



Patrick Brown

*University of
California, Davis*

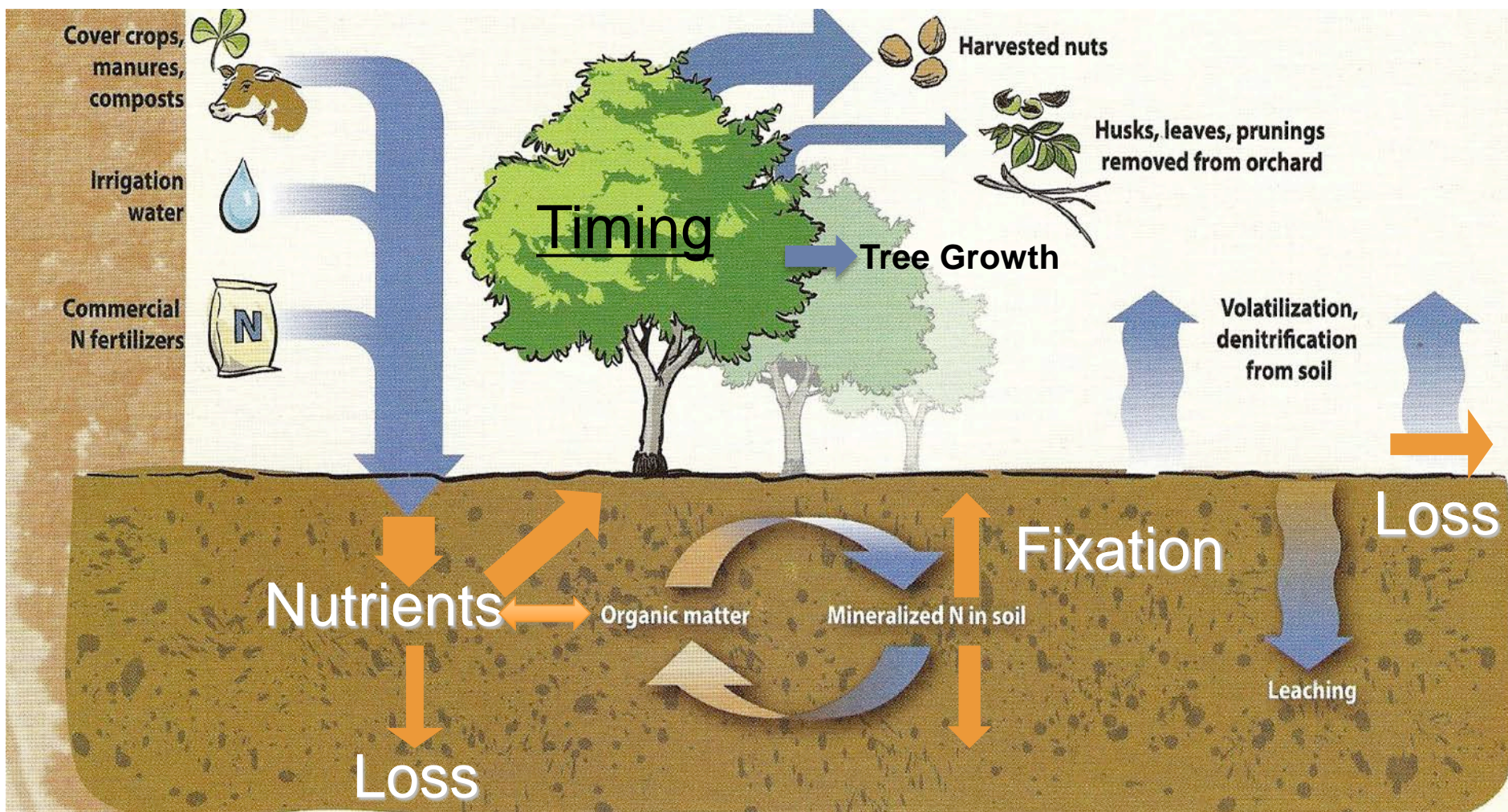
February, 2018

Nitrogen Management in Almond.

Estimating Demand and Timing of Nutrient Uptake

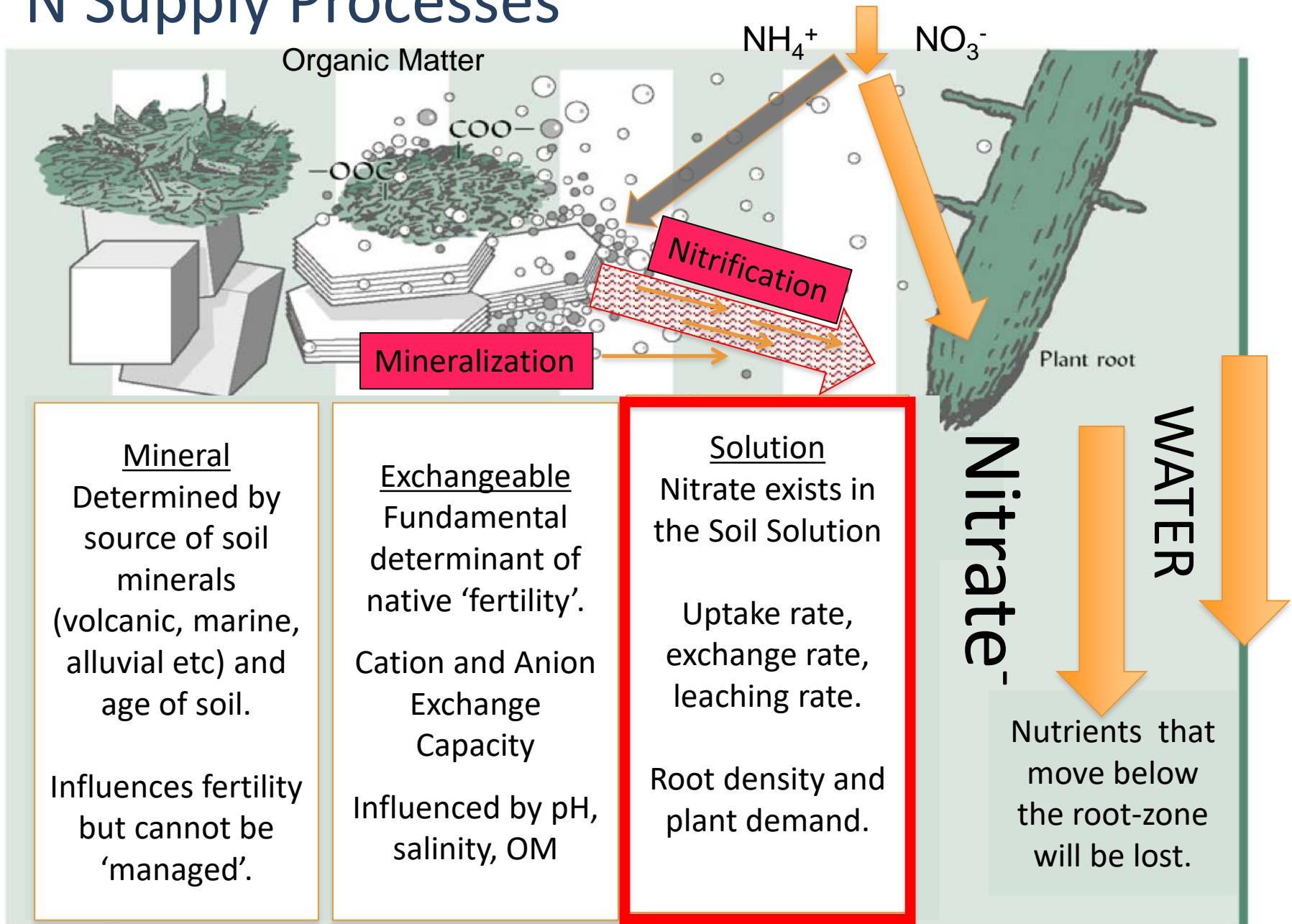
Optimizing N Use in CA Tree Crops.

$$\text{Supply (Rate)} = \text{Demand (Amount and Timing)}$$



N Supply Processes

FERTILIZER OR AMENDMENT



Mineral
 Determined by source of soil minerals (volcanic, marine, alluvial etc) and age of soil.
 Influences fertility but cannot be 'managed'.

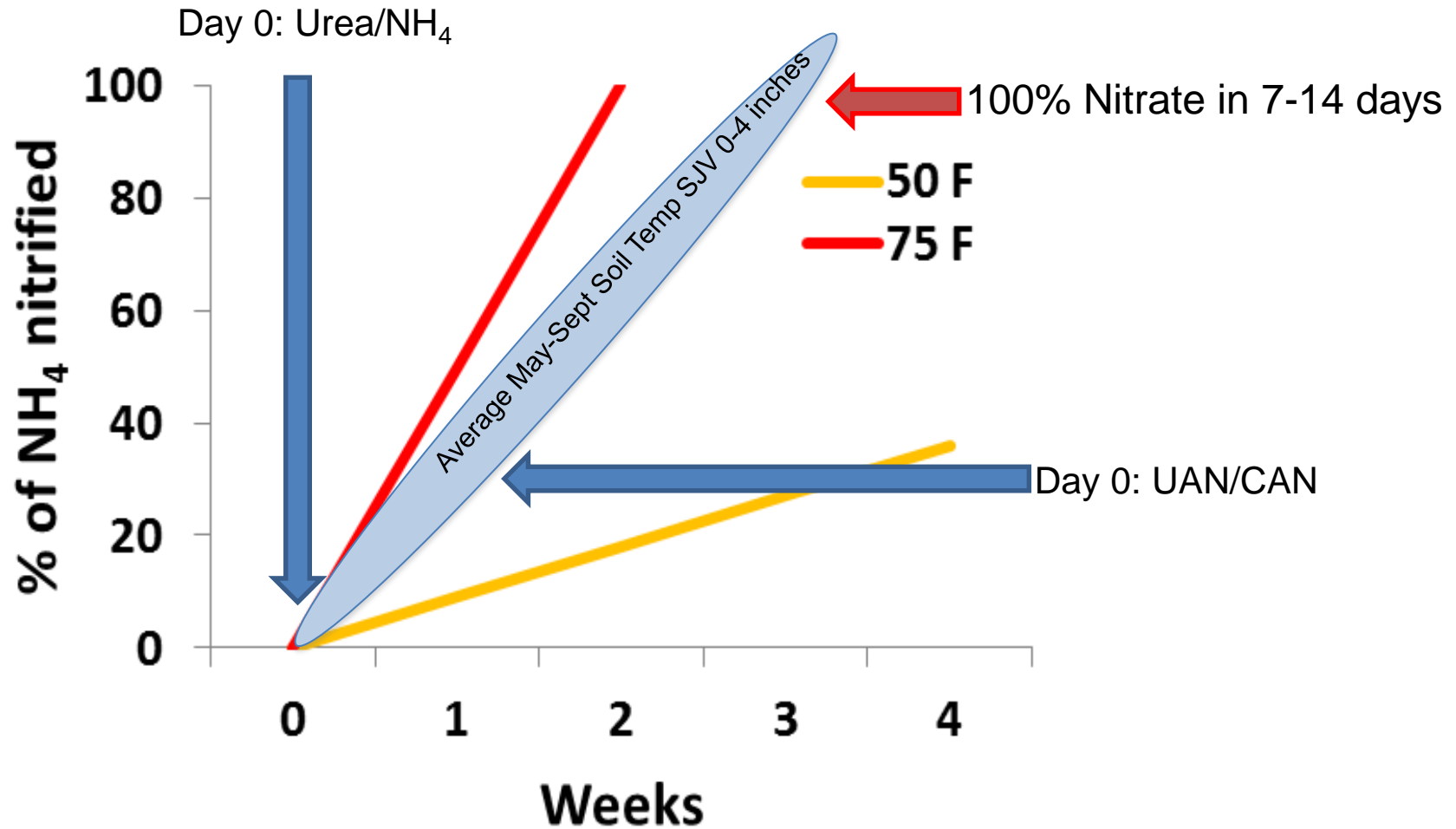
Exchangeable
 Fundamental determinant of native 'fertility'.
 Cation and Anion Exchange Capacity
 Influenced by pH, salinity, OM

Solution
 Nitrate exists in the Soil Solution
 Uptake rate, exchange rate, leaching rate.
 Root density and plant demand.

Nutrients that move below the root-zone will be lost.

Nitrification occurs very quickly!

(rate governed by temperature)



Source: Adapted from Western Fertilizer Handbook

Irrigation Rapidly Moves Nitrate through Soil (Surface applied N Followed by Irrigation: 90 minutes)

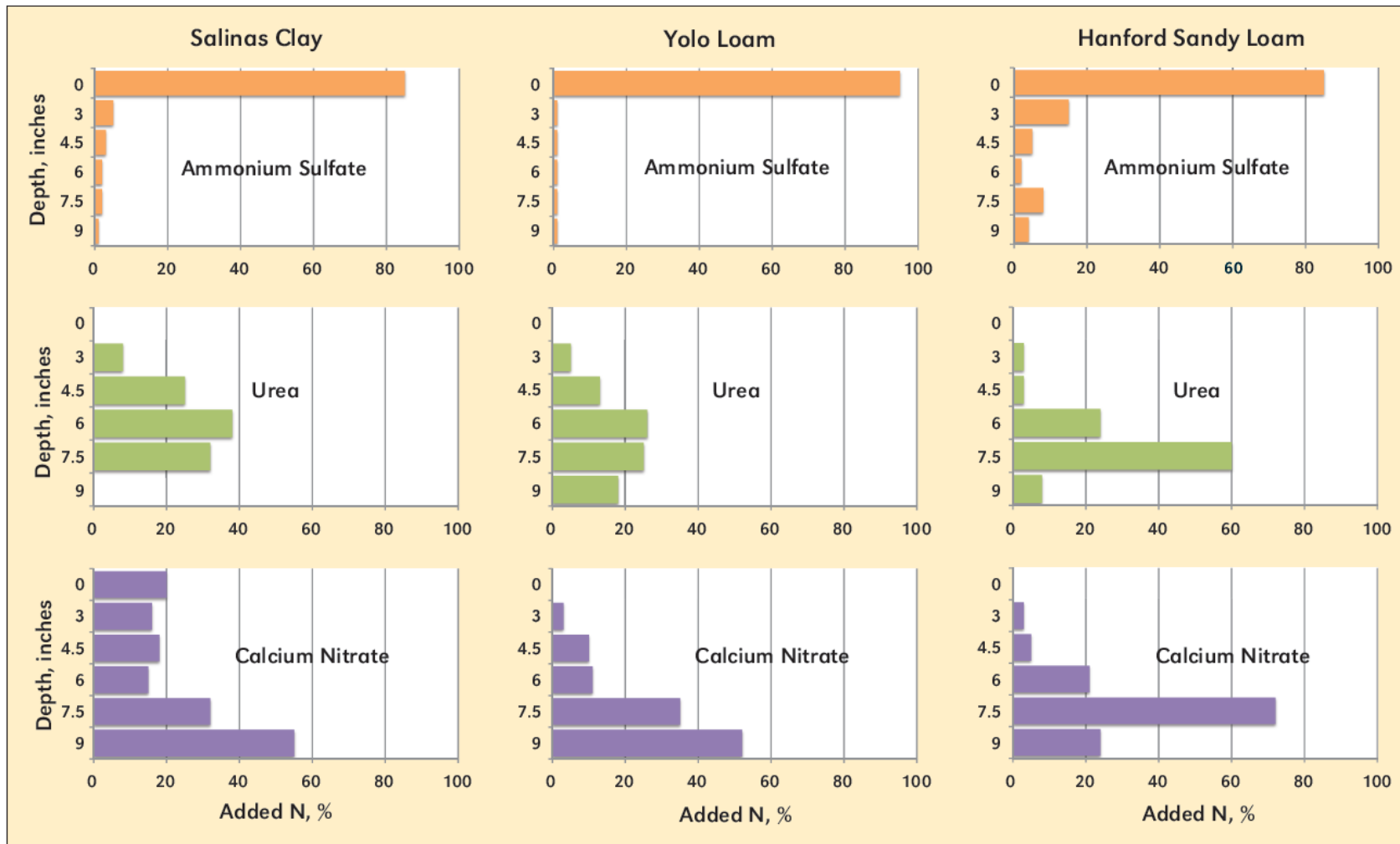
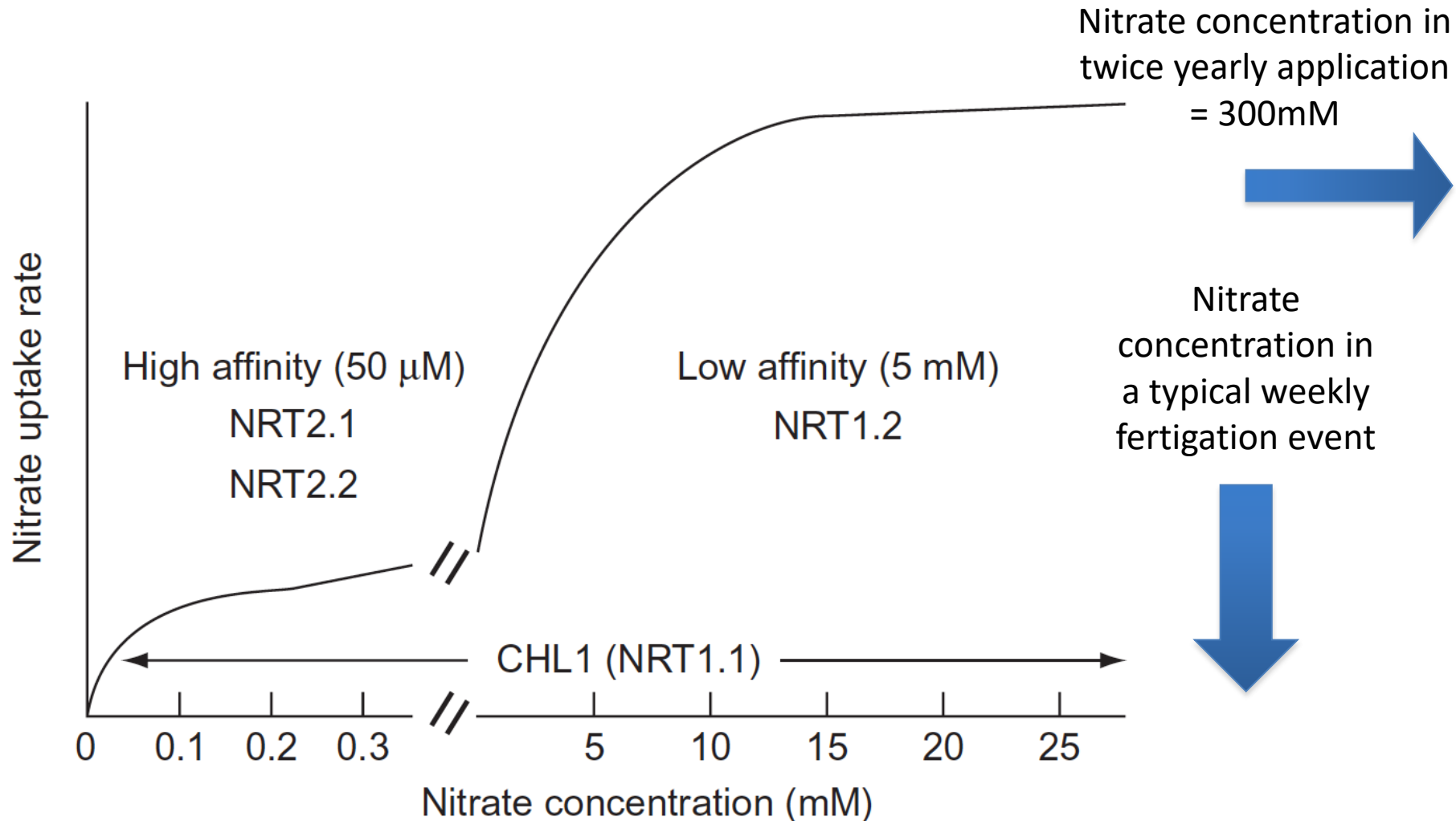


Figure 2. The movement of ammonium, urea, or nitrate in the surface 9 in. of three soils. The urea and calcium nitrate were applied to the soil surface and irrigated with a uniform amount of water. The ammonium sulfate was added as a solution. The soils were sampled 90 minutes after fertilizer and water application. (Broadbent et al., 1958).

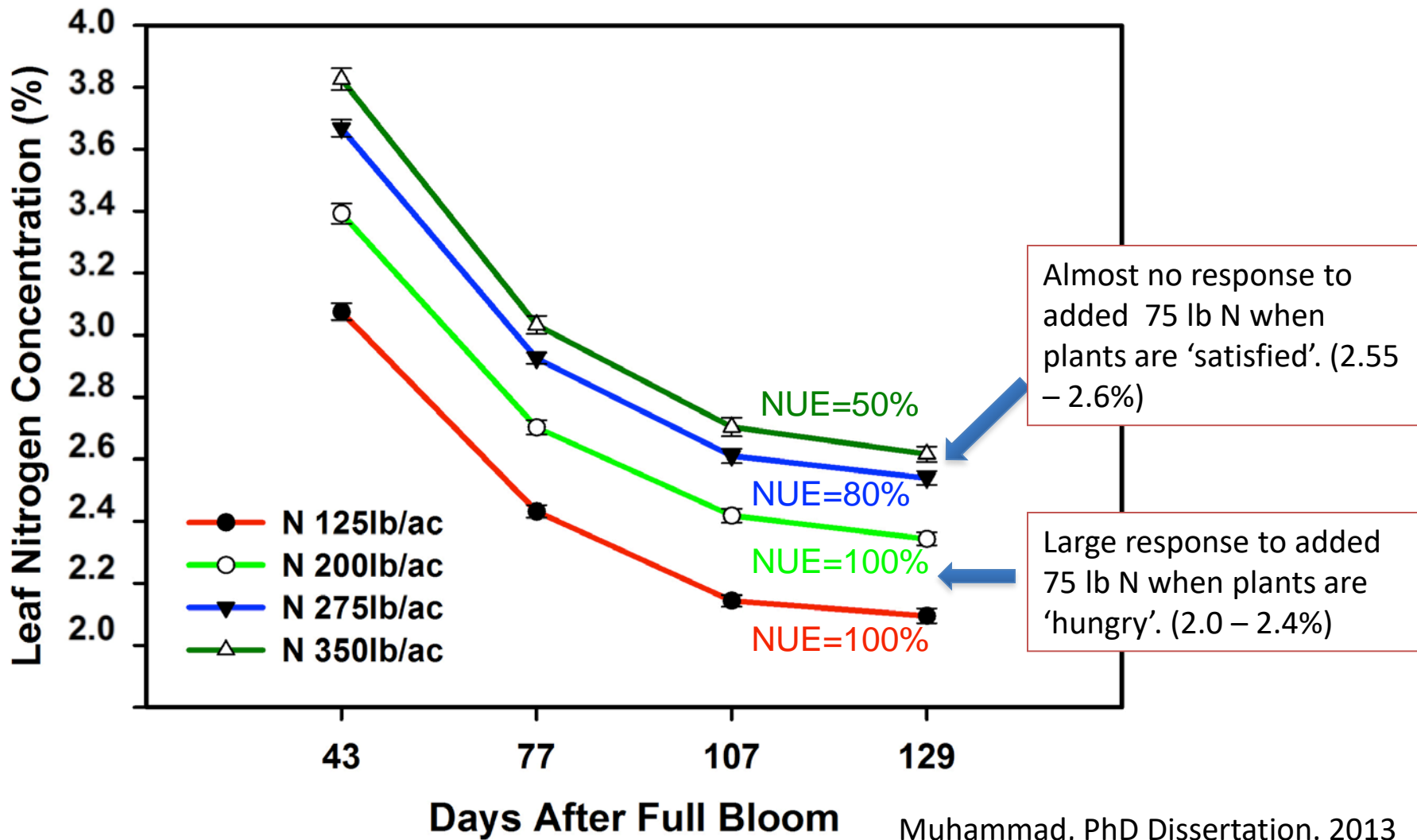
Nitrate Uptake Rate is Limited

(Fertigation concentrations are often greater than uptake rate).



N in excess of demand is inefficiently used.

(Effect of Nitrogen Rate on Leaf Nitrogen in Almond.)

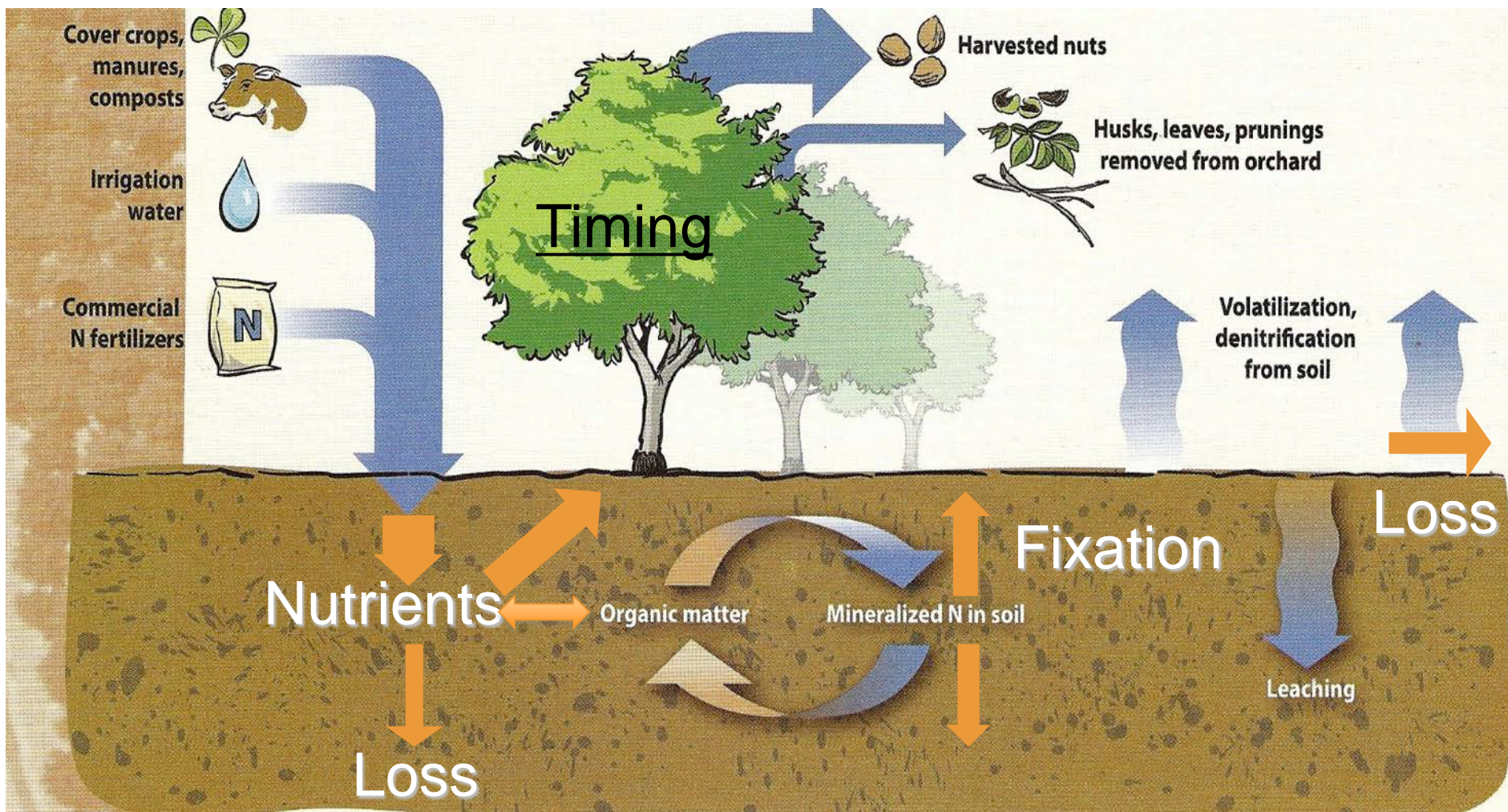


Why does NO_3^- leach?

- NO_3^- is negatively charged and therefore is not held by the soil particles which are also negatively charged
- Lack of organic matter
- If it is applied in excess of current demand
- If timing of application does not match crop demand
- If water moves nitrate beyond rooting depth

Nitrogen Uptake

$$\text{Supply (Rate)} = \text{Demand (Amount and Timing)}$$



Efficient Nutrient Management Approach

-the 4 R's-

Applying the **Right Rate**

- Match supply with tree demand
 - Determine tree demand
 - Measure all inputs- fertilizer, organic N, water, residual soil N.

At **Right Time**

- Match tree demand
- Apply coincident with root uptake.
- Apply coincident with demand

In the **Right Place**

- Ensure delivery to the active roots and with regard to orchard variability.

Using the **Right Source**

- Maximize uptake minimize loss potential.
- Eliminate limiting nutrients
- Stimulate root uptake (?)

*Minimize **Risk**, Maximize **Returns***

Determining Nutrient Demand in Trees

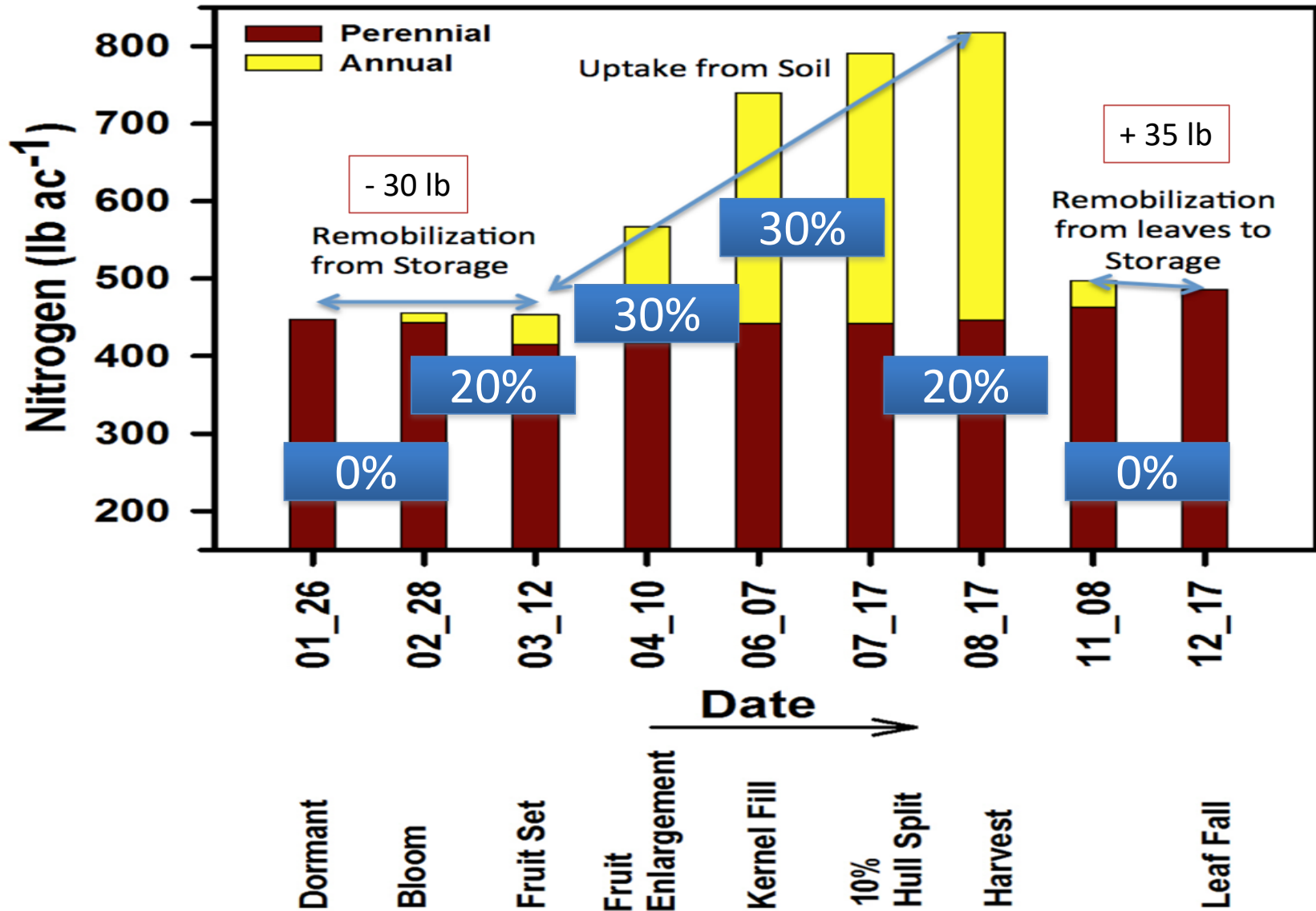
Collection, Separation and Analysis of Annual Tissues



Tree Excavation, Partitioning, and Analysis of Perennial Tissues



Total and Annual Dynamics of N in Mature Almond Tree (data from 12 year old trees)

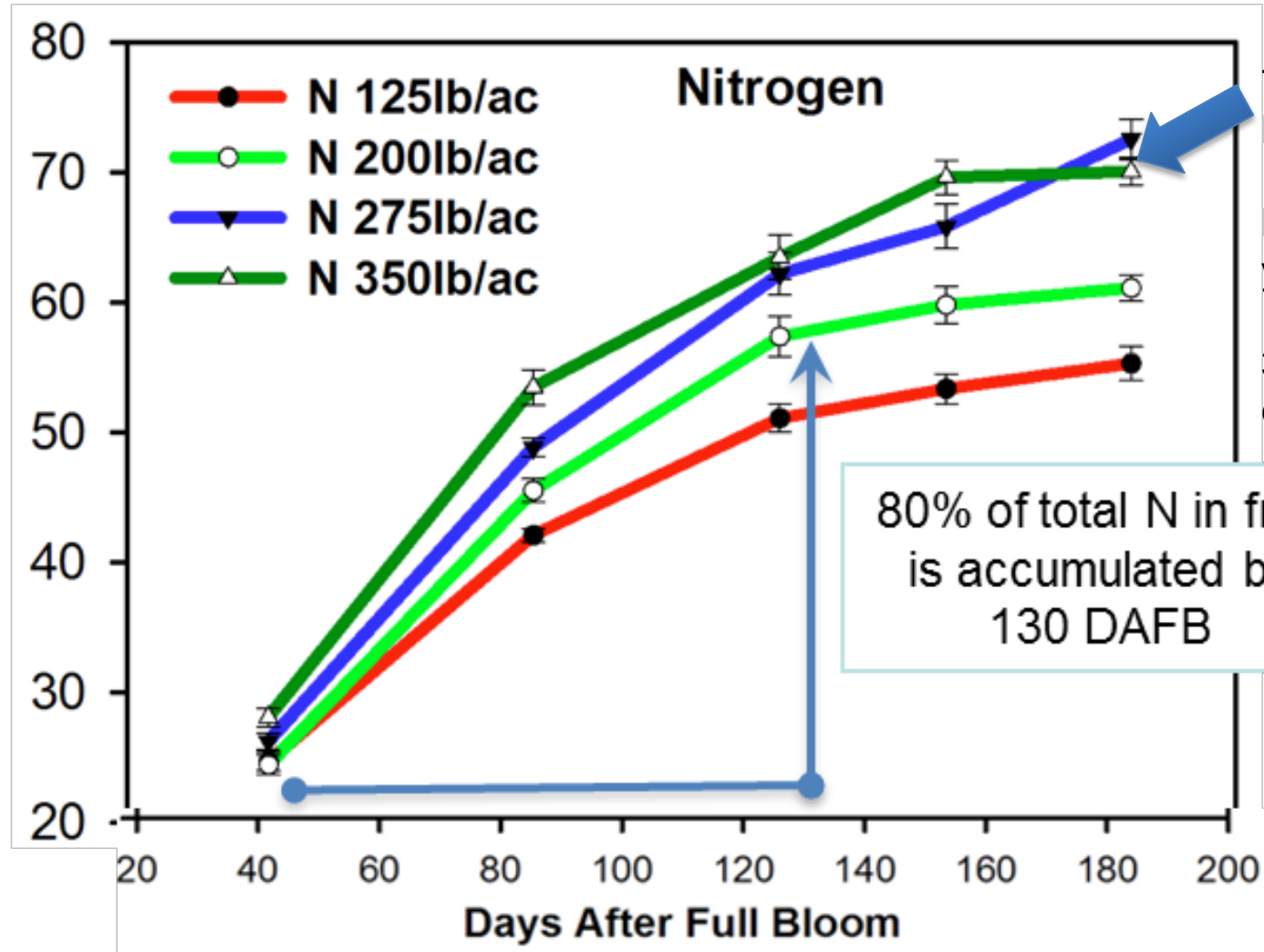


Total and Annual Dynamics of N in Mature Almond Tree (data from 12 year old trees)

- From dormancy to early-leaf out there is very little N uptake.
- Uptake commences at early-leaf out and is essentially complete by hull split.
- Demand = 68 lbs/1000 lb kernel
- Perennial N:
- 440 lb acre N in dormant perennial organs in January of 12 year old tree (from 22 - 44 lb N year)
- 410 lb N in perennial organs in March (30 lb N remobilized).
- 35 lb N accumulated in new perennial tissue

Applying more N than needed does not result in greater N uptake by fruit but does increase the potential for leaching lost.

Nitrogen Removal by 1000 Kernel (lb)



75lb increase in N application.

No increase in yield or tissue N.

30% loss in efficiency.

80% of total N in fruit is accumulated by 130 DAFB

Nutrient Demand

Nutrient removal Per 1000 lb (Kernel equivalent)

Nonpareil

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

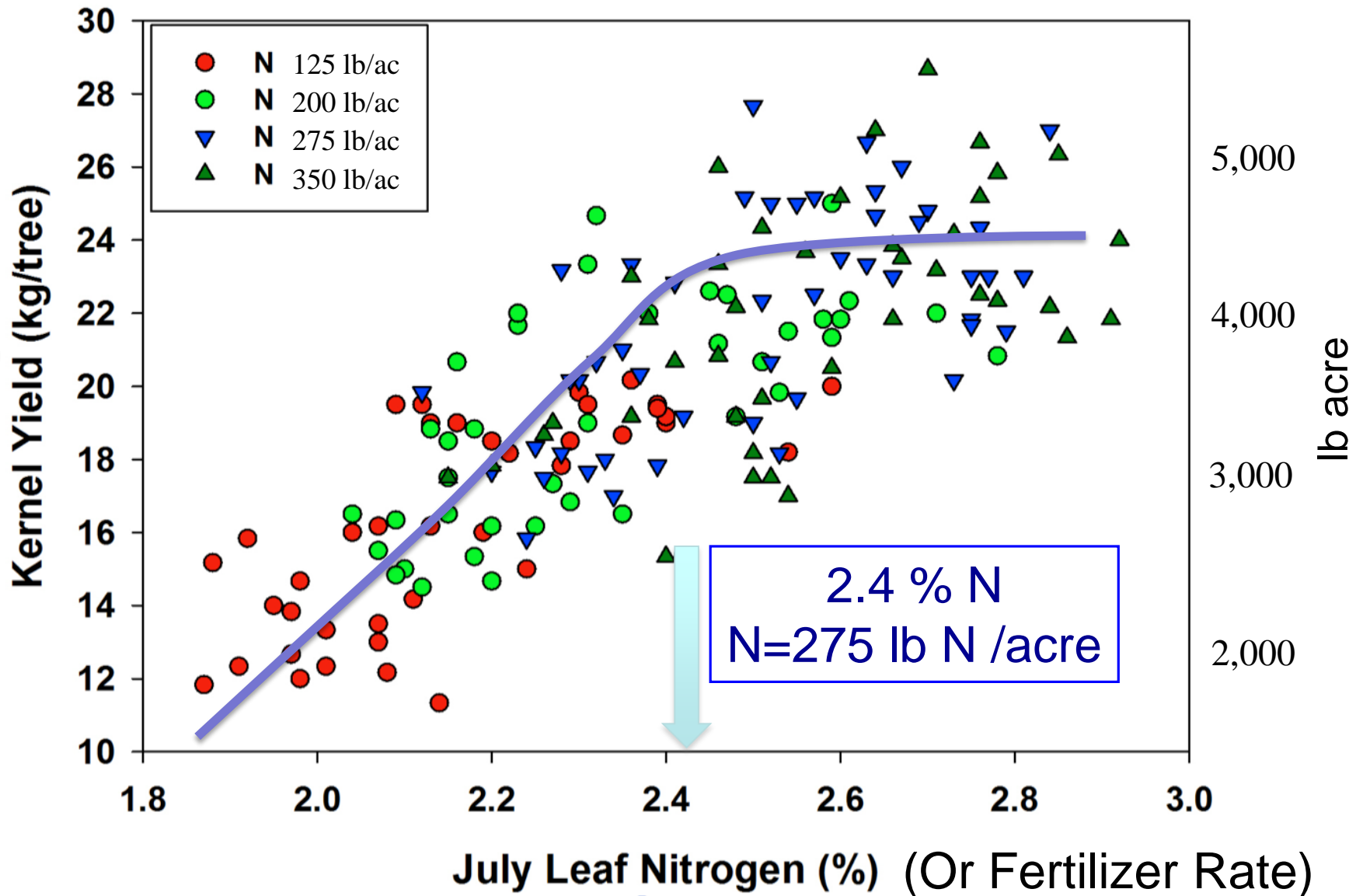
Monterrey

- N removal 67 kg per 1000
- K removal 71 kg per 1000
- P removal 7 kg per 1000

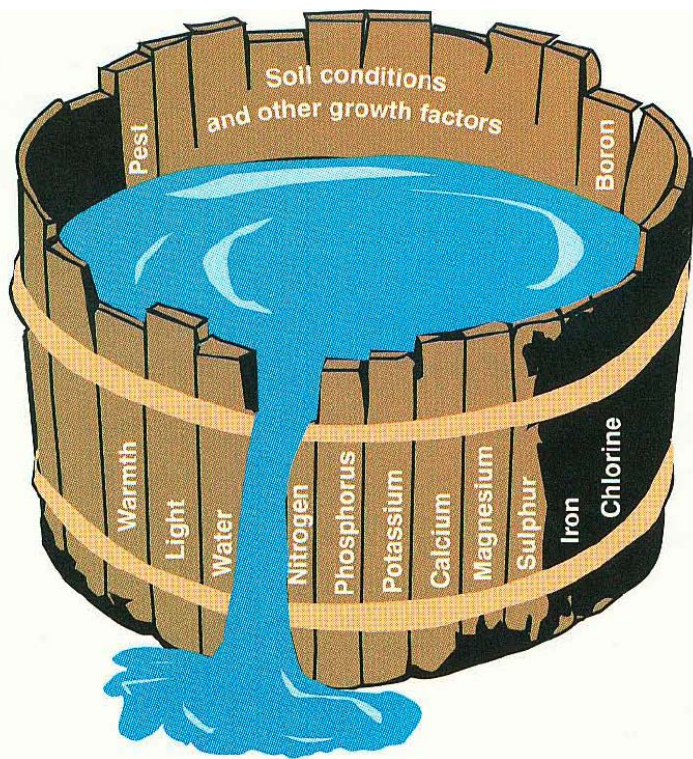
Almond: Take Home

- N Removal varies between 55 (in very N deficient trees) to 73lb per 1000 lb kernel yield (in over fertilized).
- Average of 68 +/- 3 lb per 1000 lb kernel yield for orchards managed with optimal N rates (maximal yield). This average is consistent over multiple sites and cultivars in mature trees.
- Estimated demand for perennial growth (excavations) is 22-44 lb ac (this is age dependent – more details required for young developing trees)
- The addition of N beyond that required for optimal yield does not significantly increase N content in fruit or N removal from field.

Poor Relationship Between Applied N and Yield



The Law of Minimum



“.. It is by the minimum that crops are governed, the most limiting nutrient determines the amount or survival of the crops.”

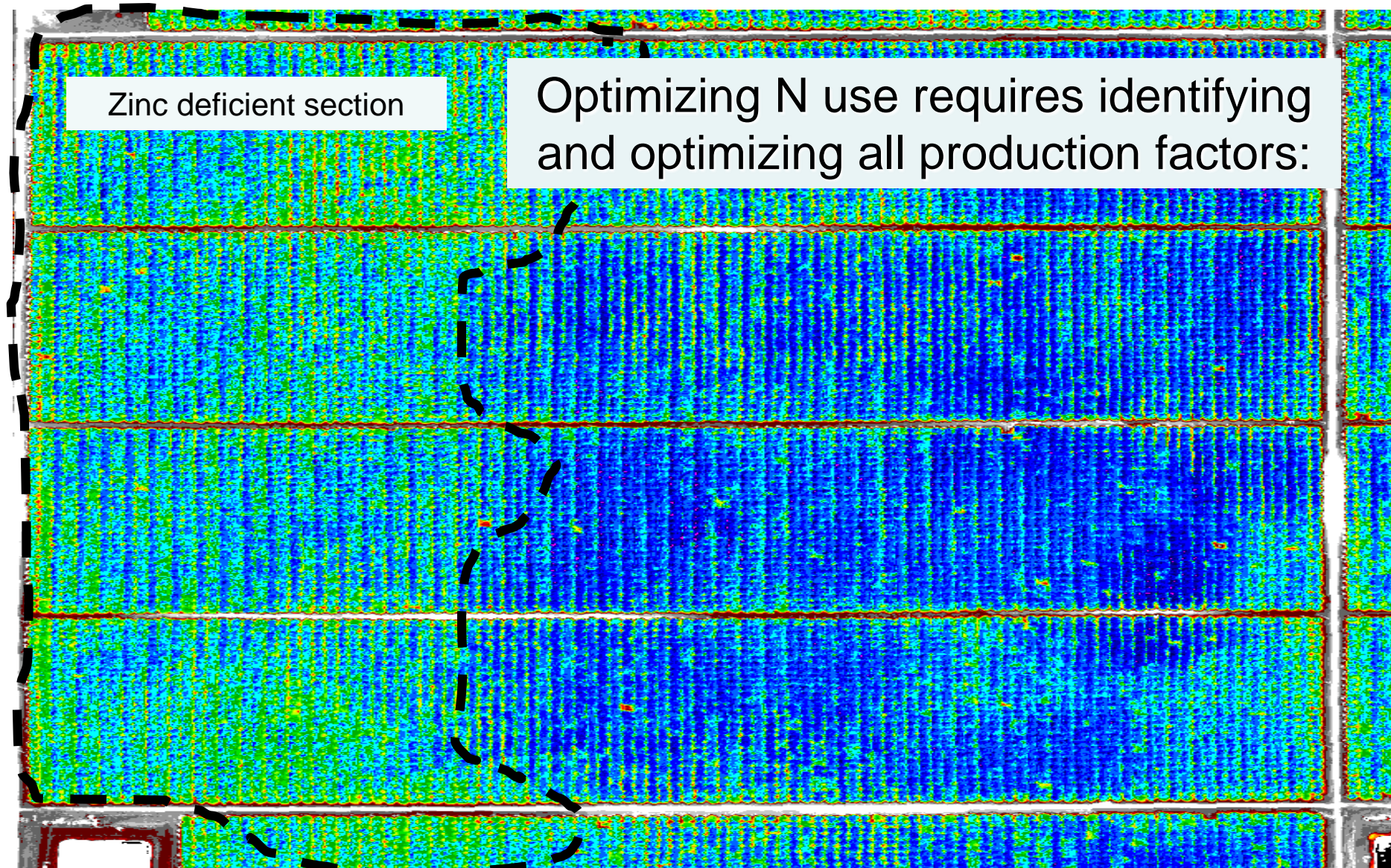
Justus Von Liebig, 1863

If any nutrient is inadequate - Yield is lost
AND response to other elements
cannot occur.

If any nutrient is oversupplied - Money is
wasted

Macronutrients: N, P, K, Mg, Ca, S
Micro: B, Fe, Cu, Mn, Cu, Ni, Zn, Mo

Optimizing N use efficiency requires Optimal Management of all Inputs: e.g. Zinc deficiency can limit crop response to N



GNDVI 29 April 2009: SmartImage (B,G, NIR only)1 m pixel (Britz Fert. Com.)

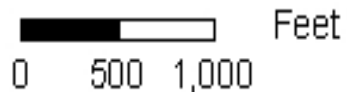
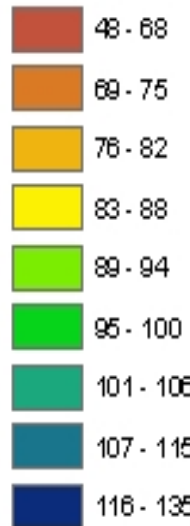
Yield is not uniform in any field.
Yield of 16040 trees

*Yield is the primary determinant of
fertilizer demand, therefore
knowledge of variations in yield is
essential for optimal management.*

but

How do we fertilize a field such as this?

Yield (lbs)



Individually controlled microsprinkler system.

Robert Coates, Michael Delwiche, Patrick Brown



Individual microsprinkler with sensor would allow for site specific fertigation.



We are not at this stage yet but growers can still make substantial improvements by separating irrigation systems by cultivar or by portions of the field.

Nitrogen Demand by 20 acre block

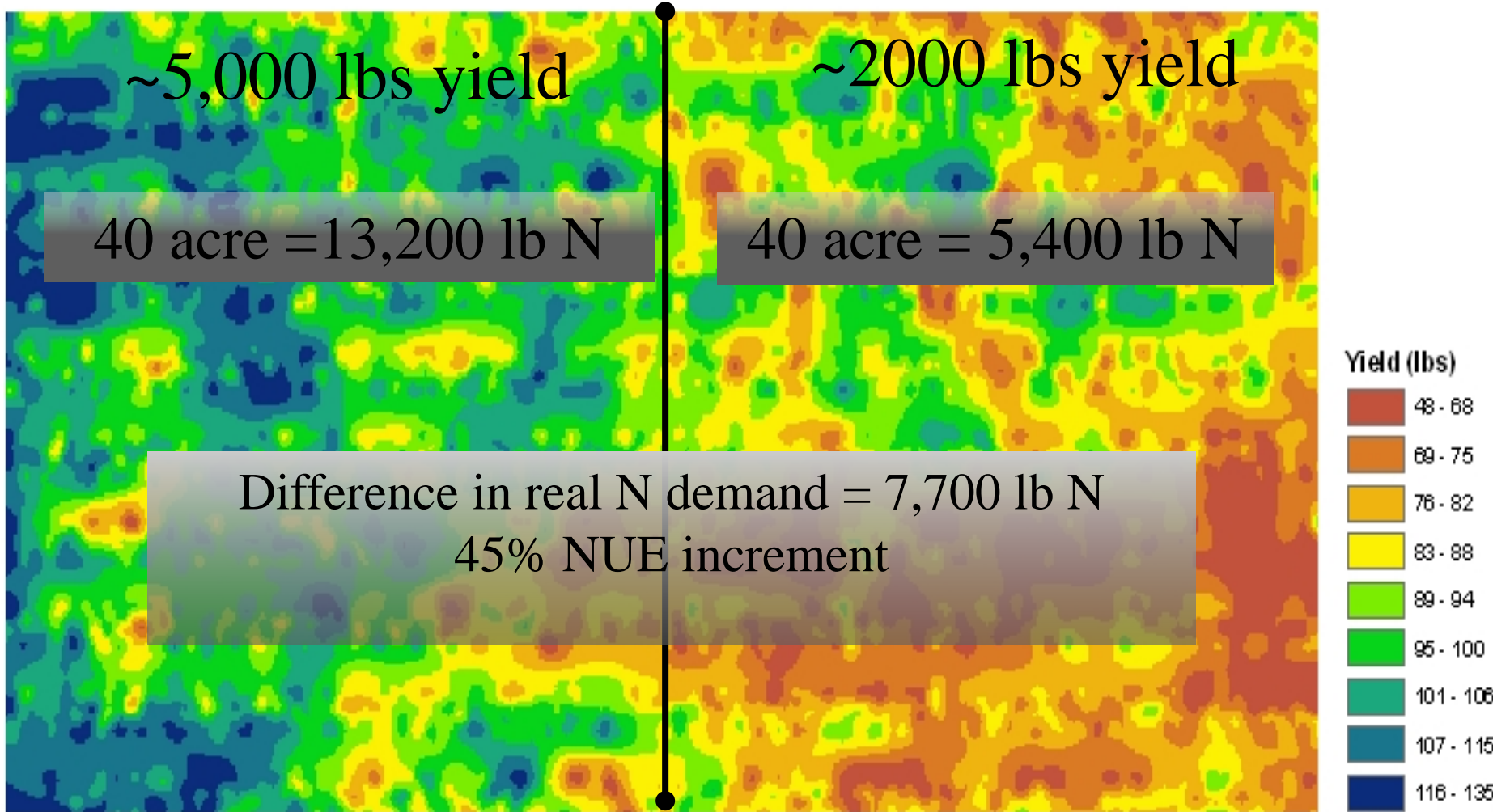


Whole Field Average N demand = 150 lbs N

Managing for Spatial Variability

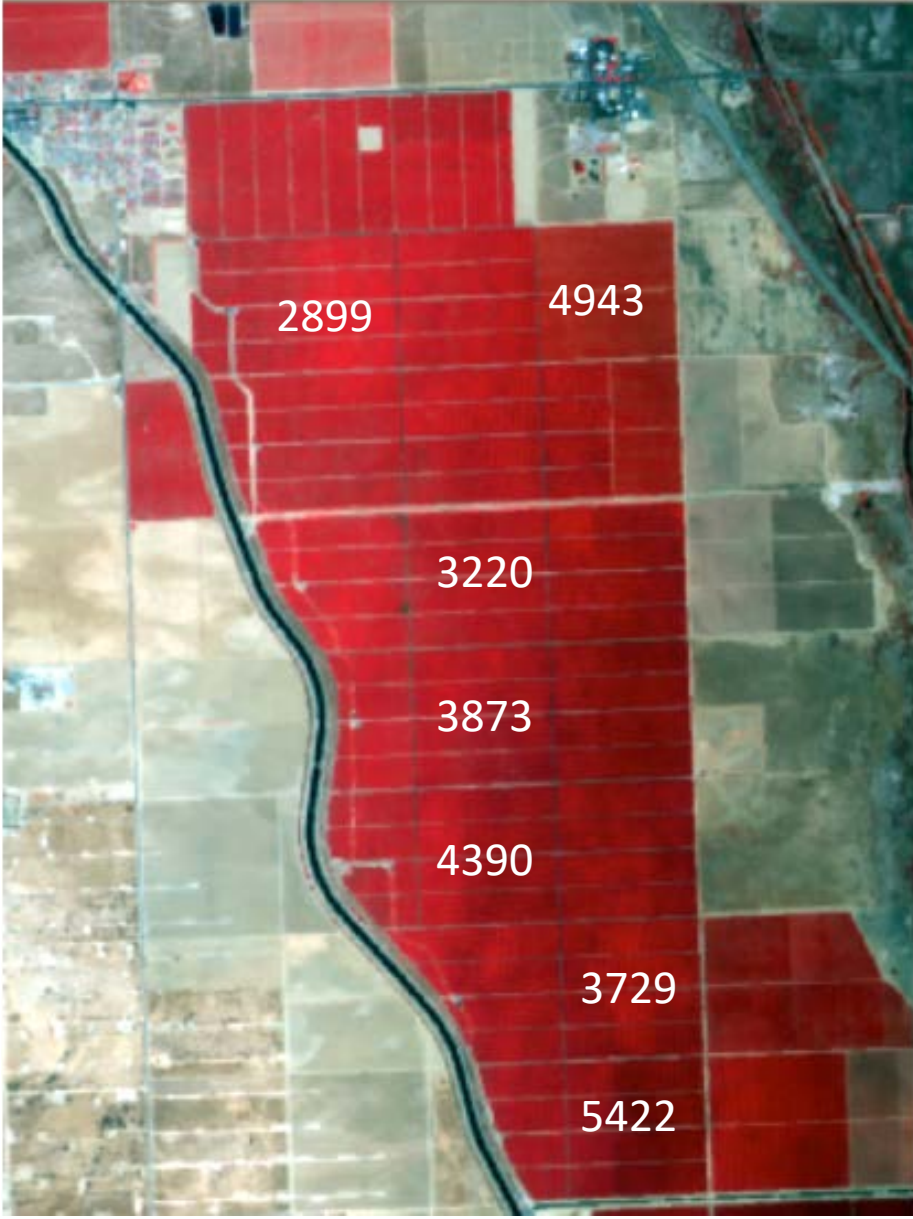
Introduces greater complexity in management

Is it worth it?



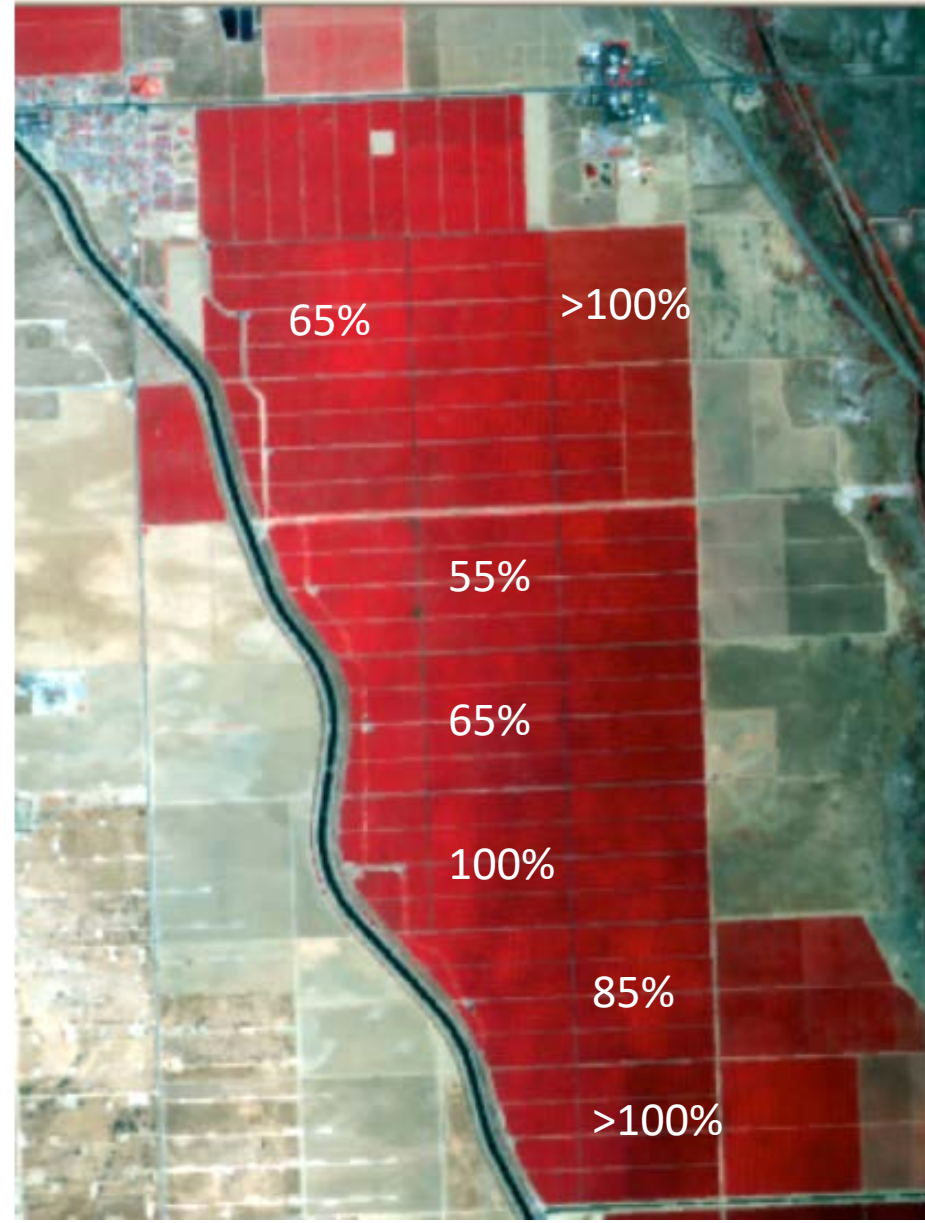
0 500 1,000 Feet

Yield and Final Nutrient Use Efficiency: 275 Lbs N Applied Hypothetical Example



Yield and Final Nutrient Use Efficiency: 275 Lbs N Applied

Hypothetical Example



CHALLENGES TO OPTIMIZING NITROGEN USE

- Estimating yield in March to plan annual fertilization
- Estimating soil residual N and root N availability
- Matching application timing to tree demand
- In field variability
- Different cultivars may have different yields
- Monitoring irrigation water N
- Preventing N losses through irrigation
- Optimizing all other factors (other nutrients, disease, pests, irrigation etc.)

Efficient Nutrient Management Approach

-the 4 R's- (14 essential elements)

Applying the **Right Rate**

- Match supply with tree demand
 - Determine tree demand
 - Measure all inputs- fertilizer, organic N, water, residual soil N.

At **Right Time**

- Match tree demand
- Apply coincident with root uptake.
- Apply coincident with demand

In the **Right Place (All)**

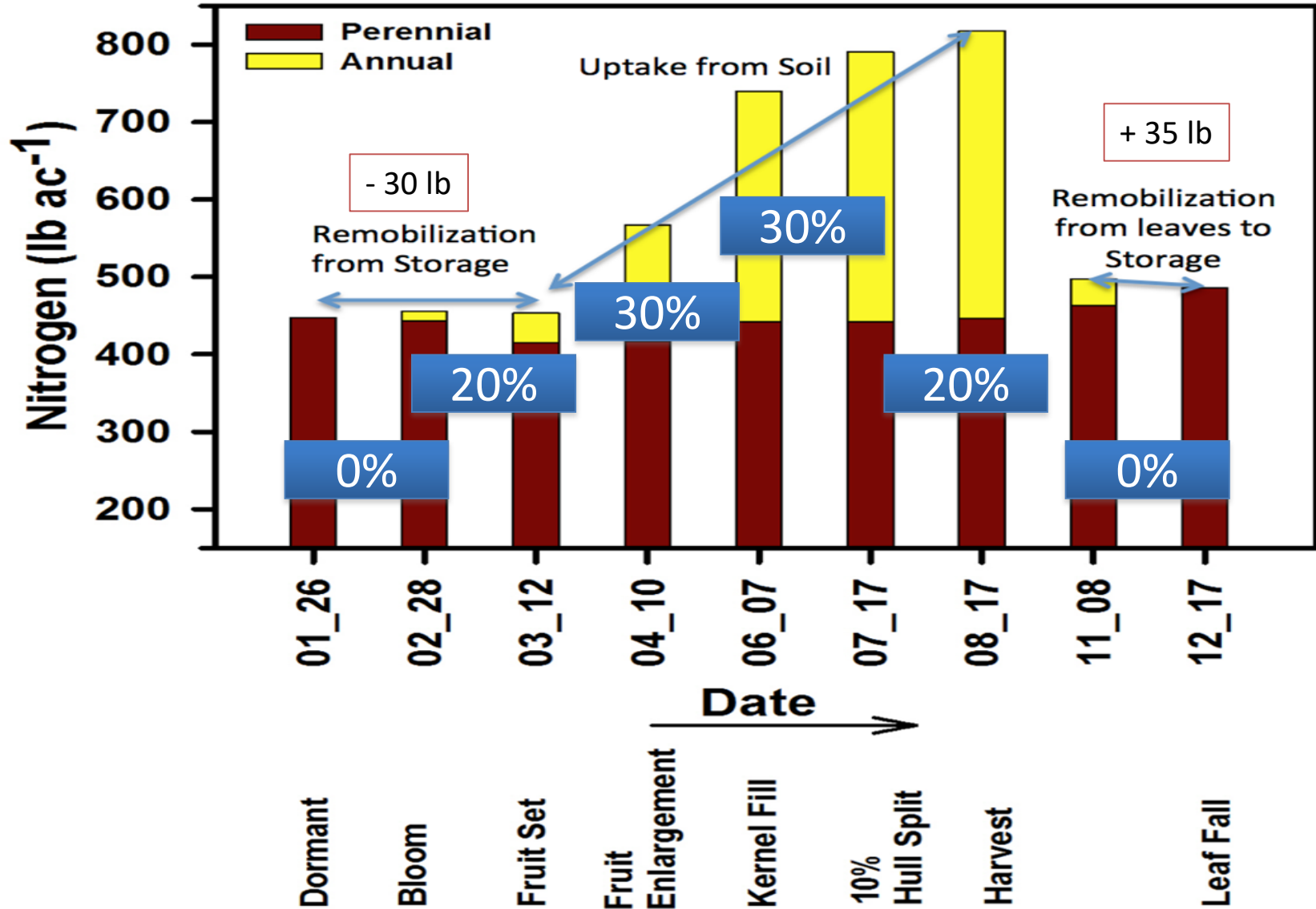
- Ensure delivery to the active roots and with regard to orchard variability.

Using the **Right Source (All)**

- Maximize uptake minimize loss potential.
- Eliminate limiting nutrients
- Stimulate root uptake (?)

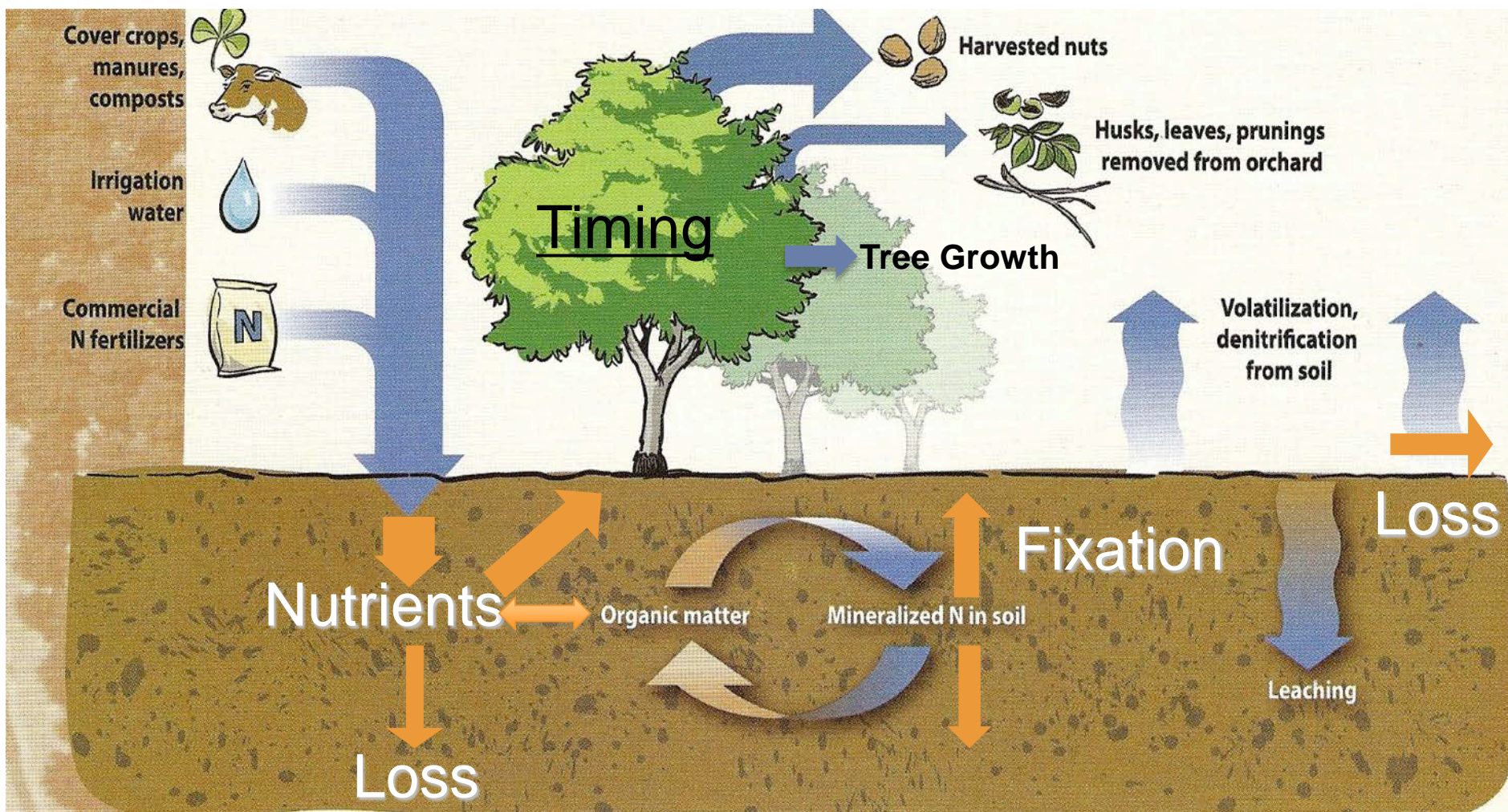
*Minimize **Risk**, Maximize **Returns***

Total and Annual Dynamics of N in Mature Almond Tree (data from 12 year old trees)

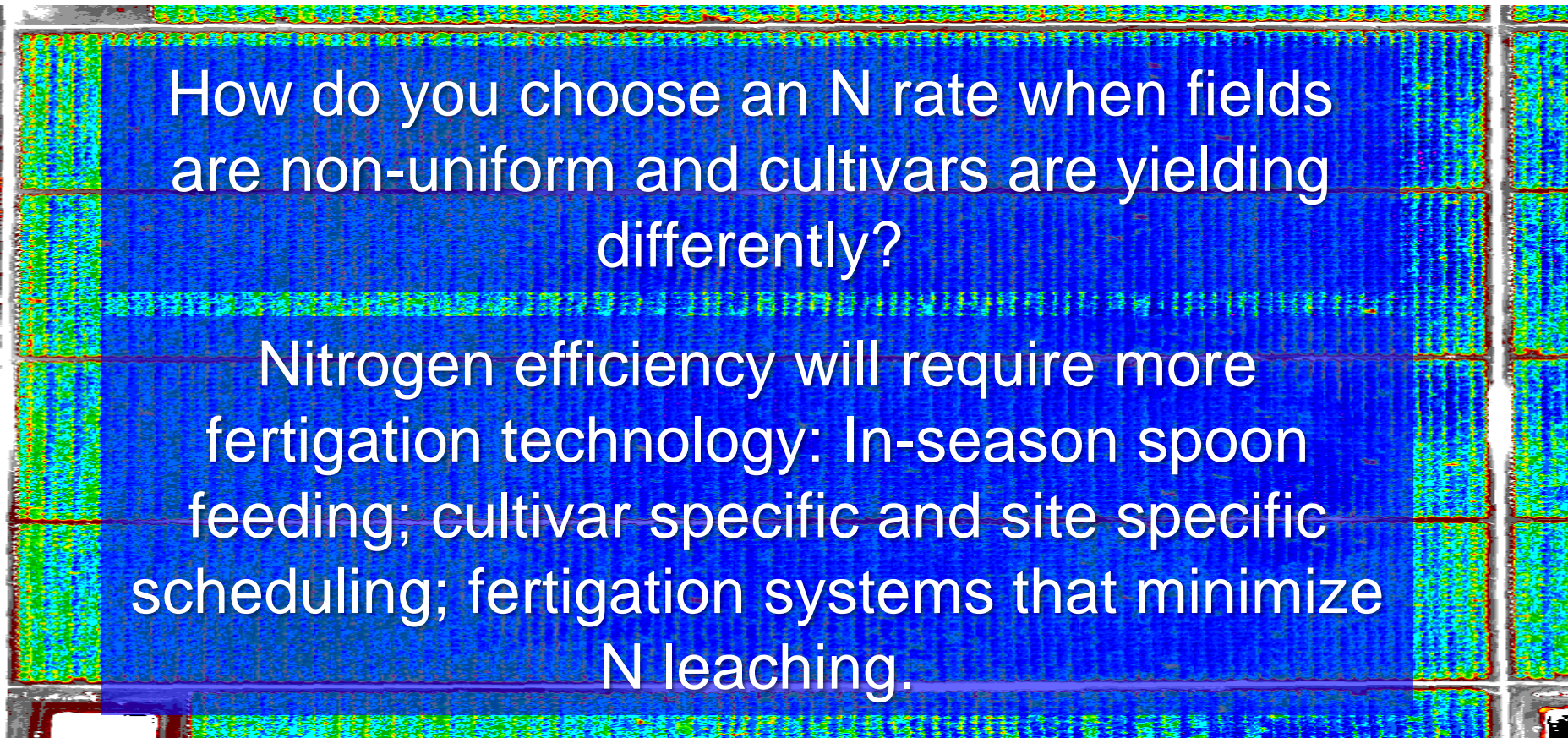


Optimizing N Use in CA Tree Crops.

$$\text{Supply (Rate)} = \text{Demand (Amount and Timing)}$$



Right Place: Fields vary in their productivity due to soils, poor irrigation design, other deficiencies or other production constraints.



How do you choose an N rate when fields are non-uniform and cultivars are yielding differently?

Nitrogen efficiency will require more fertigation technology: In-season spoon feeding; cultivar specific and site specific scheduling; fertigation systems that minimize N leaching.

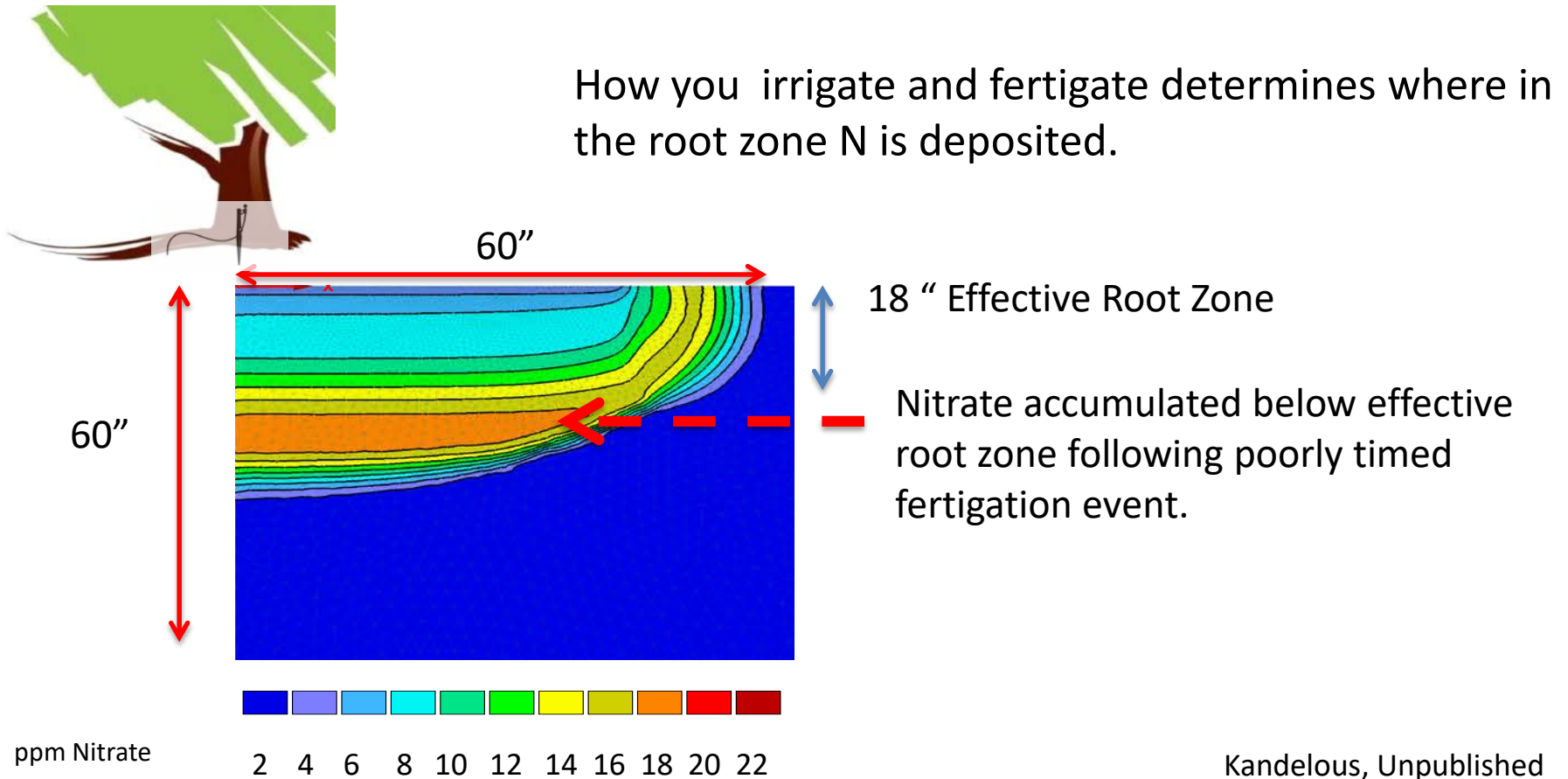
GNDVI 29 April 2009: SmartImage (B,G, NIR only) 1 m pixel (Britz Fert. Com.)

Irrigation systems can be designed to treat varieties separately.



Right Place: Impact of Fertigation Timing on Nitrate Uptake by the Tree

Bad Example: N injected in first 3 hours of 12 hour irrigation.



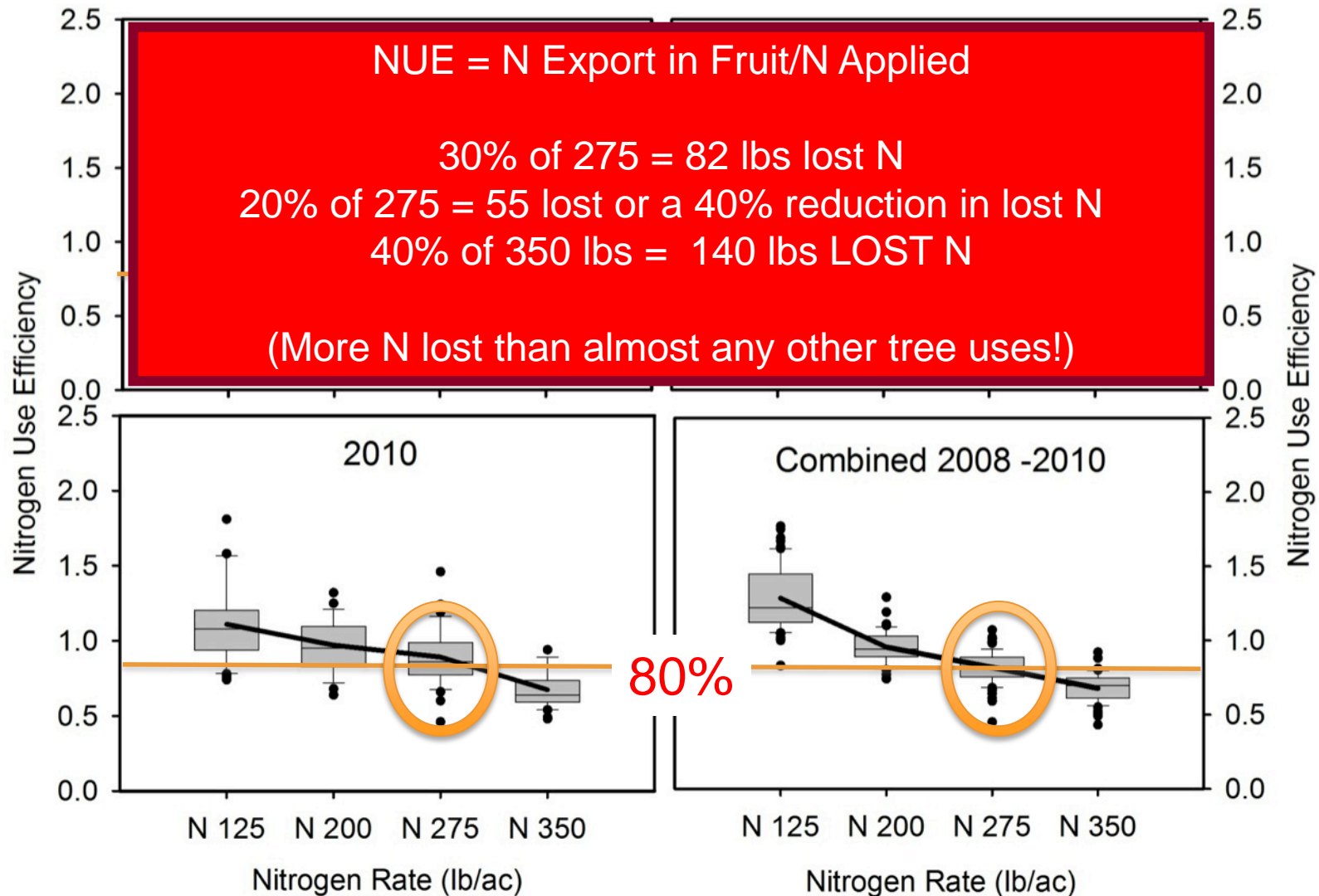


Thank you!

- **Baries Kutman**
- **Sebastian Saa**
- **Saiful Muhammad**
- **Blake Sanden**
- **Roger Duncan**
- **John Edstrom**
- **David Doll**
- **Bruce Lampinen**
- **Ken Shackel**
- **Emilio Laca**

- **Art Bowman**
- **Lagoisty Farms**
- **Paramount Farming**
- **Almond Board of California**
- **USDA, CDFA**

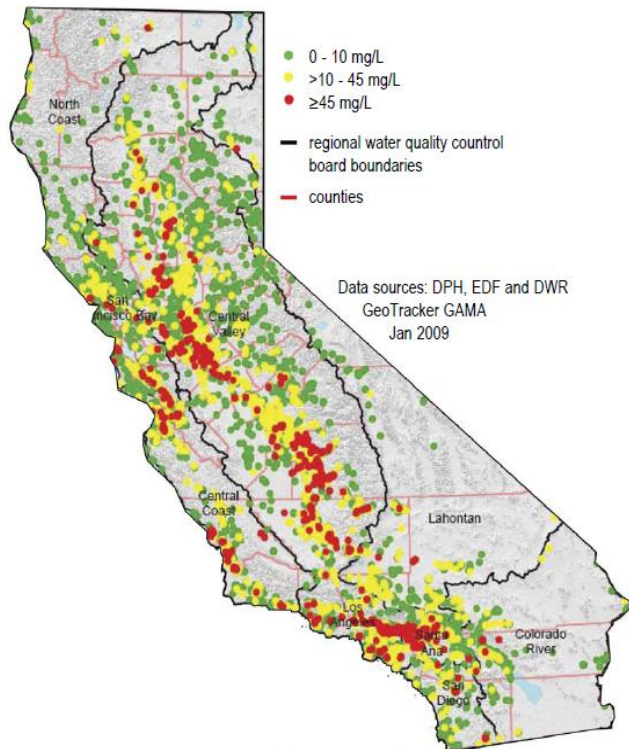
Nitrogen Use efficiency 2008 – 2010 under optimum treatment (N 275) was >80%.



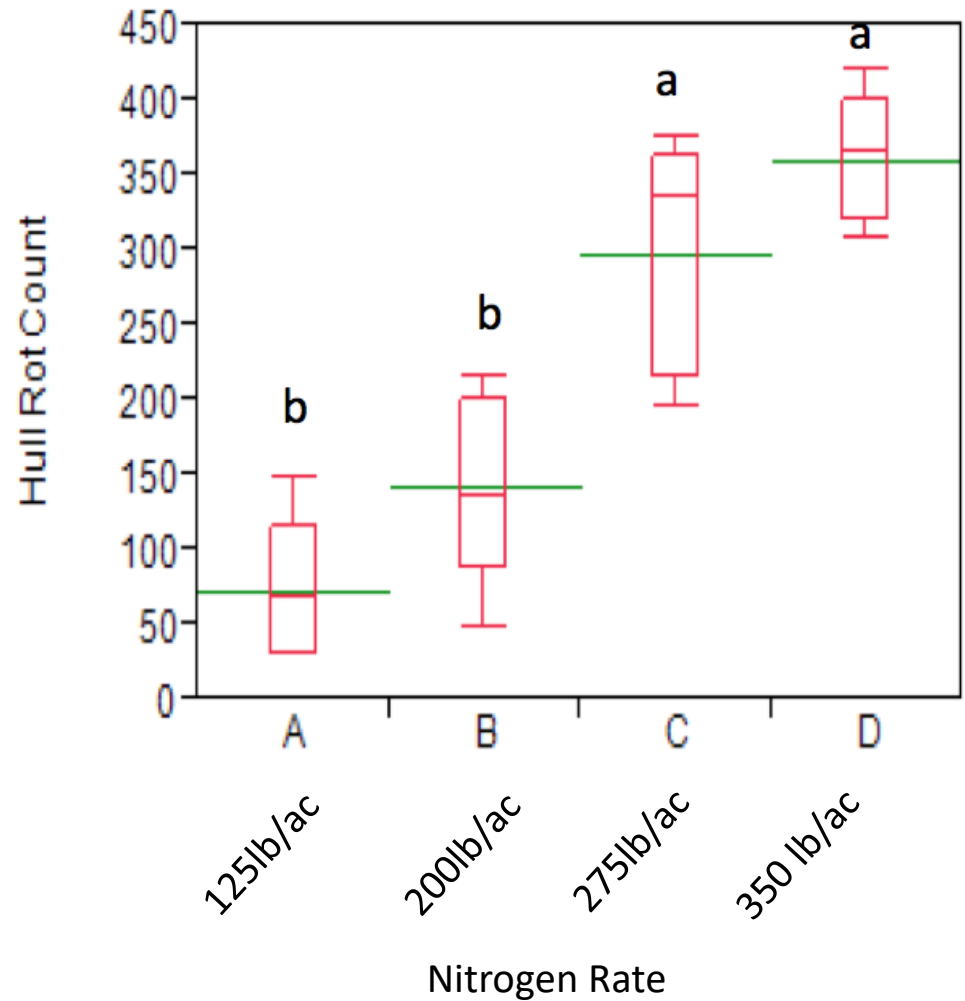
Why bother being so precise with N?

\$\$, wastage, balance, sustainability.

Water Quality

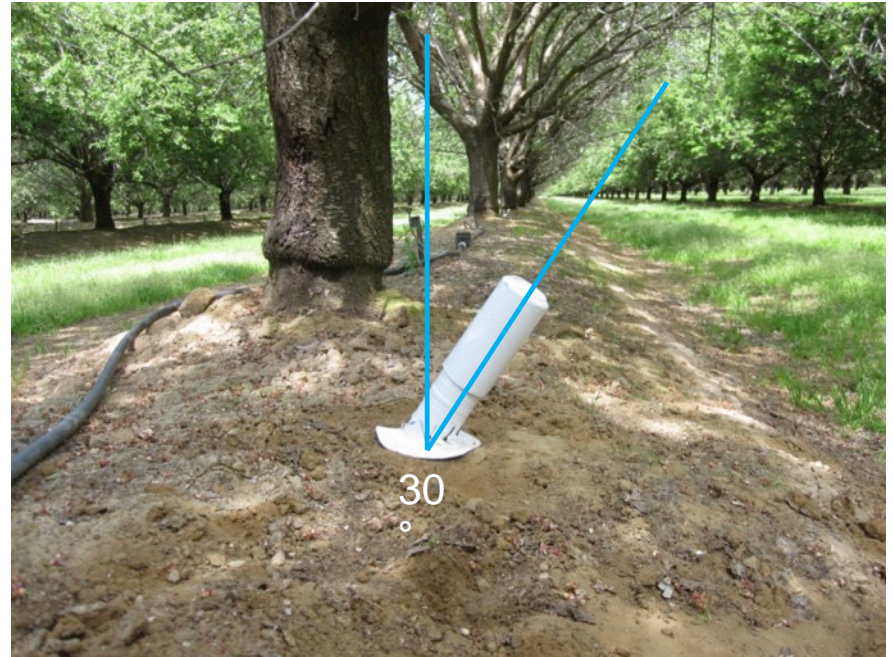


Disease Interactions



Root Growth:Minirhizotron Observations

(80 Tubes)



05/11



15/11

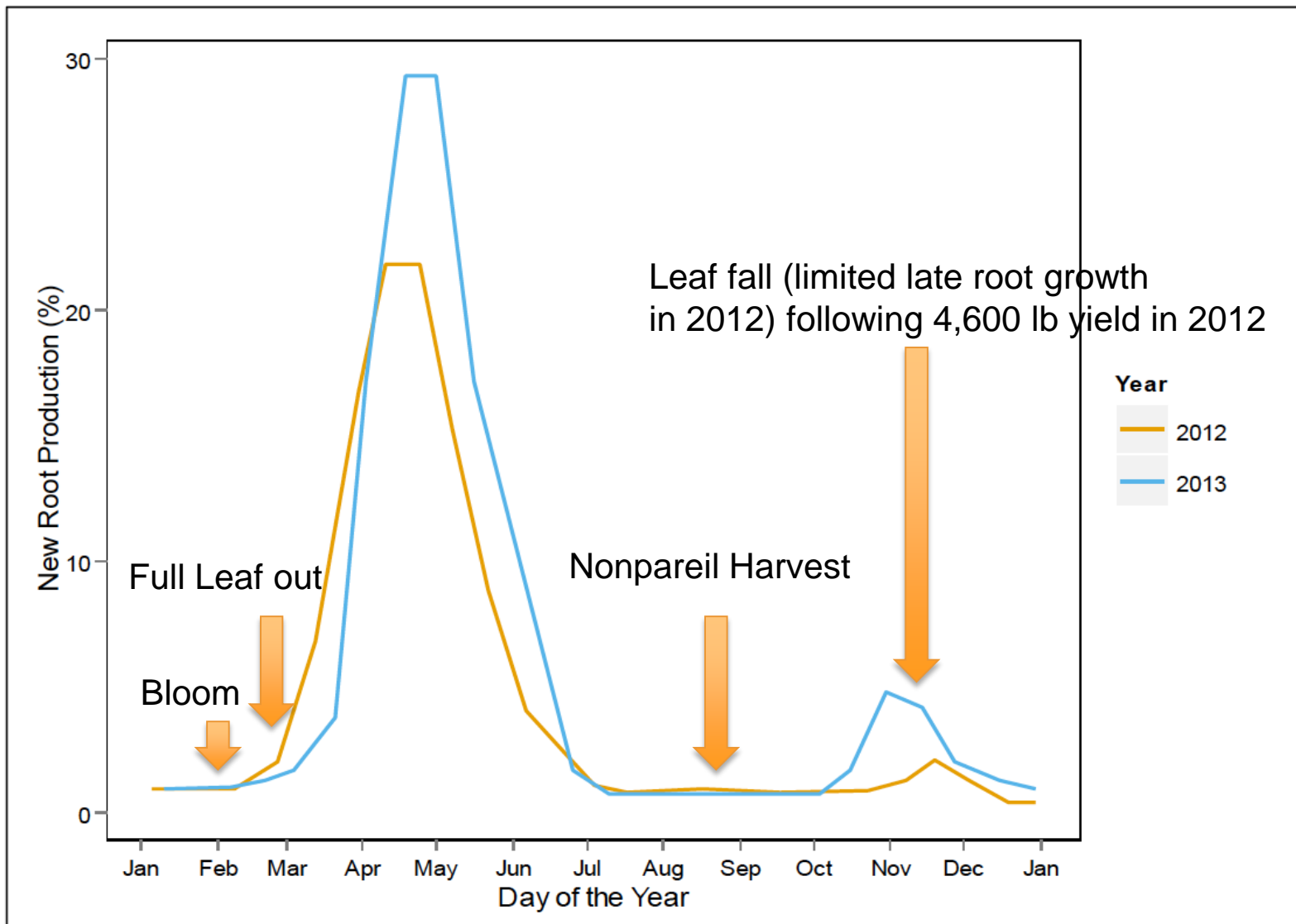


01/12

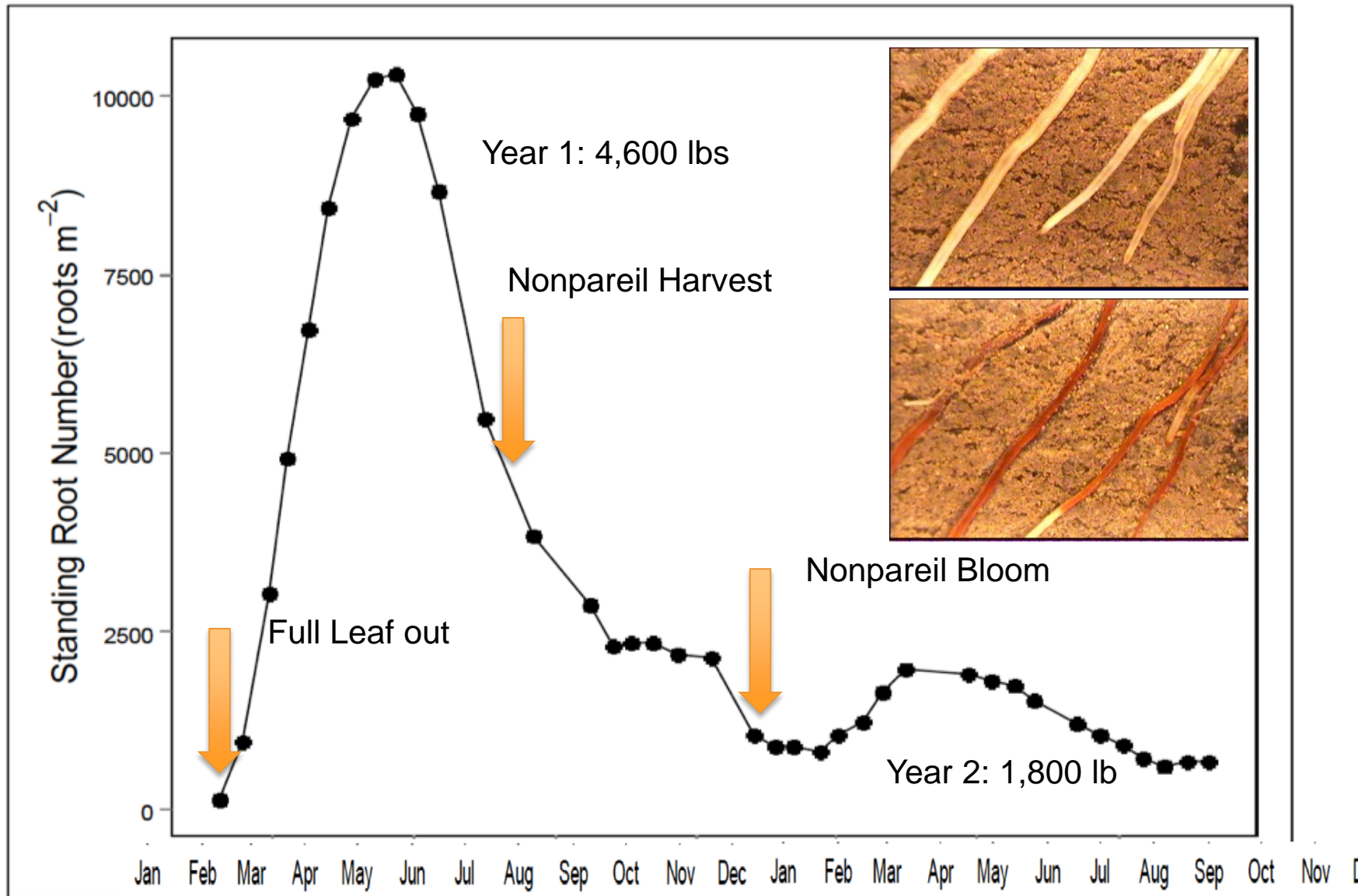


14/12

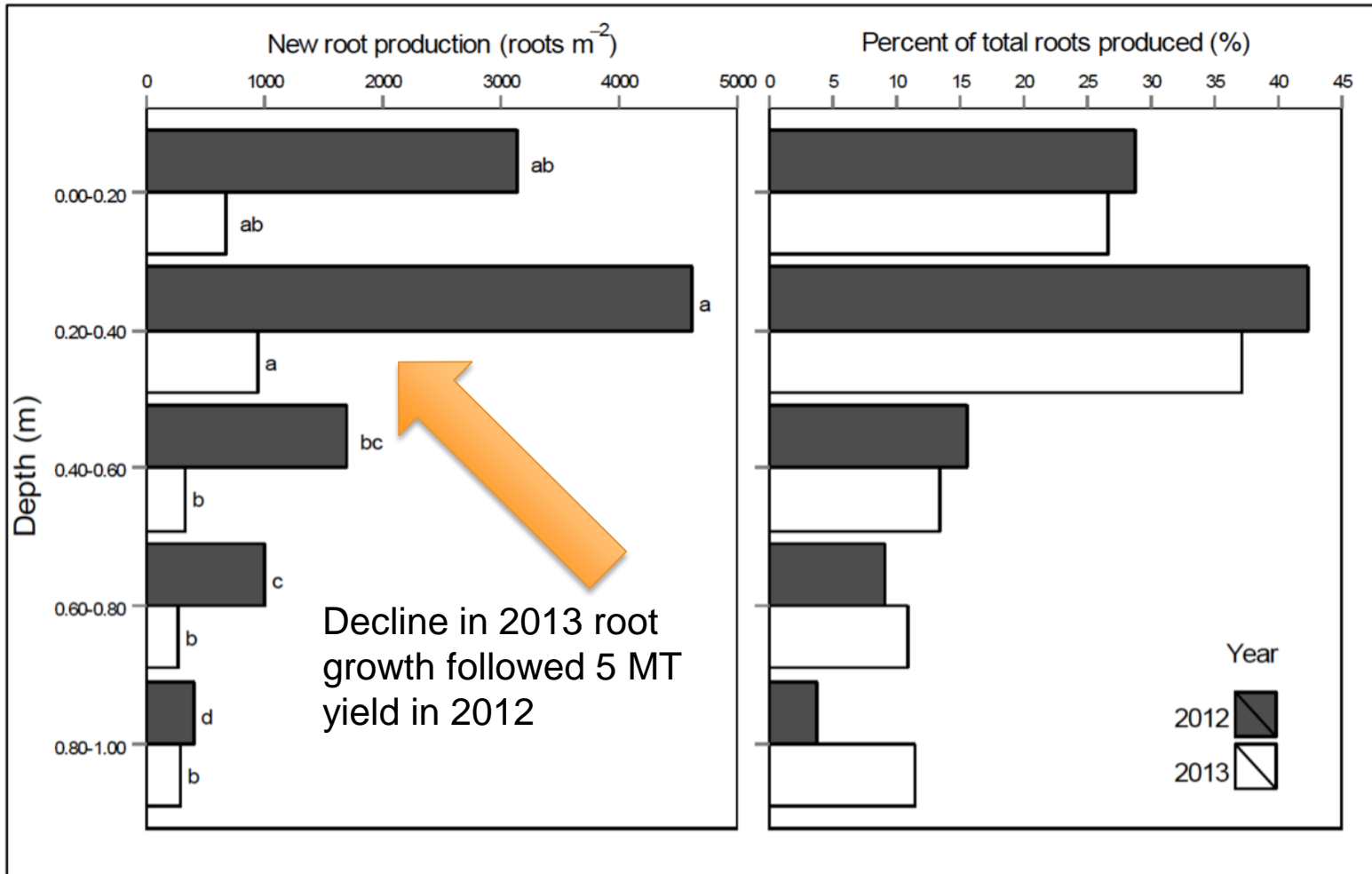
New Root Growth: Almond



Total 'Active' Root Length: Almond



Root Growth



Total new root production and percentage of new roots at each depth in irrigated almond determined over two seasons.

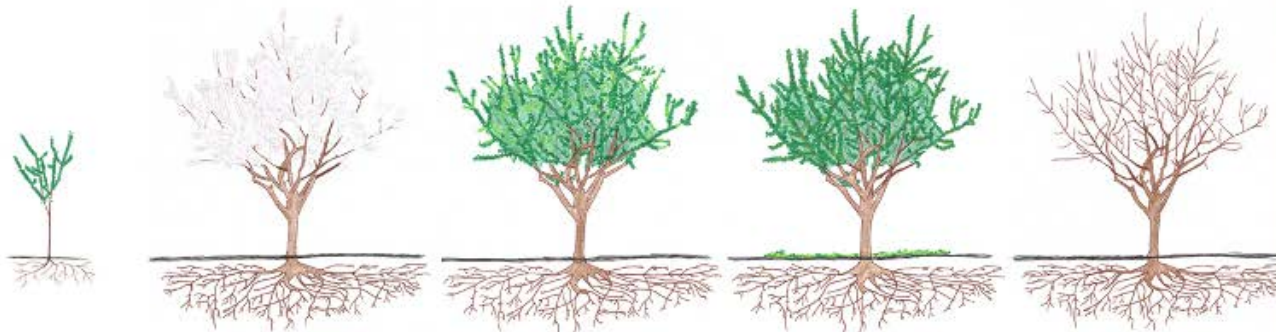
Almond Take Home

- Nitrogen demand is driven by yield.
- Nitrogen uptake from soil does not commence until N reserves in tree have been depleted.
- Soil N uptake typically commences after 50% leaf expansion coincident with early fruitlet growth and the main root flush.
- Uptake of N decreases as nuts mature and is much reduced at full maturity and during the postharvest period



Almond Fertilization Guidelines

Funding provided by:



Young Trees

Bloom
Spring

Fruit Development
Summer

Post-Harvest
Fall

Dormancy
Winter

Nitrogen (N) ⓘ

Leaf analysis ⓘ

N ⓘ

Foliar N ⓘ

Soil applied N ⓘ

Foliar N ⓘ

Phosphorus (P₂O₅) ⓘ

Soil Test ⓘ

Leaf analysis ⓘ

Soil Test ⓘ

P ⓘ

Foliar P ⓘ

Soil applied P ⓘ

Potassium (K₂O) ⓘ

Soil Test ⓘ

Leaf analysis ⓘ

Soil Test ⓘ

K ⓘ

Foliar K ⓘ

Soil applied K ⓘ

Soil applied K ⓘ

Boron (B) ⓘ

Soil Test ⓘ

Hull analysis ⓘ

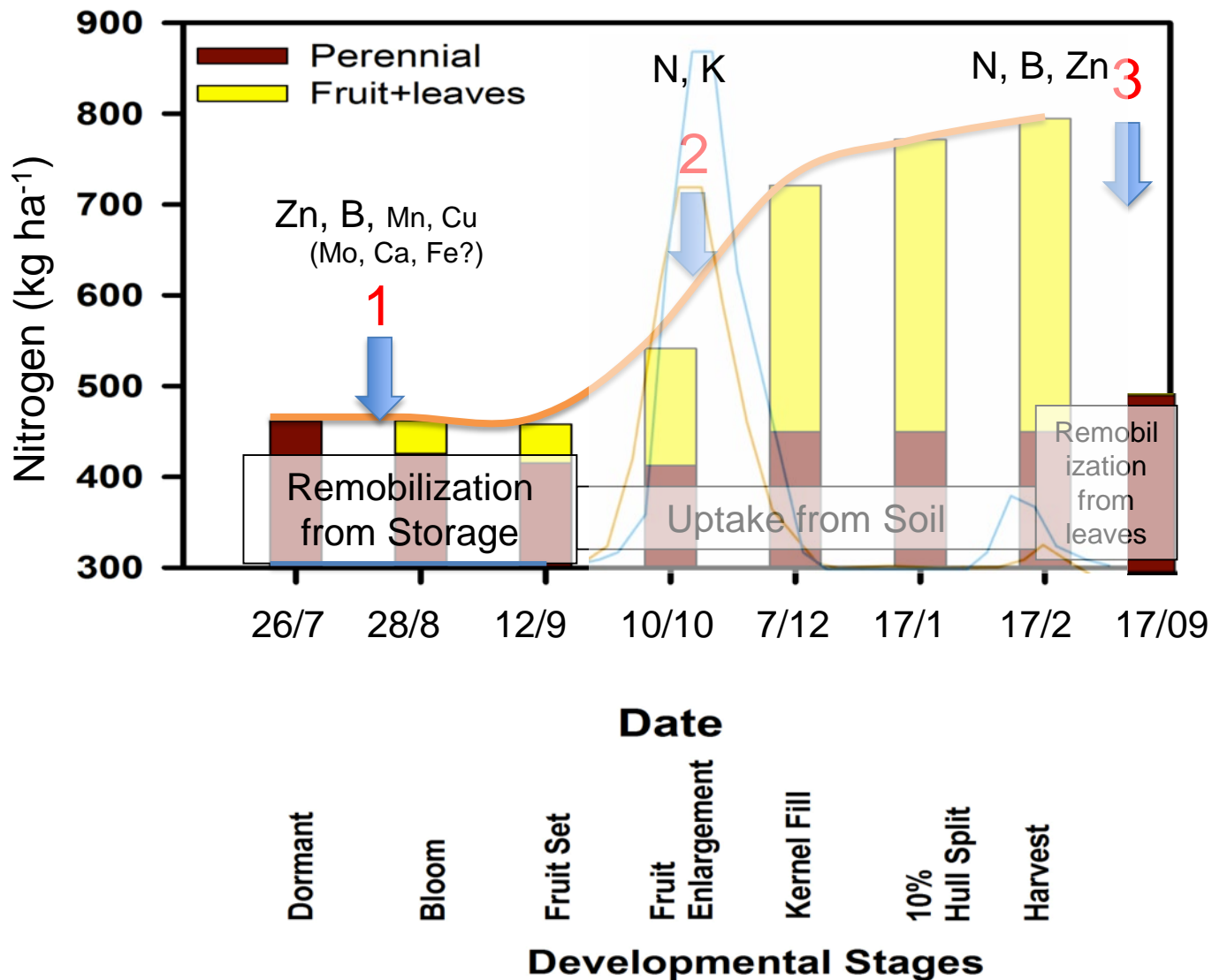
Soil Test ⓘ

B ⓘ

Foliar B ⓘ

Soil applied B ⓘ

Pattern of Nutrient Demand in Almond



Periods of Potential Short Term Deficit

1. Flowering, fruit set, early leaf growth.
 - Critical processes occurring at a time when root uptake is limited.
2. Kernel Fill
 - Large yield dependent demand
 - Limited new root growth
3. Senescence and remobilization
 - Very limited root growth
 - Harvest induced water stress
 - Shaker stress

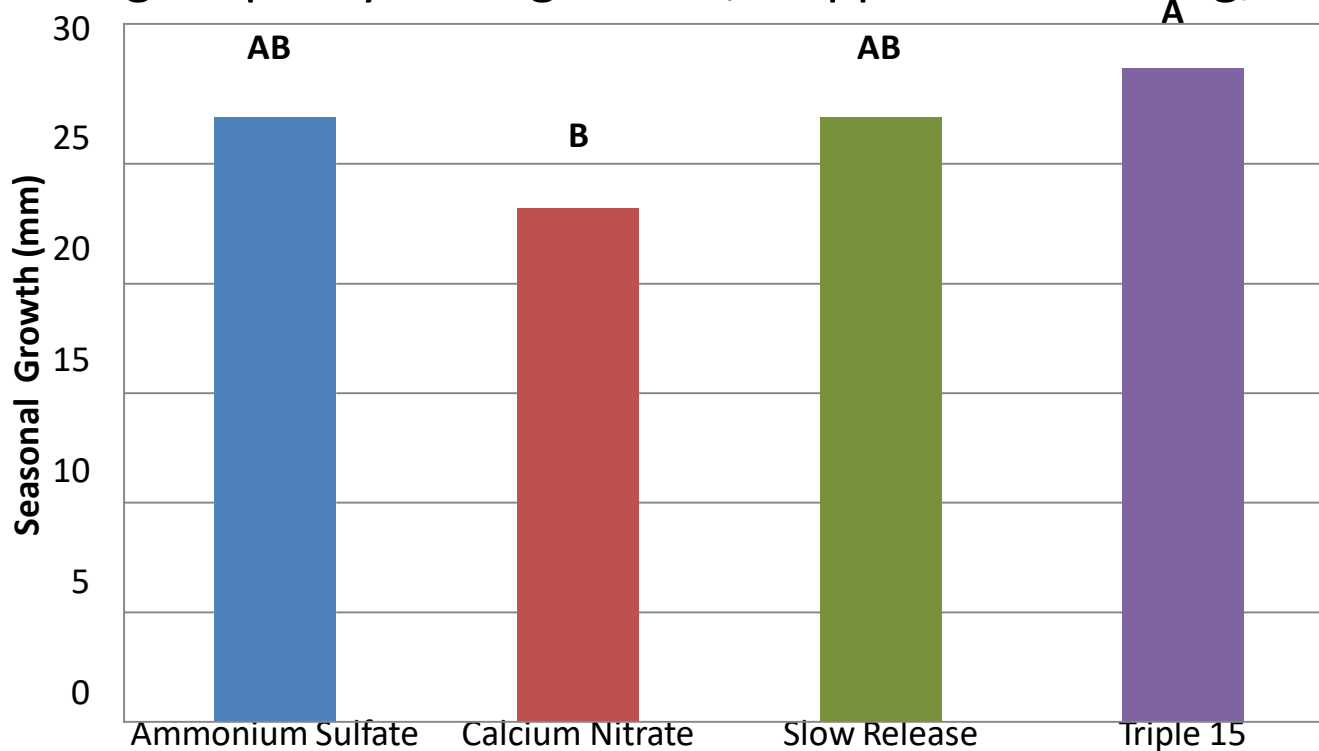
Fertilizing Young Almond Orchards



David Doll
UCCE Merced
3/28/2015

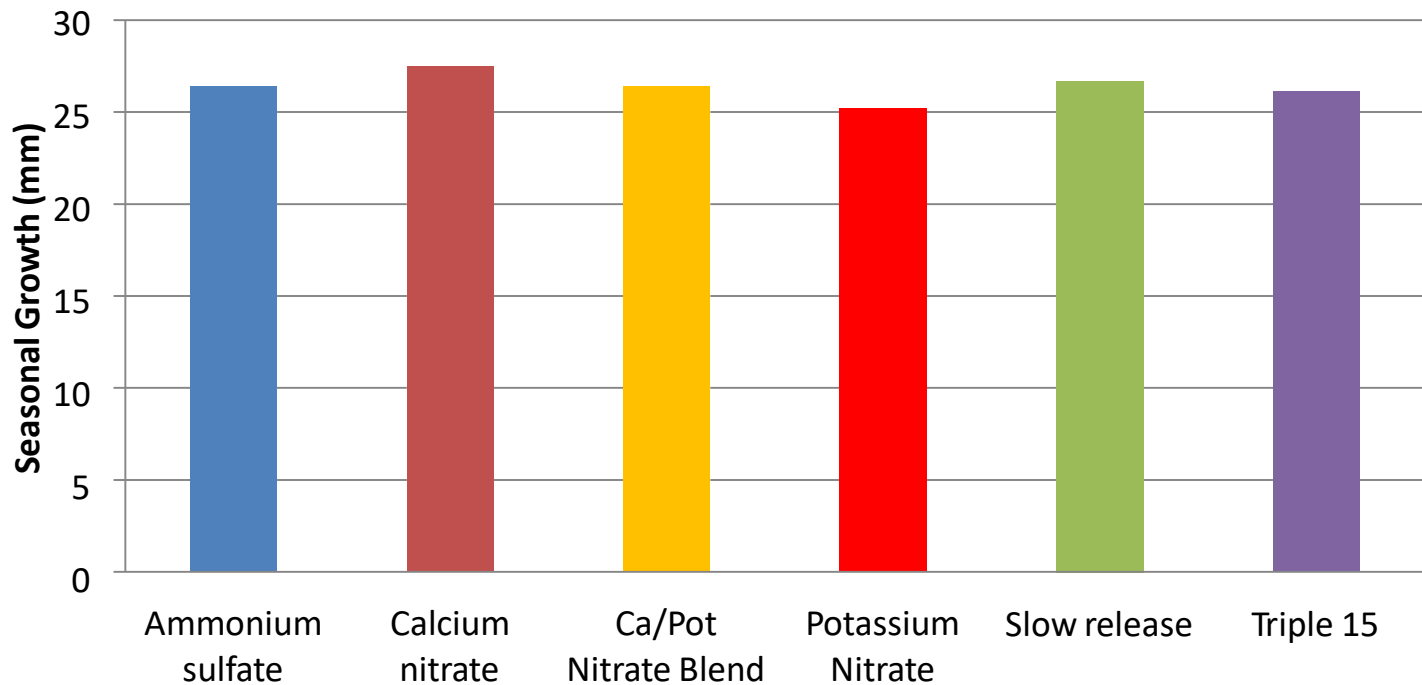
First Year Fertilizer Studies: Merced County 1

Loamy sand soil, irrigated with solid set sprinklers, neutral soils, low cation exchange capacity – 100g total N, 6 applications of 16g/tree

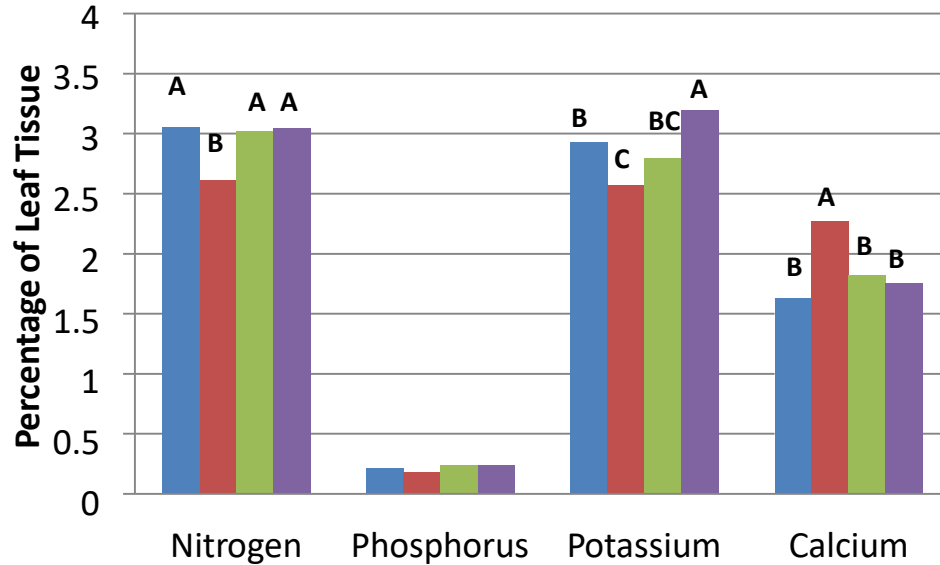


First Year Fertilizer Studies: Merced County 2

Sandy loam soil, irrigated with micro-sprinklers, acidic soils, medium cation exchange capacity – 100g total N, 6 applications of 16g/tree



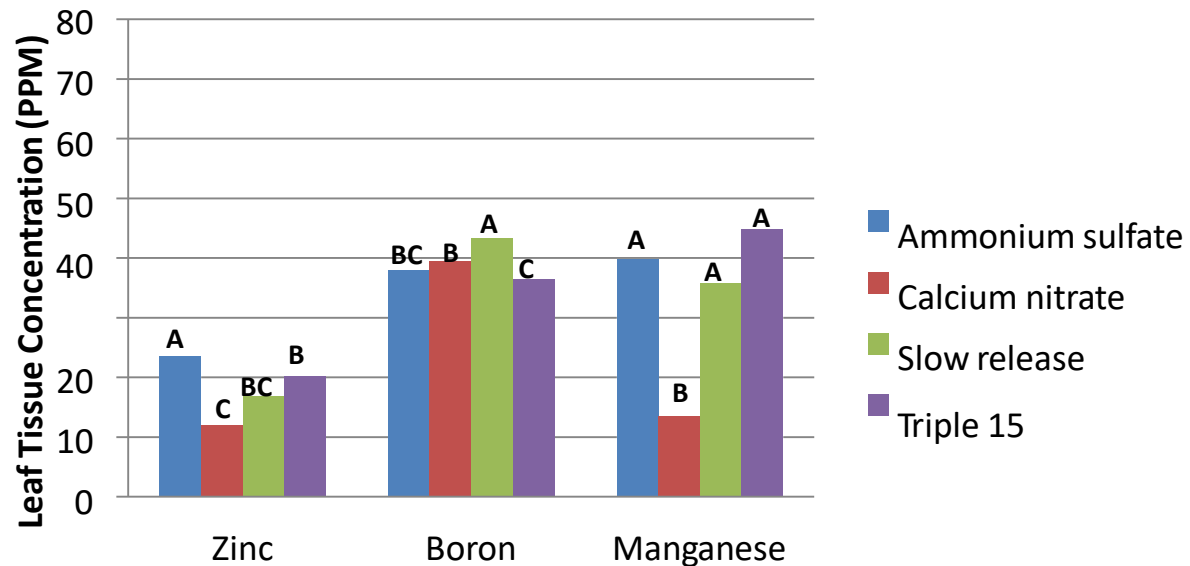
First Year Fertilizer Studies: Merced County



Major nutrients affected by fertilizer content

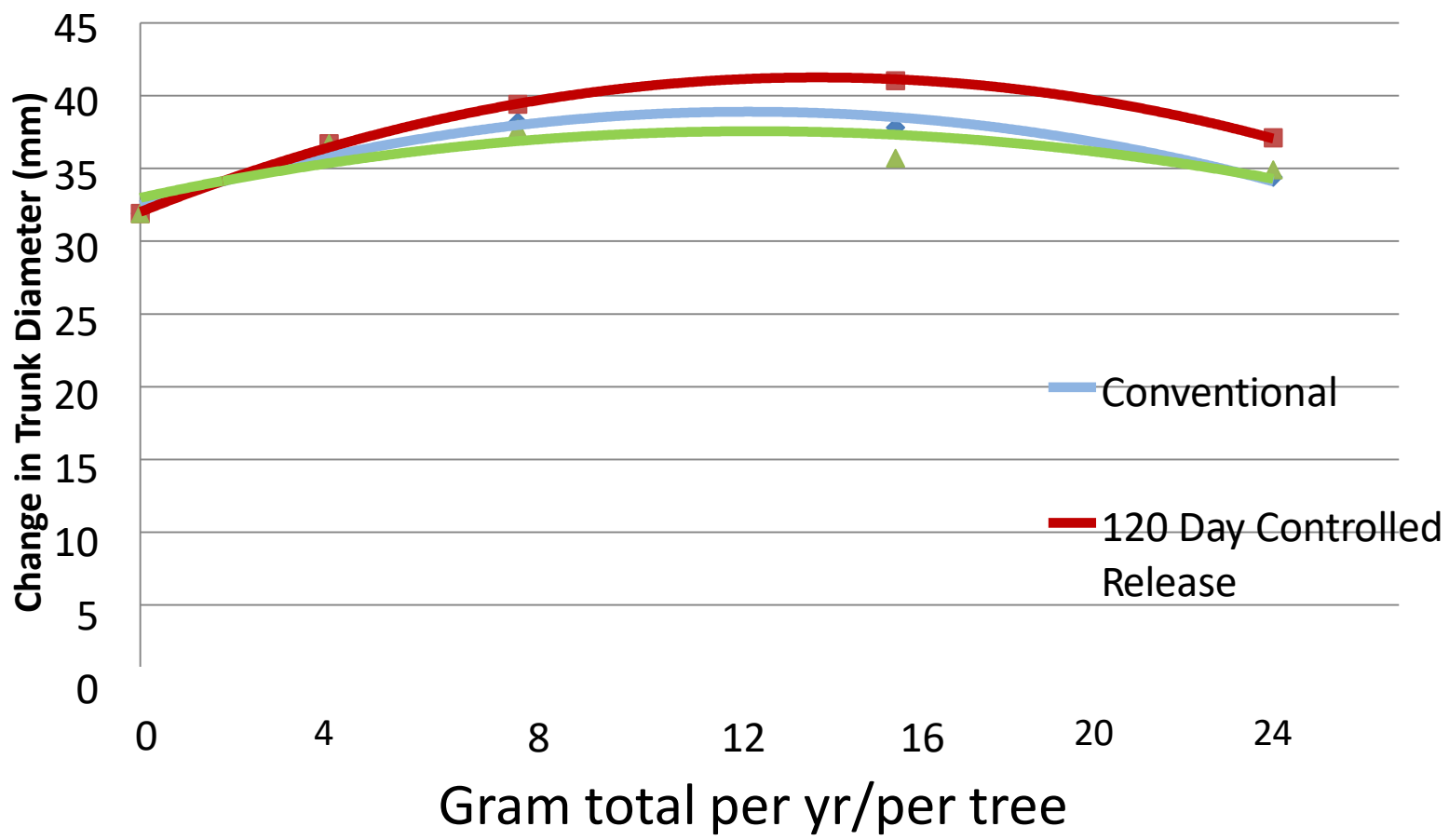
Treatments not connected by same letter indicate statistical difference at $p > 0.05$

Micro nutrients affected by fertilizers – suspect changes in soil pH

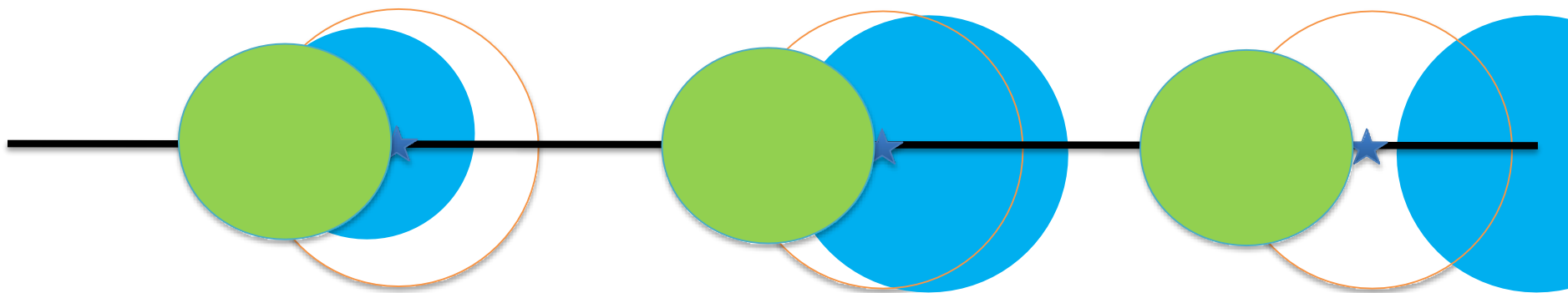


- Ammonium sulfate
- Calcium nitrate
- Slow release
- Triple 15

Merced Trials – First Year Almond Fertilization Rate



Fertilizing Young Almond Orchards: Efficiency Considerations



Application Efficiency of systems for young trees is dependent upon delivery to development root system.

Resources

Online Worksheet for calculating Nitrogen demand and credits and timing.
(US timing and metrics. US fertilizer formulations)

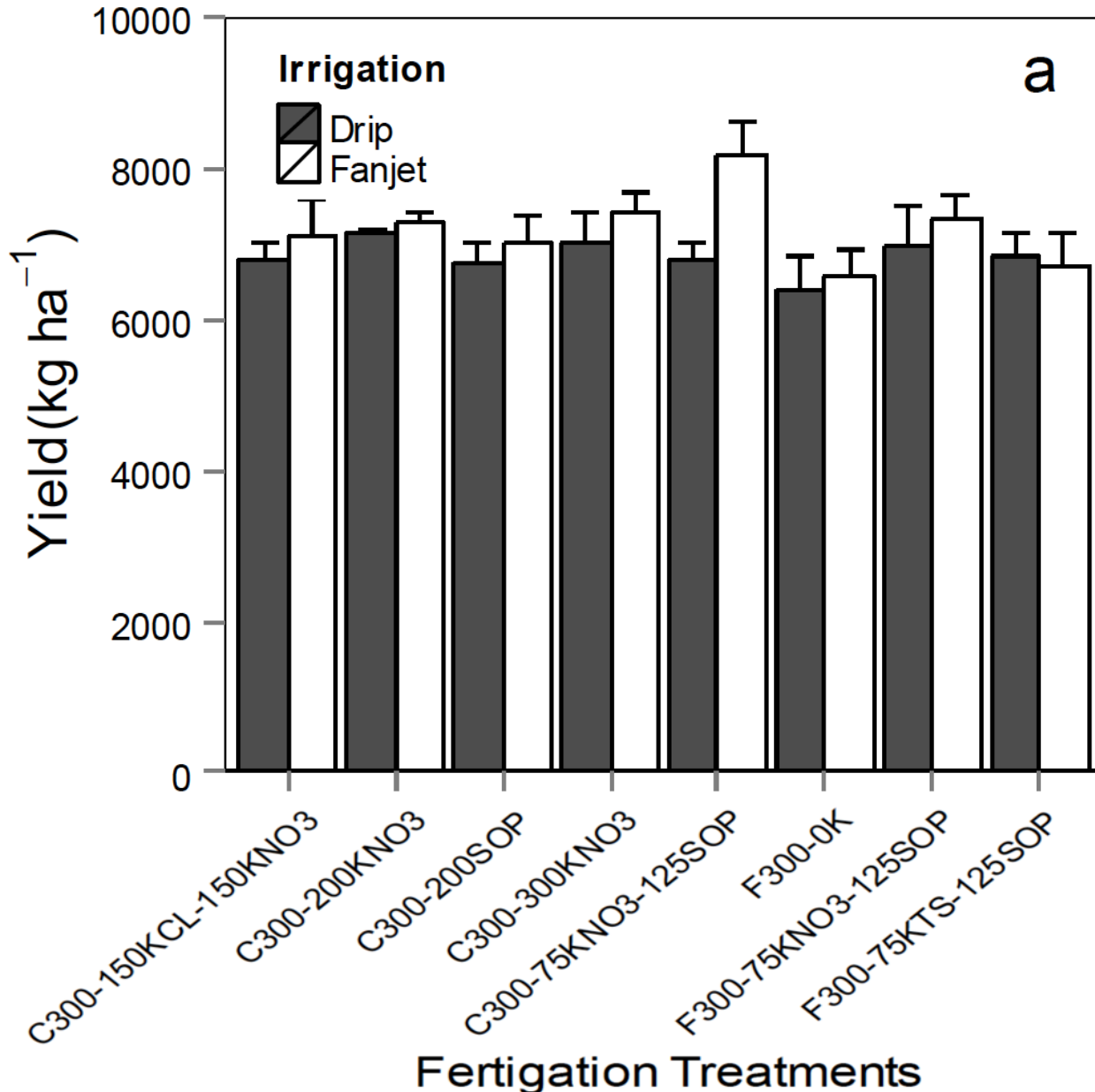
<https://www.sustainablealmondgrowing.org>

- Free and can be anonymous,
- or you can enter specific data which will also be protected and never released, but will be kept on the server for easier subsequent data entry.

<http://apps.cdfa.ca.gov/frep/docs/Almonds.html>

Fertigation Method and K Source Effects on Yield

(2012-14 cumulative)



C = Fertigation in all irrigation events

F = Fertigation 4 times per year

SOP = Potassium sulfate

KTS = Potassium thiosulfate

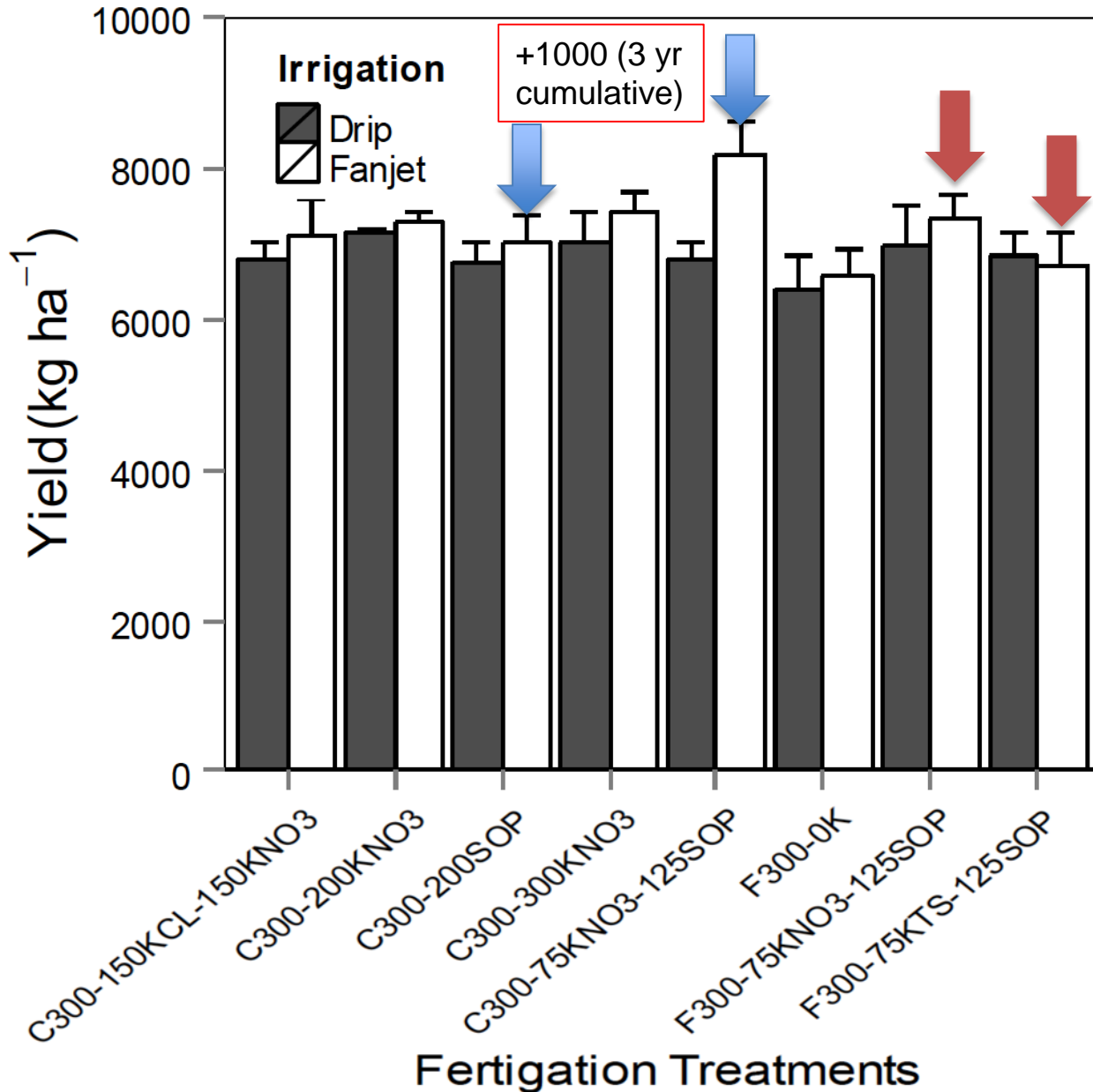
KNO₃ = Potassium nitrate

306 kg ha N supplied as Urea Ammonium Nitrate (32%) and KNO₃

eg. F300-75KN-125SOP

= 300 lbs N -75 lbs K as KNO₃ – 125 lbs K as SOP

Fertigation Method and K Source Effects on Yield



Soil: Excellent quality alluvial sandy loam. Moderate salinity. No in-season leaching.

Wetted Zone:
2 m – drip
2.7 m fanjet

Small, non-significant but consistent benefit of fanjet over drip.

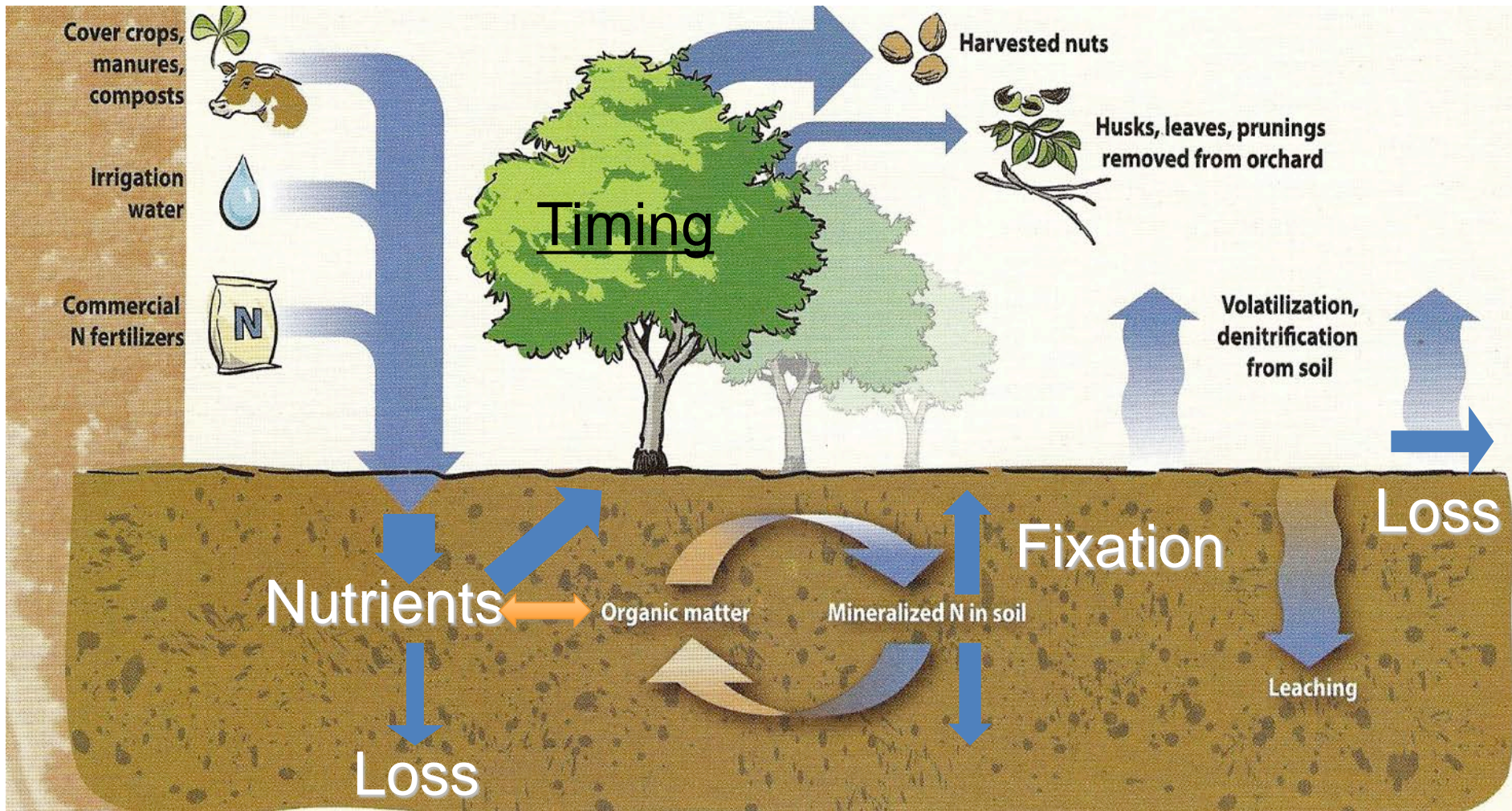
No clear benefit of (C) continuous versus (F) pulsed fertigation.

Clear benefit of a portion of K (38%) as KNO₃ over SOP, KTS or higher proportions of KNO₃.

Maintaining Good Soil Structure Allows Roots to Fully Explore the Soil, Improves Water Holding, Enhances Soil Microbial Activity, Improves Tolerance to Stress Conditions.

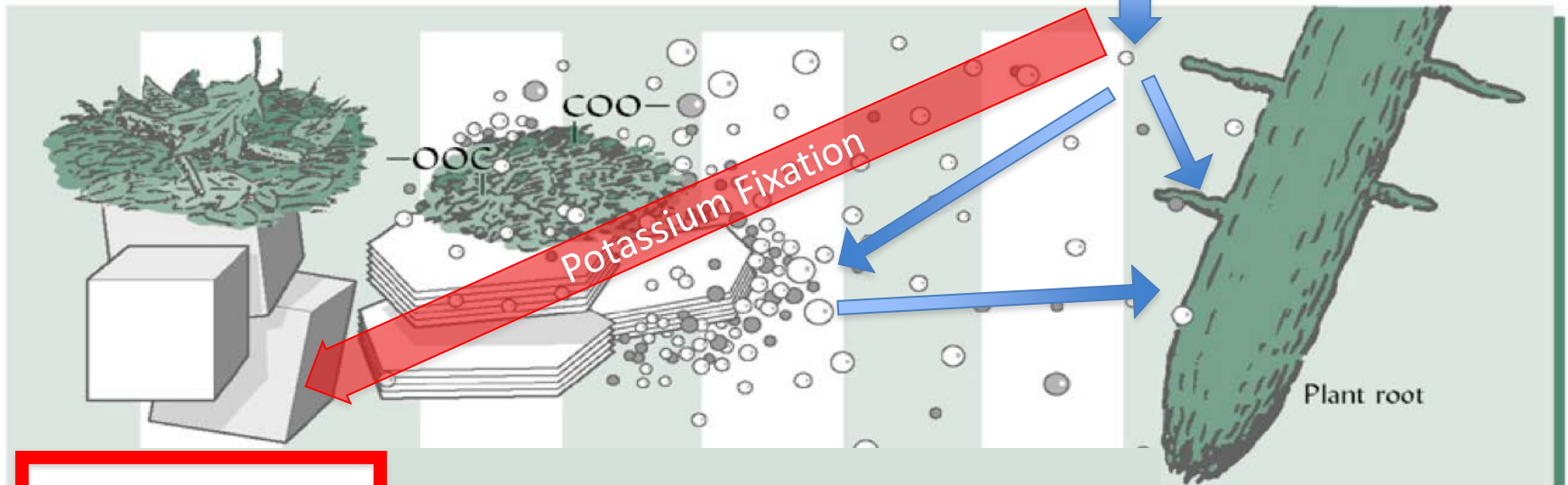


Supply (Rate) = Demand (Amount and Timing)



K Fixation: A Special Concern

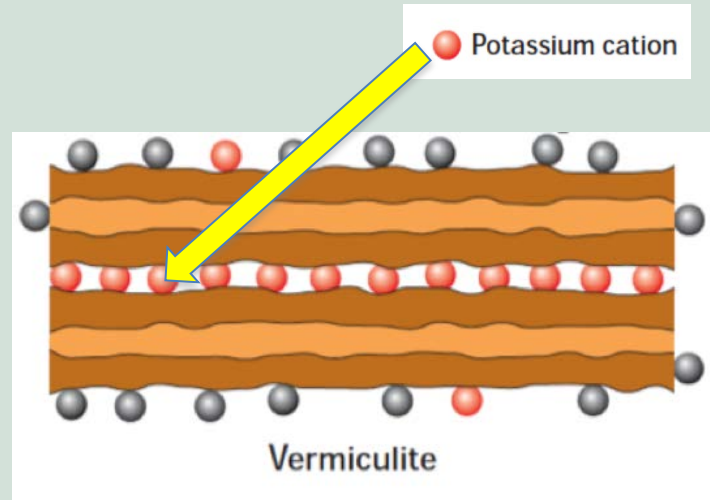
K FERTILIZER



Mineral

Determined by source of soil minerals (volcanic, marine, alluvial etc) and age of soil.

Influences fertility but cannot be 'managed'.



Potassium Fixation Occurs in Vermiculite Rich Soils

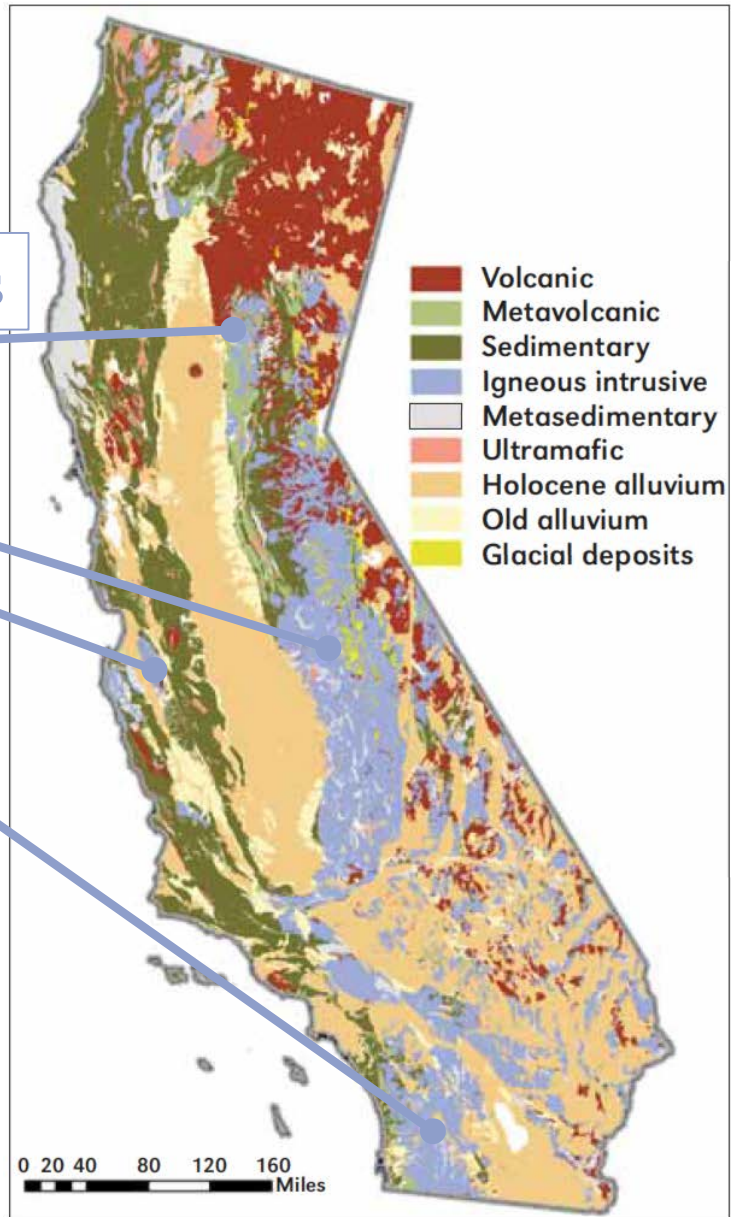
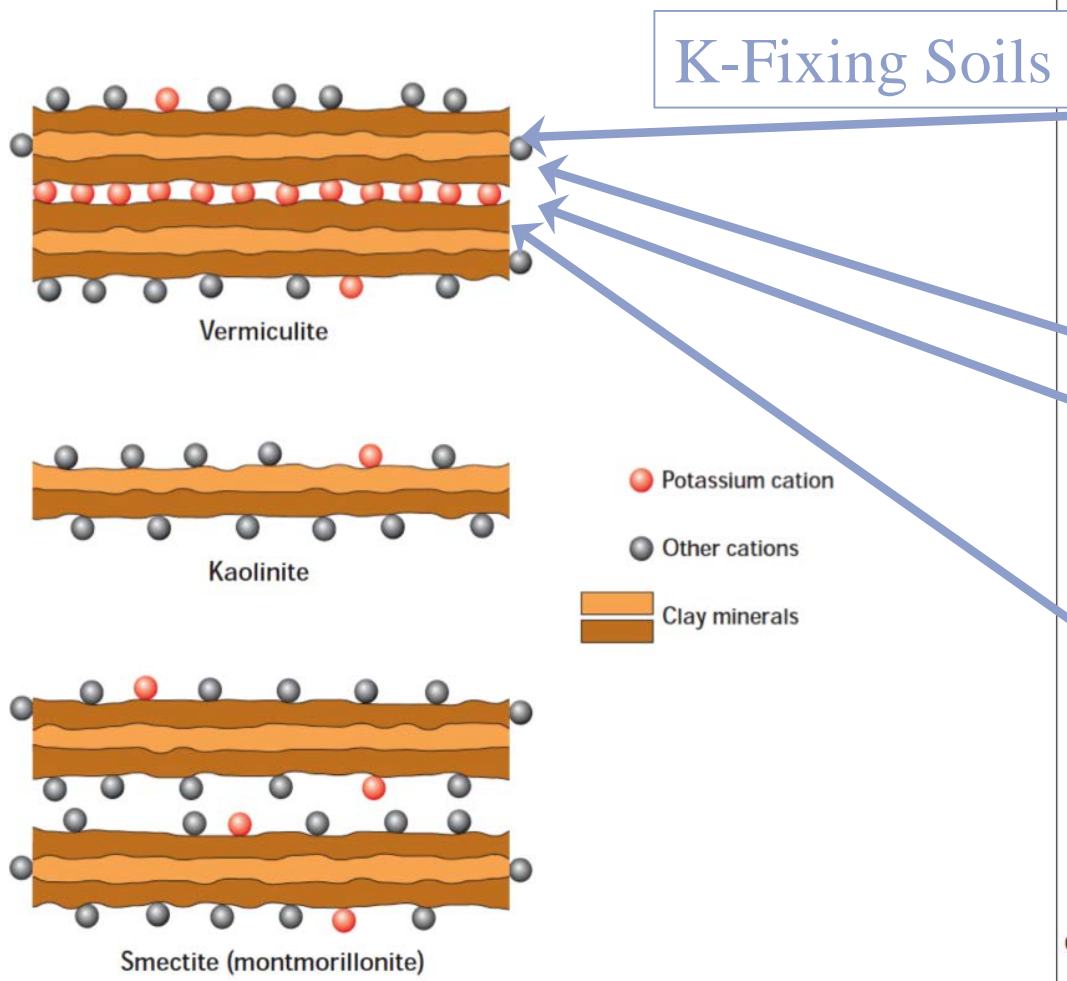
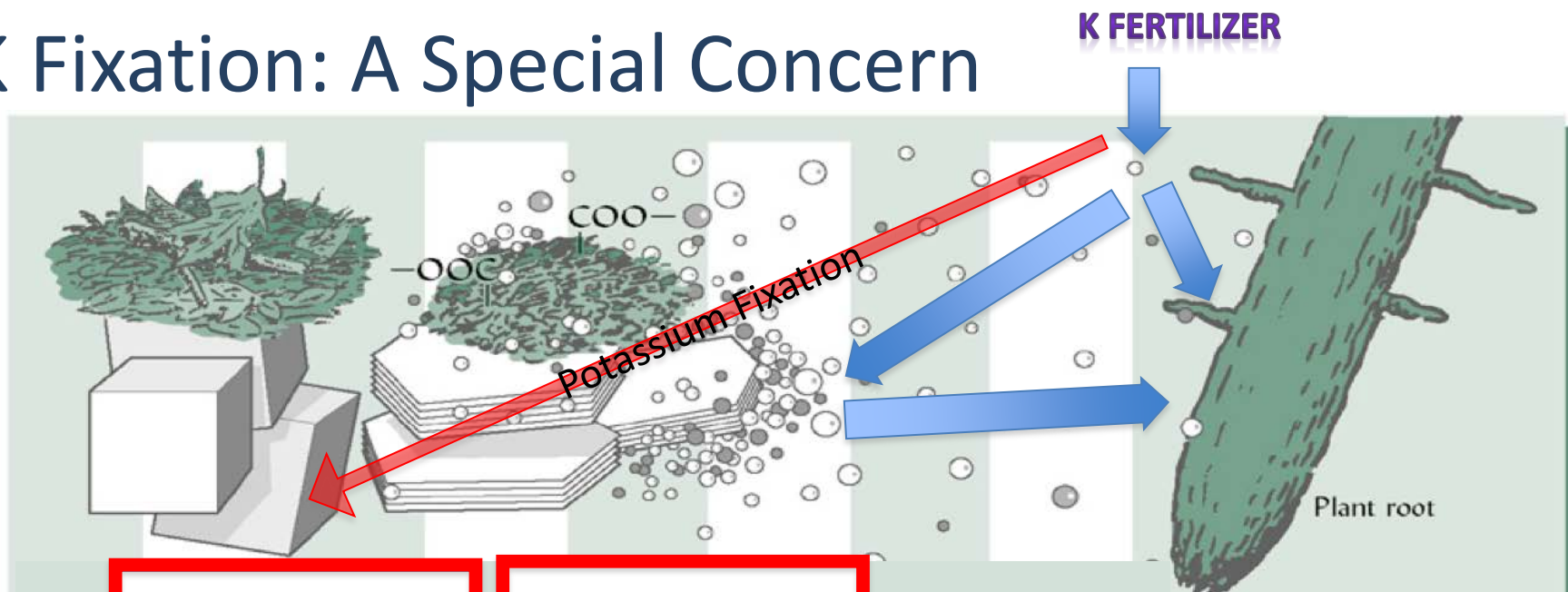


Figure 3. The soils of the Central Valley of California are primarily derived from granitic material from the East and sedimentary material from the West. Potassium-fixing soils are typically associated with granitic (igneous intrusive) parent material.

K Fixation: A Special Concern



Increase Exchangeable Fraction

Improved Cation and Anion Exchange Capacity

Increase Solution Fraction

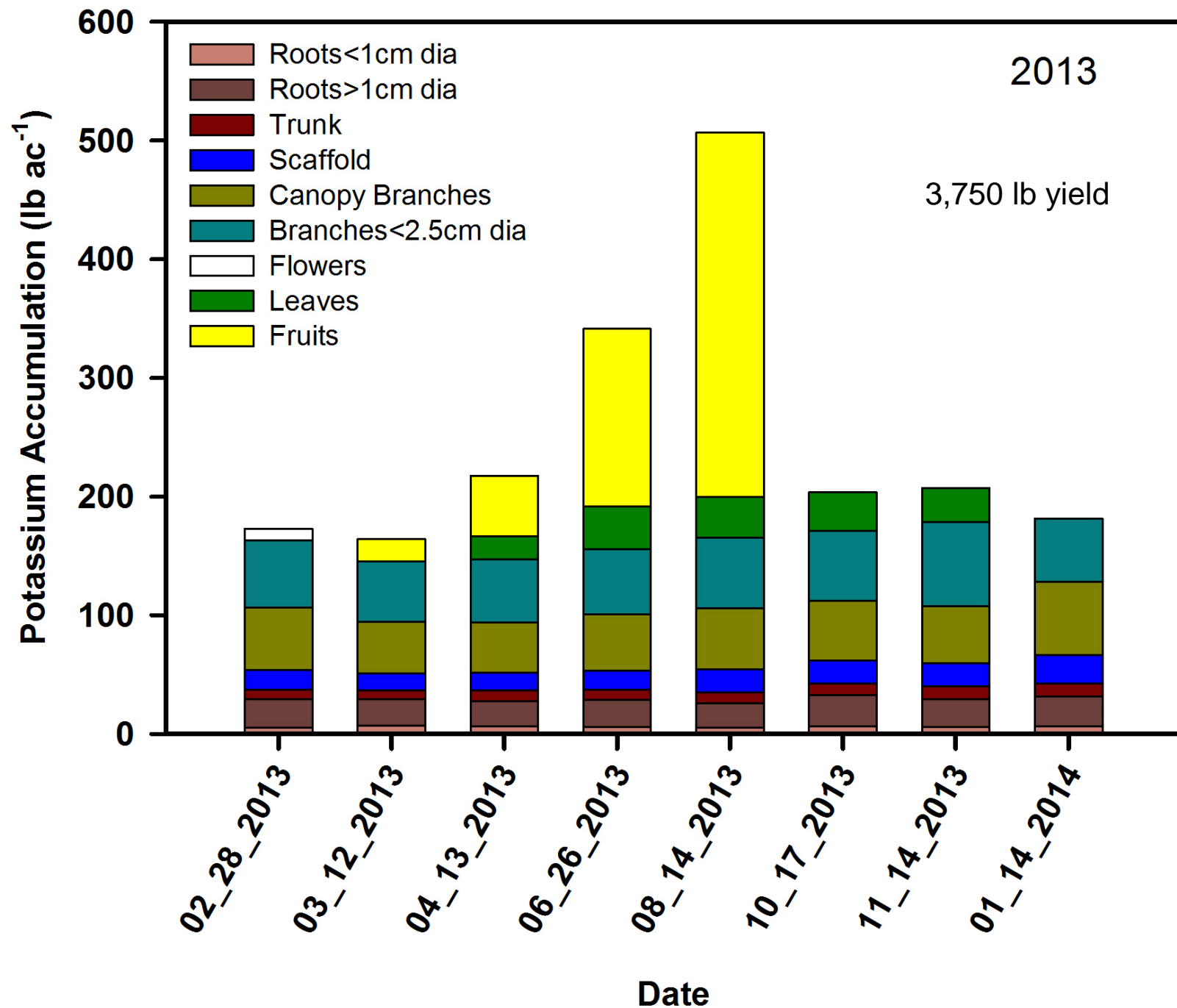
Frequent spoon feeding.

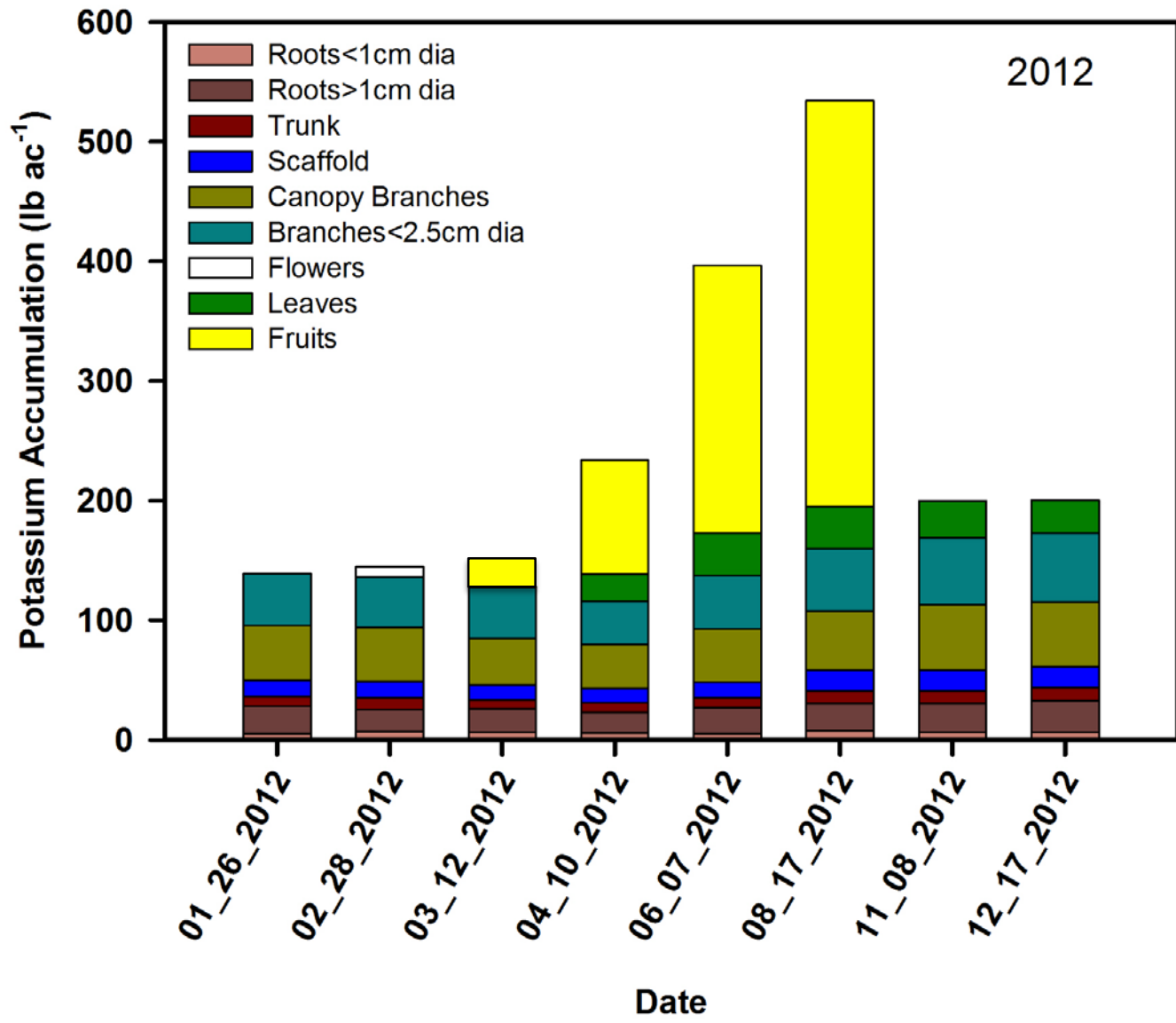
Minimize wetting drying cycles.

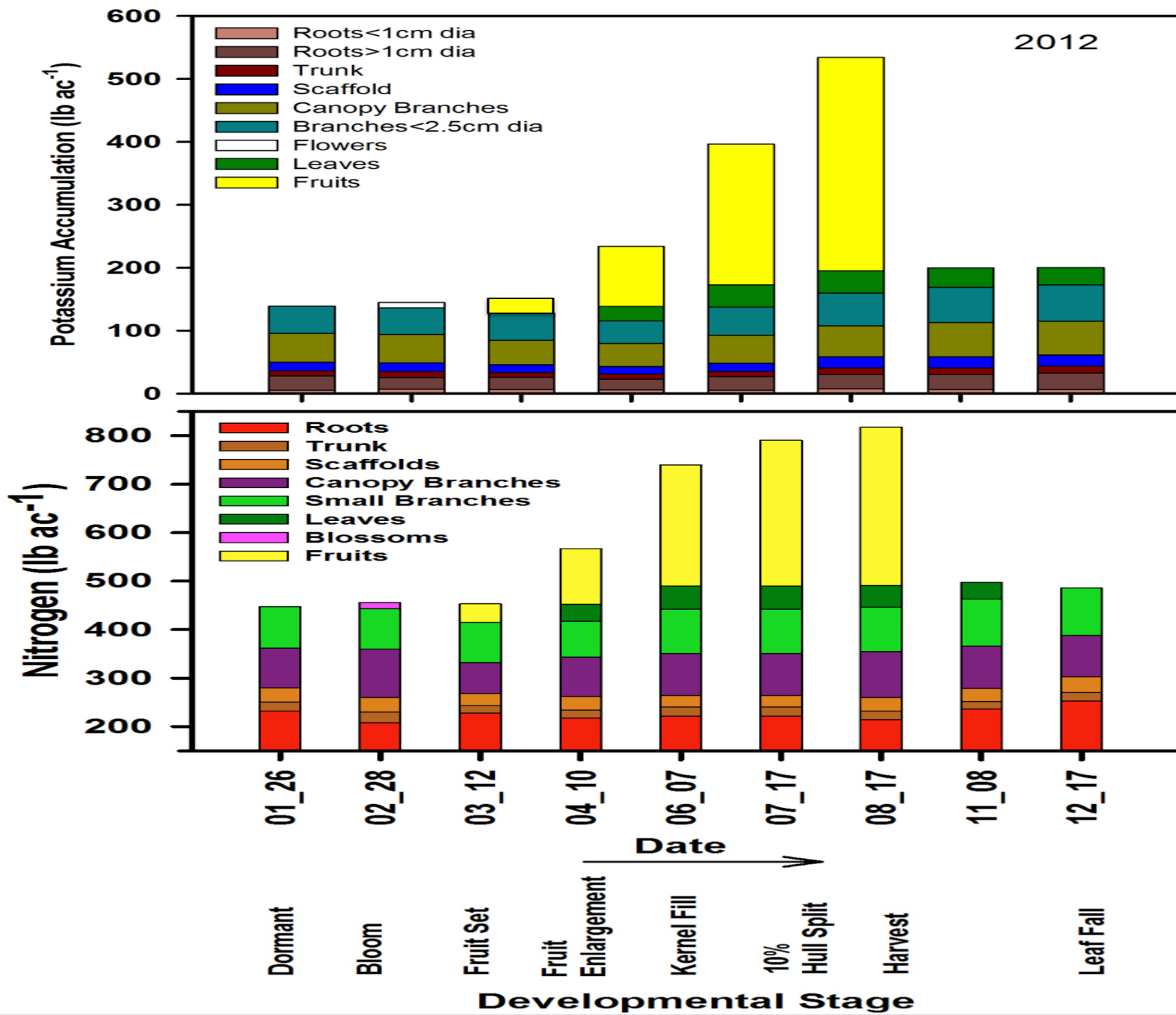
Mitigating K Fixation

Massive banded K fertilizations (oversaturates binding sites in and around fertilizer band)

Apply soluble K to roots during active uptake periods.







Growing Season (per 1000 lb kernel)

