# 2018 | THE ALMOND CONFERENCE

## SPEED TALKS: NUTRIENT, SALINITY AND SOIL HEALTH

ROOM 308-309 | DECEMBER 4, 2018

California almonds, Almond Board of California

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# Continuing Education Units (CEU’s)

- **What type of CEU’s are offered at conference?**
  - Tuesday – Certified Crop Advisor (CCA)
  - Wednesday – Certified Crop Advisor (CCA)
  - Thursday – Certified Crop Advisor (CCA) and Department of Pesticide Regulations (DPR)

- **Where are the CEU sign in sheets?**
  - CEU sign in sheets will be in the back of each session
  - There are separate forms on Thursday for the CCA and DPR credits

- **Special instructions for Thursday**
  - PCA’s will need to pick up their scantrons in the morning before the first session of the day. They will also need to return the scantron at the end of the day to the CEU booth. This is in addition to signing in and out of each session.

# AGENDA

- **Spencer Cooper**, Almond Board of California, moderator
- **Almond Board Funded Researchers**
    - Patrick Brown, UC Davis
    - Alissa Kendall, UC Davis
    - Greg Browne, USDA ARS
    - Mae Culumber, UCCE Fresno
    - Brent Holtz, UCCE San Joaquin
    - Houston Wilson, UC Riverside
    - Amélie Gaudin, UC Davis
    - Patrick Brown & Sat Darshan Khalsa, UC Davis

# Boron Management and Remediation in Almond

**Patrick H. Brown, Ph.D.**
UCD Plant Sciences
Project #18.WATER12.Brown

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# Boron Toxicity

Unlike Pistachio, Walnut, Grape etc. boron toxicity in Almond results in dieback, sticky exudates and tree death.

- **0.5 ppm B in water or 300ppm in hulls indicates potential problem**

- Hull B is best indicator of tree B
- No leaf symptoms, no accumulation.
- Brown-black necrotic lesions on bark, shoot tip die-back
- Gumming on fruits and bark
- Difficulty in shaking nuts.

# Boron Toxicity
# Cache Creek



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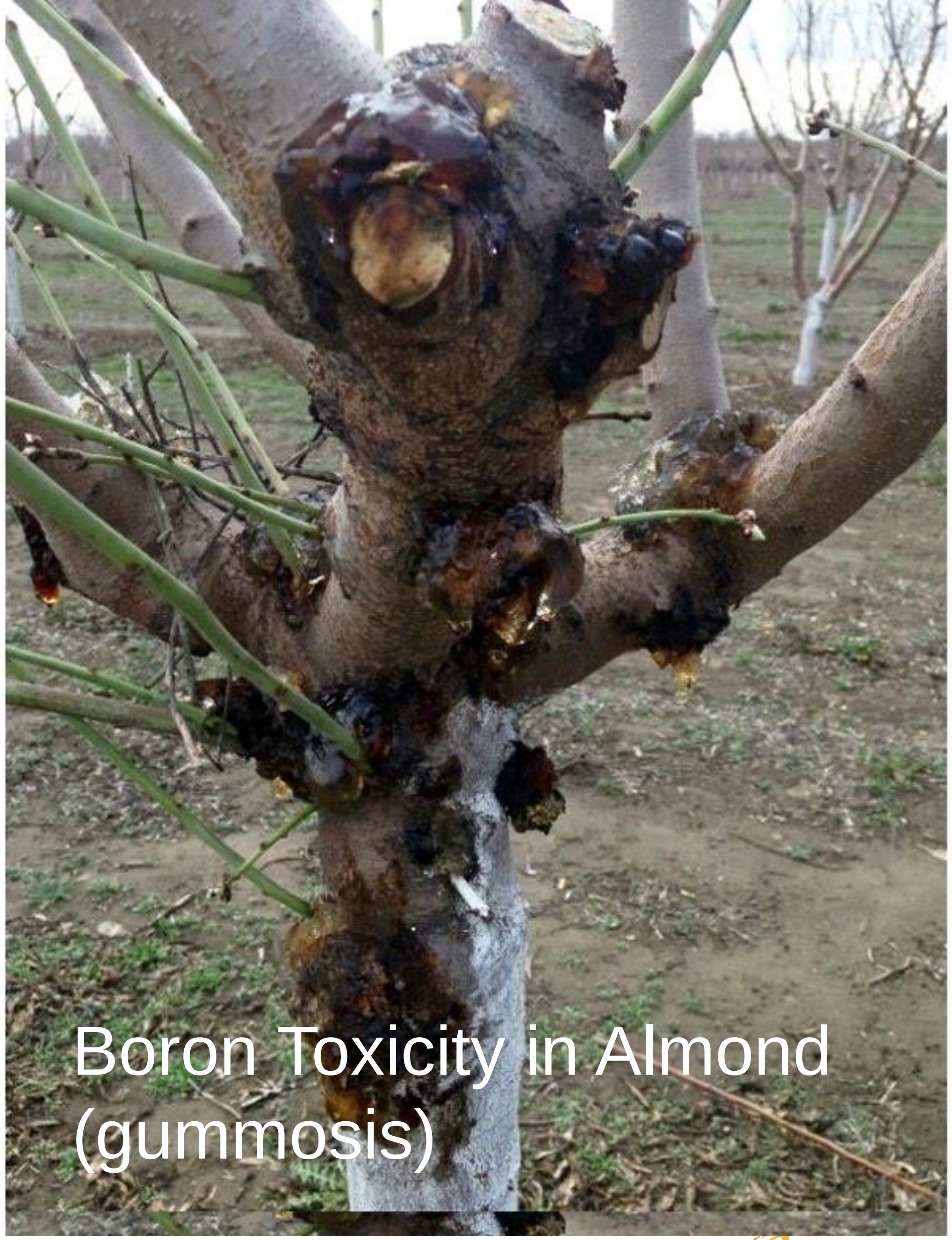
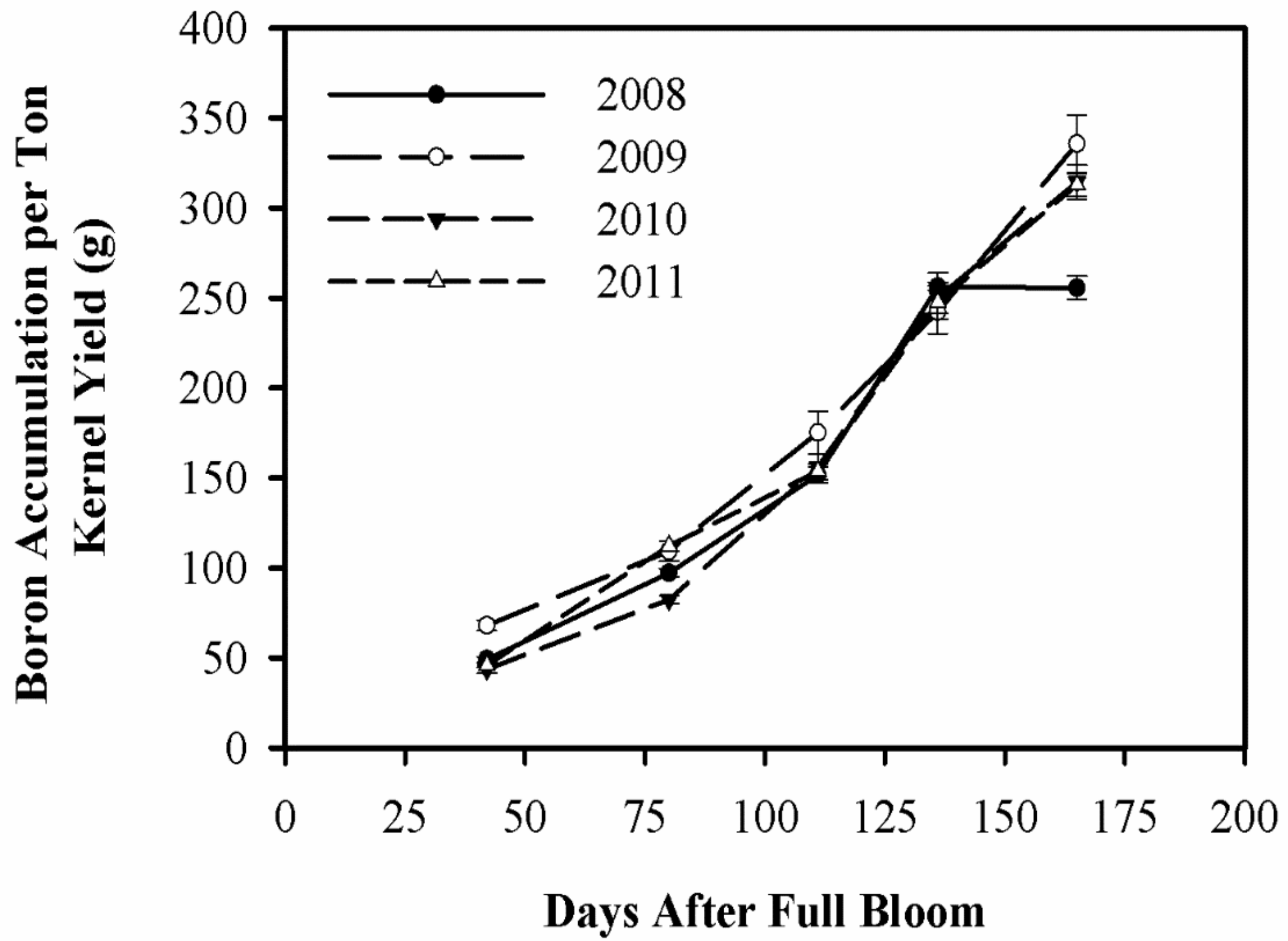


Boron Toxicity in Almond (gummosis)

# Boron Accumulates in Hulls over the Season in Direct Proportion to irrigation water B. (Leaf B is highly unreliable)




Example:

- 48 inches of 1 ppm B water = 8 lbs. of added B.
- Between 0.75 and 2 lbs. B per acre per year ‘exported’ in crop
- Without significant leaching an irrigation B of >0.5 ppm can become a problem
- Boron leaching requires 3x the volume needed to leach Na

# Rootstock can Influence B Uptake

Connell, Doll, Duncan, Pope

Almond hybrid rootstocks generally absorb less B than Peach rootstocks.

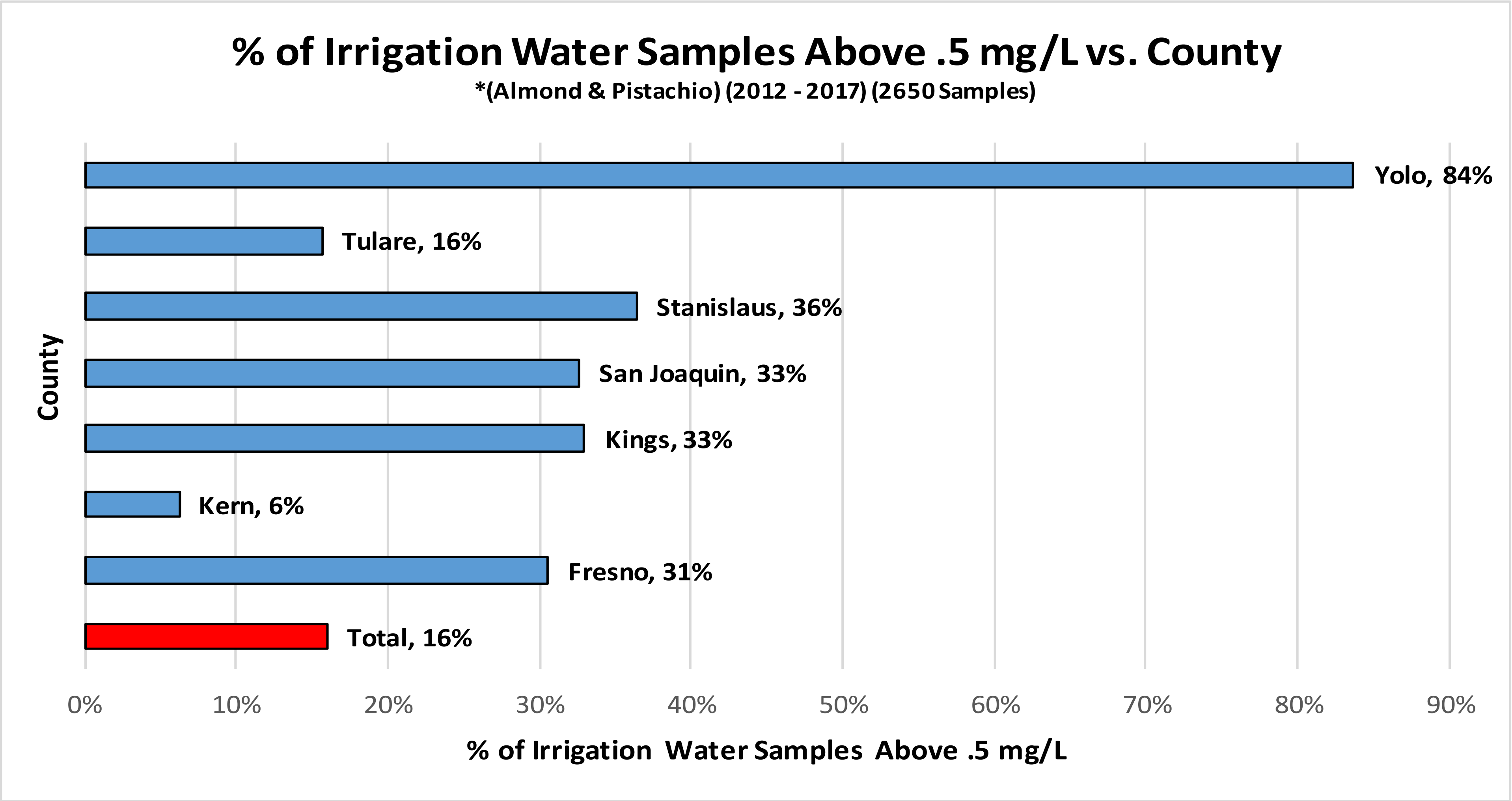
Viking, Brights << Nemaguard, Lovell

**Rootstock Influence on Leaf Sodium & Chloride and Hull Boron**

| | Leaf Chloride (%) | Leaf Sodium (%) | Hull Boron (ppm) |
|---|---|---|---|
| Lovell | 0.73 a | 0.08 ab | 180 a |
| Krymsk 86 | 0.65 b | 0.05 abc | 152 bc |
| Nemaguard | 0.43 c | 0.06 abc | 153 bc |
| Atlas | 0.37 cd | 0.07 abc | 158 ab |
| Empyrean 1 | 0.32 de | 0.09 a | 133 cd |
| Cadaman | 0.32 de | 0.06 abc | 170 ab |
| HBOK 50 | 0.30 def | 0.06 abc | 158 ab |
| PAC9908-01 | 0.28 defg | 0.06 abc | 108 e |
| Viking | 0.25 efgh | 0.07 abc | 109 e |
| Rootpac R | 0.25 efgh | 0.08 ab | 132 cd |
| Hansen | 0.23 efgh | 0.06 abc | 126 de |
| Brights 5 | 0.22 fgh | 0.06 abc | 106 e |
| BB 106 | 0.20 gh | 0.05 c | 102 e |
| Paramount | 0.20 gh | 0.05 bc | 120 de |
| F x A | 0.20 gh | 0.07 abc | 104 e |
| HM2 | 0.18 h | 0.07 abc | 116 de |

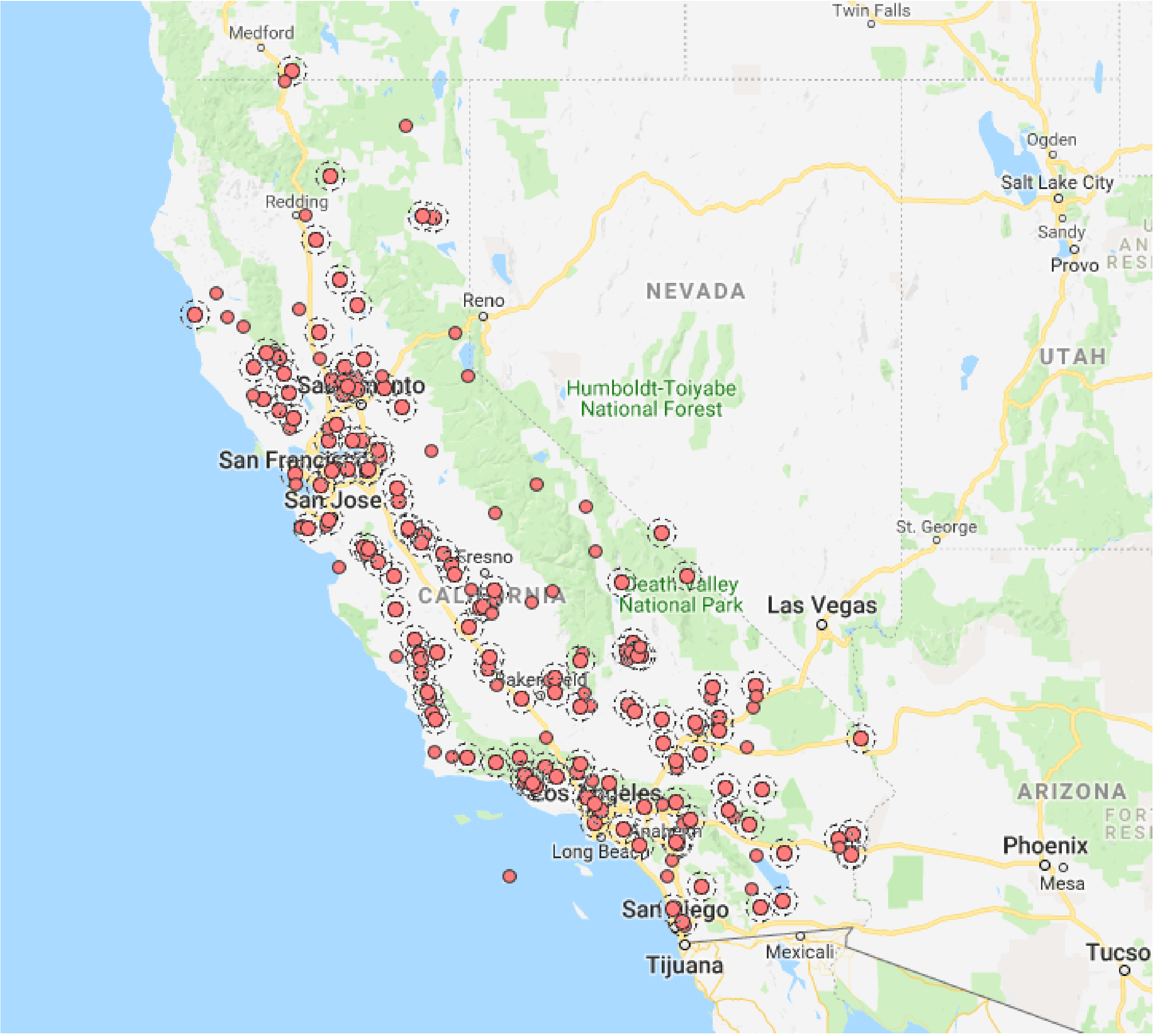
Lovell & Krymsk 86 had the highest leaf chloride levels. All of the peach x almond hybrids, Viking and Rootpac R had significantly lower chloride levels. Lovell, Atlas and HBOK 50 had the highest hull boron levels while all of the peach x almond hybrids and Viking had the lowest.

# Percent of irrigation water samples exceeding 0.5 ppm B




2650 data points provided by Dellavalle and Fruit Growers Labs for growers specifying Almond (2,034) or Pistachio (616) production).

# Groundwater Boron Over 1 mg/L




GeoTracker GAMA Groundwater Information System Online Tool
https://www.waterboards.ca.gov/water_issues/programs/gama/online_tools.html

# Boron Management and Remediation in Almond
## Project #18.WATER12.Brown

- Boron toxicity represents a significant threat to almond productivity in 10-15% of existing acreage and clearly limits expansion.
- Drought years increased high B groundwater usage.

**Questions:**

- How does B concentration, time of exposure and life-stage of the orchard interact to cause B toxicity, productivity loss and orchard decline.
- If B in irrigation water can be reduced, how much reduction is needed, when in growth cycle and for what duration?
- What is the economic return on investments in new water sources (new well development, or surface water purchases) or engineered solutions for B removal from irrigation water.

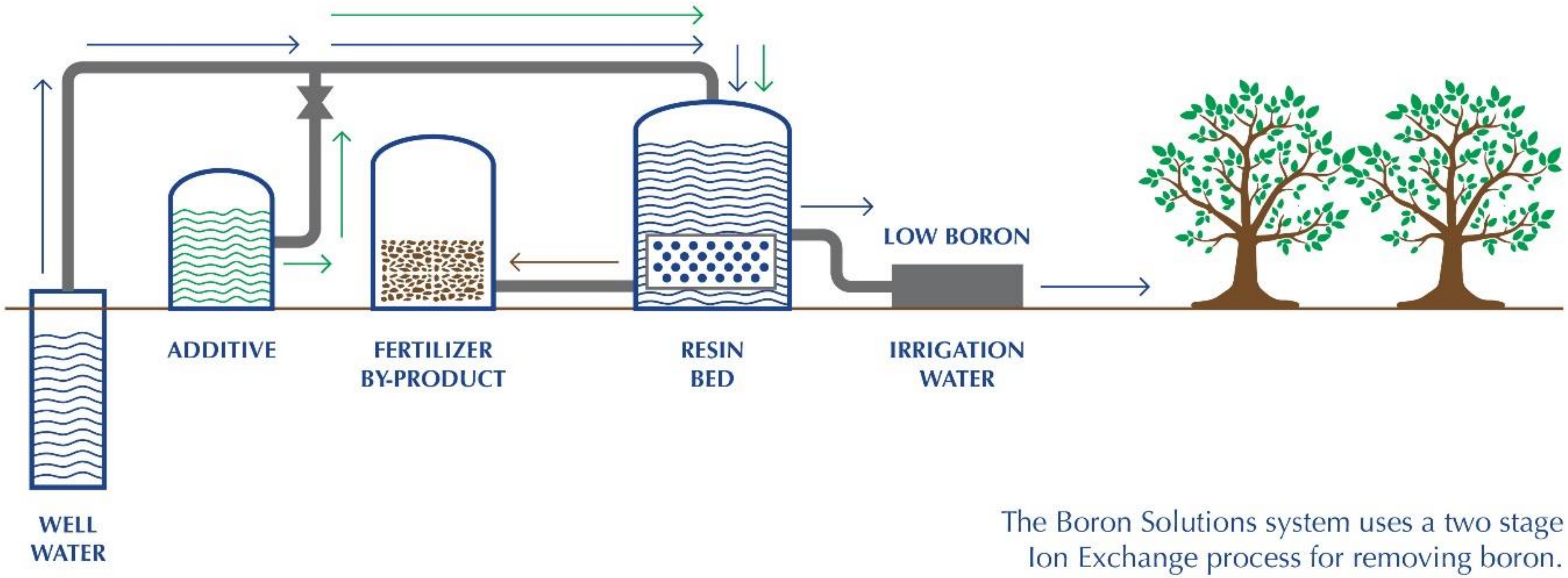
# Experimental Site
# Woodland, CA (2ppm B)


WESTWIND FARMS

Boron Solutions USA

## Method

# BORON REMOVAL PROCESS




The Boron Solutions system uses a two stage Ion Exchange process for removing boron.

**Stage 1**

Well water* is run through the resin bed which removes boron. The resulting low boron water is directed back to the irrigation system.

**Stage 2**

Additives are pumped through the resin bed to push off boron and regenerate the resin. Boron, removed from the water and resin bed, is evaporated and stored as fertilizer (boric acid/potassium borate).

*or other water source for irrigation

BORON SOLUTIONS USA

REMOVAL, RECOVERY, MANAGEMENT SYSTEMS

# Experimental Design

## Rate Trial (3x5 factorial)

- Three boron concentration levels applied all year:
  - 0.5 ppm
  - 1.0 ppm
  - 3.0 ppm
- 5 randomized blocks of 45 trees

## Season Trial (3x5 factorial)

- One boron concentration level (2 ppm) applied only during one of three seasons:
  - March to mid-June
  - Mid-June to August
  - August to December
- 5 randomized blocks of 45 trees

**Boron Trial RCBD Experimental Design**

| Variety: | B | NP | M | NP | C | NP | B | NP | M | NP | C | NP | B | NP | M | NP | C | NP | B | NP | M | NP | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree/Row | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |

| Block | Row 2 | Row 6 | Row 10 | Row 14 | Row 18 | Row 22 |
|---|---|---|---|---|---|---|
| Block 1 | 0.5 ppm | 1 ppm | 3 ppm | 2 ppm March to mid-June | 2 ppm Mid-June to August | 2 ppm August to December |
| Block 2 | 1 ppm | 3 ppm | 0.5 ppm | 2 ppm August to December | 2 ppm March to mid-June | 2 ppm Mid-June to August |
| Block 3 | 3 ppm | 0.5 ppm | 1 ppm | 2 ppm Mid-June to August | 2 ppm August to December | 2 ppm March to mid-June |
| Block 4 | 0.5 ppm | 1 ppm | 3 ppm | 2 ppm August to December | 2 ppm March to mid-June | 2 ppm Mid-June to August |
| Block 5 | 3 ppm | 0.5 ppm | 1 ppm | 2 ppm March to mid-June | 2 ppm Mid-June to August | 2 ppm August to December |
| | Rate trial | | | Season trial | | |

# Deliverables

- Provide information on the quantity and periodicity of B demand and uptake by almond
- Integrate results into a web based model that provides recommendations for B applications according to crop stage for optimal yield
- Develop a web based application for site specific return on investment (ROI) for the boron removal system verses conventional well drilling or purchase of high quality water

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# Orchard Management and Practices for Tradeoffs in Lifecycle Environmental Impacts

Principle Investigator: Prof. Alissa Kendall

Lead Researcher: Dr. Elias Marvinney

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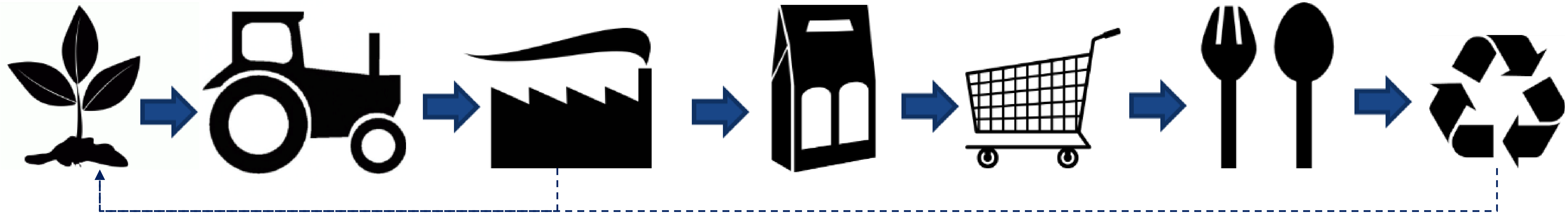
# Background: Life Cycle Assessment of Almonds

- Most retail-level food products result from long and complex production and supply chains with highly variable impacts on **environmental health** and **natural resources.**



- Stakeholders across the supply chain are increasing interested in knowing the environmental effects of food production
- Life cycle assessment (LCA) is the preferred method for understanding the environmental impacts of food products across their complete supply chain and life cycle

# Previous LCA results for Almonds

- Irrigation is dominant for energy, important for GWP
- Nutrient management (fertilizer production and $N_2O$ field emissions) dominate GWP
- Co-product credits from generating almond hulls as feed and biomass for electricity generation are important contributors to net performance
- If co-products are allocated differently, GWP can change significantly

**Summary:**

1. **Irrigation and nutrient management were the two largest contributors to orchard GHG impacts**

2. **The fate of co-products can have significant effects on the net environmental footprint of almond production**

# Current Research

- Based on previous findings, our current research focuses on:
  - Updated and improved modeling of **irrigation**, including groundwater pumping and surface water delivery
  - Modeling of alternative **biomass** co-product fates
  - Modeling of orchard **agronomic responses** to management practices and inputs

- Using datasets produced by other ABC-supported research projects as well as publically available material

**Statewide Agricultural Productivity Model** (Surface vs Groundwater): Richard Howitt, Josue Medellin-Azuara

**Groundwater Recharge Potential** (SAGBI Mapping): Toby O'Geen, Helen Dahlke

**Almond Industry Maps** (Orchard Age): Joel Kimmelshue, LandIQ

**DNDC Model Results** (Soil N2O): Bill Salas, Applied GeoSolutions

**Whole Orchard Recycling** (WOR): Brett Holtz, Amelie Gaudin

**CA Biomass Outlook:** Rick Martin, CTB Consulting LLC

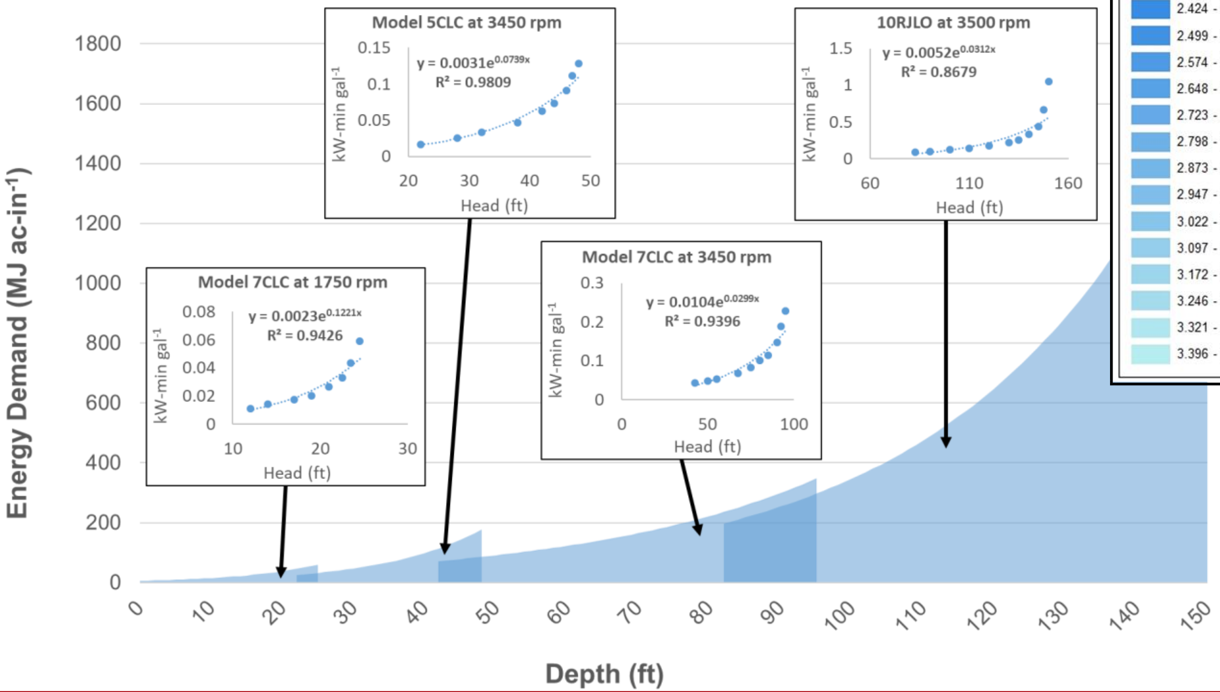
**Water Production Function** (Yield Response to Applied Water): David Goldhamer, Elias Fereres (2017)

**Planting Density, Biomass and Tree Loss** (Clearing Data): Randy Fondse, G&F Agriservices 2012

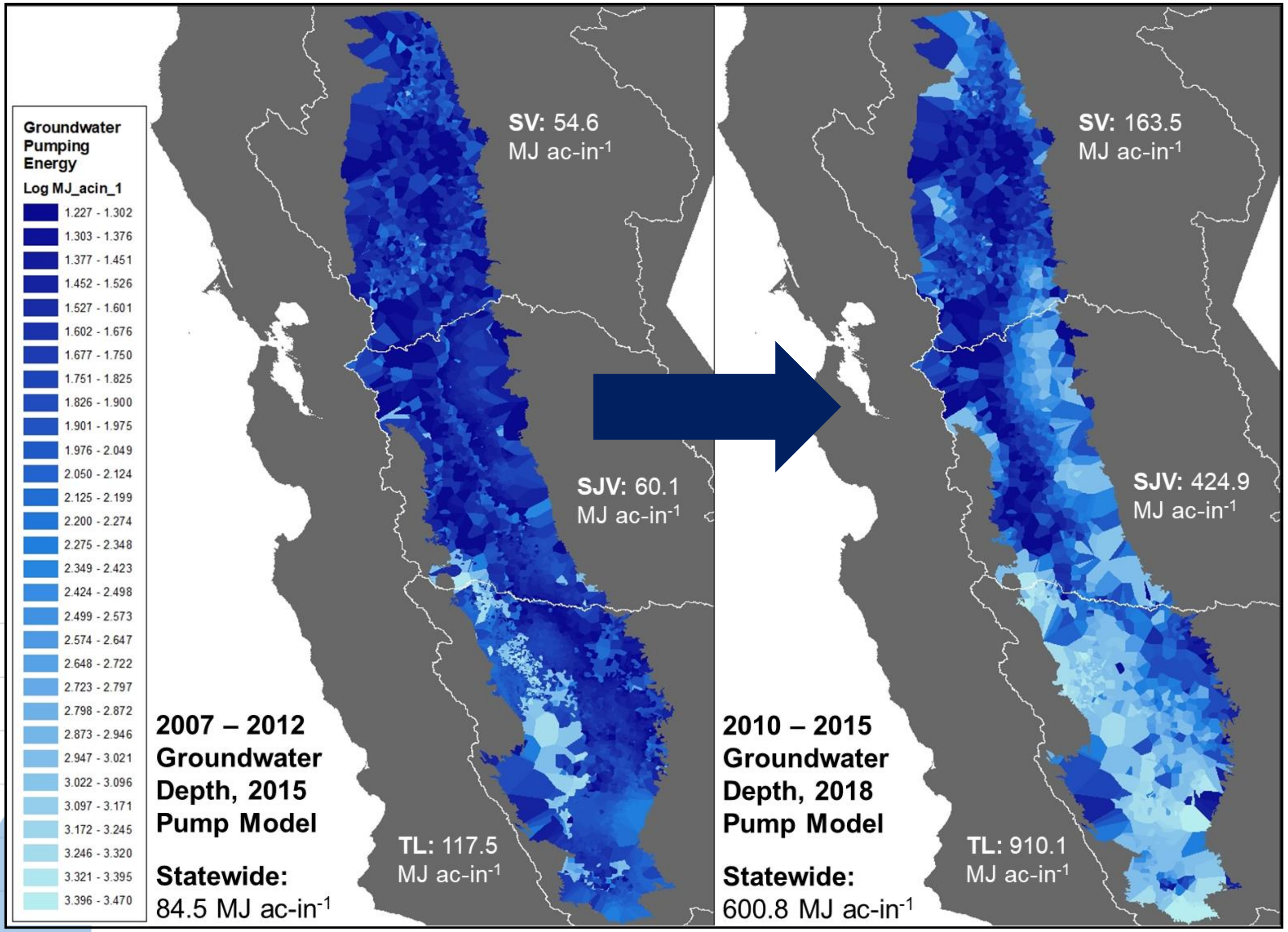
# Irrigation

Updated pump technology model and groundwater depth data (DWR)

- Pump curves account for efficiency changes at varying depth and potential to use multiple pumps
- Groundwater depth and pumping energy demand have increased substantially




Pump energy use curves

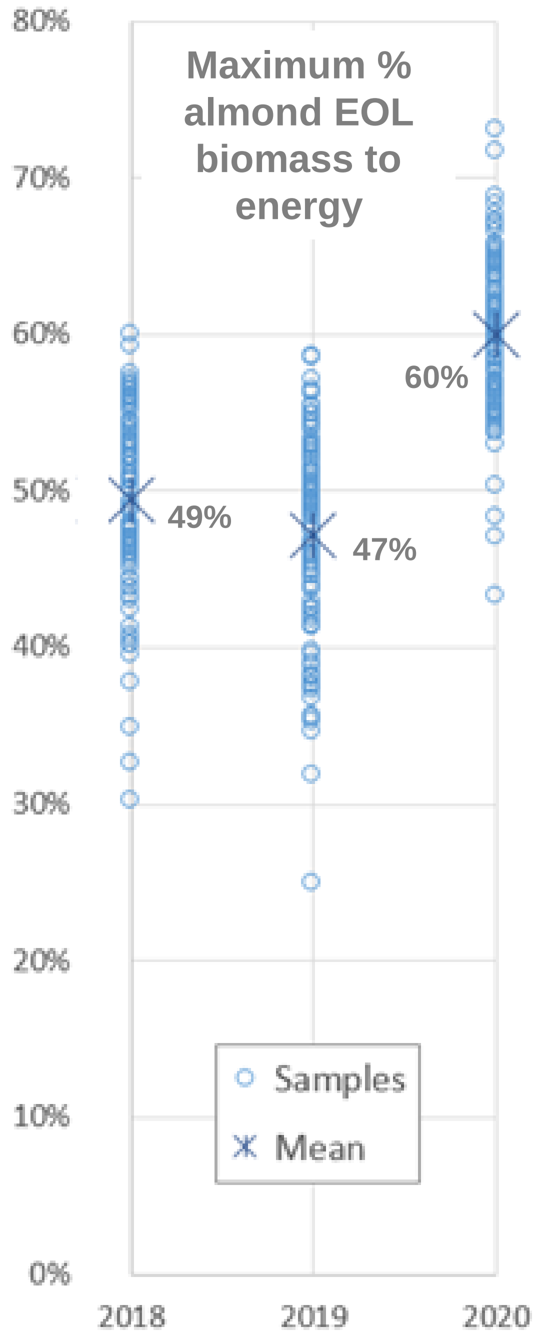


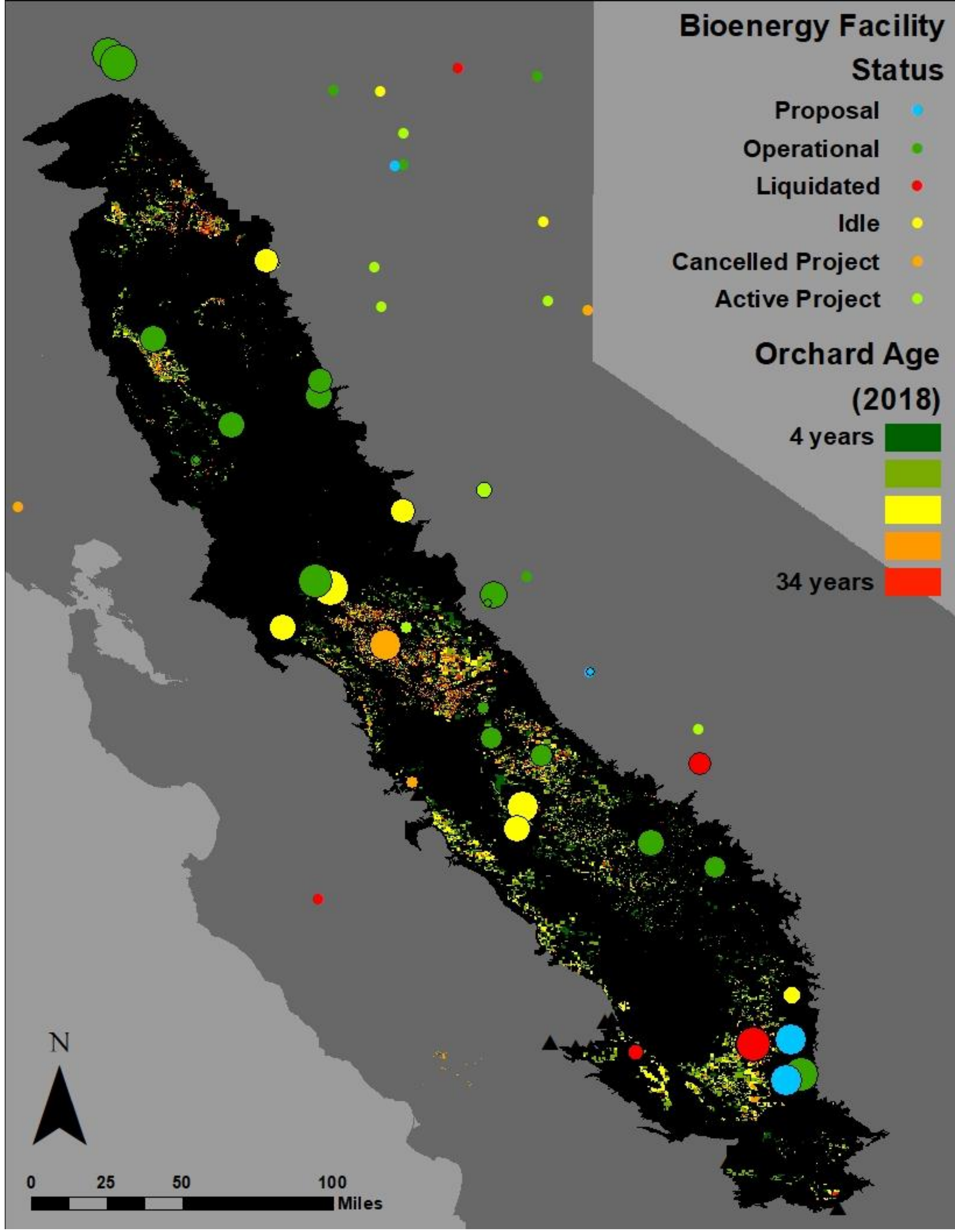

Change in energy demand for groundwater pumping

# Biomass Energy

Updated orchard end-of-life (EOL) biomass calculations

- Accounting for plant operational status and capacity to accept biomass energy feedstock
  - Biomass plants as “gatekeepers” for avoided fossil fuel credit to almond production
- USDA NASS CropScape data layer (CDL) used to estimate “competition” from other perennial crop EOL deliveries
- LandIQ orchard age dataset used to estimate block-specific EOL timing



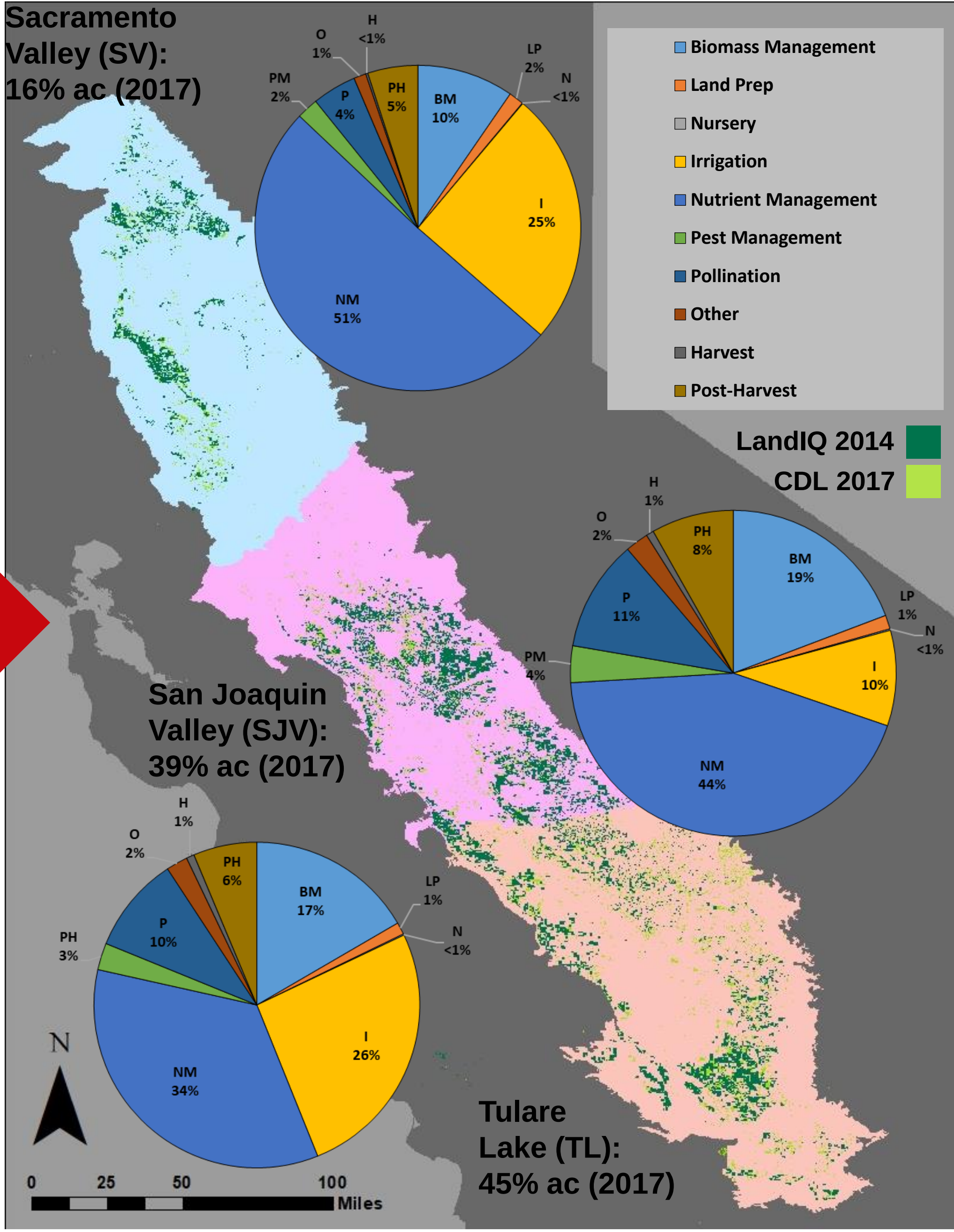



# Results

| TRACI 2.1 Impact Factors (per kg kernel) | SV | SJV | TL |
|---|---|---|---|
| [illegible] | 1.06E-02 | 6.23E-03 | 1.27E-02 |
| [illegible] | 1.07E-02 | 1.57E-02 | 1.71E-02 |
| [illegible] | 2.51E-03 | 2.05E-03 | 2.61E-03 |
| [illegible] | 3.82E-03 | 5.33E-04 | 3.41E-03 |
| [illegible] | 5.68E-09 | 4.29E-09 | 4.23E-09 |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | 4.57E-08 | 3.79E-08 | 1.93E-07 |
| [illegible] | 2.60E+00 | 4.66E+00 | 6.67E+00 |
| [illegible] | 2.19E-01 | 3.60E-02 | 2.11E-01 |
| [illegible] | 3.16E+01 | 6.40E+01 | 9.11E+01 |
| [illegible] | 4.97E+03 | 5.17E+03 | 4.48E+03 |
| [illegible] | 3.00E+00 | 2.60E+00 | 4.06E+00 |
| [illegible] | 2.74E+00 | 2.26E+00 | 3.63E+00 |

## A Note on CTU (Comparative Toxicity Units):

- Estimated number of **cases** occurring per reported unit.
- Here, **human toxicity** numbers work about to about 1 case **globally** of documentable ill effects for every **200 million kg** of almond kernel produced, mostly from **plastics production** for irrigation system components.
- This works out to about 5 cases of illness in the world per year attributable to the environmental impacts of California almond production



# Conclusion

- **Improved model calculations** and **scope** (tracking more flows), **updated datasets**, and **changing conditions** in Central Valley (CV), especially bioenergy infrastructure and groundwater, have resulted in somewhat higher GHG ($GWP_{100}$) and energy use impacts than found previously
  - **1.14** kg $CO_2$eq per kg kernel (2015) → **3.34** kg $CO_2$eq per kg kernel (2018)
  - **33** MJ per kg kernel (2015) → **79.8** MJ per kg kernel (2018)
  - Biomass co-product use generated credits amounting to **38%** and **15%** of total $GWP_{100}$ and energy use respectively in 2015 → reduced to **12%** and **11%** respectively in 2018
- **Irrigation** and **nutrient management** remain the two greatest contributors to most impact categories, but **biomass management** has increased in importance due to increased in-field biomass burning
- Important **regional differences** across impact and operational categories
  - Difference in growing conditions and input demand in SV, SJV, and TL translate to measurable differences in impacts
  - Higher yields in southern CV (TL) offset higher input demands to some extent, resulting in tradeoffs between different impact categories

**Thank you for your attention!**

**Contact: Elias Marvinney (emarvinney@ucdavis.edu)**

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# Non-fumigant Approaches and Diagnostics for Orchard Replacement and Soilborne Disease Management

**Greg Browne and Amisha Poret-Peterson**

**Cooperating :**
(alphabetical order): Brar, G, Culumber, M., Gaudin, A., Holtz, B., Khan, A., Lampinen, B., McCoy, D., Metcalf, S., Ott, N., Sanchez, K., Stanghellini, M., Westphal, A., Yaghmour, M.

**Acknowledgements:**

- Almond Board of California
- California Department of Pesticide Regulation
- TriCal, Inc.
- Wonderful Orchards
- Kearney Research and Education Center
- Cornaggia Farms
- Burchell Nursery, Inc.
- Sierra Gold Nursery

"Tools for starting over, well"

# Objective 1a.

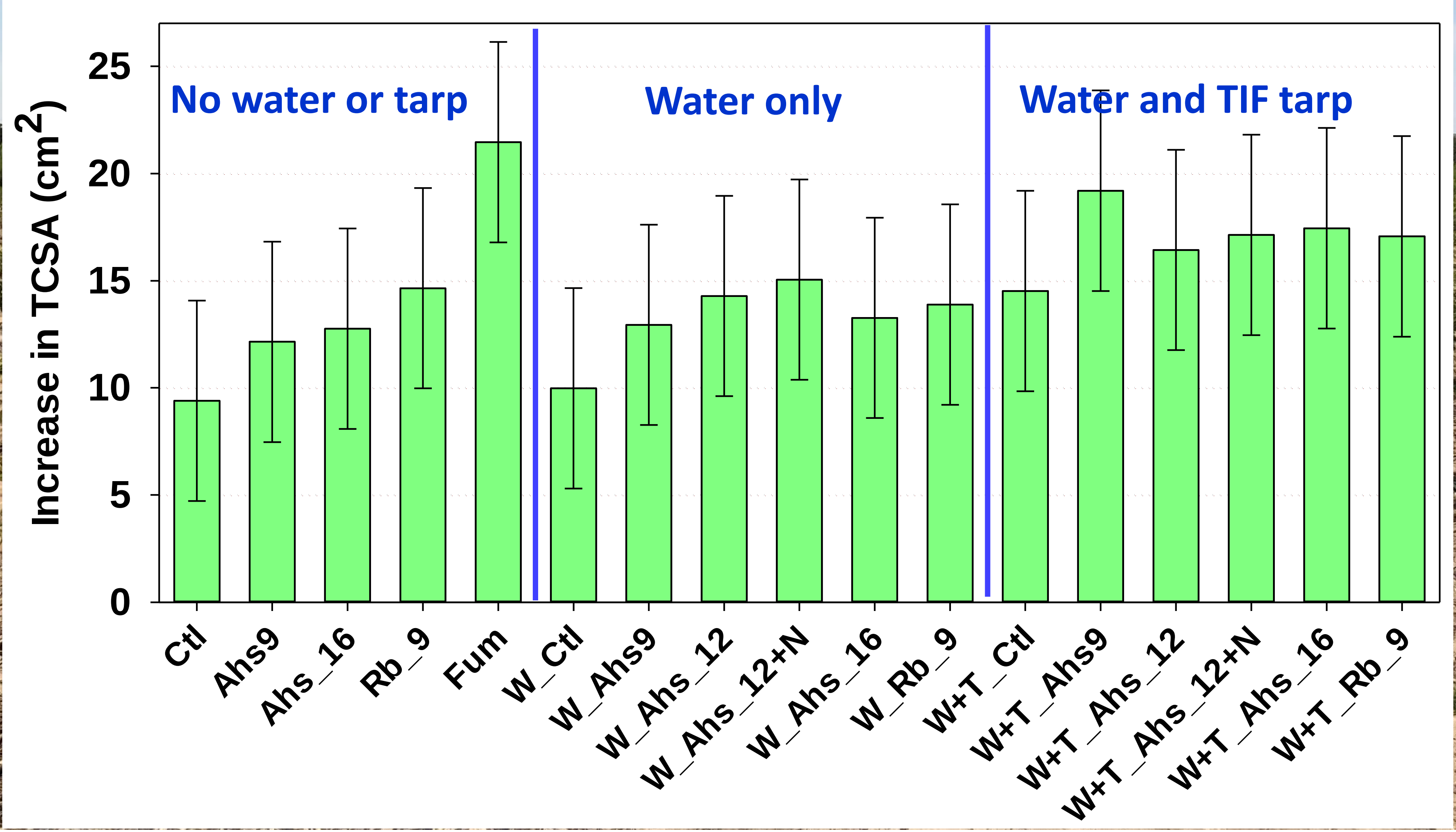
**Determine impacts of ASD components on PRD control, via testing of:**

- Alternative ASD substrates
  1. Ground almond hull + shell ($100/t)
  2. Tomato pomace ($185/t)
  3. Rice bran ($290/t)
- The importance of tarp and high soil moisture profile during ASD
- Impacts of WOR residues on ASD

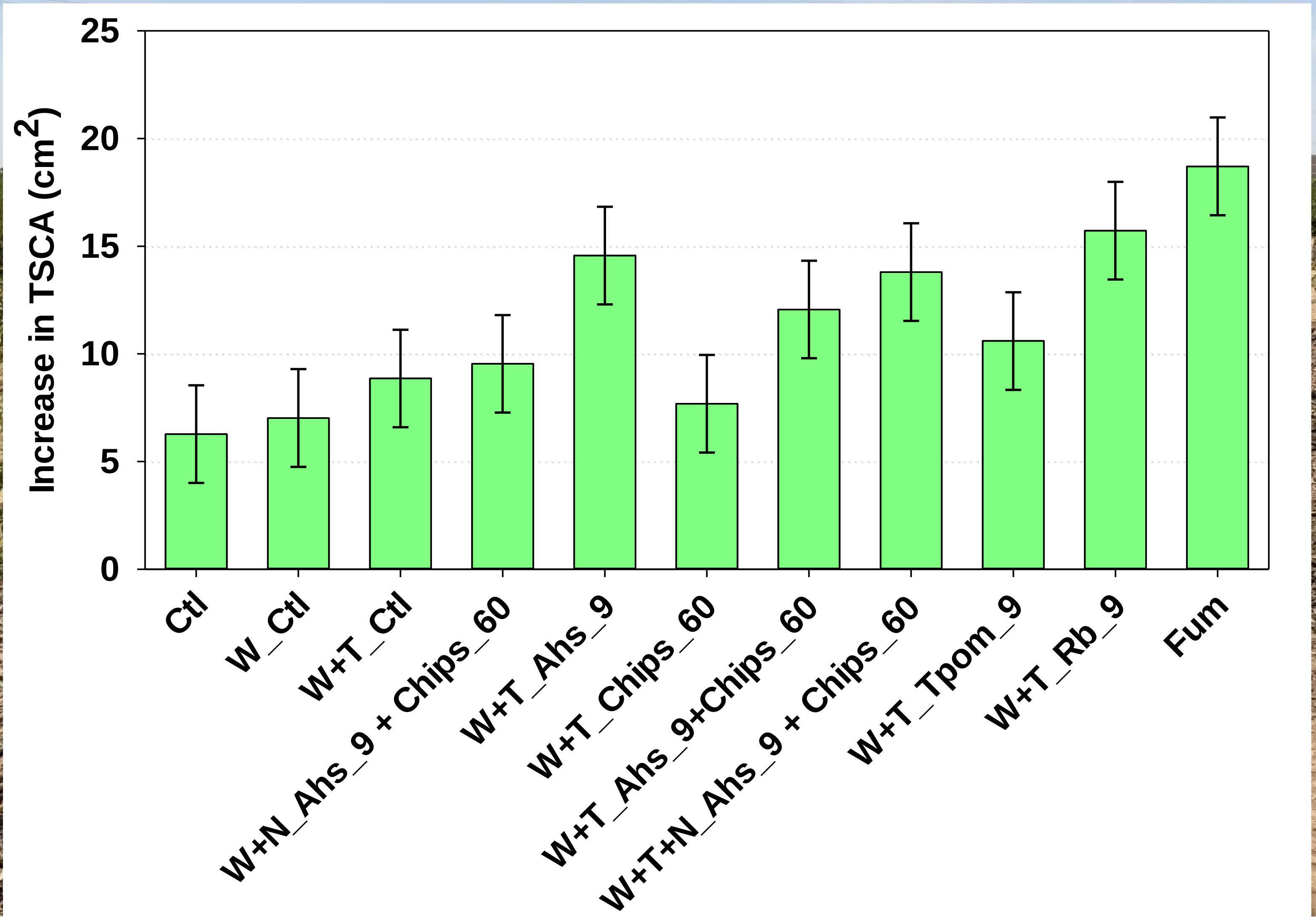




# CSUF Almond Replant Experiment 1: ASD components, no WOR, results as of November 2018



# CSUF Almond Replant Experiment 2: ASD components, incl. WOR, results as of November 2018



# Objective 1b.

**Determine effects of ASD with ground almond hull-shell mixture, rice bran, and whole orchard recycling (WOR) chips on** **incidence and severity of Phytophthora root and crown rot.**

# Phytophthora suppression experiment:

## Soil sampled from treatments in CSUF Trial

### 7 field soil treatments, 4 blocks

- Control
- Fumigation
- Chips
- Almond hull + shell ASD
- Almond hull + shell ASD + Chips
- Ground Almond hull + shell ASD + Chips + N
- Rice Bran ASD

### 8 greenhouse treatment combinations

**Steamed**

- Phytophthora Inoculated: Flood / No Flood
- Control Inoculated: Flood / No Flood

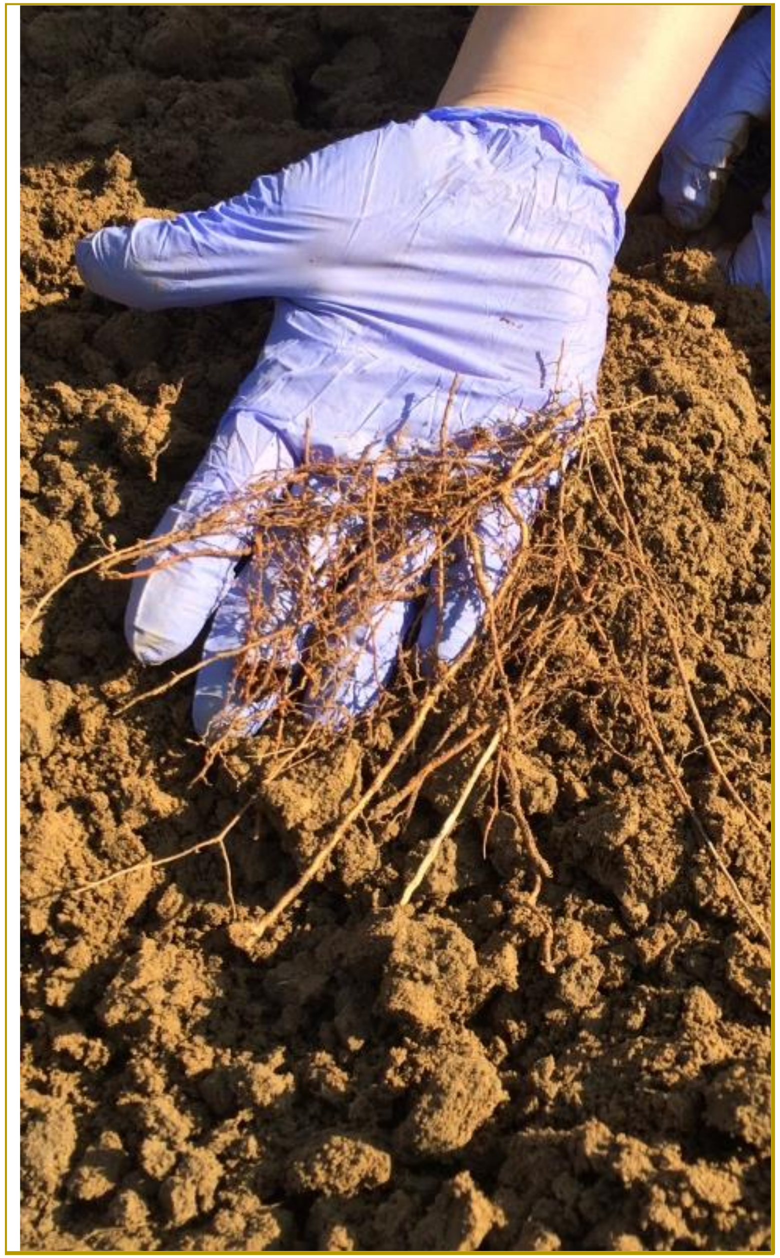
**Not Steamed**

- Phytophthora Inoculated: Flood / No Flood
- Control Inoculated: Flood / No Flood

# Objective 2.

**Relate effects of the organic byproduct and ASD treatments on replanted orchard growth to underlying impacts of the materials and treatments on <u>parameters</u> in soil:**

- **Microbial**
- **Chemical**
- **Physical**



# Objective 3.

**Improve decision support methods for managing almond replant soils.**

For example, to fumigate, or not?

# Approach:

- **Conduct soil and root sampling with ≥25 growers throughout Central Valley.**
- **Site criteria:**
  - **The old *Prunus* orchard present or just removed.**
  - **New almond trees ordered for following year.**
  - **Grower will fumigate but also has area that can not (or will not) be fumigated (e.g., buffer due to well or dwelling)**
  - **Manager has willingness to track cultural inputs.**
- **Characterize soil parameters**
  - **Physical (e.g. texture, bulk density)**
  - **Chemical (pH, EC, key nutrients)**
  - **Microbial**
  - **Mearurement of tree growth**
- **Relate tree growth and health to preplant soil treatment, soil parameters, rootstock, management.**

Gregory.Browne@ars.usda.gov

gtbrowne@ucdavis.edu

# Thank You!

## Hope to see you at our poster…

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Catherine Mae Culumber
UCCE Fresno County

# Young Orchard Responses to Orchard Recycling

Suduan Gao USDA-ARS Parlier, Brent Holtz UCCE San Joaquin County, Greg Browne USDA-ARS Davis, Amelie Gaudin UCD, Amisha Poret-Peterson USDA-ARS Davis, Elias Marvinney UCD

# Objectives:

Determine how WOR systems differ from conventional blocks in:

1) Tree growth and fertility needs

2) Spatial differences in soil C and N retention or losses (e.g. GHG emissions and leaching) ?

# Trial Details: Orchard Recycling and Establishment

- Location: Parlier Ca.
- Stone-fruit orchard removal WOR process from August to October 2017
- Chloropicrin fumigation October, 2017
- Nonpareil and Monterey on Viking
- (18’ x 22’ ft spacing) planted January, 2018
- 4 wood chip treatment plots and 4 control plots

# Current recommendations for newly planted almond trees

| Rate/Tree | 18’x22’ (110) | 16’x22’ (123) | 14’x22’ (141) |
|---|---|---|---|
| 3 oz | 20 lbs N | 23 lbs N | 27 lbs N |
| 4 oz | **28 lbs N** | 31 lbs N | 35 lbs N |

Wood chips have a ~160:1 C:N woodchip amendment ratio

How much supplemental N is necessary in 1st leaf?

# Fertigation

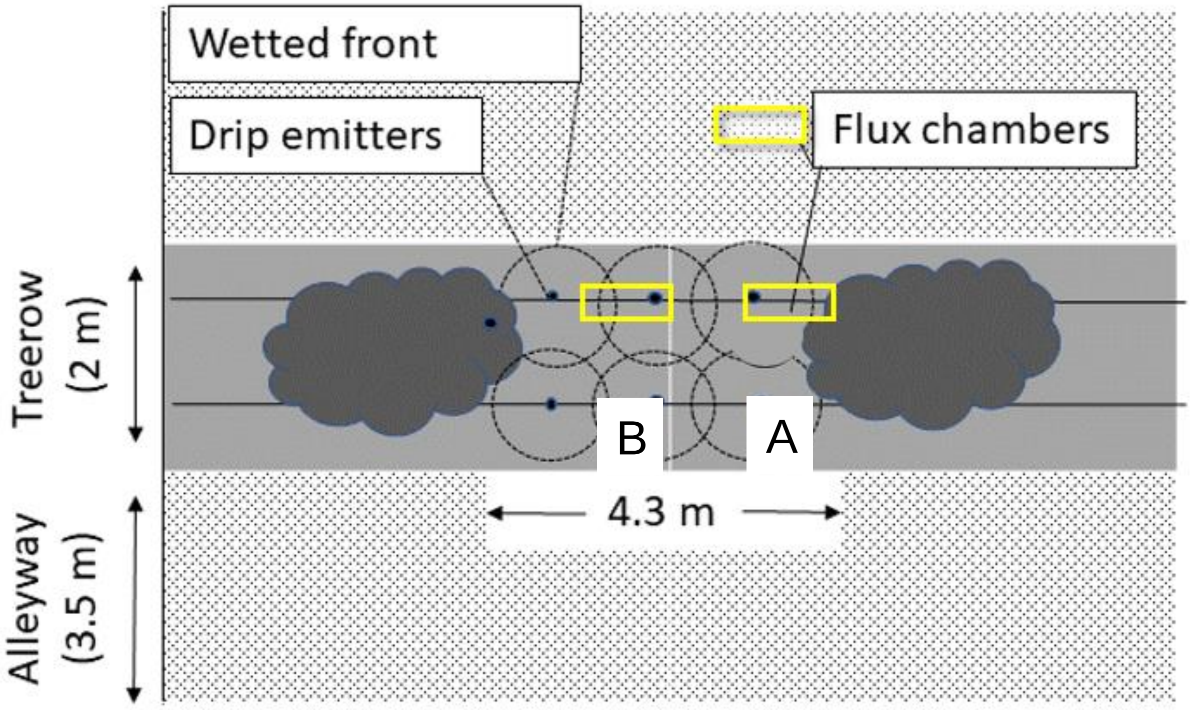
| | lbs N / acre fertilizer | estimated lbs N / acre from irrigation* | oz / tree |
|---|---|---|---|
| **April 19** | 12.48 | 1.28 | 1.90 |
| **May 15** | 5.79 | 1.65 | 1.03 |
| **June 1** | 12.48 | 1.16 | 1.89 |
| **June 25** | 12.48 | 2.57 | 2.08 |
| **July 22** | 12.48 | 4.78 | 2.39 |
| **August 20** | 12.48 | 2.45 | 2.07 |
| **August 21-November 21** | - | 6.73 | 0.93 |
| **Total lbs N** | **88.83** | | **12.32** |

*6.9 ppm N-$NO_3^-$ in 10/2017 water analysis, 12.6 cumulative inches water applied

# 1st leaf tree nutrition

| 2018 tree leaf nitrogen | Cumulative N applied by May tissue sampling (oz/tree) | May % N | Cumulative N applied by July tissue sampling (oz/tree) | July %N |
|---|---|---|---|---|
| conventional | 2.8 | 4.1 | 8.9 | 3.1 |
| woodchips | 2.8 | 2.4 | 8.9 | 3.1 |

# Measuring soil C and N emissions and other soil characteristics*

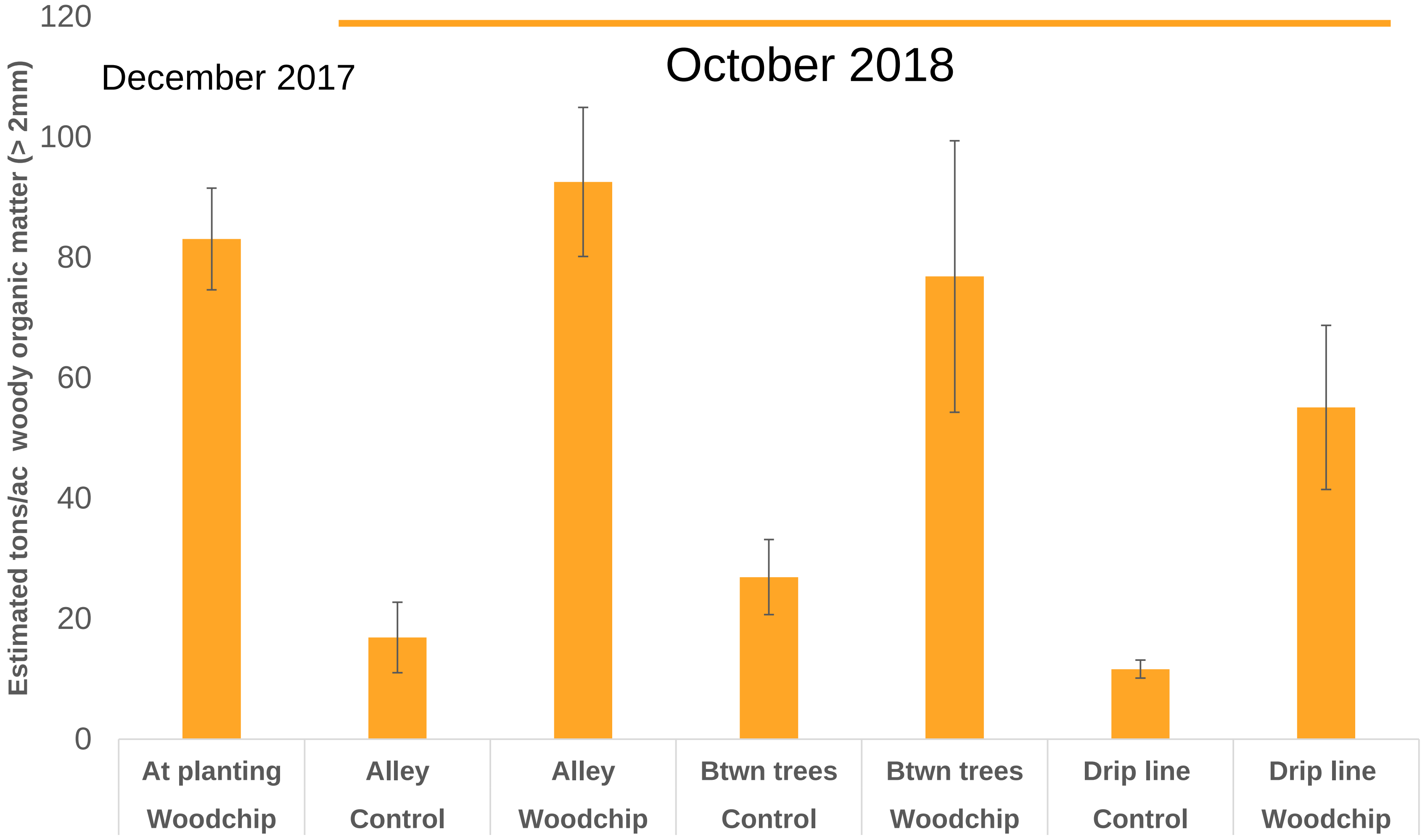



Alleyway chamber readings 3-4 times per season
Year-round chambers: tree-row middle and tree drip-zone

4 wood chip treatment plots and 4 control plots with 2 chambers per plot = 16 chamber sites
Monitoring initiated in April 2018 prior to first fertigation

* See 2018 results at poster 108 17.AIR10.Culumber

# Organic debris in conventional and WOR soil



# Conclusions:

- 1st leaf trees initially showed signs of deficiency, but increased fertigation applications improved nutrition later in growing season
  - – Tree growth data and N rate trial will provide optimal N application rate with WOR
- Wood chip soils have higher $CO_2$ and $N_2O$ emissions compared to conventional in the fertigated drip line, but little difference in alleyway where no irrigation or fertilizers*
  - – Nitrate leaching in the drip line under investigation
- Alleyway woodchips showed little change in 11 months since incorporation suggesting slow degradation and potential for long term C storage

*See 1st year GHG monitoring results at poster 108 17.AIR10.Culumber

# Acknowledgments:

**Collaborators:** Suduan Gao, Brent Holtz, Amisha Poret-Peterson, Greg Browne, Amelie Gaudin, Emad Jahanzad, Elias Marvinney

**Data collection:** Tom Pflaum, Robert Shenk, Julio Perez, Diana Camarena, Aileen Hendratna, Jamie Blackburn, Luis Toledo, Dan Rivers, Cheryl Gartner, Shirley Alvarez, Lorena Ramos, Mario Salinas, Cameron Zuber

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# Whole Orchard Recycling

***Holtz, B.***[1], Browne, G.[2], Doll, D.[3], Westphal, A. [8], Gaudin, A.[4], Culumber, M.[5], Yaghmour, M.[6], Marvinney, E.[4], Gordon, P.[7], Niederholzer, F.[9], and Jahanzad, E.[4]

*University of California Cooperative Extension, San Joaquin[1], Merced[3], Fresno[5], Kern[6], Madera[7], and Colusa-Sutter-Yuba Counties[9], USA*

*[2]USDA-ARS, University of California, Davis, USA*

*[4]Plant Science, University of California, Davis, USA*

*[8] Nematology, University of California, Riverside, USA*

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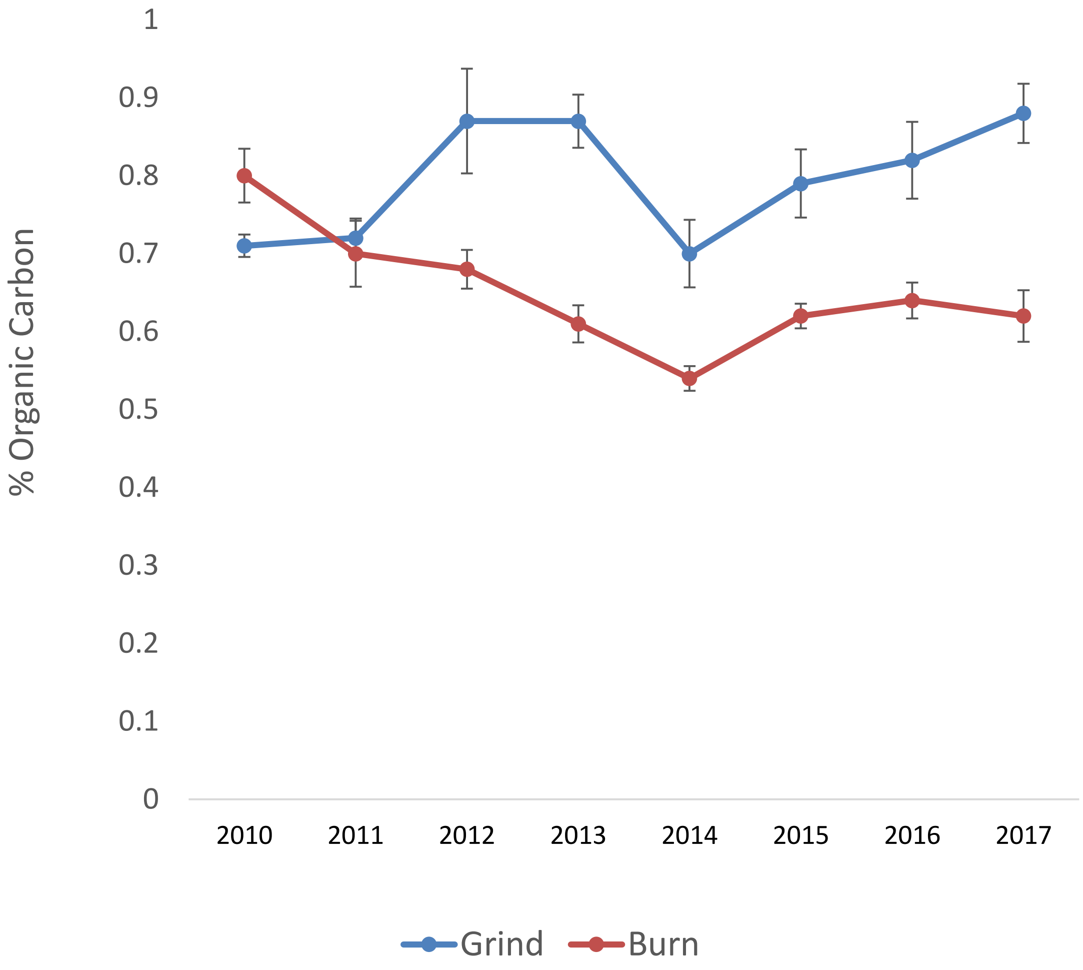
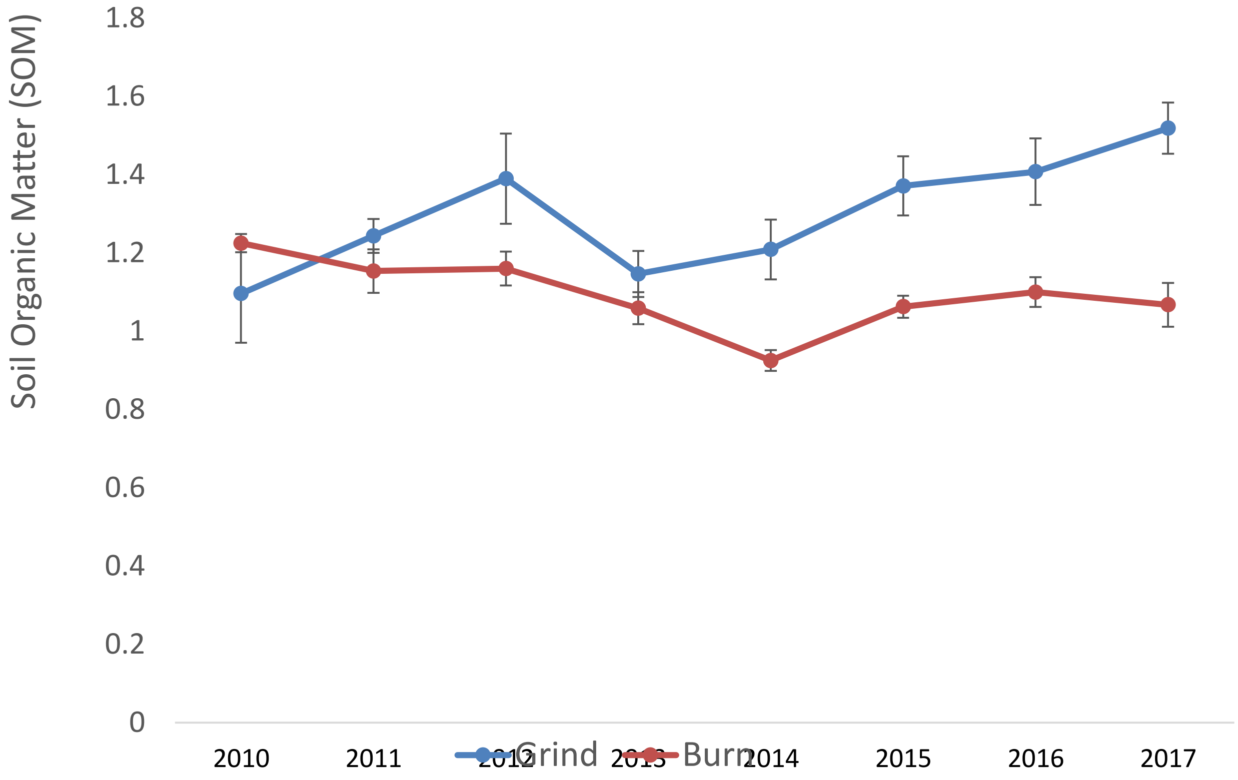
Can whole orchards be incorporated into the soil when they are removed and not burned in the field or in a co-generation plant?

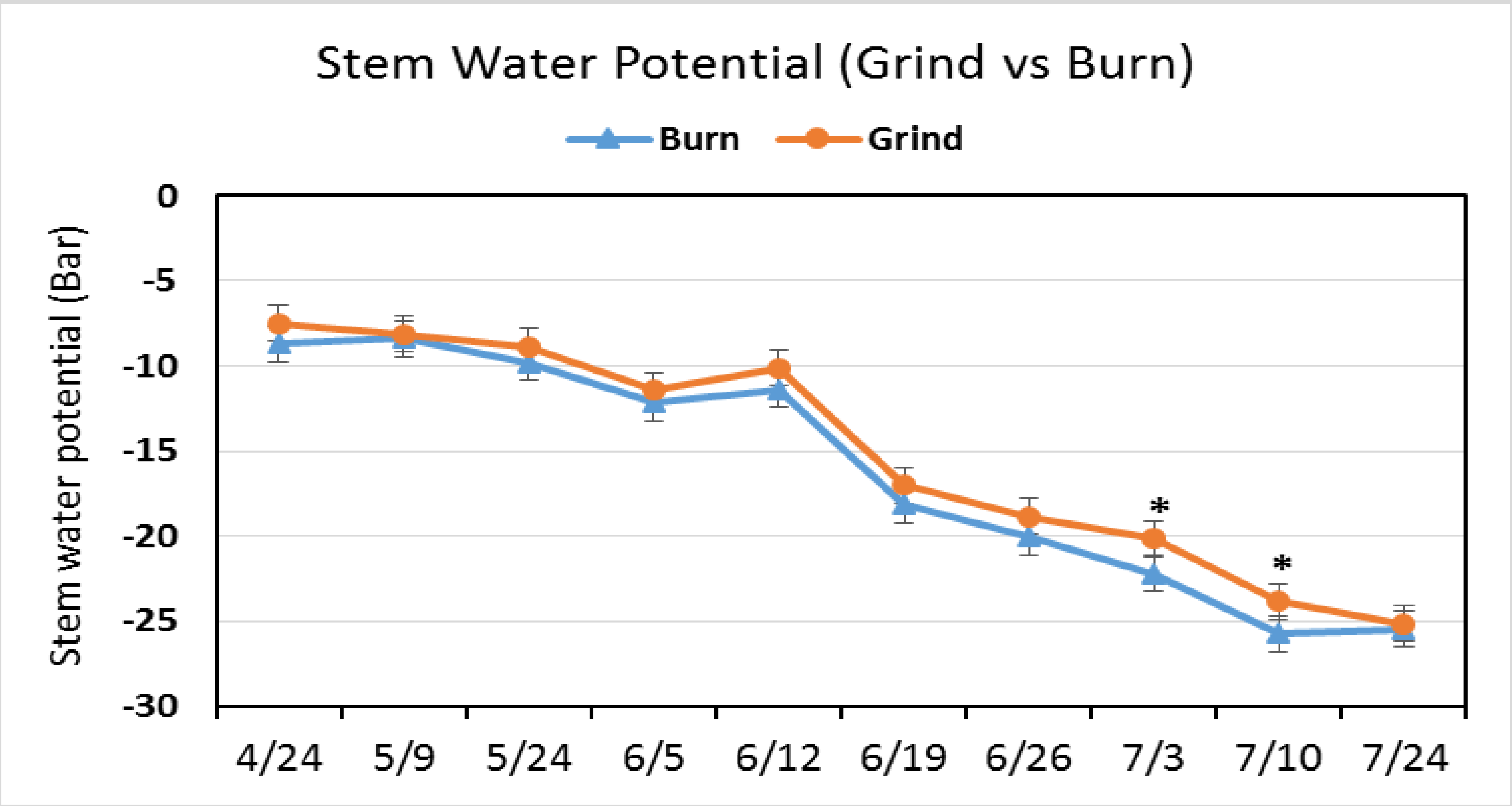
Can we return this organic matter to our orchard soils without negatively effecting the next orchard that will be planted?

# The Iron Wolf

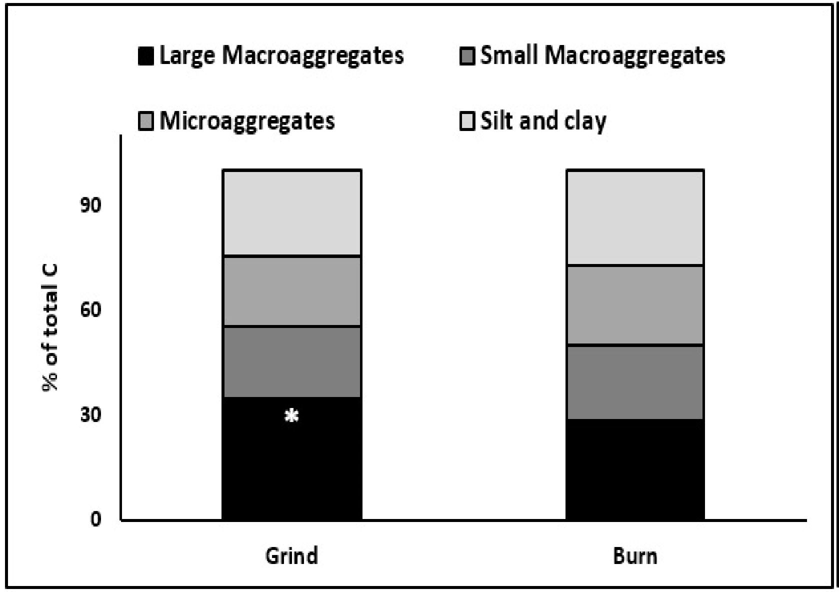


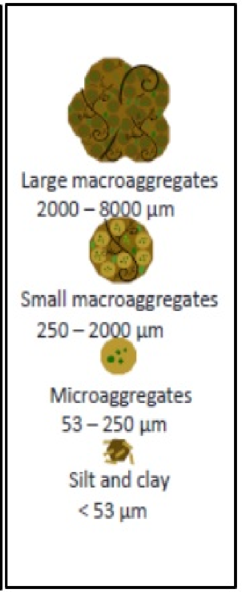




University *of* California
Agriculture and Natural Resources

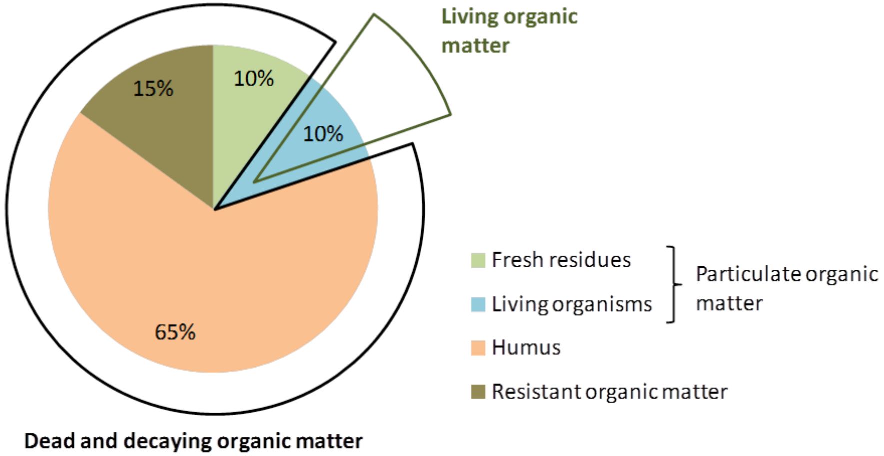

Stem Water Potential (Grind vs Burn)
Burn
Grind
Stem water potential (Bar)
0
-5
-10
-15
-20
-25
-30
4/24
5/9
5/24
6/5
6/12
6/19
6/26
7/3
7/10
7/24
*
*

# Soil TC storage in soil aggregates




- 14% increase in large macroaggreagate TC storage in the Grind treatment compared to the Burn

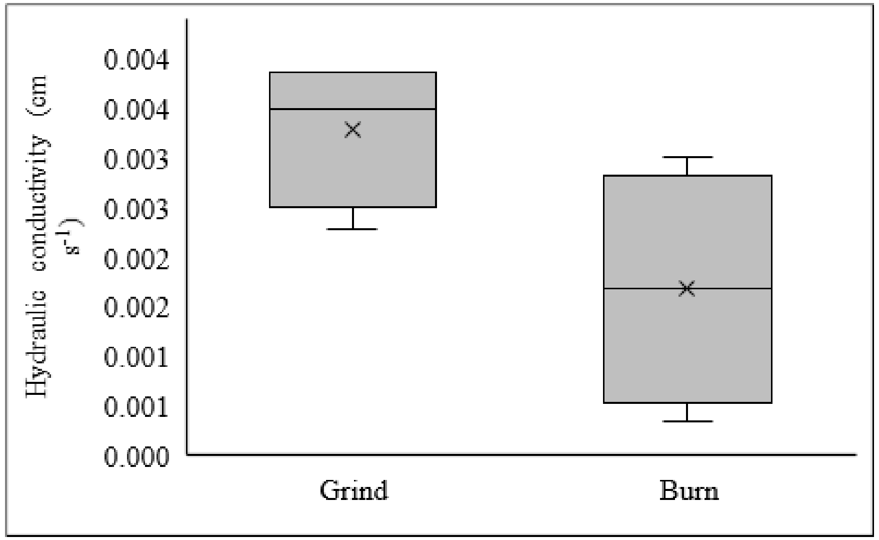


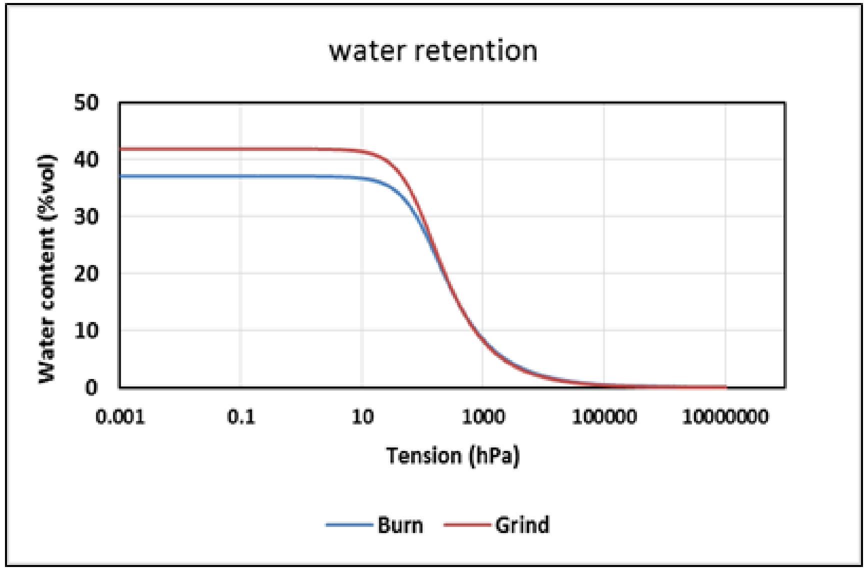

Soil organisms are more abundant and more active

- Soil microbial biomass carbon (MBC) increased (+ 47%)
- Soil microbial biomass nitrogen (MBN) was slightly higher
- Overall, higher N and C cycling enzyme activity rates in the Grind treatment compared to the Burn

# Impacts on soil hydraulic properties?

- Improved soil aggregation (significant higher Mean Weight Diameter in the Grind treatment (610 vs 534)
- Compaction was reduced in the Grind plots (- 27%)
- Higher infiltration rate in the Grind treatment (0.003 vs 0.001 cm/s)
- Increased water retention (+ 13% at FC) in the Grind plots



# Whole Orchard Recycling has:

- Increased soil organic matter
- Increased soil organic carbon
- Increased soil nutrients
- Increase soil microbial diversity
- Increased orchard productivity

A few growers have used manure spreaders to spread wood chips back on the soil surface

**Closure of more biomass plants reduces options**

By Christine Souza

The closure or threatened closure of more California biomass power plants leaves farmers with fewer options for disposing of tree prunings or of trees uprooted during planned orchard removals.

"The last few projects that we've done,

AgAlert®

THE WEEKLY NEWSPAPER FOR CALIFORNIA AGRICULTURE


# Will Whole Orchard Recycling:

- Increase water holding capacity?
- Bind pesticides and fertilizers?
- Increase Nitrogen efficiency?
- Increase/decrease Green House Gas production?
- Provide carbon credits to farmers?

# Whole Orchard Recycling

1 UC Kearney Research and Extension Center (KREC) 2008, Fresno County
2 UC Kearney (KREC) Micro-plot study 2016, Fresno County
3 Agriland Farming, Chowchilla, Madera County 2016
4 Wonderful Orchards, Ranch 3371, Kern County 2016
5 Wonderful Orchards, Ranch 3381, Kern County 2016
6 Tallerico Orchards, Manteca, San Joaquin County 2016
7 Warkentin Ranches, Parlier, Fresno County 2017
8 Fresno State, CSUF, Fresno County 2017
9 Nickels Estate, Arbuckle, Colusa County 2017
10 UC Kearney 2018 Experiment



G & F Ag Services orchard removal typically involves 5 machines and costs ~$600 acre

The Morbark horizontal chipper can chip up 15-20 acres per day.

Screens can be used to limit chip size to 2 inches or less.

The Iron Wolf is being compared to this Morbark Chipper at Agriland Farming in Chowchilla.

Kuhn & Knight Spreaders were modified for spreading wood chips.

Keeping the chips and having them spread back onto your orchard floor will cost and additional $400 acre.

Wood chips are spread uniformly over entire field surface

When 64 tons of wood chips are returned to the soil per acre:

N=   0.31 %, 396 lbs/ac
K=   0.20 %, 256 lbs/ac
Ca= 0.60 %, 768 lbs/ac
C=   50 %, 64,000 lbs/ac

The nutrients will be released gradually and naturally


FLAGLER'S
New Holland
T9050

After spreading the woodchips growers can proceed with typical land preparation practices for the next orchard: ripping, disking, fumigation….

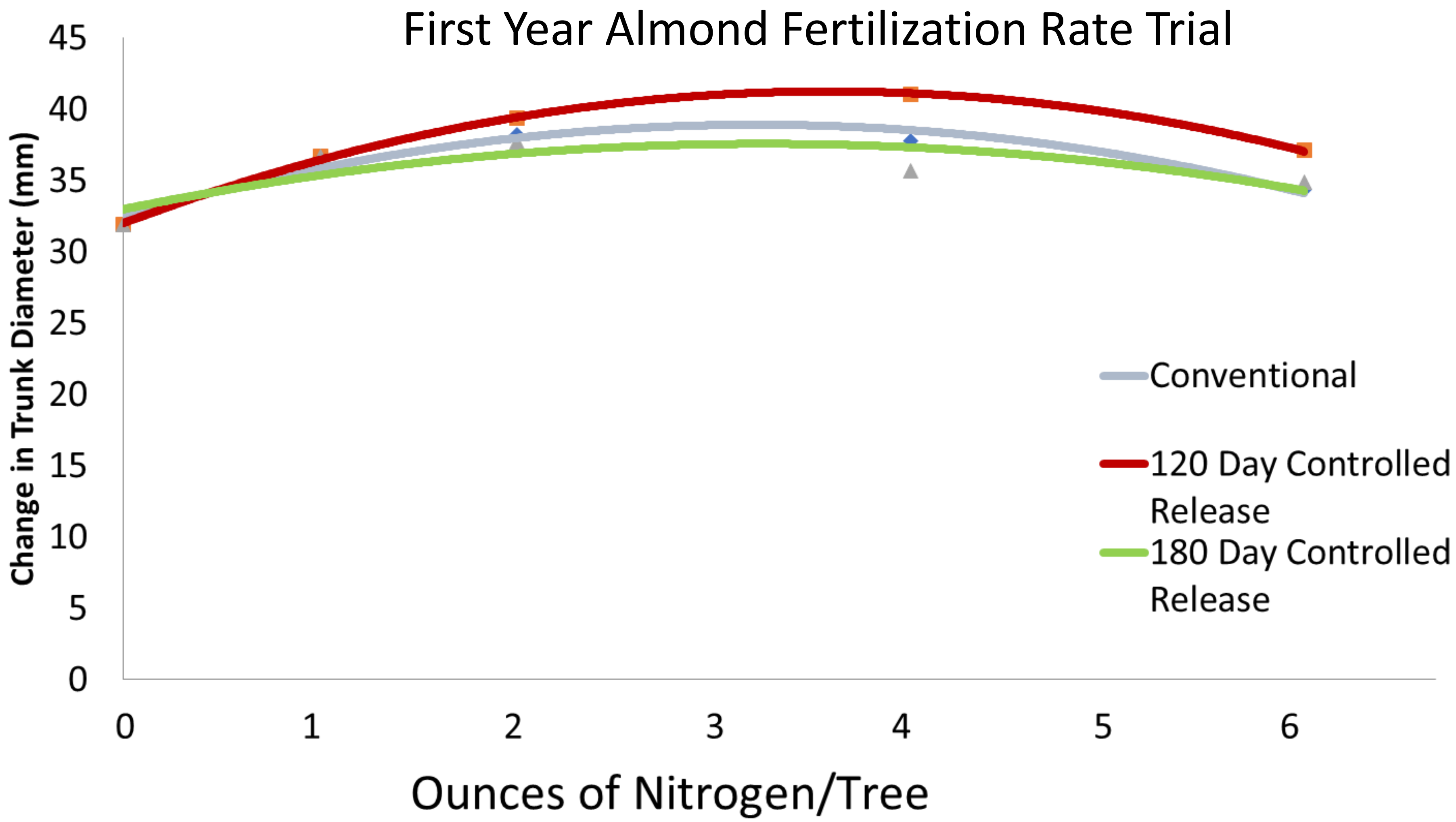
Tallerico Orchard in Manteca:

64 tons per acre

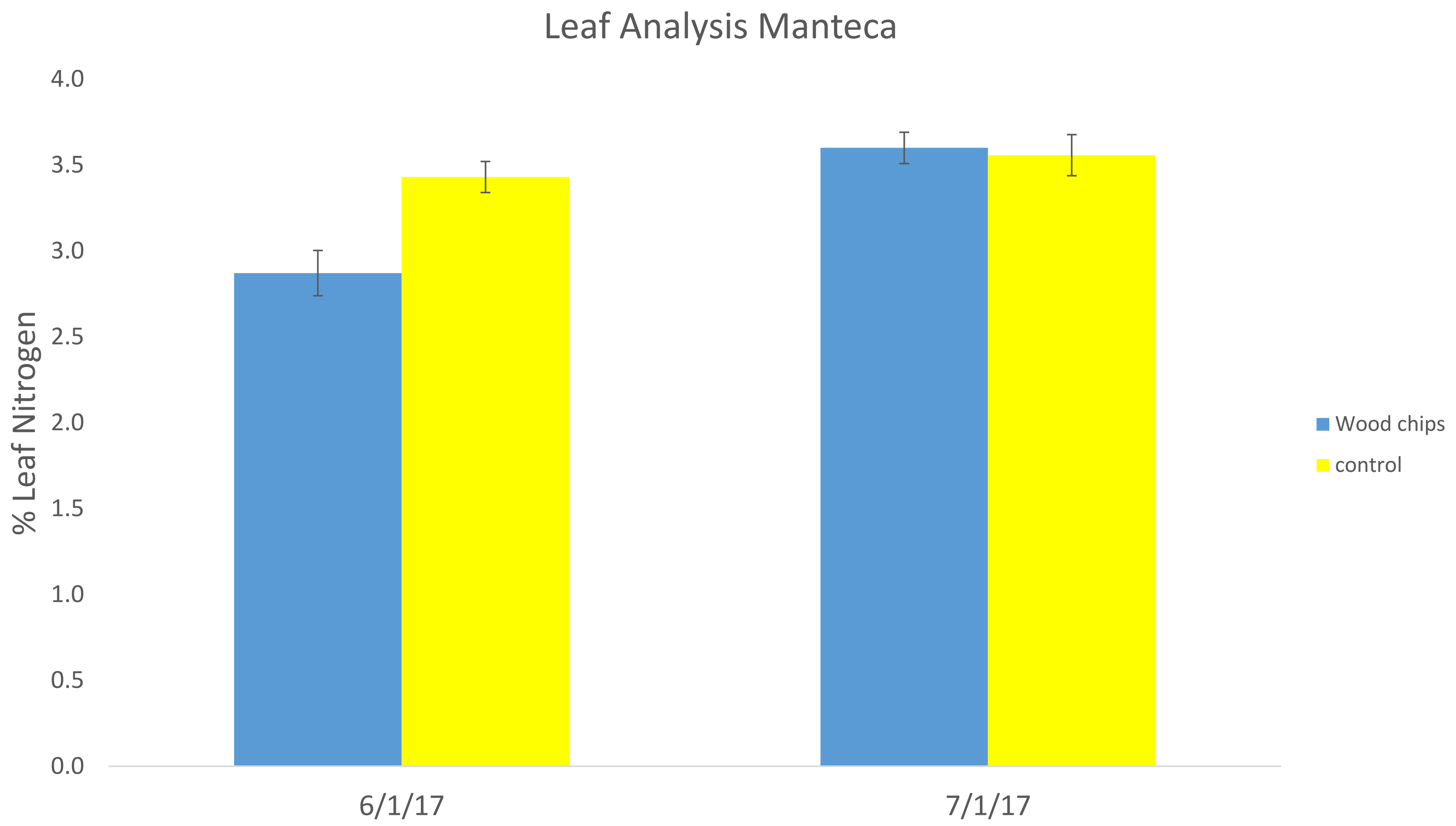
In the portion of the orchard where the wood chip piles were—there was total weed suppression.

We doubled our nitrogen applications through fertigation in order to get the desired growth.

# Current recommendations for newly planted almond trees




UCCE Merced David Doll


Leaf Analysis Manteca
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
% Leaf Nitrogen
6/1/17
7/1/17
Wood chips
control

Northwest Tiller
till, level, and roll in one pass

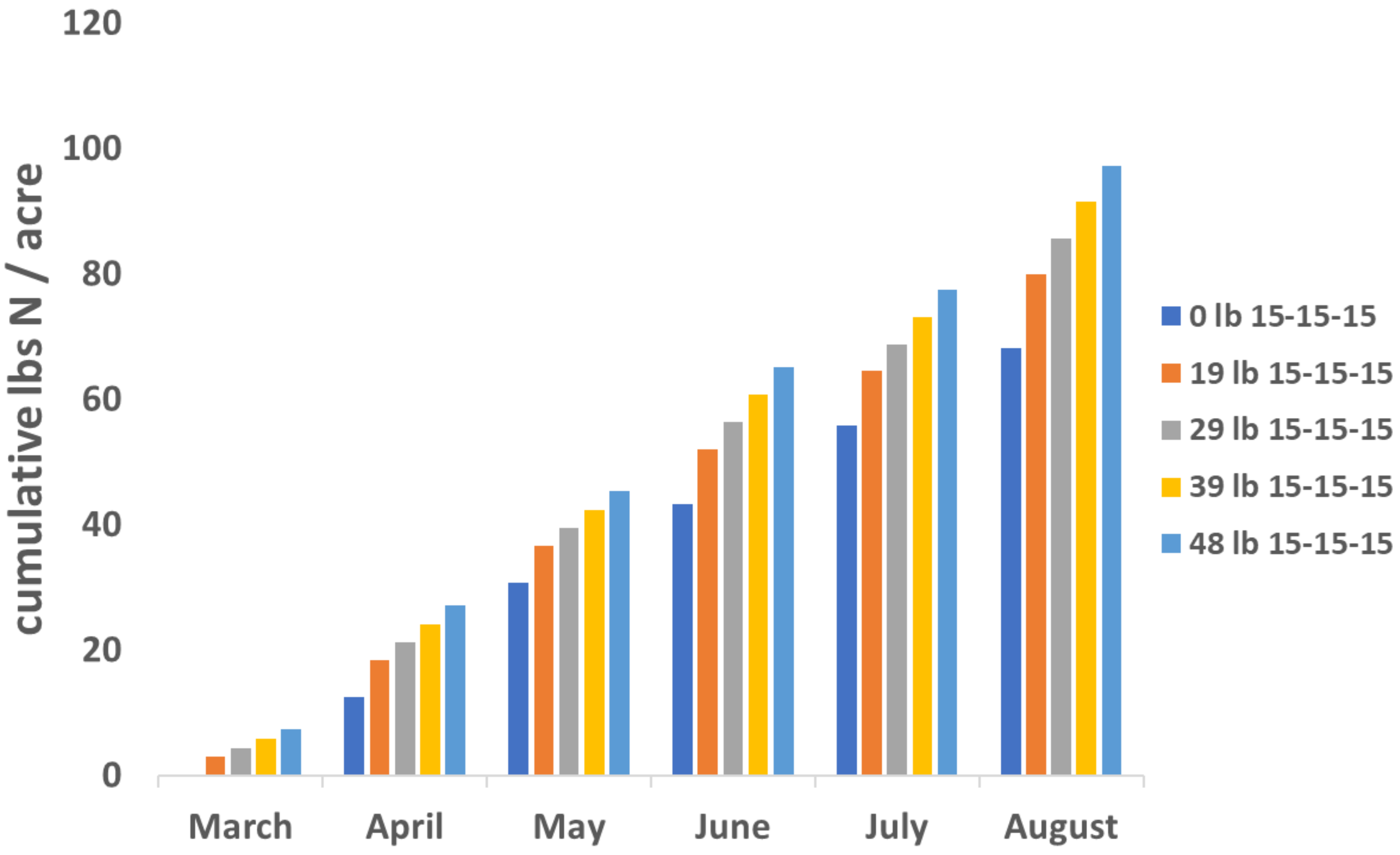
| | 100% efficiency<br>total N oz/tree/year | 22% efficiency of UAN 32<br>total N oz/tree/year |
|---|---|---|
| White | 8.65 | 1.91 |
| Blue | 12.78 | 4.31 |
| Yellow | 13.98 | 5.51 |
| Orange | 15.18 | 6.71 |
| Red | 16.38 | 7.91 |

| | 100% efficiency<br>total lbs N /acre | 22% efficiency<br>total lbs N /acre |
|---|---|---|
| White | 62.70 | 13.84 |
| Blue | 92.60 | 31.24 |
| Yellow | 101.35 | 39.94 |
| Orange | 110.05 | 48.64 |
| Red | 118.75 | 57.34 |

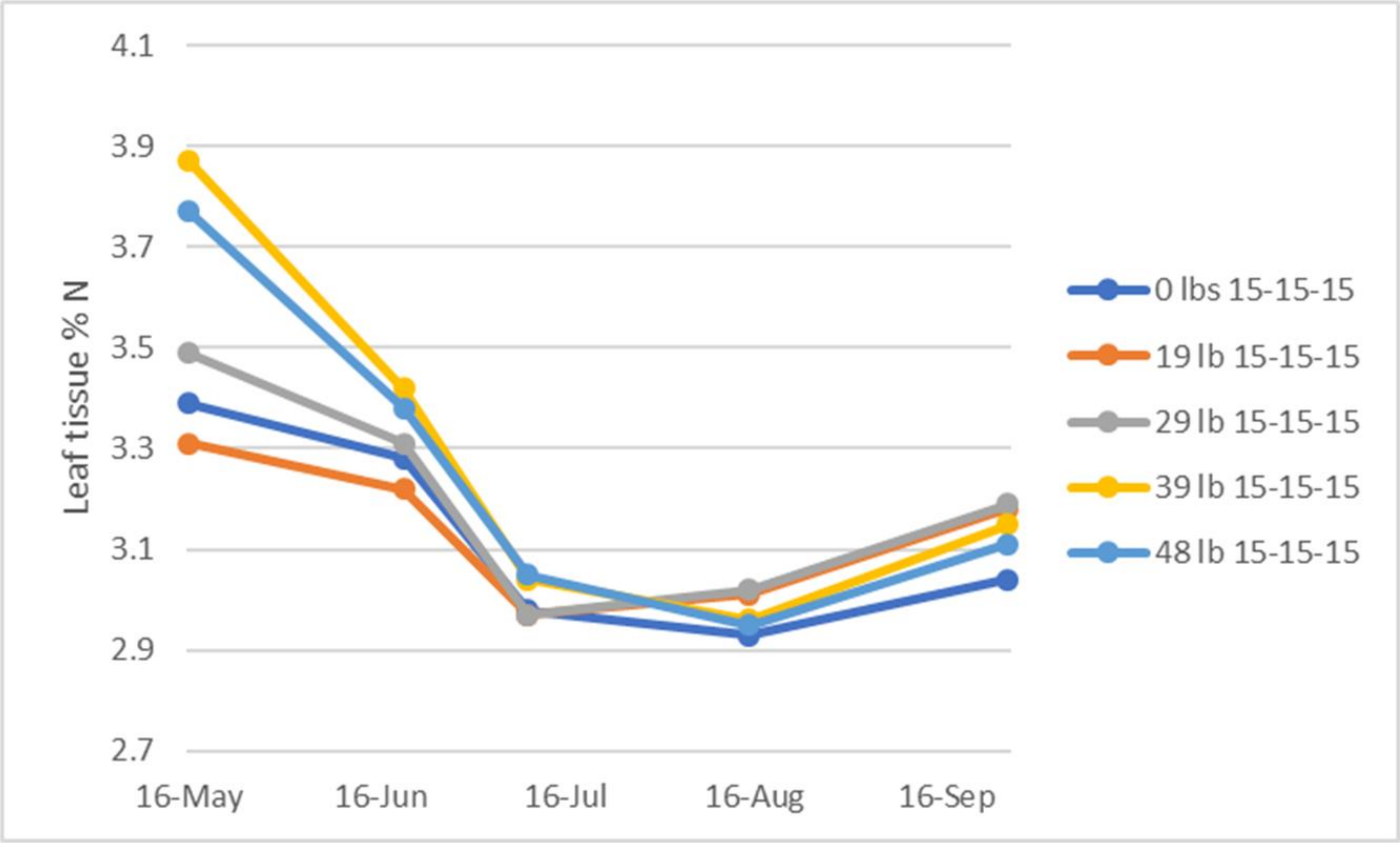
Control


0.8 oz of N applied in March

# First leaf almond orchard trial:
# 15-15-15 + 4 gallons (12.5 lb N/ac) UAN 32 monthly April to August

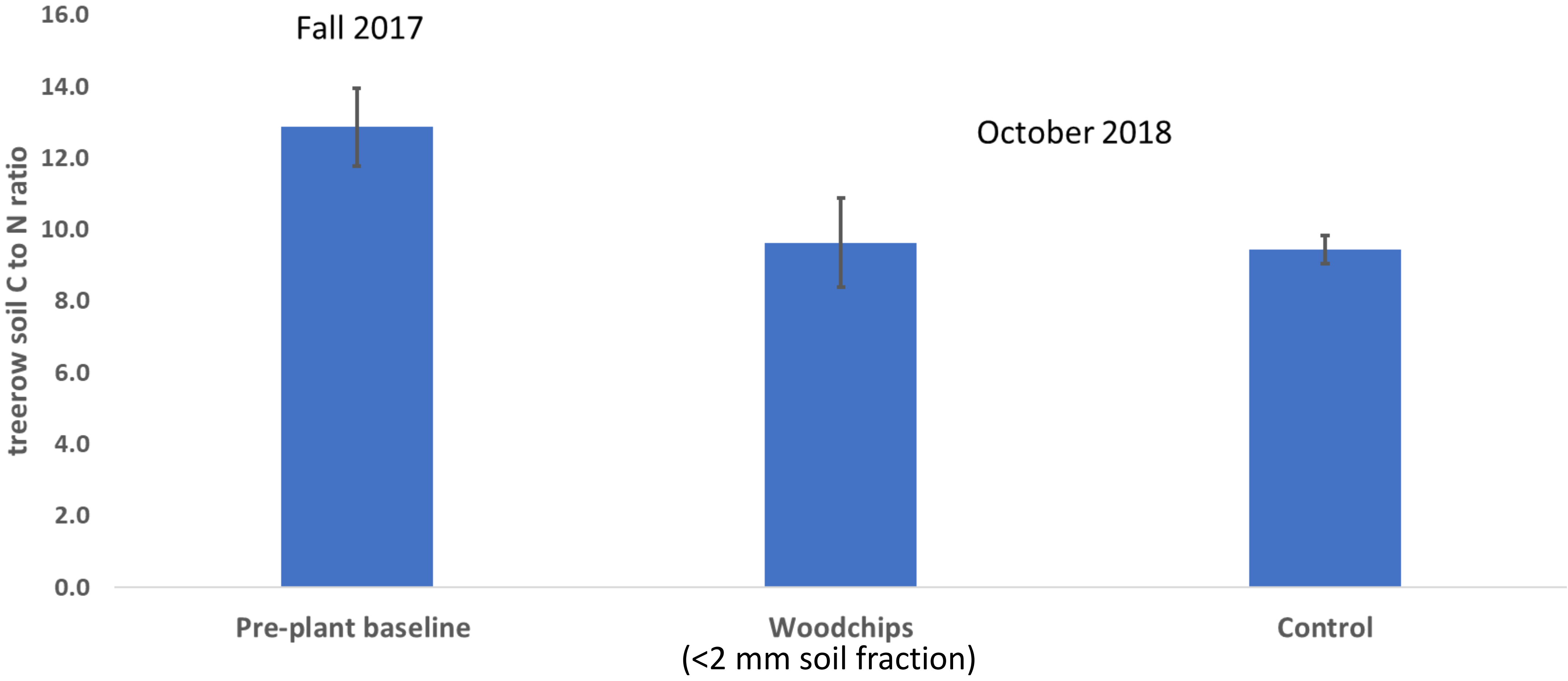


# 15-15-15 rates and leaf tissue %N




No clear rate effect, timing may be more critical

# Soil C to N one year after woodchips application and fertigation (68 lbs N /ac) commercial site



# Conclusions:

- Wood chip amendments can delay tree growth in newly planted orchards
- Whole Orchard Recycling may require early supplemental N to offset amending the soil with high C containing woodchips
- Applications of N after June didn’t seem to effect leaf N content
- We believe that N efficiency will ultimately be improved with the whole orchard recycling
- We believe that additional rates of N will not be necessary the second year after whole orchard recycling

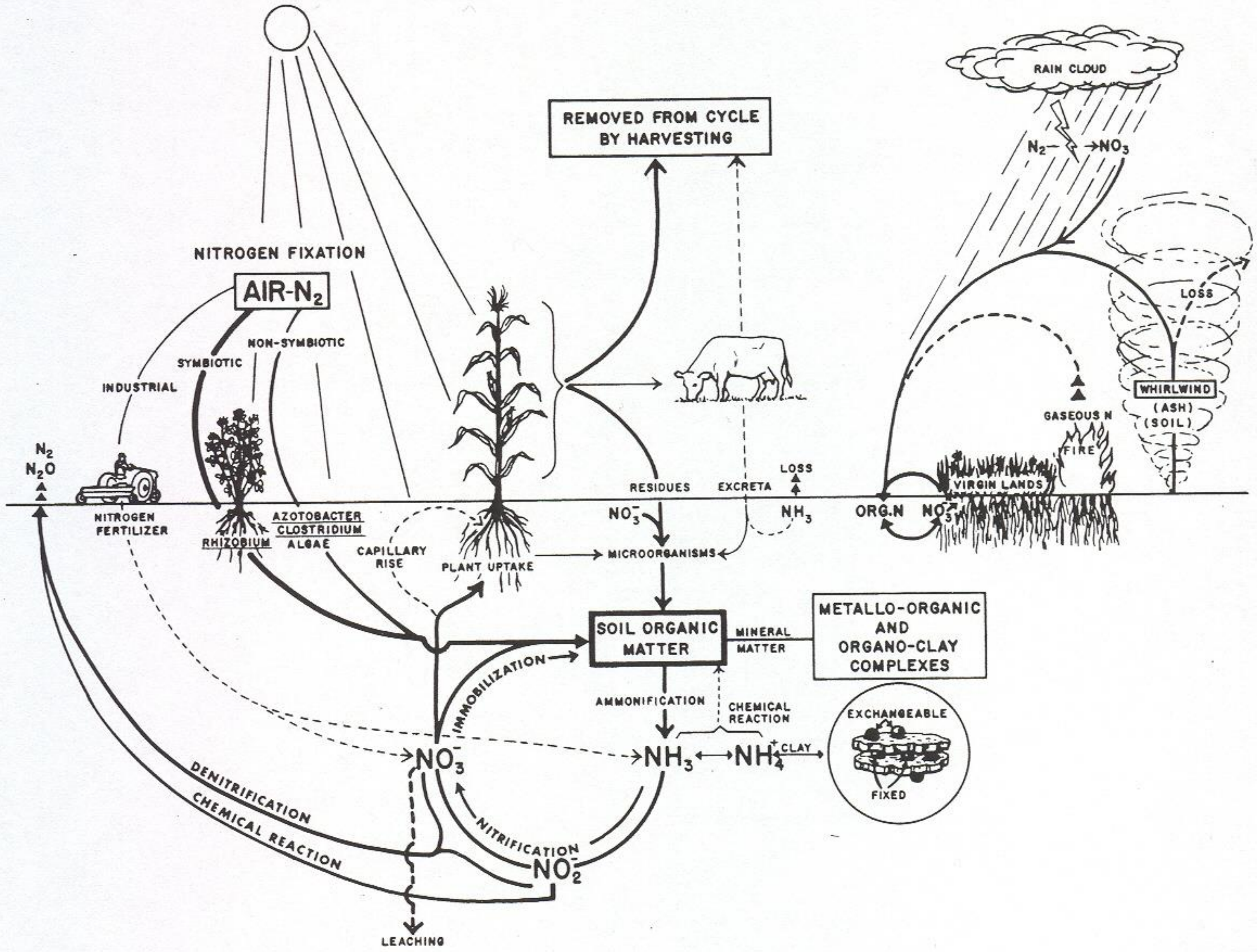
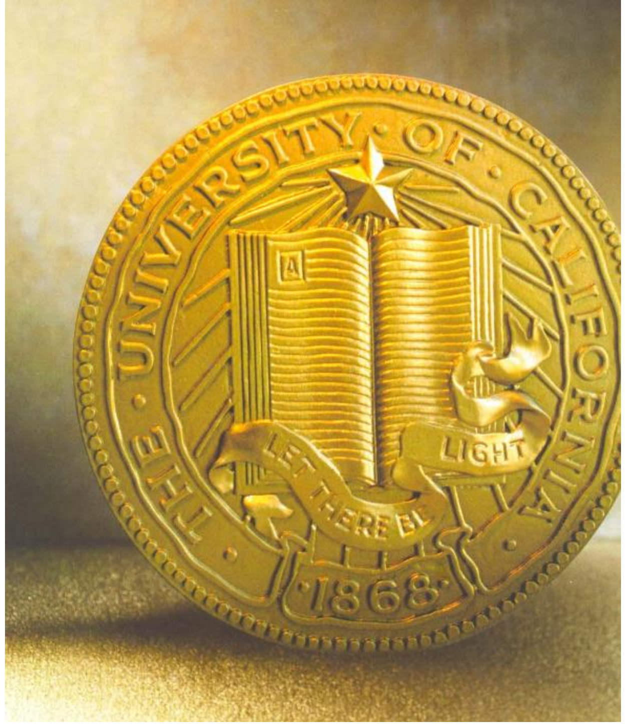



**Figure 8.1.** Nitrogen cycle in soil. (From Stevenson, 1982.)


This Duratech grinder is mobile and spreads the wood chips evenly as it grinds.

Efficiencies are improved every year that whole orchard recycling is performed.


Morbark mobile horizontal grinder




# Thank You!

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# SPEED TALKS: NUTRIENT, SALINITY AND SOIL HEALTH

ROOM 308-309 | DECEMBER 4, 2018

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# Influence of Different Cover Crop Systems on Navel Orangeworm

Houston Wilson | Dept. Entomology, UC Riverside

Kent Daane | Dept. Enviro. Sci. Policy Mgmt., UC Berkeley

Amelie Gaudin | Dept. Plant Sciences, UC Davis

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# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials – Dr. Amelie Gaudin (UC Davis)

# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials – Dr. Amelie Gaudin (UC Davis)

### Potential Benefits (Ecosystem Services)

- Soil health, quality, fertility etc.
- Water infiltration
- Pollinator forage
- Biological control of pests
- Weed suppression

# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials – Dr. Amelie Gaudin (UC Davis)

### Potential Costs (Ecosystem Dis-Services)

- Tractor/labor costs to establish
- Competition with main crop
- Water requirements
- Attracts/harbors pests
- Interferes with sanitation

# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials – Dr. Amelie Gaudin (UC Davis)

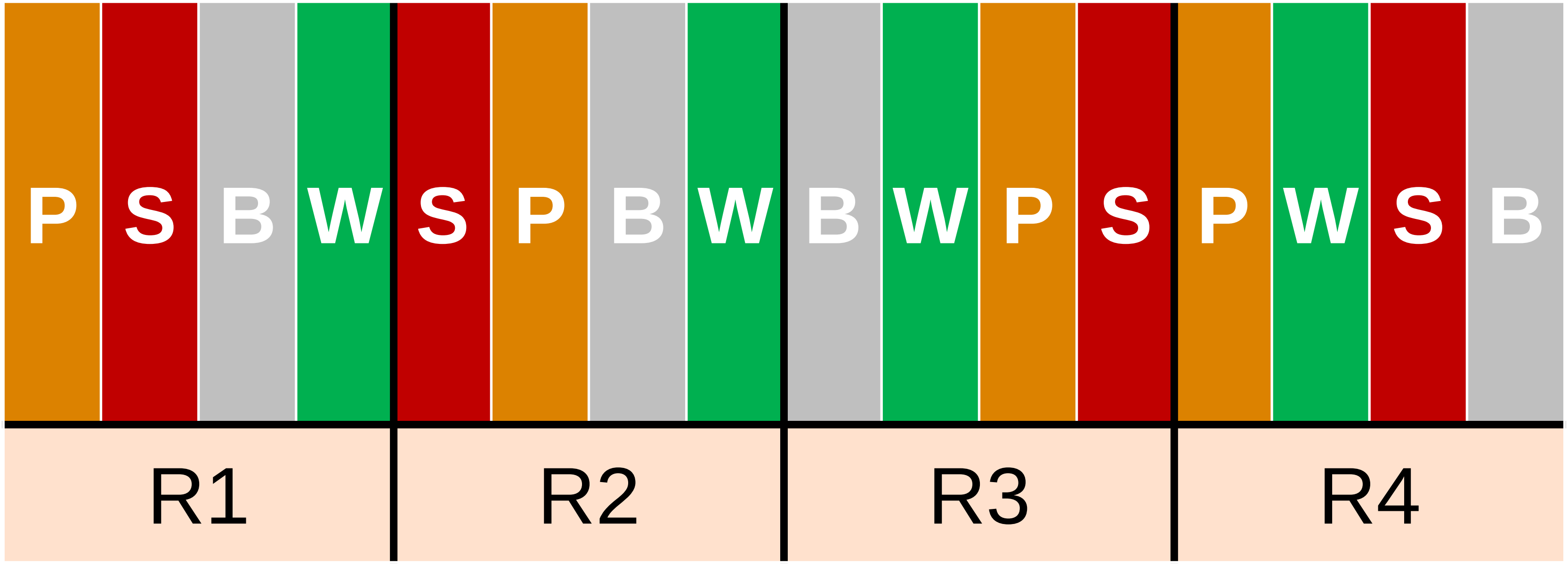
| Collaborator | Institution | Focus |
|---|---|---|
| A. Gaudin | UC Davis | Soil health |
| N. Williams | UC Davis | Pollination |
| A.Hodson | UC Davis | Soil food web |
| J. Mitchell | UC Davis | Water balance |
| B. Hanson | UC Davis | Weed pressure |
| A.Westphal | UC Riverside | Nematodes |
| D. Doll | UC Coop. Extension | Yield<br>Biomass<br>Water stress |
| M. Culumber | | |
| M. Yaghmour | | |
| D. Lightle | | Frost |
| H. Wilson / K. Daane | UC Riverside / UC Berkeley | Biological control |

# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials

### Treatments

- **Pollinator Mix = mustards and radish**
- **Soil Mix = mustards, radish, grasses, legumes**
- **Weedy = resident weedy vegetation**
- **Bare = bare soil**



# Assessing Ecosystem Services in Almond Production

## Cover Crop Trials

Bare Soil

Soil Mix

Weedy

# Assessing Ecosystem Services in Almond Production

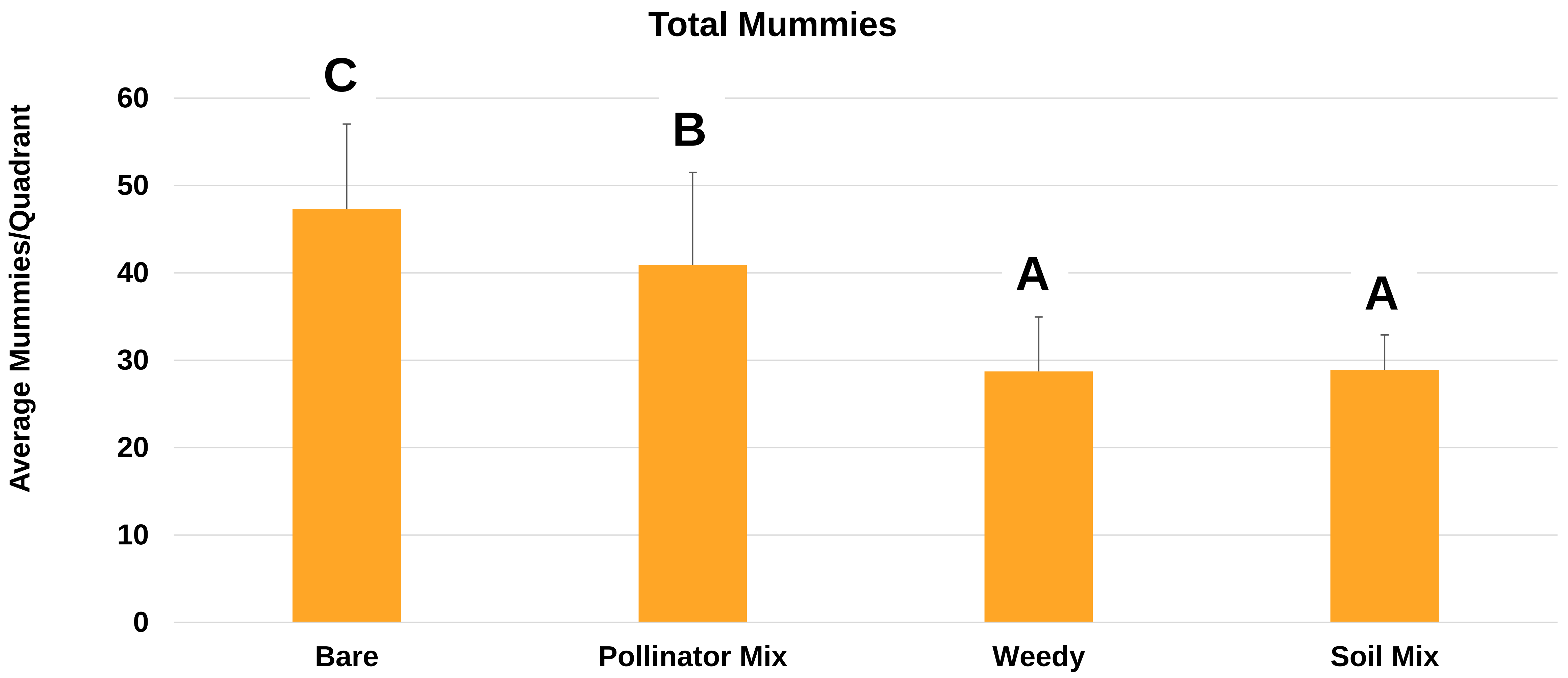
## Cover Crop Trials

### Preliminary Sampling – 2018

- Mummy nuts
- Insects on ground covers + tree canopy
- Crop damage

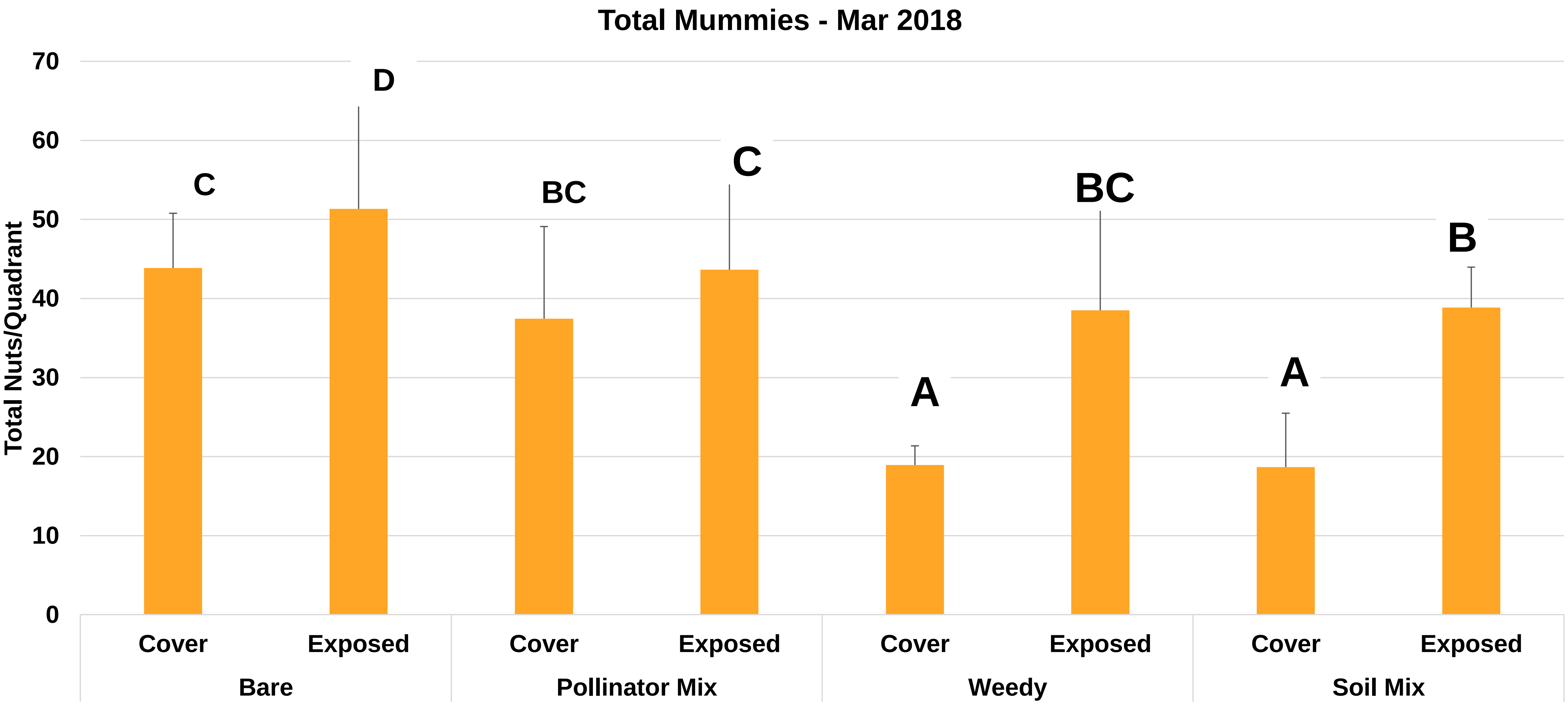
# Total Mummy Nuts – Mar 2018

GLMM
*P* <0.001
X2 = 278.2



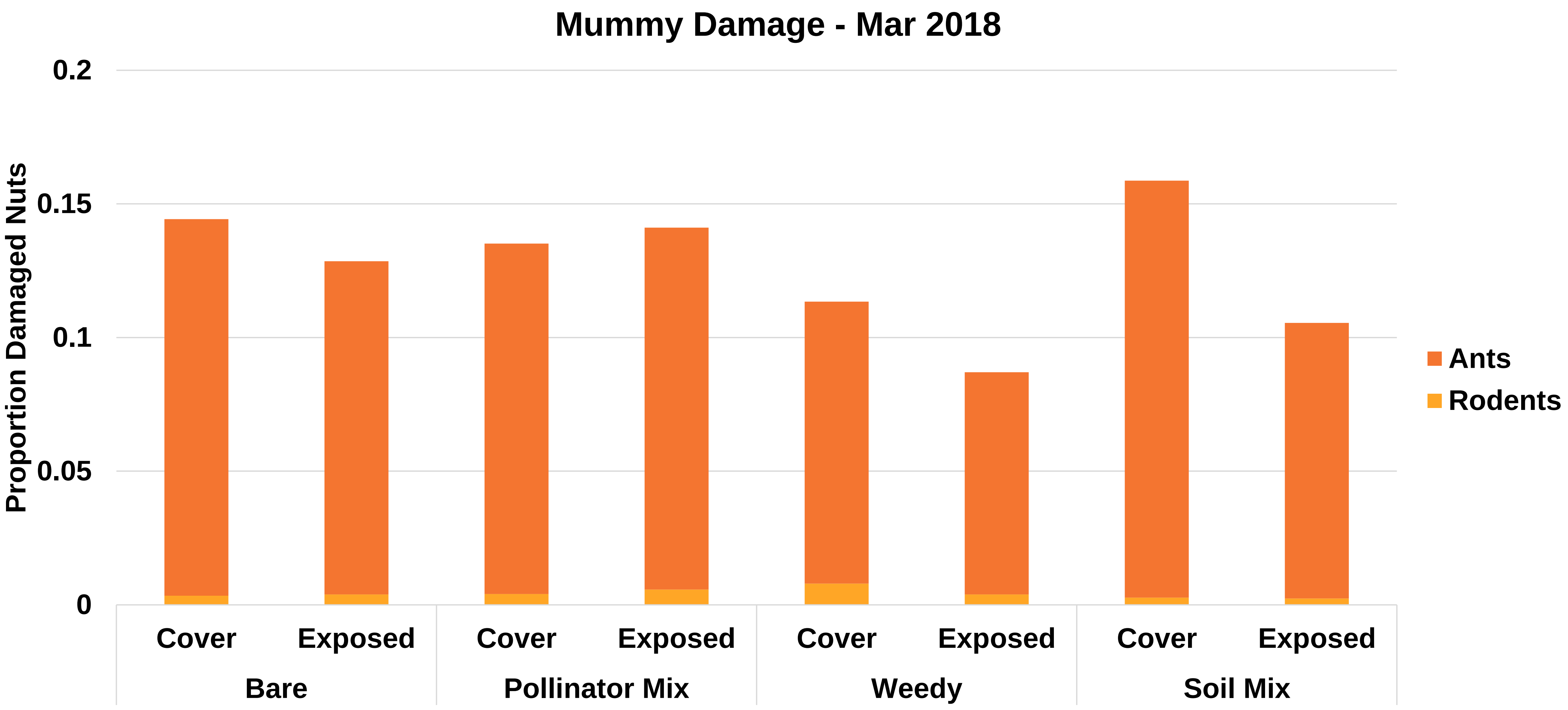
# Total Mummy Nuts – Mar 2018

GLMM
*P* <0.001
X2 = 539



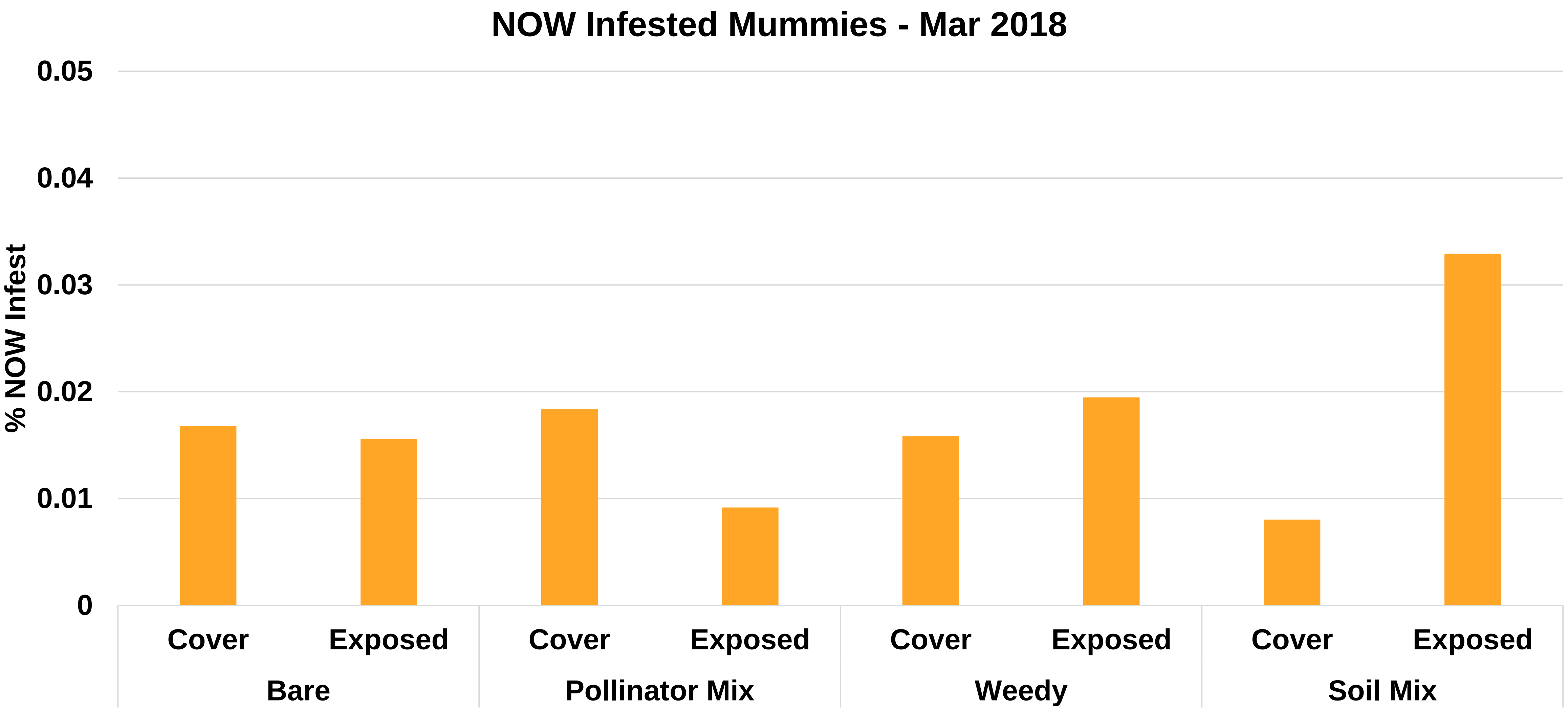
# Damage to Mummy Nuts – Mar 2018

NSD

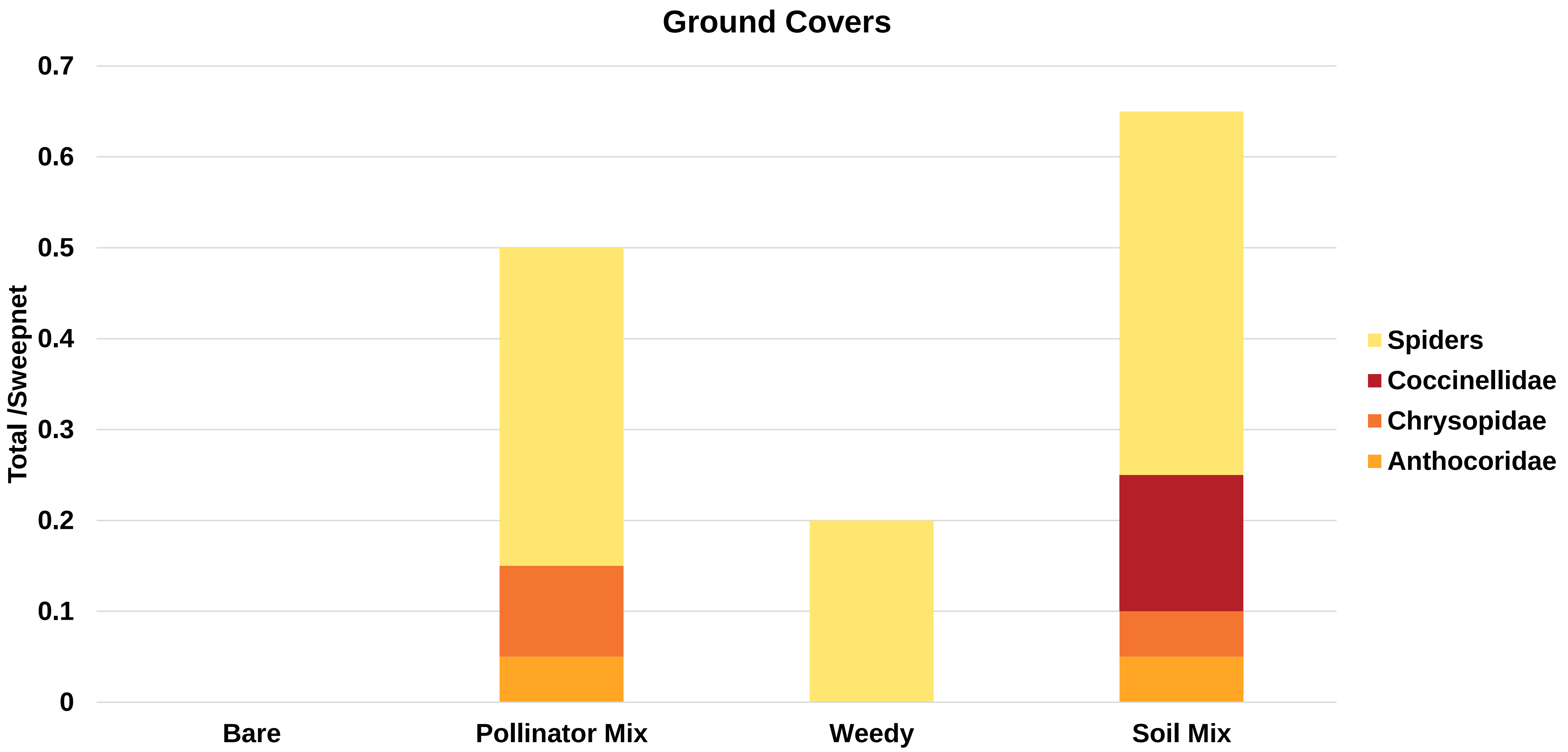


# Damage to Mummy Nuts – Mar 2018

NSD

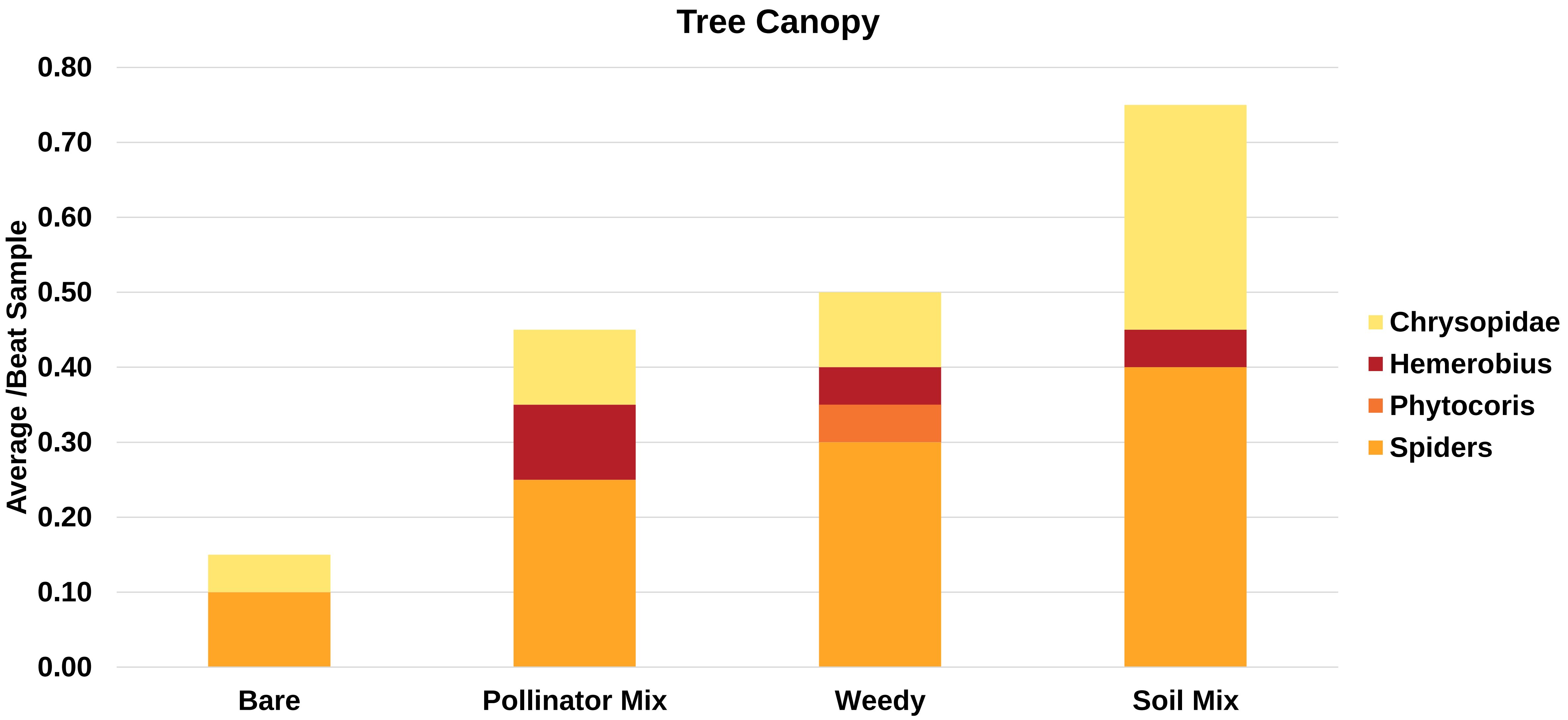


# Cover Crops – March 2018



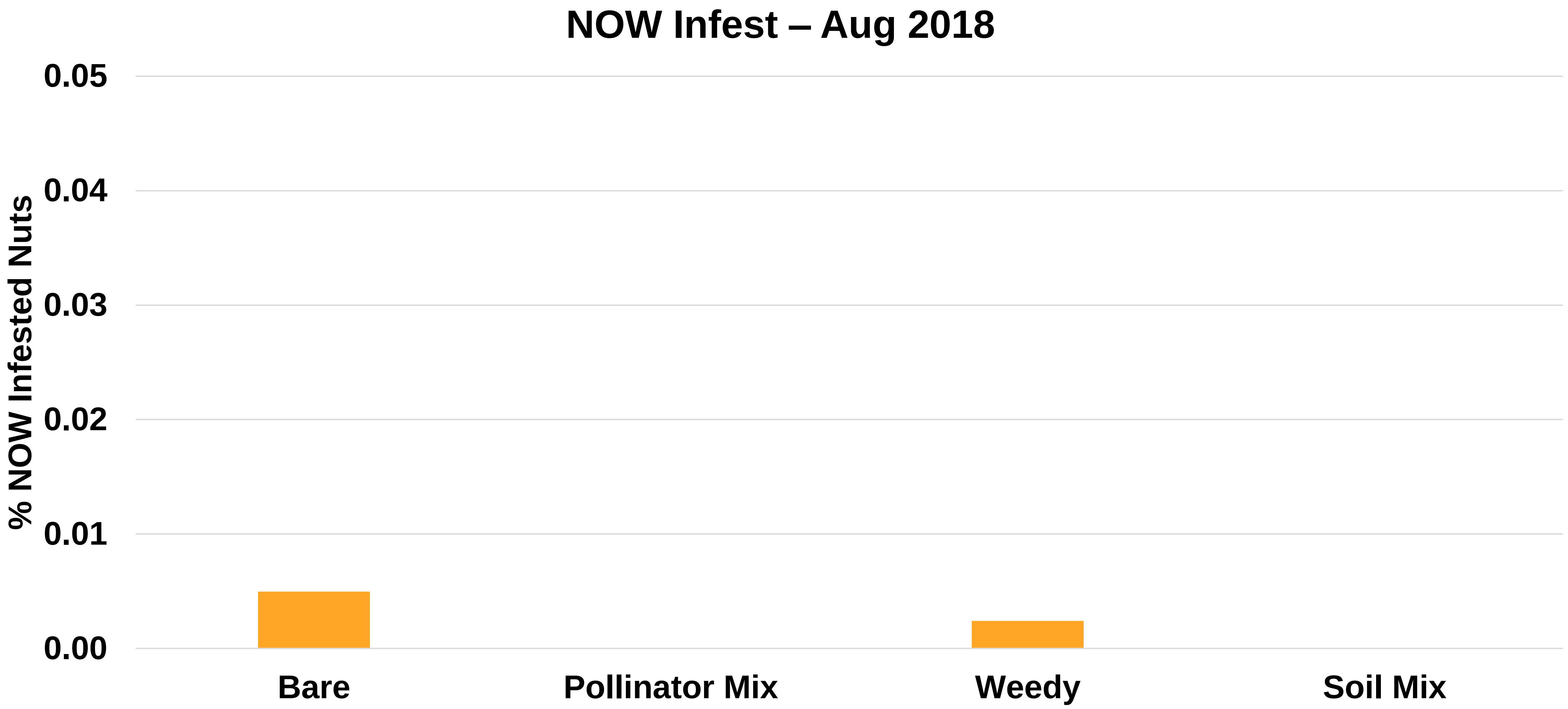
# Tree Canopy – May 2018

NSD



# Crop Damage – Aug 2018

NSD



# Conclusions

## Key Points

- No immediate impact on NOW damage/infest
- Beneficial insects respond to cover crops, higher densities in canopy
- Experimental setup not ideal for IPM studies though

# Research Plans for 2019

## Experimental Setup – 2019

- Paired plots with greater separation
- Similar issue with pollinator studies

## Refocus Research Efforts

- Biological control difficult with low damage thresholds
  - Not your typical "habitat → beneficials → biocontrol" situation
  - Pests will still be monitored of course
- Stronger focus on…
  - Sanitation efficacy
  - Mummy mortality in cover crops

# THANK YOU!

## Contact

Houston Wilson – Houston.Wilson@UCR.edu

## Acknowledgements

Amelie Gaudin (UC Davis), Kent Daane (UC Berkeley)

## Funding

Almond Board CA

## Collaborating Growers/PCAs

Jeff Bergeron, Castle Farms

UC RIVERSIDE UNIVERSITY OF CALIFORNIA

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## SPEED TALKS: NUTRIENT, SALINITY AND SOIL HEALTH

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Amélie Gaudin
Assistant Professor of Agroecology,
Department of Plant Science UC Davis

# Developing cover crop systems for almond orchards

*C.Creze, J.Mitchell, A.Westphal, D.Doll, D.Lightle, M.Yaghmour, B.Hanson, N.Williams, A.Hodson, H.Wilson*

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# Winter cover crops are not frequently planted in California orchards (~5% has vegetation)

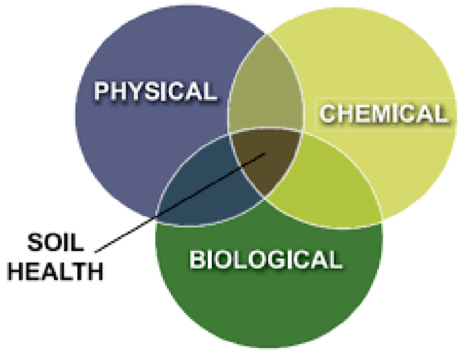

- Risk of frost
- Increase in water usage
- Issues at harvest
- Additional difficulties in management
  - Weed control
  - Winter sanitation
  - Vertebrate pest management

- Cost and uncertainties of economic return
- Difficult access to equipment (Drill, soil prep)
- Lack of information on cover crop management (species, planting dates, termination…)

**Resident vegetation is common**
Clean berms, unmanaged middles
Mowed during bloom
Allowed to die or terminated prior to harvest

# ……despite potential benefits

- Build up of organic matter and healthier soils
  - Decrease compaction
  - Improve aggregation/infiltration
  - Conservation of precip/irrigation water
  - Decrease N losses
  - Earlier field access
  - Dust reduction
- Pollinator health
- Management of problematic weeds
- Management of soil born pests
- Host beneficial organisms




Pictures: D.Doll

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# Team members


Dr. Jeff Mitchell (PI)


Dr. Andreas Westphal (PI)


Dr. Amélie Gaudin (PI)


Dr. Dani Lightle, UCCE Glenn


Dr. Mohammad Yaghmour, UCCE Kern


David Doll, UCCE Merced


Dr. Neal Williams


Dr. Brad Hanson


Dr. Amanda Hodson


Dr. Wilson Houston


Dr. Kent Daane


Cynthia Crézé, PhD Student


Steve Haring, PhD Student


Kimiora Ward


Cameron A.T. Zuber

- Weed sciences
- Entomology
- Nematology
- Soil Science
- Orchard production

2 PhD thesis

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Cap and Trade Dollars at Work

WESTERN SARE
Sustainable Agriculture Research & Education



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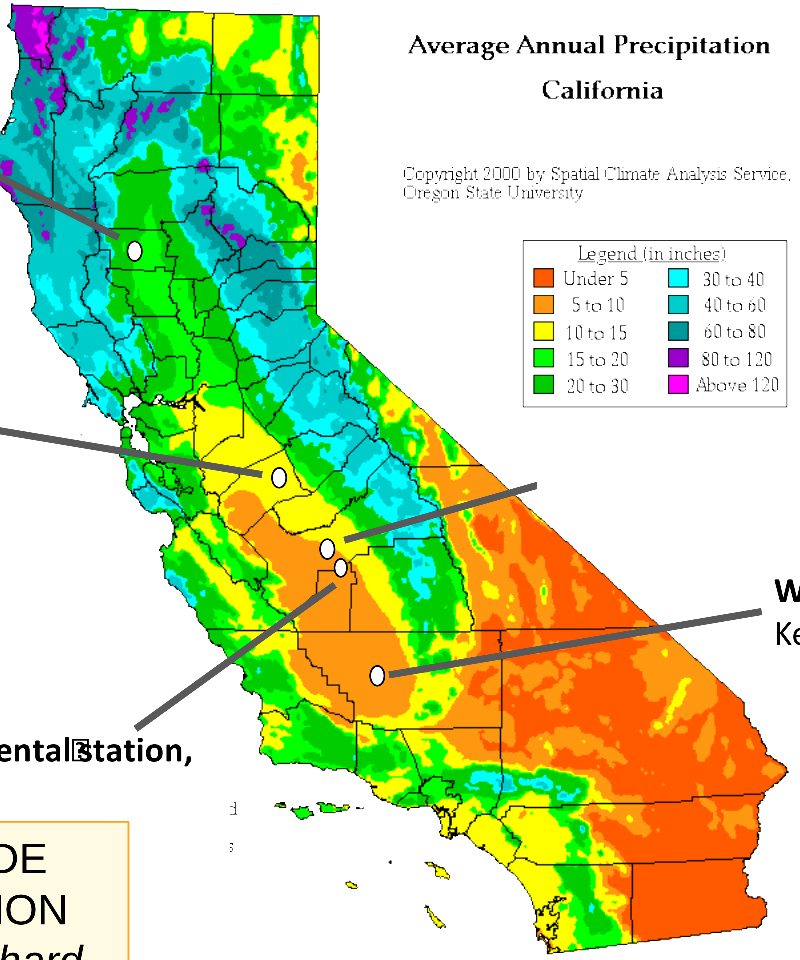
# Study sites across rainfall gradient

**Bosque Verde LLC**
Glenn Country

**Castle Farm**
Merced County




**Wegis & Young**
Kern County

**Kearney experimental station,**
Fresno County

NEMATODE
SUPRESSION
*Infected orchard*

## Rainfall gradient

### 4 treatments, replicated designs

- **PAM "Pollinator mix"**

*Bracco White Mustard, Diakon Radish, Nemfix Yellow Mustard, Common Yellow Mustard, Canola*

- **"Soil mix"**

*Bracco White Mustard, Diakon Radish, Merced ryegrass, Berseem clover, Common vetch*

- **Perennial resident vegetation**
- **Bare soil**

*Conventional herbicide control*

Project Apis m.

Kamprath Seeds

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# Our system's approach to evaluating winter cover crop options

**#1 :** Feasible and practice
Maximize agronomic benefits and reduce operational concerns

What levels of C and N capture and increased in **soil health** may be provided by common cover crop mixtures or natural vegetation during the winter?

Do cover crop **use or help conserve** water in our climate?

How does it impact soil and surface temperature and **frost risk** at blooming?

Can cover crops be used to **deter soil born-pests such as nematodes**? Does it interfere/helps with **NOW control**?

Do cover crop impact weed pressure and help **control noxious weeds**?

What is the impact on **pollination** of almond orchards?

# Our system's approach to evaluating winter cover crop options

**#2 : Work toward developing best management practices**

- Termination dates
  *Before bloom or summer*
- Species composition

2nd field season
3-year study
All sites recently planted





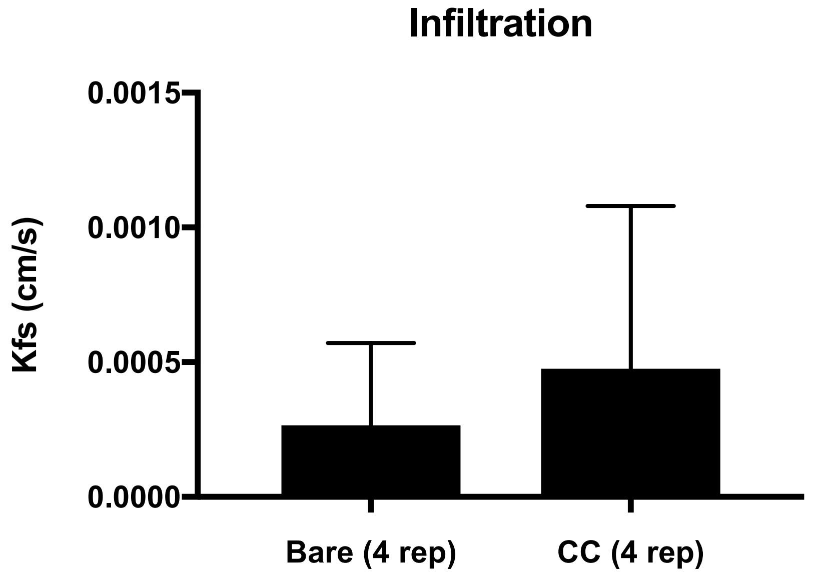
# What have we learned?

- What you seed is not always what you get
  - C:N ratios varied from 10:1 to 18:1
  - But compared to resident vegetation, the seeded CC can produce up to 300% more dry matter biomass.
- Treat it as a crop to be successful
- Does not interfere with and can even facilitate NOW sanitation (trafficability - shake and mow)
- Probably little to none competition for pollination
- Changes in frost risk still being evaluated
- Harvest: possible to get clean harvest without conditioner (April termination)
- 1-2 more irrigations (Merced/Corning)
- No negative impacts on yields and tree water status

Visit us @ our poster locations
Weeds #23
Soil health #112
NOW #98
Pollinator #113/114

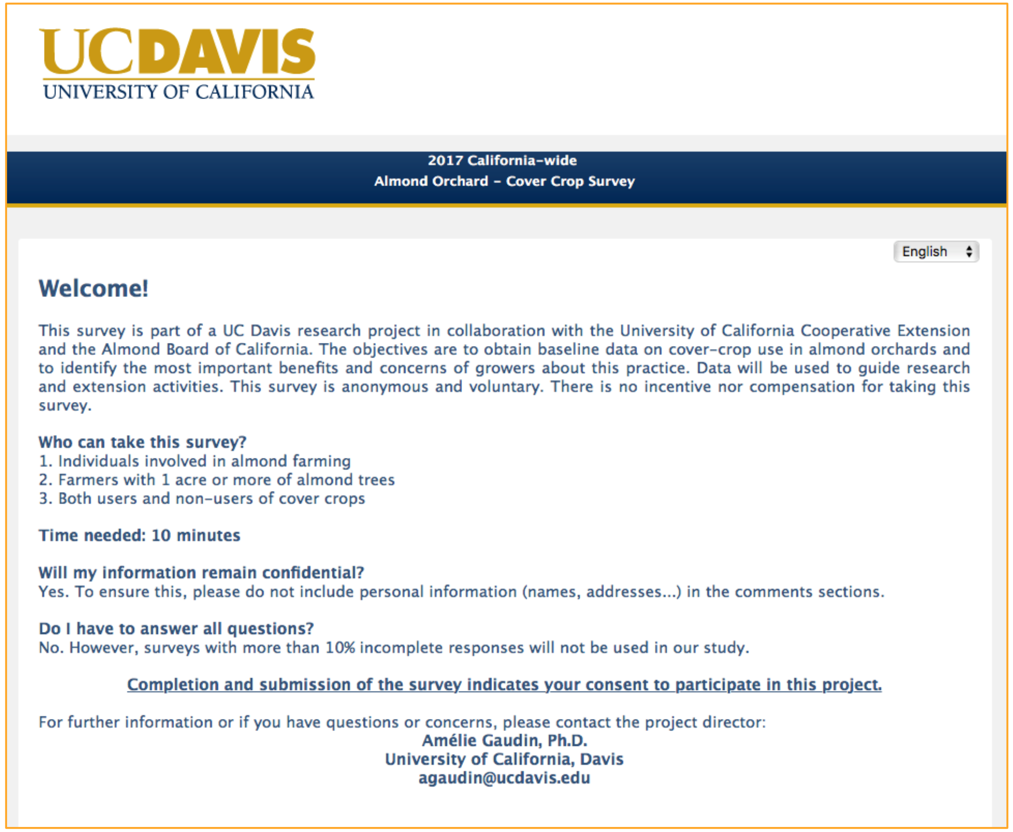
# What have we learned?

- Biomass production is a key factor for SH increase
  - Water infiltration increase in CC
- In micro sprinkler irrigated orchards, wetting zone vs. rainfed soil have different initial soil health
  - Greater C+N in center where residues are piled + shredded
- Overlap of irrigation + CC is important to increase benefits
  - wider CC will be more beneficial for soil health
  - May be difficult to get wider seeding in older orchards –> requires 2 drill passes and potential hedging of branches




# Follow us and our results : https://almondcovercrop.faculty.ucdavis.edu
# Grower Survey – we want to learn from you

## Online



UCDAVIS
UNIVERSITY OF CALIFORNIA

2017 California-wide
Almond Orchard – Cover Crop Survey

English

**Welcome!**

This survey is part of a UC Davis research project in collaboration with the University of California Cooperative Extension and the Almond Board of California. The objectives are to obtain baseline data on cover-crop use in almond orchards and to identify the most important benefits and concerns of growers about this practice. Data will be used to guide research and extension activities. This survey is anonymous and voluntary. There is no incentive nor compensation for taking this survey.

**Who can take this survey?**
1. Individuals involved in almond farming
2. Farmers with 1 acre or more of almond trees
3. Both users and non-users of cover crops

**Time needed: 10 minutes**

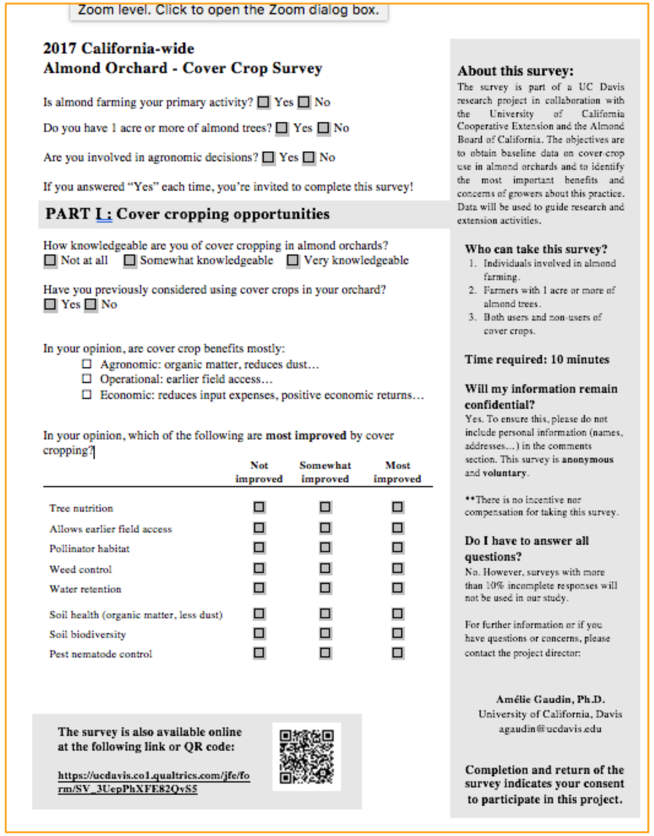
**Will my information remain confidential?**
Yes. To ensure this, please do not include personal information (names, addresses...) in the comments sections.

**Do I have to answer all questions?**
No. However, surveys with more than 10% incomplete responses will not be used in our study.

Completion and submission of the survey indicates your consent to participate in this project.

For further information or if you have questions or concerns, please contact the project director:
**Amélie Gaudin, Ph.D.**
**University of California, Davis**
**agaudin@ucdavis.edu**

## Paper – mail / available here



Zoom level. Click to open the Zoom dialog box.

**2017 California-wide**
**Almond Orchard - Cover Crop Survey**

Is almond farming your primary activity? ☐ Yes ☐ No

Do you have 1 acre or more of almond trees? ☐ Yes ☐ No

Are you involved in agronomic decisions? ☐ Yes ☐ No

If you answered "Yes" each time, you're invited to complete this survey!

**PART I: Cover cropping opportunities**

How knowledgeable are you of cover cropping in almond orchards?
☐ Not at all ☐ Somewhat knowledgeable ☐ Very knowledgeable

Have you previously considered using cover crops in your orchard?
☐ Yes ☐ No

In your opinion, are cover crop benefits mostly:
- ☐ Agronomic: organic matter, reduces dust…
- ☐ Operational: earlier field access…
- ☐ Economic: reduces input expenses, positive economic returns…

In your opinion, which of the following are **most improved** by cover cropping?

| | Not improved | Somewhat improved | Most improved |
|---|---|---|---|
| Tree nutrition | ☐ | ☐ | ☐ |
| Allows earlier field access | ☐ | ☐ | ☐ |
| Pollinator habitat | ☐ | ☐ | ☐ |
| Weed control | ☐ | ☐ | ☐ |
| Water retention | ☐ | ☐ | ☐ |
| Soil health (organic matter, less dust) | ☐ | ☐ | ☐ |
| Soil biodiversity | ☐ | ☐ | ☐ |
| Pest nematode control | ☐ | ☐ | ☐ |

**The survey is also available online at the following link or QR code:**

**https://ucdavis.co1.qualtrics.com/jfe/form/SV_3UepPhXFE82QvS5**

**About this survey:**
The survey is part of a UC Davis research project in collaboration with the University of California Cooperative Extension and the Almond Board of California. The objectives are to obtain baseline data on cover-crop use in almond orchards and to identify the most important benefits and concerns of growers about this practice. Data will be used to guide research and extension activities.

**Who can take this survey?**
1. Individuals involved in almond farming.
2. Farmers with 1 acre or more of almond trees.
3. Both users and non-users of cover crops.

**Time required: 10 minutes**

**Will my information remain confidential?**
Yes. To ensure this, please do not include personal information (names, addresses...) in the comments section. This survey is **anonymous** and **voluntary**.

**There is no incentive nor compensation for taking this survey.

**Do I have to answer all questions?**
No. However, surveys with more than 10% incomplete responses will not be used in our study.

For further information or if you have questions or concerns, please contact the project director:

**Amélie Gaudin, Ph.D.**
University of California, Davis
agaudin@ucdavis.edu

**Completion and return of the survey indicates your consent to participate in this project.**

Visit us @ our poster location
#112

**Thank you**

**agaudin@ucdavis.edu**
**web: gaudin.ucdavis.edu**

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Soil health #112
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# 2018 | THE ALMOND CONFERENCE

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# Effects of Timing Food Safe Sources of Organic Matter Amendments on Nutrient Cycling and Water Use

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# Experimental Design

- 7 tons $ac^{-1}$ $yr^{-1}$
- OMA Source
  - Grower control
  - Composted manure
  - Green waste compost
- Application Timing
  - Fall 2015 and 2016
  - Spring 2016 and 2017
- Data Collection 2016 and 2017
  - Summer Leaf Nutrients
  - Residual Soil Nutrients Postharvest
  - Soil Organic Matter Postharvest
  - Soil N Availability using Ion Exchange Resins
    - 2016 = October 2015 through October 2016
    - 2017 = October 2016 through October 2017

# Leaf Nutrients

**Table 1.** Leaf N, P and K (%) sampled in July 2016 and 2017 between organic matter amendment (OMA) sources of composted manure and green waste compost and an unamended control and OMA timing of application in spring or fall. Values are means with significant ($p$ < 0.05) differences between treatments using a Tukey test.

| | Leaf N | | Leaf P | | Leaf K | |
|---|---|---|---|---|---|---|
| | % | | % | | % | |
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| **Source** | | | | | | |
| **Control** | 1.99 a | 2.19 a | 0.108 a | 0.103 a | 1.48 a | 0.99 a |
| **Composted manure** | 2.04 a | 2.25 a | 0.101 a | 0.106 a | 1.29 a | 1.12 a |
| **Green waste compost** | 1.97 a | 2.22 a | 0.100 a | 0.108 a | 1.36 a | 1.08 a |
| **p value** | **0.37** | **0.41** | **0.20** | **0.20** | **0.30** | **0.17** |
| **Timing** | | | | | | |
| **Spring application** | 2.00 a | 2.21 a | 0.105 a | 0.104 b | 1.38 a | 1.13 a |
| **Fall application** | 2.01 a | 2.26 a | 0.096 b | 0.110 a | 1.27 b | 1.07 a |
| **p value** | **0.63** | ***0.06*** | *<0.01* | *<0.01* | *<0.05* | ***0.06*** |

# Residual Soil Nutrients

**Table 2.** Soil ammonium ($NH_4^+$) and nitrate ($NO_3^-$), Olsen-phosphate ($PO_4^{3-}$), exchangeable potassium ($K^+$) from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and an unamended control and OMA timing of application in spring or fall. Values are means with significant (*p* < 0.05) differences between treatments using a Tukey test.

| | $NH_4^+$-N + $NO_3^-$-N | | $PO_4^{3-}$-P | | $K^+$ | |
|---|---|---|---|---|---|---|
| | mg N $kg^{-1}$ soil | | mg P $kg^{-1}$ soil | | mg K $kg^{-1}$ soil | |
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| **Source** | | | | | | |
| **Control** | 15.1 a | 12.2 a | 6.86 a | 6.18 a | 143 b | 133 a |
| **Composted manure** | 14.3 a | 15.1 a | 10.5 a | 9.03 a | 186 a | 147 a |
| **Green waste compost** | 16.4 a | 16.4 a | 10.0 a | 6.60 a | 167 ab | 154 a |
| **p value** | **0.90** | **0.70** | ***0.06*** | **0.14** | *0.02* | **0.51** |
| **Timing** | | | | | | |
| **Spring application** | 21.4 a | 14.1 a | 8.07 b | 7.01 a | 156 b | 155 a |
| **Fall application** | 9.31 b | 17.3 a | 12.4 a | 8.62 a | 198 a | 146 a |
| **p value** | *0.01* | **0.30** | *<0.01* | **0.26** | *0.01* | **0.65** |

# Soil Organic Matter

**Table 3.** Total organic carbon (g C $kg^{-1}$ soil) and nitrogen (g N $kg^{-1}$ soil) sampled in October 2016 and 2017 from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and an unamended control and OMA timing of application in spring or fall. Values are means with significant ($p < 0.05$) differences between treatments using a Tukey test.

| | **Total organic carbon** | | **Total nitrogen** | |
|---|---|---|---|---|
| | g C $kg^{-1}$ soil | | g N $kg^{-1}$ soil | |
| | 2016 | 2017 | 2016 | 2017 |
| **Source** | | | | |
| **Control** | 4.74 b | 4.28 a | 0.50 a | 0.43 a |
| **Composted manure** | 5.21 b | 4.70 a | 0.54 a | 0.46 a |
| **Green waste compost** | 5.74 a | 5.26 a | 0.57 a | 0.49 a |
| **p value** | *0.04* | **0.12** | **0.19** | **0.42** |
| **Timing** | | | | |
| **Spring application** | 5.16 b | 4.65 a | 0.54 a | 0.46 a |
| **Fall application** | 5.78 a | 4.84 a | 0.58 a | 0.46 a |
| **p value** | *0.02* | ***0.09*** | **0.16** | **0.77** |

# Soil N Availability

**Table 4.** Nitrogen (N) availability (mg N $kg^{-1}$ soil $yr^{-1}$) represented by the sum of potential N leaching and net N mineralization for organic matter amendment (OMA) sources of composted manure and green waste compost and an unamended control and OMA timing of application in spring or fall. Potential N leaching was estimated by the adsorption of inorganic N ($NH_4^+$ + $NO_3^-$) to resin beads (0 – 50 cm) attached to the base of a soil core. Net mineralization was estimated by changes in soil inorganic N ($NH_4^+$ + $NO_3^-$) within the same soil core. Values are means with significant ($p$ < 0.05) differences between treatments using a Tukey test.

| | **N availability** | |
|---|---|---|
| | mg N $kg^{-1}$ soil $yr^{-1}$ | |
| | 2016 | 2017 |
| **Source** | | |
| **Control** | 10.4 a | 7.45 b |
| **Composted manure** | 12.9 a | 19.1 a |
| **Green waste compost** | 14.2 a | 19.2 a |
| **p value** | **0.60** | *0.02* |
| **Timing** | | |
| **Spring application** | 16.3 a | 15.7 b |
| **Fall application** | 10.8 b | 22.1 a |
| **p value** | *<0.01* | *<0.01* |

# Conclusions

- Leaf Nitrogen and Potassium levels are building over time
- Increase in N and K uptake is reflected in residual soil nutrients
- Soil organic matter levels decreased from 2016 to 2017
- Soil N availability increased from 2016 to 2017
- Future examination of *partial substitution* of N and K fertilizer with OMA

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- Steve Hart – School of Natural Resource, UC Merced
- Gabriele Ludwig – Almond Board of California

# Research Poster Sessions

**Tuesday, December 4**
*5:30 – 6:30 p.m.*

Featured topics:

- Pollination and bee health
- Soil heath
- Nutrient and nitrogen management

# What’s Next

**Tuesday, December 4 at 1:45 p.m.**

- Managing Nutrients and Salt Under Current Water Quality Regulations – Room 308-309
- What's Happening in DC? - 312-313
- The Almond Aflatoxin Menace: Addressing It Head On – Room 306-307
- Sustainability: Aligning with Food Manufacturers' Needs for the Future – Room 314


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# What's Next

## Tuesday, December 4

- State of the Industry – Hall C at 4:15 p.m.

*Be sure to join us at 5:30 p.m. in Hall A+B for Dedicated Trade Show Time and Opening Reception, sponsored by FMC Agricultural Solutions*