Managing Nitrogen Efficiently

Patrick Brown

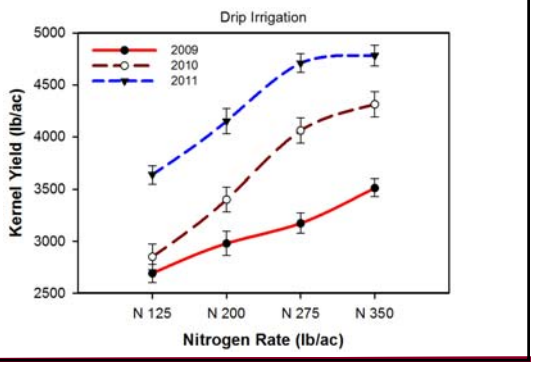
Background

Why the focus on Nitrogen?

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

Satisfy Demand, Prevent Losses, Maximize Efficiency?

Nitrogen is essential for Almond yields

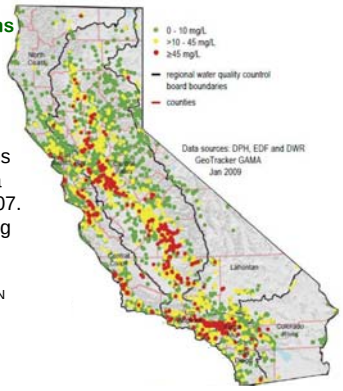


Environmental concerns

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

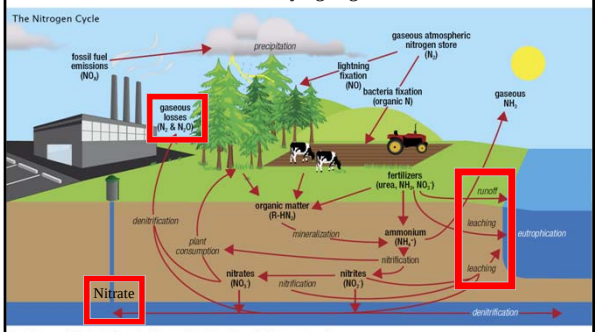
44 mg/L NO_3 = 10 mg/L NO_3-N

(some from animal manure)



(Ekdahl and others, 2009)

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.



(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 (4 R's)

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

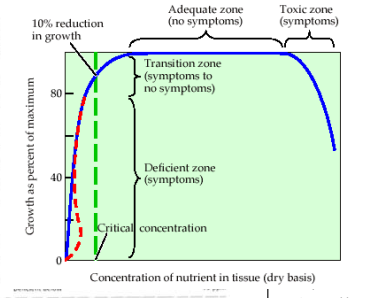
1. Assess all available nutrient inputs (water, legumes etc)
2. Determine plant demand
3. Optimize fertilizer use efficiency

Source | Rate | Time | Place

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

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

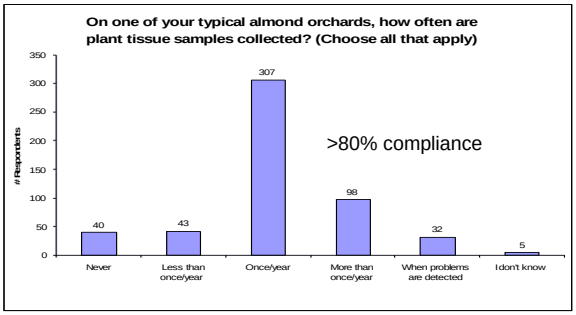
What do we know and how do we manage?
Leaf Sampling and Critical Value Analysis



ols are well defined
pur leaves
uadrant at 6'.
analysis with standard Critical
d in Almond Production Manual
als (N, K, B)
nptoms (P, S, Mg, Ca, Mn, Zn, Fe,
n (Ni, Cl, Mo)
results (NO R'S!)
can indicate a shortage but cannot
espond.
er decisions are currently based on
l an 'estimate' of fertilizer needs

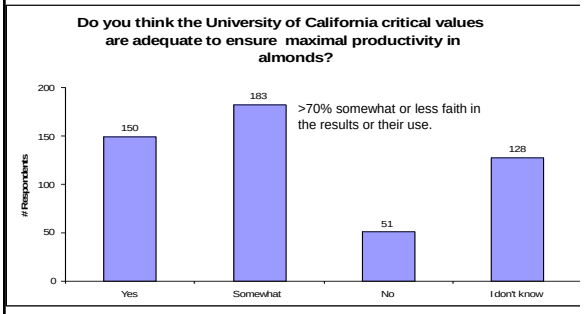
➢No guidance on Rate, Timing, Placement or Source

Are tissue samples collected and if so how often?

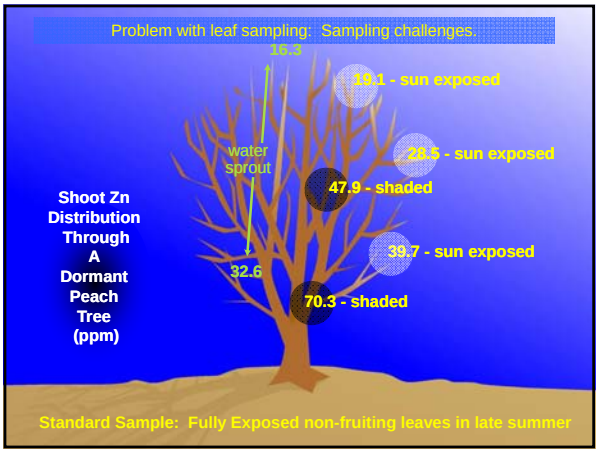


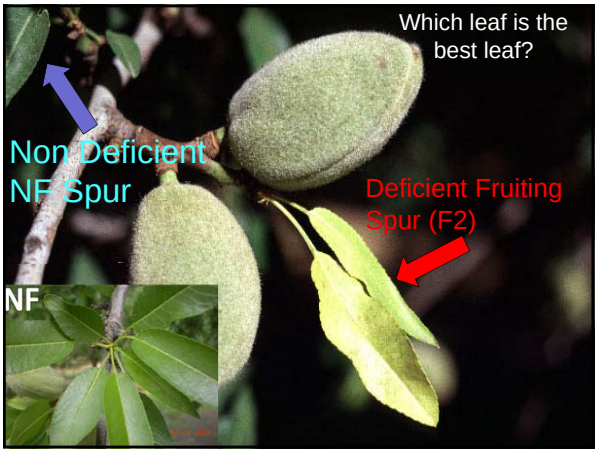
Brown et al, 2004

Are tissue samples being used to guide fertilizer management?

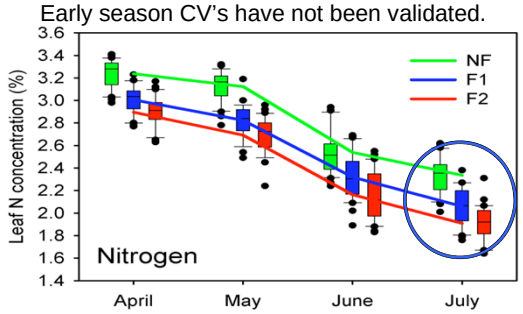


Brown et al, 2004





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



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

Challenge: Develop early season sampling and interpretation methodologies.

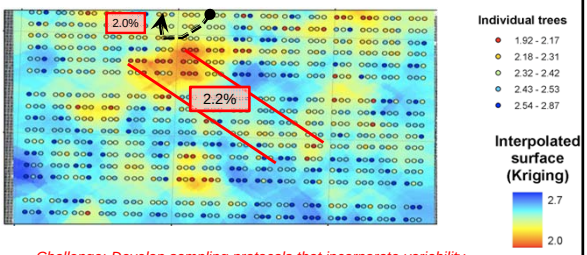
Challenges of Sampling: Field Variability

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

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

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

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



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

Summary: Tissue Testing for Almonds

Problems.

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

Solutions

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

Alternatives?

Alternate Approach: Nutrient Budgeting

Efficiently replace the nutrients removed from the field

Estimate current year demand

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

Measure and control inputs and losses

- Soil, fertilizer, irrigation, leaching, volatilization

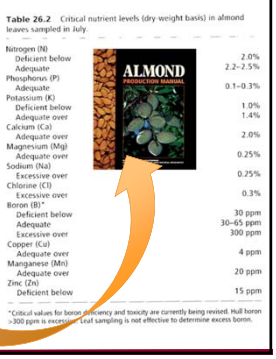
Manage efficiencies and interactions

- Synchronization and location of nutrient applications
- Monitoring crop response

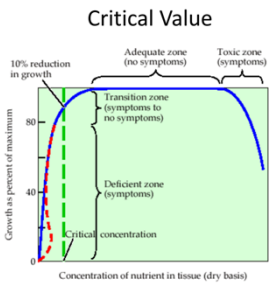
How?

What do we currently do to manage our orchards?

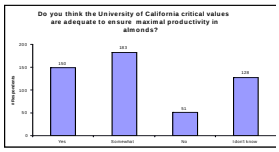
Sample in July



Problem Statement: Recall to Dr. Brown's lecture



Are tissue samples being used to guide fertilizer management?



Possible Reasons for this problem:

- **Current Sampling Protocol is too late in year to make in season adjustments.**
- **Samples collected do not always represent the true nutrient status of the orchard as a whole.**
- **Our current CV's may not apply in all cases or may be wrong.**

Objectives:

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

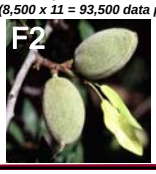
Experiment:

- **Four sites from California's major almond producing regions**

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

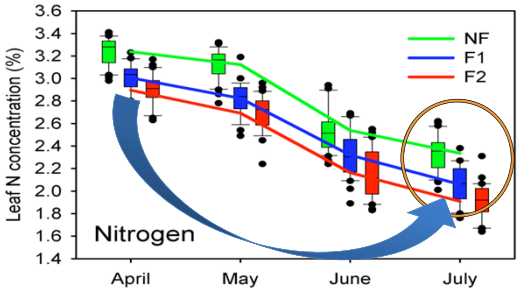
Design and Sampling

- 114 trees x 4 Sites x 3 years.
- Yield.
  (About 1,130 data points)
- 5 in-season nutrient samples.
  (8,500 x 11 = 93,500 data points)



Time of Sampling Problem.

Can we sample in April and predict July?



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

Two Models to answer the same Q.

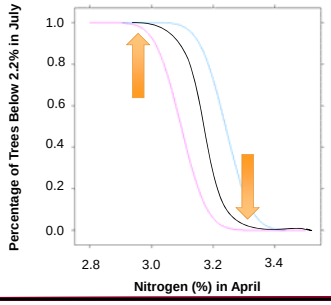
- Model one uses all the April information from F2 spurs to predict the July nitrogen value.
- Model two uses the nitrogen NF information from April to predict the July nitrogen value.
- Both models also predict what percentage of the trees are above or below the current July nitrogen critical value.
- Both models work well but we do not yet

Results 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

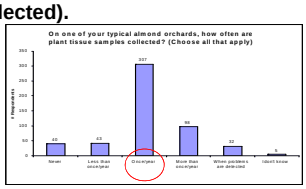
<3.1 in April likely to be deficient in July

>3.2 in April unlikely to be deficient in July

ALL DEPENDS ON YOUR YIELD!

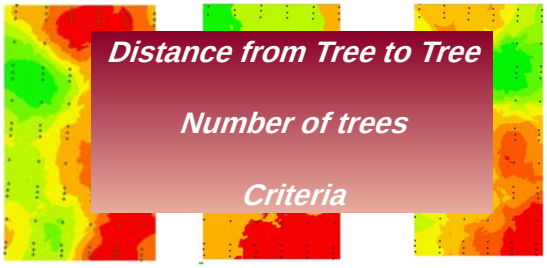
Objectives:

- 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).



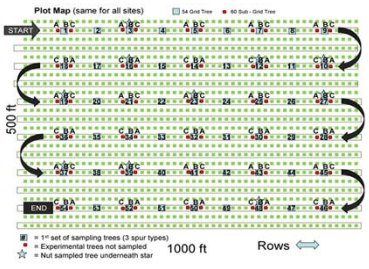
If you can only collect one sample…

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



Spatial Correlation Concept

➔**We attempt to test if and when trees are giving independent information.**



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 (43 days after full bloom (DAFB) +/- 6 days). April 20 in 2011.**
- **if you would like to collect samples in July, then collect samples at 143 DAFB +/- 4 days. July 27 in 2011.**
- **Always make note of date of sampling.**

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).**
- **Even if you sample well and predict from April to July IT IS STILL NOT GOOD ENOUGH.**

ALTERNATIVE APPROACH

Nutrient Budget for Almond

Saiful Muhammad
UC Davis

Nutrient Budgeting

Efficiently replace the nutrients removed from the field

Estimate current year demand

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

Measure and control inputs and losses

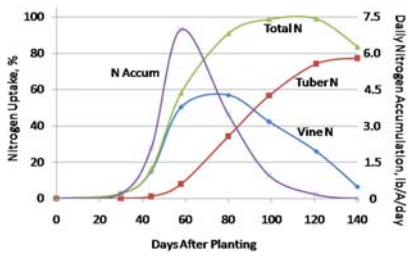
- Soil, fertilizer, irrigation, leaching, volatilization

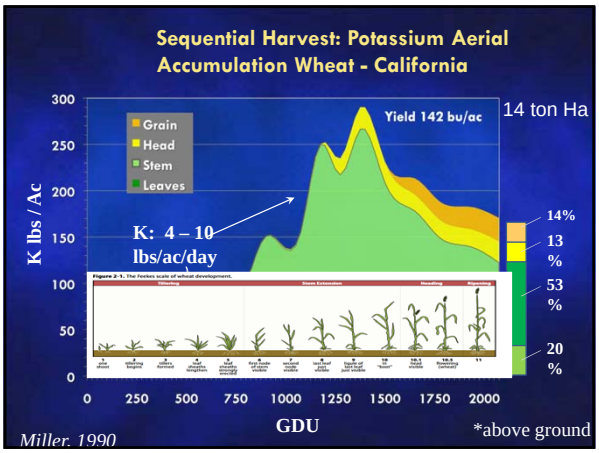
Manage efficiencies and interactions

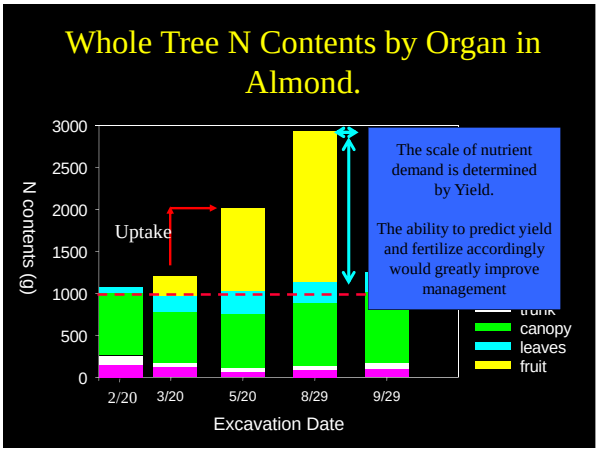
- Synchronization and location of nutrient applications
- Monitoring crop response

How?

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



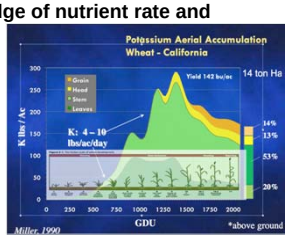




Determining the Right Rate and Timing

Nutrient Budget Approach

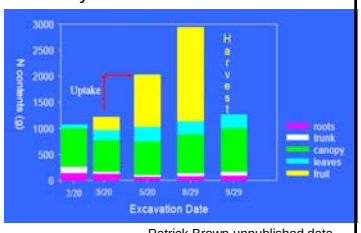
- **Provides information on total annual demand**
- **Develops knowledge of growth and development and derives nutrient demand curves**
- **Provide information nowledge of nutrient rate and timing**



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

- Theoretically, continuous nutrient feeding is better than 2 or 3 fertigation events.
- More work on relative efficiency of fertilizer source is needed.



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**

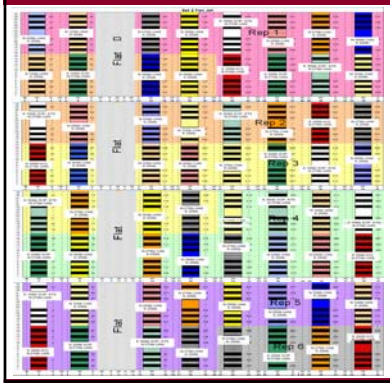
Fertigation

- **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

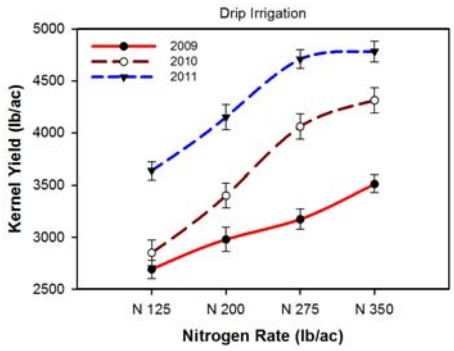
Experiment:

- **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

Preliminary Findings

Yield Response to Nitrogen



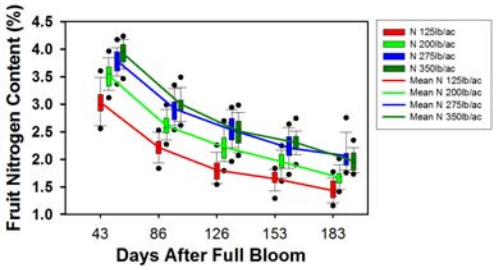
Cumulative Kernel Yield 2009-11

Cumulative Kernel Yield 2009-2011 (lb/ac)

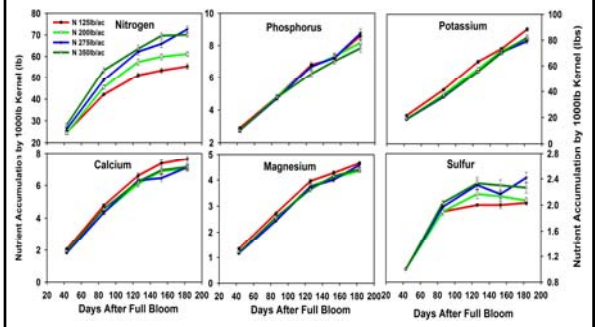
	N UAN 32				N CAN 17			
Irrigation	125	200	275	350	125	200	275	350
Drip	9,328	10,642	11,667	12,356	8,796	10,298	11,844	12,139
	d	c	b	a	c	b	a	a
Fan Jet	9,156	10,245	11,201	11,314	9,563	10,345	11,539	11,109
	c	b	a	a	c	b	a	a

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

Nitrogen Fertilization and Fruit N Content (2010)



Nutrient Export by 1000lb kernel



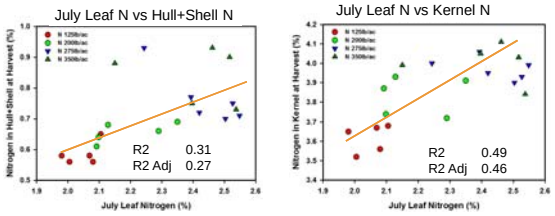
NPK Export by 1000lb Kernel at Harvest 2009-10

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

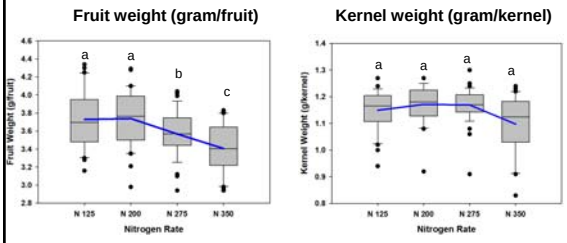
Nutrient	2009 Nitrogen Rate (lb/ac)				2010 Nitrogen Rate (lb/ac)			
	125	200	275	350	125	200	275	350
N	53	56	58	59	55	61	73	70
	b	ab	a	a	c	b	a	a
P	7.5	7.4	7.2	6.7	8.6	8.2	8.9	7.8
	a	a	ab	b	ab	ab	a	b
K	75	73	73	72	88	81	80	82
					ab	b	b	b

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

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



Fruit and Kernel weight



N Fertilization increases Shelling Percentage

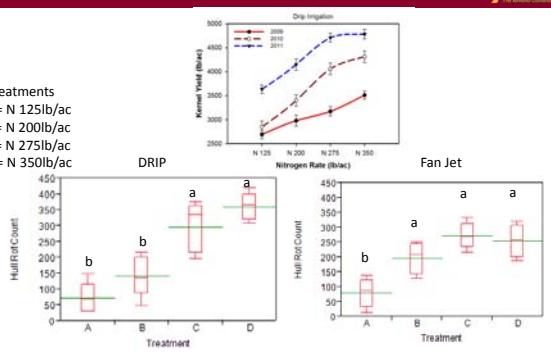
Shelling Percentage (%)

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

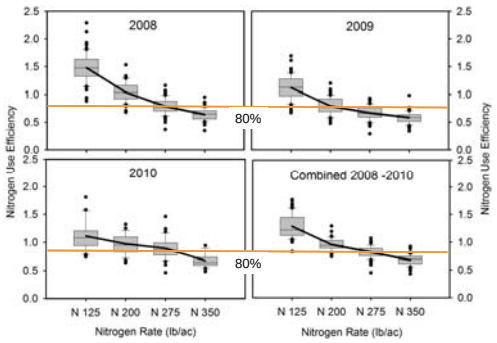
Means not followed by the same letter are significantly different at 10%.
Statistics are only within irrigation type.
Shelling percentage is on the basis of clean 4lb sample

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

Why is this Orchard so Efficient?

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

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

At Right Time
- Fertigate coincident with demand.

In the Right Place
- Ensure delivery to the active roots.

Using the Right Source
- Soluble, compatible and balanced.

Conclusions

- **1000lb kernel removes from 55 - 70lb N (at a leaf N of 2.0 to 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.**

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%.

Secrets to High Efficiency:

Adapt fertilization to real yield potential (next step)

Apply N coincident with tree demand

Keep fertilizer N in the root zone

Manage variability (next step)

Monitor for soil and plant N accumulation

Conclusions: Managing Nitrogen

Base your Fertilization Rate on Realistic, Orchard Specific Yield
- **Estimate your current yield and try to get as close to 'replacement' as possible.**
- **1000lb kernel removes from 55-70 lb N (July leaf N 2.0 – 2.4%) , 8lb P and 80lb K.**
- **Apply 70-80% from bloom to mid-June.**
- **Apply 20-30% post harvest but only if trees are healthy.**
- **Every field is a unique decision**
- **Include all inputs (fertilizer, water, manures etc)**

Conclusions: Managing Nitrogen

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

Follow the sampling rules!
- **18 trees/one bag/each two trees apart. You can sample in April to estimate July. (Labs will have guidelines by April)**
- **Use leaf analysis in conjunction with yield estimate to adjust in-season fertilization.**
- **Keep good records and sample consistently (right) over the years.**

Estimate yield, measure leaf nutrients in April, adjust accordingly

Efficient Nutrient Management Approach
-the 3 R's-

Applying the Right Rate
- Match supply with demand (yield estimation)
- Determine nutrient content (leaf sampling)

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

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

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