Research Update: Nutrient Management
Session Speakers

Sebastian Saa, ABC
Steve Petrie, Yara North America
Jesse Roseman, ABC
Patrick Brown, UC Davis
Upcoming Sessions at 3:30 p.m.

• Almond Production Estimates: Nuts and Bolts of Different Models (Room 1)

• Why Does My Handler Want Me to Participate in the California Almond Sustainability Program? (Room 2)

• Bees: What’s New in Pollination? (Room 3)
Research Update: Nutrient Management

Moderator, Sebastian Saa, Senior Manager, ABC
Research Update: Nutrient Management

• Steve Petrie, Director of Agronomic Services, Yara North America Inc., Platinum Sponsor
  – Overall nutrient management

• Jesse Roseman, Principle Analyst, Almond Board of California
  – Regulatory Updates

• Patrick Brown, Professor, UC Davis
  – Almond nutrient management
Nutrient Management
Good enough is not enough

Dr. Steve Petrie
Director of Agronomic Services
Thank you to the Yara almond team in California

- Katelin Britton, Sales Agronomist
- Devin Clarke, Tree Nut Crop Manager
- Allison Couch, Sales Agronomist
- Peter DeBoer, Regional Sales Manager
- Chris Gallo, Regional Sales Manager
- Dave Morgan, YaraVita Specialist
- Vanessa Vicencio, Sales Agronomist
Crop production is all about GEMs

Emeralds

Diamonds

Rubies

Genetics

Environment

Management
Crop yield and quality are driven by three factors:

- Genetics
- Environment
- Management
Almonds: A Complex Life Cycle

Vegetative Cycle
- shoot elongation / leaf development
- spur development
- bud formation
- heat dormancy (summer)

Winter dormancy
- shoot initiation
- endo-dormancy
- dormancy break
- chilling requirement

Reproductive cycle
- bloom
- kernel growth
  - hull growth
  - embryo growth
  - increase in seed size

Chilling requirement
- shoot elongation / leaf development
- spur development
- bud formation
- heat dormancy (summer)
- shoot initiation
- dormancy break
- chill requirement
- hull split / maturity

Hull split / maturity
- shoot elongation / leaf development
- spur development
- bud formation
- heat dormancy (summer)
- shoot initiation
- dormancy break
- chill requirement
- hull split / maturity
Balanced nutrition is key

Comprehensive nutrient management improves many aspects of almond growth, yield, and quality

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- Improved ▲
- Reduction ▼
- No clear trend △
Good enough is not enough

Farmer
Processor
Retailer
Consumer

Carbon footprint
Water quality
Water footprint
Air quality
Profitability
Crop nutrition

Regulations
Human nutrition
Water consumption
Pesticides
Why increased nutrient and water use efficiency?

Increased crop yield and quality
Why increased nutrient and water use efficiency?

- Increased crop yield and quality
- Increased profitability
Why increased nutrient and water use efficiency?

- Increased crop yield and quality
- Increased profitability
- Respond to value chain needs
Why increased nutrient and water use efficiency?

- Increased crop yield and quality
- Increased profitability
- Respond to value chain needs
- Protect the planet
Nutrient use efficiency

4R Nutrient Stewardship can help grow crops sustainably.

The 4Rs work to increase production/profitability for farmers while ensuring the future of the agricultural industry.

- RIGHT SOURCE
- RIGHT RATE
- RIGHT TIME
- RIGHT PLACE
Water use efficiency

4 R’s of irrigation water stewardship

- **Right rate**: how much does the tree need
- **Right placement**: Where the roots are taking up water, high DU, etc.
- **Right timing**: When does the tree need the water
- **Right source**: High quality water (no salts or toxic elements, etc.)

Improved water stewardship will help ensure top yields and minimize nutrient and water losses
Monitoring is the key to managing

Monitoring almond nutrient status
- Leaf nutrient concentration during the growing season
- Sap analysis
- Trunk diameter measurement
- Carbohydrate analysis
- Soil nutrient status

Implementing the 4 R’s of nutrient stewardship will help ensure top yields and minimize nutrient losses
Monitoring is the key to managing

Monitoring almond water status

• Leaf water status – pressure bomb
• Water balance models – Yara Water Advisor app
• Soil water status - tensiometers

Improved water stewardship will help ensure top yields and minimize nutrient and water losses
Removing mental shackles: HLB in citrus

HLB, a bacterial disease vectored by a psyllid, has devastated the Florida citrus industry.

An aggressive research program has not yet found a viable solution.

A comprehensive approach using vector control and improved nutrient management has been effective in mitigating the effects of HLB.

Photo: ufgi.ufl.edu
HLB mitigation: nutrient & vector management

University of FL trial, average of six years

- Check: 110 lbs/tree
- Nutrition: +5 lbs, 115 lbs/tree
- Insecticide: +15 lbs, 125 lbs/tree
- Nutr. + insecticide: +33 lbs, 148 lbs/tree
Maury Boyd’s Farm in Florida

Pre-HLB infection

Hamlin variety

Orange Hammock:

Maury Boyd, Grower
Maury Boyd’s Farm in Florida

Hamlin variety

Post-HLB infection

Orange Hammock:
- Enhanced nutrient management
- No removal of HLB-symptomatic trees

- Grove looking better than in 2003
- Fruit yields still increasing
- HLB infection ~100%

Acknowledgements:
Google Earth, 2011
Maury Boyd’s comprehensive citrus nutrition program

**Soil Application (4x / yr)**
- N – Calcium nitrate
- P – 0-45-0
- K – KCl, K-Mag
- Ca – Calcium nitrate
- Mg – K-Mag
- S – K-Mag
- Micronutrients

**Foliar Applications**
- N – KNO3
- K – KNO3
- Mg – MgSO4
- S – MgSO4, ZnSO4
- B – Solubor
- Zn – ZnSO4
- Mo – Sodium molybdate
Comprehensive nutrient solution maintained citrus yields

![Bar chart showing boxes per acre for Hamlin and Valencia varieties, comparing pre-HLB and HLB infected conditions.](chart.png)
Summary

• Improved nutrition can play a key role in helping plants mitigate the effects of HLB:
  • N form and rate
  • K
  • Ca
  • Micronutrients
• Improved nutrition is NOT a cure
• Improved nutrition can help buy time until a solution is found
# Carbohydrate deprivation and walnut quality

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<td>Thin shell</td>
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<td>Yellow pellicle</td>
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<td>Bronze pellicle</td>
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Photo: sacvalleyorchards.com
Soil water interaction with frost damage

- Walnut damage due to cold injury
- Sudden November frost
- Rapid temperature drop and wide diurnal temperature swings
- Trees did not have time for carbohydrates to convert to sugars
- Trees that had been recently irrigated suffered less damage

Photos: Luke Milliron
Removing mental shackles: off-ground harvesting

Past
Never happen, too impractical, too costly, etc.

Present
Some are trying, challenges to overcome, equipment innovation needed

Future
No nut touches the ground; cleaner air and cleaner crop
Good enough is not enough

Yara Incubator Farm -- an example of integrating research and production in a farm scale setting

Comprehensive crop management including nutrients, irrigation, and pests to achieve optimum yield and protect the planet
Removing mental shackles: high yields and clean water

Past
Can’t happen, too impractical, too costly, etc.

Present
Many are trying, still many challenges

Future
Clean water, happy consumer, profitable farmer.
Nitrates and groundwater protection

Jesse Roseman
Principal Analyst, Almond Board of California
Human Right to Water

• California has signed significant legislation to ensure all Californians access to clean drinking water
• Focus on nitrates and Disadvantaged Communities, many in central valley
• 2019: Safe & Affordable Drinking Water Fund to receive $130M annually from the Greenhouse Gas Reduction Fund, to be disbursed through competitive scoring to smaller districts
• Near-term solutions include temporary connections to safe drinking water sources, point-of-use treatment systems, drilling wells into uncontaminated aquifers, and trucking water directly to communities (State Water Board)

“every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes”
AB685, 2012

“help water systems provide an adequate and affordable supply of safe drinking water in both the near and long terms”
SB200, 2019
Irrigated Lands Regulatory Program (ILRP)

- 2003 Central Valley Water Quality Control Board created ILRP, with Waste Discharge Requirements managed by grower member Water Quality Coalitions
- Growers prepare Irrigation Nutrient Management Plans, with goal to optimize nutrient efficiency
- Coalitions are developing Groundwater Protection Targets to identify the amount of N that growers can apply across a township based on the associated nitrate leaching potential
- The GWP value = applied N – removed N +/- other variables (soil type, irrigation system, attenuation of nitrate, etc.)
- 20+ years to meet the targets
- Separately developing groundwater well networks for Groundwater Trend Monitoring (by Central Valley Groundwater Monitoring Collaborative)

Starting in 2020, all growers must submit Irrigation Nitrogen Management Plans (INMP) Summary Reports include:
- Nitrogen applied (from all sources including irrigation water)
- Crop yield
- Estimate of nitrogen removed
- **NEW** Irrigation management (method, ET, amount, efficiency practice)

Starting in 2019, East San Joaquin members required to do Drinking Water Well Monitoring.
- If water above 10 ppm, must notify drinking water user
- Results posted to Geotracker website
CV-SALTS

• 2019 State Water Board approved Basin Plan Amendments with new regulatory approaches for nitrates and salts, following over decade of work

• ILRP still implements new rules

• Under the current nutrient management laws, compliance is difficult to impossible

• Most farmers complying through ag waiver that is sunsetting

• Goal is to allow for continued farming, while providing protections and even recovery for aquifers with high levels of nitrate

• Initial short-term actions are providing replacement drinking water

• No longer just ag- includes cities and industries

GOALS

1. Provide Safe Drinking Water Supplies through development of short-term and long-term solutions

2. Reduce Nitrate and Salt Impacts to Water Supplies by slowing increases in Salt and Nitrate in groundwater

3. Restore Groundwater Quality to meet standards where reasonable and feasible
Nitrate Control Implementation

- **Priority 1 Area (Red)**
  - Notice to Comply *within one year of Basin Plan amendments* becoming effective

- **Priority 2 Area (Orange)**
  - Notice to Comply *within 2-4 years of Basin Plan amendments* becoming effective

- **Remaining Areas (Green)**
  - Implementation to be phased in at a later date

*Courtesy Central Valley Salinity Coalition*
What is a Management Zone?

- **Defined area** – for nitrate compliance
- **Collective implementation** – for safe drinking water
- **Discharger cooperative** – to control nitrates
- Two Pilot Management Zones- Turlock Groundwater Subbasin (Stanislaus and Merced Counties), Alta Irrigation District and Kings River East GSA (Fresno and Tulare Counties)
- Both developing draft Management Zone proposals
- Management Zone boundaries and initial participants
- Initial mapping of nitrate levels
- Identification of water supplies exceeding nitrate objective
- Early Action Plan

*Courtesy Central Valley Salinity Coalition*

- **Near-term**: best practicable treatment or control
- **Long-term**: achieve balance and restore groundwater, where feasible
Sustainable Groundwater Management Act (SGMA)

- Legislation passed in 2014
- Groundwater Sustainability Agencies (GSAs) and Management Zones could fit together
- Growers participate in SGMA through GSA formation, Groundwater Sustainability Plan (GSP) preparation, implementation
- Undesirable result #4: avoid causing “significant and unreasonable degraded water quality” throughout the basin, largely through a “minimum threshold” aligned to existing water quality standards
- Consider whether groundwater pumping, even if sustainable, may exacerbate existing contaminants or impact drinking water quality
- Consider impact of GSP management actions (e.g., recharge projects, water banking) on water quality
- Likely overlap with monitoring requirements under ILRP
Thanks!

Jesse Roseman
jroseman@almondboard.com
Nutrition Update

Patrick H. Brown Lab
The New Irrigated Lands Regulatory Program

Nitrogen Management, impact on orchard fertilization.

Essential Nutrients
(Lifecycle cannot be completed in their absence)

Photosynthesis
Carbon
Oxygen
Hydrogen

Macro Nutrients
- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulfur

Micro Nutrients
- Zinc
- Iron
- Boron
- Manganese
- Copper
- Chlorine
- Nickel
- Molybdenum

- Always Manage
- Monitor and Manage, Prevent/React
- Isolated occurrence (Monitor)
- Unknown
N = 68 lbs/1000 yield
K = 80 lbs/1000 yield
Ideal Fertilization: Multiple Applications in season timed with demand

Demand driven by yield (every orchard and cultivar may be different)

No significant uptake prior to leaf out

Minimal uptake after harvest (8% or 10-20 lbs).

Applications managed to keep N in the irrigated root zone

To optimize N use, all inputs must be optimized
Fixation

Nutrients

Optimizing Nitrogen and Potassium in Almond.
(ANR Publications 283984)

Supply (Rate) = Demand (Amount and Timing)

N

N

N, K

K, N

Nutrients

Fixation

Loss

Timing

N

Available Soil Nutrients

Cover crops, manures, composts

Irrigation water

Commercial fertilizers

Husks, leaves, prunings removed from orchard

Harvested nuts

Volatilization, denitrification from soil

Leaching

Mineralized N in soil

Organic matter

Adapted from Kathy Kelley-Anderson et al: ANR Pub # 21623

N = 68 lbs/1000 yield

K = 80 lbs/1000 yield
Fields are variable, how do you choose and apply the optimal N rate?

- Zones differ in productivity
- Cultivars differ in productivity.
- Precision fertigation will be come essential for efficiency
Essential Nutrients: Almond
(Lifecycle cannot be completed in their absence)

Photosynthesis
Carbon
Oxygen
Hydrogen

Macro Nutrients
- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulfur

Micro Nutrients
- Zinc
- Iron
- Boron
- Manganese
- Copper
- Chlorine
- Nickel
- Molybdenum

- Always Manage
- Monitor and Manage, Prevent/React
- Isolated occurrence (Monitor)
- Unknown
**Zinc**

**Function:** Zinc is required for bud expansion, flowering, leaf expansion, shoot extension and tolerance to stress.

Zinc deficiencies tend to occur in **early spring** though **impact** can persist through year.

- **Symptoms**— Characterized by late bud emergence, erratic flowering, small leaves with reduced internode length (little leaf and rosette)

- **Spring Fever** - Most prevalent in cold wet early springs followed by a warm period indicting a reduced soil Zn uptake and high Zn demand.
Small pale leaves. Short internodes. Rosette leaves.

Photo: Jack Kelly Clark
Zinc Deficiency Compromises Flowering

Zn Deficient

Zn Sufficient

Photo: Scott Johnson
Zinc (red) concentrates at base of bud, ready for rapid mobilization into opening leaves.

Zinc (red) concentrates at base of flower bud, ready for rapid mobilization into ovary for effective fruit set.
Zinc Fertilization

Critical summer leaf value 20 ppm - fields with an average Zn of <30ppm will frequently respond to Zinc.

- Early Spring Foliar (post bloom - full leaf out)
  - Zn Sulfate
  - Zn chelate, Zn nitrate, Zn carbonate, Zn polyol, Zn Amino or complex
- Low rate frequent in-season Zn???
- Fall Foliar
  - Low to mid rates in August-October may be effective if leaves are healthy.
  - Late season, higher rate foliar Zn provides very limited Zn to trees.
Zinc Fertilization

Critical summer leaf value 20 ppm - fields with an average Zn of <30ppm will frequently respond to Zinc. Analysis of soil pH is important (>7.2 can be problematic)

• Soil Applications
  – Efficacy is highly dependent on soil pH and Zn fixation
    • High pH, highly fixing soils will need a combination of soil and foliar treatments
  – Applications through micro-irrigation are most effective
    • Frequent soluble Zn sources during growing season
    • In high pH fixing soils, drip is likely more effective than micro.
  – Reducing soil pH (5.5-7.0) will improve Zn availability
    • Acid injection or use of ammoniacal N sources.
Boron (B)

• Nutrient Uptake and Assimilation
  – Uncharged element, not fixed in soils. No significant soil pH effect.
  – Irrigation water is frequently the most important B source.
  – Boron is leachable and deficiency will occur more often in orchards supplied with low B irrigation water.
  – Boron deficiency can compromise fruit set even if vegetative symptoms are absent.

• Function
  – Reproductive and vegetative growth.
  – Pollen formation and fruit set

• Mobility
  – Highly mobile in Almond (tends to accumulate in fruit).
Rarely Seen!

Boron Deficiency Symptoms Identified in Almonds

C. J. Hansen
D. E. Kester
K. Uriu

Normal almond shoot at the left is from a tree that received a boron spray. The shoot at the right is from a boron-deficient tree. This photograph taken on March 31 illustrates the first symptom.
More Common: Boron Deficiency Primarily Affects Fruit Set or Nut Retention in Almond.
Boron Fertilization

Critical value 80-160 ppm in hulls at fruit maturity. Fields with an average B of <100ppm in hulls will frequently respond to Boron.

• Soil Applications
  – Boron is not easily fixed in soils and hence any soluble B source will be effective.
  – Applications of B through irrigation are effective if timed to coincide with early fruit growth (post bloom) and bud maturation (August – October)
  – Almond trees utilize between 0.5 and 1.5 lbs of B per year per acre.
  – Groundwater frequently contains B and should be considered in all fertilization plans.
Boron Fertilization

Critical value 80-160 ppm in hulls at fruit maturity. Fields with an average B of <100ppm in hulls will frequently respond to Boron.

• Foliar Applications
  – Any high quality, soluble B source can be used.
  – Application pre-bloom, early post bloom and post fruit maturity are most effective. DO NOT SPRAY OPEN FLOWERS OR BEES!
Essential Nutrients: Almond
(Lifecycle cannot be completed in their absence)

**Photosynthesis**
Carbon
Oxygen
Hydrogen

**Macro Nutrients**
- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulfur

**Micro Nutrients**
- Zinc
- Iron
- Boron
- Manganese
- Copper
- Chlorine
- Nickel
- Molybdenum
## Critical Values (mid-summer)

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*Boron concentration in mature hull. Leaf analysis is not effective in determining boron deficiency, sufficiency and toxicity; hull boron analysis has been found to be a better indicator of tree boron status.
Recommended Sampling Criteria

Average Orchard (10-100 acre block. Spring or Summer Sampling)

- Collect leaves from 18 trees in one bag.
- Each tree sampled around the canopy from at least 8 well exposed spurs located between 2 meter from the ground, trees at least 30 meters apart.
- In spring, collect samples soon after full leaf expansion (approx. 30-50 days after full bloom (DAFB)).
- Spring Samples: Analyze for P, S, B, Mn, Cu, N, K, Ca, Mg. Apply developed Early Sampling formula and contrast with established critical values.

Non-Uniform Orchard:

- Repeat this process in each orchard zone of similar performance.
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 Leibig, 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

Optimizing N use requires identifying and optimizing all production factors:

Zinc deficient section

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

• **ILRP N Rules are forcing a new thinking**
  – N Application based upon yield, Accounting for all inputs (water, OM etc.)
  – More frequent applications of low rates are preferred. Cultivar and ultimately site specific N delivery will be required for high efficiency.
    
    68 lbs N per 1000 lb yield

**Zinc**

• Critical for flowering, fruit set and leaf out, adequate Zn in buds is the key, buds develop late June-October.

• Early season foliars (March, April, May), in season fertigation, soil pH amendments. (Frequent low level in season may assist (?)

**Boron**

• In season foliar or soil applications are effective. Bud push foliar is good insurance
Variability and
Soil Quality: Maintaining Good Soil Structure and Health Allows Roots to Fully Explore the Soil, Improves Water Holding, Enhances Soil Microbial Activity, Improves Tolerance to Stress Conditions.

Thank You