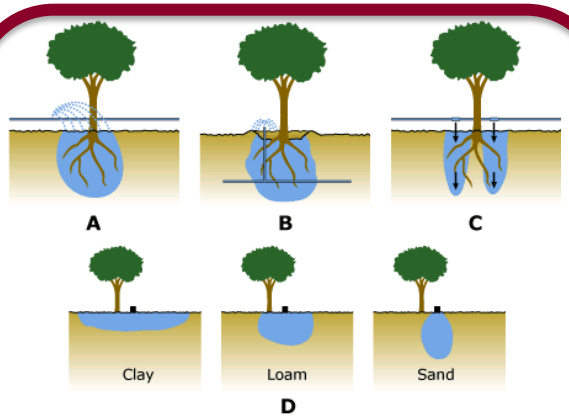
  <u>General background</u>

- **How to monitor root water/nutrient uptake?**

  <u>Paramount Farms</u>

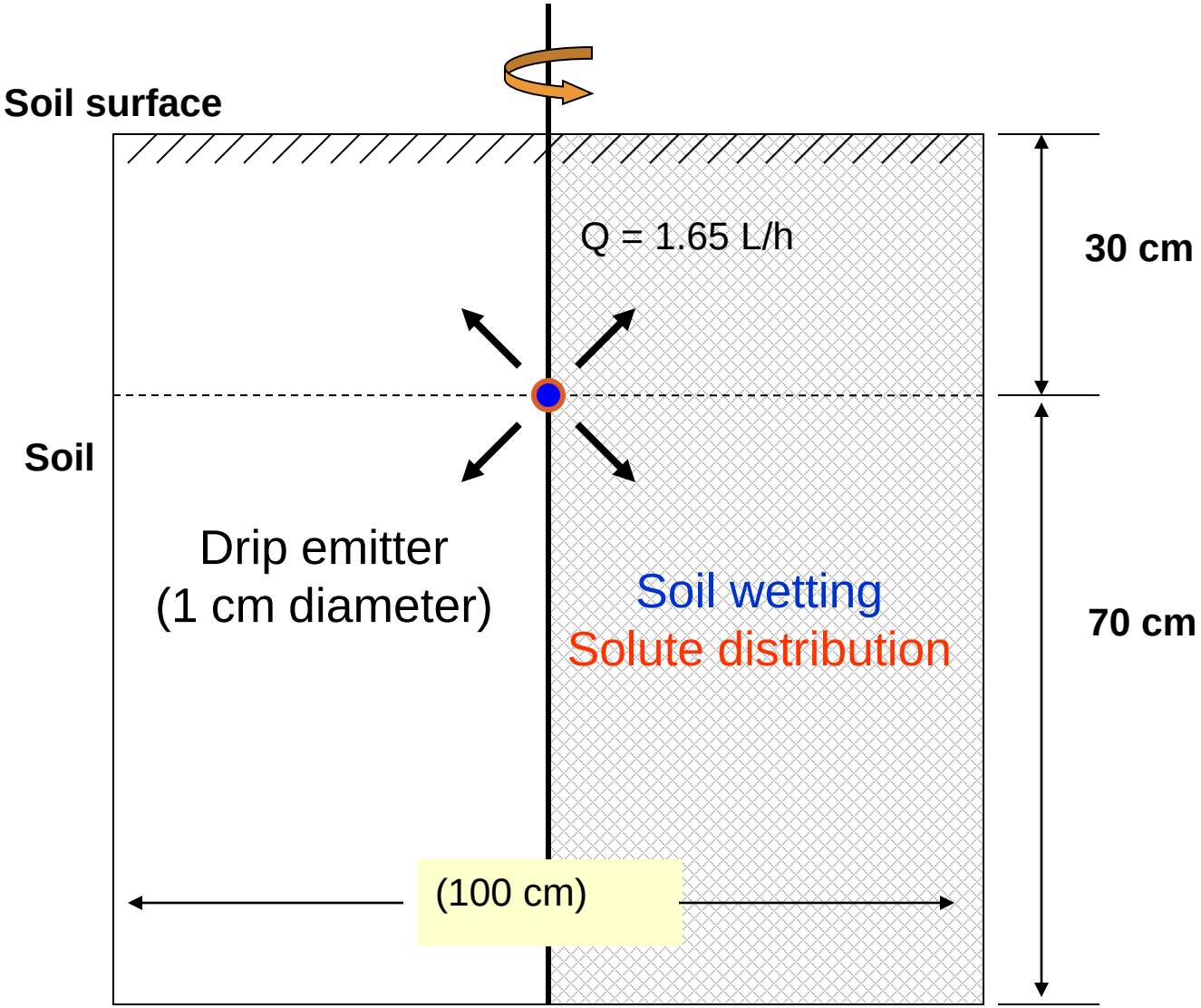
Movement of Water and Nutrients in Soils





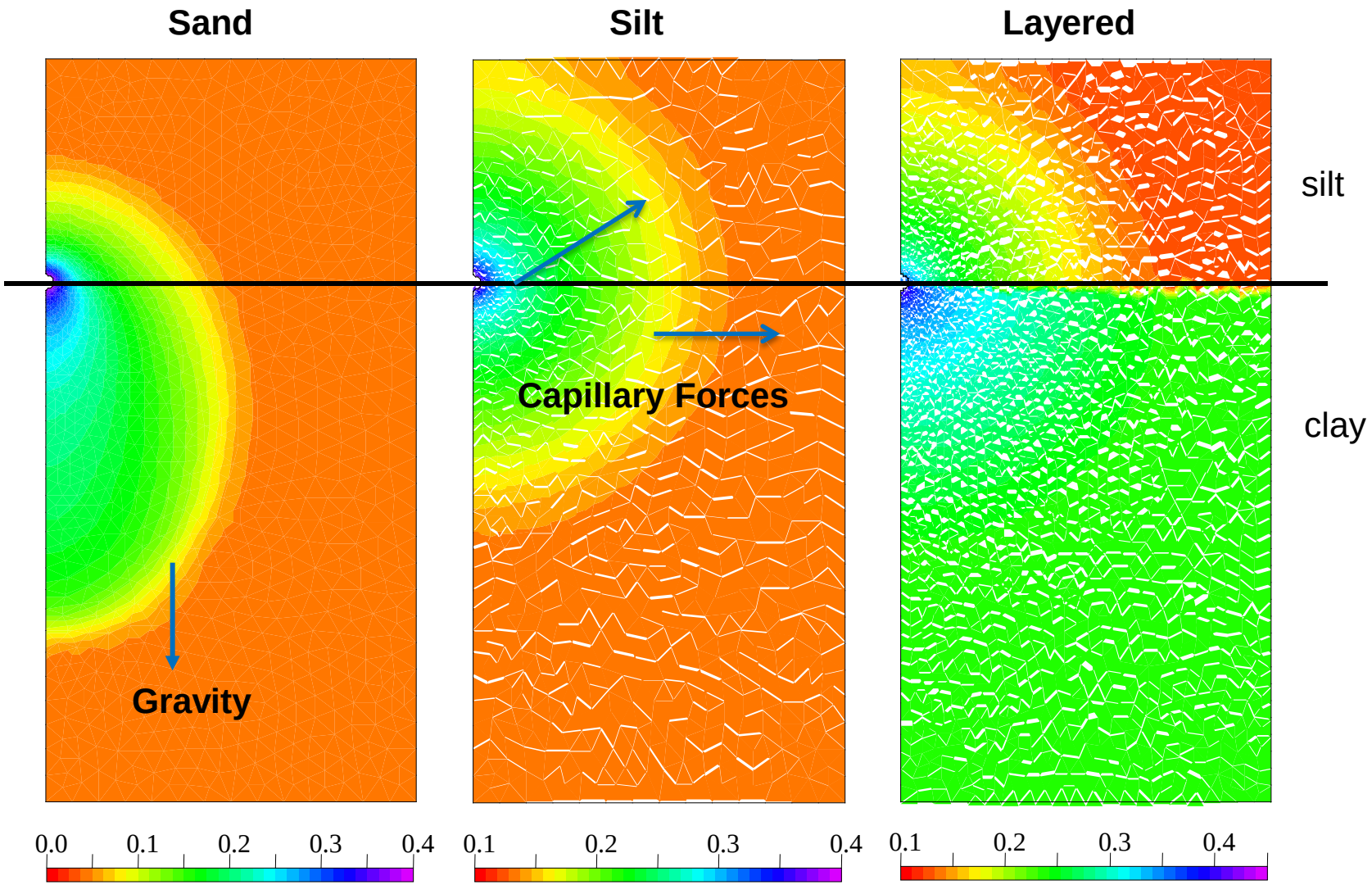
Non-uniform water applications

The Soil System Simplified (Subsurface Drip: Model HYDRUS)



Cote, C.M., K.L. Bristow et al. 2003. Irrigation Science. Analysis of soil wetting and solute transport in trickle irrigation.

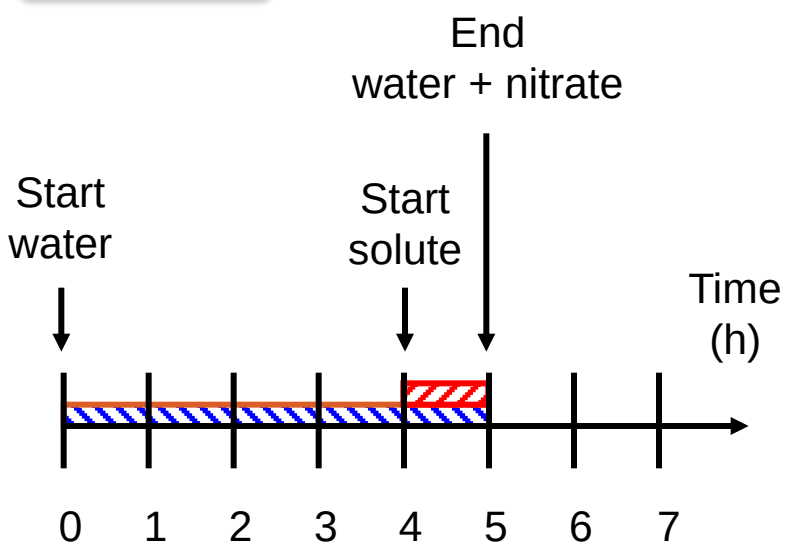
Wetting Front After Applying 6.3 L Water in Dry Soil



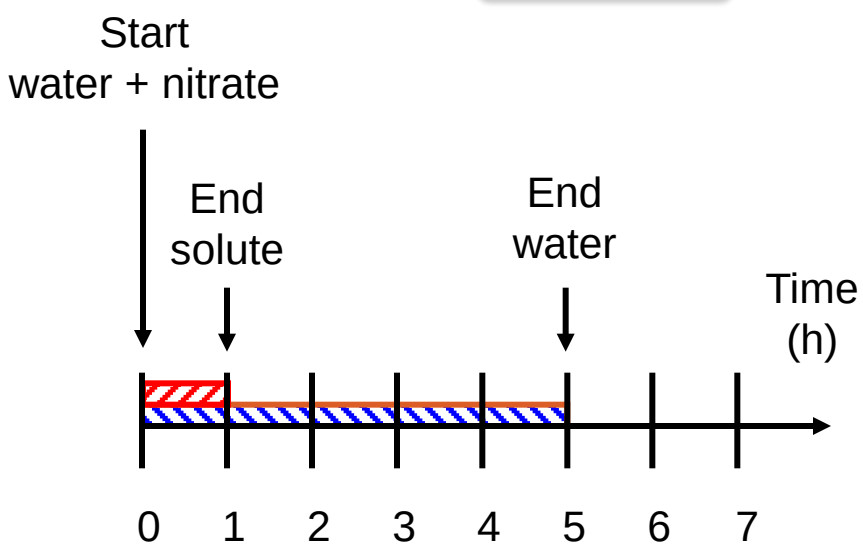
Fertigation Strategies

Concentration is 2.3 g/L nitrate

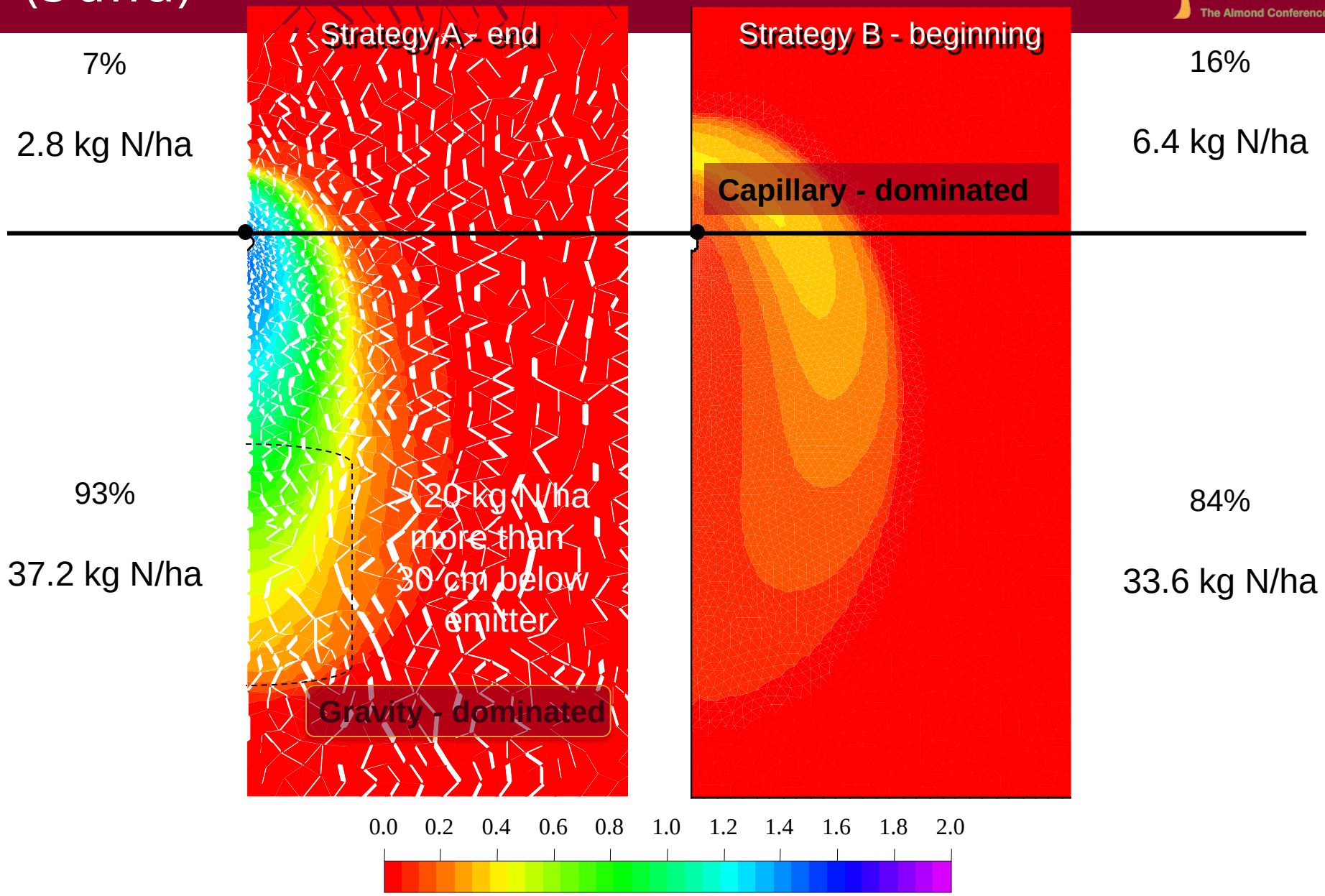
Strategy A



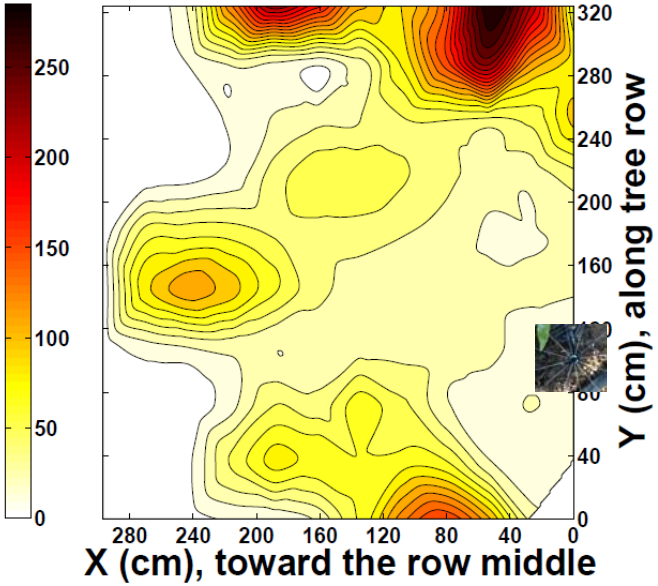
Strategy B



Increase in Soil Nitrate After 10 Hours (Sand)



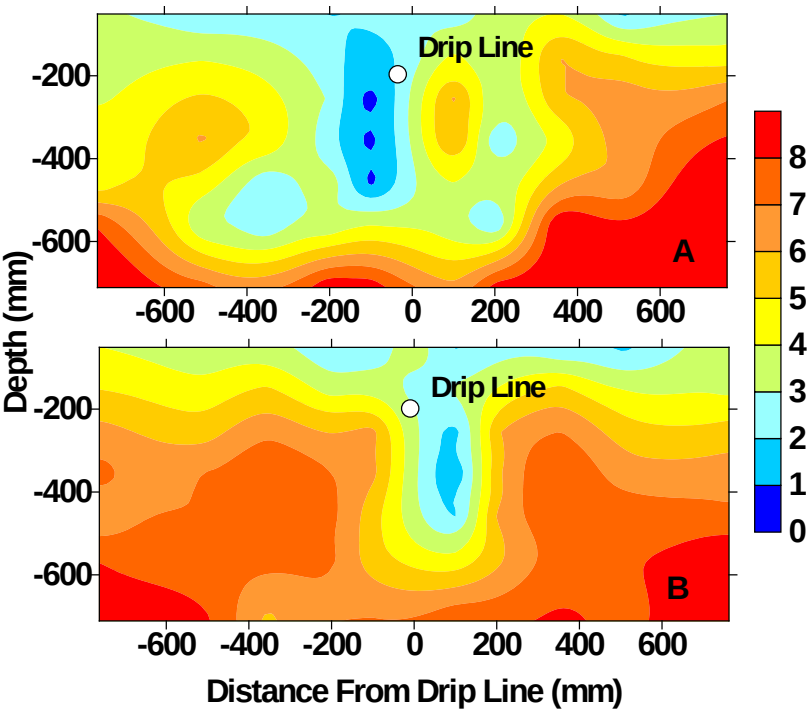
Paramount Farms (Lost Hills):
Fanjet Versus Surface Drip



Non-uniform Water Application for both Micro-irrigation systems

Leaching Fraction (LF) Revisited

$$\textbf{LF (field scale)} = \frac{\text{Water Applied} - \text{EvapoTranspiration (ET)}}{\text{Water Applied}}$$



Hanson BR, Šimůnek J, Hopmans JW. 2008. Leaching with subsurface drip irrigation under saline, shallow groundwater conditions. Vad Zone J 7(2):810–8.

- Field-wide approach to estimate LF is **not appropriate** for application to drip irrigation, as irrigation water is applied to only fraction of the orchard area;
- Significant leaching may occur for water applications much less than 100% ET (field-scale), because of localized leaching.
- Note: roots grow where the soil is wetted. . . .

Soil Layering – Paramount Farms

Fan Jet	Clay (%)	Silt (%)	Sand (%)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Drip
Sandy clay loam	21	18	61	10	73	12	15	Sandy loam
				20				
				30				
	27	26	47	40	75	13	12	
				50				
				60				
	21	26	53	70	72	15	13	
				80				
				90				
Loam	28	27	45	100				
				110	37	32	31	Clay loam
				120				
Clay	54	27	19	130	43	38	19	loam
				140				
Sandy loam	19	25	56	150				
				160	48	27	25	Sandy clay loam
loam	23	32	45	170				
Sandy loam	14	12	74	180				
				190	21	37	42	Clay
Silt clay	44	47	6	200				
				210				
Clay loam	29	37	34	220	37	29	34	Clay loam
				230				
				240				
				250	62	19	19	Sandy loam
				260				
				270				

- **Similar soil types between two experimental sites of Fan Jet and Surface Drip**
- **<u>More sandy</u> in top 4 ft for Drip site; with both sites relatively coarse-textured;**
- **Finer Textured clay at 4 ft (Fan Jet) and at 6 feet (Surface Drip).**

Soil Layering – Paramount Farms

Fan Jet	Clay (%)	Silt (%)	Sand (%)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Drip
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				60				
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				80				
				90				
Loam	28	27	45	100				
				110	37	32	31	Clay loam
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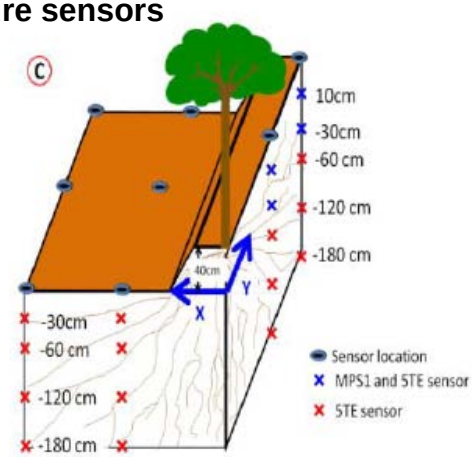
				140				
Sandy loam	19	25	56	150				
				160	48	27	25	Sandy clay loam
loam	23	32	45	170				
Sandy loam	14	12	74	180				
				190	21	37	42	Clay
Silt clay	44	47	6	200				
				210				
Clay loam	29	37	34	220	37	29	34	Clay loam
				230				
				240				
				250	62	19	19	Sandy loam
				260				
				270				

- **Similar soil types between two experimental sites of Fan Jet and Surface Drip**
- **<u>More sandy</u> in top 4 ft for Drip site; with both sites relatively coarse-textured;**
- **Finer Textured clay at 4 ft (Fan Jet) and at 6 feet (Surface Drip).**

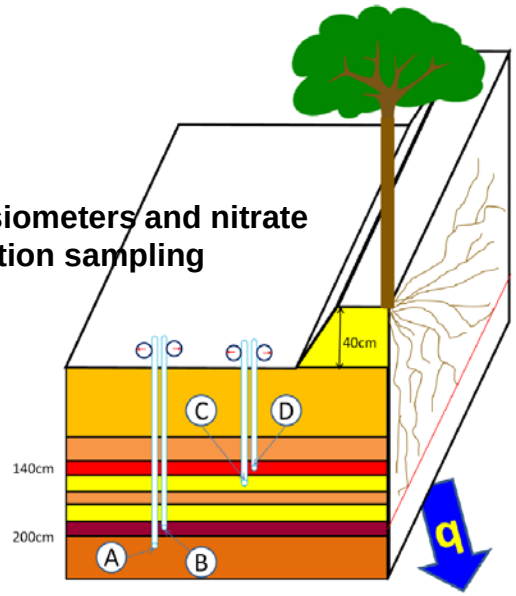
How to Monitor ? (Paramount Farms)

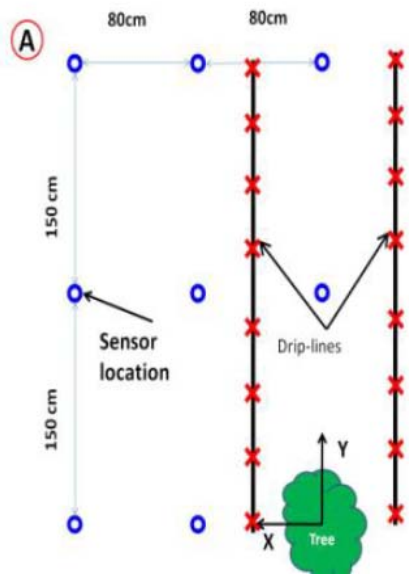
Soil moisture sensors



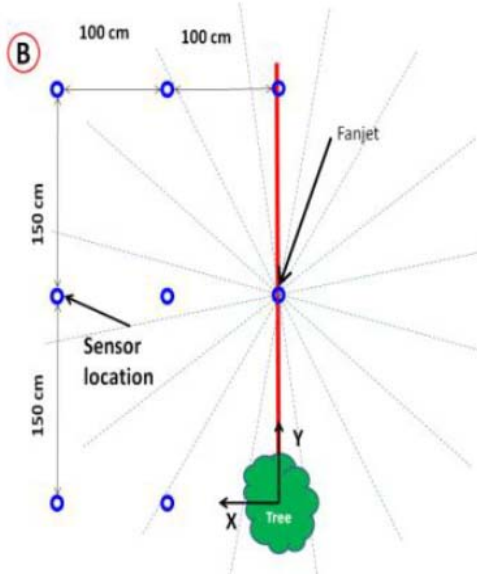
- **Use a three-dimensional grid of sensors to capture soil and root heterogeneities;**
- **Assume that single quadrant is representative for the whole tree;**
- **Experimental data will be used to train 3-dimensional HYDRUS model to simulate water and nitrate transport in rooting zone.**

Tensiometers and nitrate solution sampling





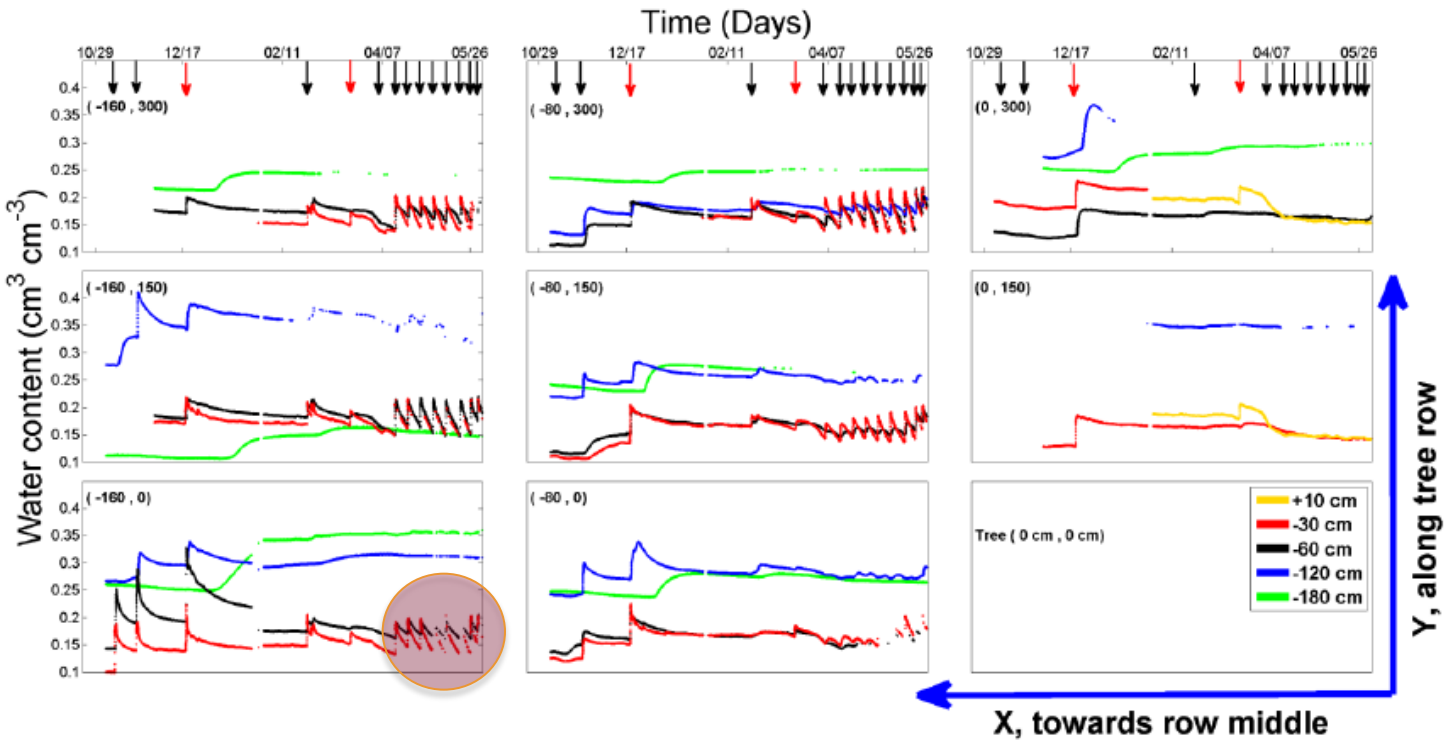
Surface drip



Fan jet

SURFACE DRIP, Paramount

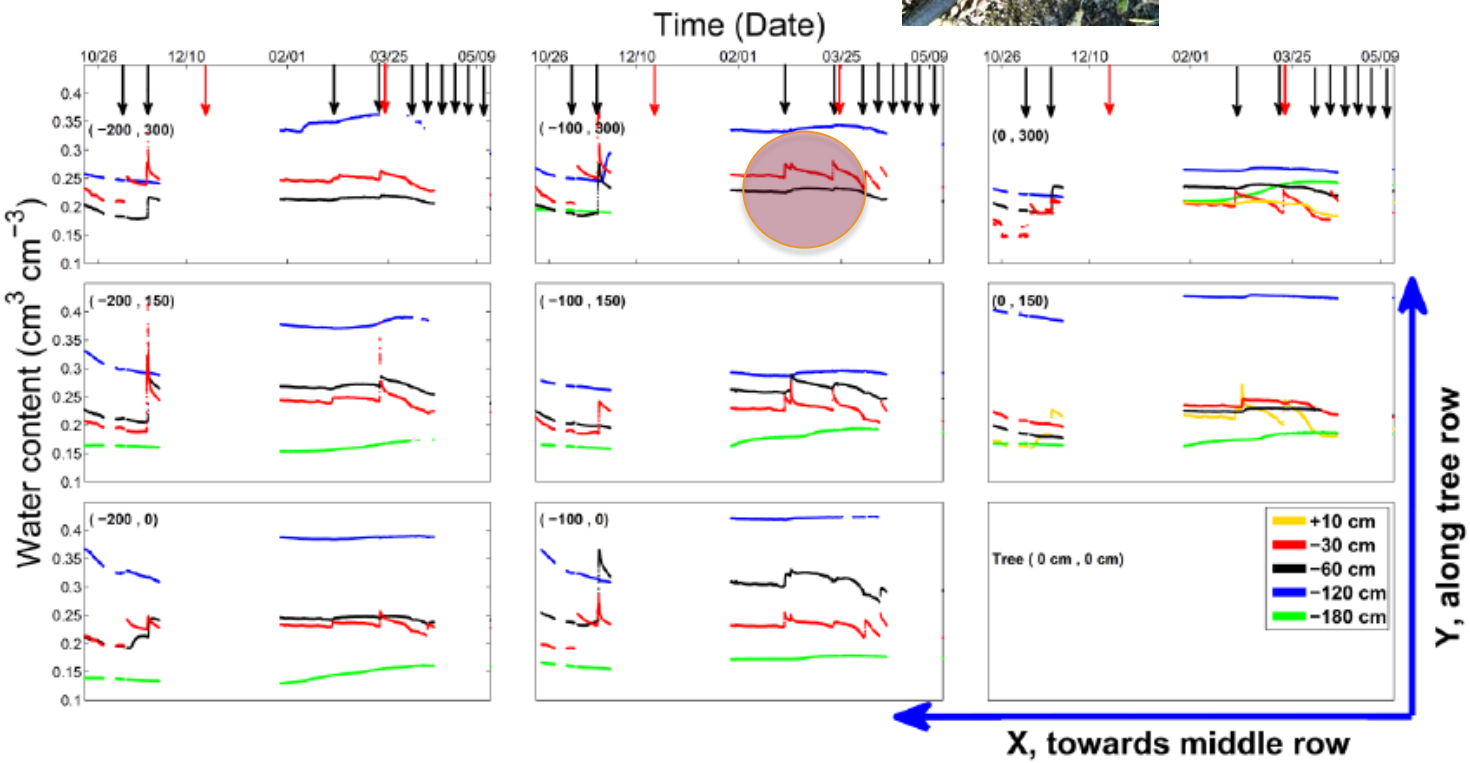
Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Drip
10	73	12	15	Sandy loam
20				
30				
40	75	13	12	
50				
60				
70	72	15	13	
80				
90				
100				
110	37	32	31	Clay loam
120				
130	43	38	19	loam
140				
150				
160	48	27	25	Sandy clay loam
170				
180				
190	21	37	42	Clay
200				
210				
220	37	29	34	Clay loam
230				
240				
250	62	19	19	Sandy loam
260				
270				



- Near surface sensors respond to irrigation events, but **not in the berm**;
- Lowest water content in top 60 cm (black/red), because of root water uptake **and sandy soil**;
- Clay layer at about 6-7 ft (green);
- 120 (blue) and 180 cm (green) deep sensors respond to winter rains, with 180 cm delayed;
- Deep sensors at 180 cm remain uniformly wet during the summer – **indication of absence of leaching below 7 feet**;

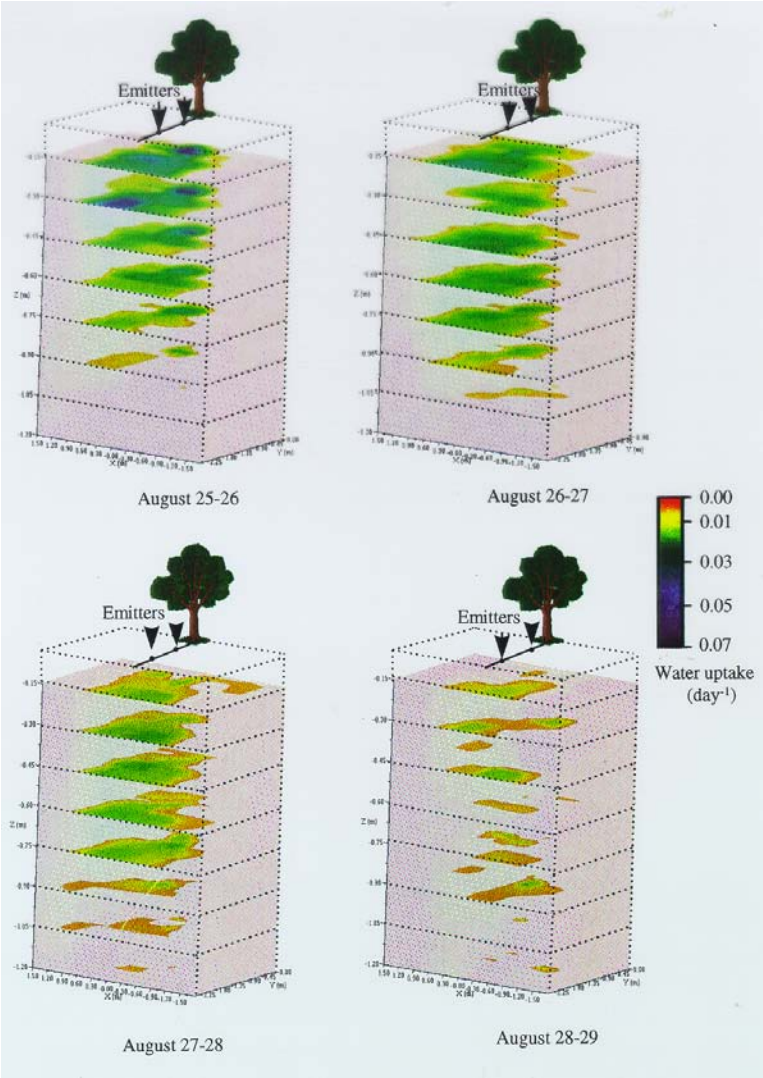
FAN JET, Paramount

Fan Jet	Clay (%)	Silt (%)	Sand (%)	Depth (cm)
Sandy clay loam	21	18	61	10
				20
				30
	27	26	47	40
				50
				60
	21	26	53	70
				80
				90
Loam	28	27	45	100
				110
				120
Clay	54	27	19	130
				140
Sandy loam	19	25	56	150
				160
loam	23	32	45	170
Sandy loam	14	12	74	180
				190
Silt clay	44	47	6	200
				210
Clay loam	29	37	34	220
				230
				240
				250
				260
				270



- Shallow sensors at 30 cm (red) respond to irrigation, except at emitter location, but less than drip site, because of larger wetted soil surface area; **NOTE: higher water content than drip;**
- Clay layer at about 120 cm (blue), resulting in uniform high water content at or above 120 cm;
- Uniform low water content at 180 cm (green) depth – **indicates absence of leaching**
- More uniform water application – **less likelihood of leaching of water and nitrates**

Compensation by Roots to Differentially Take Up Soil Water From Less-Stressed Rooting Zone, as Soil Dries



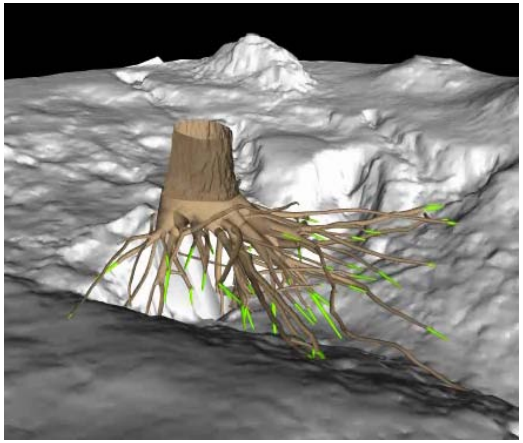
Three-dimensional spatial distribution of root water uptake for a drip-irrigated almond tree (Andreu, Schwankl and Hopmans, 1997) at Nichols Ranch.

Shifting of uptake pattern in time, controlled by local water stress conditions

Magnitude of compensation may depend on crop/tree species and level of stress

If uptake compensation occurs, the spatial root distribution becomes less important

Root Excavation – Kings River Experimental Watershed – White Fir

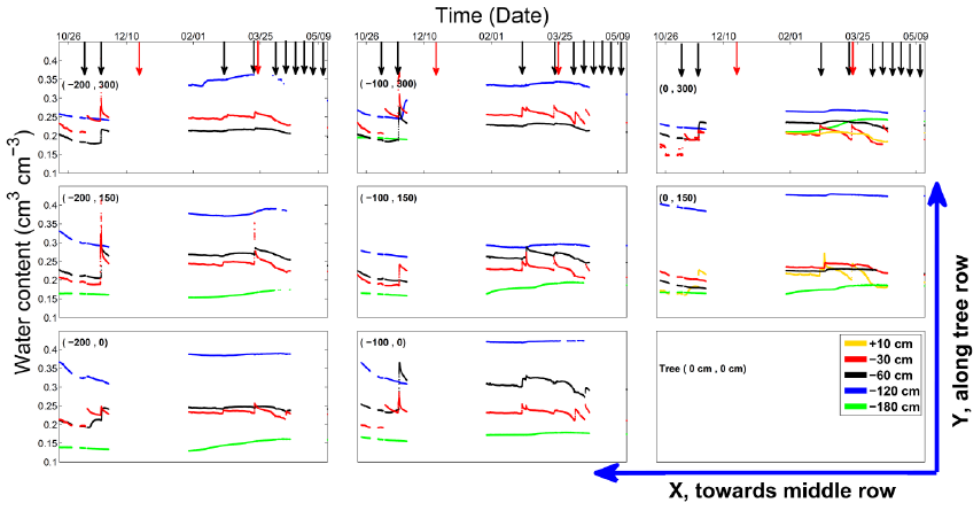


Root Distribution and Root Water/Nitrate Uptake

Trench wall method & Soil Coring

Andres Olivos/Patrick Brown

Inverse modeling, whereby local soil water content and nitrate solution measurements will be matched with HYDRUS model results. End result is spatial distribution of effective root water and nutrient uptake



Soil Solution Nitrate Concentration

Nitrate will be monitored by soil solution samplers, installed at various depths (30 – 60 – 90 cm), including some at larger depths.

Something to Think About:

- **Accept that there is no one solution for all situations, and adjust design for different soil types;**
  - Match design and management to soil type and crop needs;
  - Manage water application rates - want wide radius and managed vertical depth of wetting;
  - Manage fertigation - want to keep nutrients in root zone.

- **Leaching is minimized by:**
  - Irrigating more frequently with less water so as to minimize reliance on soil water storage for ET between irrigation events, thereby reducing probability of leaching;
  - Using micro-sprinkler rather than drip, if using same amounts and frequency, as larger soil and rooting volume is accessed with sprinkler irrigation;
  - Presence of soil layering.

- **How can we group soils hydraulically and chemically for development of guidelines which minimize leaching of water and nitrate?**

  Use soil properties: texture, structure, layering, chemical properties together with HYDRUS simulations and simplify.

Acknowledgements:

CA Almond Board
UC Davis and
Agricultural Experiment Station
NSF

Graduate Students:

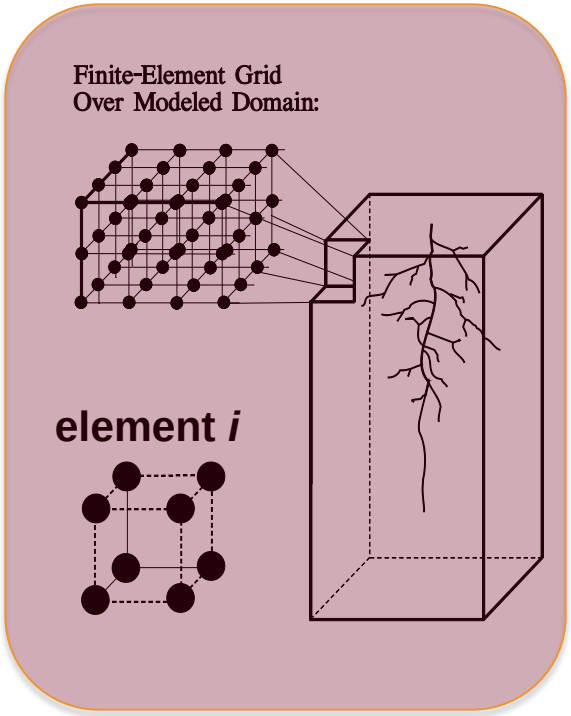
Maziar Kandalous
Andres Olivos

Coupling of Root Water With Nutrient Uptake

For each small root zone element *i*:

$$S' = f_1 Sc + f_2 N$$

Total N uptake **Passive** **Active**



S' – Total Nutrient uptake (g/day)

S – passive nutrient uptake (coupled with root water uptake)

c – nitrate concentration in soil solution

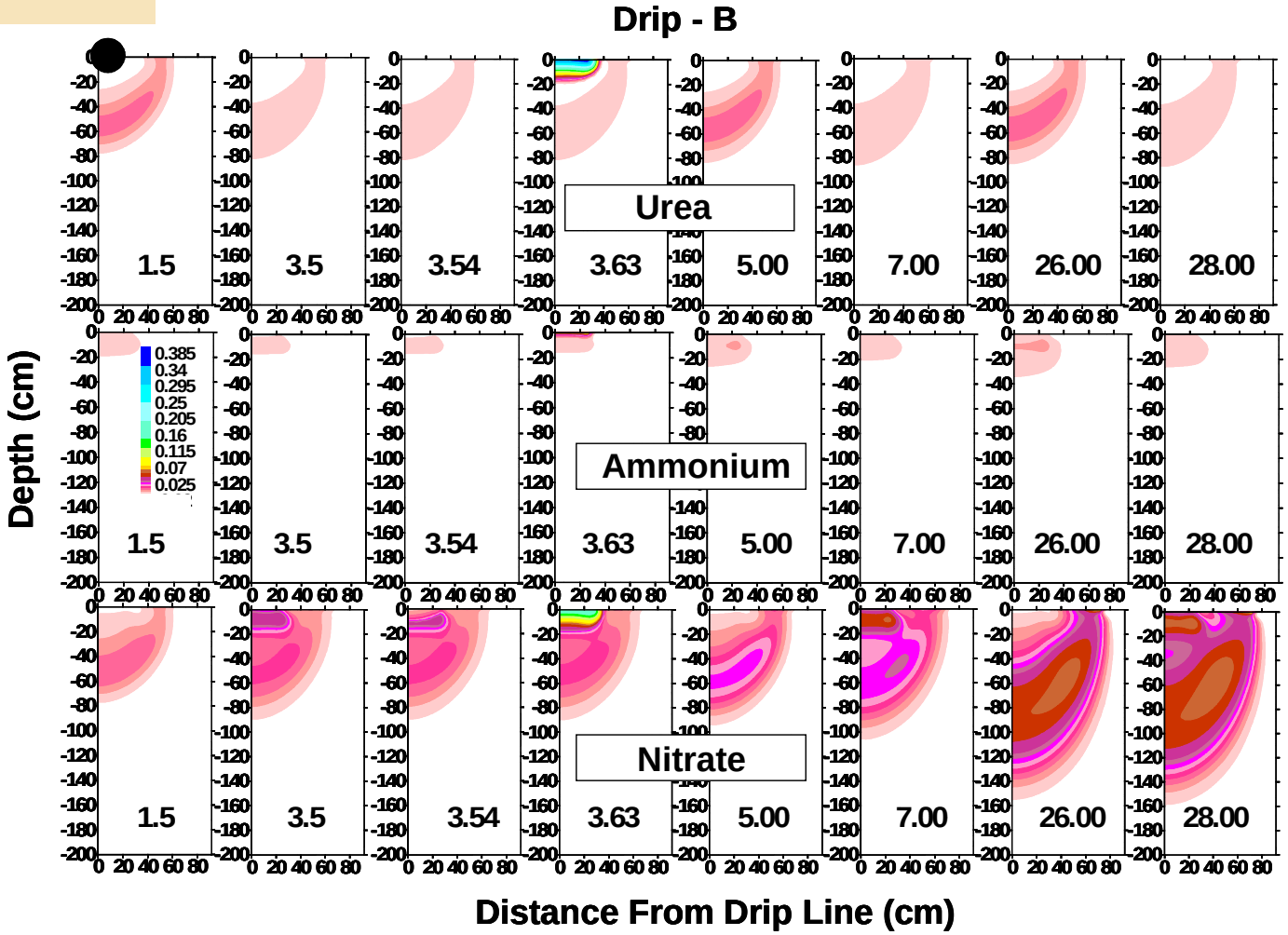
N – active nutrient uptake (independent of root water uptake)

Values of f_1 and f_2 partition total nitrate uptake between passive (S) and active (N).

The relative magnitude of N (active uptake) may be controlled by (1) availability of nitrate by root water uptake (S), relative to total tree nutrient demand.

Fate of Urea/Ammonium/Nitrate Fertilizer, As Applied By Surface Drip System - HYDRUS

Hanson BR, Šimůnek J, Hopmans JW. 2006. Numerical modeling of urea-ammonium-nitrate fertigation under microirrigation. Ag Water Mgt 86:102–13.



Organic matter considerations:

How to Manage Organic Matter for Tree Nutrition

William R. Horwath, Department Land, Air and Water Resources

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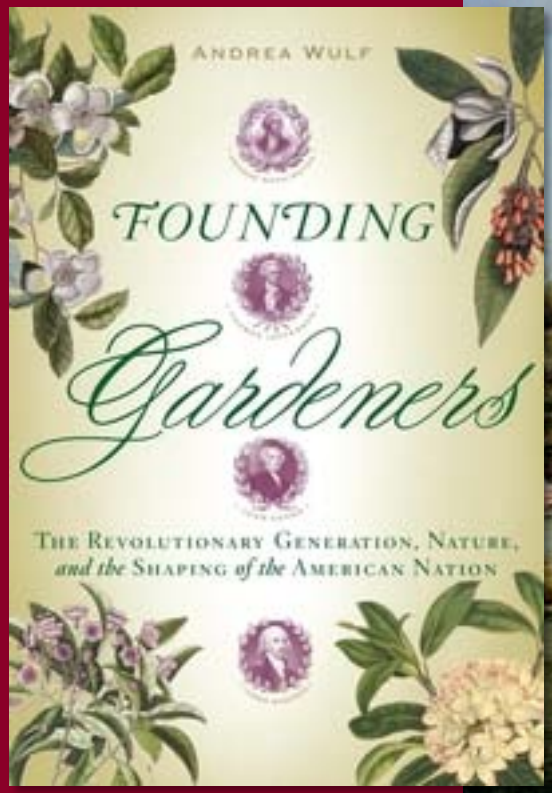


The founding fathers were infatuated with manure.

Talking Points

Soil organic matter:

- What is it?
- What is its function?

Managing soil organic matter

- Cover crops, manure and compost

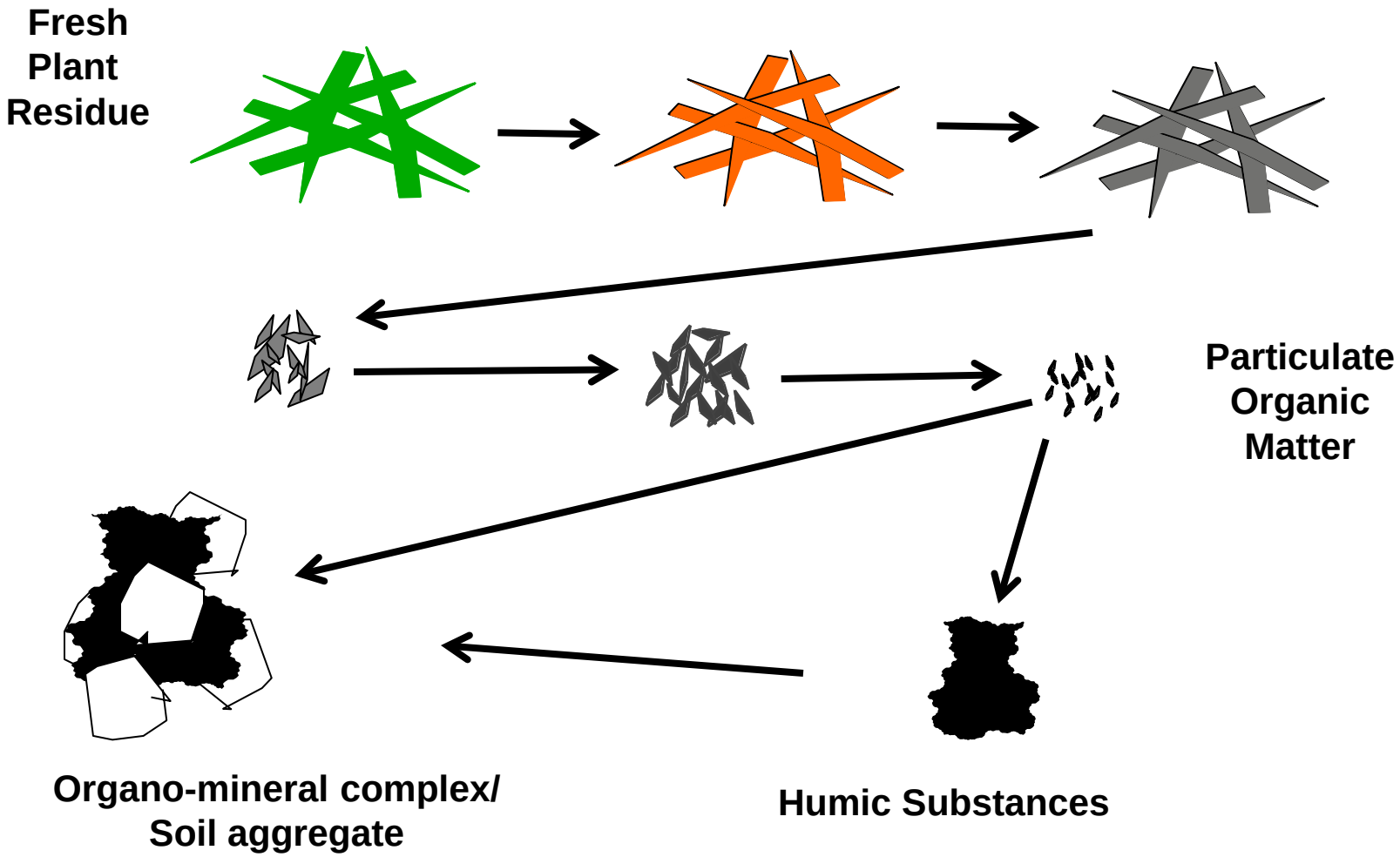
Manipulating nutrient availability

- Optimizing synchrony
- Preventing nutrient loss

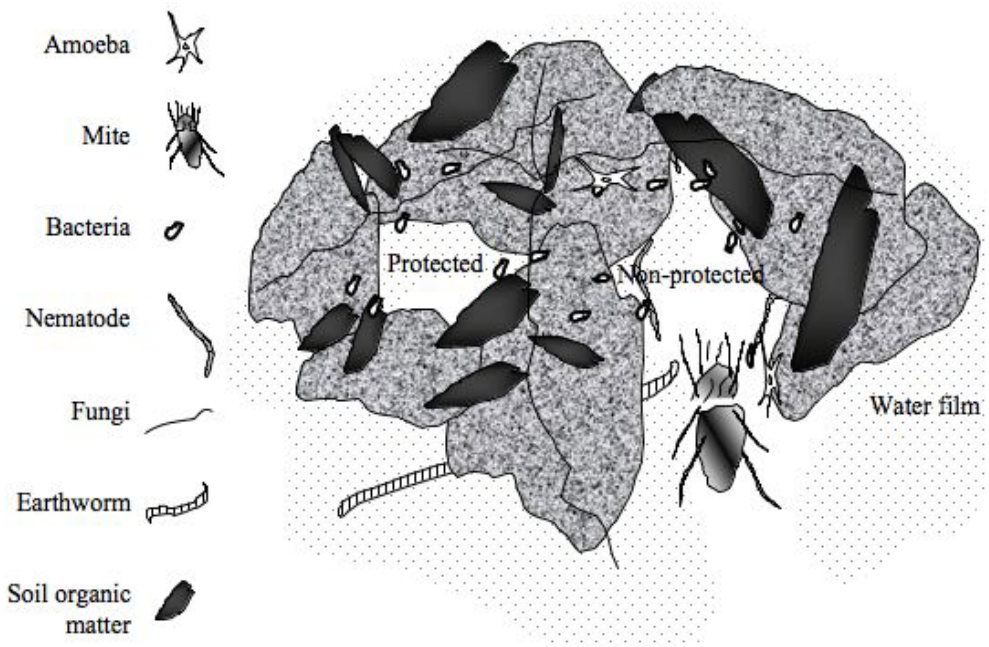
Soil Organic Matter is Humus

Humus is a complex and recalcitrant mixture of brown and dark brown substances derived from plant biomass components and soil organisms

Plant Residue Decomposition and Soil Organic Matter Formation

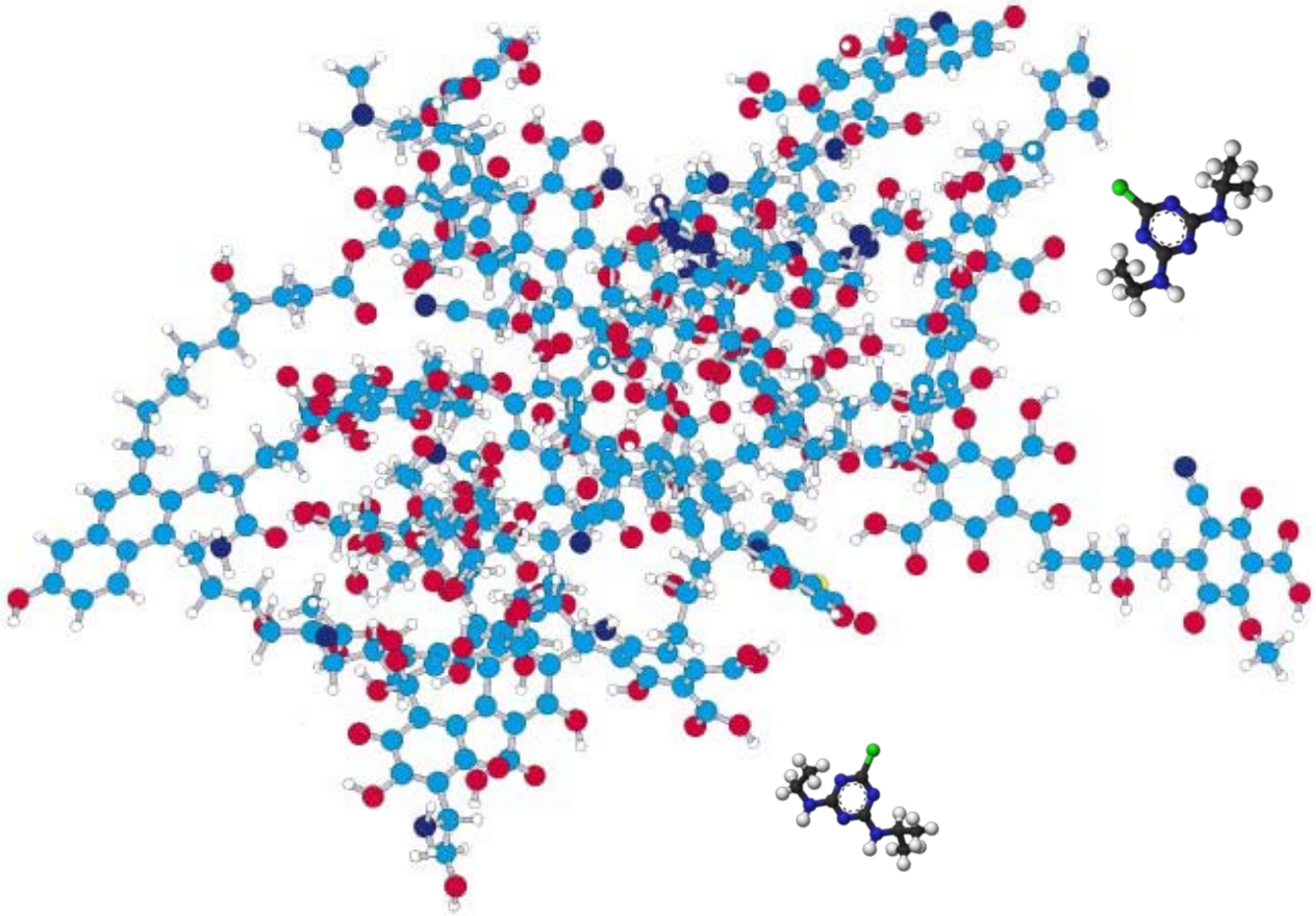


Soil Organic Matter



- Cation Ion Exchange capacity
  - 300 to 700 cmol(+)/kg
- Capacity to chelate metals
- Enhance soil physical properties
  - Water Holding capacity
- Source of nutrients
  - C/N/S/P = 100/10/1/1
- Positive influence on soil properties

Soil Organic Matter
And It's Role In Affecting The Efficacy Of Pesticides



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Soil Organic Matter

Fraction	C:N Ratio
SOM	8-12:1
Plant Litter	20-400:1
Bacteria	4 to 7:1
Fungi	8 to 12:1

SOM Element %	
55%	C
4-5%	N
0.5%	P
0.5%	S

Living

Soil Biomass (fungi, bacteria, fauna) 2-5%

Nonliving

Non humic substances 20-30% of SOM

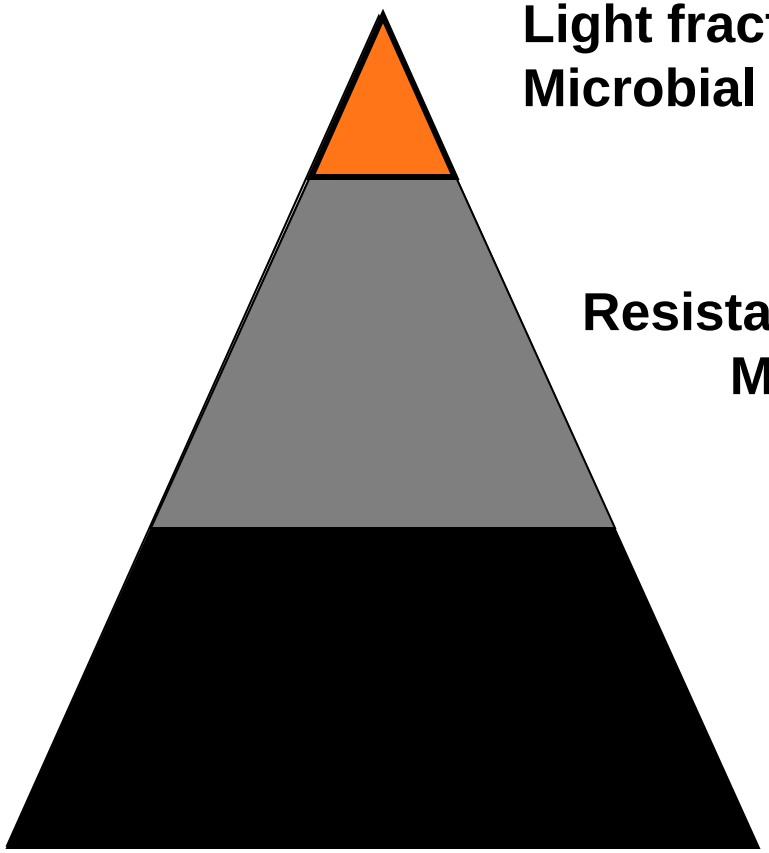
Humic substances 60-80% of SOM

Soil Organic Matter

Labile SOM
Active fraction
~2 year old

Resistant SOM
~5 to 100 years old

Stable SOM
>1000 years old

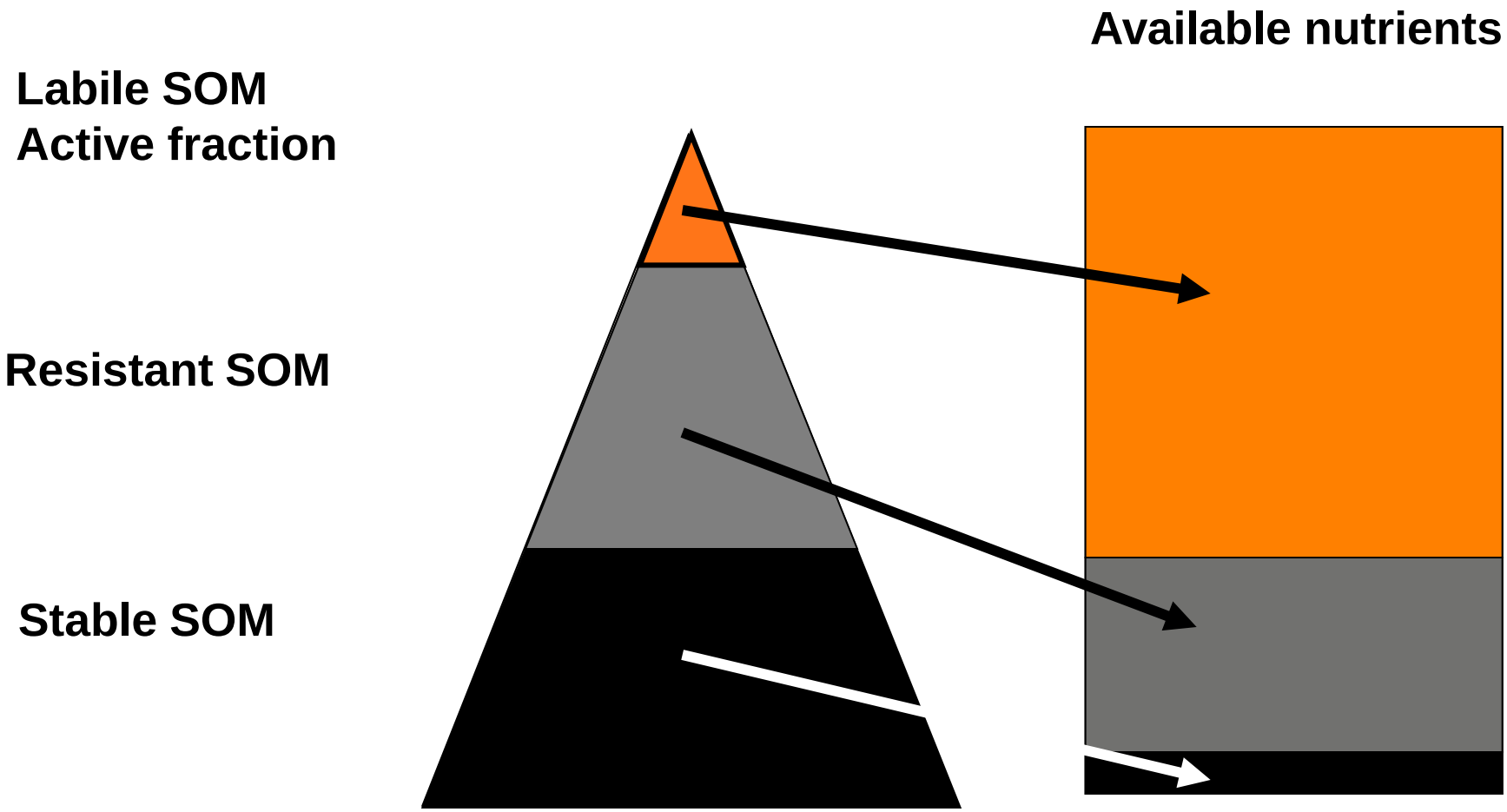


Light fraction/
Microbial biomass

Resistant Organic Matter

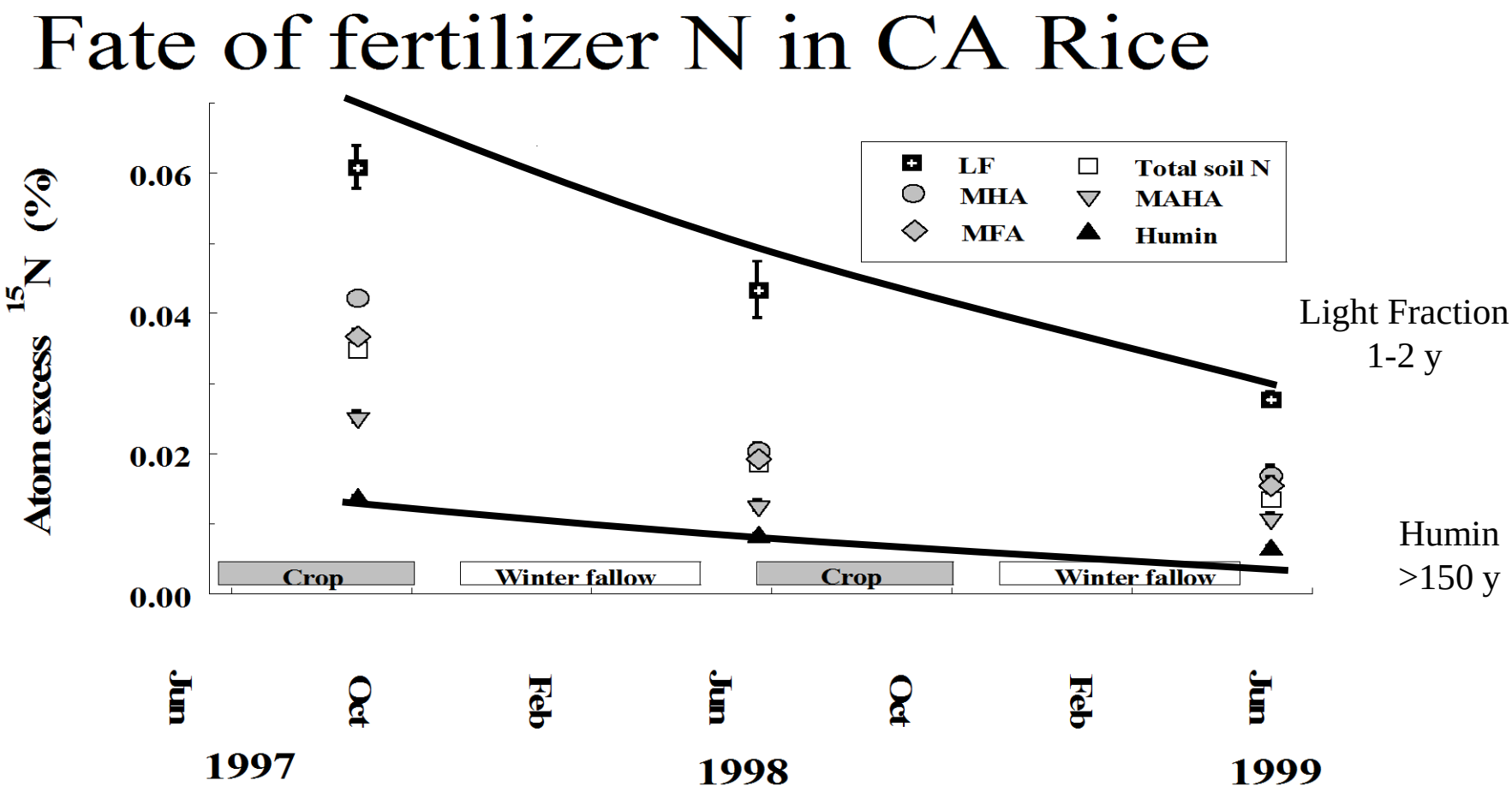
Very Stable Organic Matter

Contribution of Soil Organic Matter Fractions to Available Soil Nitrogen

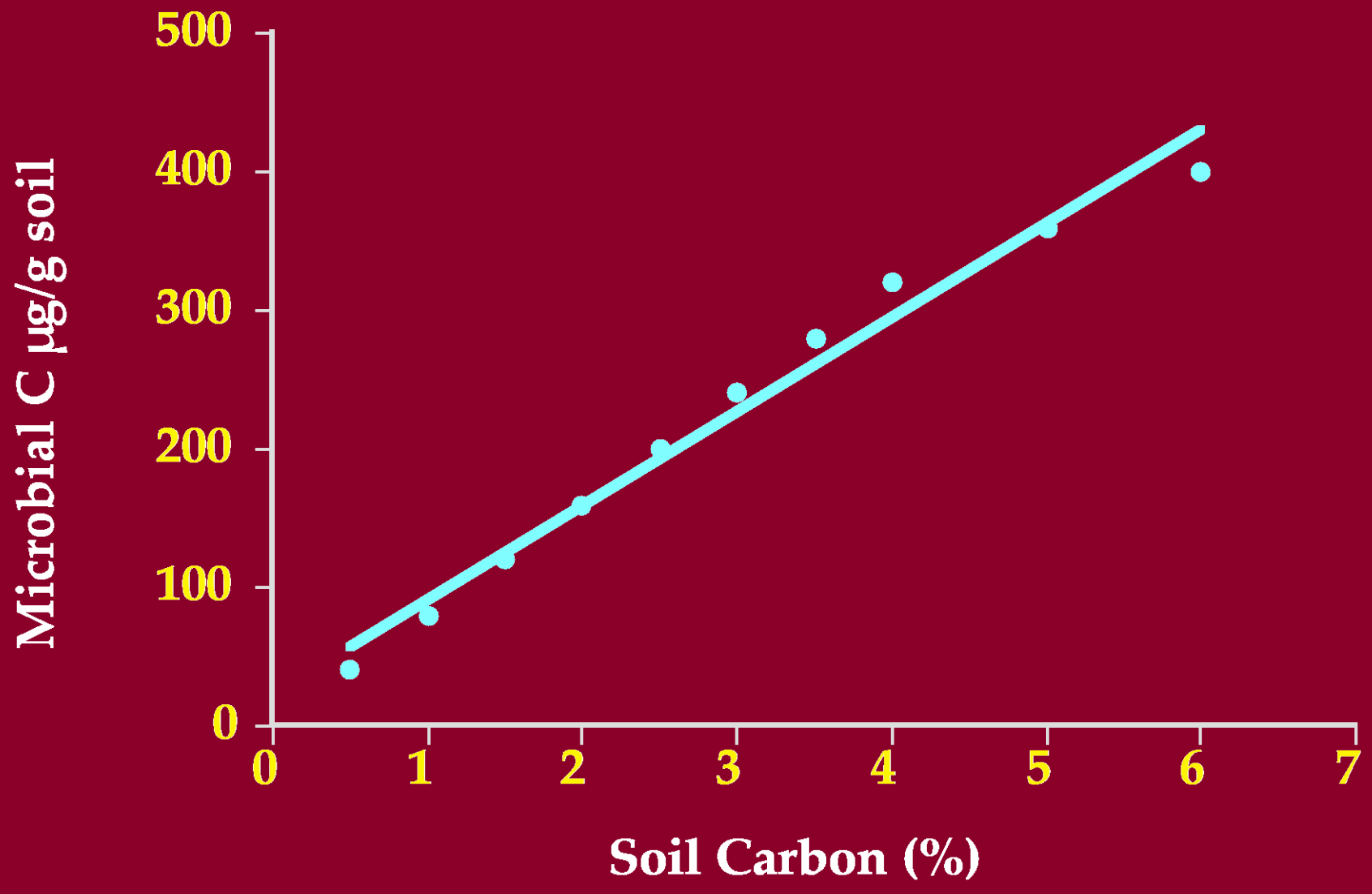


Classical Humic Fractions (operationally defined)

Nitrogen turnover in rice through operationally defined organic matter fractions



Relationship of soil Carbon to Microbial Carbon



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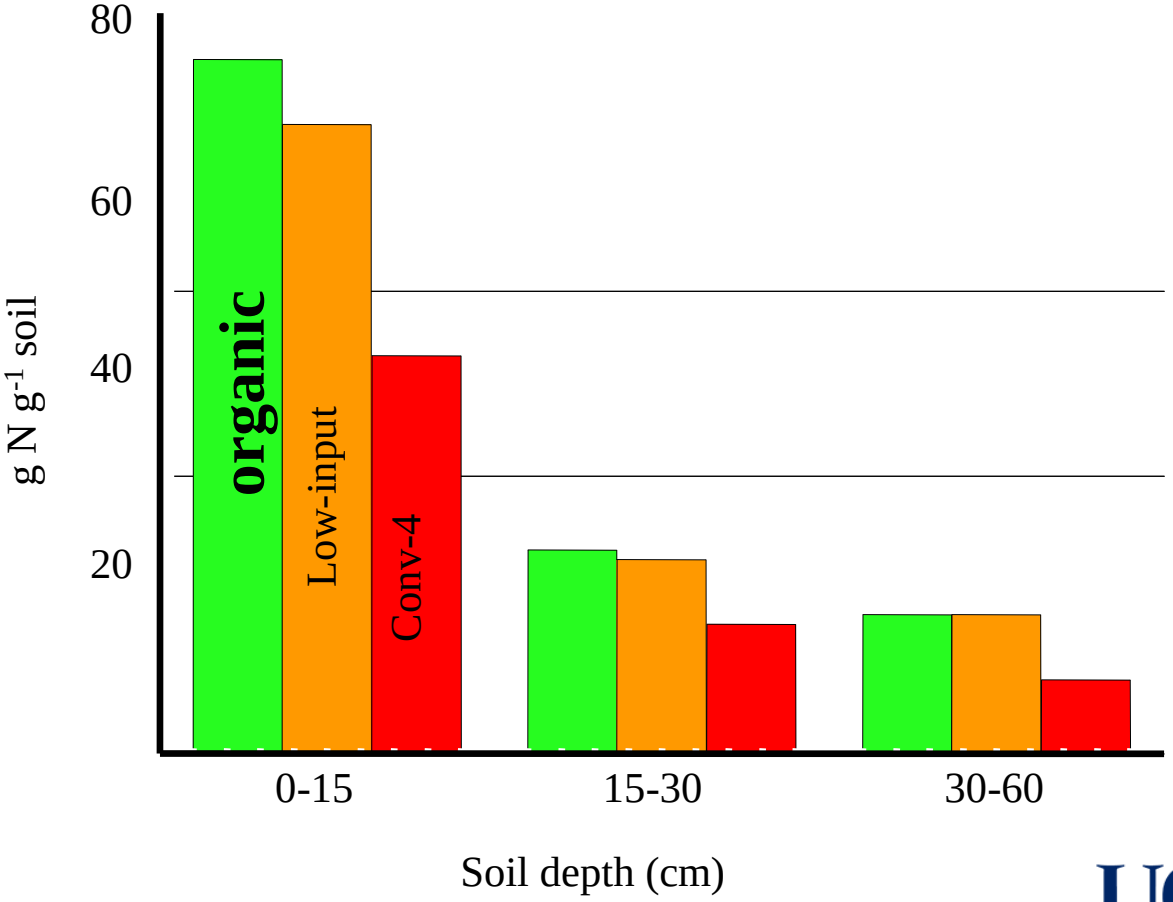
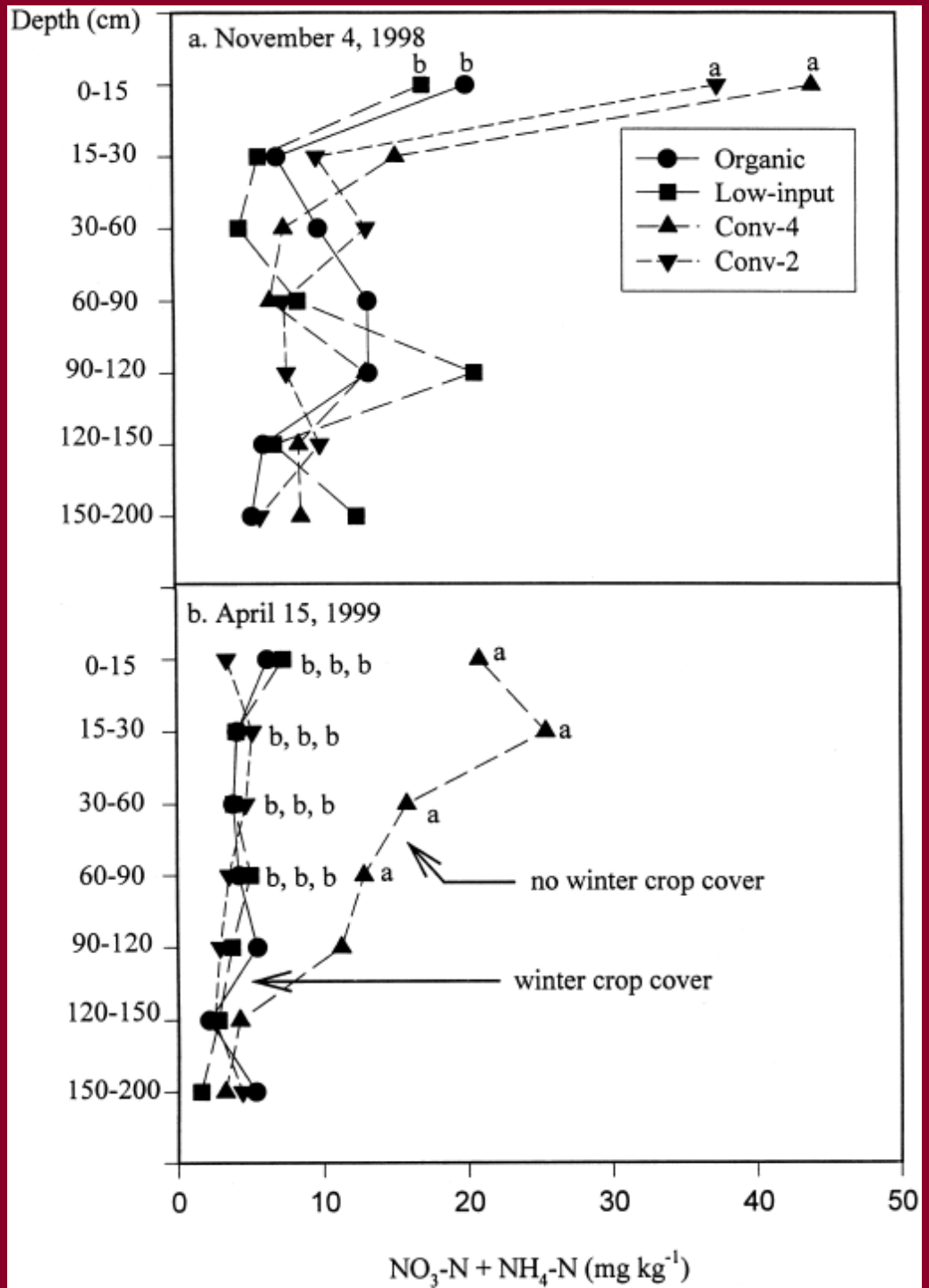
Microbial Nutrients

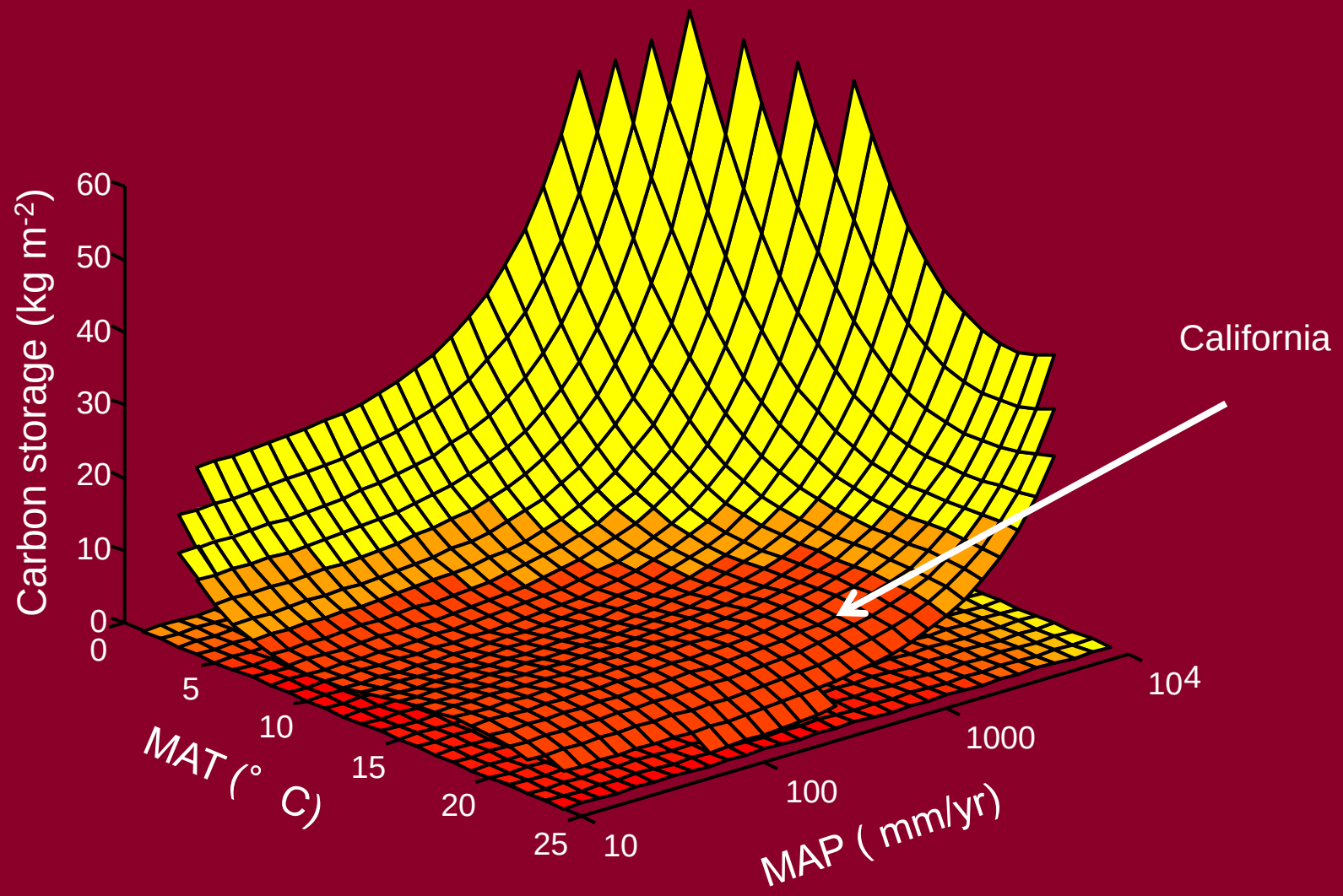
Microbial Biomass after 10 years of organic, integrated and conventional management at SAFS



Cover crop usage and management for soil organic matter can prevent N losses.



Soil C Storage as a Function of Climate



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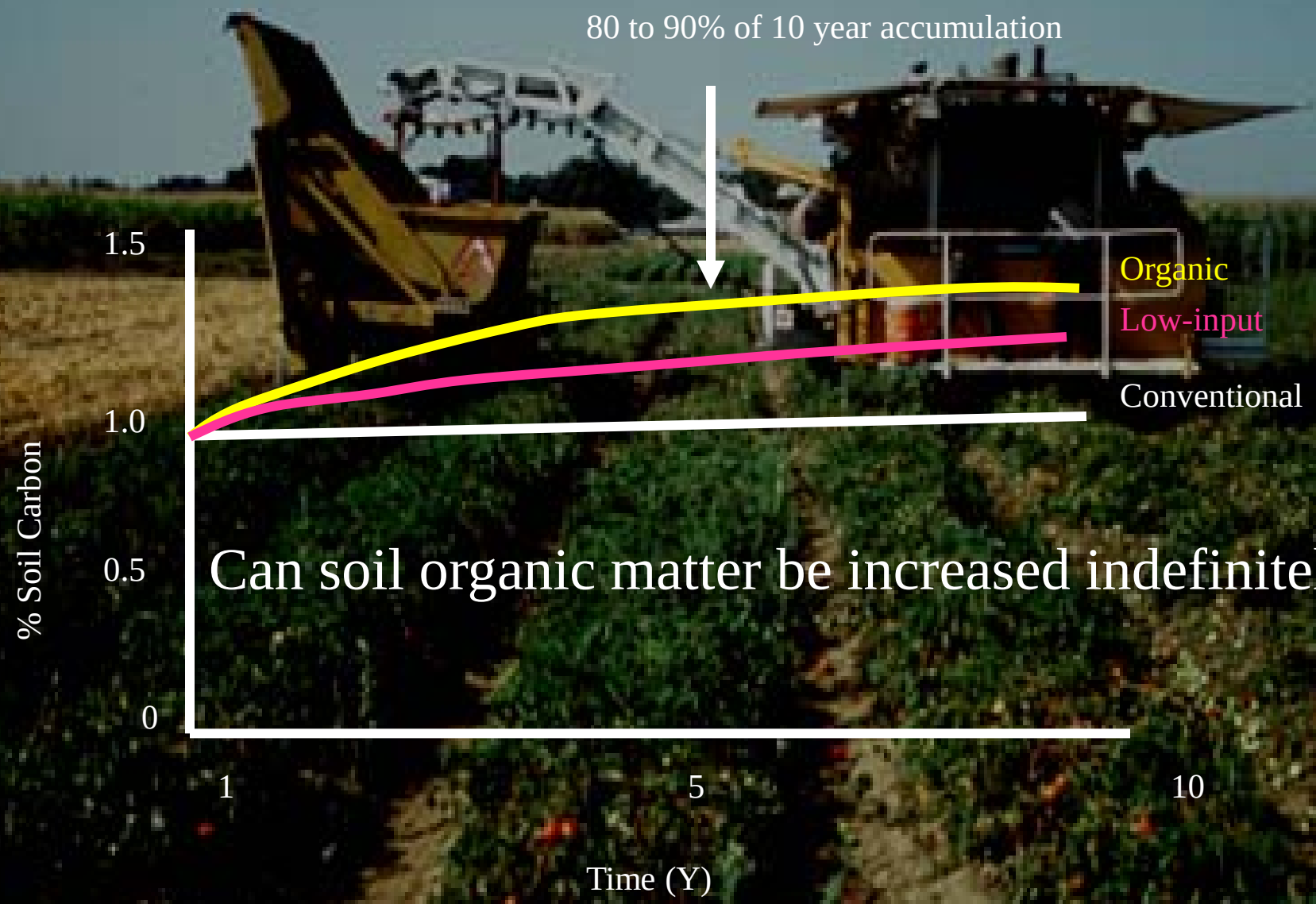
Soil Carbon Change over 10 years



Can soil organic matter be increased indefinitely?

Distribution of N and its location in a *Populus* plantation (tree and soil)

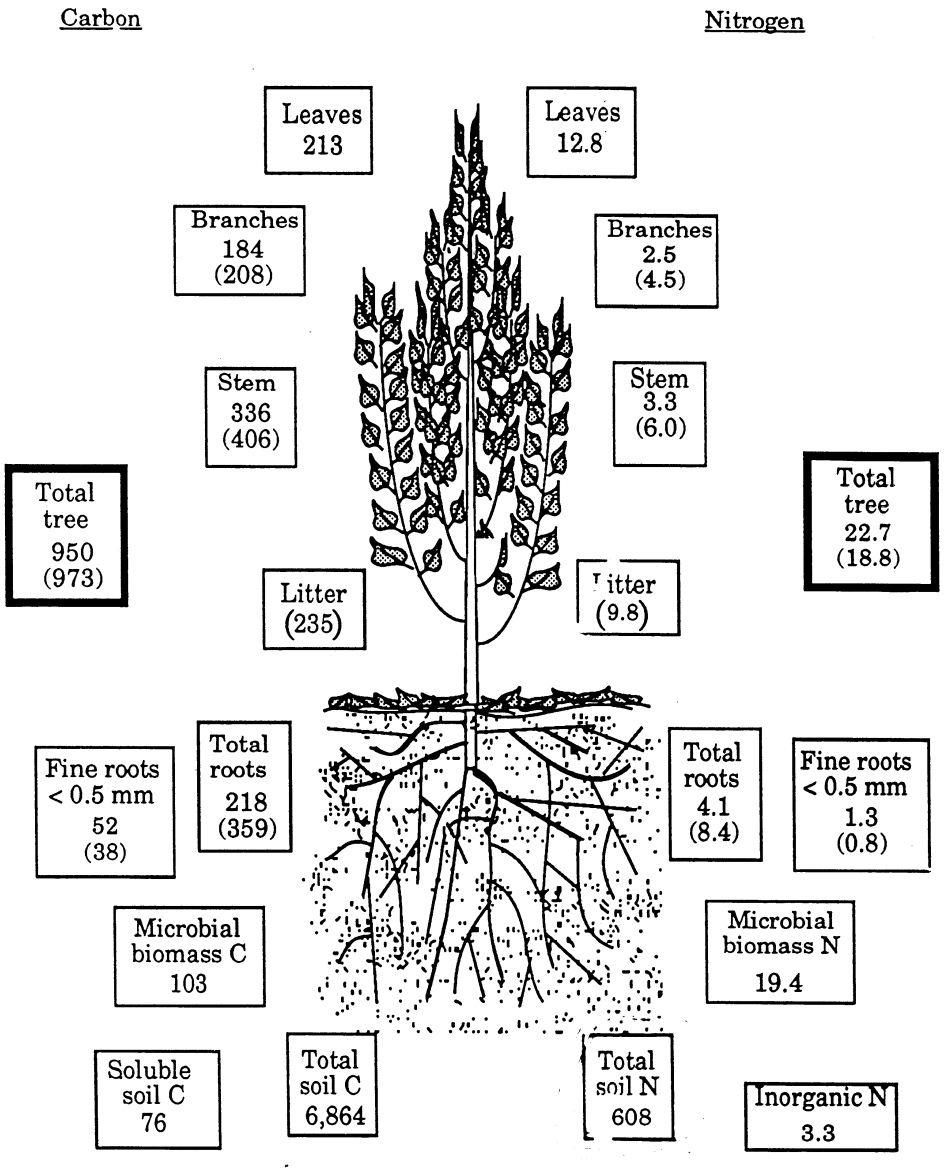


Figure 4.1. The distribution of C and N (g) in the *Populus*-soil system for July 19, 1990 labeled trees sampled August 2, 1990. The values in parentheses represent the amount of C and N for the November 2, 1990 sampling.

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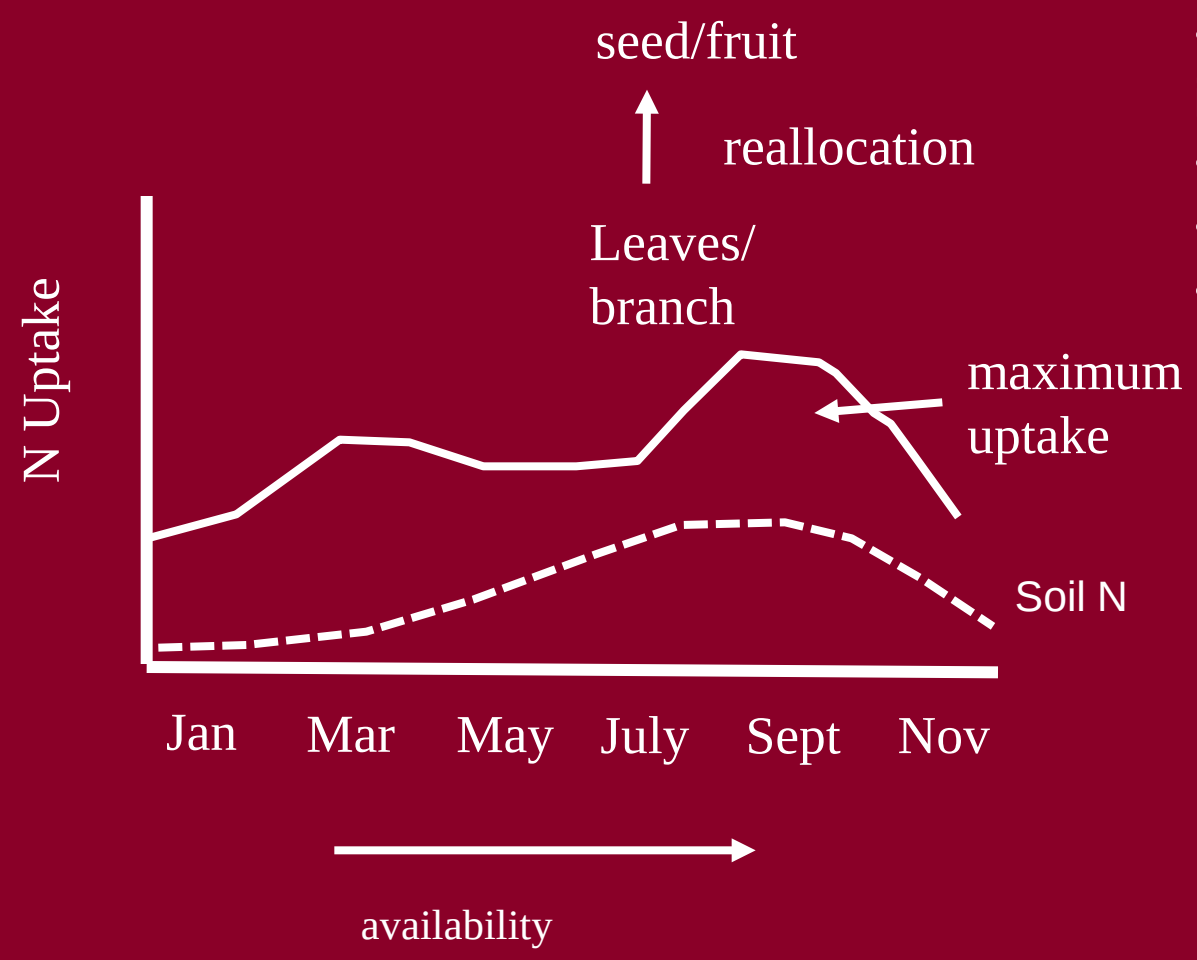
Fertilizer & Soil N Availability and Synchrony in Tree Crops



- **Manure /cover crop**
  - **Timing of incorporation**
  - **decomposition**
  - **quality (C/N)**
  - **amount**

Soil N not sufficient

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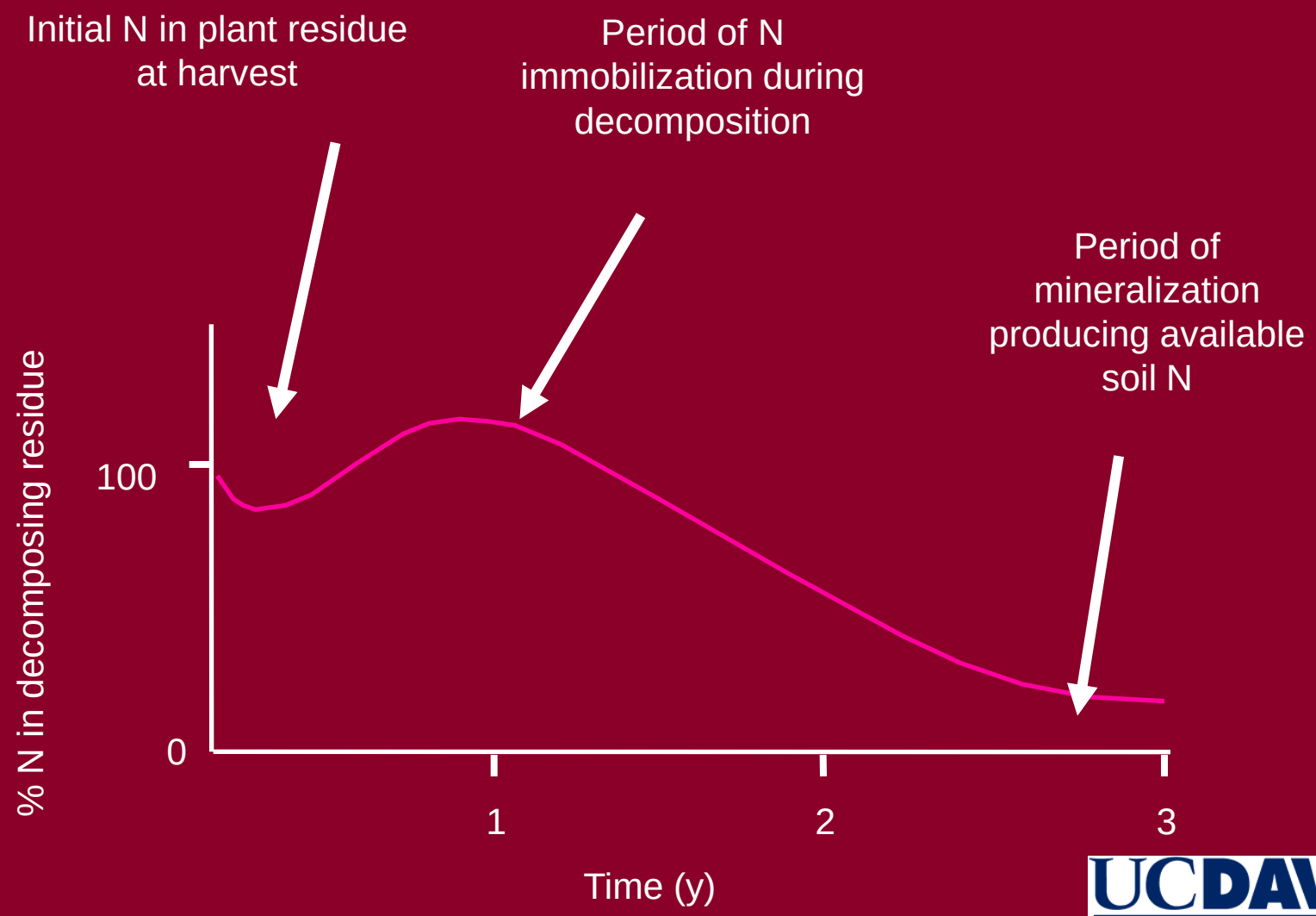
Fate of Plant Residue (cover crop, manure, compost) N During Decomposition



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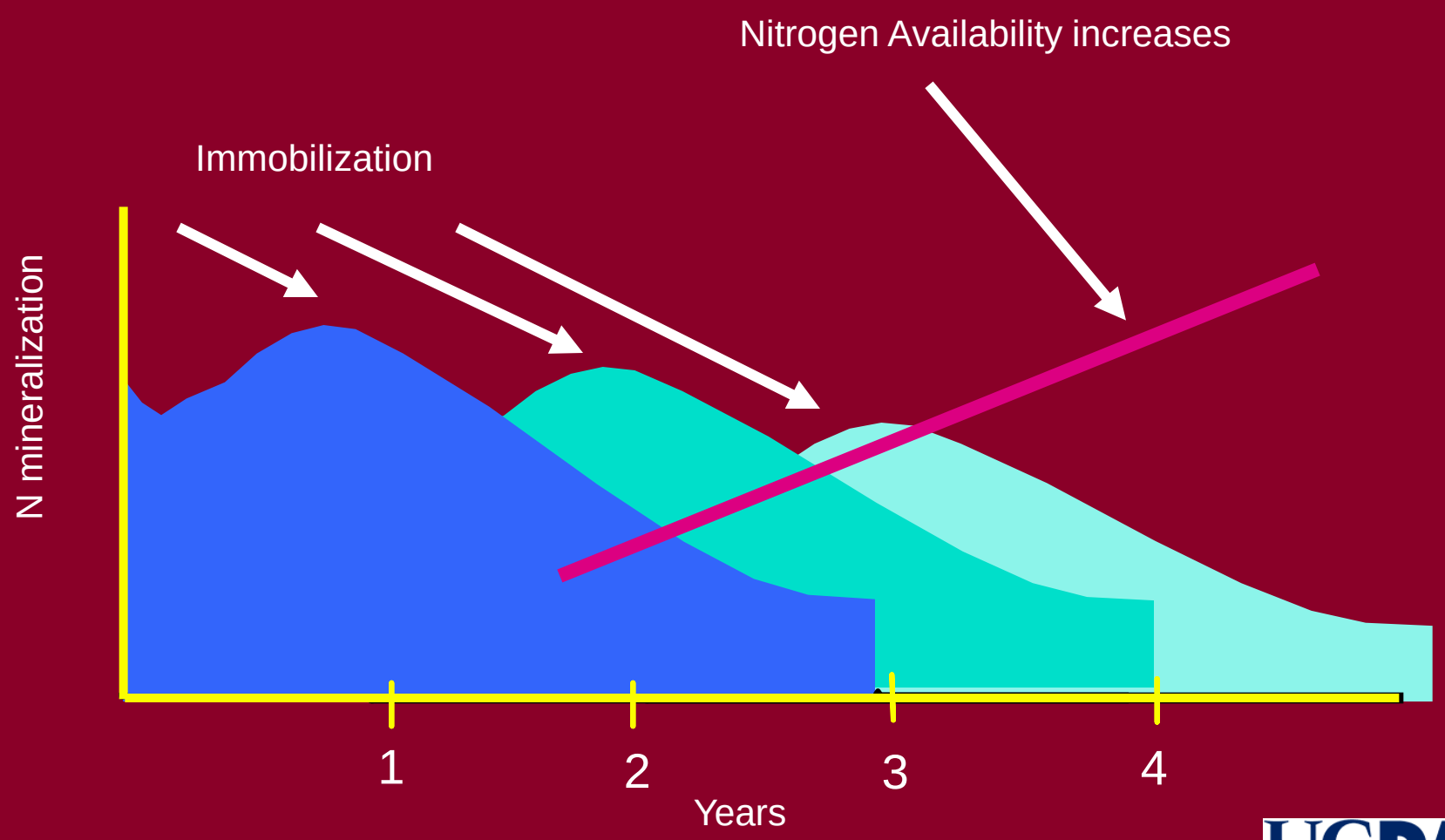
Long-Term Nitrogen Availability Under Consistent Management To Increase Soil Organic Matter



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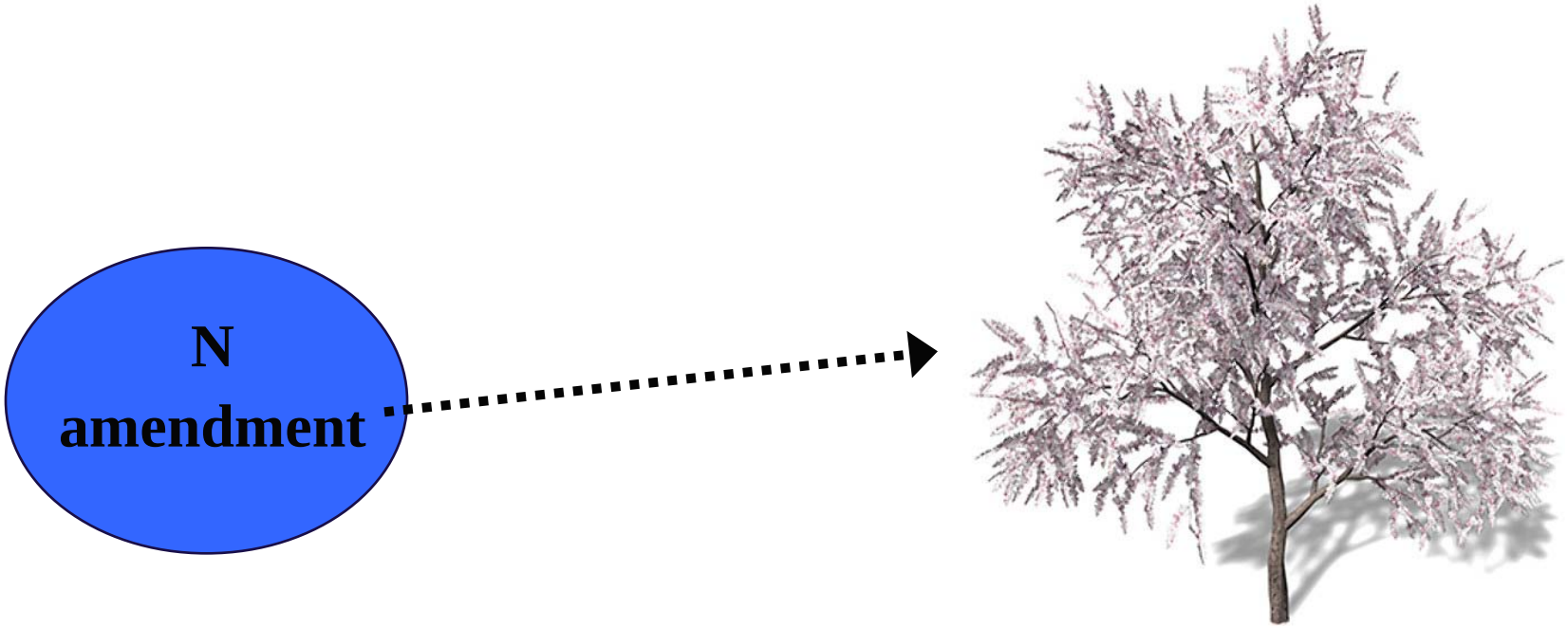
Fertilizer and Soil N Availability

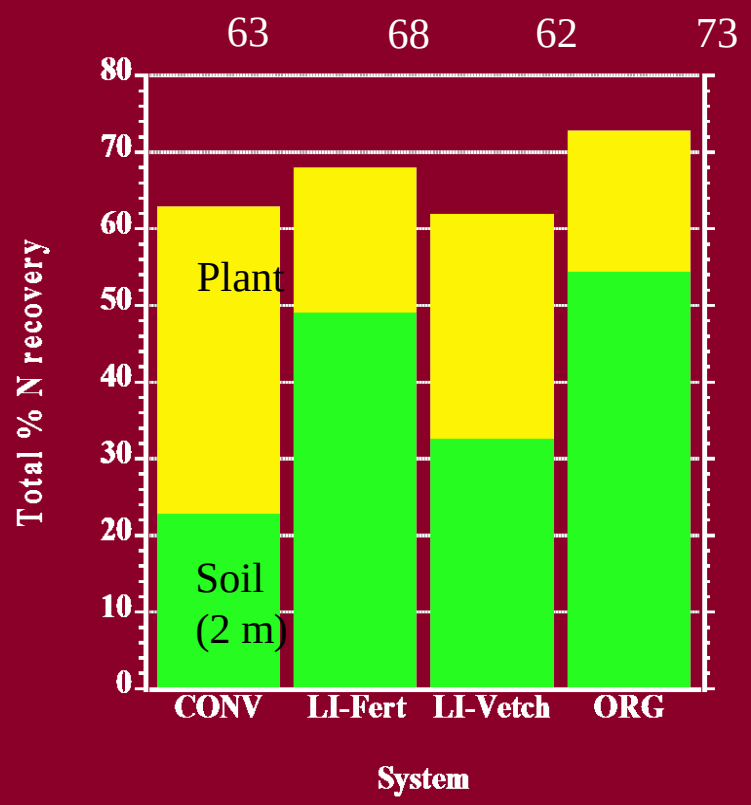


Is fertilizer N directly taken up by trees?

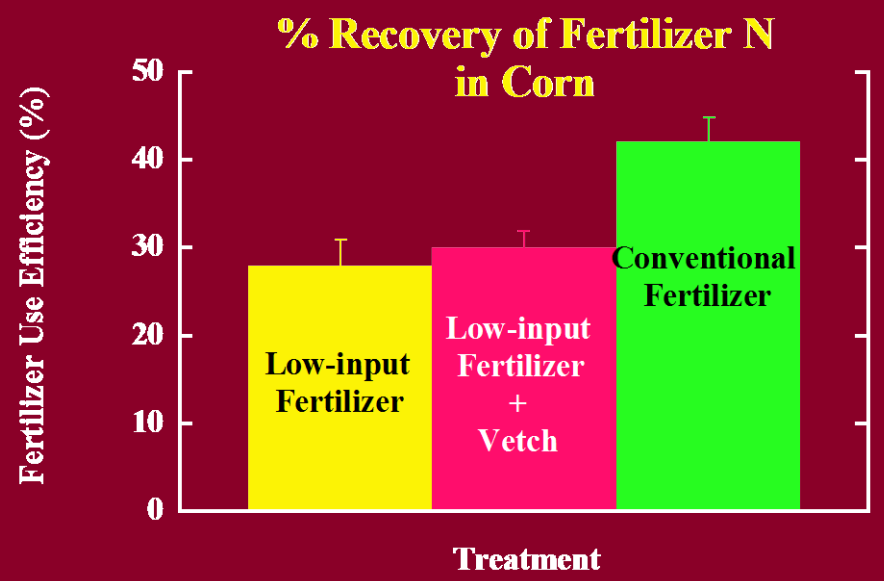
Systems N Recovery Using Stable N Isotope Methods SAFS

N allocation differs by system

No significant difference in N recovery



Fertilizer use highest in conventional management



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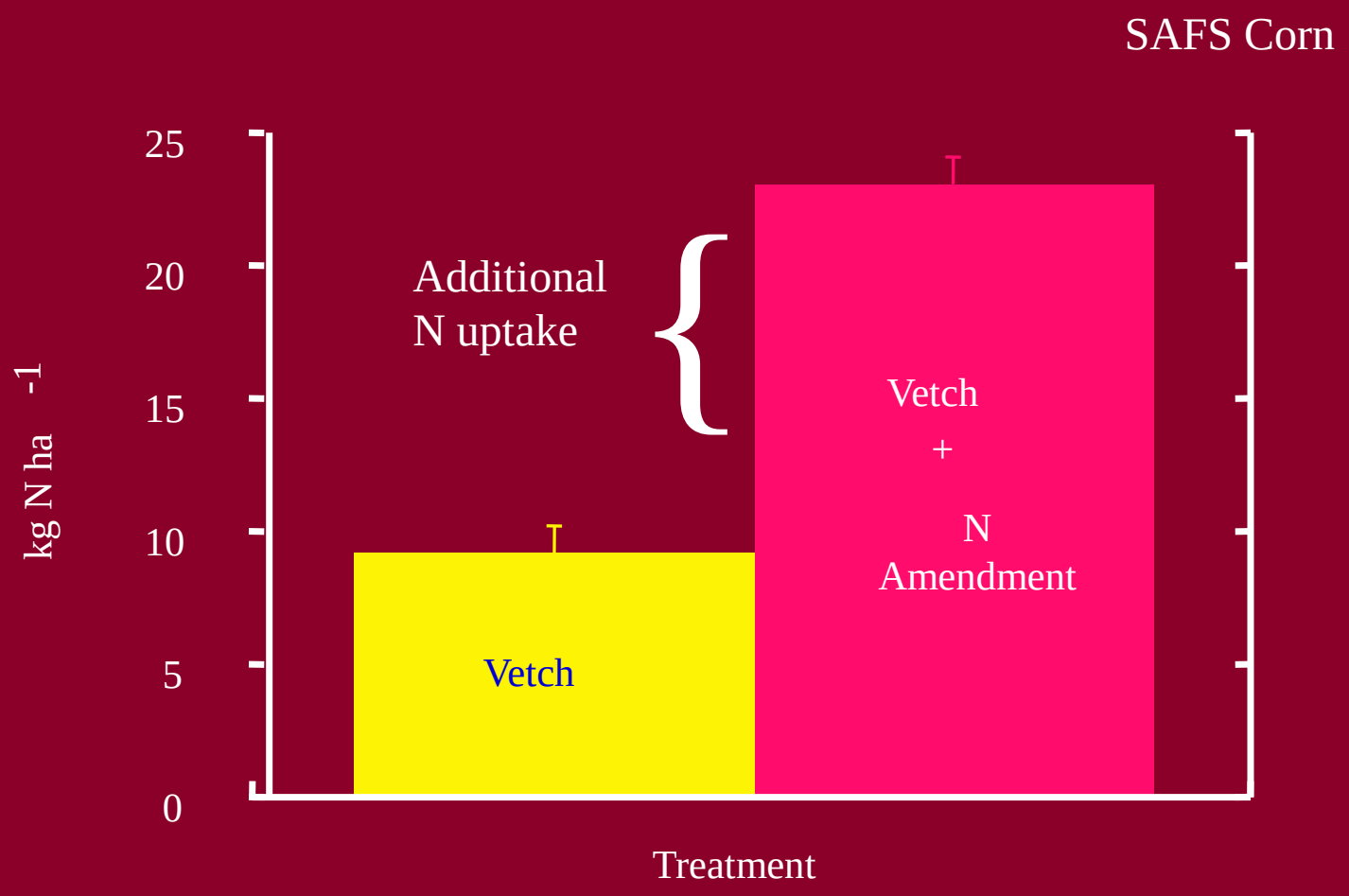
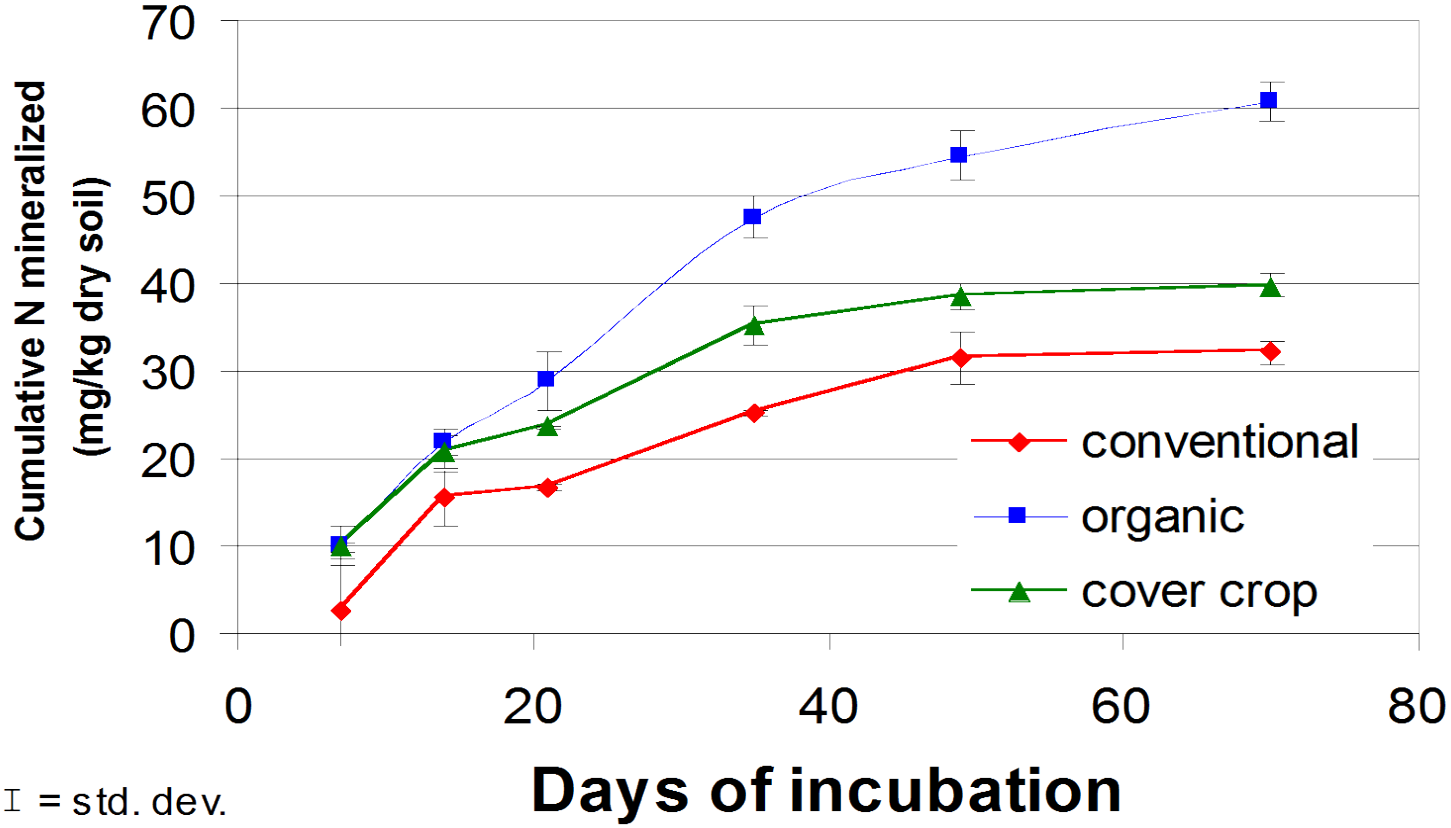
Fertilizer and Soil N Availability



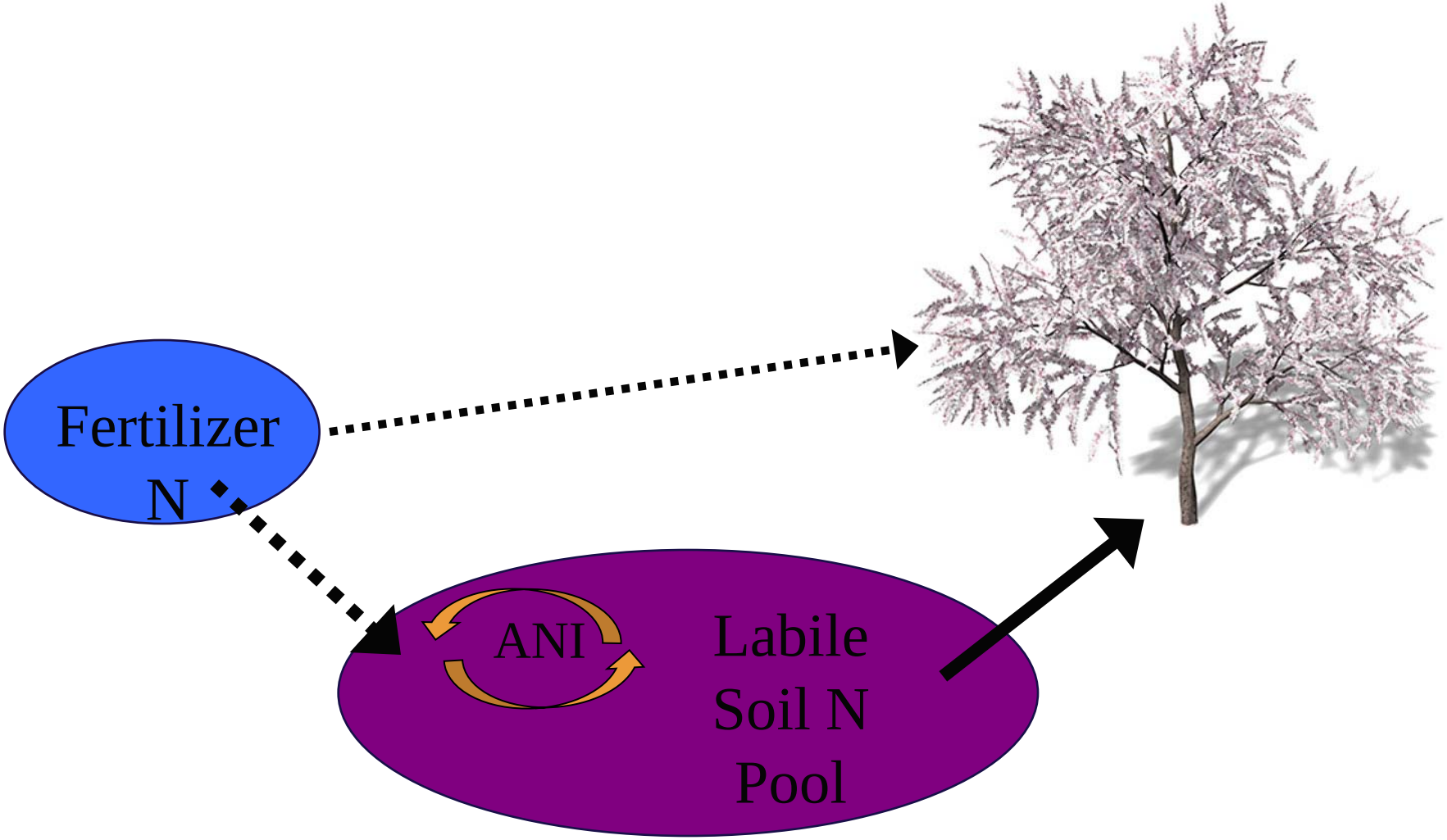
Fertilizer N causes additional uptake of soil N

Nitrogen Mineralization Potential in Different Farming Systems



I = std. dev.

Fertilizer and Soil N Availability



Fertilizer management can change pathways and availability of of N to the tree

Summary

The management of soil organic matter is essential to increase and maintain almond productivity

Soil organic matter provides a source of nutrients to ensure adequate tree nutrition (provides resiliency).

Appropriate combination of amendments can increase synchrony of nutrient delivery

- Limiting factor is the soil can only store finite N
- Key is to manipulate the size of mineralizable N pool

Organic management prevents nutrient loss

Interactions of amendments with other amendments and soil nutrient pools needs further research to fine tune nutrient delivery

P2G Progressive Genetics Group

growing ADVANTAGE
The Almond Conference

P2G Progressive Genetics Group

Moderator: Richard Waycott, ABC

Presenters:

Jack Poukish, Sierra Gold Nurseries

John Ireland, Fowler Nurseries

Chuck Fleck, Fowler Nurseries

John Duarte, Duarte Nursery


P2G™
Progressive Genetics
Group

- Dave Weil, Varieties International
- Rootstocks from U.S., Europe, Russia
- 2007: P2G™ Founded with Four Member Nurseries
- P2G™ Mission:

  Dedicated to the Professional and Ethical Introduction of Novel Rootstocks and Varieties to the Diverse Orchard Industries

Four P2G™ Nurseries:

Bright's Nursery

DUARTE TREES & VINES

Fowler NURSERIES, INC. 1912 2012

SG Sierra Gold Nurseries

P2G™

Why Is P2G™ of Interest to Almond Growers?

Why Should you Care?

P2G™ Works in Tandem with Breeding Programs Worldwide to Bring Interesting Plant Material to California for Testing.

From This Work... We Bring Information To Growers.

P2G™ is a Service Organization for the Industry.....Bringing New and Innovative Solutions to Almond Growers.

P2G™ Combines the Strength of Four California Nurseries

Advantages of Clonal Rootstocks

- Uniform Vigor and Production
- Hybrids
  - Hybrid Vigor
  - Adaptation and Resistance Traits Associated with Both Hybrid Parents

P2G™ Rootstocks for Almonds

- **Empyrean®1**
  - Peach X Peach Hybrid
  - Originated in Italy
- **Bright Hybrid®5**
  - Peach X Almond Hybrid
  - Selected by Bright's Nursery
- **Krymsk®86**
  - Peach X Plum Hybrid
  - Originated in Russia

Empyrean® 1 Rootstock

- **High Vigor**
  - **Large Tree Canopy and Trunk Size**

Trunk Cross Sectional Area:

5th Leaf, Stanislaus County:

Nonpareil	151% of Nemaguard
Carmel	152% of Nemaguard

Data from Roger Duncan, UCCE Stanislaus`

4th Leaf, Kern County:

Nonpareil	126% of Nemaguard

3rd Leaf, Colusa County:

Nonpareil	145% of Lovell

Empyrean® 1 Rootstock

- **High Vigor**
  - **Large Tree Canopy and Trunk Size**
  - **Reaches Productive Harvests Sooner**

Almond Yields:

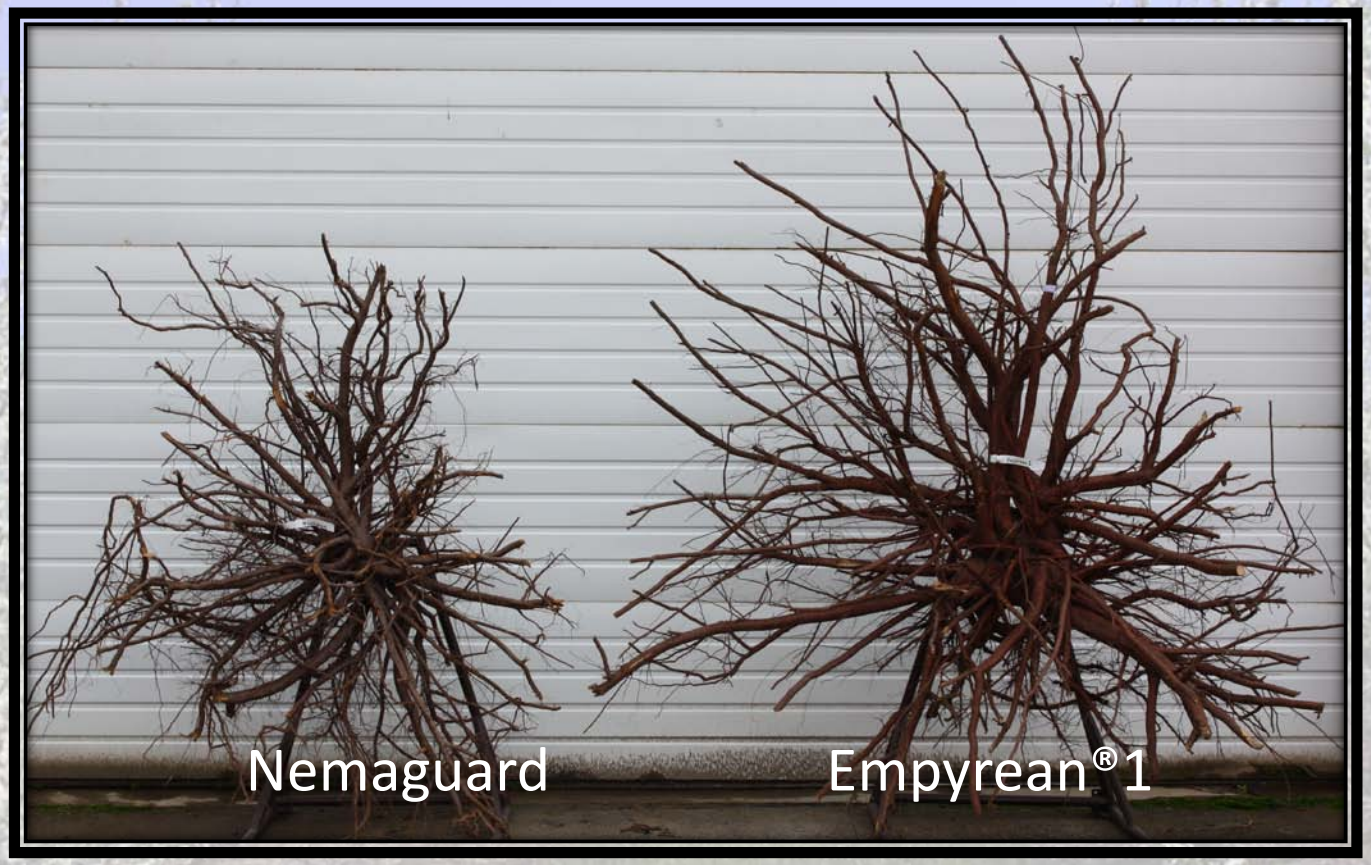
Year	Variety	Lbs/ Acre	% of Nemaguard
2008	Nonpareil	4381	161%
	Carmel	2719	147%
2009	Nonpareil	3285	106%
	Carmel	4155	190%
2010	Nonpareil	2668	137%

Data from Roger Duncan, UCCE Stanislaus`

Empyrean® 1 Rootstock

- High Vigor
  - Large Tree Canopy and Trunk Size
  - Reaches Productive Harvests Sooner
- Good Anchorage
  - Vigorous Root System

Empyrean® 1 Rootstock



Empyrean® 1 Rootstock

- High Vigor
  - Large Tree Canopy and Trunk Size
  - Reaches Productive Harvests Sooner
- Good Anchorage
  - Vigorous Root System
- Adapted to Soils Suitable for Nemaguard
  - Root Knot Nematode Resistance Similar to Nemaguard

Empyrean® 1 Rootstock

- Fast Growing
- Quick to Achieve Impressive Harvests
- Medium and Lighter Soils
- Good Anchorage

Bright Hybrid®5 Rootstock

- Selected in an Orchard with High pH
- Vigor
  - Intermediate Between Nemaguard and Hansen 536
  - Tree Slightly Wider than Nemaguard

Trunk Cross Sectional Area:

5th Leaf - Stanislaus County:

Nonpareil 110% of Nemaguard

3rd Leaf - Madera County:

Nonpareil 122% of Nemaguard

3rd Leaf - Colusa County:

Nonpareil 129% of Lovell

Bright Hybrid®5 Rootstock

- Selected in an Orchard with High pH
- Vigor
  - Intermediate Between Nemaguard and Hansen 536
  - Tree Slightly Wider than Nemaguard
- Productivity – Can exceed that of Nemaguard
- Good Anchorage - Similar to Hansen 536
- Root Knot Nematode Resistance
  - Similar to Nemaguard
- Wet soils performance
  - Similar to Nemaguard

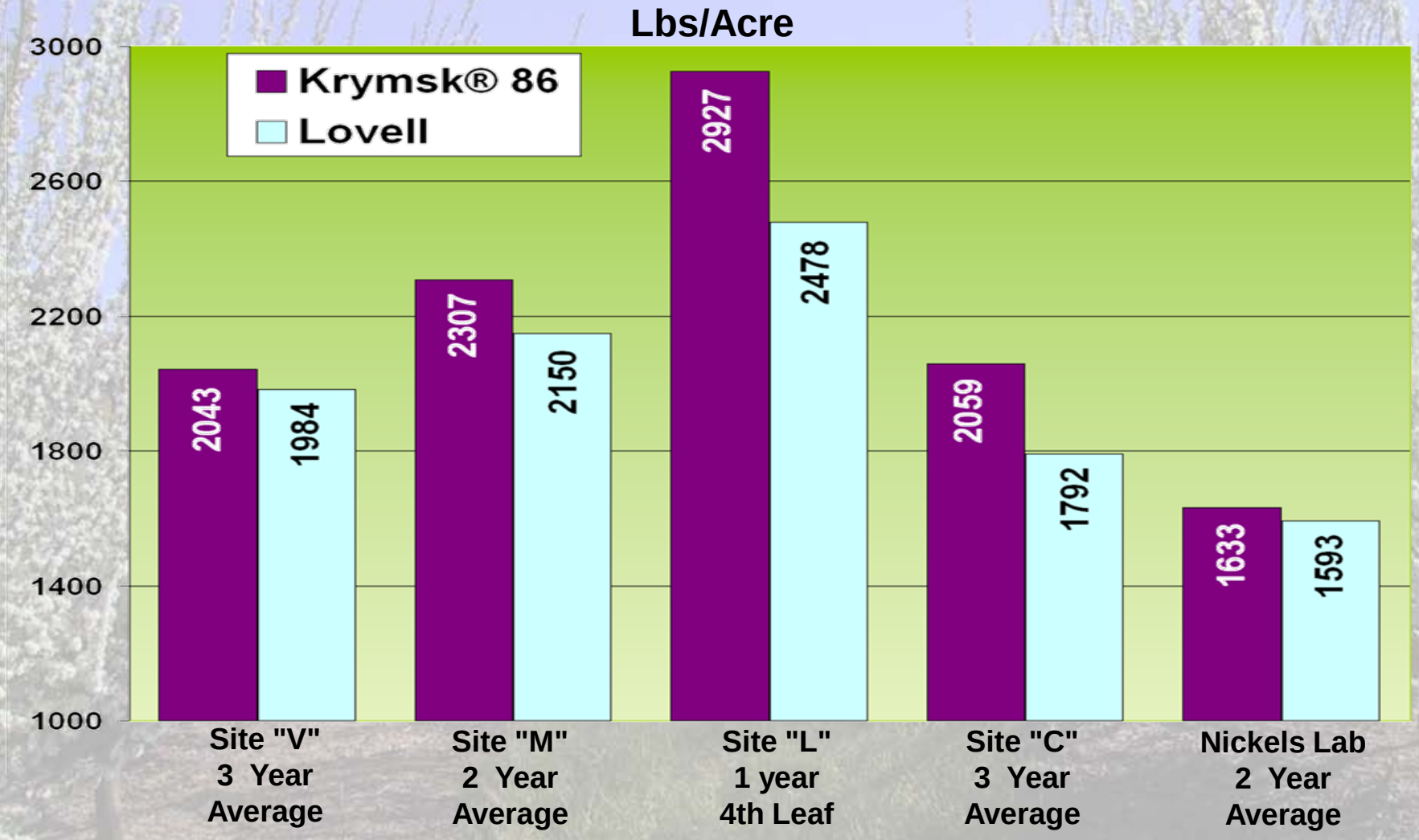
Bright Hybrid®5 Rootstock

- Moderate Vigor
- Salty, Alkaline Soils
- Medium Texture and Lighter Soils
- Good Anchorage

Krymsk®86 Rootstock

Krymsk®86 Rootstock

Nonpareil Almond Nut Meats

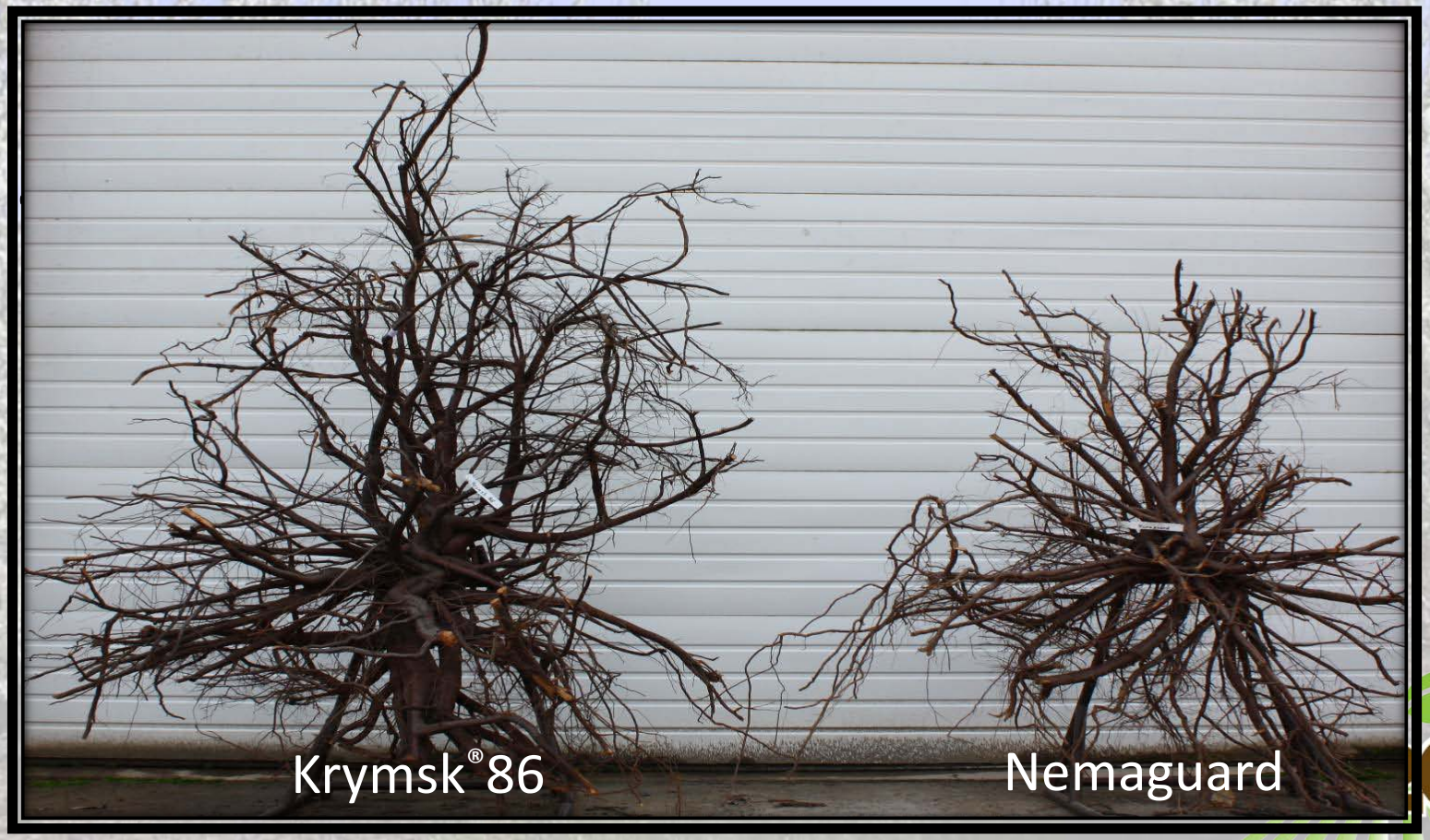


Krymsk®86 Rootstock

- Peach x Plum Hybrid
- Amazing Root Strength and Outstanding Anchorage
- Good Compatibility with Almond*
- Productivity Similar to Lovell
- Adapted to Soils Suitable for Lovell and Heavier soils

Krymsk®86 Rootstock

- Resistant to Phytophthora Root Rot
- Wide Spreading Root System

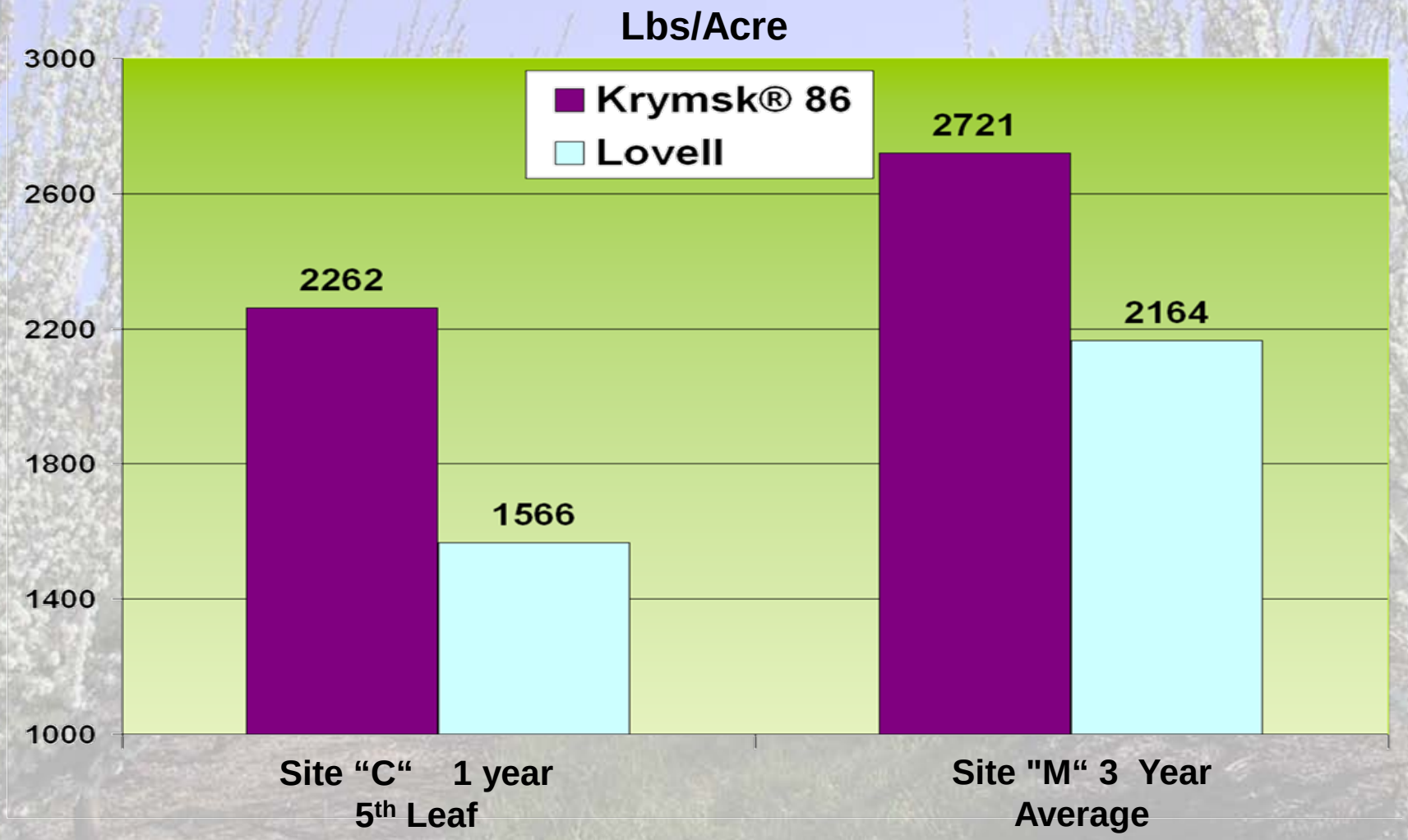


*YCL
Yellow, Cupped Leaves

- Rainy Springs of 2010 and 2011: 1st, 2nd, 3rd, and 4th Leaf Monterey Trees Developed YCL
- Monterey 35%
- Much Lowe onpareil.
  - -Most Trees R ng Season
- Most Mont ng Trends
- A Small % onterey Have Not R

Krymsk®86 Rootstock

Monterey Almond Nut Meats



Krymsk®86
vs.
Marianna 2624

Carmel / Krymsk®86

Carmel / Marianna

Krymsk®86

- Superior Anchorage
- Standard Productivity
- Diverse Soil Adaptation
- Nonpareil Compatibility

What's To Come From P2G™:

- New Peach x Almond Hybrids for Drought and Salt Tolerance

  Tempropac® HM-2 ®
- Testing New Rootstocks for Oak Root Fungus Resistance
- Testing New Rootstocks for Tolerance of Replant Disorder
- Newer Arrivals From Russia and Spain

P2G™

Progressive Genetics Group

Bright's Nursery

DUARTE TREES & VINES

Fowler NURSERIES, INC. 1912 2012

SG Sierra Gold Nurseries

AHPA General Meeting

Pistache-Ginko

4:30 – 5:30

Dedicated Trade Show

Exhibit Hall and Tent

4:50 – 5:30

Cocktail Reception

Exhibit Hall and Tent

5:30 – 7:30

Gala Dinner

Grand North Tent

7:00 – 9:00