Managing Pistachio Nutrition

Patrick Brown

Muhammad Ismail Siddiqui

How Should I Fertigate?
Focus on N, K (and Mg)

- What tools (leaf, soil, water) should I be using, and how?
  - All of them, plus a little bit of plant nutrition understanding, and:
  - Fertilize according to yield potential of CURRENT year
- Are university guidelines for critical values still viable?
  - Yes for all elements except Mg which should be reduced to 0.4%.
  - However, doing leaf sampling right is really difficult
  - You cannot manage nutrition based on leaf analysis alone.

Principles of Nutrient Management- Optimizing Fertilization by Applying the 4 R's

- Applying the Right Rate
  - Match demand with supply
- At Right Time
  - Determine when uptake from the soil occur
  - Maximize uptake minimize loss potential.
- In the Right Place
  - Ensure delivery to the active roots.
  - Managing variability across the orchard
- Using the Right Source
  - Maximize uptake minimize loss potential.

Are our current guidelines for pistachio fertilization adequate to achieve this?

Plant Nutrition Principles

- Nutrients are obtained by living, active roots and growing plants
  – Requires water for uptake
  – No uptake during dormancy
  – Soils must provide adequate water and oxygen for root growth.

- Demand drives uptake. Yield potential determines your fertilizer rate, fertilizer rate does NOT determine yield.

- There is an ‘optimal’ tissue nutrient concentration above which no benefit occurs- Critical Value.

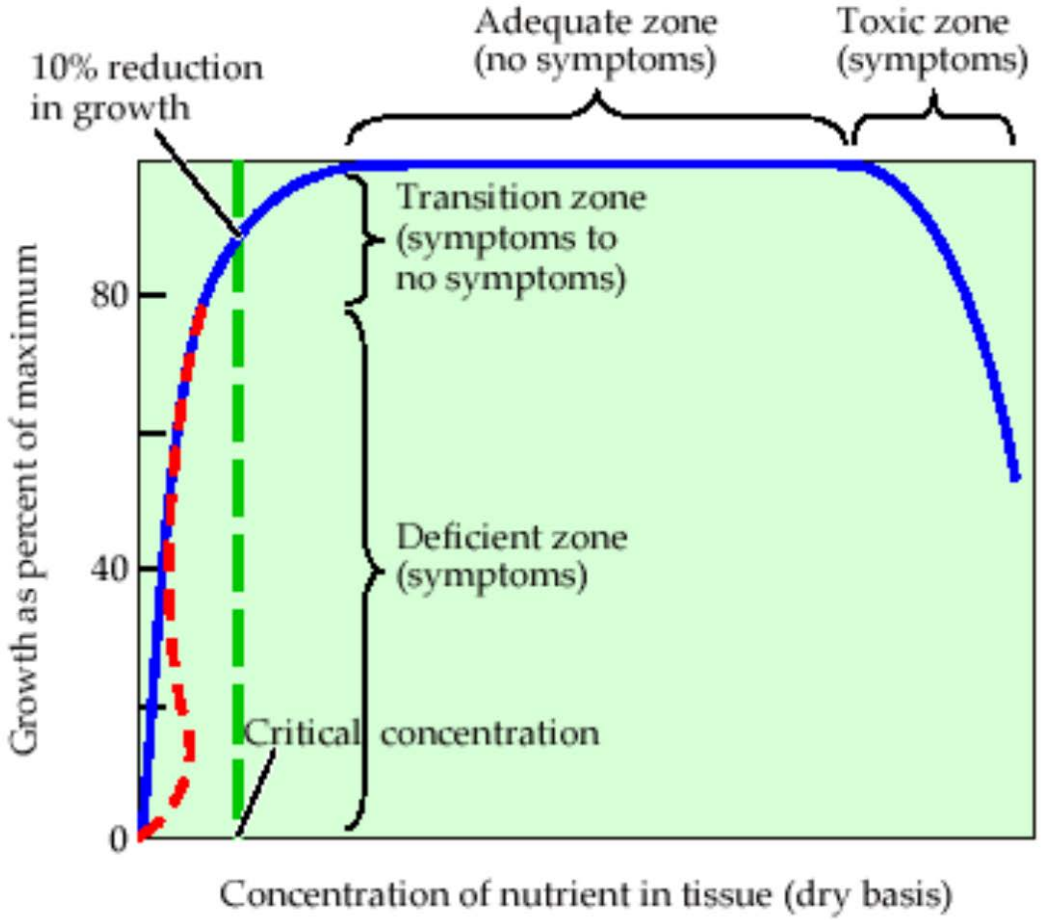
Leaf Sampling and Critical Values

Still valid after all these years??

What do we know and how do we manage?

Leaf Sampling and Critical Value Analysis in Orchard crops

(based on Ulrich @ U Calif in 1950-70's)



*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.

g the right leaf is difficult, sampling the
rly is very hard

ly valid for July/August

' s are not yield based

ld trials (N, K, B)

af symptoms (P, S, Mg, Ca, Mn, Zn, Fe,

known (Ni, Cl, Mo)

n of results (NO R' S!)

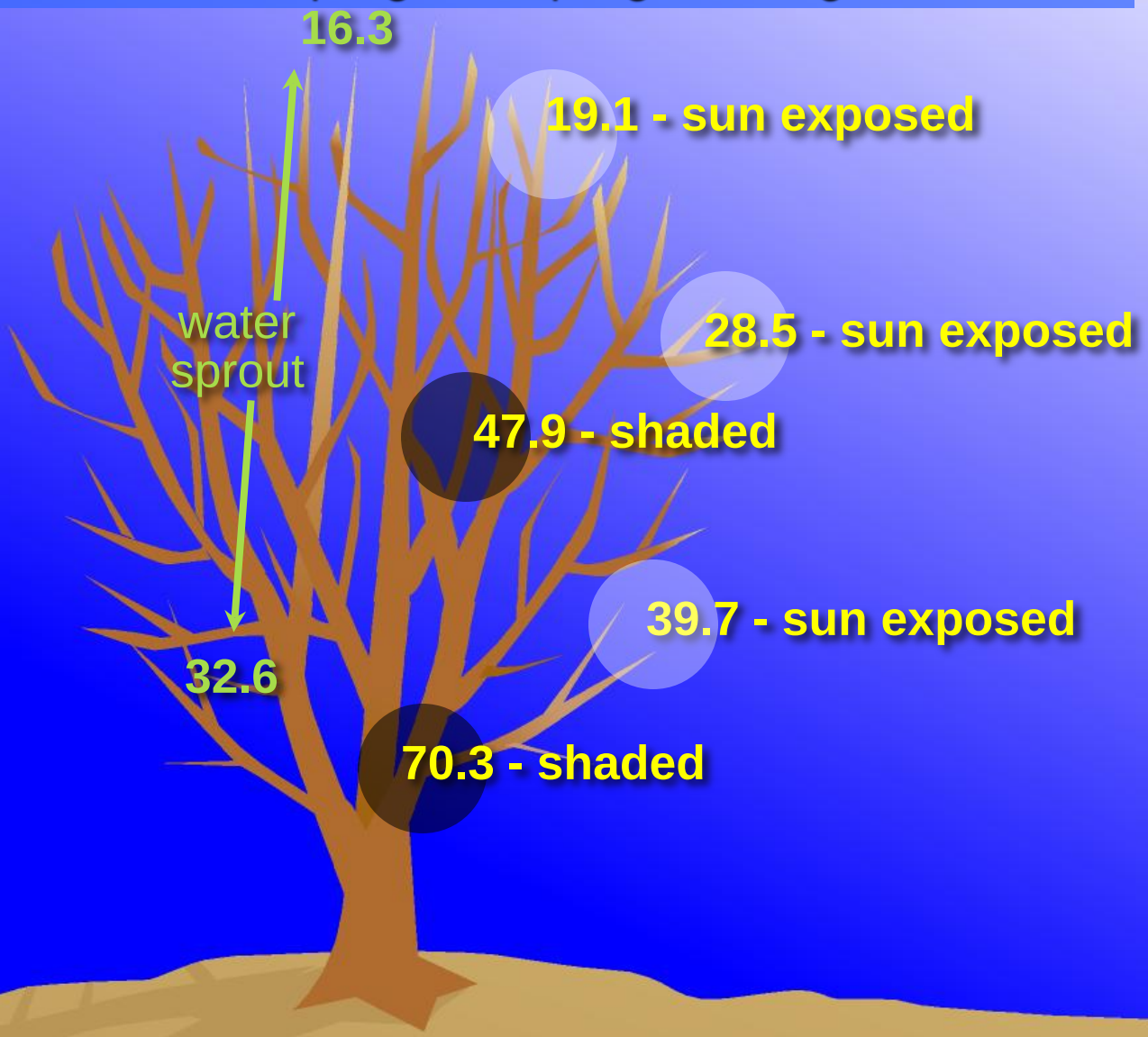
lysis can indicate a shortage but
ine how to respond.

nation on cause of deficiency

nce on Rate, Timing, Placement or

Source

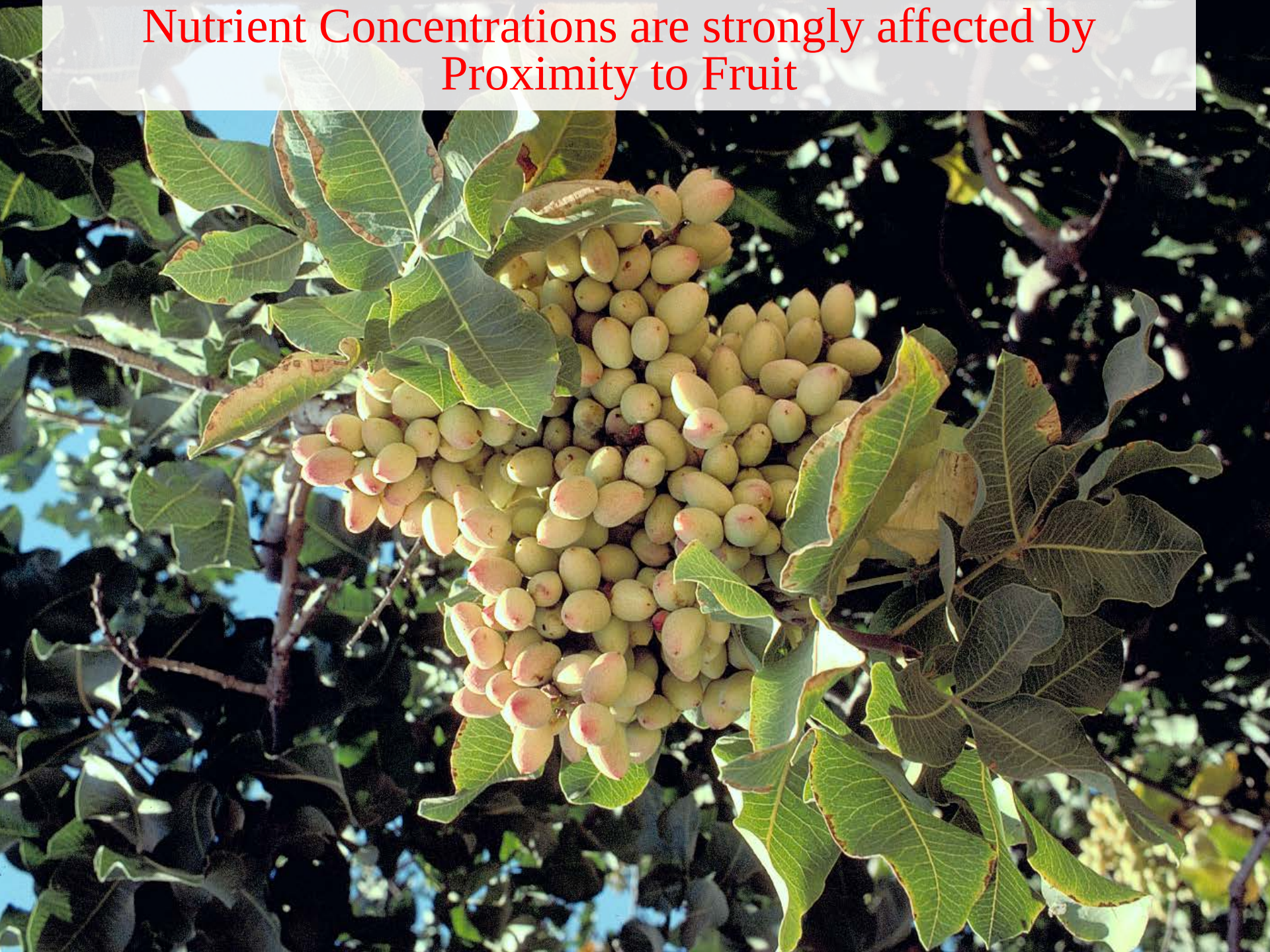
Problem with leaf sampling: Sampling challenges.



Shoot Zn Distribution Through A Dormant Tree (ppm)

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

Nutrient Concentrations are strongly affected by Proximity to Fruit



Challenges of Sampling: Field Variability

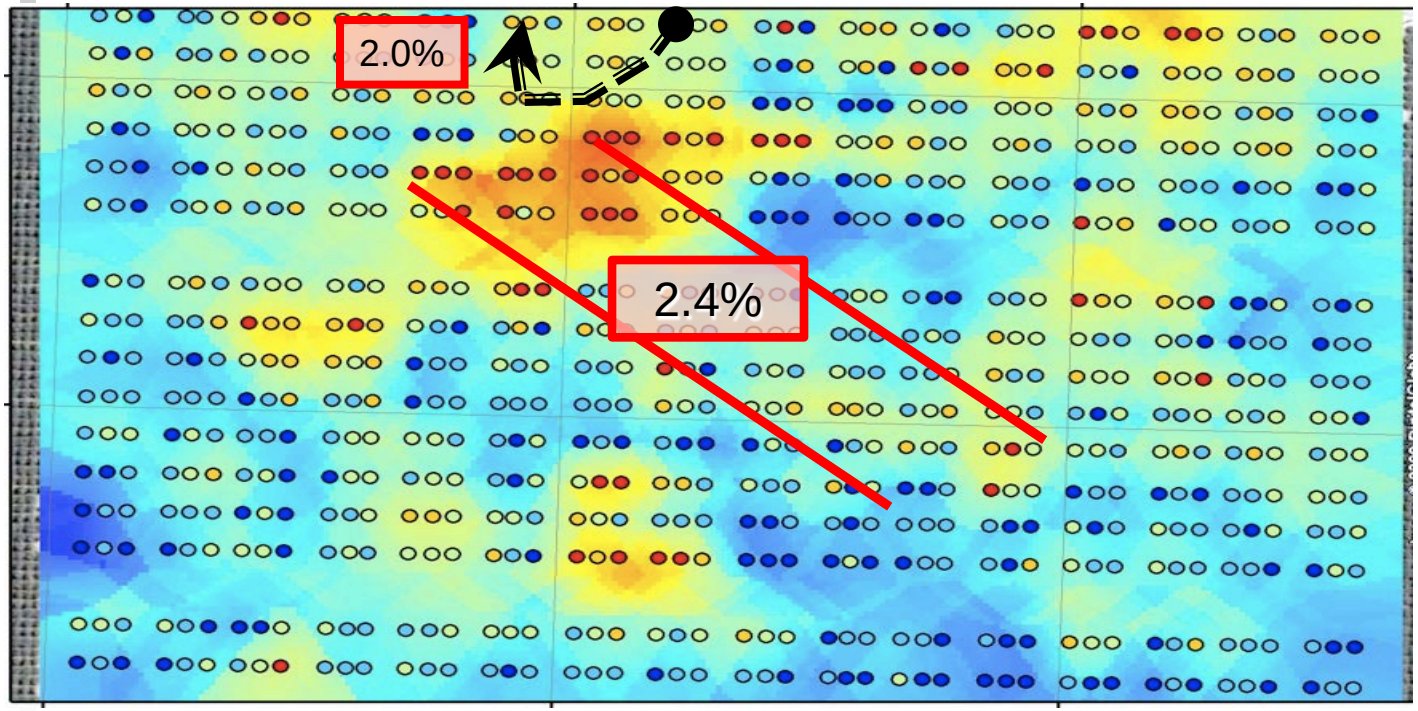
(768 individual tree samples. High producing 'uniform' orchard)

Typical Sampling: 1 pooled sample per management unit

(Hypothetical) Field Mean 2.4% N (June): Critical Value 2.4% = OK?

***No!**: Full productivity can only be achieved when all individuals are above 2.4%*

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)

Summary: Tissue Testing for Pistachio

- **Challenges**.
  - Difficult to sample properly and hard to interpret. Sampling in the way most people currently do it, is a waste of money.
  - Are our UC critical values correct?
  - Tissue analysis does not inform management practice**

Do we have any Alternatives?

Leaf Sampling Alone Does not Address the 4 R's

- Applying the Right Rate
  - Match demand with supply
- At Right Time
  - Determine when uptake from the soil occur
  - Maximize uptake minimize loss potential.
- In the Right Place
  - Ensure delivery to the active roots.
  - Managing variability across the orchard
- Using the Right Source
  - Maximize uptake minimize loss potential.

Are our current guidelines for pistachio fertilization adequate to achieve this?

Ongoing Research to Improve Nutrient Management

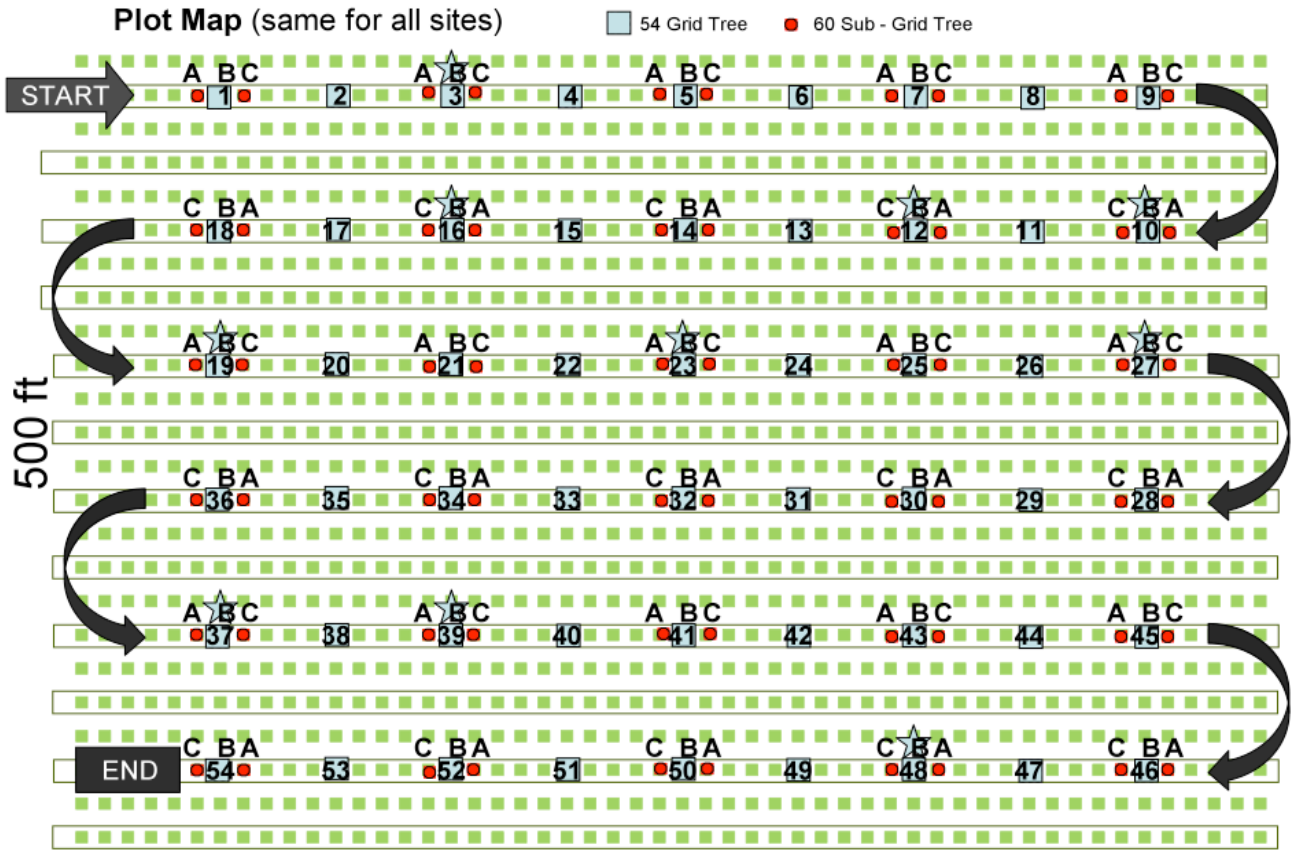
- Improve Sampling Methodologies
- Quantify Nutrient use and Develop Nutrient Budget
- Validate Critical Values
- Investigate Nutrient Interactions and Ratios

Experimental Design

4 High Yielding Sites, 4 years

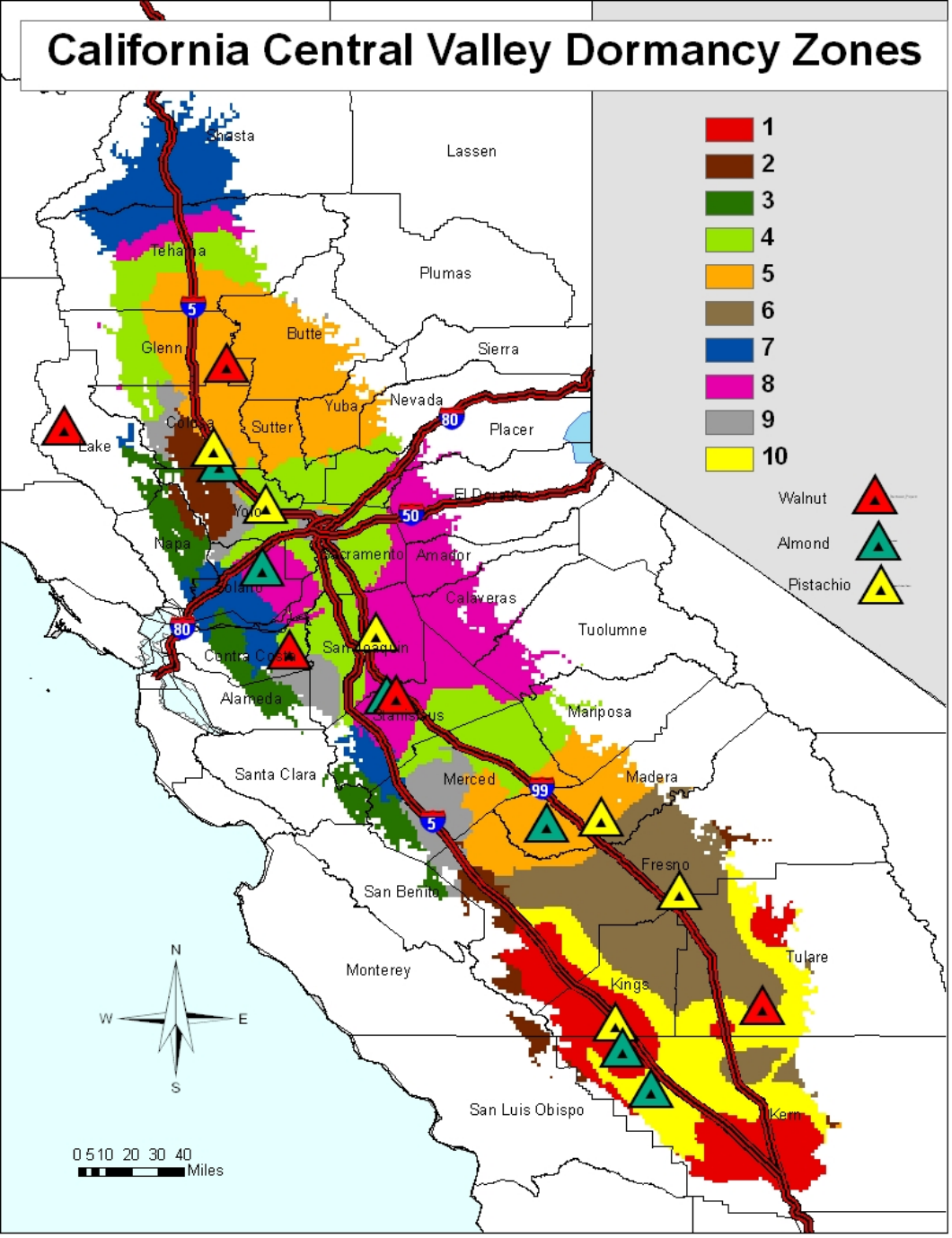
Leaf, Nut sample through year, individual tree yield

Nutrient Analysis



All Sites: (54 trees)

- **5 in-season full nutrient analysis**
- **Yield (individual trees)**



6 Almond and 5 Pistachio Orchard Sites

All Sites: (>100 trees)

- 5 in-season full nutrient analysis
- 5 in-season Spectral Analysis
- 5 in-season Plant Water Status
- Soil water and irrigation volume
- Yield (100 + individual trees)
- Nitrogen Use Efficiency (NUE)
- Aerial and satellite imagery

Two Sites:

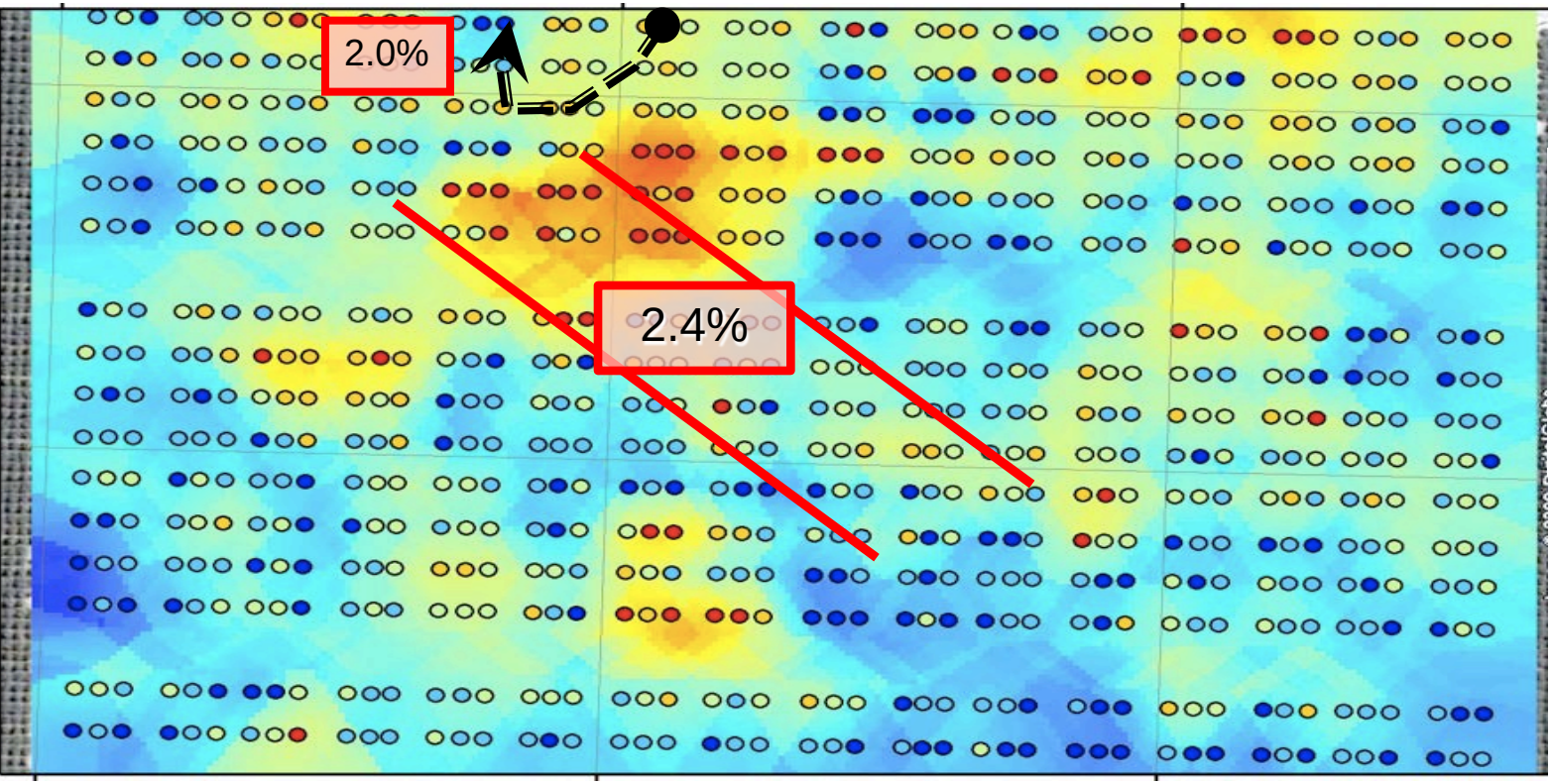
- Gaseous nitrogen loss
- NUE

One Site: 50 x 2 acre, (drip/Fan Jet)

- Factorial 4N x 4K x source x Irrigation Trial

- 5 in-season full nutrient analysis, 5 in-season Stem WP, Soil water and irrigation volume, Yield (768 individual trees)
- NUE
- Canopy level imagery
- Aerial and satellite imagery

Challenges of Sampling: Field Variability
How do we sample properly?



We estimated the number of samples needed for 90% confidence level for July leaf samples at four research sites.

Paramount (Kings County)

This sampling protocol is valid for orchards of average variability. Growers must collect leaves from at least 17 trees each spaced at least 25 yards apart. To minimize cost, leaves of all trees can be pooled in one bag. If clear areas of differential tree behavior are known, these areas should be sampled and managed separately.

2010	3	3	18	21
2011	5	2	11	17

Madera (Madera County)

Year	N	P	K	Mg
2009	8	6	21	15
2010	8	8	23	21
2011	7	8	38	40

Over what size orchard is this valid ? Depends on field variability! If the variance is identical at all distances then the sample size is good for all field sizes.

Alternate Approaches to Nutrient Management

Nutrient Budgeting

Replacing nutrients removed from the field

Essential Components and Challenges:

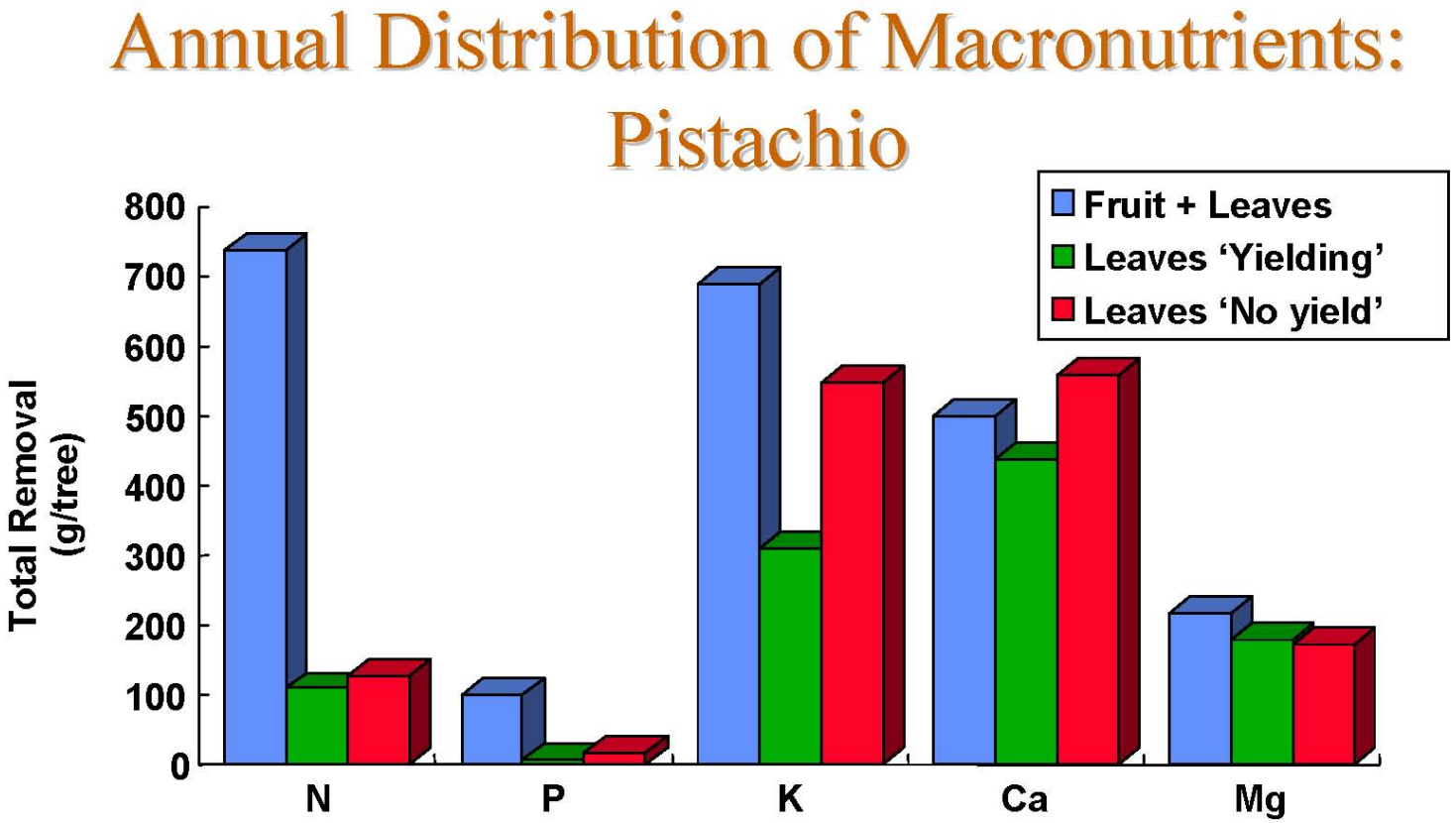
Right Rate

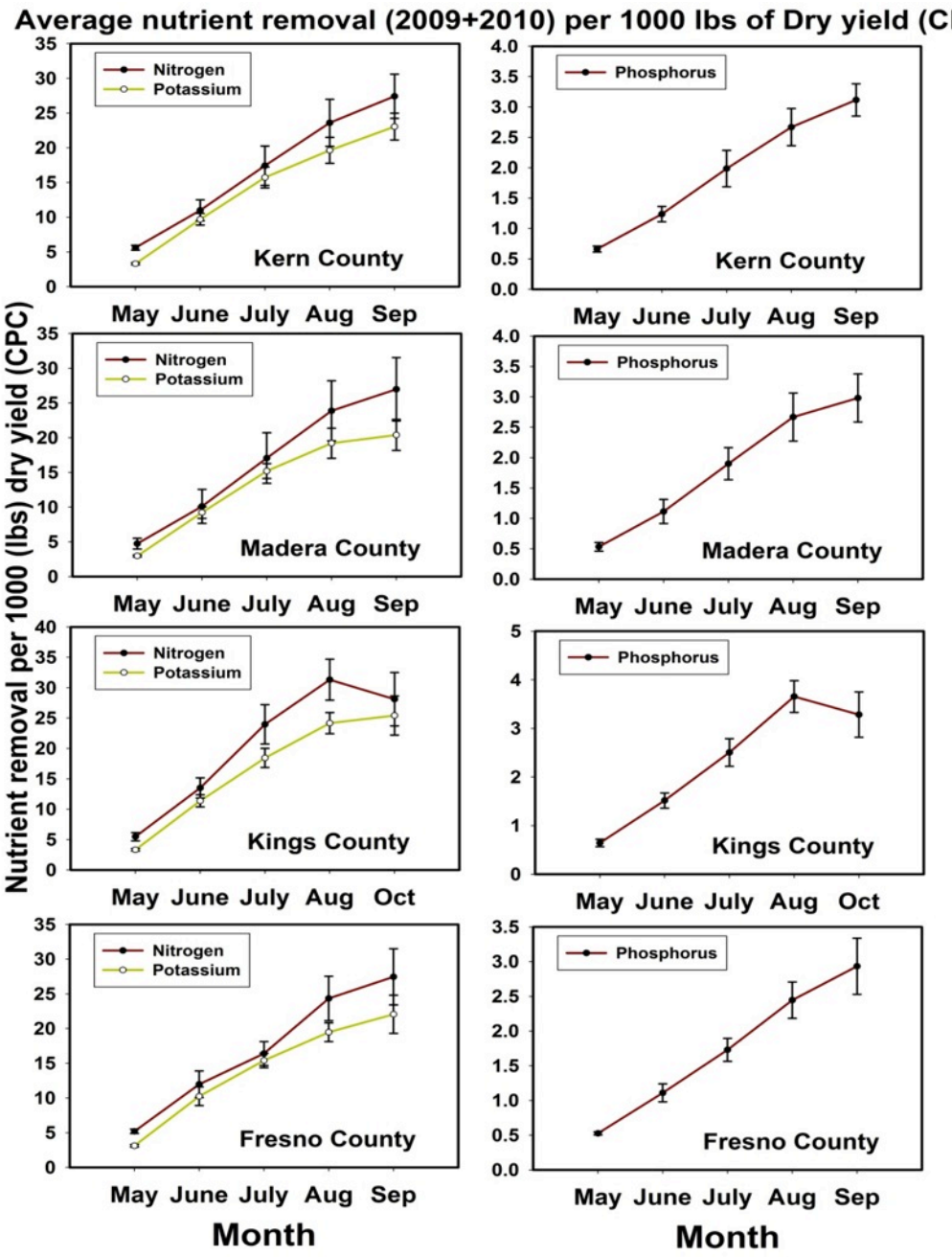
- Estimate demand (Last years yield, this years estimated yield, tree age, common sense)
- Measure and control inputs and losses (soil, fertilizer, irrigation, leaching, volatilization)
- Manage efficiencies and interactions
  - Right Place, Right Time, Right Source
  - Monitoring crop response

How?

Nutrient Budget Approach

- Mature pistachio tree is relatively determinate in growth pattern.
- Majority of nutrients are partitioned to fruit.



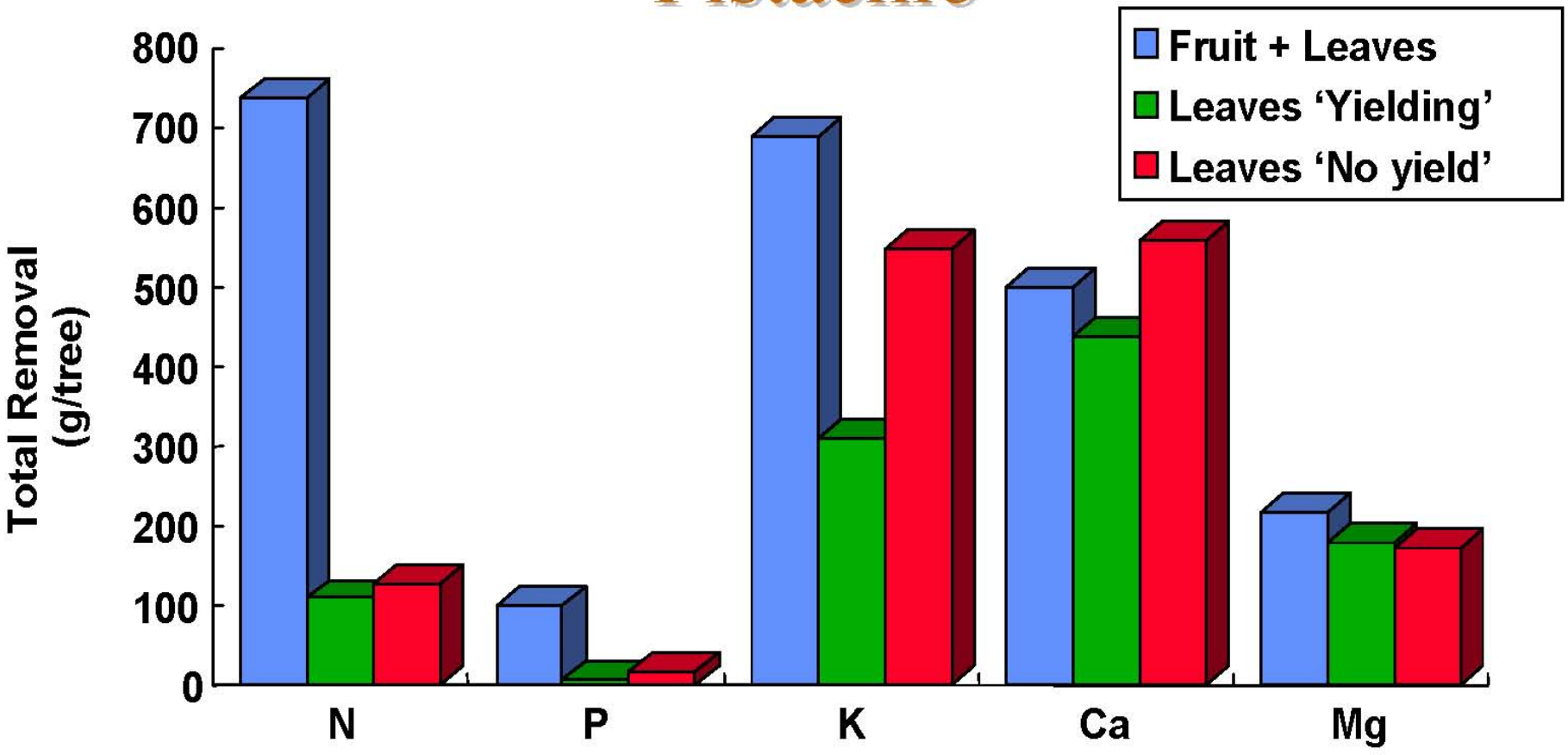


Nutrient removal Per 1000 lbs (CPC yield)

- Valuable for estimating demand or replacing nutrient export
- Provides insight into efficiencies
  - N removal 28 lbs per 1000
  - K removal 25 lbs per 1000
  - P removal 3 lbs per 1000

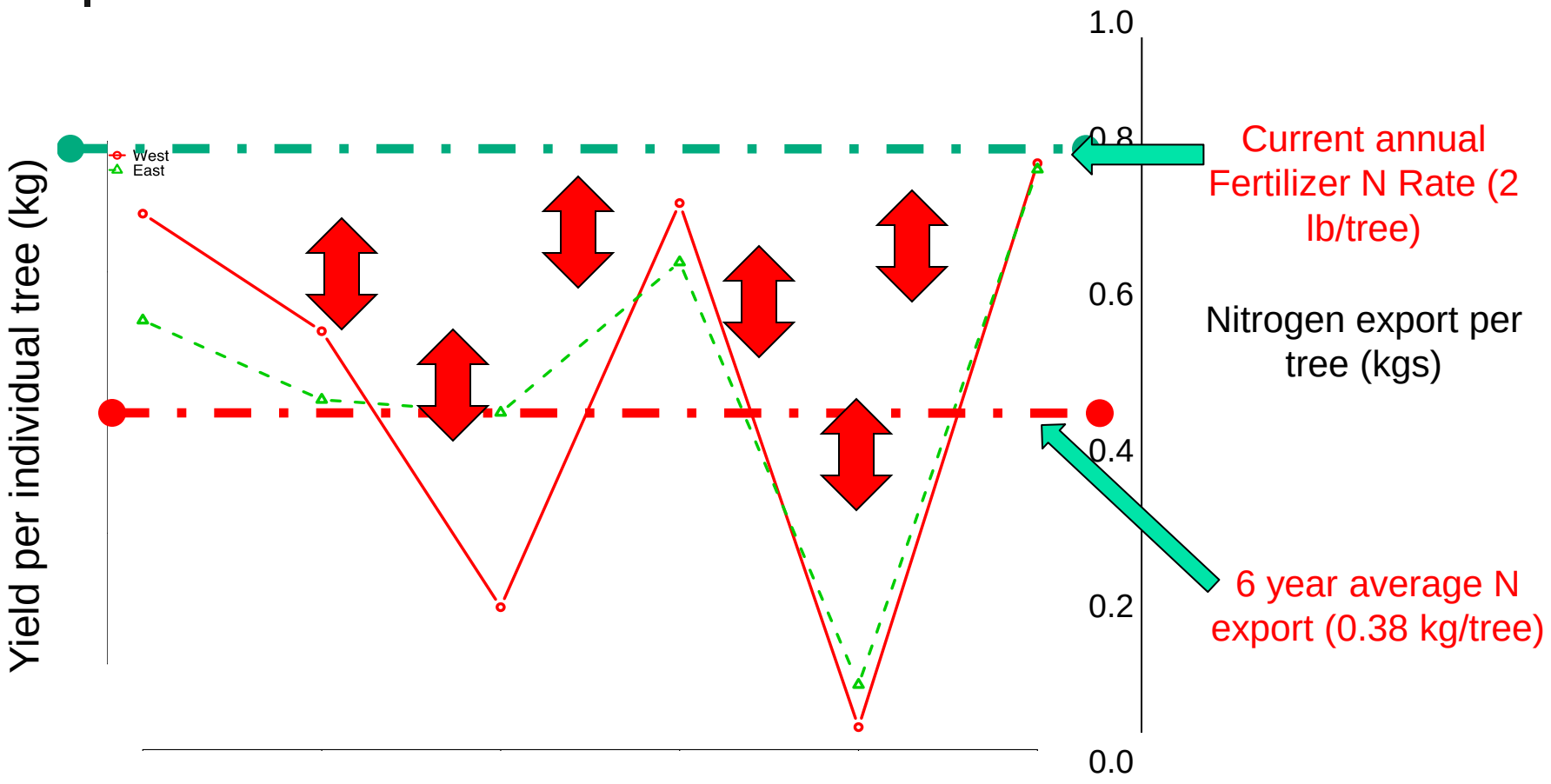
Brown and Siddiqui-unpublished

Annual Distribution of Macronutrients: Pistachio



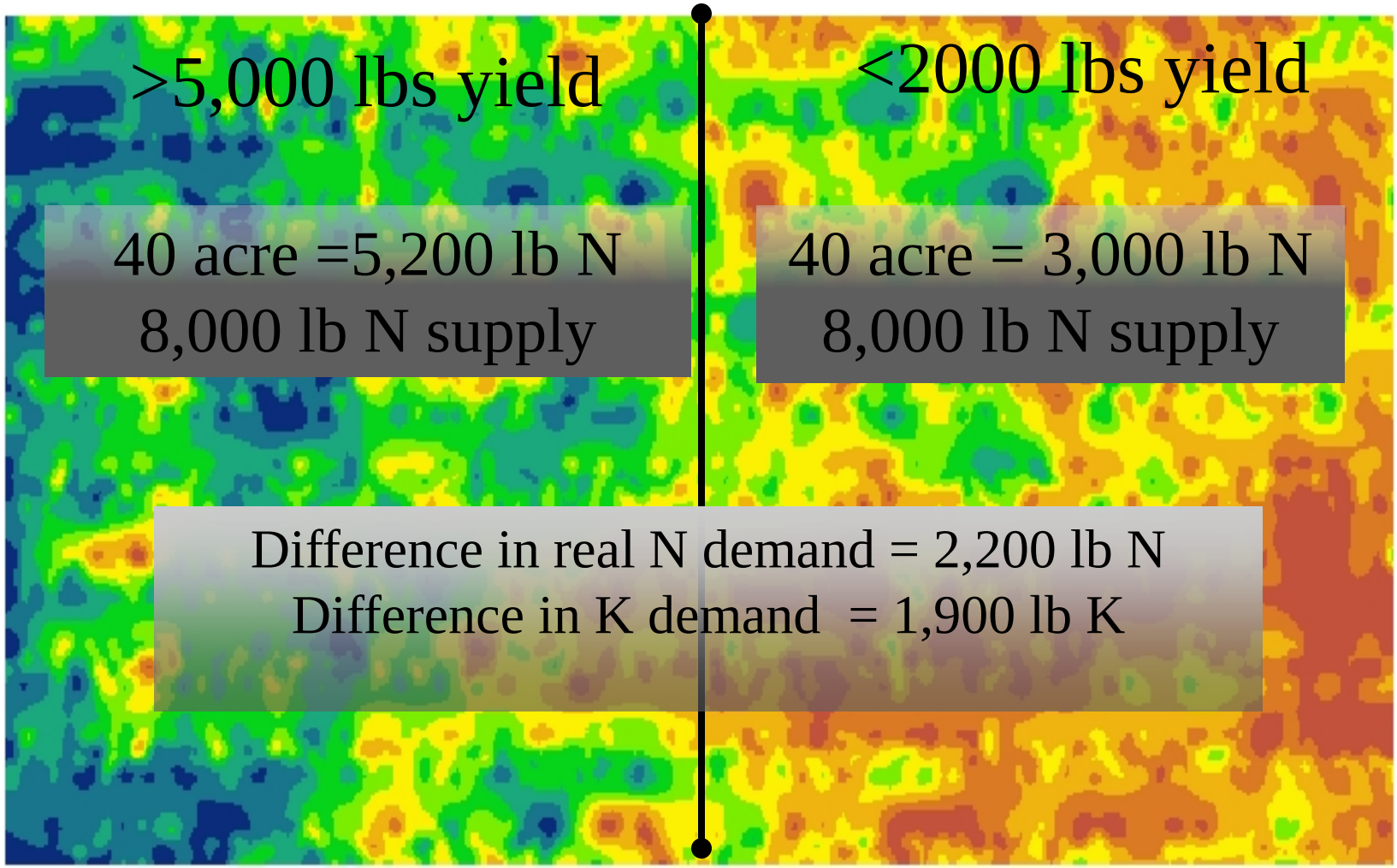
Variation in Yield over Time

Pistachio 4820 trees individually harvested.



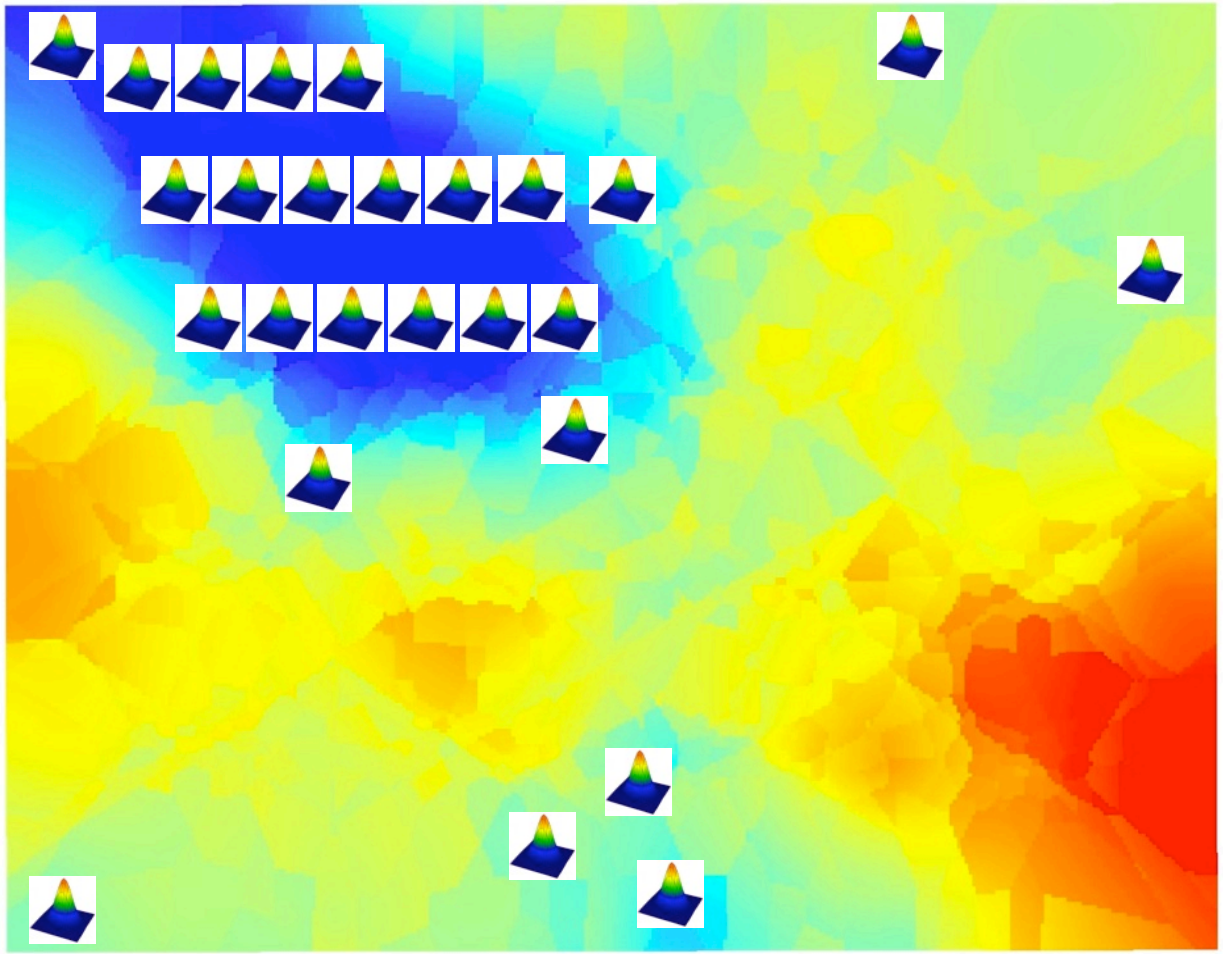
Managing for Spatial Variability

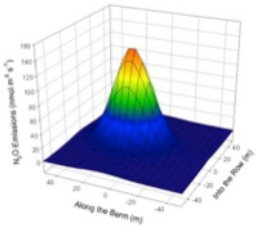
Variability in Yield alters N demand?



Spatial distribution of N

Sites of Excess Fertilization have the highest potential for Nitrogen release





Leaf N (%)

Supra Optimal

Adequate

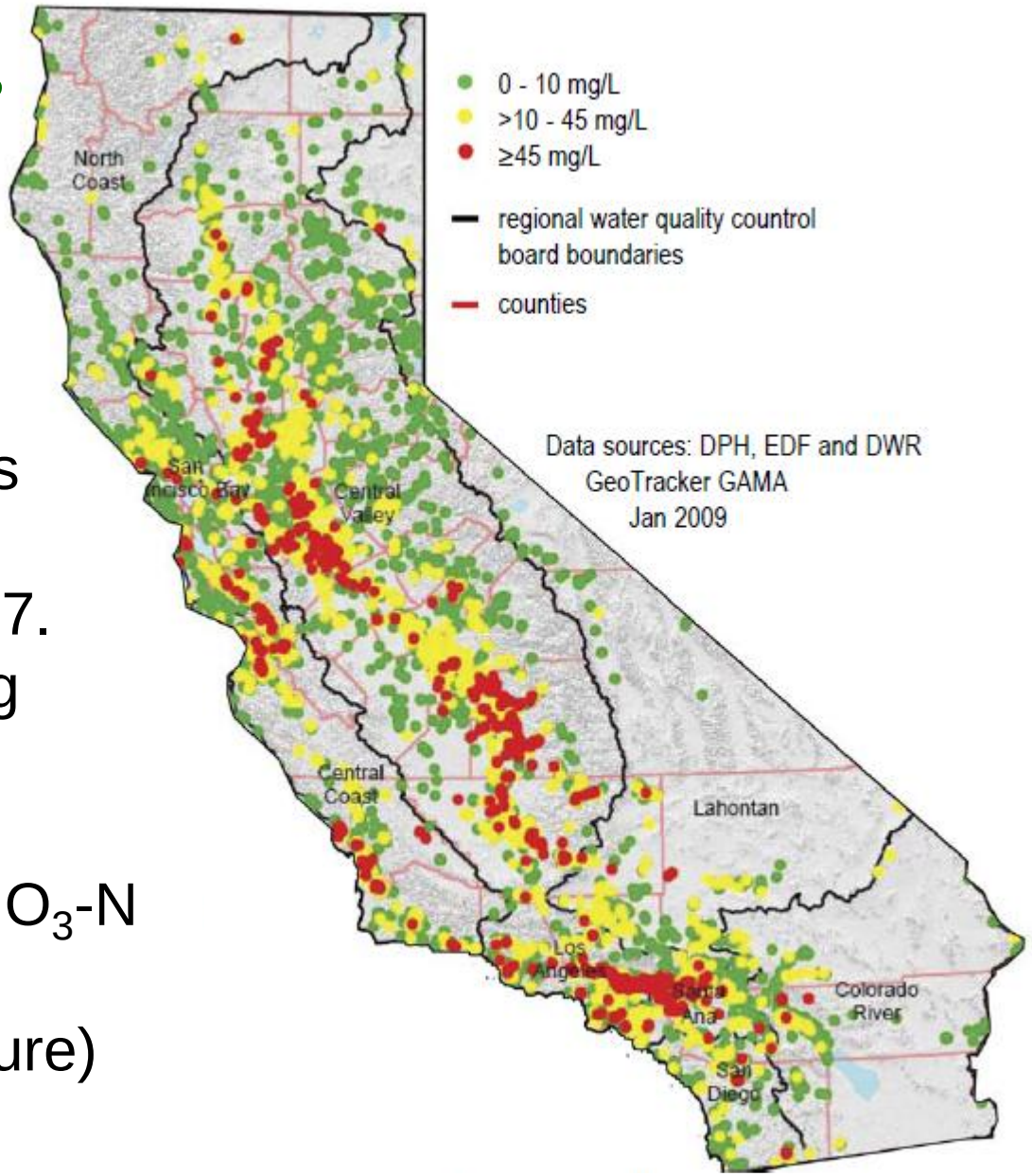
N

0 20 40

Meters

D. Smart et al

Environmental concerns



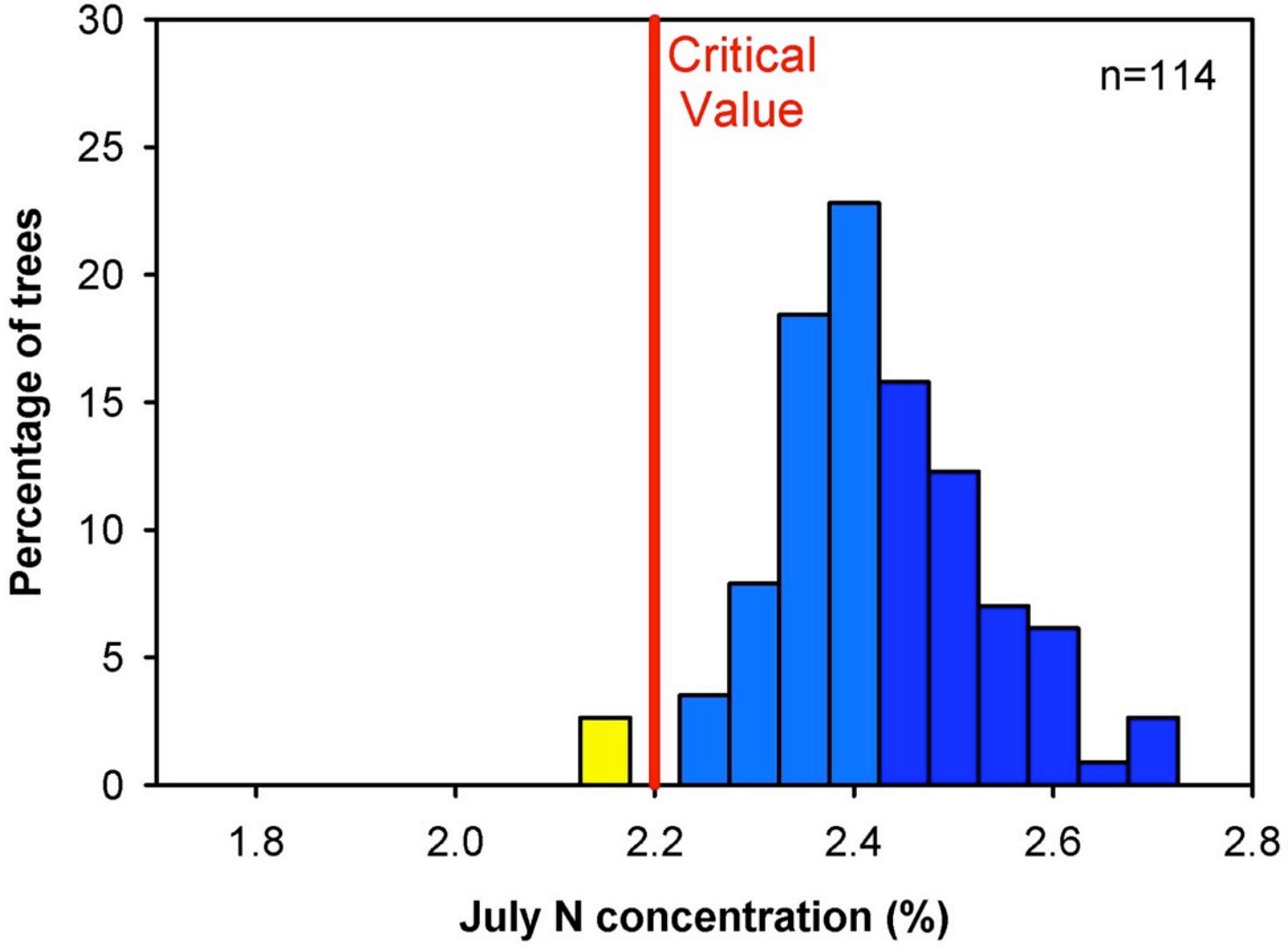
Nitrate concentrations in various California wells measured in 2007. Many exceed drinking standards

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

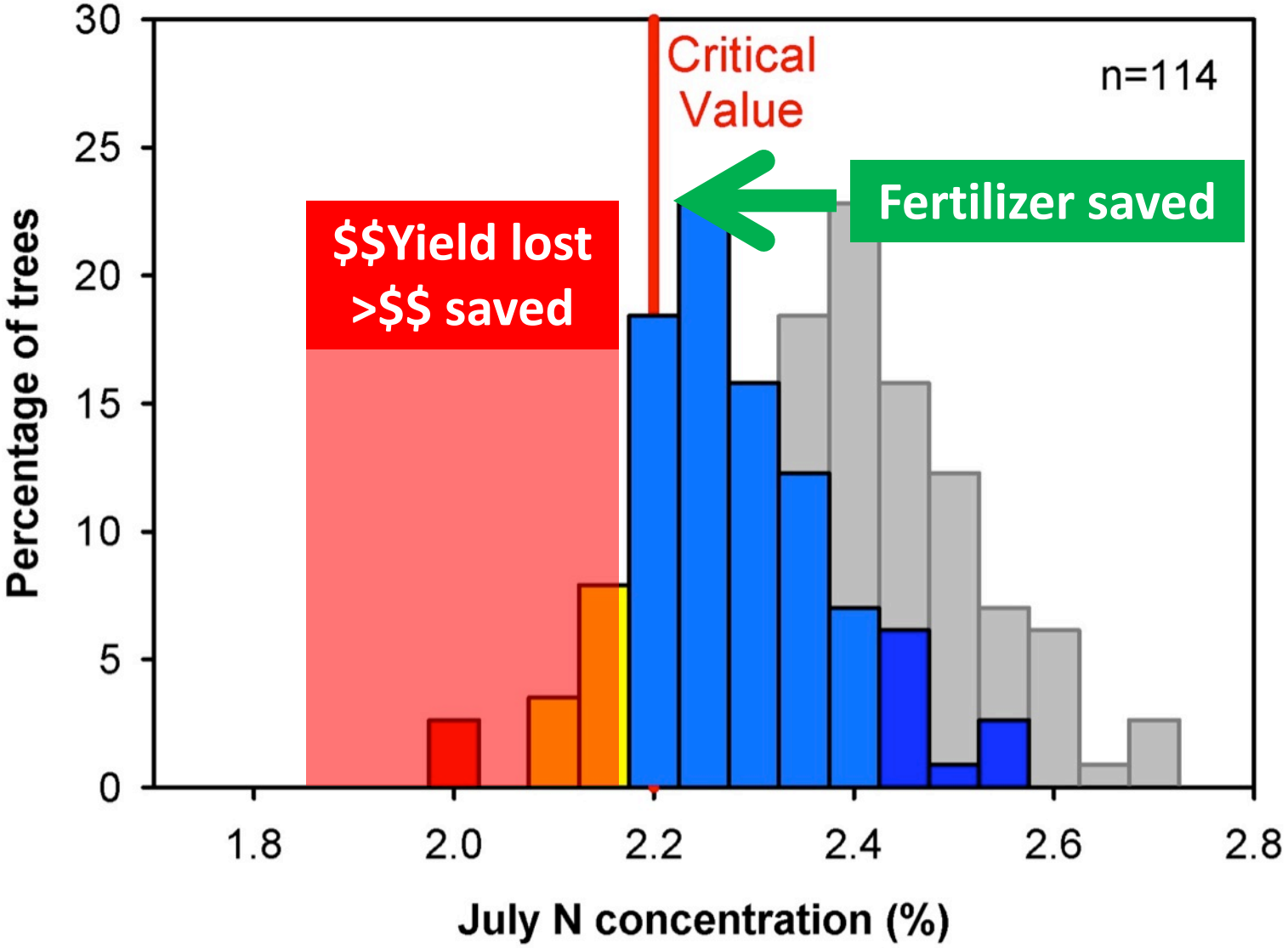
(much from animal manure)

(Ekdahl and others, 2009)

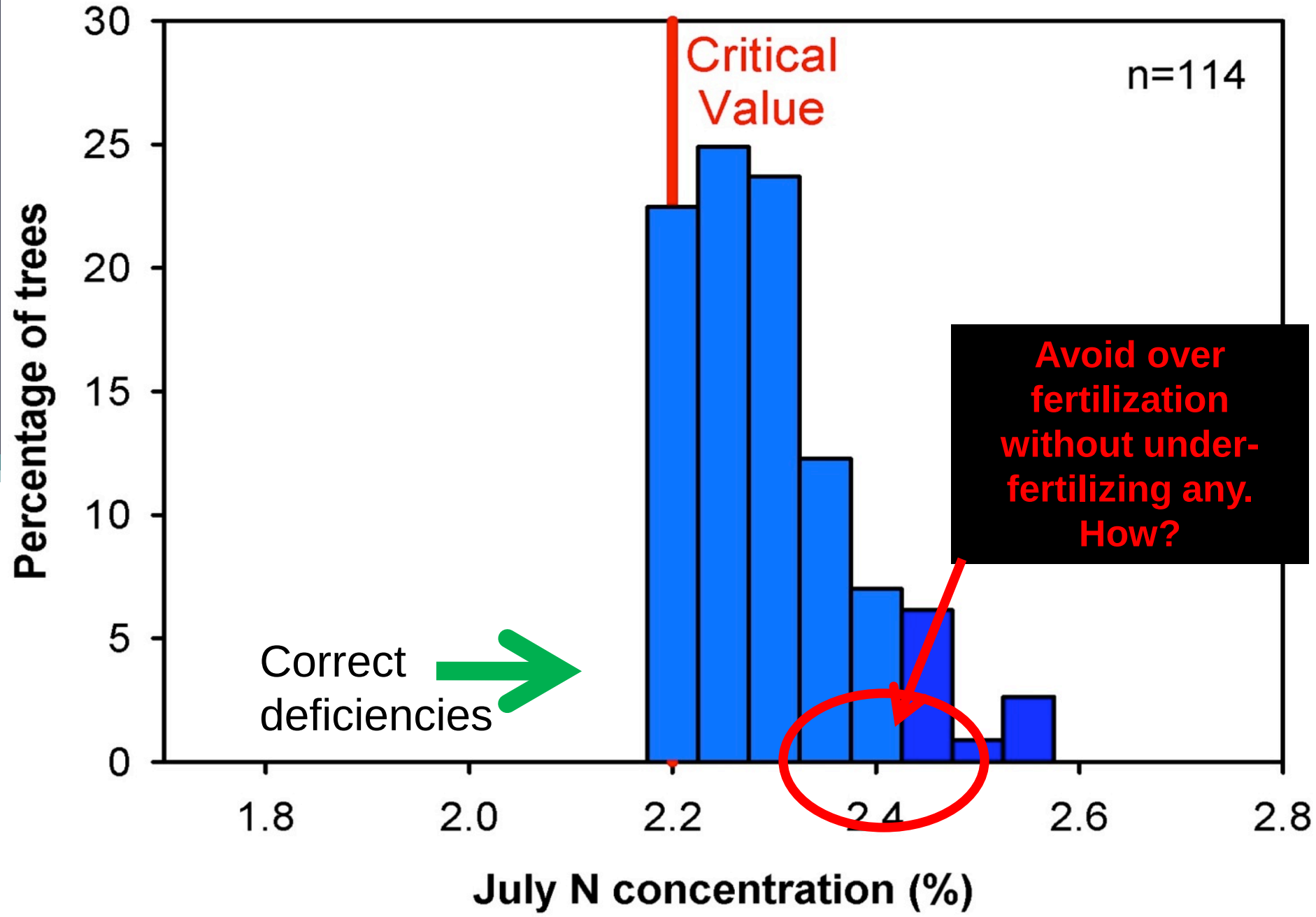
Survey of leaf N distributions in Californian Orchards
114 Orchards surveyed



Reducing Inputs without Considering Variability May Reduce Yield



Managing Nutrition of High Value Crops



Are our Current CV's Adequate?

Current Critical Values for Pistachio July Sample

Element	Critical Value	Suggested Range	Reference
Nitrogen (N)	1.8%	2.2 -2.5%	Weinbaum, et.al. 1988, 1995
Phosphorus (P)	0.14%	0.14-0.17%	
Potassium (K)	1.6%	1.8 - 2.0 %	Brown, et.al. 1999
Calcium (Ca)	1.3% (?)	1.3-4.0%	
Magnesium (Mg)	0.6% (?)	0.6-1.2%	
Sodium (Na)	(?)	(?)	
Chlorine (Cl)	(?)	0.1-0.3%	
Manganese (Mn)	30 ppm	30-80 ppm	
Boron (Bo)	90 ppm	150-250 ppm	Uriu,1984; Brown, et.al.,1993
Zinc (Zn)	7 ppm	10-15 ppm	Uriu and Pearson.1981, 1983,1984,1986
Copper (Cu)	4 ppm	6-10 ppm	Uriu, et.al. 1989

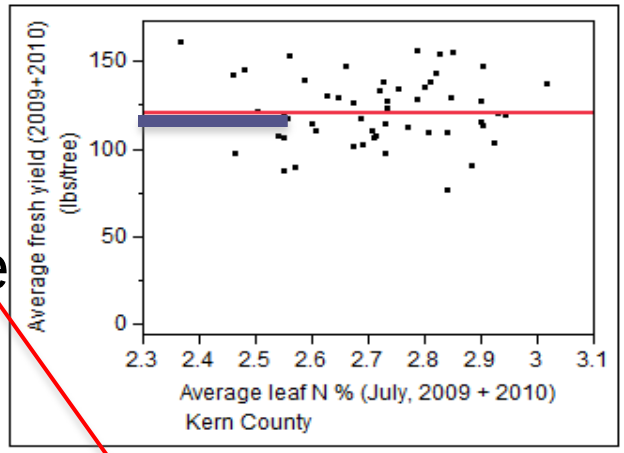
ppm = parts per million or milligrams/kilogram dry weight.

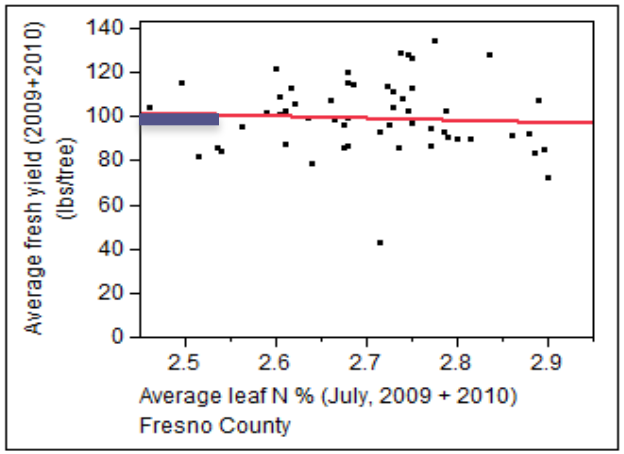
% = parts per hundred or grams/kilogram dry weight

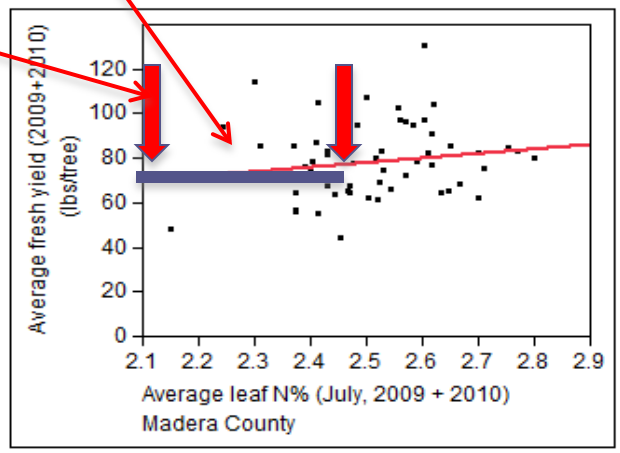
Validation of Existing Critical Values – (N)

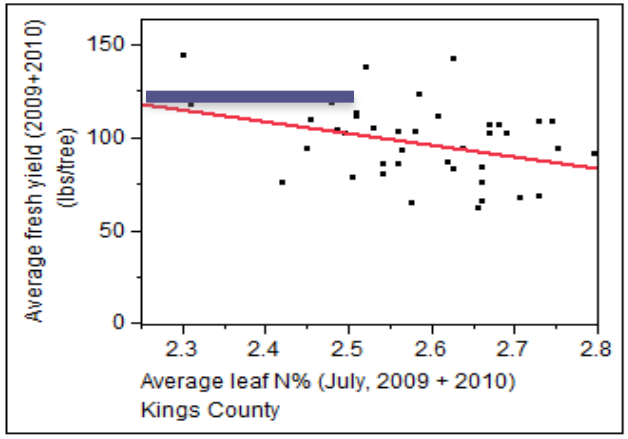
Range

CV



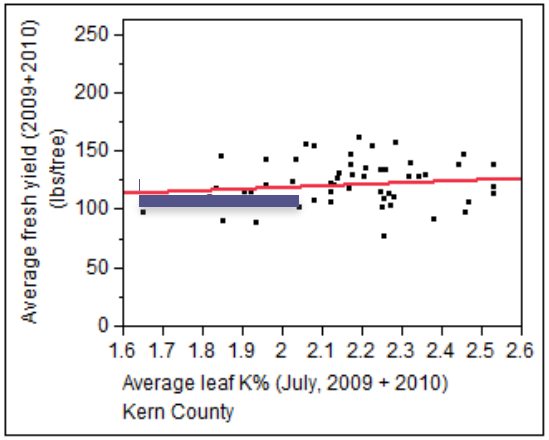


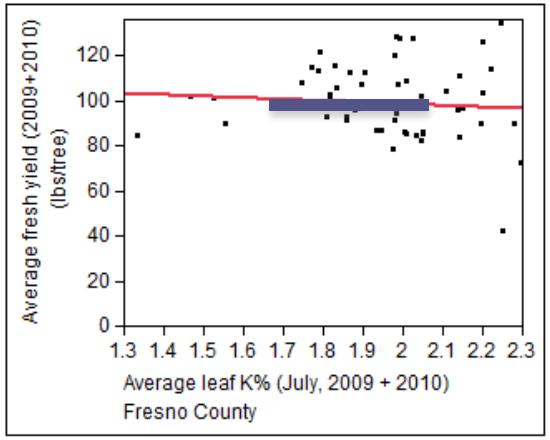


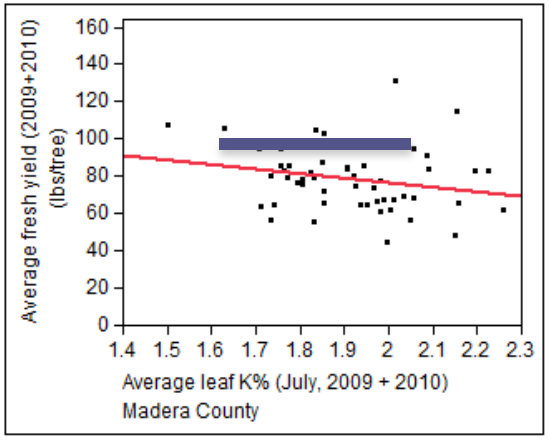


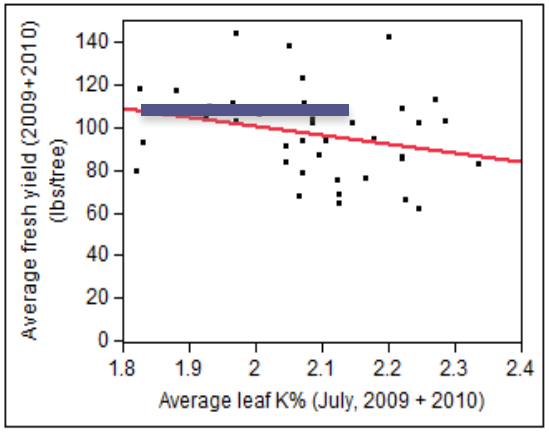
Relationship of average leaf nitrogen (July, 2009 + 2010) with average yield (2009 + 2010). Data represents averages from 54 individual trees at Kern, Fresno, Madera and Kings Counties.

Validation of Existing Critical Values – (K)



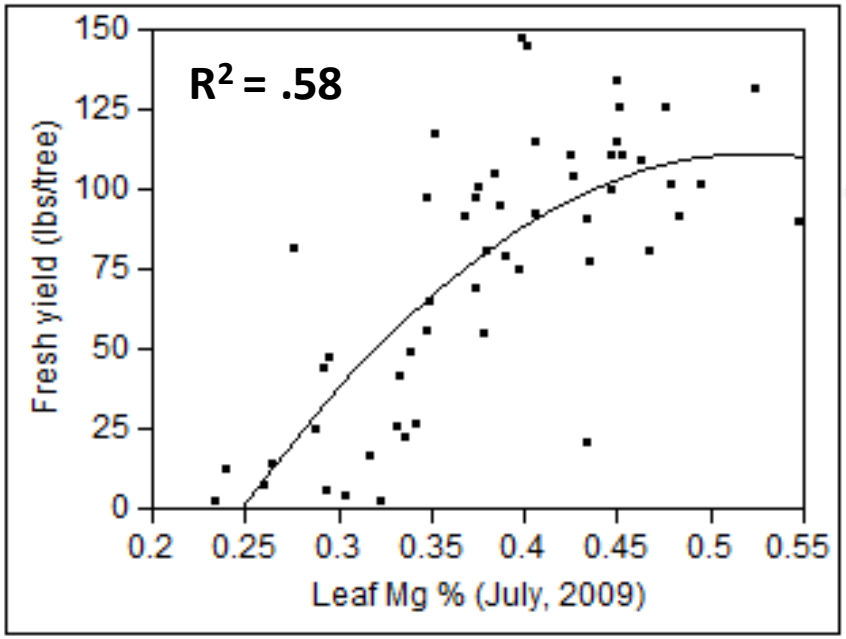


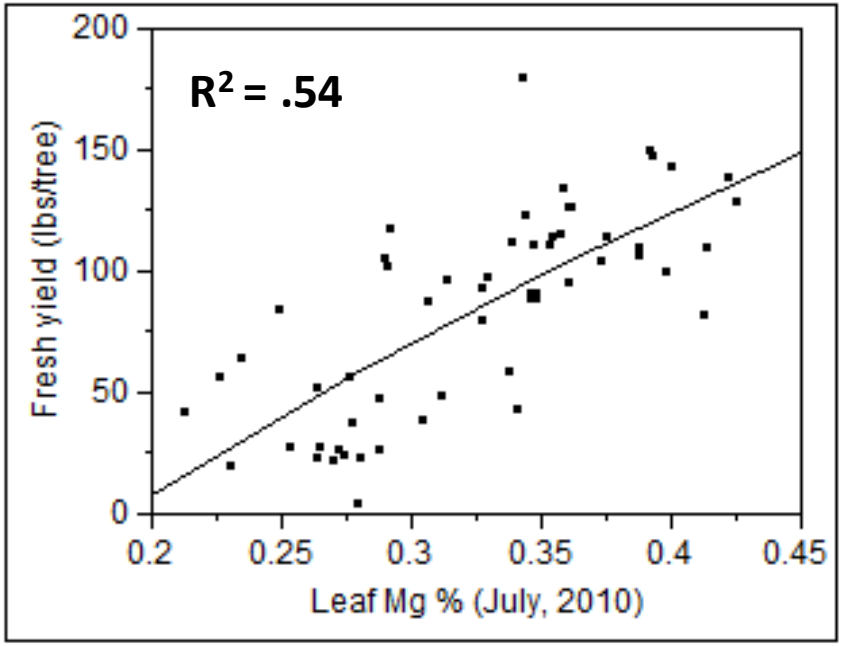




Relationship of average leaf potassium (July, 2009 + 2010) with average yield (2009 + 2010). Data represents averages from 54 individual trees at Kern, Fresno, Madera and Kings Counties.

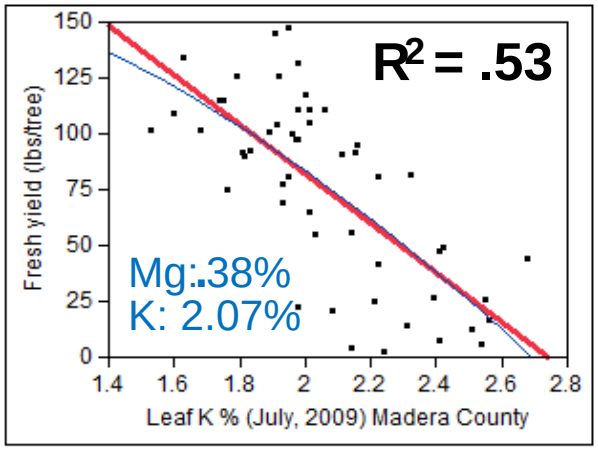
Validation of Existing Critical Values – (Mg)

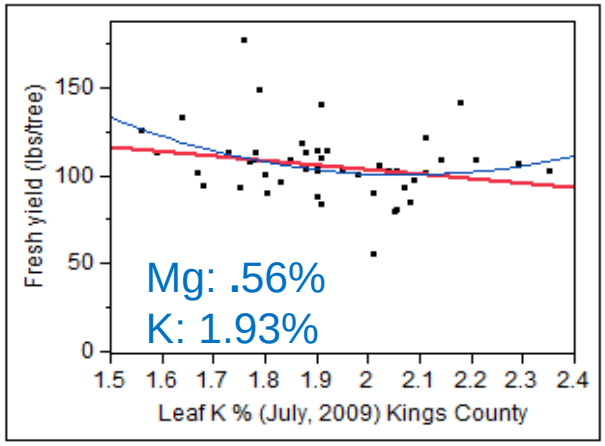


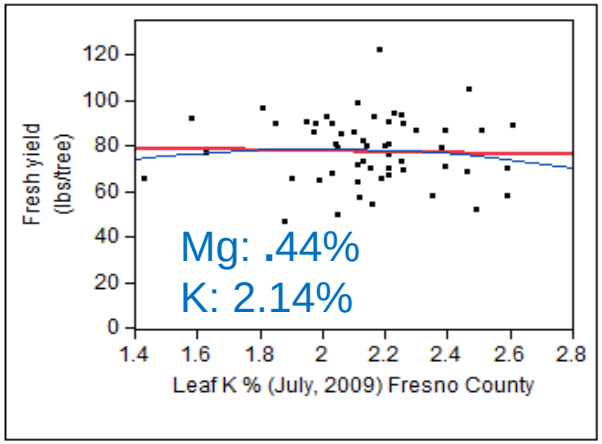


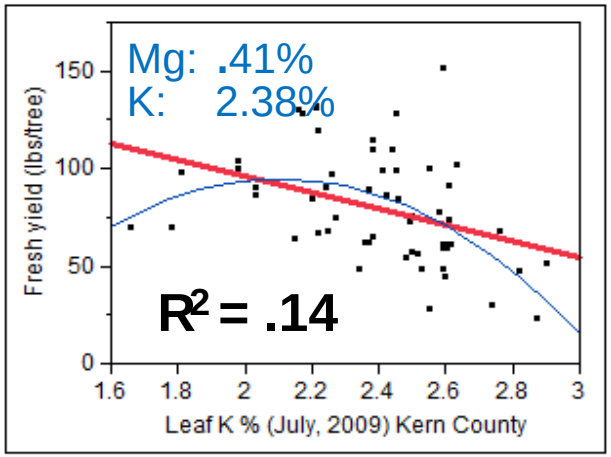
These analyses suggests that CV's presented in the current Pistachio production manual, for Mg should be lowered from the current 0.6% to 0.45%.

Yield Response to Leaf K Across Four Locations

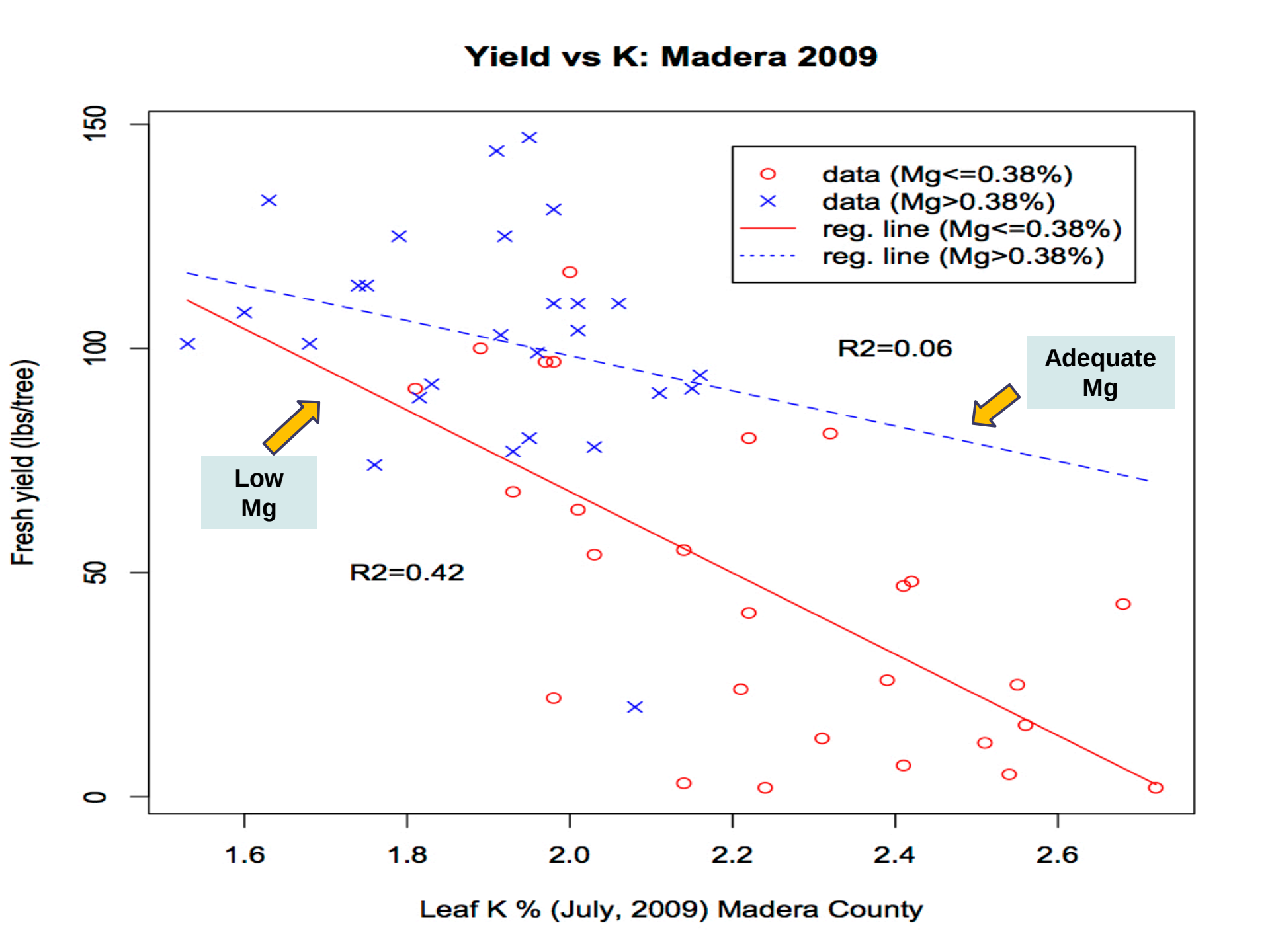


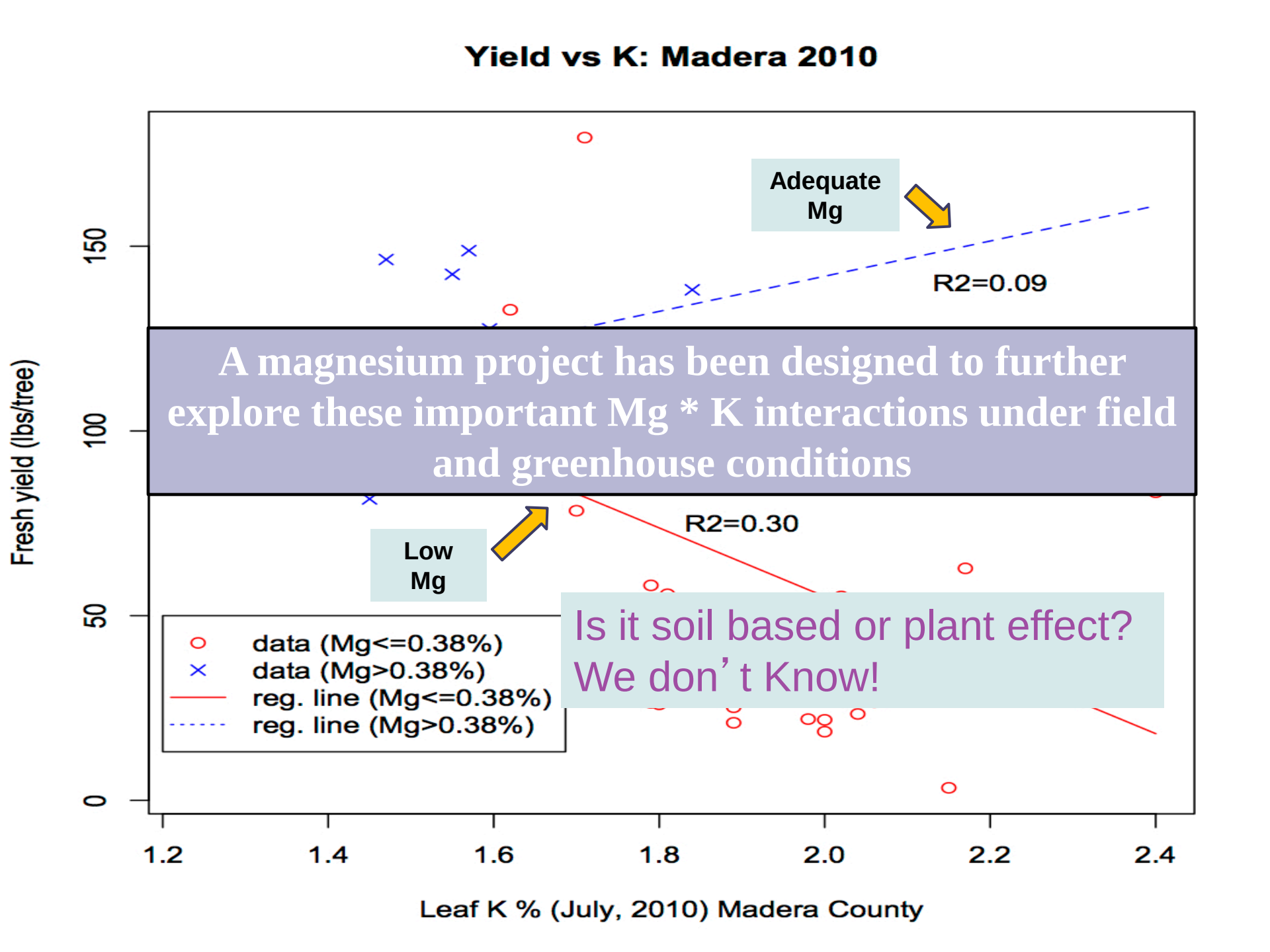






Statistical and observational analysis suggested that the apparent negative effect of K on yield may be a consequence of an induced deficiency of Mg ?

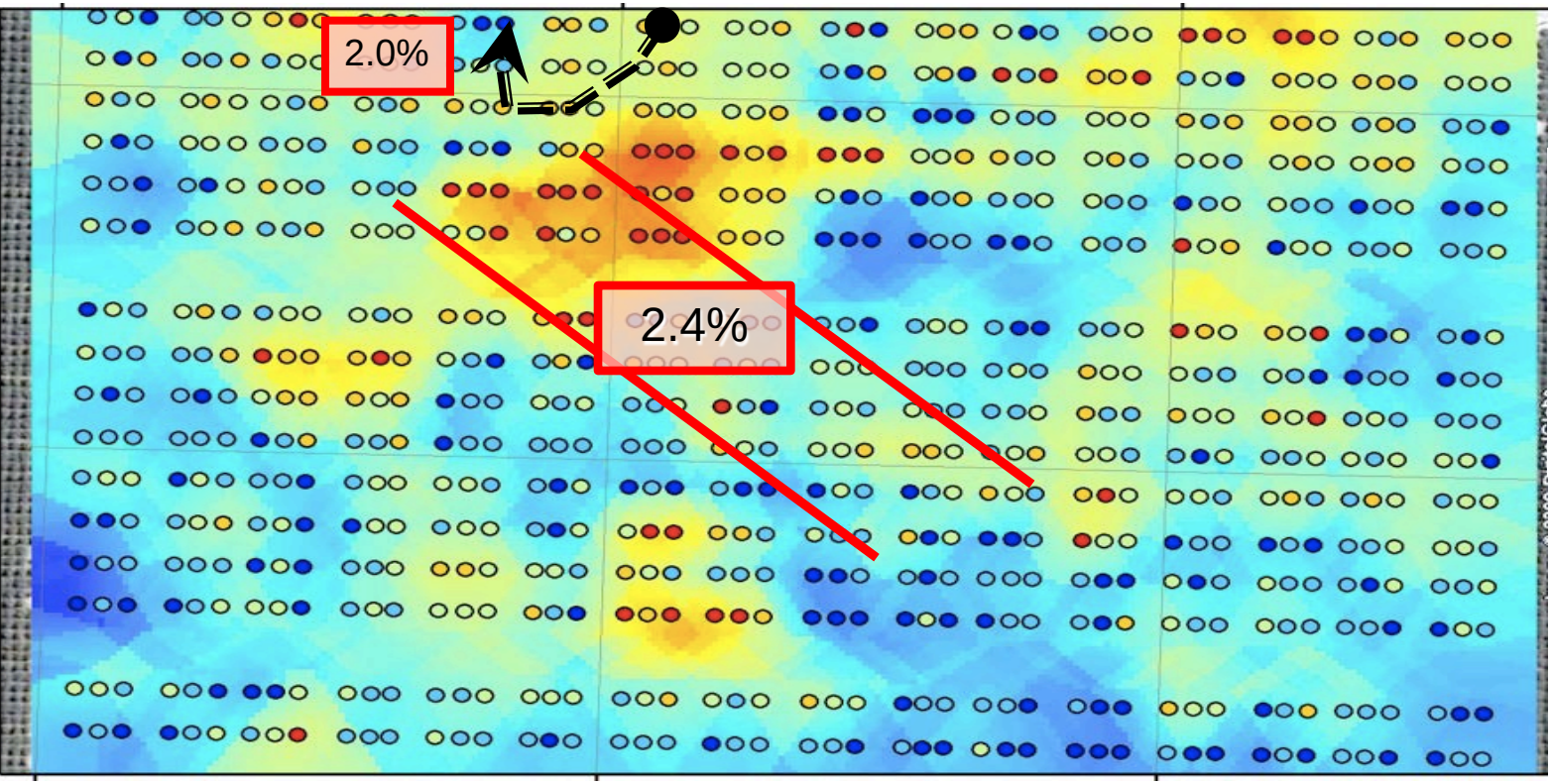

Yield vs K: Madera 2009
data (Mg<=0.38%)
data (Mg>0.38%)
reg. line (Mg<=0.38%)
reg. line (Mg>0.38%)
R2=0.06
R2=0.42
Adequate Mg
Low Mg
Fresh yield (lbs/tree)
0
50
100
150
1.6
1.8
2.0
2.2
2.4
2.6
Leaf K % (July, 2009) Madera County


Yield vs K: Madera 2010
Adequate Mg
R2=0.09
A magnesium project has been designed to further explore these important Mg * K interactions under field and greenhouse conditions
Low Mg
R2=0.30
Is it soil based or plant effect? We don't Know!
data (Mg<=0.38%)
data (Mg>0.38%)
reg. line (Mg<=0.38%)
reg. line (Mg>0.38%)
Fresh yield (lbs/tree)
0
50
100
150
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Leaf K % (July, 2010) Madera County

Summary: How Should I Fertigate?

- What tools (leaf, soil, water) should I be using?
  - All of them, plus a little bit of plant nutrition understanding, and:
  - Fertilize according to yield potential of CURRENT year
  - Pay attention to field variability and year-year variability
- Are university guidelines for critical values still viable?
  - Yes for all elements except Mg which should be reduced to 0.4%.
  - Recognize that leaf sampling properly is really difficult to do well.
  - You cannot manage on leaf analysis alone, nutrient budgets must be incorporated,

Challenges of Sampling: Field Variability
How do we sample properly?



We estimated the number of samples needed for 90% confidence level for July leaf samples at four research sites.

¤

Paramount (Kings County)				
Year	N	P	K	Mg
2009	8	9	11	13
2010	5	6	11	15
2011	6	10	13	14
Buttonwillow (Kern County)				
Year	N	P	K	Mg
2009	9	8	15	21
2010	3	5	13	15
2011	7	5	12	19
KammAvenue (Fresno County)				
Year	N	P	K	Mg
2009	5	5	15	15
2010	3	3	18	21
2011	5	2	11	17
Madera (Madera County)				
Year	N	P	K	Mg
2009	8	6	21	15
2010	8	8	23	21
2011	7	8	38	40

Current Critical Values for Pistachio July Sample

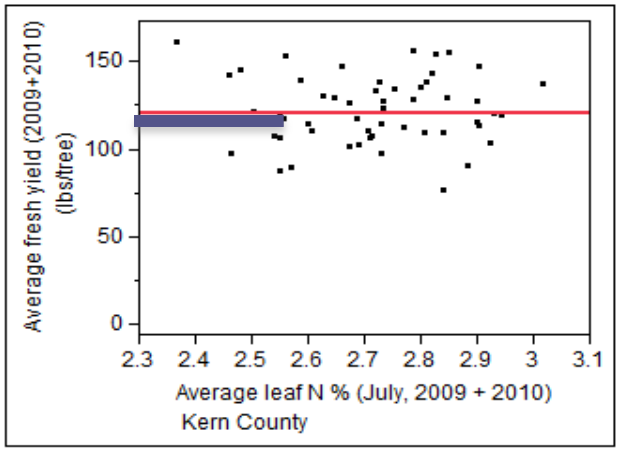
Element	Critical Value	Suggested Range	Reference
Nitrogen (N)	1.8%	2.2 -2.5%	Weinbaum, et.al. 1988, 1995
Phosphorus (P)	0.14%	0.14-0.17%	
Potassium (K)	1.6%	1.8 - 2.0 %	Brown, et.al. 1999
Calcium (Ca)	1.3% (?)	1.3-4.0%	
Magnesium (Mg)	0.6% (?)	0.6-1.2%	
Sodium (Na)	(?)	(?)	
Chlorine (Cl)	(?)	0.1-0.3%	
Manganese (Mn)	30 ppm	30-80 ppm	
Boron (Bo)	90 ppm	150-250 ppm	Uriu,1984; Brown, et.al.,1993
Zinc (Zn)	7 ppm	10-15 ppm	Uriu and Pearson.1981, 1983,1984,1986
Copper (Cu)	4 ppm	6-10 ppm	Uriu, et.al. 1989

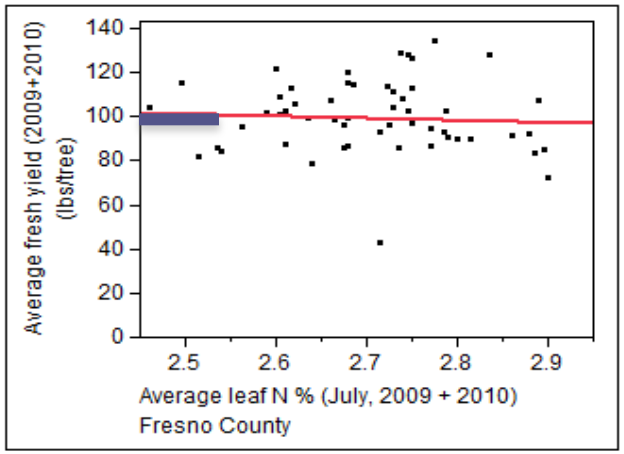
0.4%

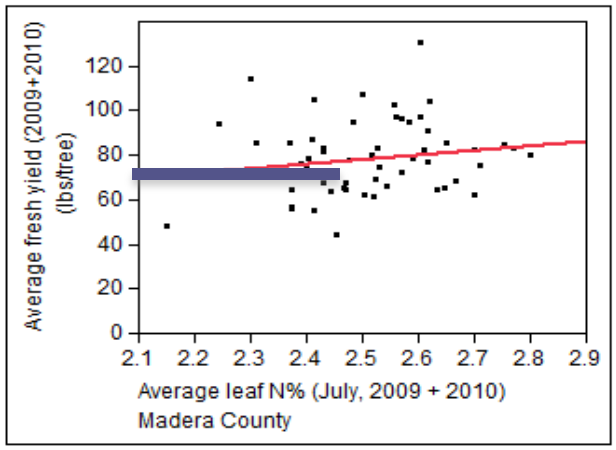
ppm = parts per million or milligrams/kilogram dry weight.

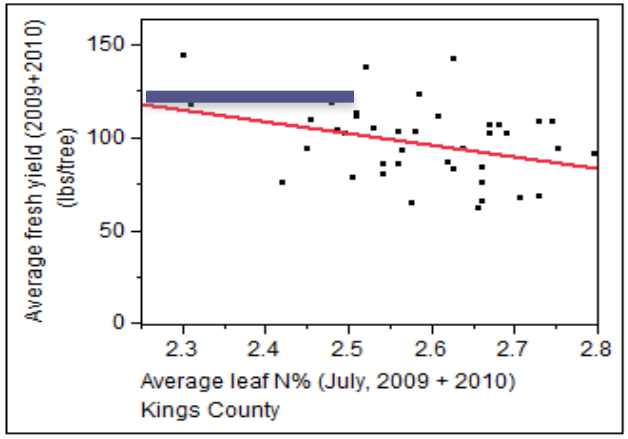
% = parts per hundred or grams/kilogram dry weight

Validation of Existing Critical Values – (N)

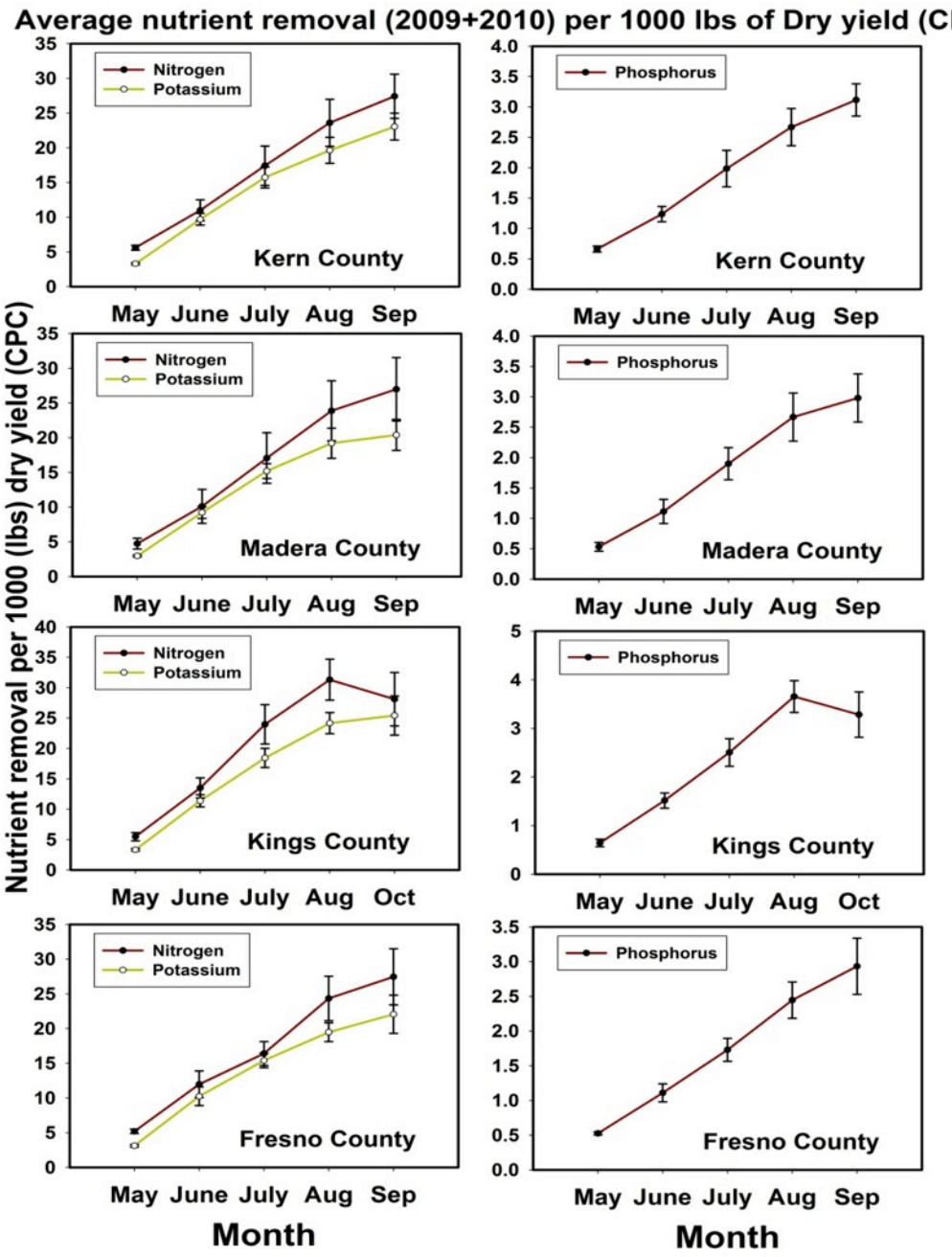








Relationship of average leaf nitrogen (July, 2009 + 2010) with average yield (2009 + 2010). Data represents averages from 54 individual trees at Kern, Fresno, Madera and Kings Counties.



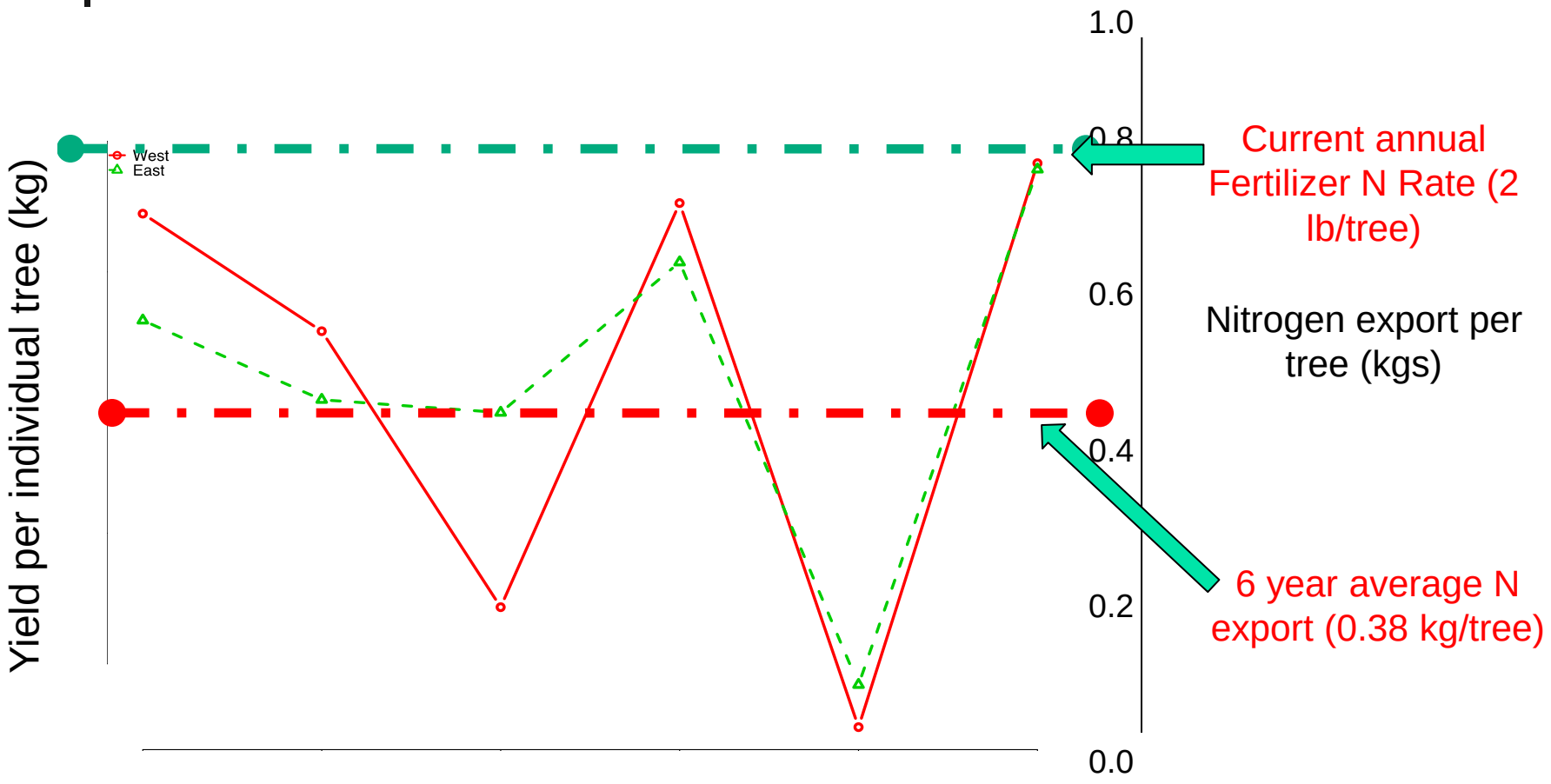
Nutrient removal Per 1000 lbs (CPC yield)

- Valuable for estimating demand or replacing nutrient export
- Provides insight into efficiencies
  - N removal 28 lbs per 1000
  - K removal 25 lbs per 1000
  - P removal 3 lbs per 1000

Brown and Siddiqui-unpublished

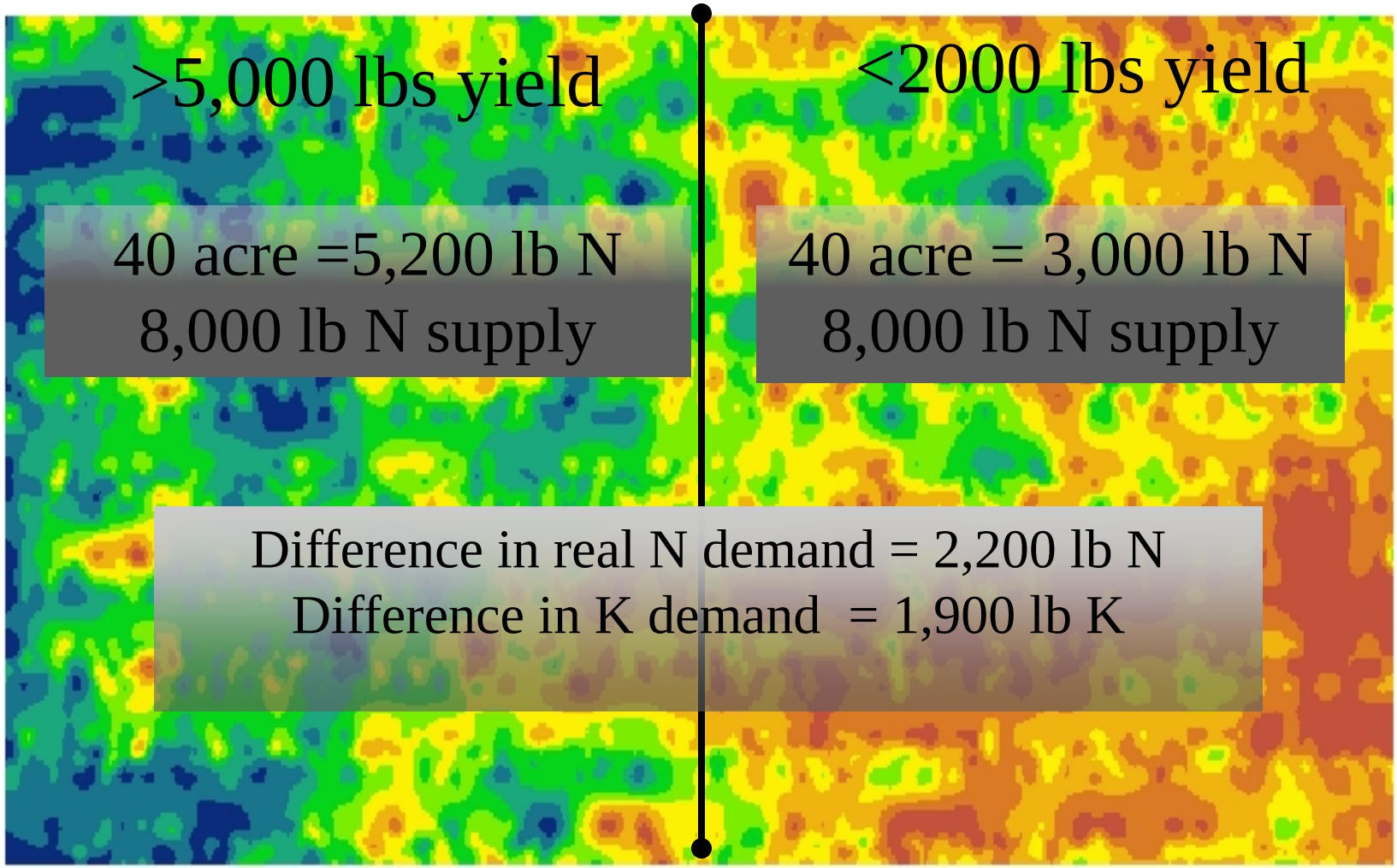
Variation in Yield over Time

Pistachio 4820 trees individually harvested.



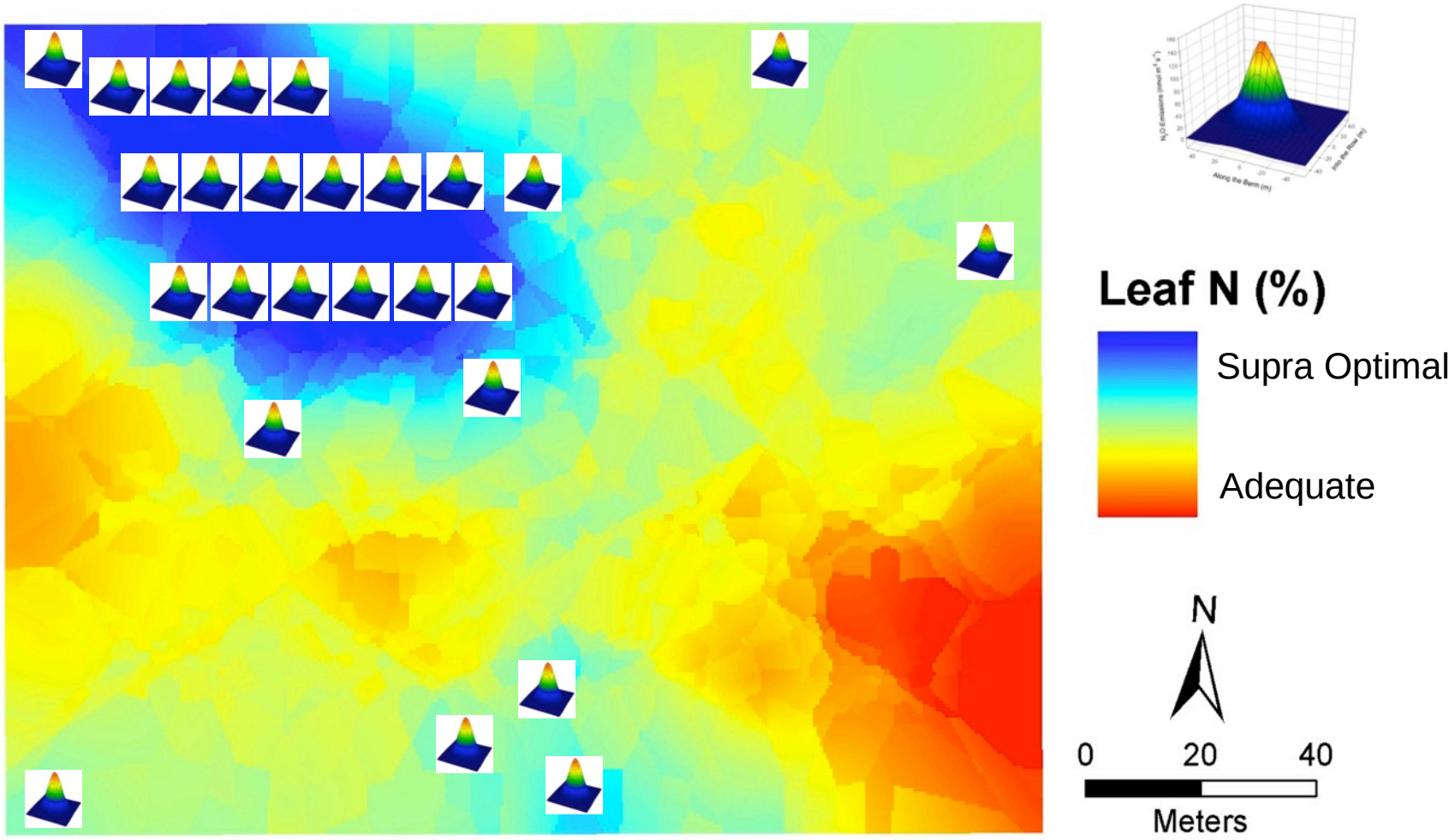
Managing for Spatial Variability

Variability in Yield alters N demand?



Spatial distribution of N

Sites of Excess Fertilization have the highest potential for Nitrogen release



D. Smart et al

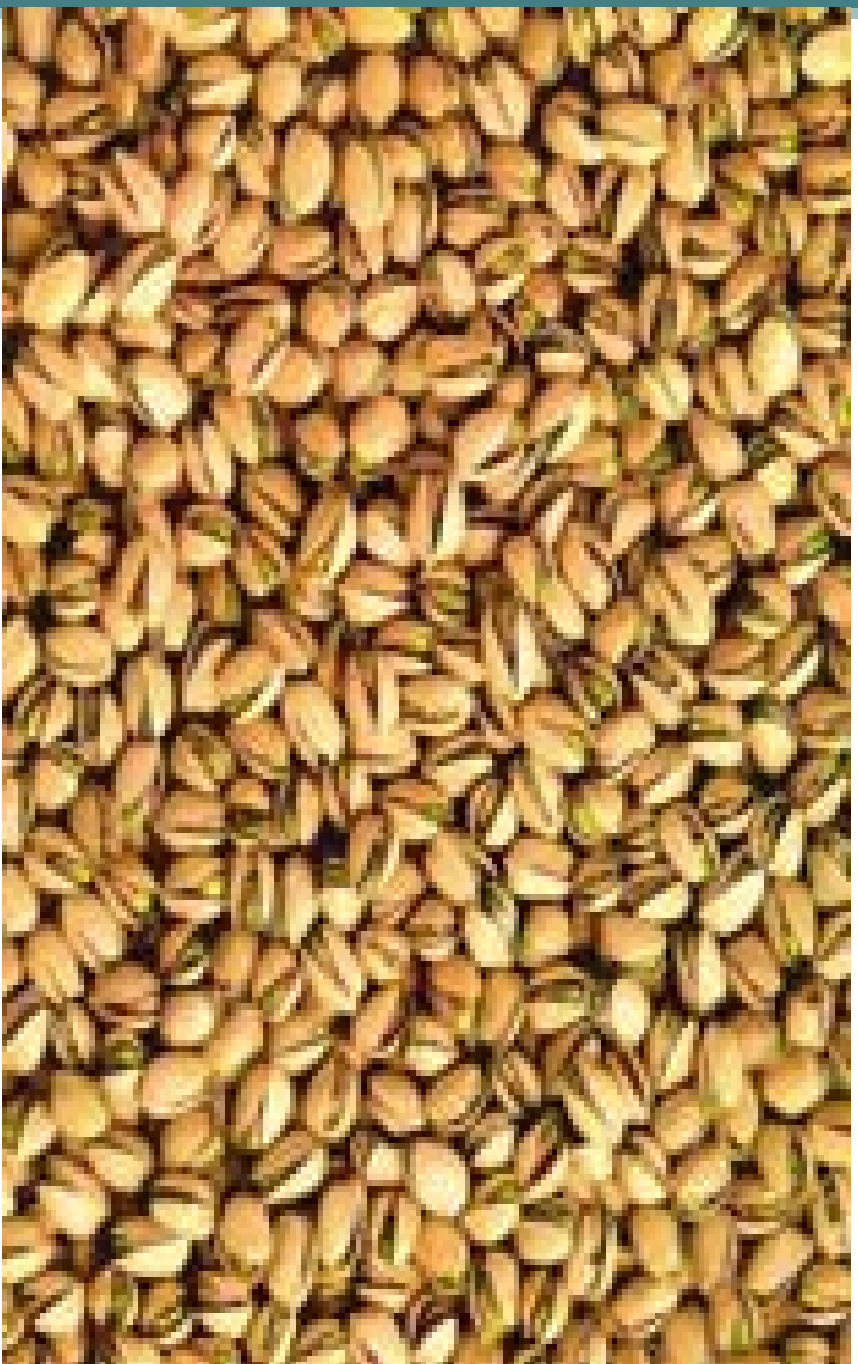
How Should I Fertigate?
Focus on N, K (and Mg)

- What tools (leaf, soil, water) should I be using, and how?
  - All of them, plus a little bit of plant nutrition understanding, and:
  - Fertilize according to yield potential of CURRENT year
  - Manage your variability
- Are university guidelines for critical values still viable?
  - Yes for all elements except Mg which should be reduced to 0.4%.
  - However, doing leaf sampling right is really difficult
  - You cannot manage nutrition based on leaf analysis alone.

Principles of Nutrient Management- Optimizing Fertilization by Applying the 4 R's

- Applying the Right Rate
  - Match demand with supply
- At Right Time
  - Determine when uptake from the soil occur
  - Maximize uptake minimize loss potential.
- In the Right Place
  - Ensure delivery to the active roots.
  - Managing variability across the orchard
- Using the Right Source
  - Maximize uptake minimize loss potential.

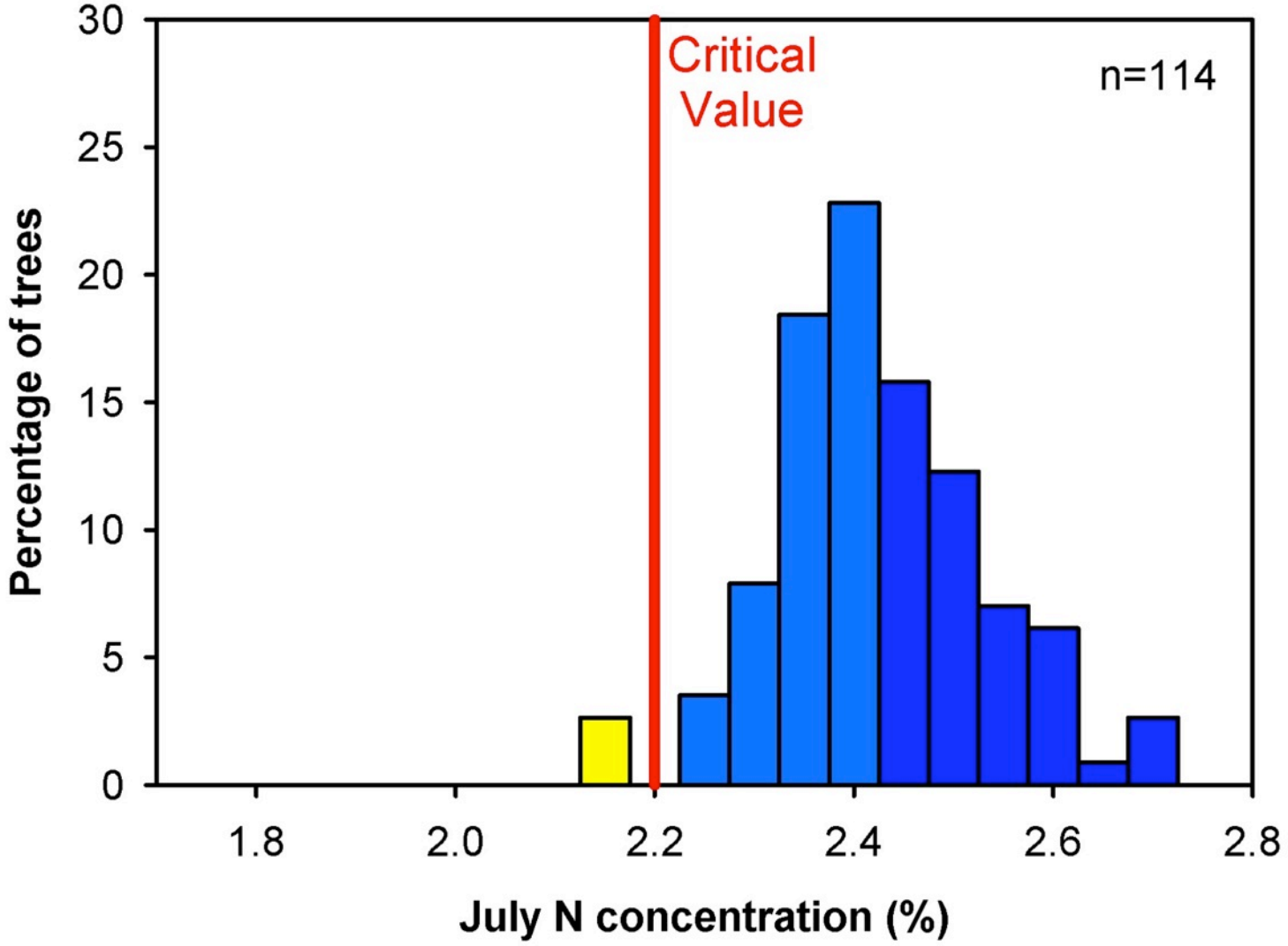
Are our current guidelines for pistachio fertilization adequate to achieve this?



Thank you

How Widespread is this ‘Problem’?

Survey of leaf N distributions in Californian Orchards



Managing Nutrition of High Value Crops