Research Update: Irrigation and Growing Almonds

December 9, 2015

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Continuing Education Credits

- **Continuing Education Credits** are available for many of today's symposiums. To receive CCA credit, you must sign in before and after each individual symposium at the back of the room.

Speakers

Bob Curtis, Almond Board (Moderator)

University of California, Davis

Bruce Lampinen

Matthew Gilbert

Astrid Volder

Patrick Brown

Daniel Schellenberg

Fraser Shilling

Shrini Upadhyaya

Ken Shackel

Amelie Gaudin

Georgia Drakakaki

David Smart

Tom Gradziel

Blake Sanden, UCCE – Kern County

Roger Duncan, UCCE – Stanislaus County

Bruce Lampinen,
University of California, Davis

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Development and Testing of a Mobile Platform for Measuring Canopy Light Interception and Water Stress in Almond

Bruce Lampinen, Greg Browne, Shrini Upadhyaya, Sam Metcalf, Bill Stewart, Ignacio Porris Gómez, David Doll, Roger Duncan, Dani Lightle, Franz Niederholzer and Katherine Pope.

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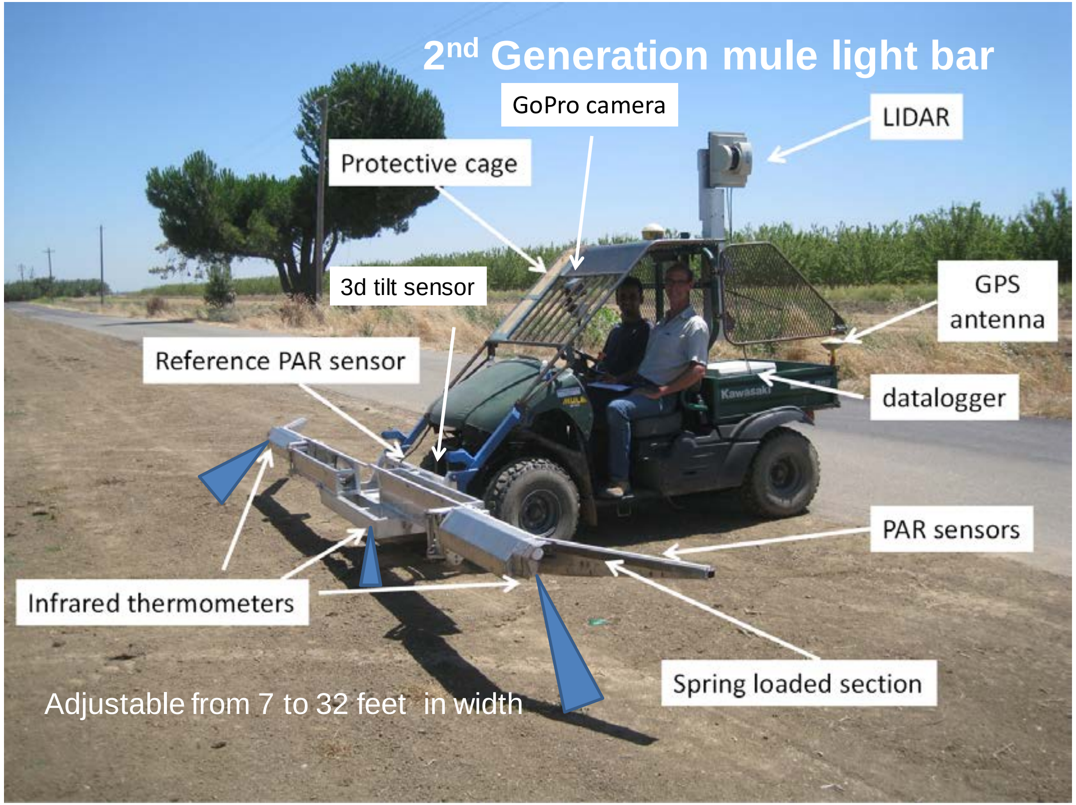
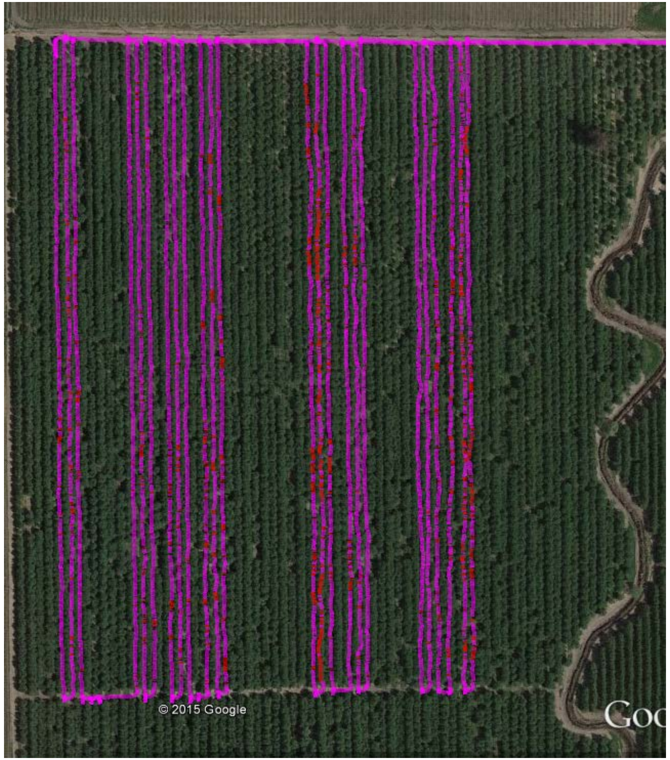
Mobile platform lightbar is used in numerous research trials



Mobile platform is run through the orchard at midday in mid-summer and path is plotted on Google Earth

We set up a portable weather station with temp, RH, windspeed and PAR sensors outside orchard

Normal speed of travel is 6.2 miles/hr so we can map about 12.4 miles within 1 hour of midday



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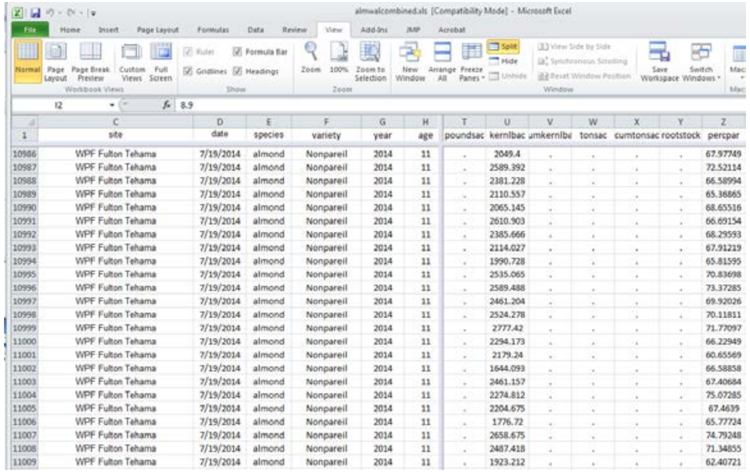
Heads up display allows marking plot boundaries which are then shown on Google Earth

Data is then exported to an Excel file



	C	D	E	F	G	H	T	U	V	W	X	Y	Z
1	site	date	species	variety	year	age	poundsac	kernlbac	umkernlbe	tonsac	cumtonsac	rootstock	percpar
10986	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2049.4	.	.	.	.	67.97749
10987	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2589.392	.	.	.	.	72.52114
10988	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2381.228	.	.	.	.	66.58994
10989	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2110.557	.	.	.	.	65.36865
10990	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2065.145	.	.	.	.	68.65516
10991	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2610.903	.	.	.	.	66.69154
10992	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2385.666	.	.	.	.	68.29593
10993	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2114.027	.	.	.	.	67.91219
10994	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	1990.728	.	.	.	.	65.81595
10995	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2535.065	.	.	.	.	70.83698
10996	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2589.488	.	.	.	.	73.37285
10997	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2461.204	.	.	.	.	69.92026
10998	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2524.278	.	.	.	.	70.11811
10999	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2777.42	.	.	.	.	71.77097
11000	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2294.173	.	.	.	.	66.22949
11001	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2179.24	.	.	.	.	60.65569
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11003	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2461.157	.	.	.	.	67.40684
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11005	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2204.675	.	.	.	.	67.4639
11006	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	1776.72	.	.	.	.	65.77724
11007	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	2658.675	.	.	.	.	74.79248
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11009	WPF Fulton Tehama	7/19/2014	almond	Nonpareil	2014	11	.	1923.212	.	.	.	.	62.40721

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Weigh trailer with load cells, the same GPS and an autosampler are then use to pick up same area

Self contained hydraulic system for operating augers, autosampler and elevator

Trimble GPS acts as datalogger to collect continuous yield data

Front skirt to prevent nuts from overflowing as cart fills

Wireless controller for hydraulically operated auto sampler

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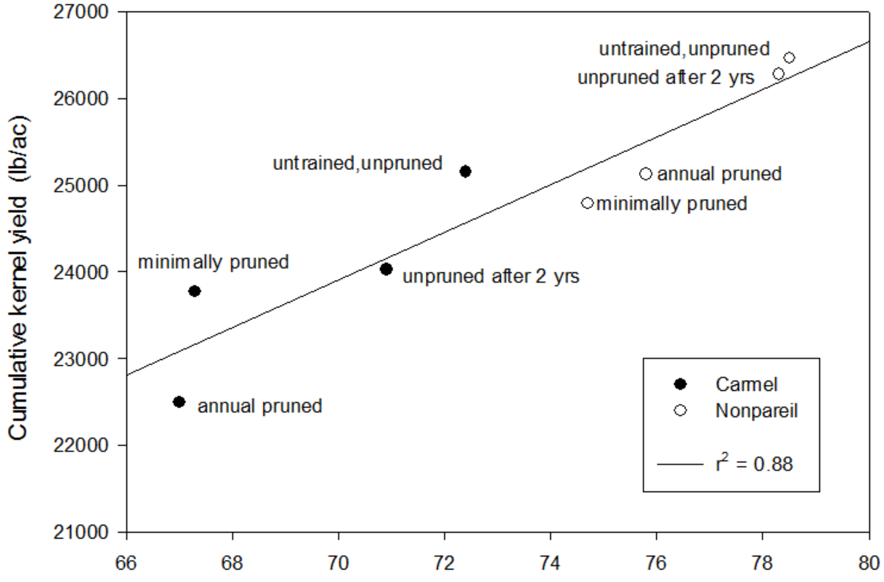
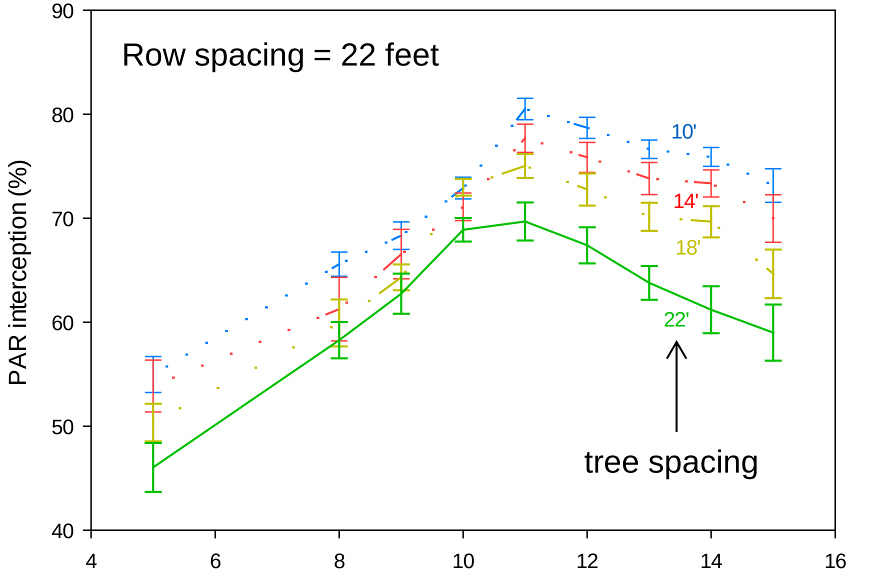
Mobile platform lightbar is used in numerous research trials

- Rootstock trials
- Variety trials
- Pruning/training trials
- Mechanical hedging trials
- Methyl bromide alternative trials
- Nutrition trials
- Water production function trials
- Remote sensing trials
- Ground water recharge trials

Stanislaus County Pruning/spacing/rootstock trial



Midday canopy PAR interception (%)



Orchard age (years)

Light interception at end of year 12 is a good predictor of the cumulative yield by treatment and variety

Light interception tended to peak at about 11 years of age at all in row tree spacings

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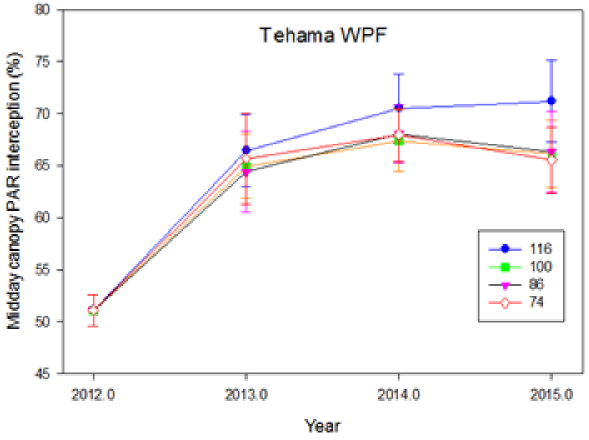
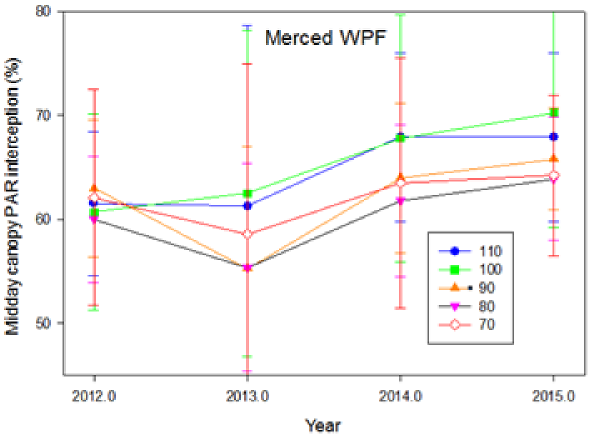
Water production function trials- yield and yield per unit light interception data are essential for interpreting results

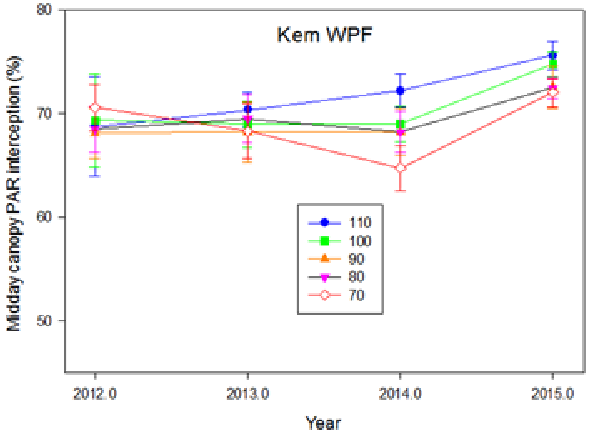
Tehama



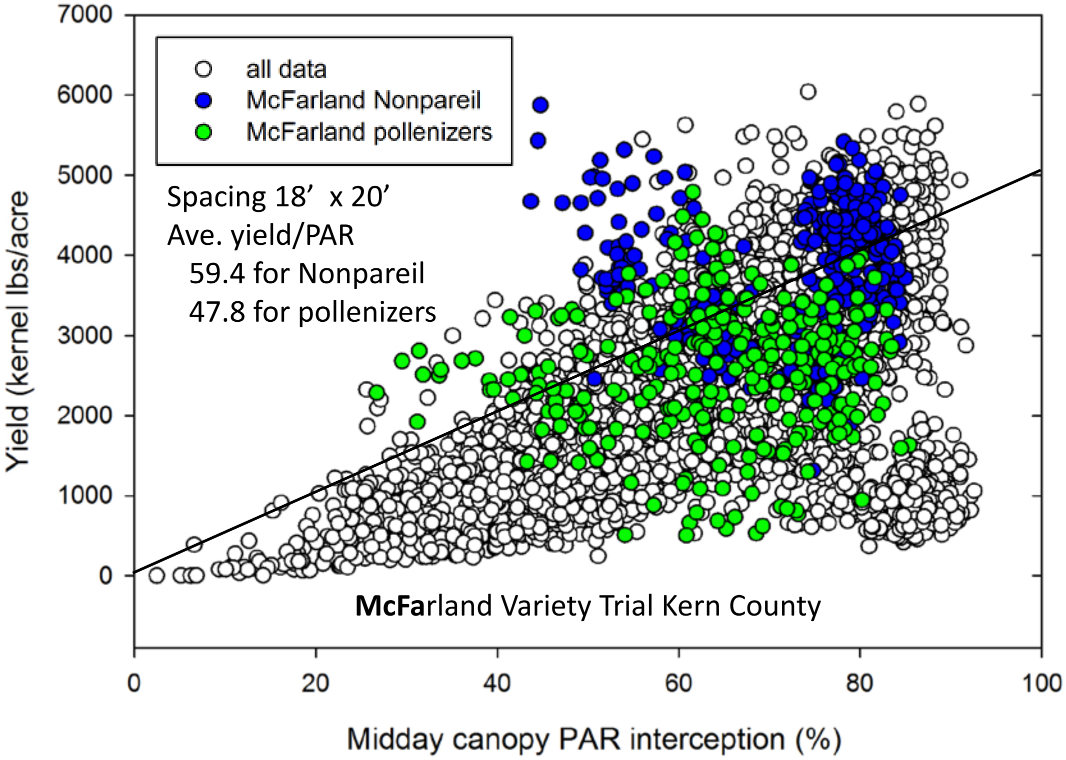
Merced



Kern



Example from McFarland Variety Trial Kern County



Variety	Height (feet)
Marcona	25.1 a
Nonpareil 7	24.2 b
Nonpareil 6	24.1 b
Nonpareil 38270	23.6 bc
Kochi	23.2 cd
Sweetheart	23.1 cd
Nonpareil Nico	23.0 cd
Nonpareil 5	23.0 cd
Nonpareil Newel	22.7 de
Nonpareil Dr	22.1 e
Nonpareil J	21.9 e
Kahl	21.9 e
Chips	21.8 f
2-19e (Kester)	20.9 f
Winters	20.0 g

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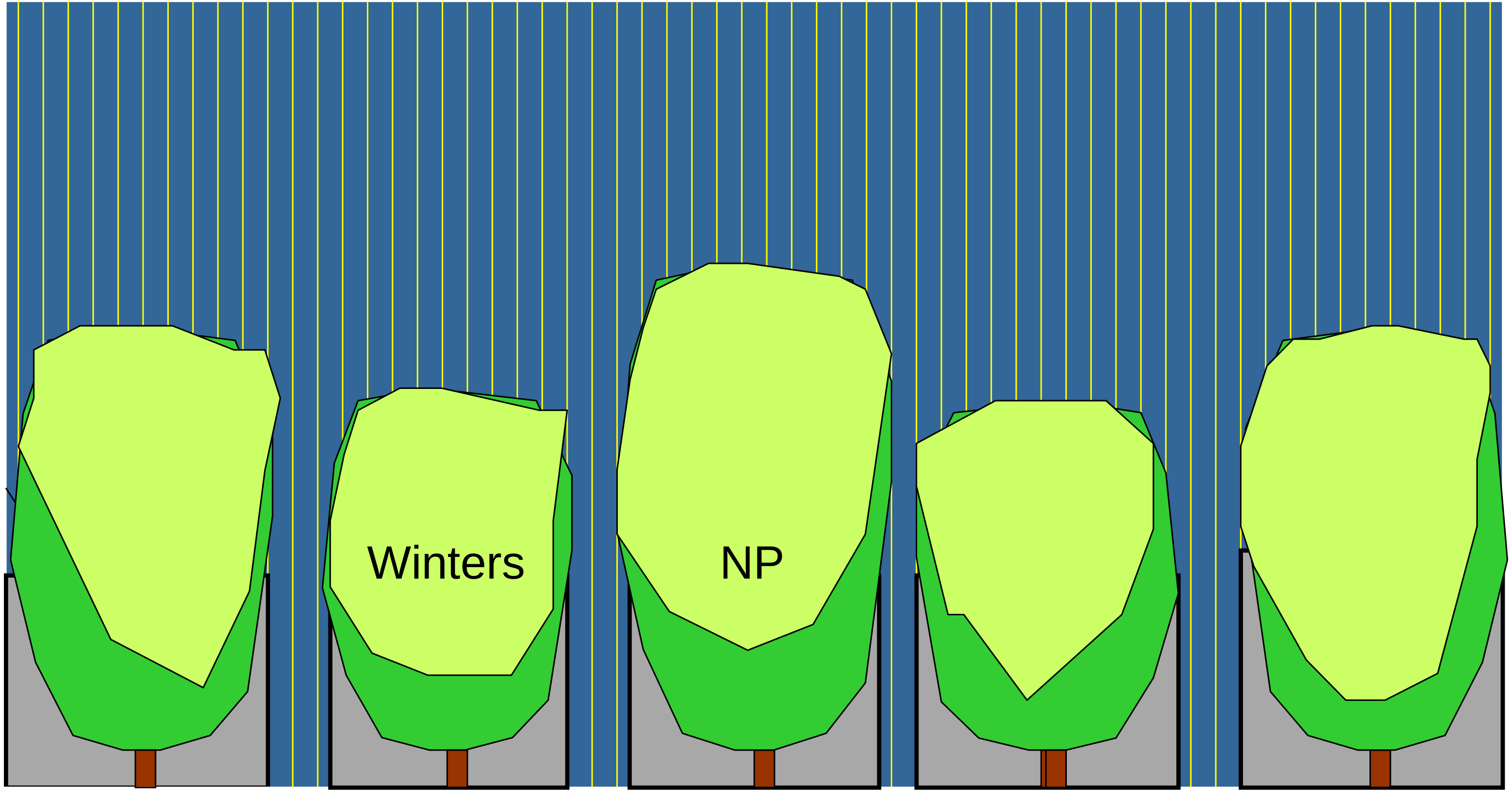
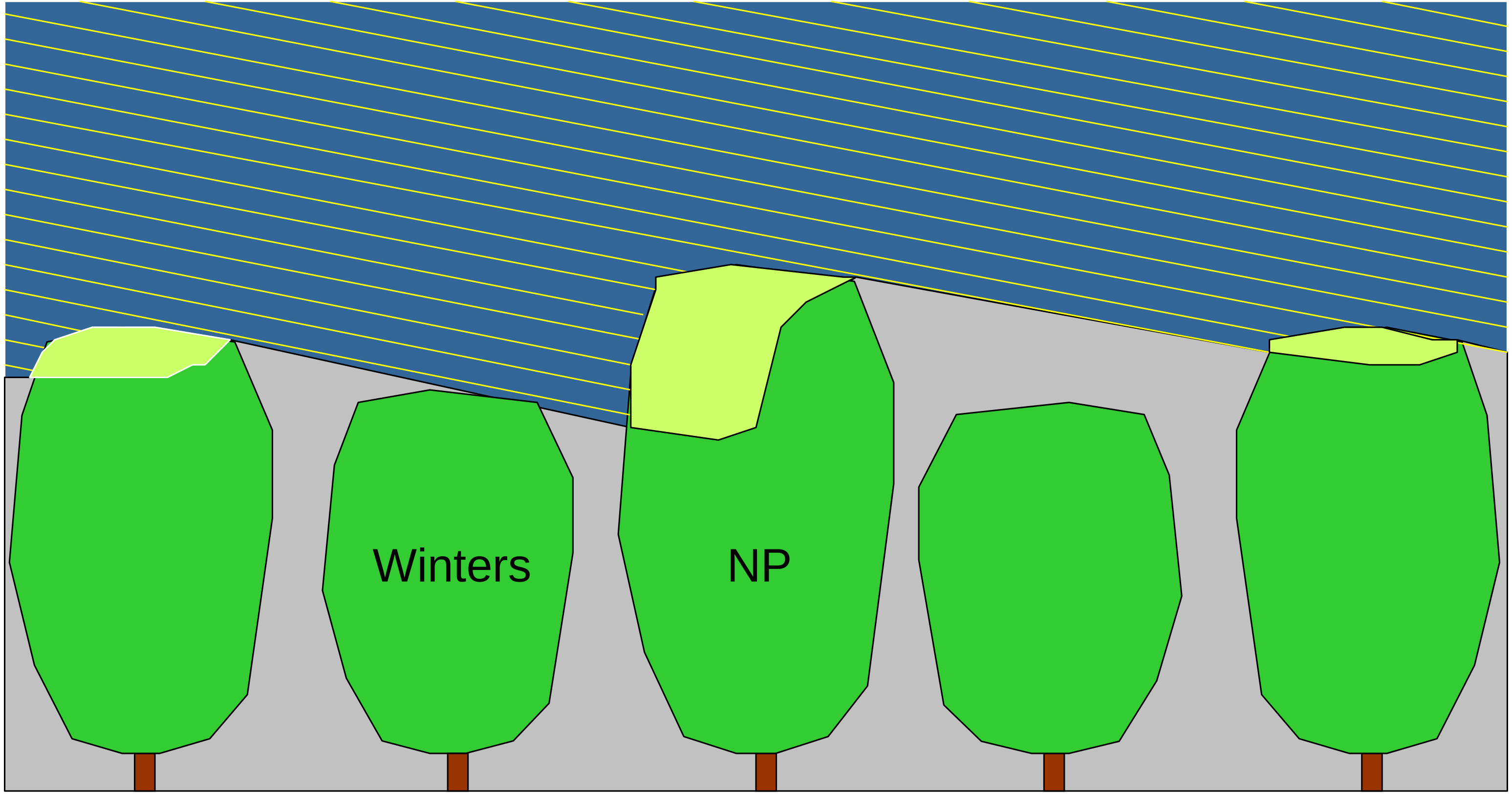
At midday tree height differences are irrelevant



Mid-morning and mid-afternoon, taller trees capture more light



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GoPro camera images of orchard floor shadows taken (2 photos per second)

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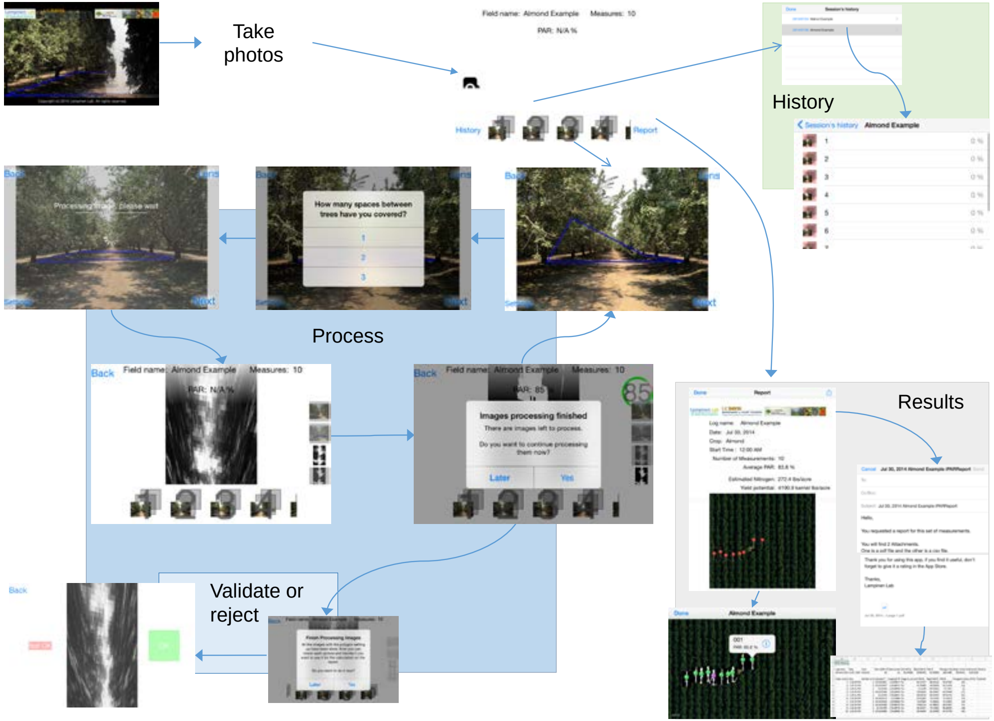
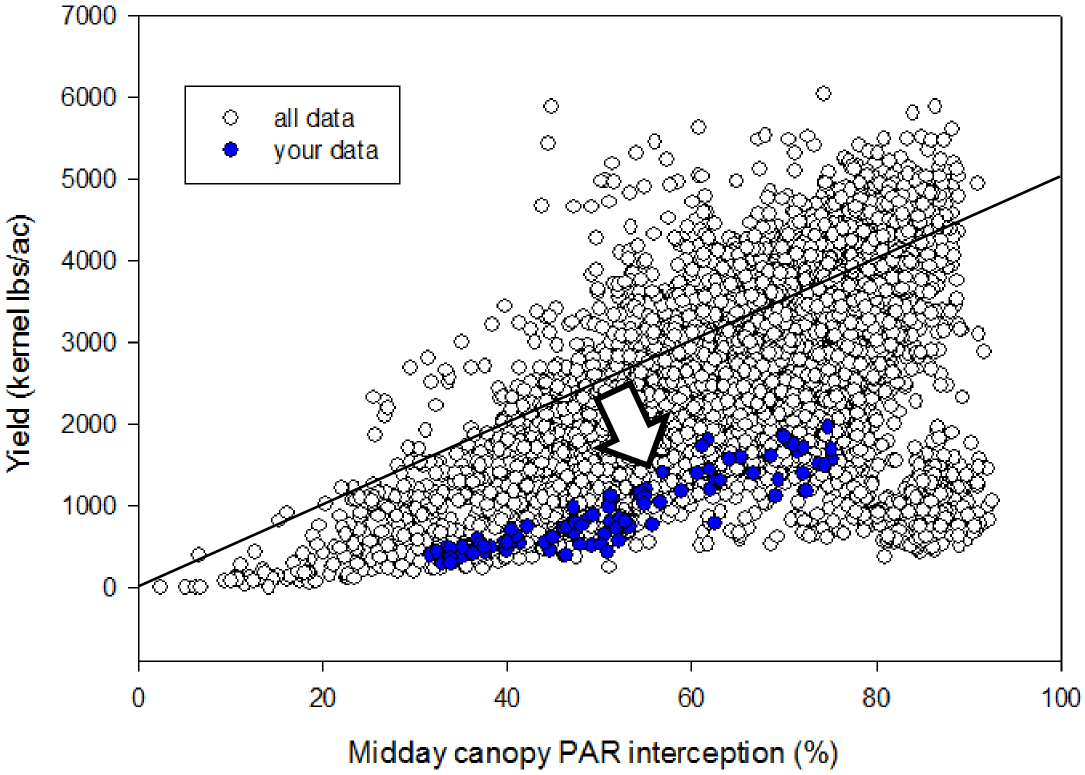
GoPro camera images of orchard floor shadows taken (2 photos per second)

These photos of ground shadows were used to calibrate iPhone app

iPhone app is released on trial basis to farm advisors and select growers and should be in the Apple store in the next couple of months



iPhone app will allow you to assess your orchard performance



Orchard well below line?
Usual reasons

- Irrigation problems?
- Pruning?
- Nutrition problems?
- Poor bloom weather?

More information on the iPhone app at poster session as well as at the Lampinen lab website-
http://ucanr.edu/sites/LampinenLab/Canopy_Management/iPAR/

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Shrini Upadhyaya,
University of California, Davis

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A Leaf Monitoring System for Continuous Measurement of Plant Water Status to Assist with Irrigation Management of Specialty Crops

- Shrini K. Upadhyaya, Professor; Francisco Rojo, Post Doc; Seluk Ozmen, Visiting Scholar; Erin Kizer, Graduate Student; Channing Ko-Madden, Under Graduate Student; Mike Delwiche, Emeritus Prof., Bio. And Agr. Eng. Dept.

- Bruce Lampinen, Ext. Specialist, Plant Sciences Dept.

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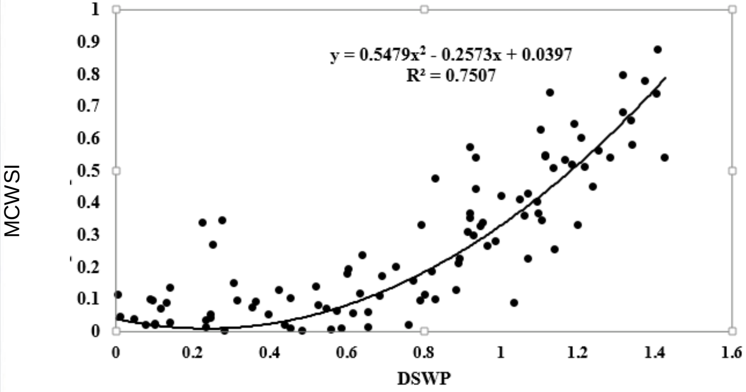
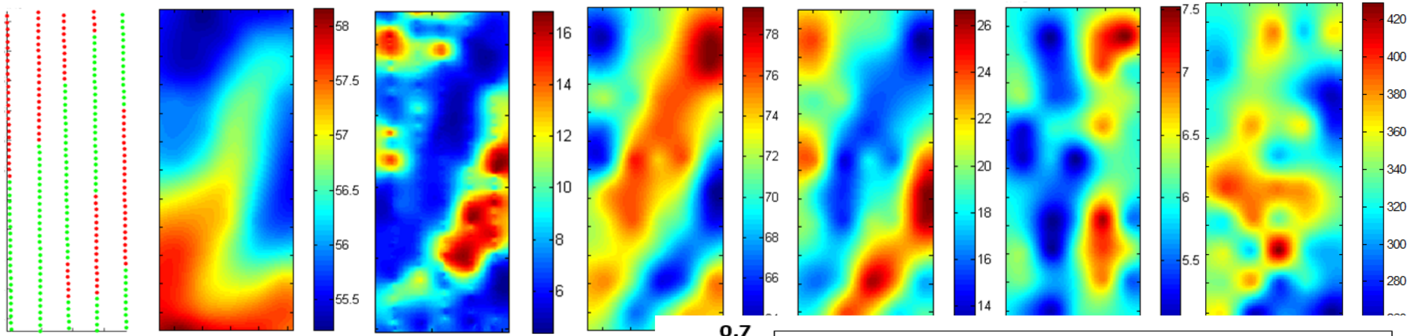
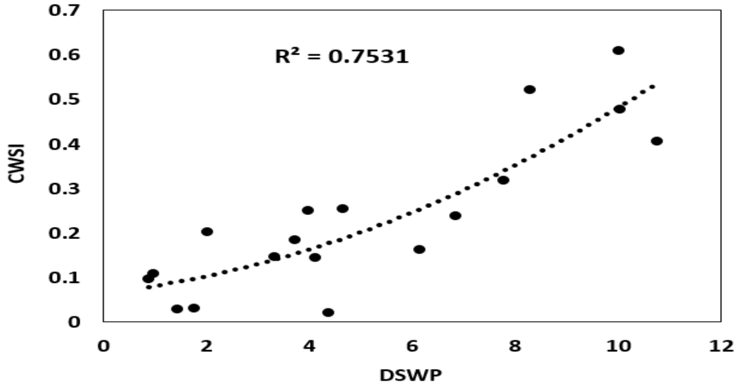
Soil Moisture/ Plant water Status

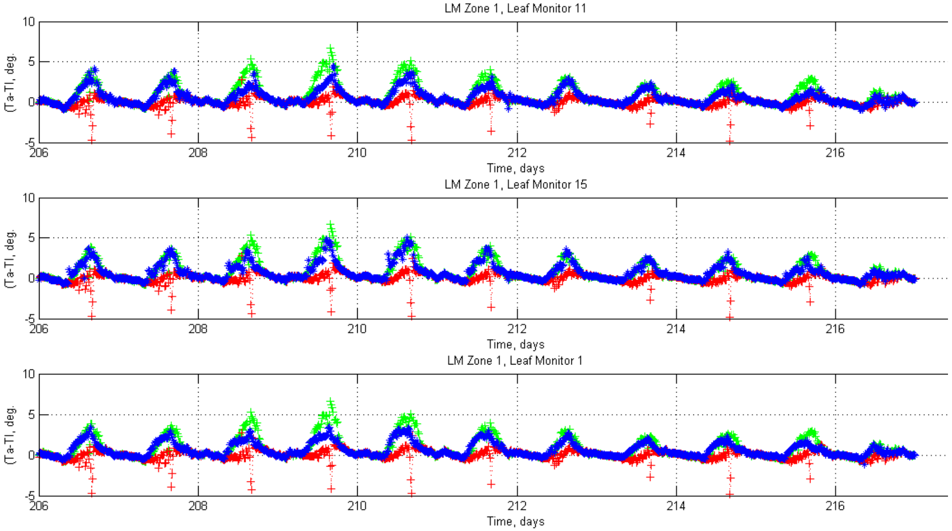


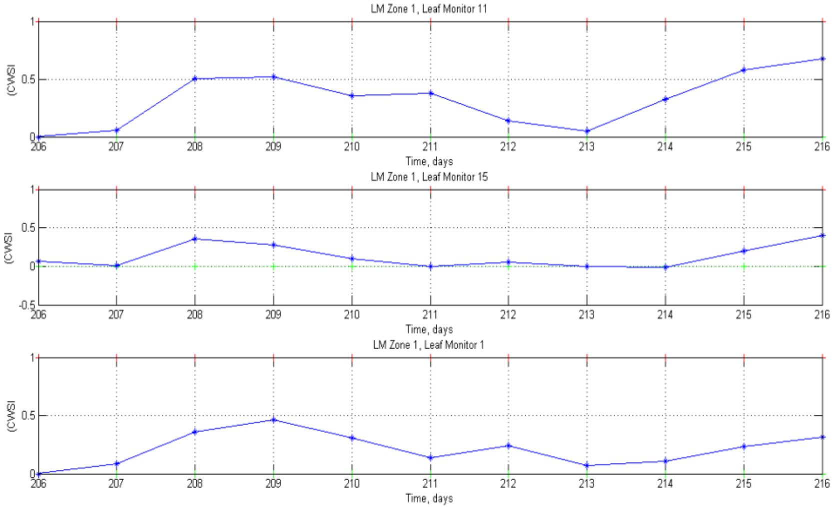
Management Zone based Precision Irrigation





Tree Response to Irrigation in Zone #1





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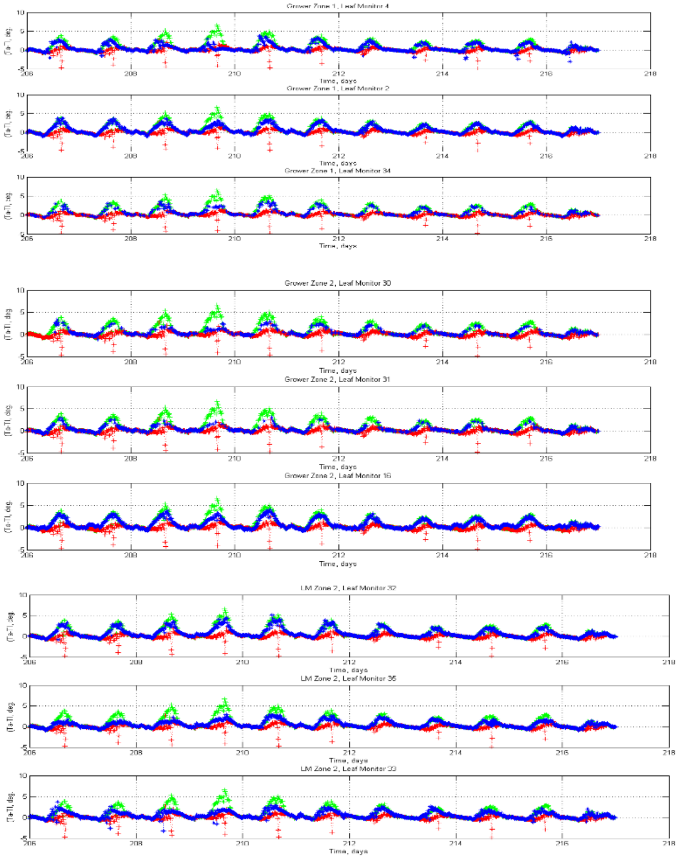
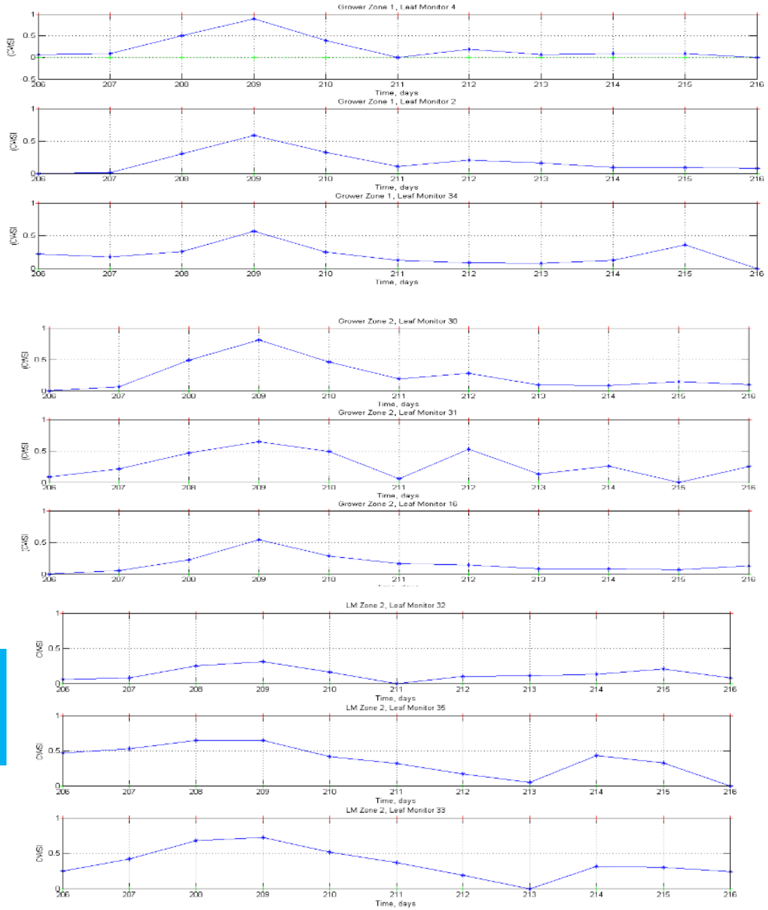
Otl



Stress Based Zone 1

Grower Zone 1

Grower Zone 2



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Results/Conclusions

Zone 1: 80% of ET or 70% of grower application
Zone 2: 105% of ET or 90% of grower application

Acknowledgements
CDFA & Almond Board of California

Thank You!

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Matthew Gilbert,
University of California, Davis

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Applying new sap flow technology to almonds (2015)
and
Evaluation of almond leaf heat tolerance (2014)

Matthew E. Gilbert, Heather Vice and Nicolas Bambach
Dept. Plant Sciences, UC Davis

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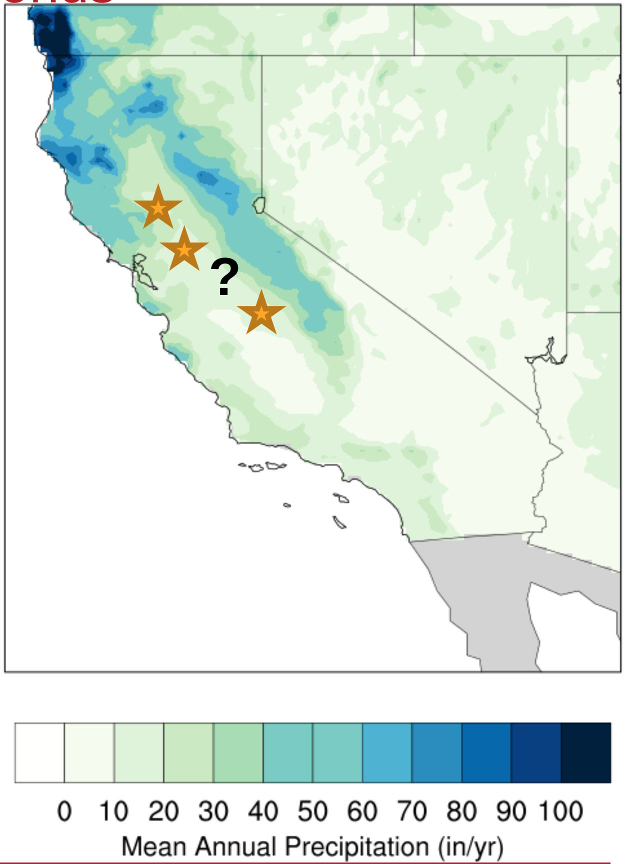
Applying a new sap flow technology to almonds

- Why is a new technology needed?
- Where can it be used?
- How does it work?
- What will it be used for?



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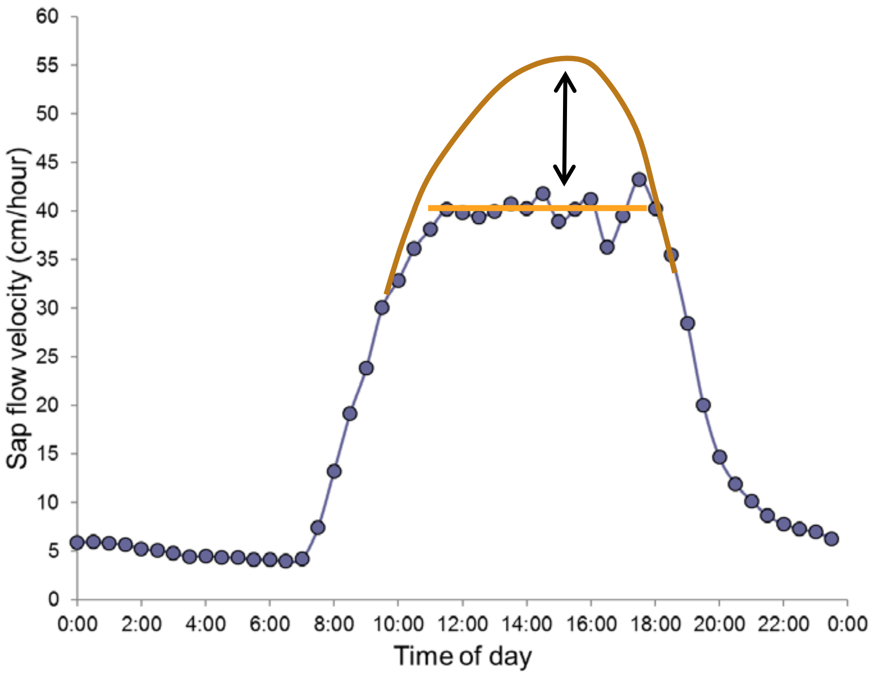

Data courtesy of Gerardo Spinelli

Applying a new sap flow technology to almonds

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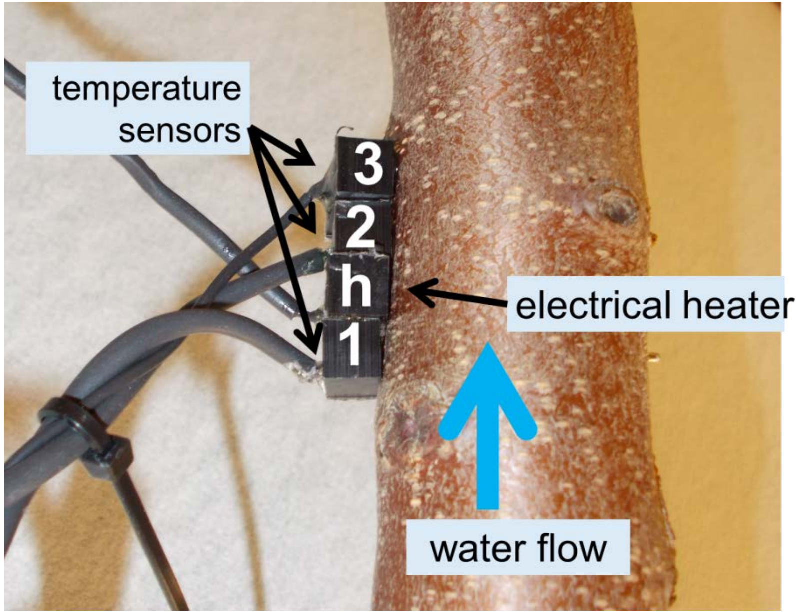

Sensors constructed by Heather Vice

Applying a new sap flow technology to almonds

- Why is a new technology needed?
- Where can it be used?
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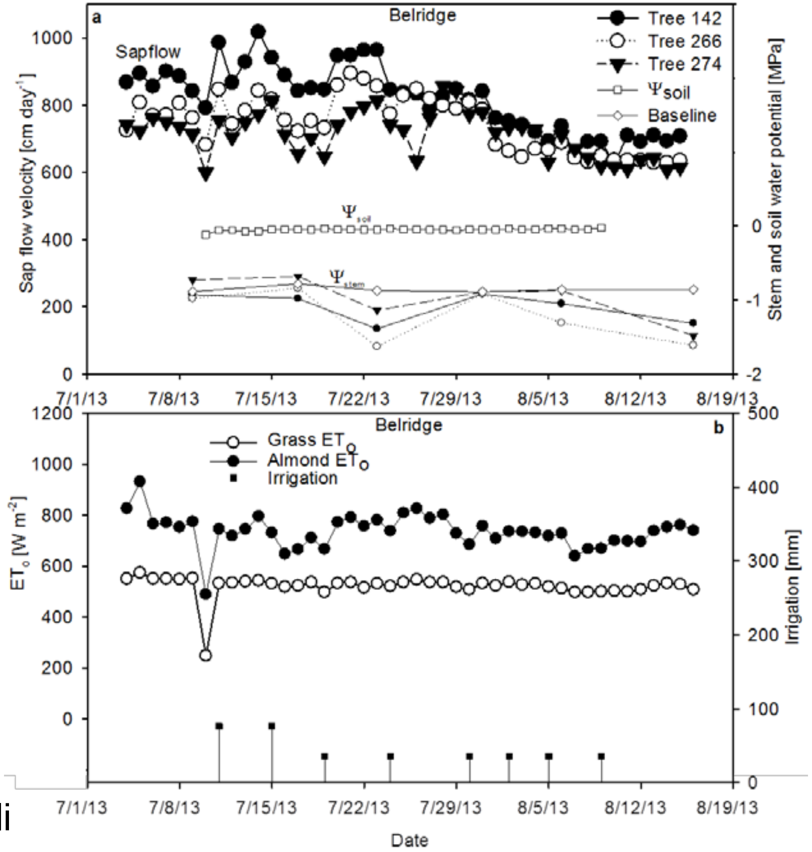
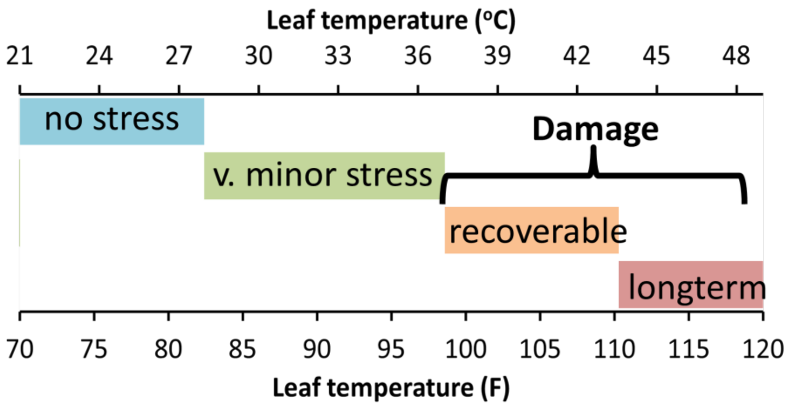


From Gerardo Spinelli

Evaluation of almond leaf heat tolerance

- What does leaf heat tolerance mean?
- How does it vary between available almond varieties?



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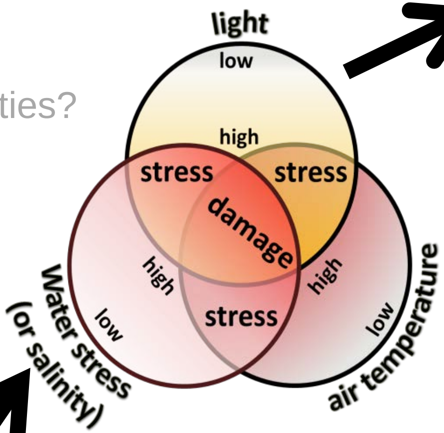

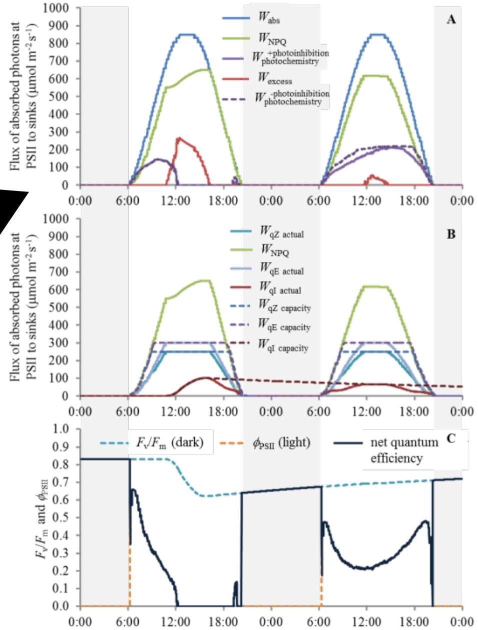

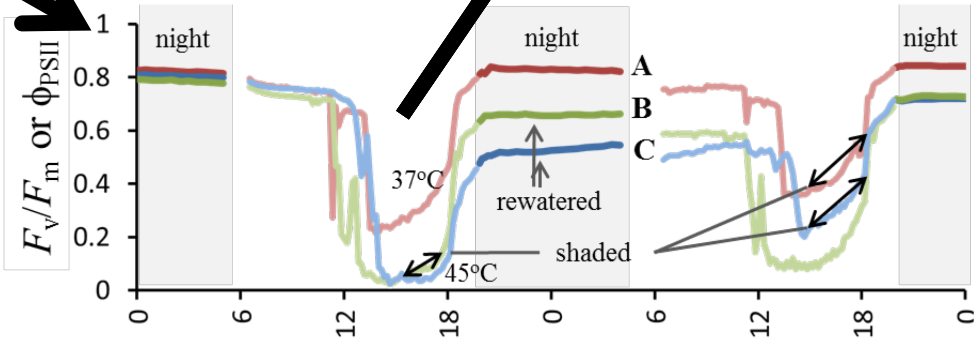

Modeling by
Nicolas Bambach

Heat tolerance

- What does leaf heat tolerance mean?
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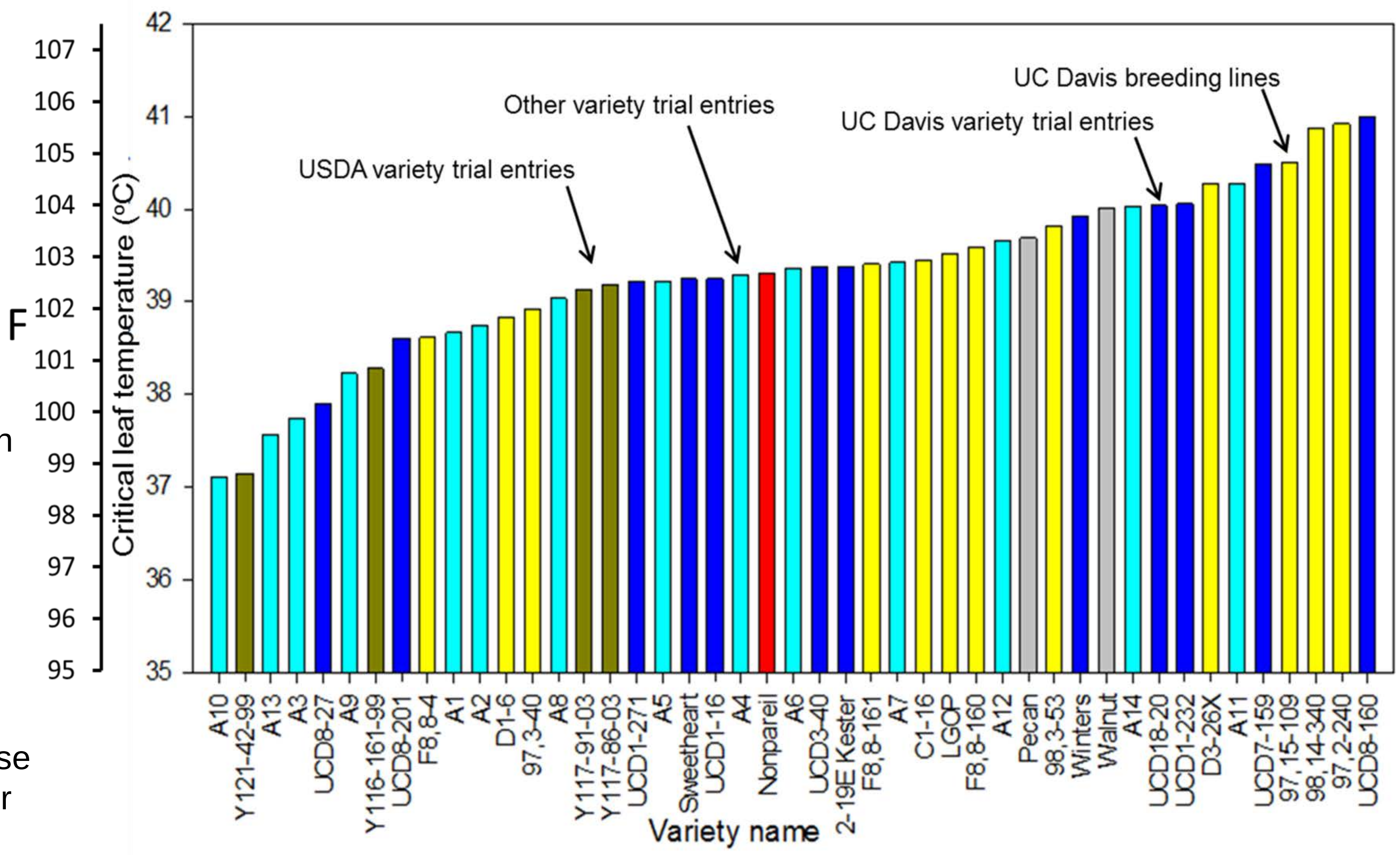

Thanks to:
Tom Gradziel
Richard Rosecranse
Franz Niederholzer
Craig Ledbetter

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Ken Shackel,
University of California, Davis

Winter Water Management in Almond

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2 “Goldilocks” questions about winter soil water and almonds:

1) How much water is too much?

- If fully dormant almonds (Dec/Jan) can tolerate saturated soil conditions, maybe we can use almond orchards as groundwater recharge sites.

- This project is currently sampling soils and instrumenting 3 field sites to test this idea, no results yet. Helen Dahlke and others are discussing groundwater recharge today, 3:00 – 3:45 in room 307

2) How much water is not enough?

- When should growers consider winter irrigation?

- The same field sites will be used to winter irrigate if it is a dry winter, but in the meantime we are testing if potted plants can be used to answer this question.

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Using a cover crop to dry the soil of a dormant potted almond tree.

(February/March, 2015)

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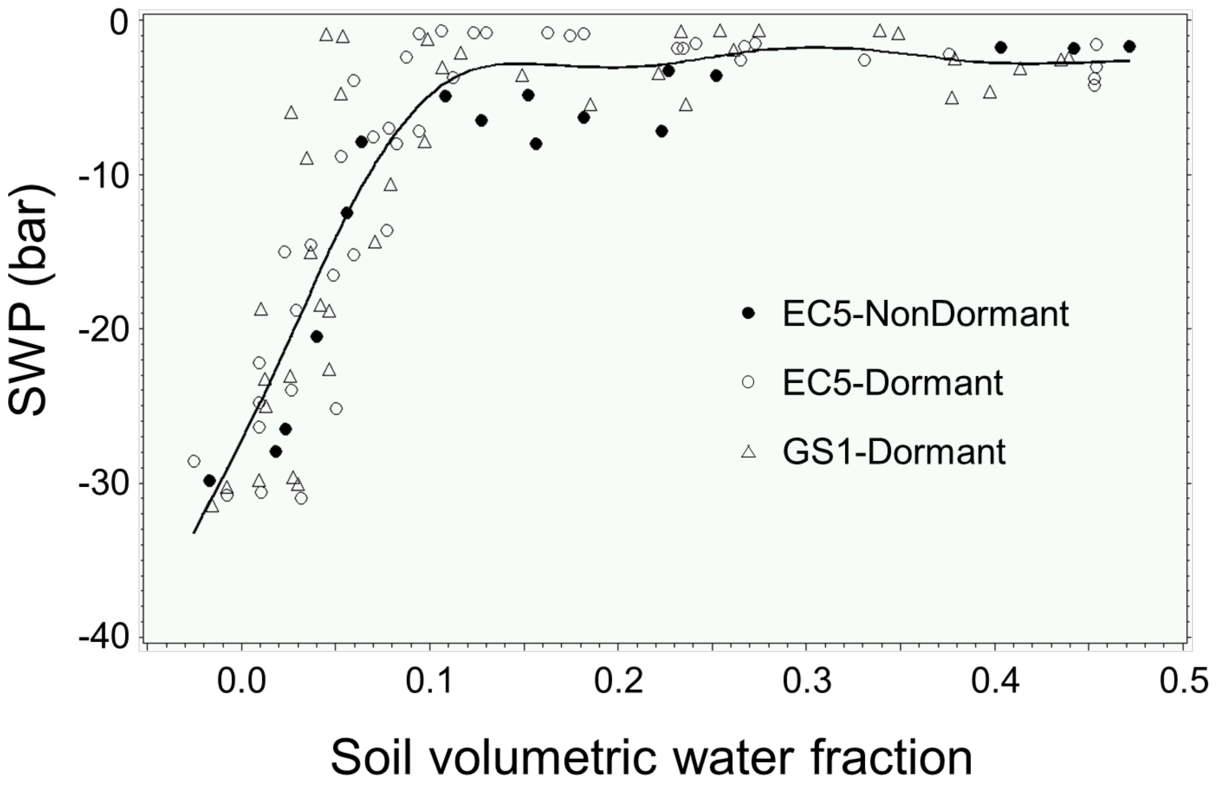
As soil dries, so does the tree, whether the tree is dormant or not.



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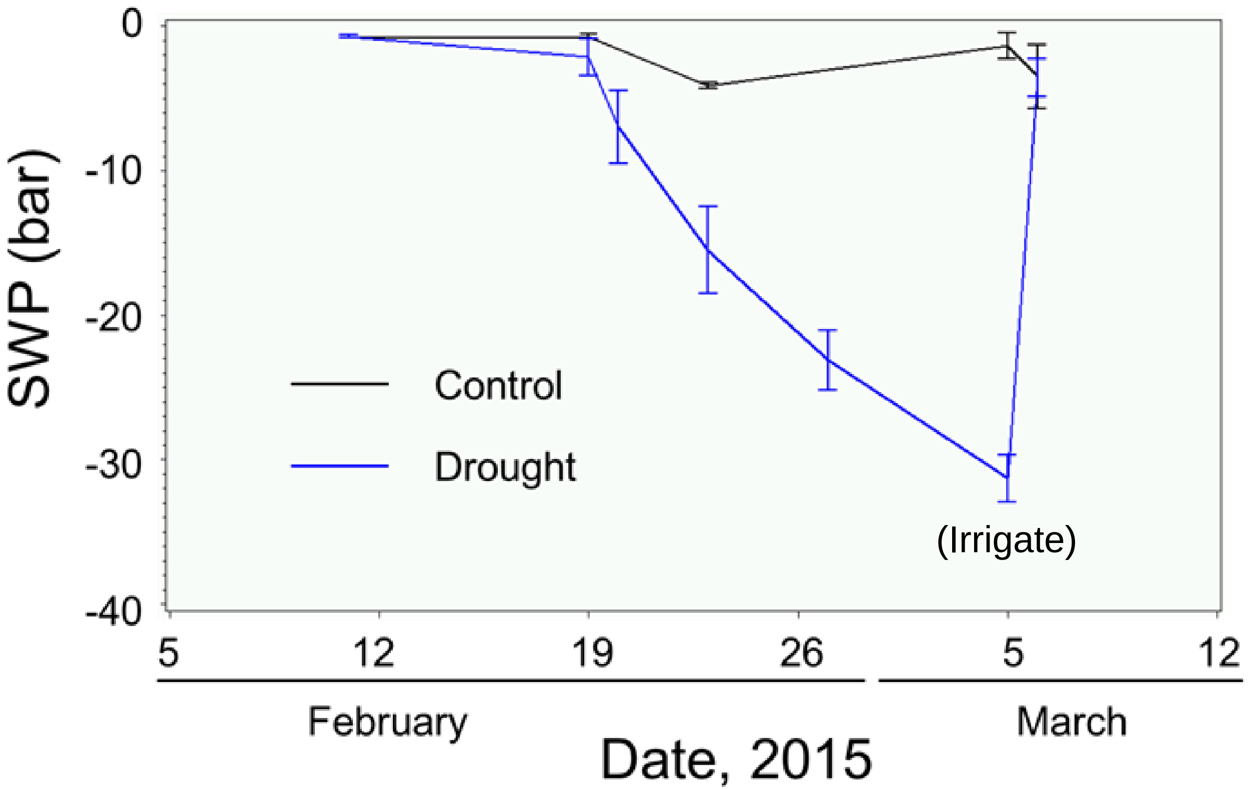
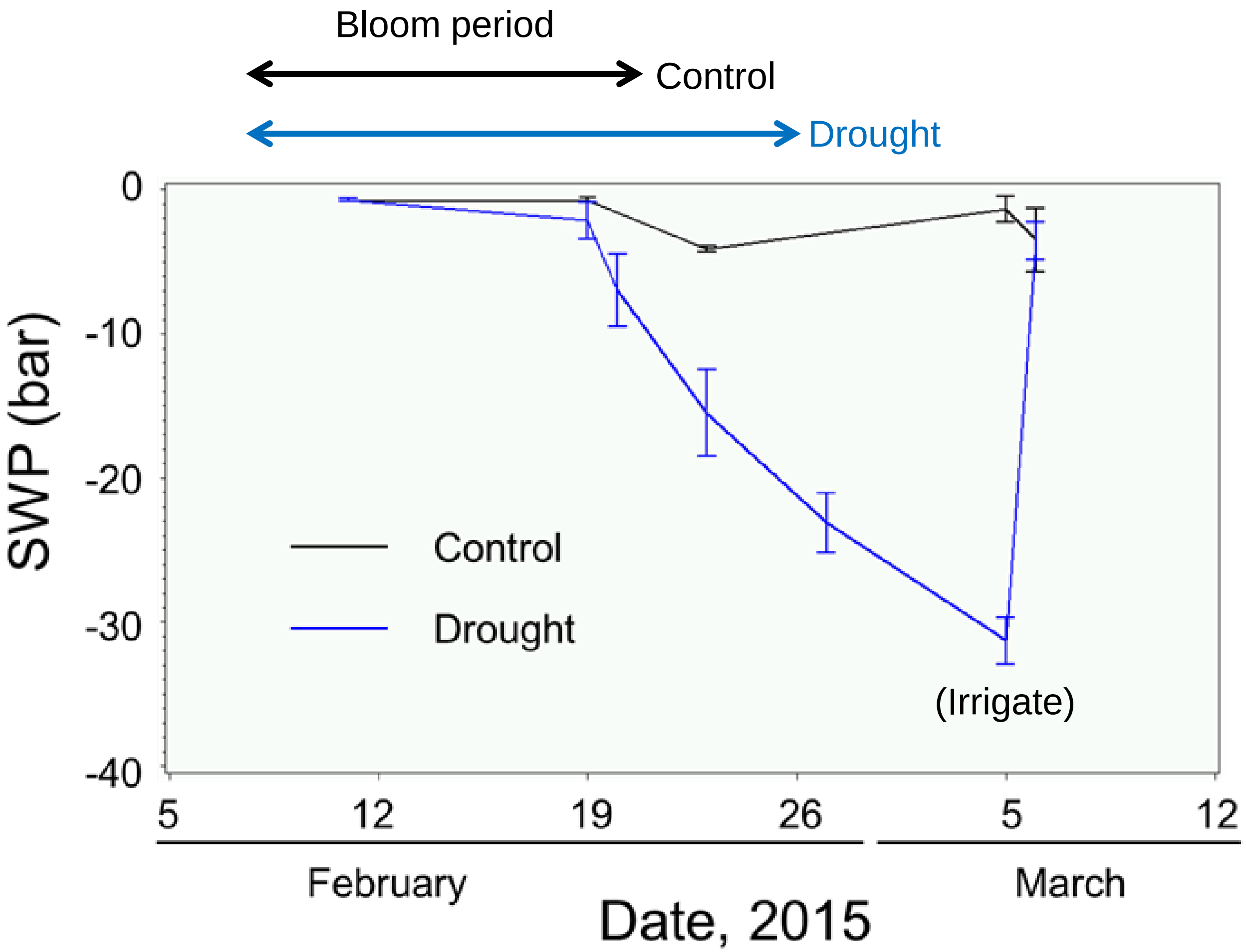
Trees in the drought treatment became progressively more stressed over time.



Trees in the drought treatment became progressively more stressed over time.

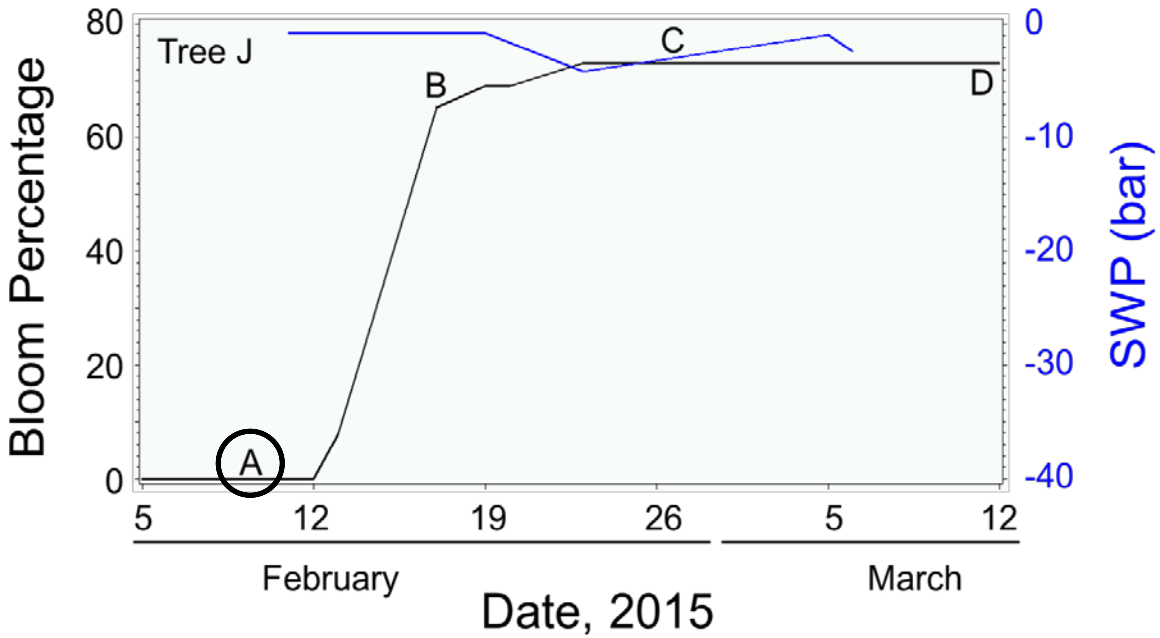
Drought reduced bloom, but also appeared to delay bloom development.

Different trees dried at different rates.



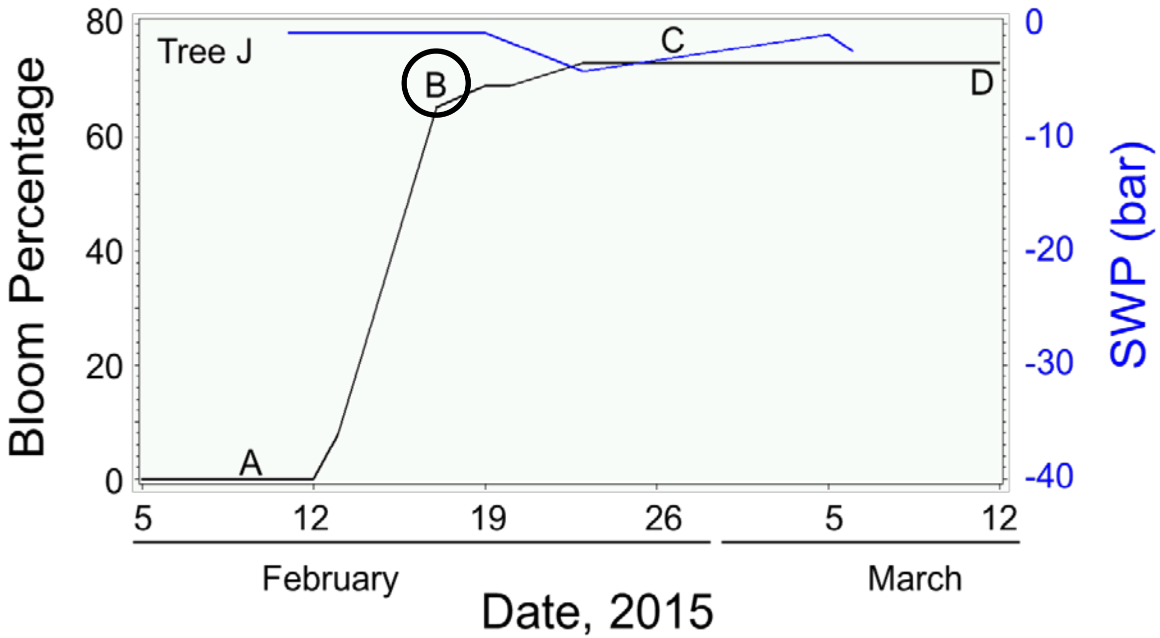
Progress of bloom for a control tree.

A: Flowering buds
N=26 (Feb 09)



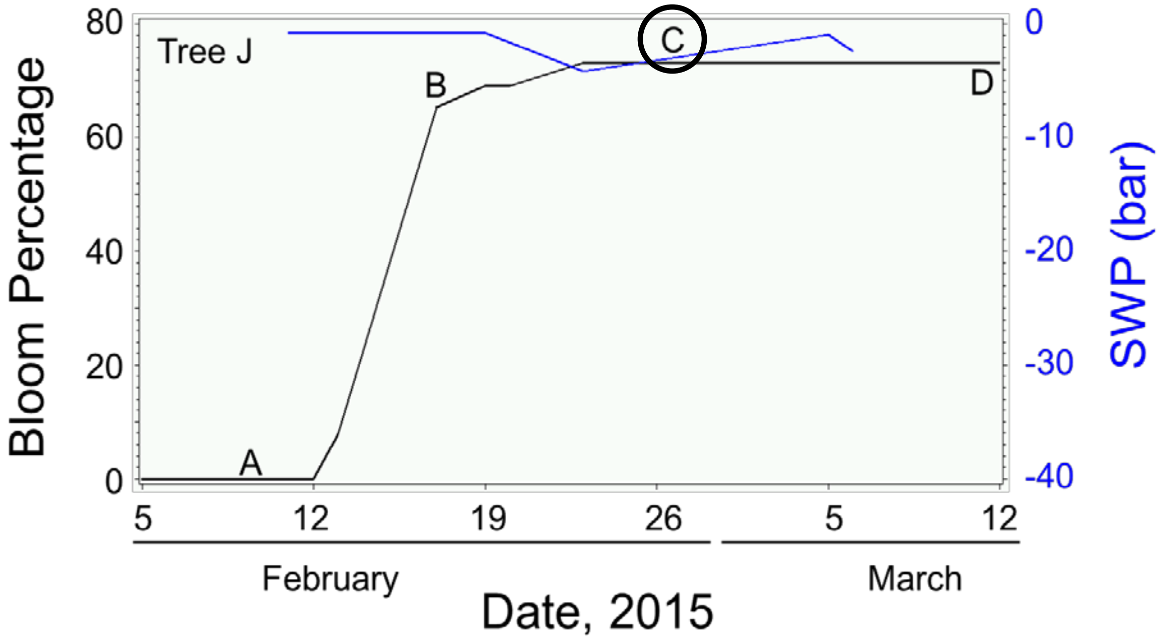
Progress of bloom for a control tree.

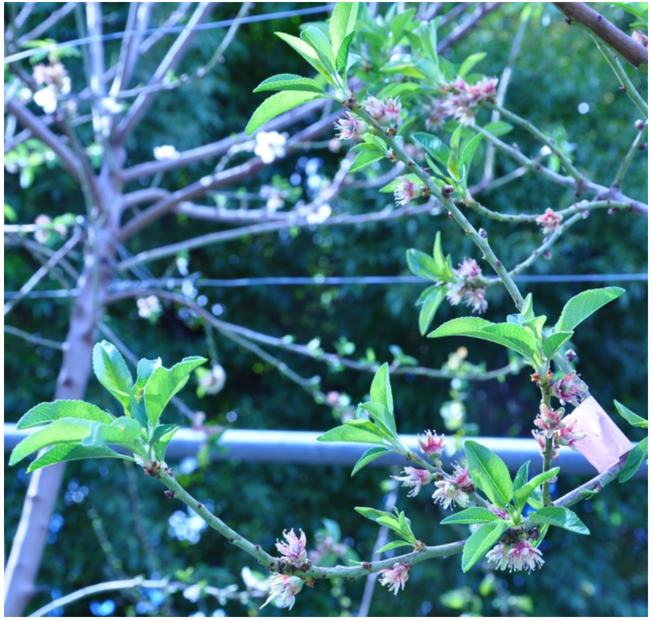
B: Bloomed
n=17 (Feb 17)



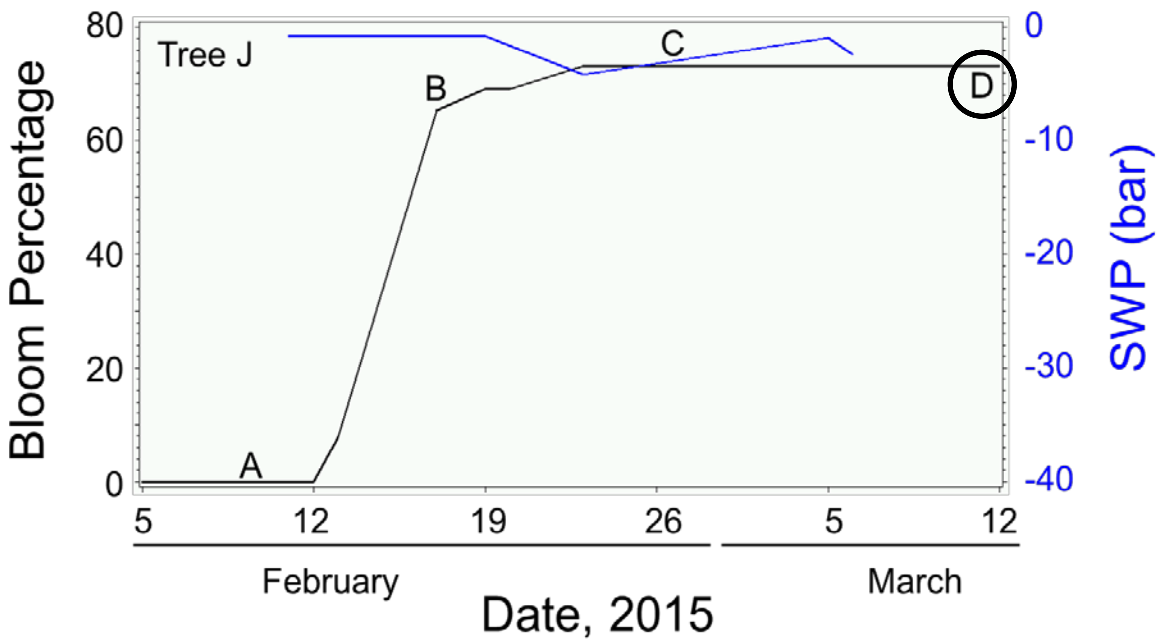
Progress of bloom for a control tree.

C: Bloomed
n=19 (Feb 27)



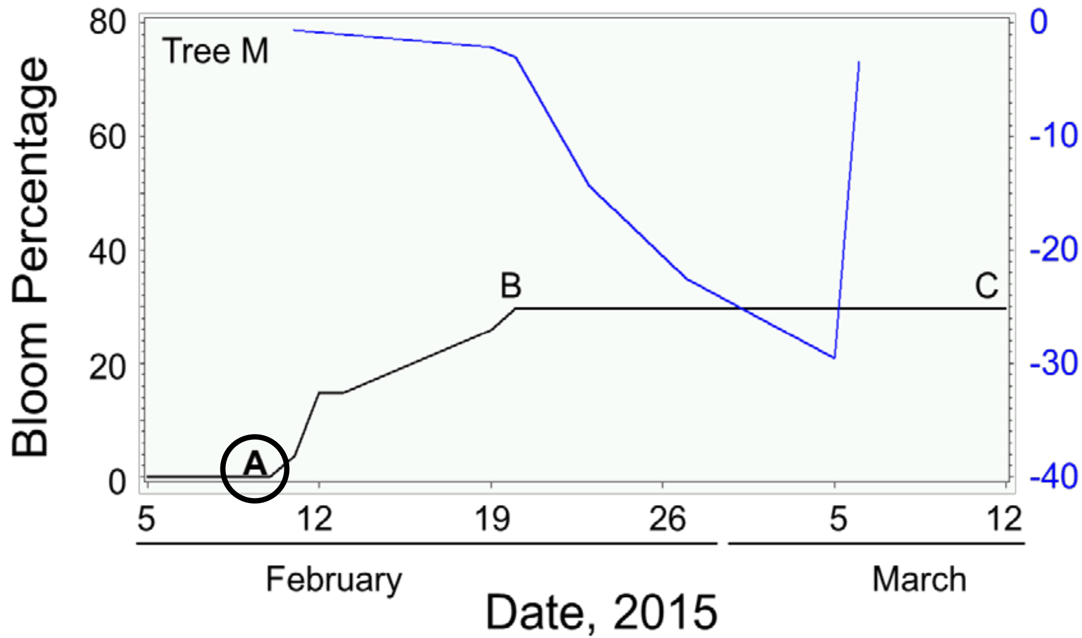


Progress of bloom for a control tree.



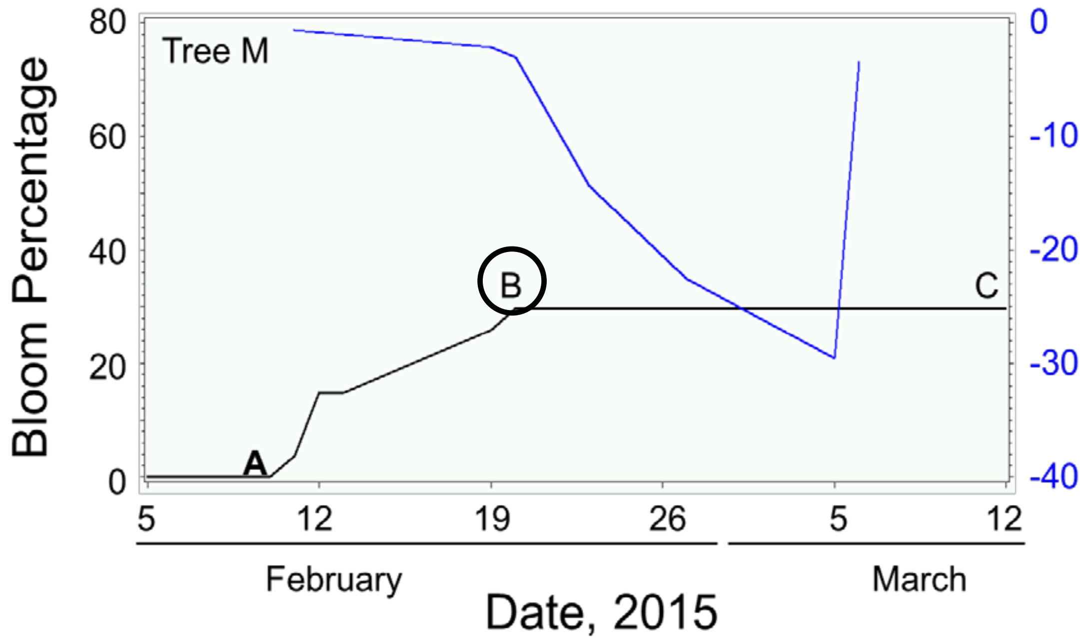
D: Nut set
(Mar 12)

Progress of bloom for a drought tree.



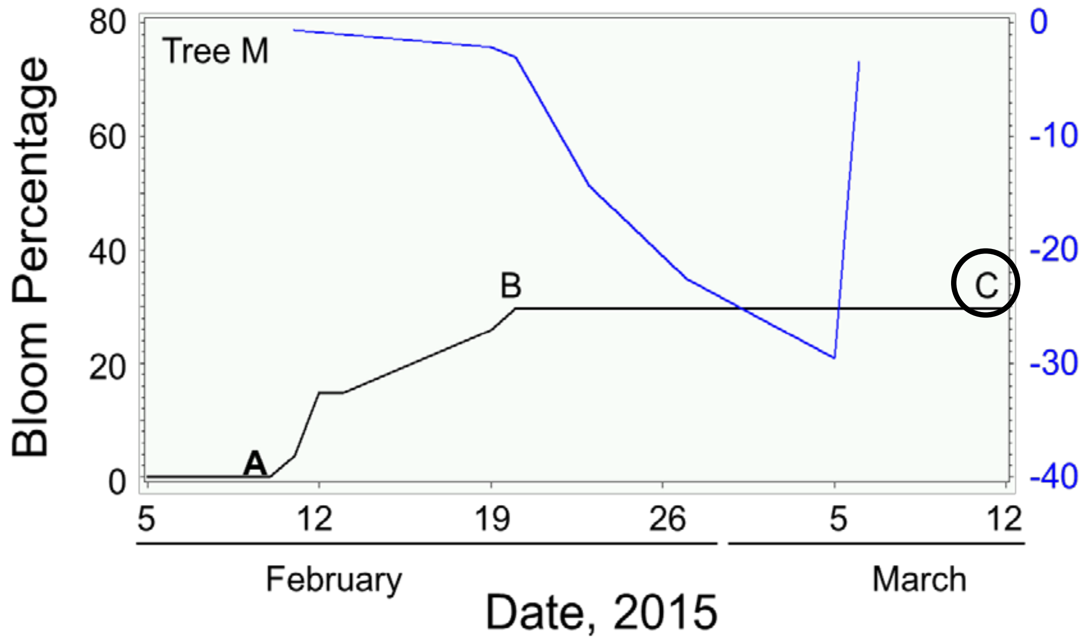
A: Flowering buds
N=27 (Feb 10)

Progress of bloom for a drought tree.



B: Bloomed
n=8 (Feb 20)

Progress of bloom for a drought tree.



C: (No nut set on any drought tree)

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Observations and preliminary conclusions:

1) Water stress during bloom reduced bloom % and prevented set.

2) Some bloom did open at -20 bar SWP (!), and leafout also occurred.

- This suggests that prior to bloom, during dormancy, flower and vegetative buds may be fairly tolerant of water stress.

3) If so, growers may be able to wait longer in the winter before considering the need for a winter irrigation.

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Thanks to my cooperators:

Jiong Fei
Bruce Lampinen
Astrid Volder
Helen Dhalke

Thanks for your support and attention!

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Whole Tree Response to Water Stress

Question: how much water stress does it take to reduce orchard ET?

1) Imposing mild/moderate water stress (14-18 bars) at hull split is beneficial (less hull rot, better harvestability).

2) Is it valid to claim that almond orchards actually use less water at that time because of this practice?

3) Are the current estimates of almond Kc accurate?

The only <u>direct</u> method to measure ET: a **lysimeter**.

(Kearny Ag. Center, Fresno)

Big enough for trees

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3 acres.

Orchard: 50% Nonpareil, 25% Wood Colony, 25% Monterey.

Planted: Feb 3, 2015.

Photo: August 26, 2015.

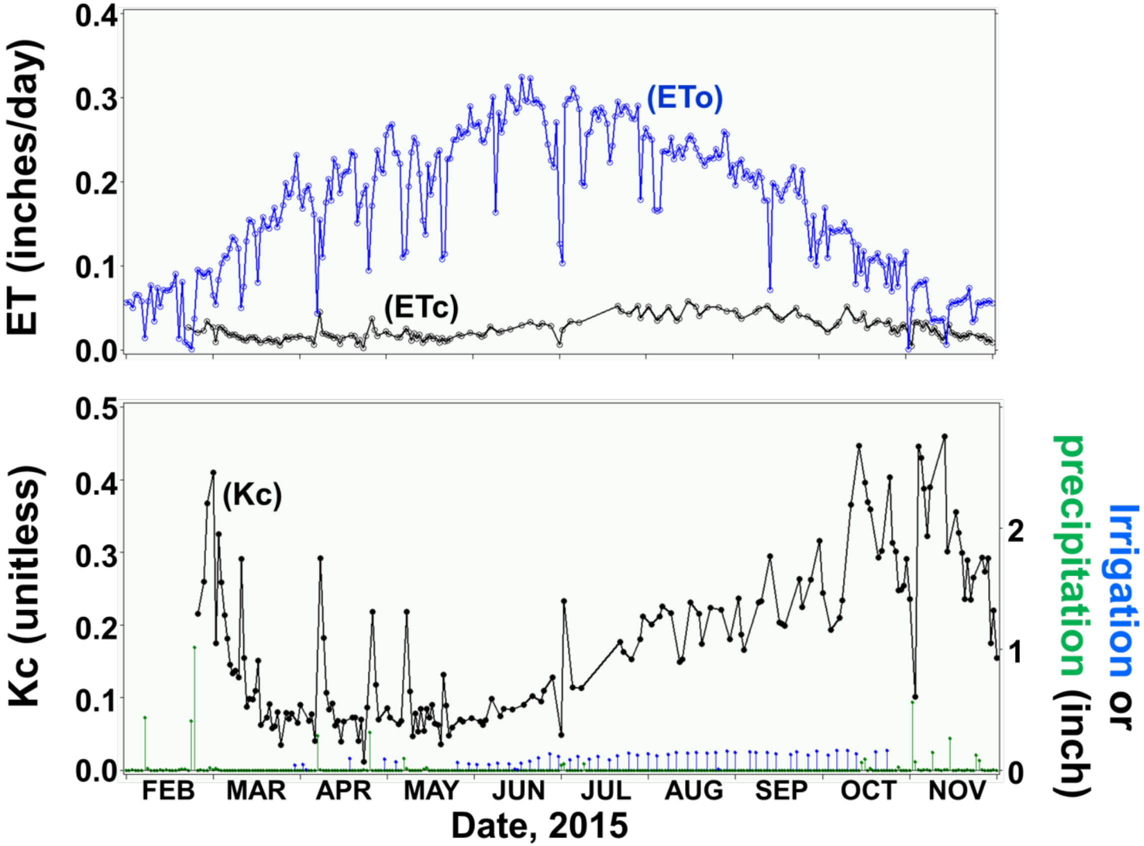
Plan: establish the orchard first, then impose stress.

First year ET data.

Reference (ETo) data is from Parlier CIMIS.

Young almond tree ETc starts at about 0.1”/week, climbing to about 0.35”/week, as canopy grows.

Kc shows peaks when soil evaporation is high (rain).



Even though we didn't <u>plan</u> on imposing any water stress, some trees were more stressed than others, and showed less vigorous growth.

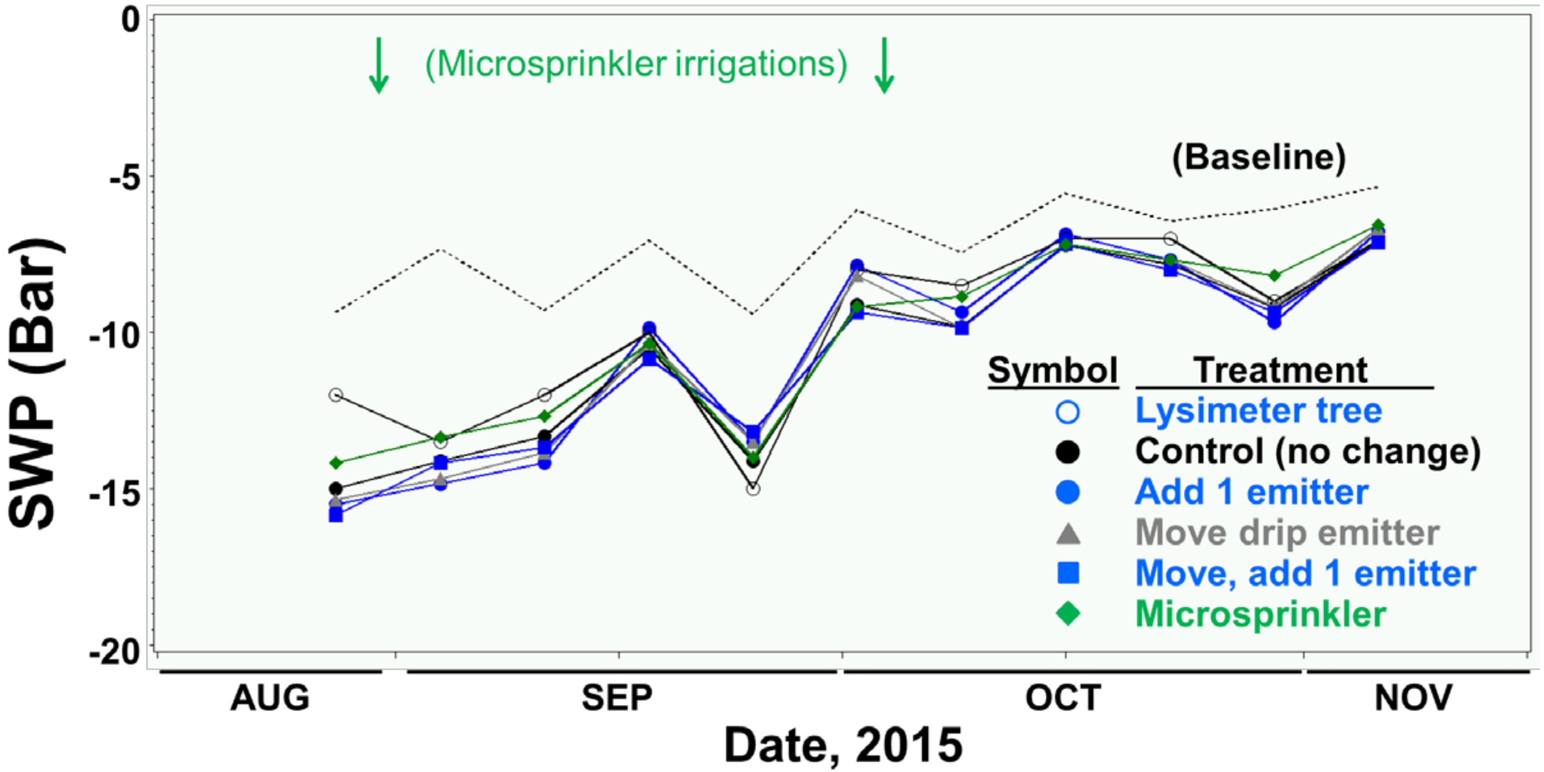
Tree #1:
SWP through May: -12.6 bar
Emitter flow: 2.20 gph

Tree #2:
SWP through May: -9.3 bar
Emitter flow: 2.16 gph

In late August, some irrigation tests were performed on border trees.

36h microsprinkler irrigation
(4” of water)

Increasing water (a lot) had no effect. No easy answer yet.



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Observations and preliminary conclusions:

1) The lysimster scale is working properly and giving reliable data.

2) Most trees reached a height of about 8’, so 1st year growth was OK.

3) The reason(s) for lower-than-baseline SWP for much of the season is not clear. Nearby established (3ed leaf) almonds showed baseline values in the spring, when the 1st year trees were below baseline.

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Thanks to my cooperators:

Gurreet Brarr
Bruce Lampinen
Jim Ayars

Thanks for your support and attention!

Almond Water Production Function

Question: how does almond yield respond to water?

How much irrigation is required for maximum yield?

Is it the same on different soils?

Do you get the same ‘crop per drop’ as irrigation increases?

…etc…

Best estimate so far: about 70 kernel pounds per acre increase for every inch of water

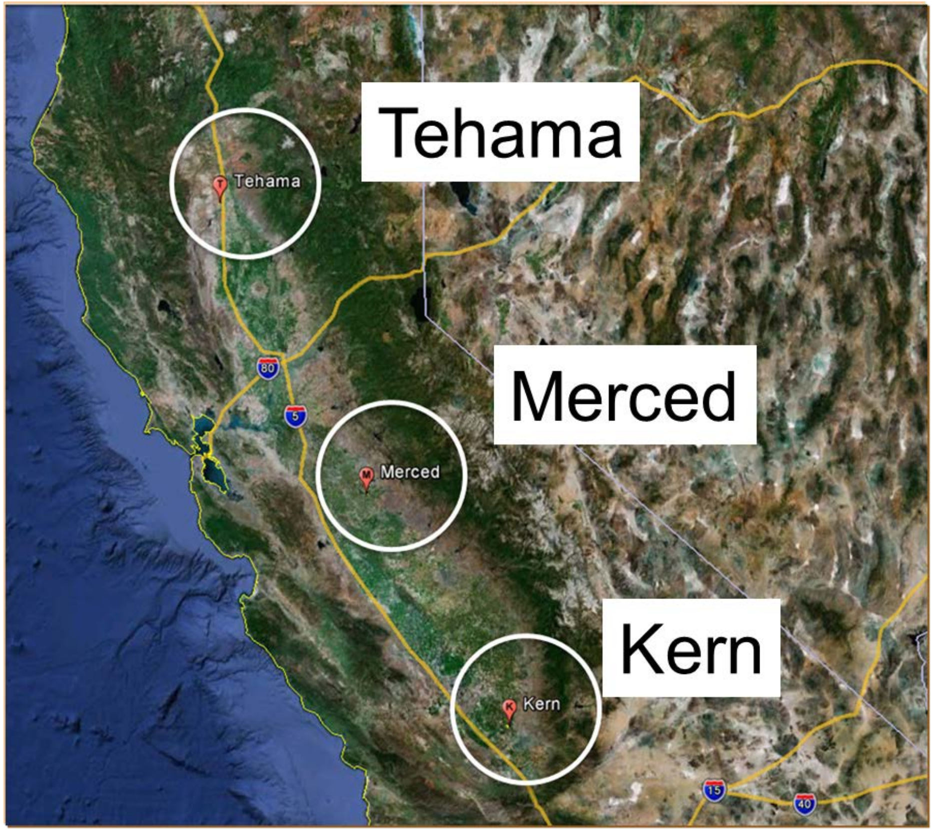
Water production function

3 sites.

3-4 irrigation levels per site, range: 70% to 110% ET.

Irrigation treatments since 2013.

Yield since 2012 (pre-treatment).



Irrigation treatments and irrigation range in 2015

Treatment target (%ET)	Applied water (inch) March 1 - September 1		
	Kern	Merced	Tehama
110	43.4	42.8	34.9
100	41.3	41.0	29.2
90	35.7	35.0	24.0
80	32.1	30.6	22.0
70	26.8	30.3	
High to Low Difference	16.6”	12.5”	12.9”

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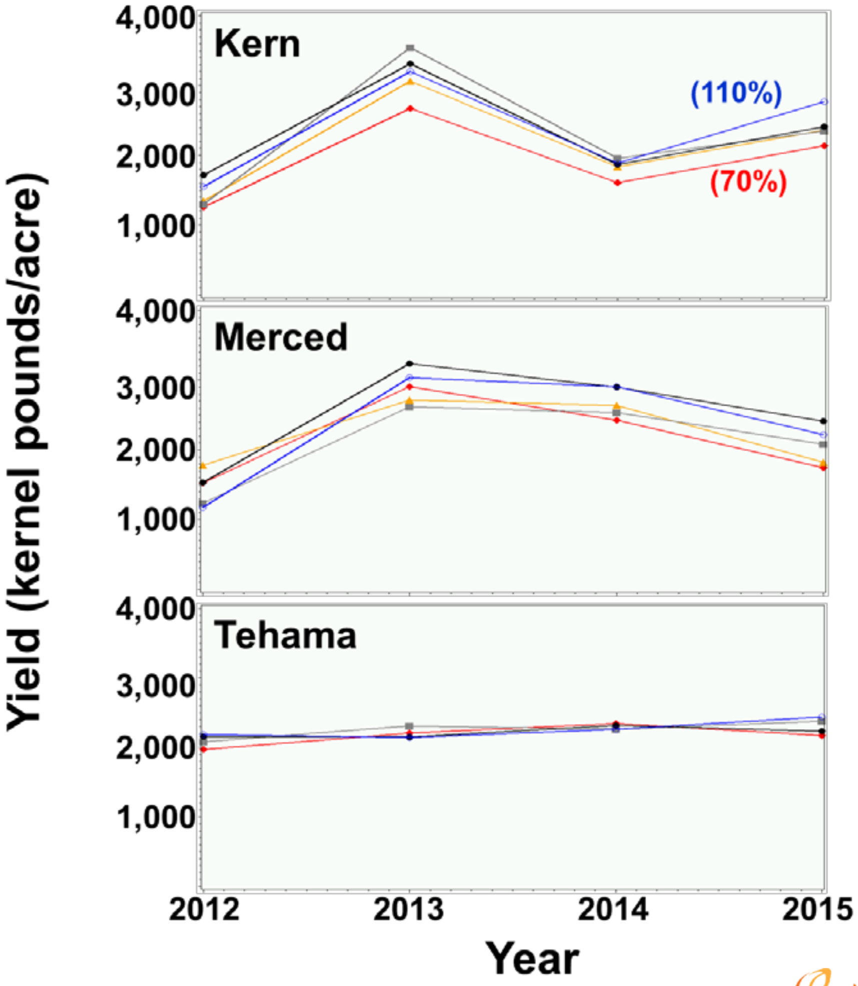
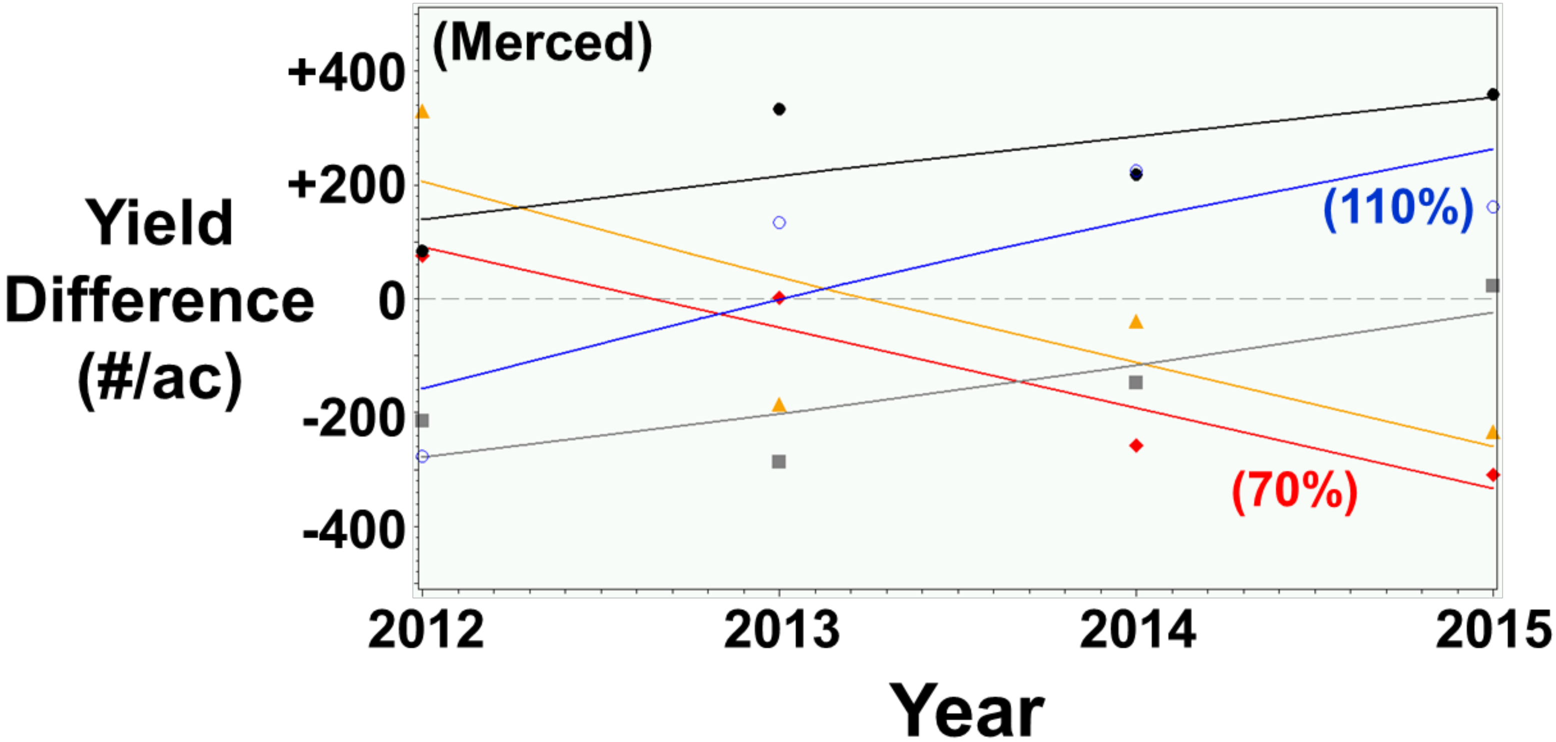
Yield patterns



Trend analysis: yearly difference between the treatment yield and the mean yield



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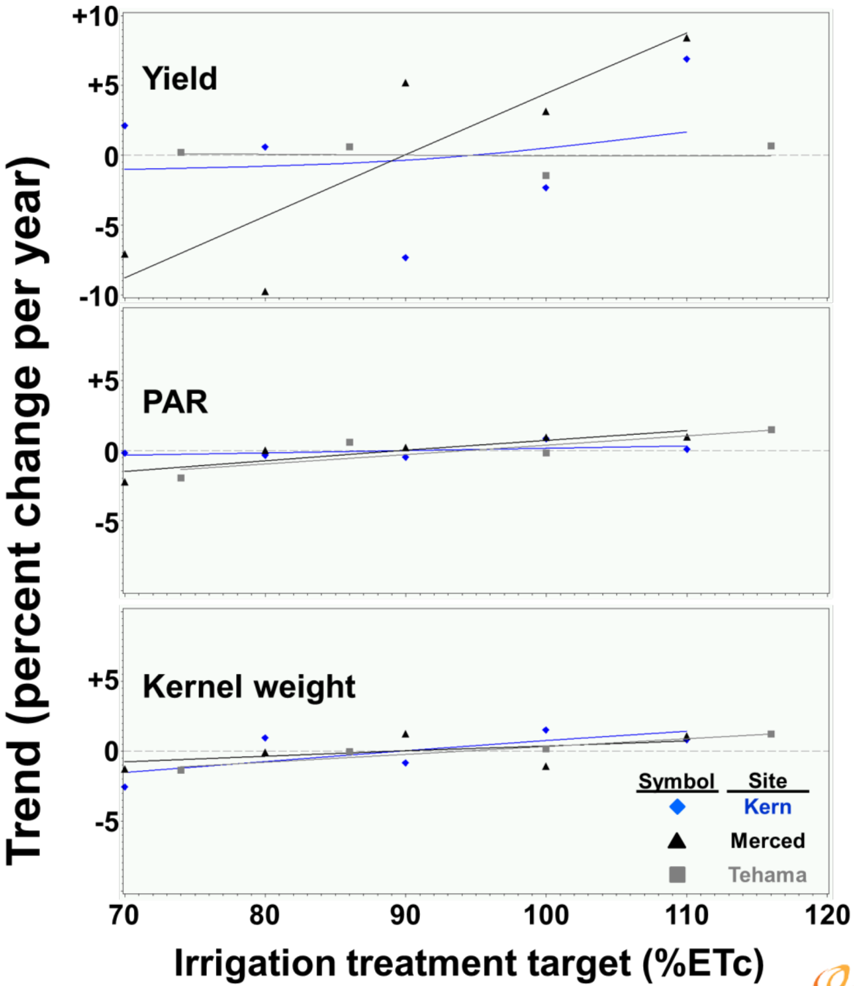
Yield: Merced is the only site showing a clear trend of increasing yield with more water.

PAR: Only Merced and Tehama show small increases in canopy with more water.

Kernel weight: All sites show small increases in kernel weight with more water.



Conclusions thus far: is water “Different strokes for different folks?”

1) Yield may be responsive to water in some locations, not others.

- Tree physiology (SWP) and kernel weight have been responsive at all locations, so it is important to determine what yield components are/are not changing and why.

2) None of the orchards have consistently achieved 50# per percent PAR.

- Determining the reasons for this are very important to the industry, particularly so that a valid “Crop per Drop” calculation can be made.

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Thanks to my cooperators:

Dave Doll
Allan Fulton
Bruce Lampinen
Blake Sanden

Thanks for your support and attention!

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Astrid Volder,
University of California, Davis

growing ADVANTAGE
The Almond Conference

Impact of Drought Stress on Roots

Fine roots

- Vast majority of absorptive surface are fine roots (<0.5 mm diameter)
- Lack of suberization and small diameter may leave fine roots vulnerable to drought
- Different types of drought may differentially impact fine roots
  - Severe drought may kill fine roots
  - Chronic mild drought (deficit irrigation) may alter root traits (diameter distribution, suberization)
- Suberized and/or larger diameter roots have reduced absorptive capacity

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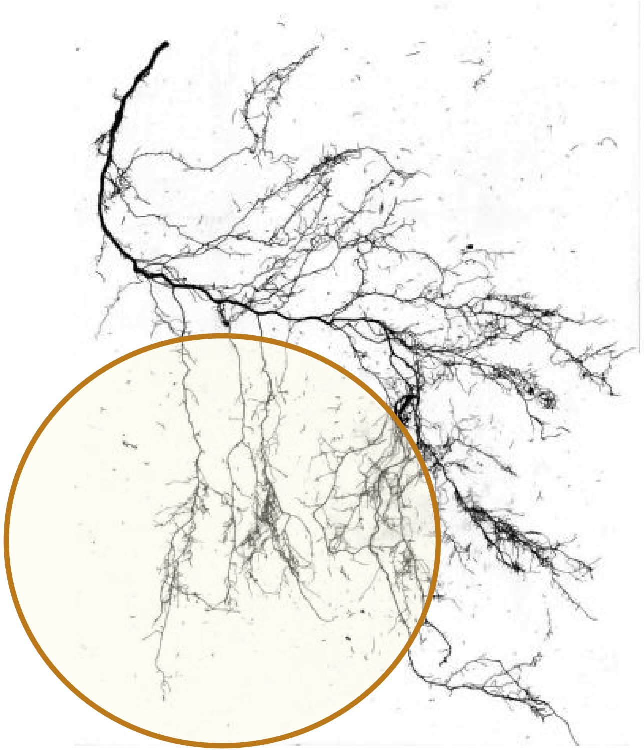
Root classification

Most external roots = absorptive roots



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Objectives:

Survey fine root traits in existing irrigation trials

- Samples collected in Merced in July, November and March

Impact of irrigation on the ability of roots to acquire water & nutrients

- Established controlled test site at UC Davis
- 360 trees, comparing bare root versus potted trees (root pruning vs ellepot)
- Krimsky 86 rootstock, Nonpareil, Wood Colony and Monterey
- Edge row heading/pruning experiment in 2015

- Irrigation treatments to be started in 2016

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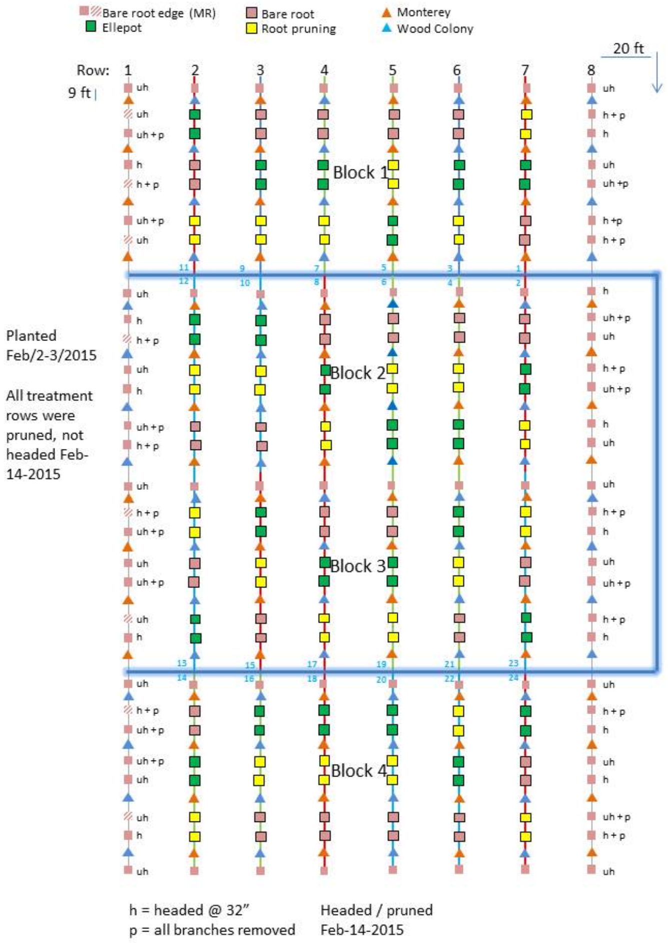
Edge row heading/pruning experiment

- Planted Feb 2/3
- Four treatments (imposed Feb 14)
  - Headed at 32” (laterals below heading height left on)
  - Headed & pruned
  - Pruned, but not headed
  - Not headed or pruned
- Data collected:
  - Diameter growth
  - Stem water potential
  - Root growth (start in June)



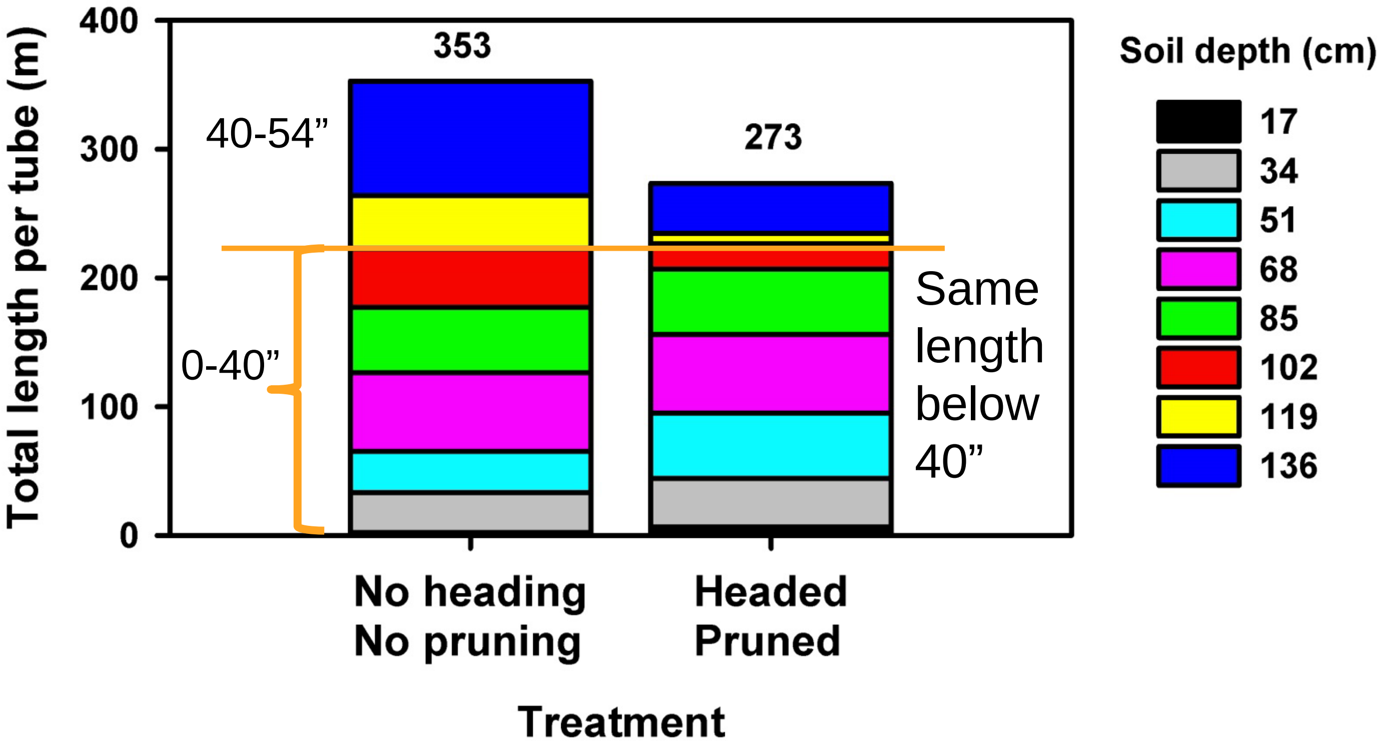

JOHN DEERE

One week interval

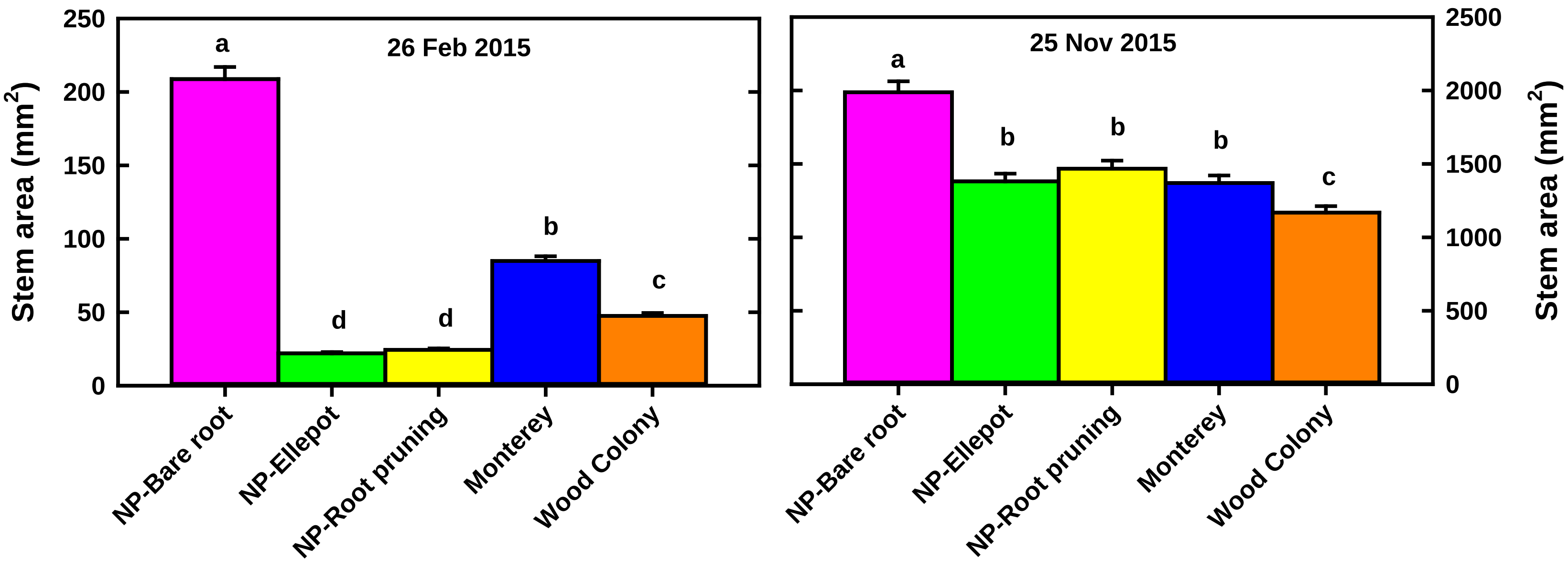
- fine laterals appear and disappear
- higher order root turns brown

In June, standing root length was reduced at depth in the headed/pruned trees

3 x more root length < 40” in unheaded & unpruned trees



Pot grown trees were the fastest growing trees



There was no effect of heading/pruning on stem area growth rate

Potential use of these data

- We will keep track of the longer-term development of the headed/pruned trees as well as the potted versus bare root trees
- These data will be used to develop a management strategy aimed at maintaining the most effective root system (not necessary highest root density) through
  - Water management
  - Canopy management
  - Nutrient management

Amelie Gaudin,
University of California, Davis

growing ADVANTAGE
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Building soil health to mitigate environmental stresses

Amélie Gaudin

Assistant Professor of Agroecology, Department of Plant Science UC Davis

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Complementary approaches to sustainable management

Eliminate/reduce pests	Decrease deficiencies and stresses	Improve tree traits / nut characteristics
Pesticides, repellents, IPM	*Water & nutrient management*	*Breeding & physiology*

↓

Developing best practices for tree nutrition and pest management

↑

Soil physical properties (Soil C)	⟲	Soil microbial communities	⟲	Nutrient and carbon cycling

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Research on how to build and harness benefits of greater soil health to decrease inputs and reduce stresses. *Practices - Practical, Profitable*

Soil physical properties (Soil C) ⟲ Soil microbial communities ⟲ Nutrient and carbon cycling

Sequester more carbon?
Decrease GHG emissions

Integrated nutrient management?
N regulation

Conserve more soil water?
Deficit irrigation, water shortages

Decrease host attractiveness?
Next generation IPM

Row crops / Integrated crop livestock systems
Cropping system diversity and organic amendments

United States Department of Agriculture
National Institute of Food and Agriculture

California Tomato Research Institute

Resilience to drought, insect pests and the virus they vector

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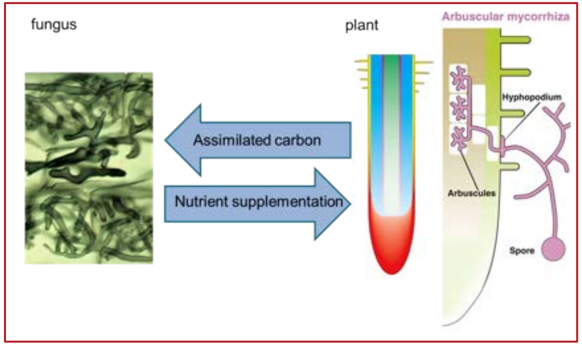
Potential of Mycorrhizae to Mitigate Water Stress in Almond

Astrid Volder, Bruce Lampinen et al



Promote interactions between almond trees and the soil microbial community to improve water and nutrient use efficiency

- Does mycorrhizal inoculation improve water/nutrient uptake and tree water status under water stress?
- Are roots of commercial almond orchards colonized ?
- Differences between rootstocks?
- Which management practices promote root colonization and benefits ? Soil carbon?

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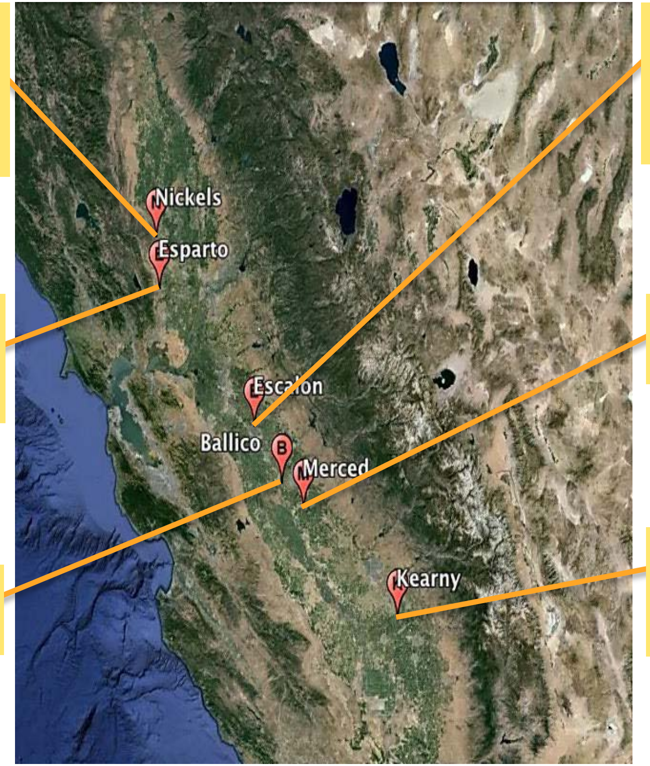
First survey of mycorrhizal colonization of almond orchards in CA

7 Rootstocks
Organic
Conventional
Nickels RS

Organic
Conventional
B.Paddock, L.Ralston

Fumigation
D.Doll



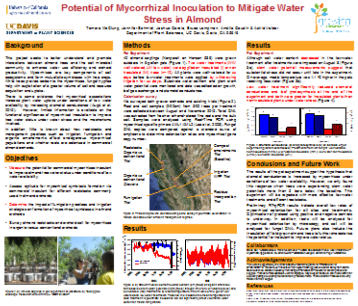
Compost amendments
D.Schellenberg, P.Brown

Irrigation
A.Volder

Residue incorporation
B.Holz

Pot experiment

Inoculated / non inoculated
Well watered / water stress



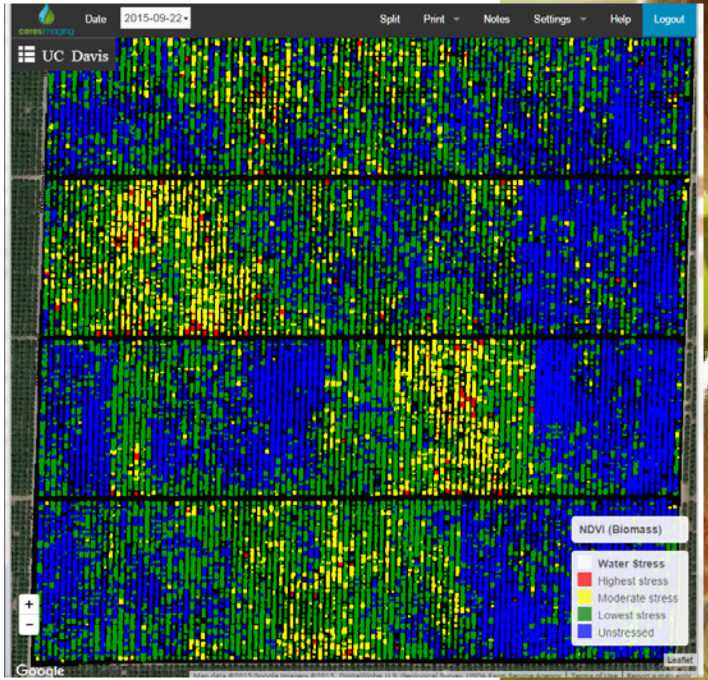
Location 69


Research and knowledge network on alternative orchard management practices
agaudin@ucdavis.edu
Web: gaudin.ucdavis.edu

Blake Sanden,
UCCE – Kern County

Remote Sensing for Tree Water Stress Using Aerial Imagery

Blake Sanden
UCCE Irrigation/Soils Advisor, Kern Co.



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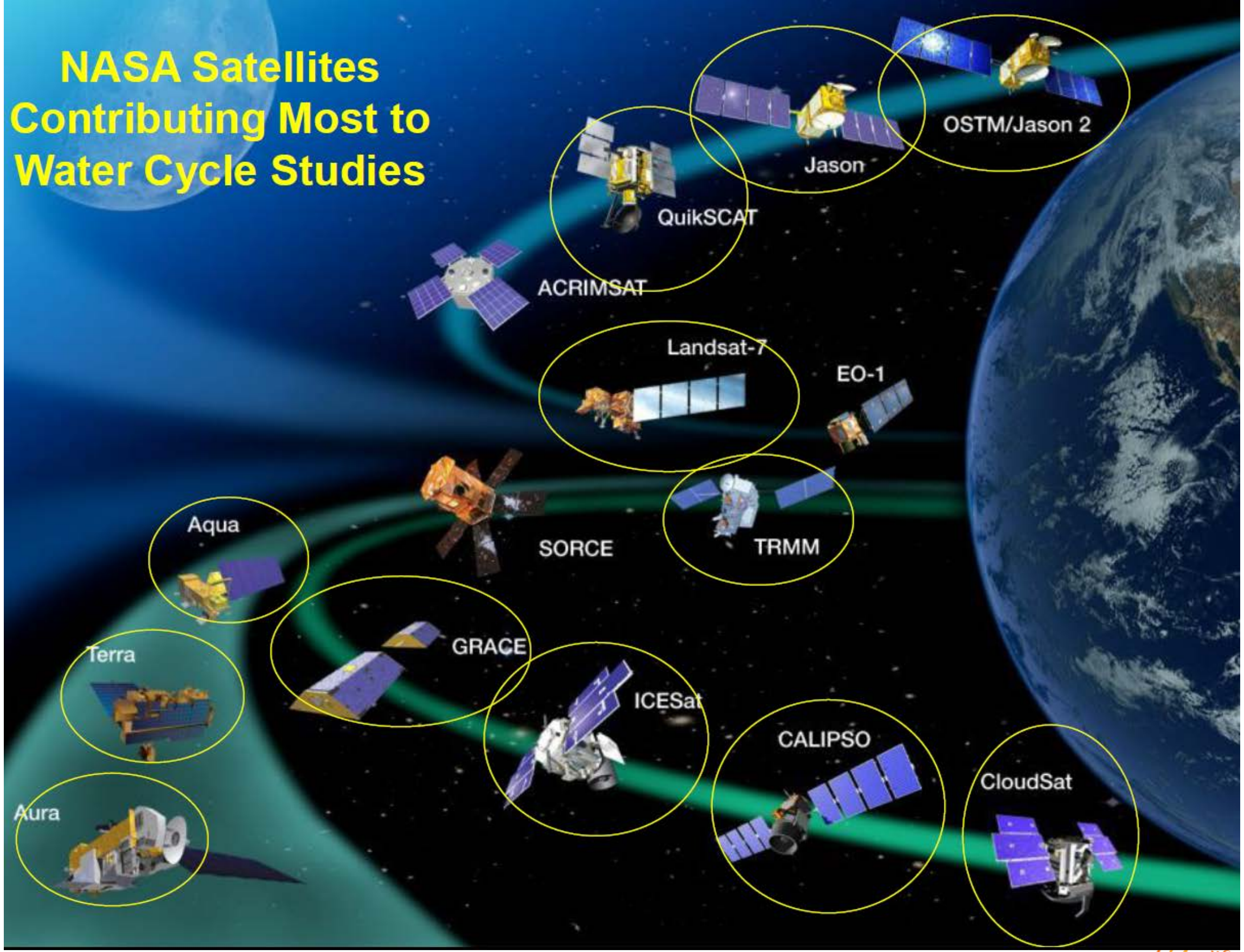
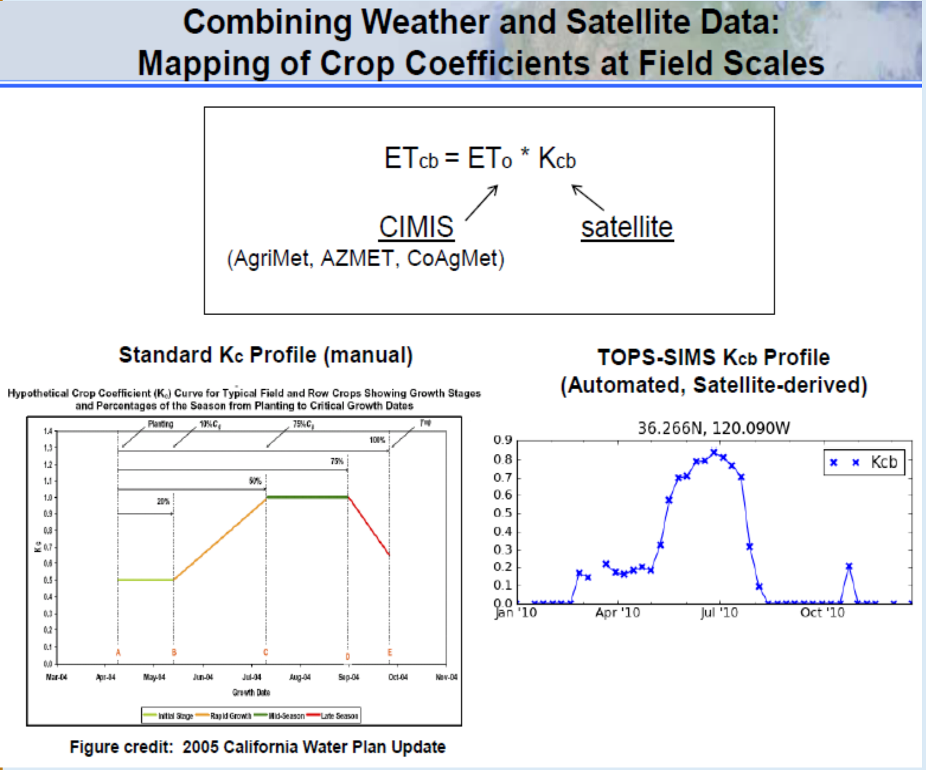
Multiple satellite platforms carry different cameras capable of varying spectral frequency monitoring. The GRACE satelites actually measure gravity to estimate groundwater reservoirs

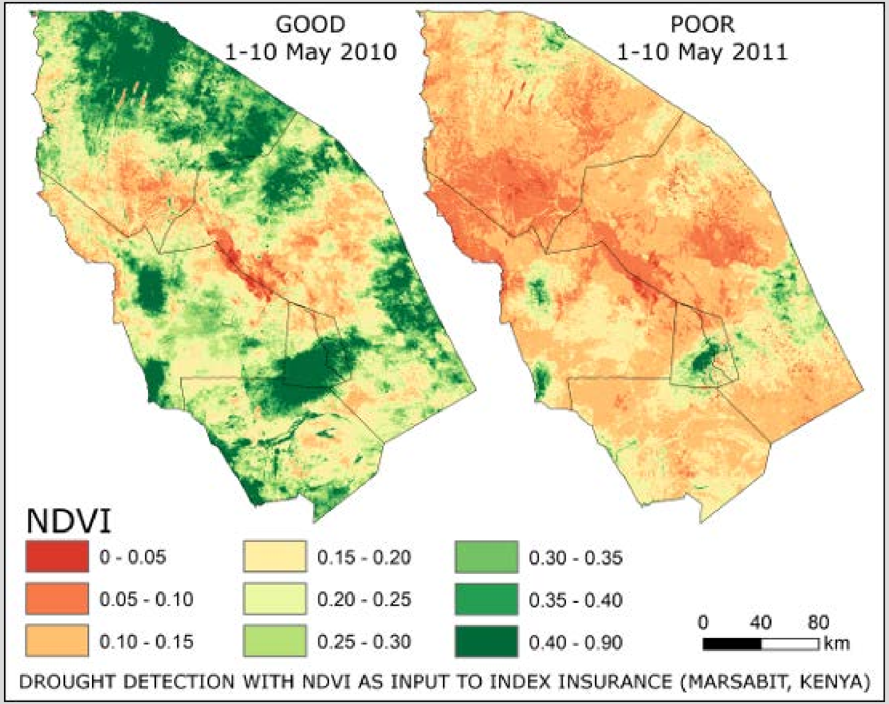


2 Main Objectives of Remote Sensing: Estimate –

Crop Water Stress/Use – ET (Evapotranspiration)



Plant Health/Cover – NDVI (Normalized Differential Vegetative Index)



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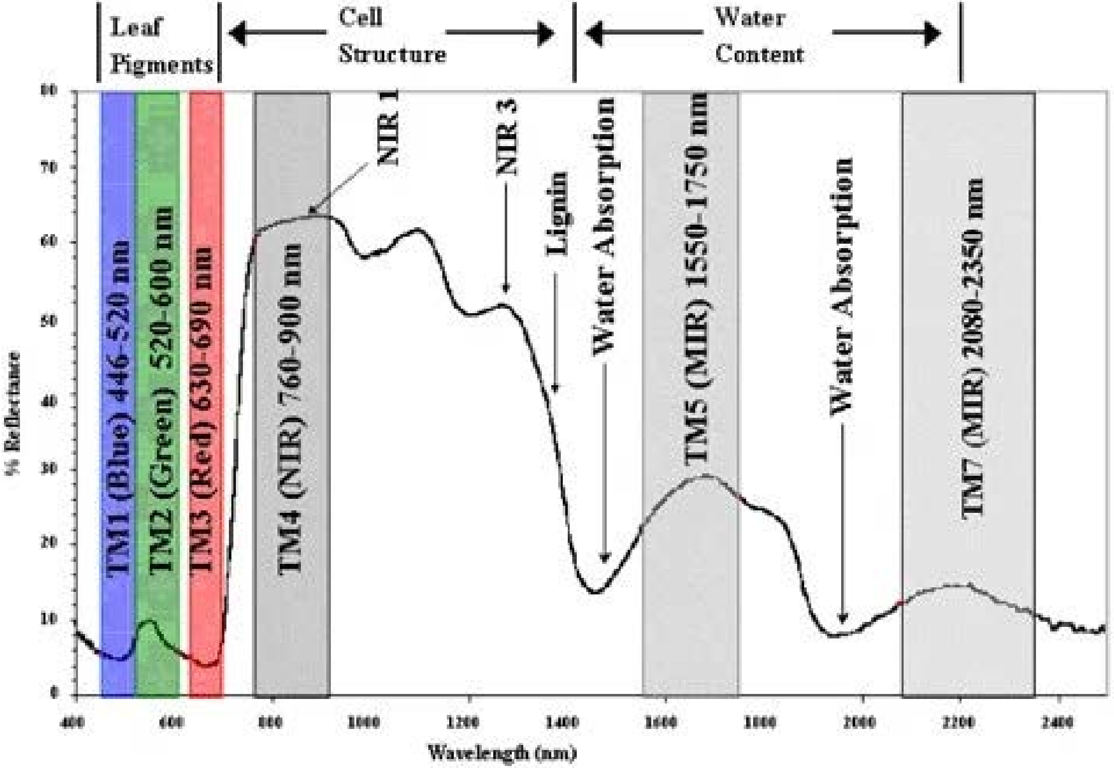
Wavelength and different light spectrums for plant characteristics



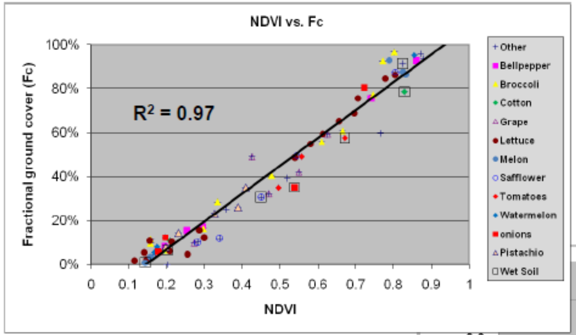
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

- **Simple calculation of Normalized Differential Vegetative Index (using measured reflectance in the Near Infrared and Red light spectra) used to estimate plant biomass and general vigor.**

Satellite Irrigation Management Support Project
"Managing irrigation from space", Forest Melton, et. al.

SIMS

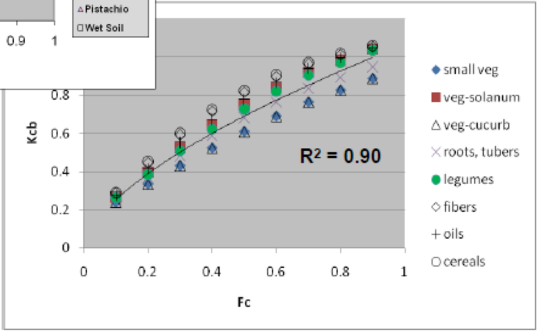
Mapping Crop Coefficients and Indicators of Crop Water Requirements from Satellite Data



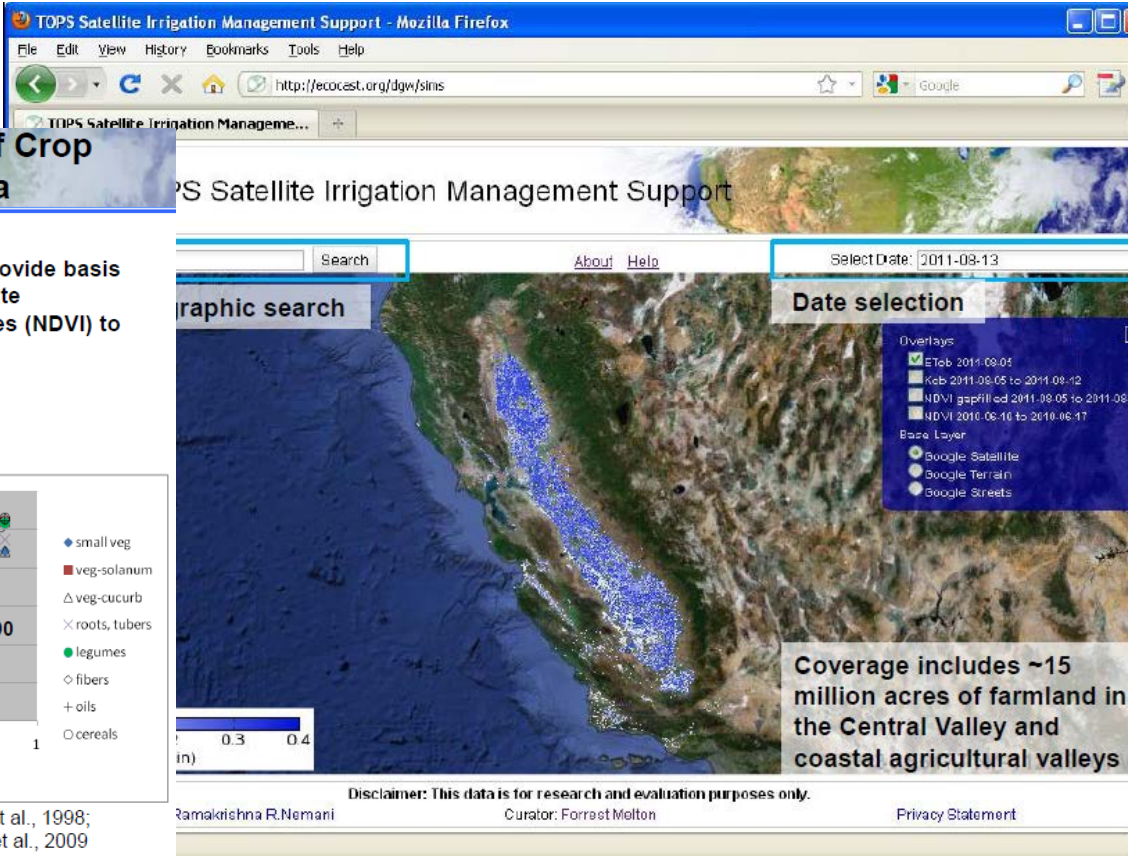
Trout et al., 2008; Johnson & Trout, 2011

USDA studies provide basis for linking satellite vegetation indices (NDVI) to fractional cover.

Recent studies by Allen & Pereira (2009) and others provide basis for linking fractional cover to Kcb for a range of crops. ***Additional studies ongoing in collaboration with CSU Fresno and UC West Side Research & Extension Center***



Also see Bryla et al., 2010; Grattan et al., 1998; Hanson & May, 2006; Lopez-Urrea et al., 2009



Resolution of Satellite Imagery

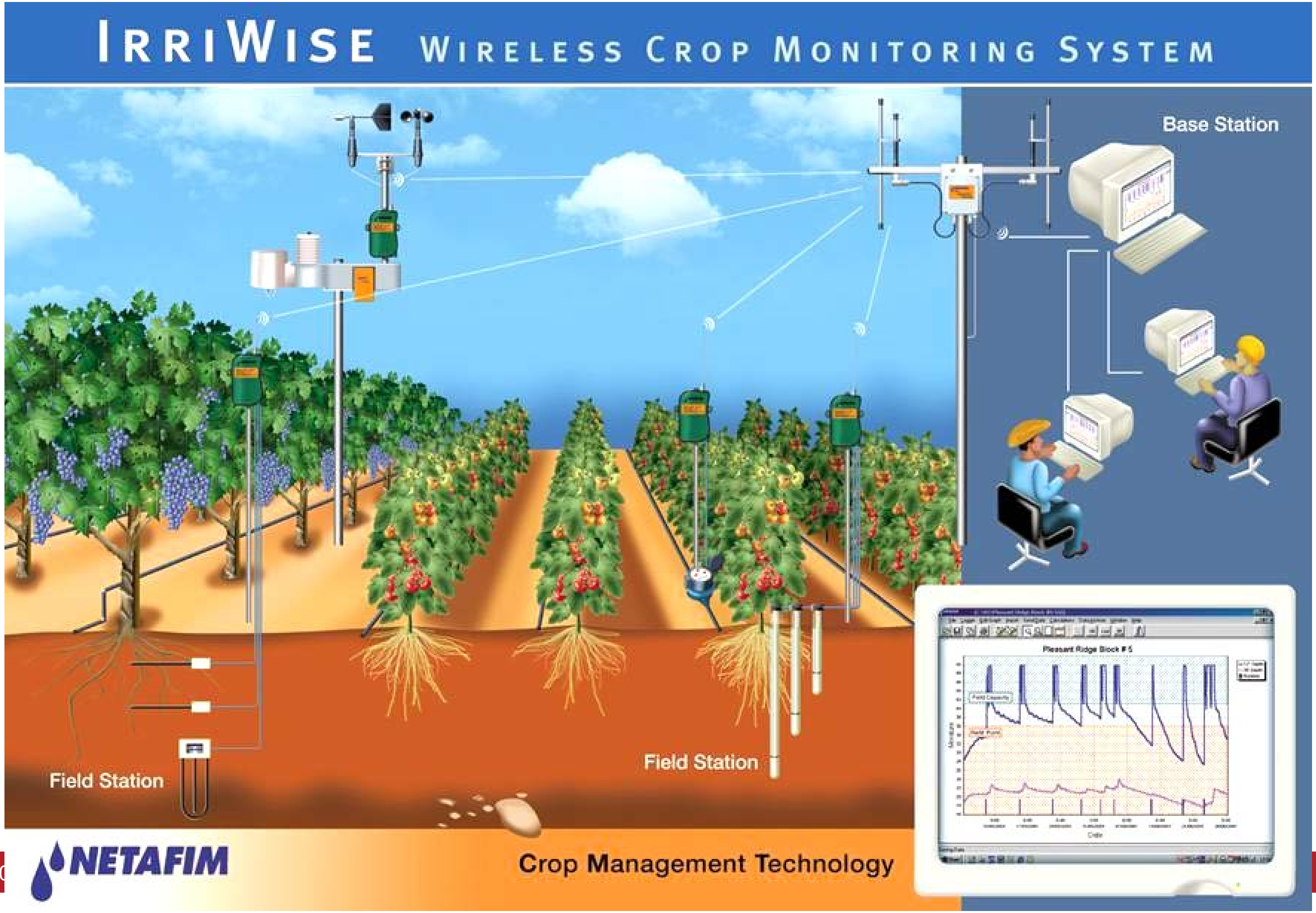
Landsat 5 and 7 (TM / ETM+)

30m pixel size = 0.22 acres

Terra (MODIS)

250m pixel size = 15.4 acres

"Expert" water monitoring/control telemetry systems promise precision management from your desktop.



SMARTFIELD infrared sensor to measure canopy temperature

Almond ET/Yield Production Function

Ken Shackel, David Doll, Allan Fulton, Bruce Lampinen, Blake Sanden

Tehama, Merced and Kern County Locations

Kern County trial: most complex. Cooperation with Paramount Farming Company (now Wonderful), Jain Irrigation, Galcon Controllers, CERES Imaging, Phytech International, Smartfield, Inc., Rainbird and Hortau.

TREATMENTS: 70, 80, 90, 100 and 110% ET irrigation with Hull Split Regulated Deficit Irrigation

Objectives:

1) **Quantify kernel yield in lbs/inch ET (applied water + depletion – leaching) under non-limiting fertility levels by varying depths of applied irrigation. (Primary objective common to all 3 sites.)**
2) Quantify the interaction of hull-split Regulated Deficit Irrigation on the yield function with a simplified 50% ET irrigation application from mid-June to Nonpareil harvest irrigation cutoff – about 6 weeks.
3) Assess the yield benefit of "pulsed" (6 hours on, 6 hours off for 4 cycles over 48 hours) vs. continuous (24 hour set) irrigation.
4) Assess the grower friendliness, benefits and accuracy of in-situ data collection using web-based monitoring of trunk diameter (Phytech dendrometers), infrared sensed canopy temperature (Smartfield) and soil water content (Rainbird Climate Minder capacitance probes, Hortau tensiometers).
5) **Assess the accuracy and relationship to kernel yield of remotely sensed aerial imagery used to calculate crop water stress (Conductance) and tree biomass/vigor (NDVI, normalized differential vegetative index) using images supplied by CERES Imaging.**
6) Assess the feasibility, final water use and yield of high frequency "on-demand" plant stress and soil moisture triggers for irrigation scheduling (Unavailability of extra water due to drought canceled these treatments.)

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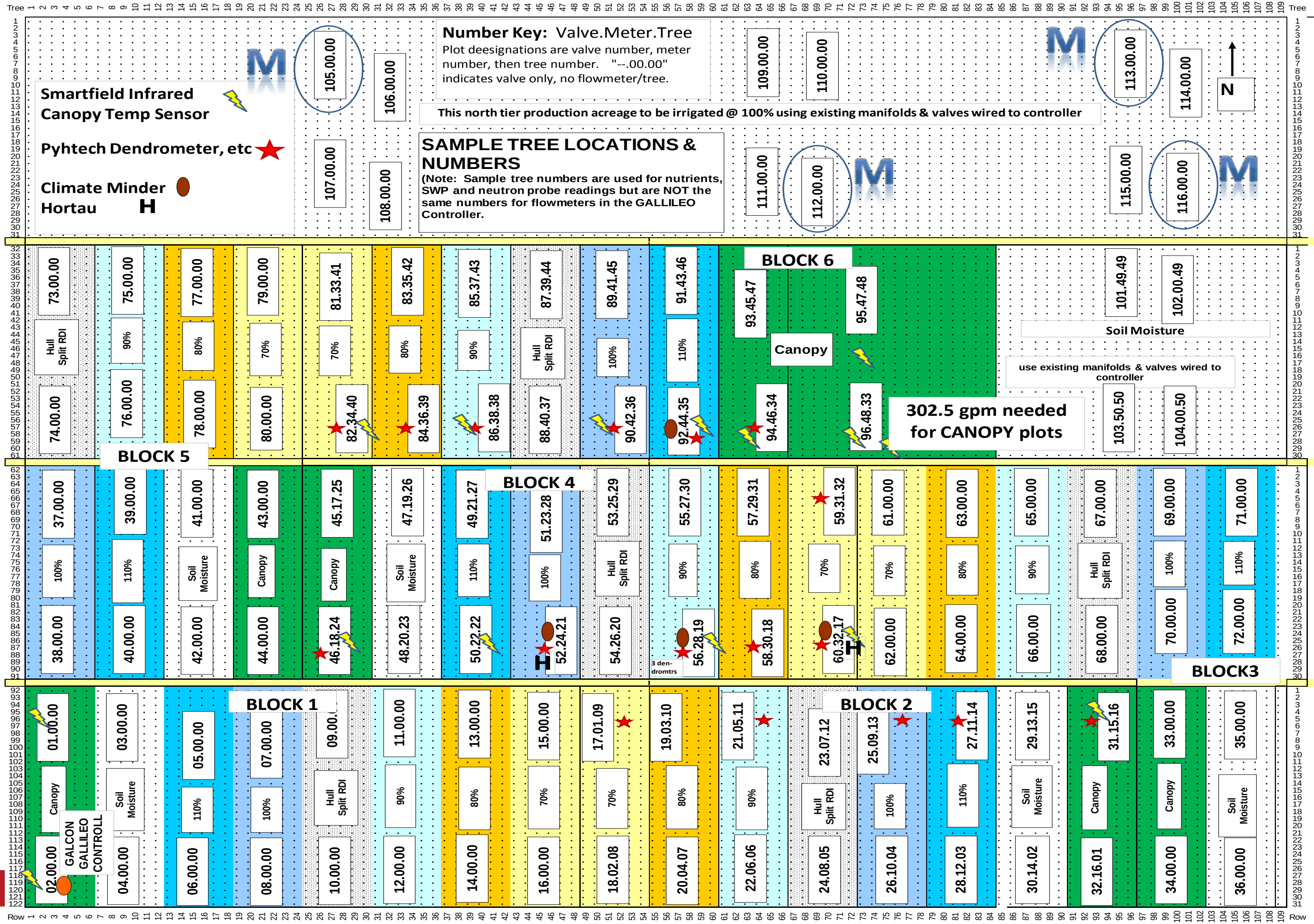
REVISED PLOT PLAN FOR ALMOND ET/YIELD PRODUCTION FUNCTION & PRECISION IRRIGATION TRIAL 2013-2016



Target ET/Irrigation	
70%	70% ET all season
80%	80% ET all season
90%	90% ET all season
Hull Split RDI	100% with RDI @ 50% 6/15-8/1
100%	100% ET all season
110%	110% ET all season

Possible Automated Sensor Threshold Treatments (Continuously monitoring sensors connected to control valves)	
Soil Moisture	Irrigation triggered by predetermined water contents and/or matric potentials
Canopy (placeholder, just 100% for now)	Irrigation triggered by predetermined changes in canopy spectral frequencies pending appropriate sensor

TRIAL DESIGN COMPONENTS

ADDITIONAL SENSORS: Sensors placed adjacent to neutron probe access tubes for addtional plant stress and soil moisture monitoring.

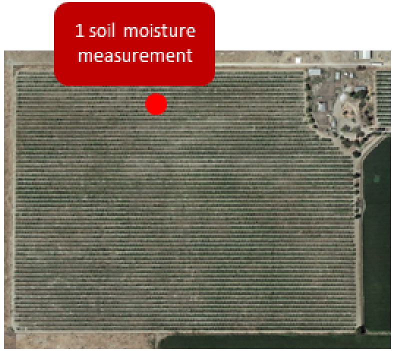
REPLICATED PLOTS: The southern 3 tiers are divided into 6 replicated blocks with plots arranged in a "line-source" design with each plot having 6 rows by 30 or 31 trees trees.

SPLIT-PLOT -- CONTINUOUS vs. PULSED IRRIGATION: a dual valve system shall be installed down the middle of each tier with the southern 15 trees irrigated continuously for the prescribed depth of water and the northern 15 trees irrigated with "pulsed" irrigation -- say 1/2 hr on and 1/2 hr off -- to achieve the same depth of irrigation. See manifold detail sheet.

Our technology optimizes water and fertilizer

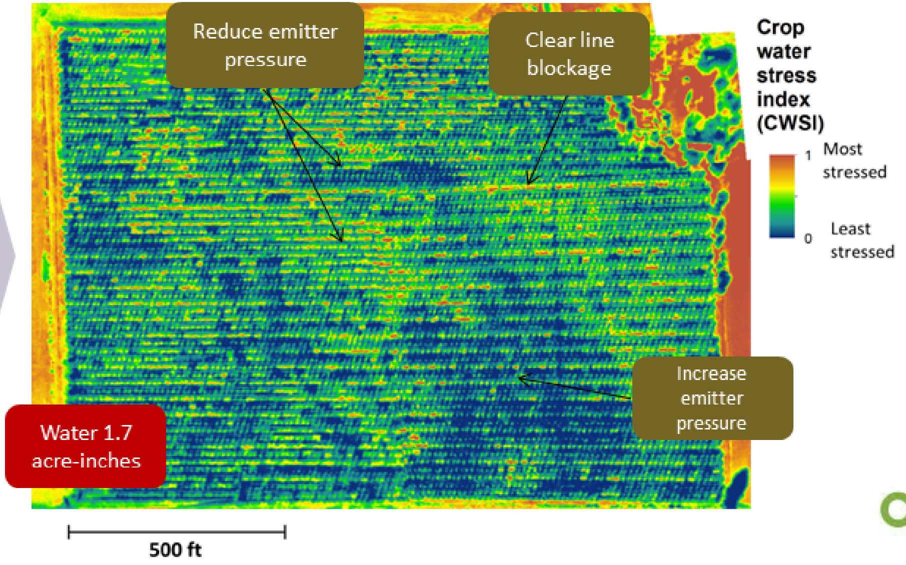
The user interface and "smart" software to analyze "big data" still has a long way to go.

The old way of irrigating (60 acre almond orchard)

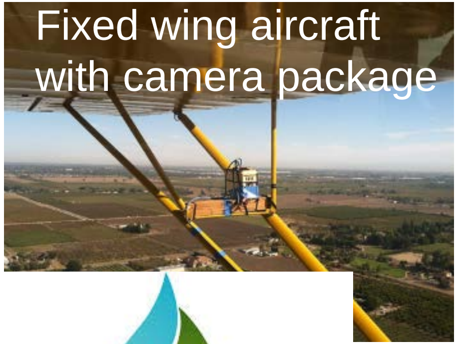


Farmer picks one spot (out of ~10k trees) to measure soil moisture and decides water application

Irrigation with our water stress prototype



Farmer gets optimized calculation of water to apply + tactical field recommendations



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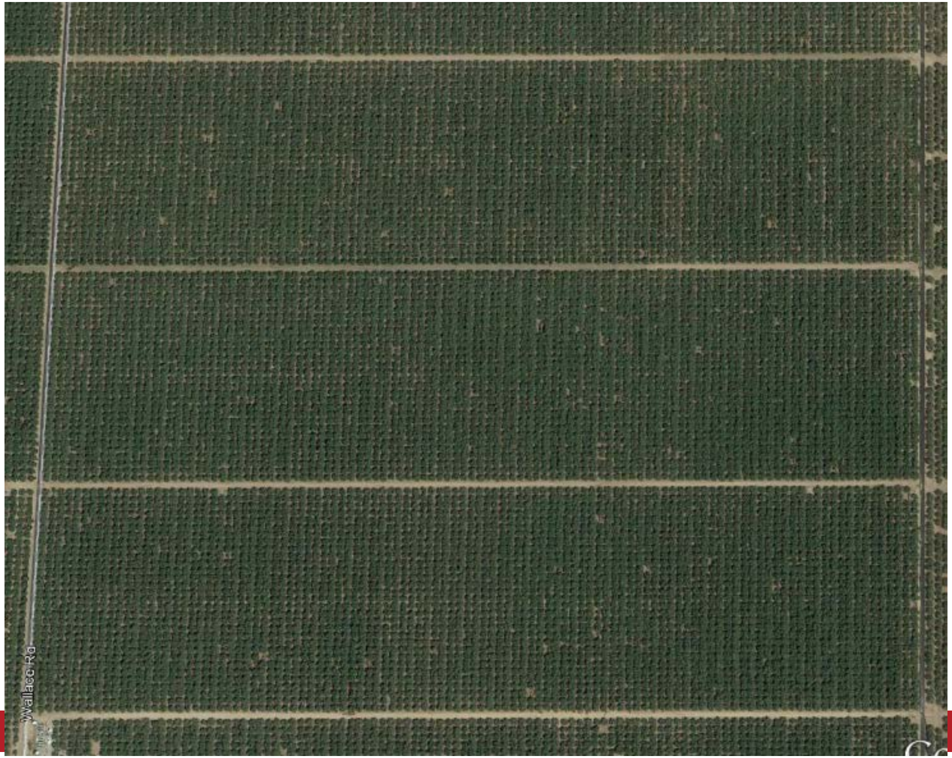
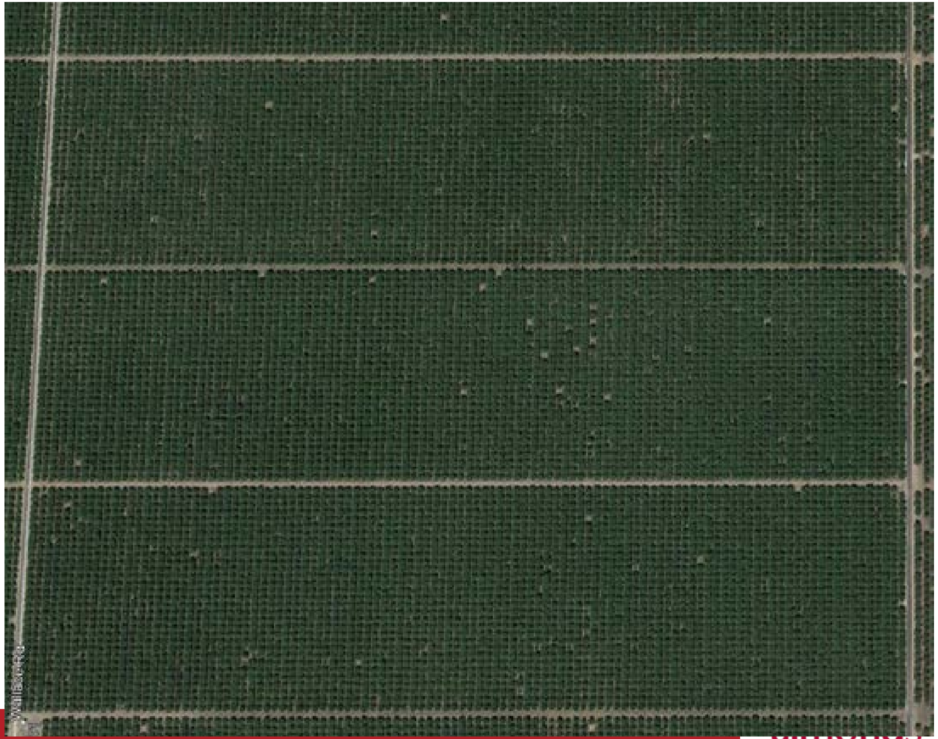
Aerial image comparison: Differential irrigation commenced spring 2013

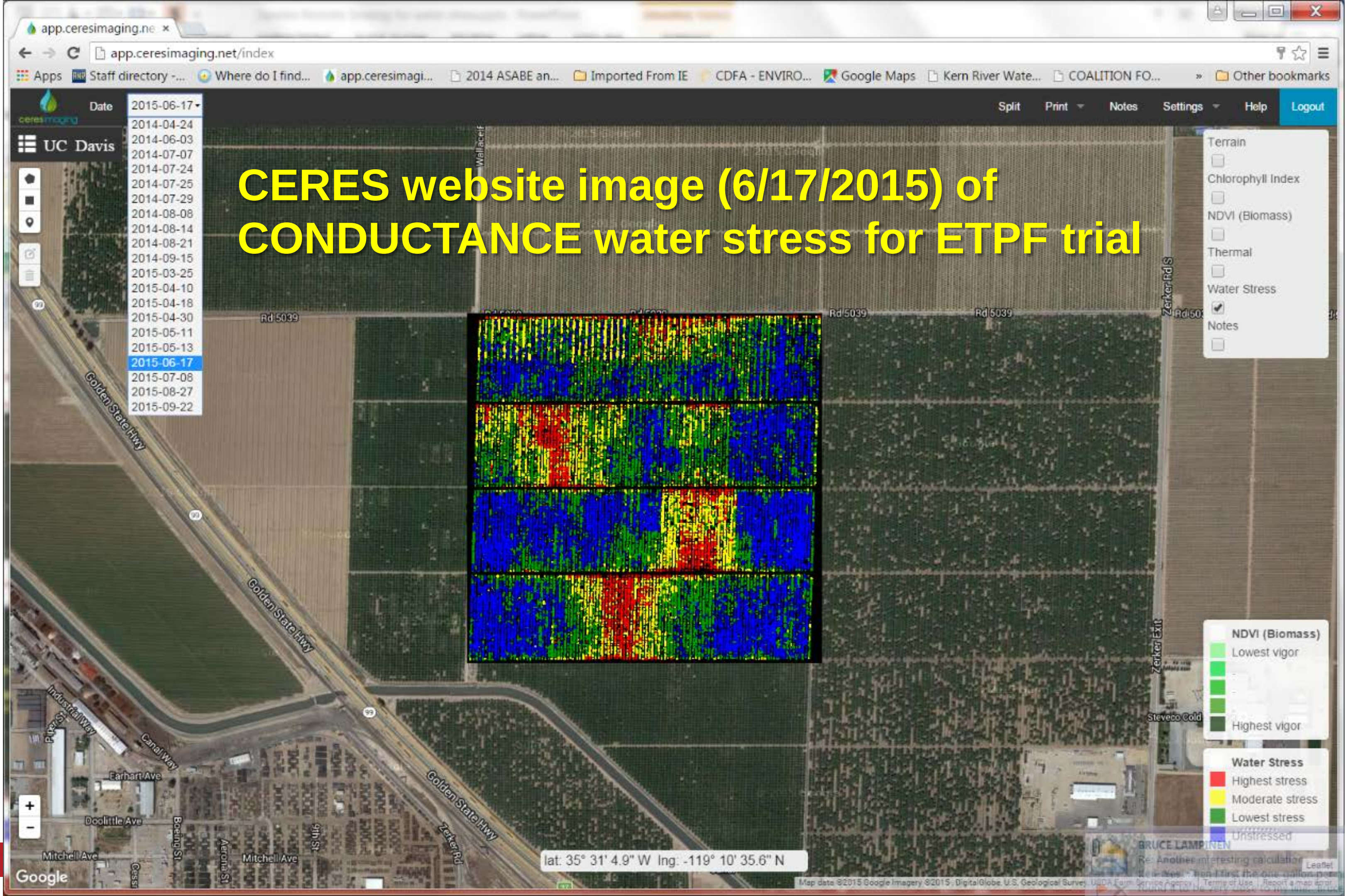
Google Earth July 2013



Google Earth March 2015



CERES website image (6/17/2015) of CONDUCTANCE water stress for ETPF trial



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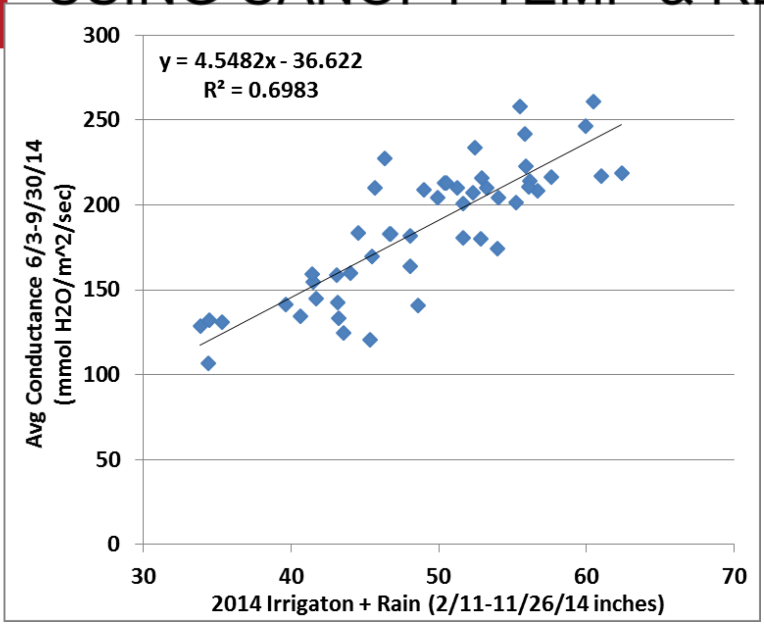
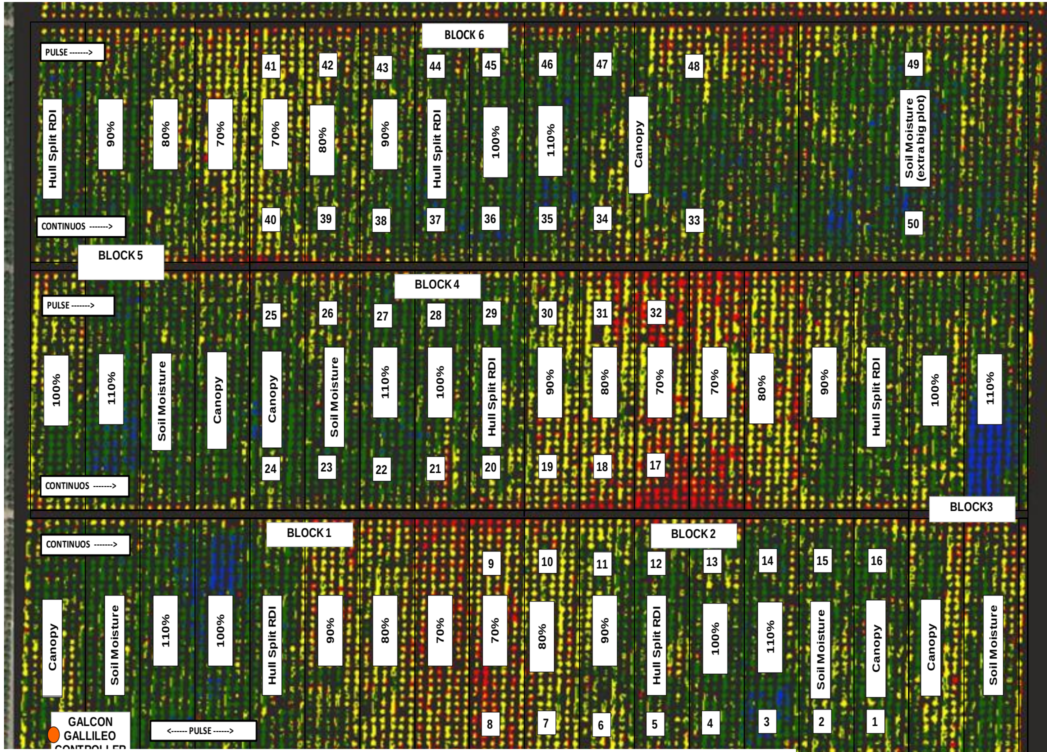
"CONDUCTANCE" AERIAL IMAGERY SHOWING WATER STRESS USING CANOPY TEMP & RELATIVE HUMIDITY CALCULATION





6/3-9/30/14 average almond plot water conductance by 2014 applied irrigation (9 flyovers)

Canopy Temp/Water Stress by Irrigation Treatment (CERES Spectral Imaging 6-3-14, Shackel, et al. Yield Production Function Trial)

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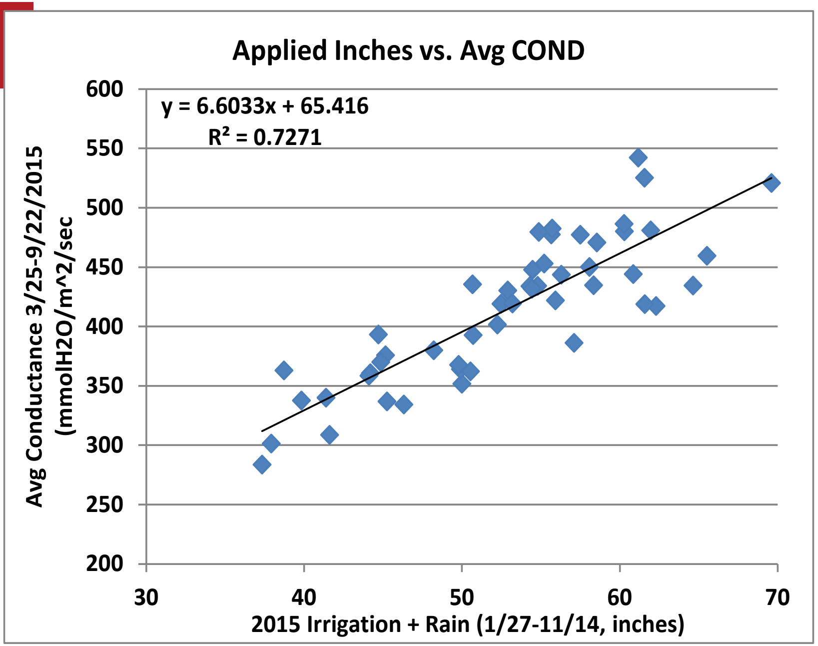
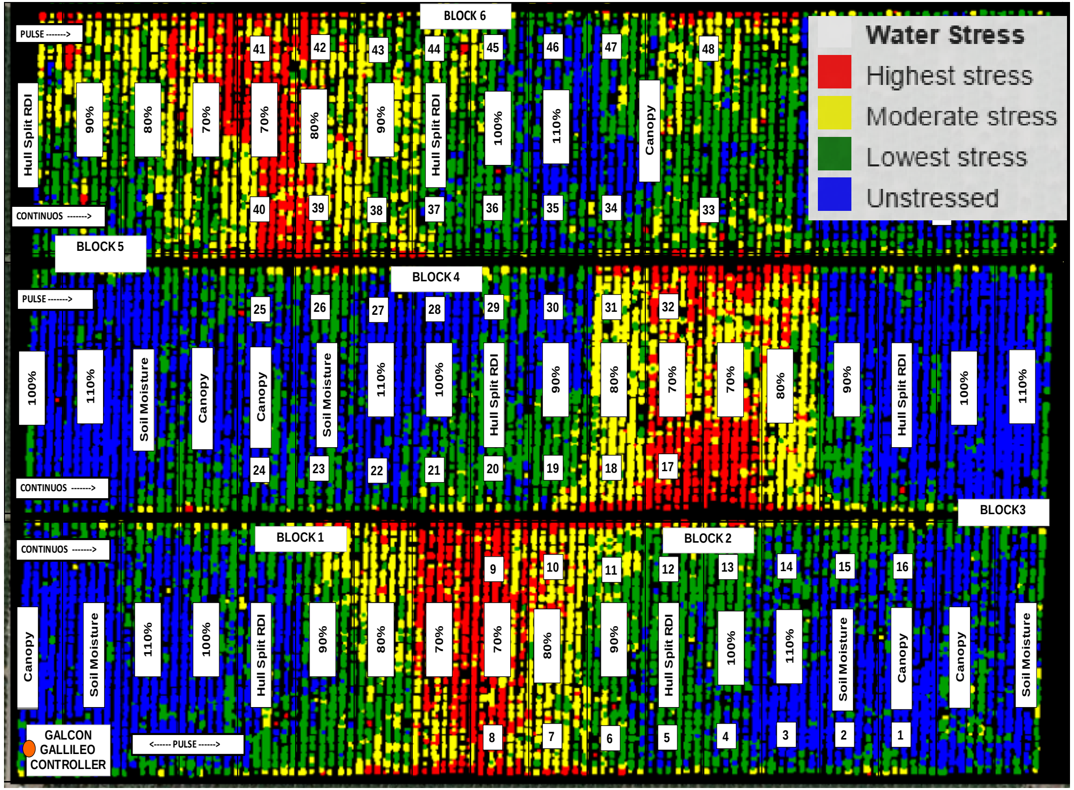
AERIAL IMAGERY CAN IDENTIFY IRRIGATION/STRESS NON-UNIFORMITY



6/3-9/30/14 average almond plot water conductance by 2014 applied irrigation



Canopy Temp/Water Stress by Irrigation Treatment (CERES Spectral Imaging 6/17/2015, Shackel, et al. Yield Production Function Trial)

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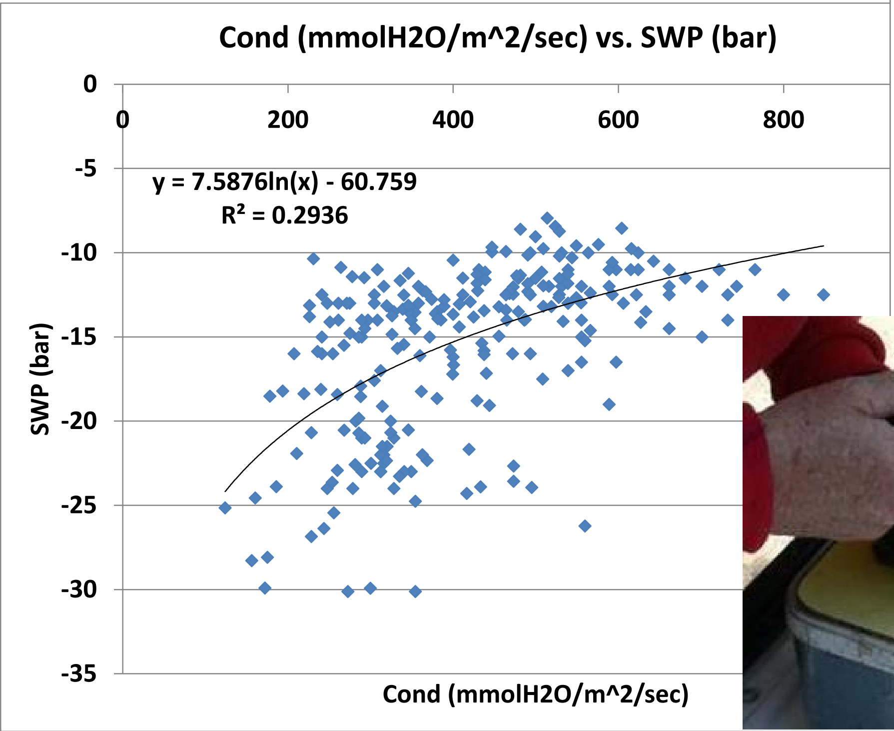
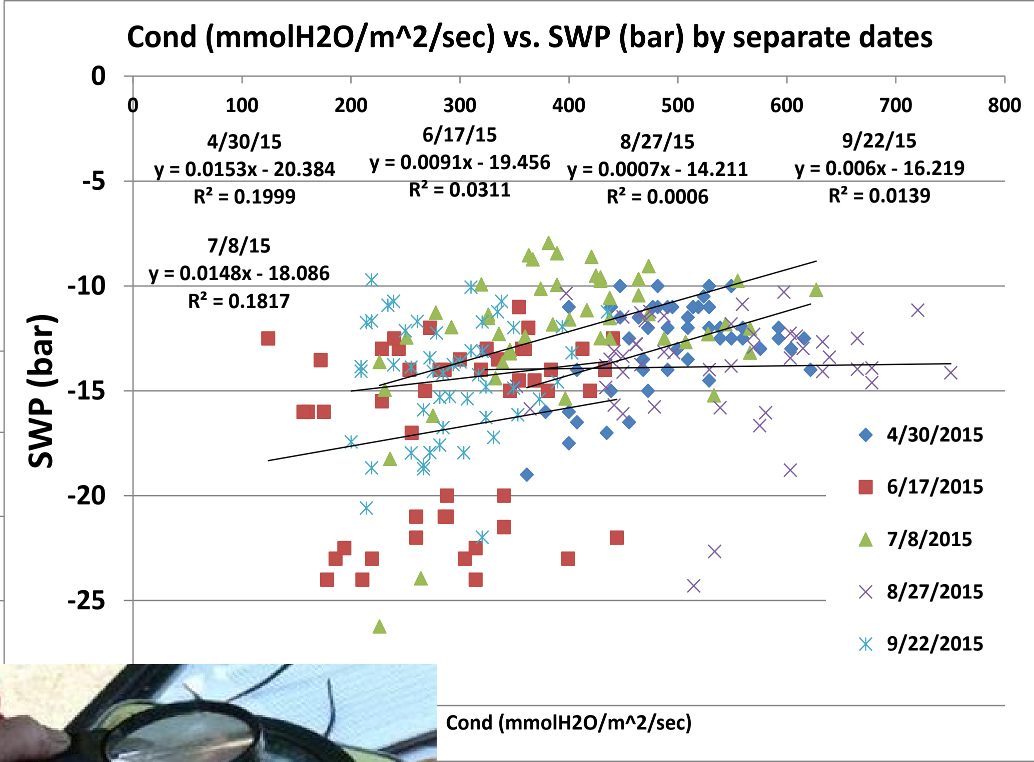
Correlation of individual tree CONDUCTANCE to pressure chamber Stem Water Potential was marginal in 2015





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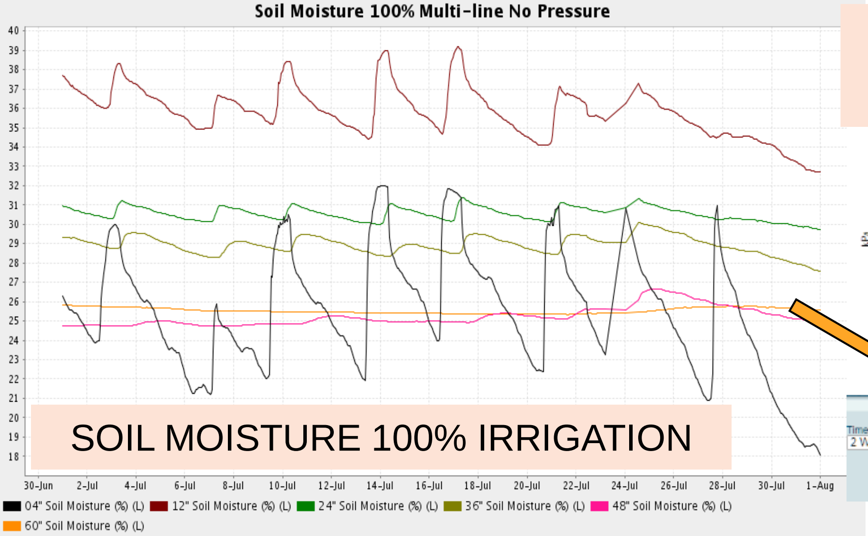
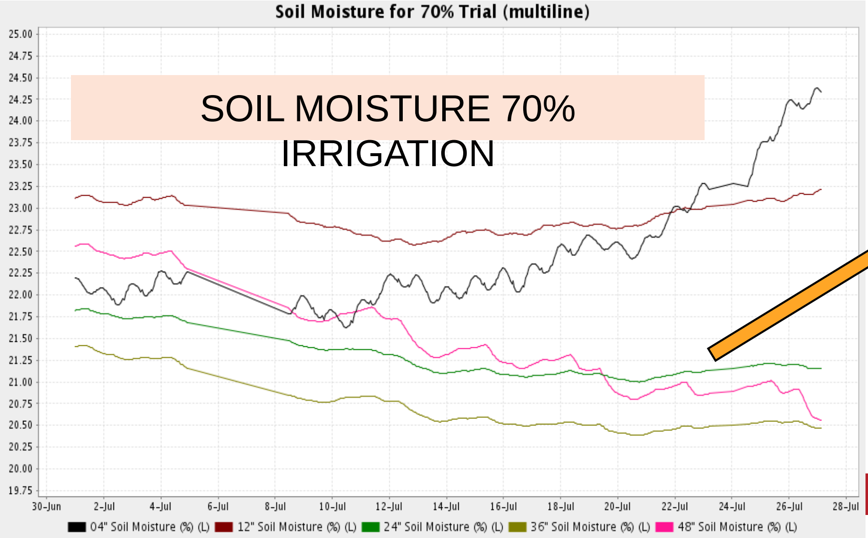
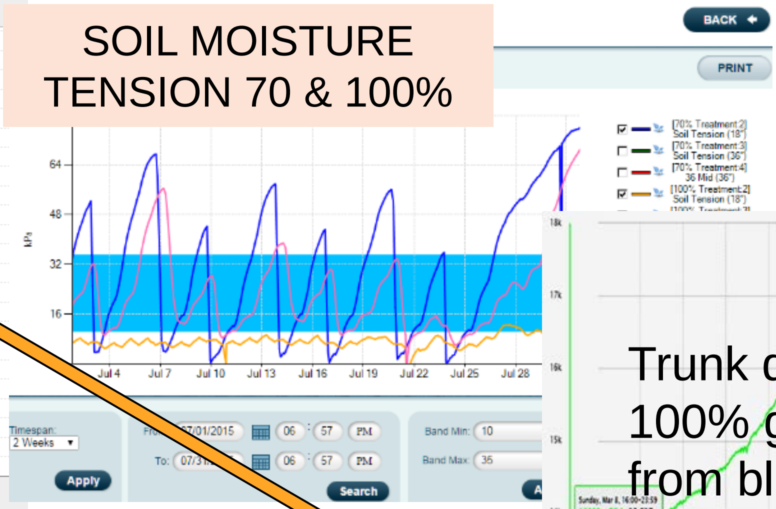
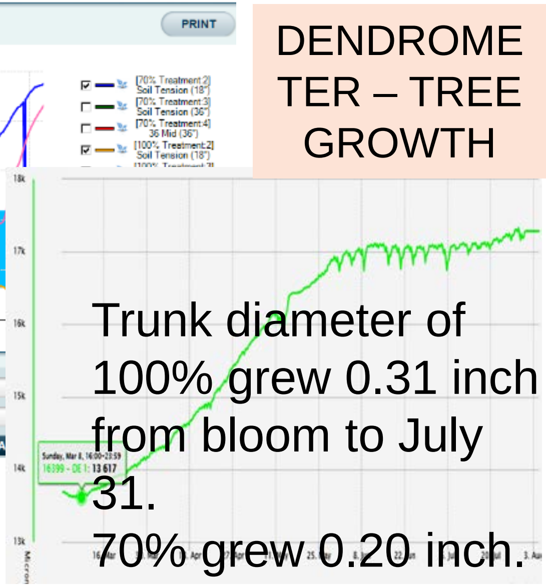
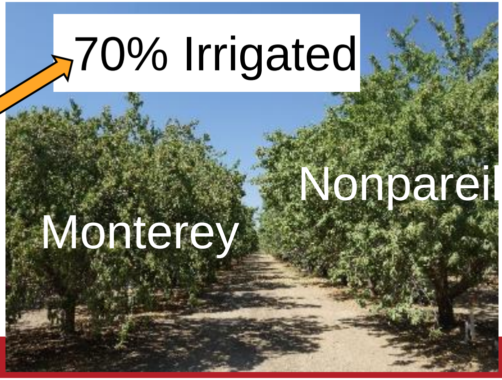
UC Almond Production Function Trial 2013-15

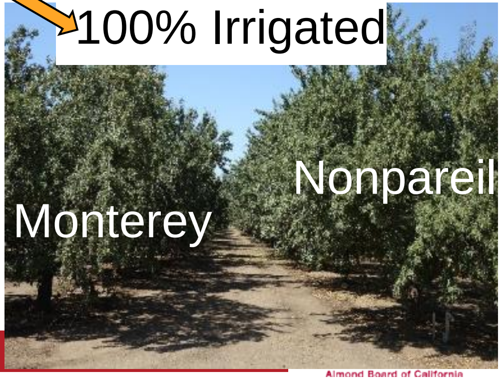












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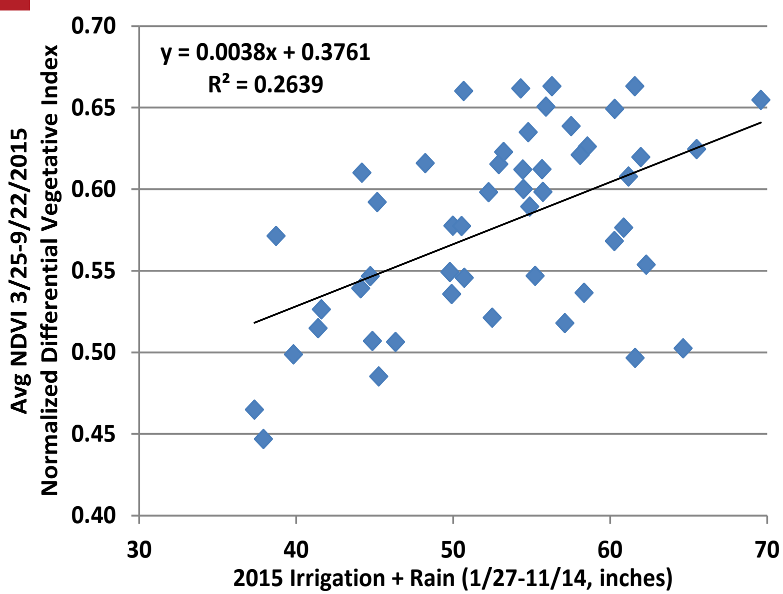
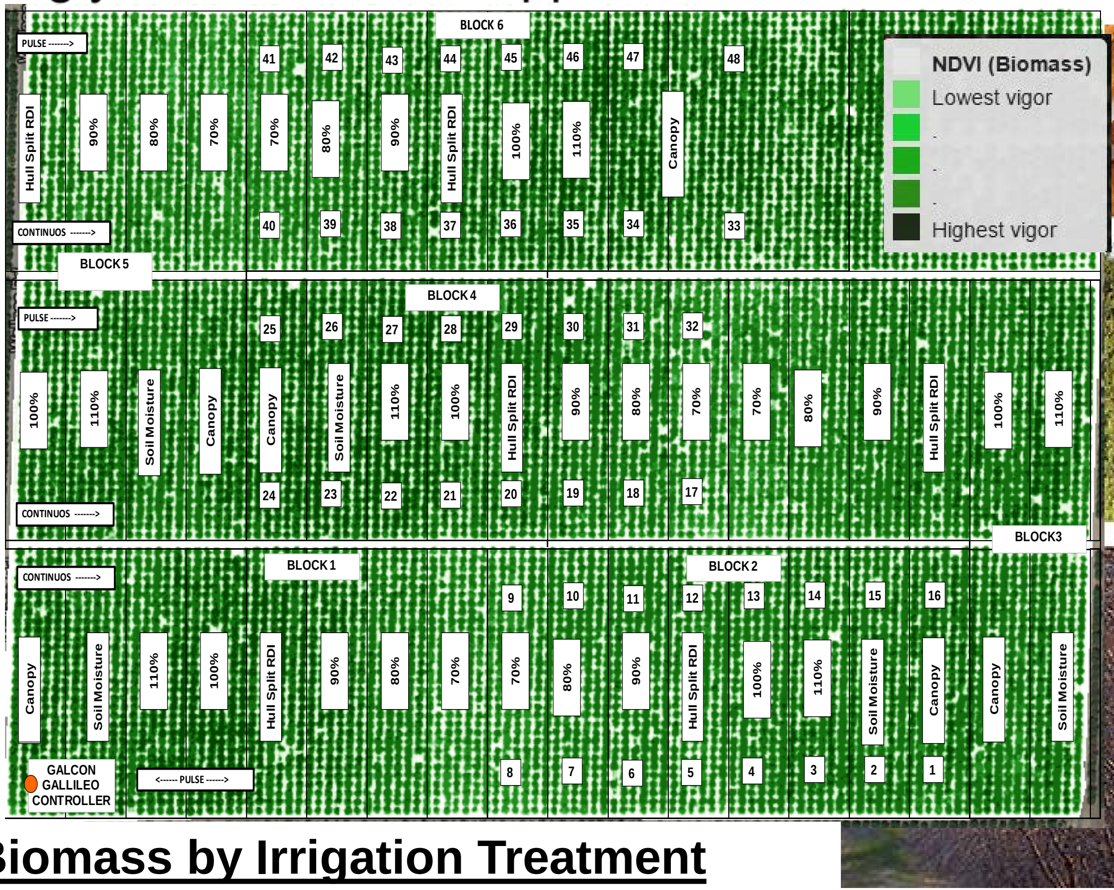
NDVI (vigor/biomass) not as strongly correlated with applied water



3/25-9/22/2015 average almond plot NDVI by 2015 applied irrigation (10 flyovers)



NDVI/Biomass by Irrigation Treatment

(CERES Spectral Imaging 6/17/2015, Shackel, et al. Yield Production Function Trial)

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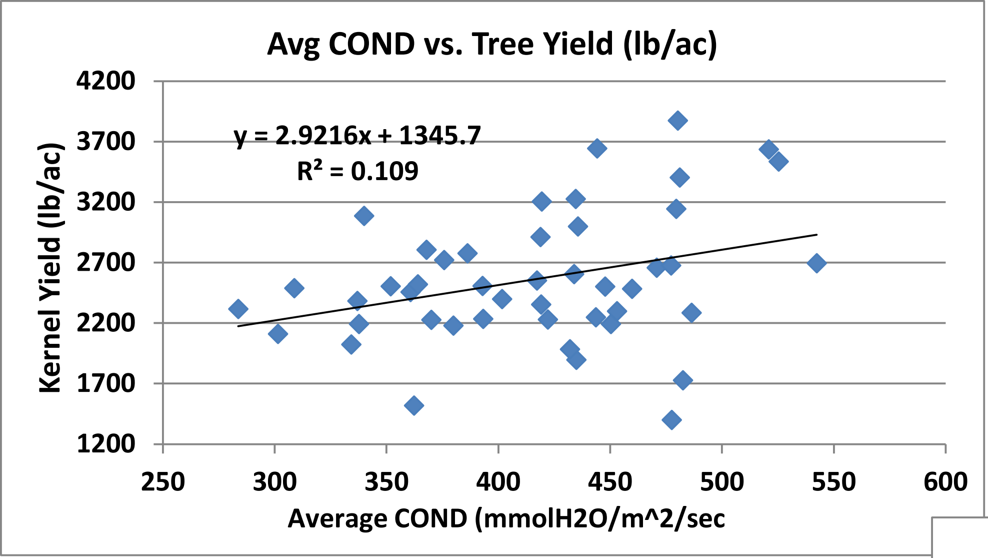
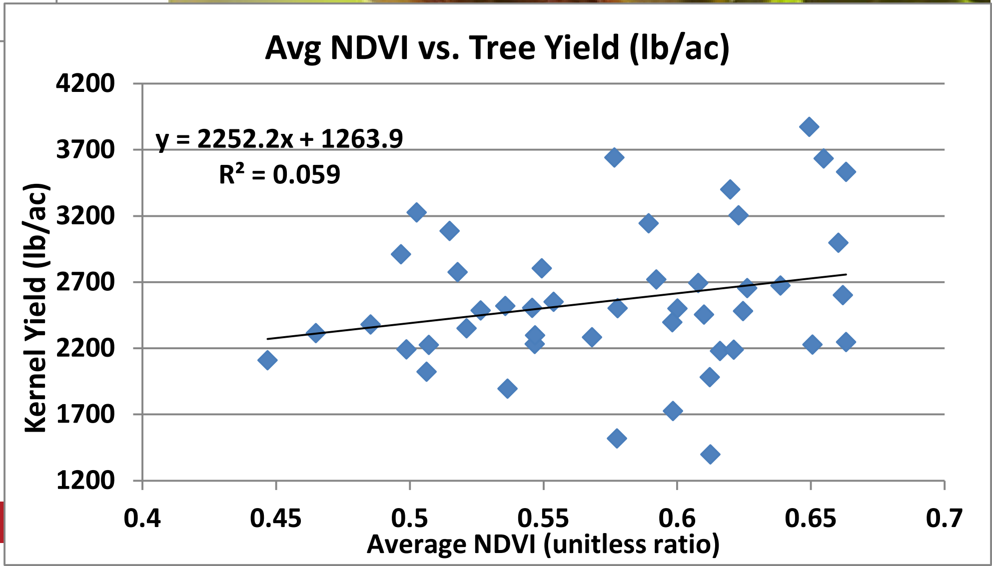


Both CONDUCTANCE & NDVI were poorly correlated to final kernel yield. Bloom density and other factors can be just as important as stress on your final yield.



Sodium, Chloride and Boron Accumulation in Almonds

Blake Sanden
UCCE Irrigation/Soils
Advisor, Kern Co.

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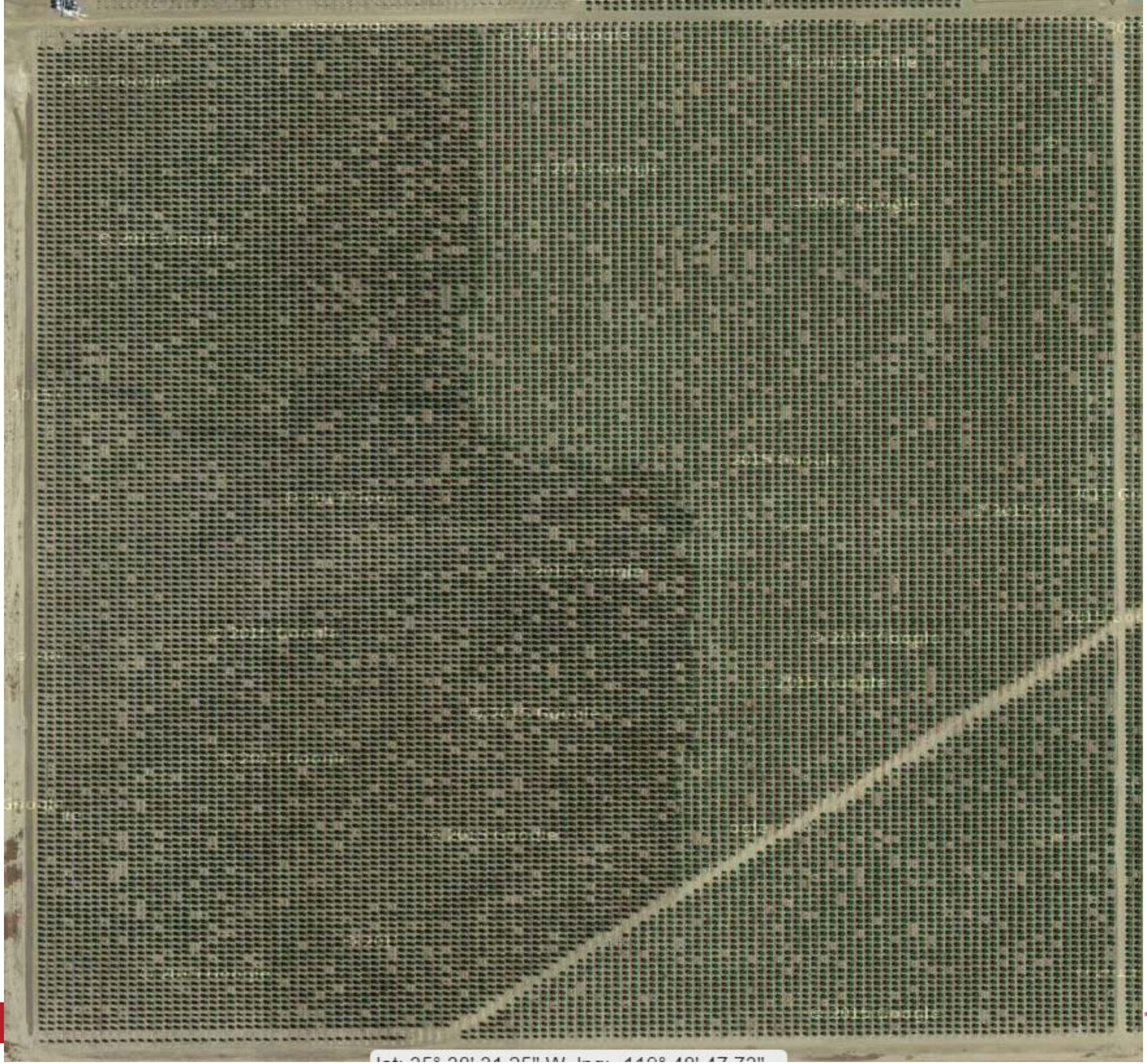
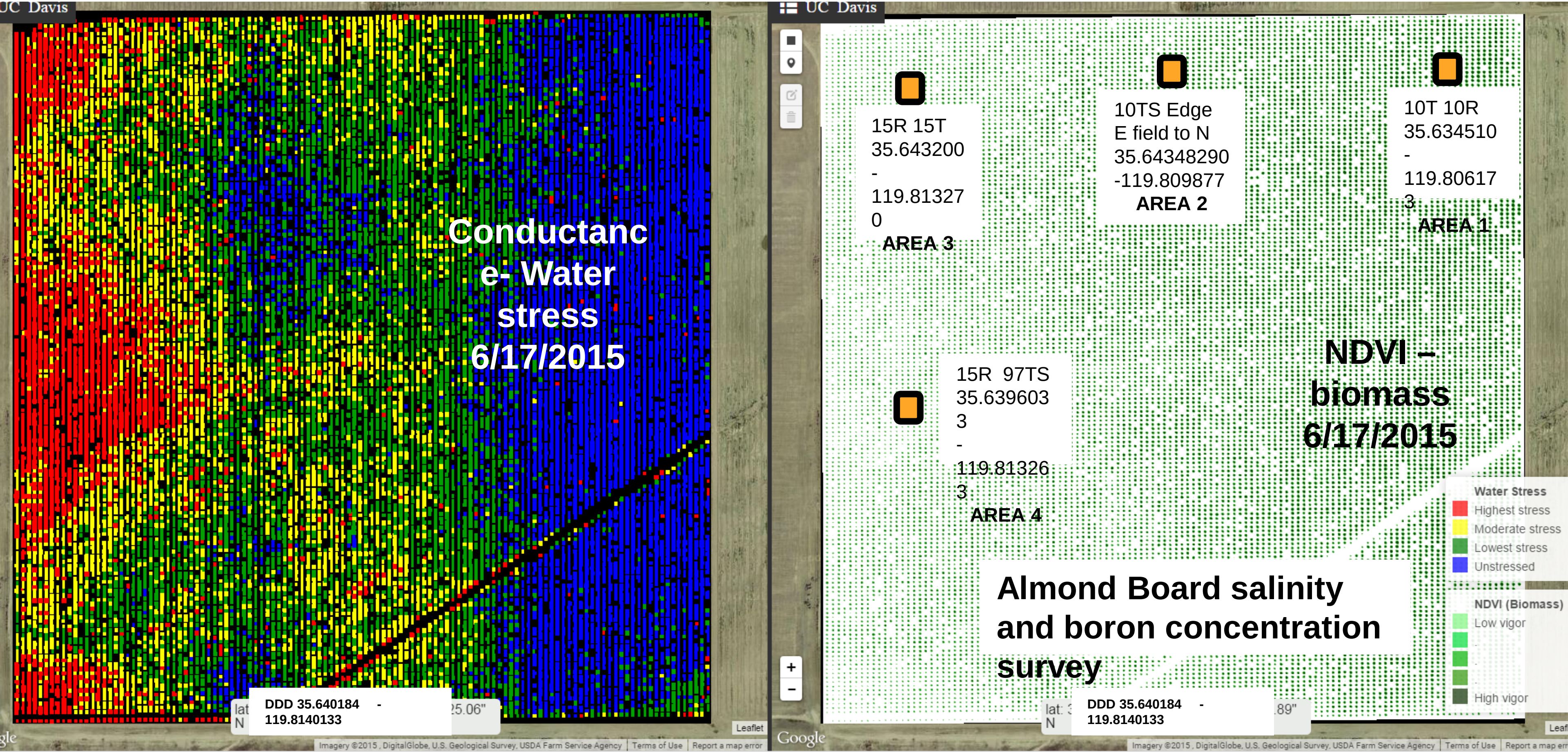
- **Project site**

Pushing the salinity limits on 3rd leaf almond on the westside

May 2015 Google Earth aerial photo of quarter section 3rd leaf project field. The scattering of missing trees appears uniform across the block – or is it!





Aerial imagery (6/17/2015) and Areas 1 to 4 salinity sampling locations

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Trees compared

Area 4 – smaller trees
Soil ECe 6.1 dS/m, B 1.0 ppm,
a few trees with bad gummosis

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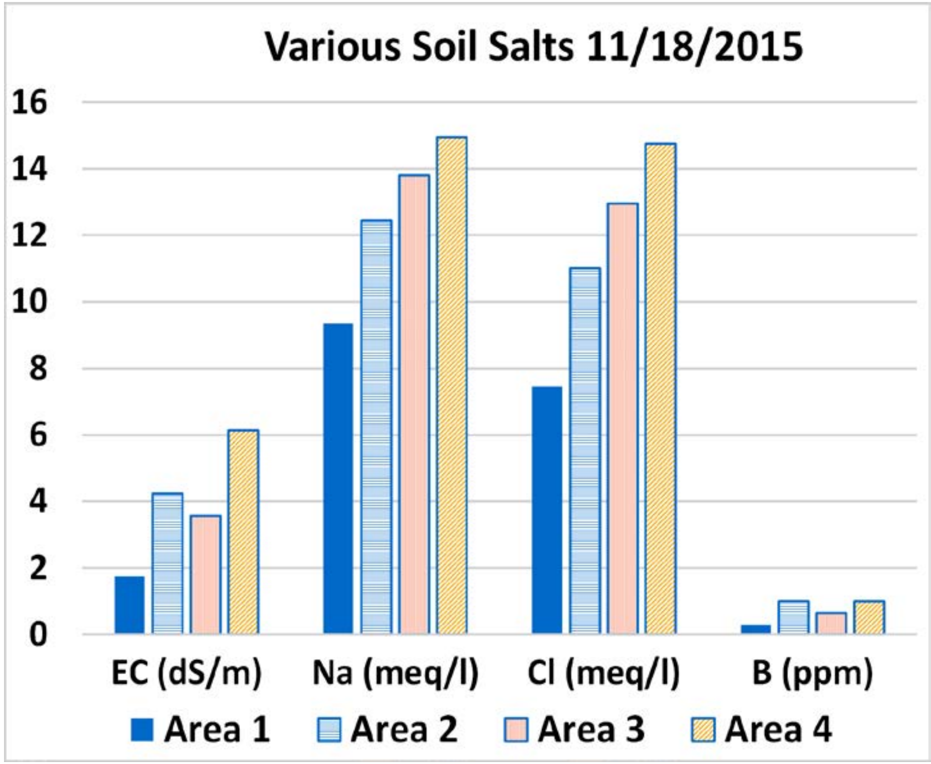
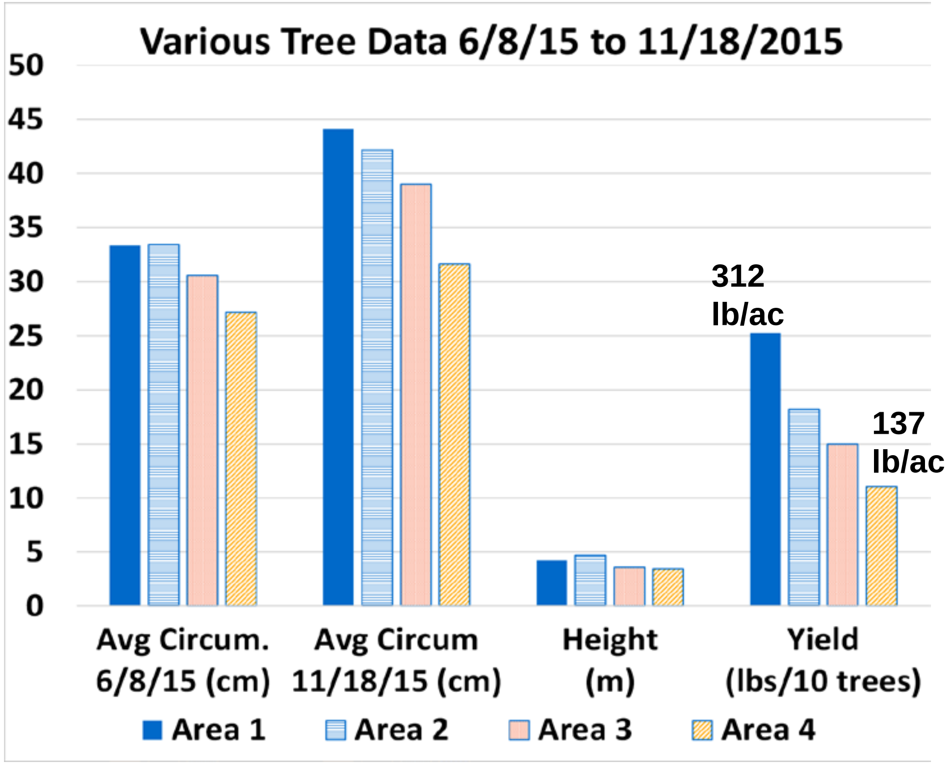
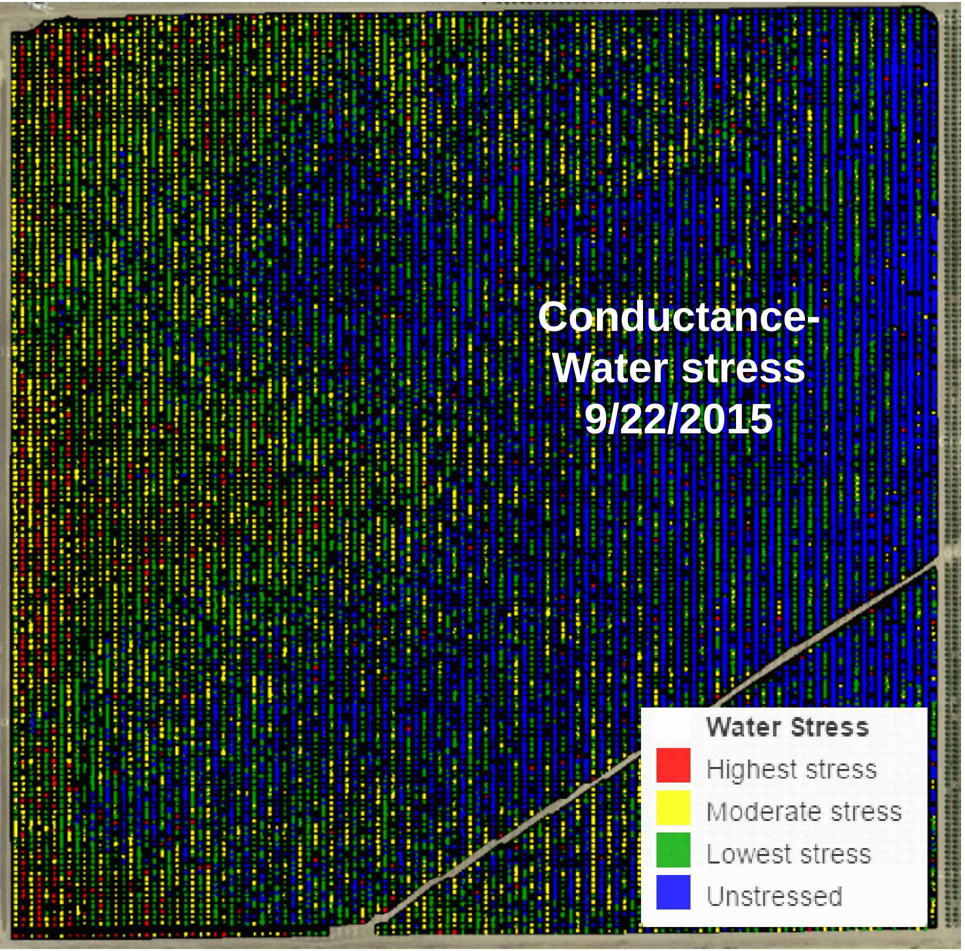
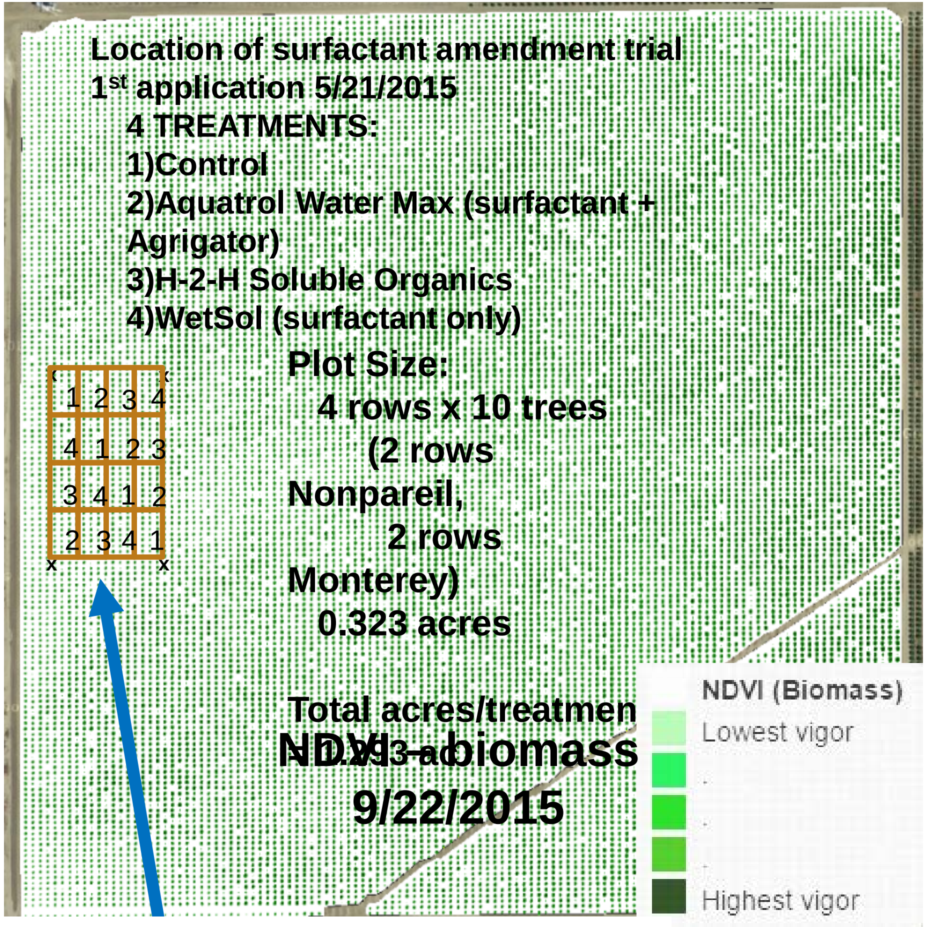
VARIOUS SOIL AND PLANT DATA COMPARED



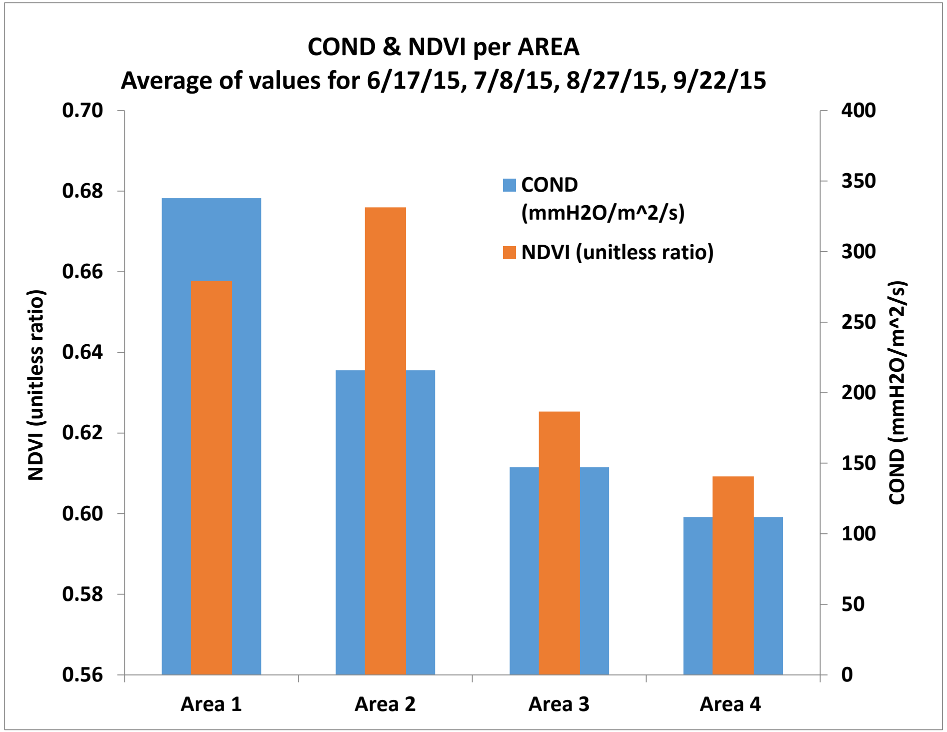




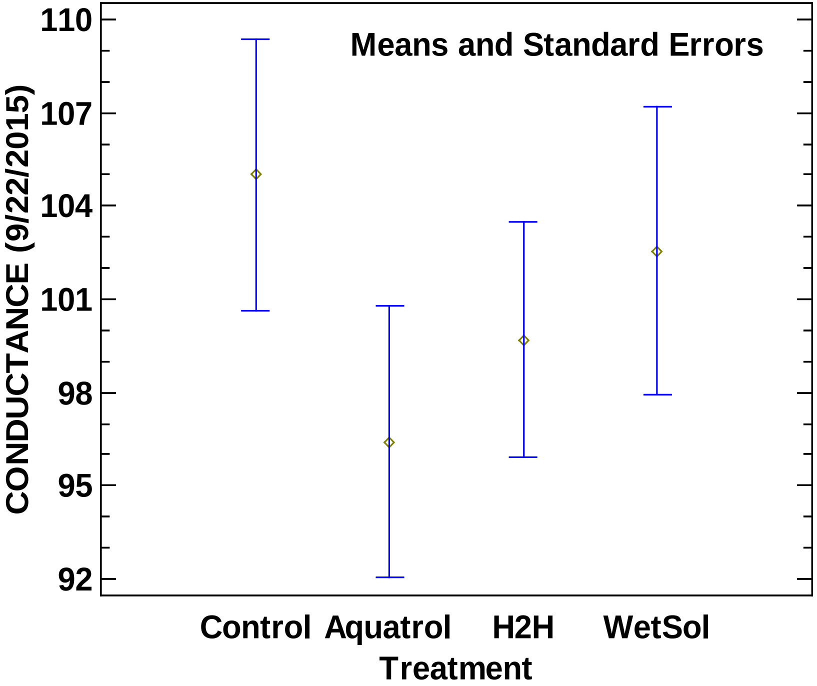


Location and plot design for amendment trial

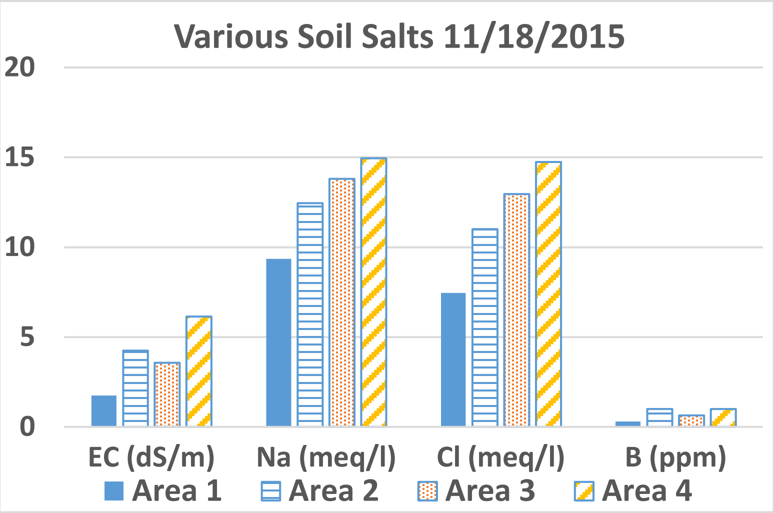
East (Area1) to West (Area4) showed a major trend in water stress (COND) and plant biomass/vigor (NDVI)

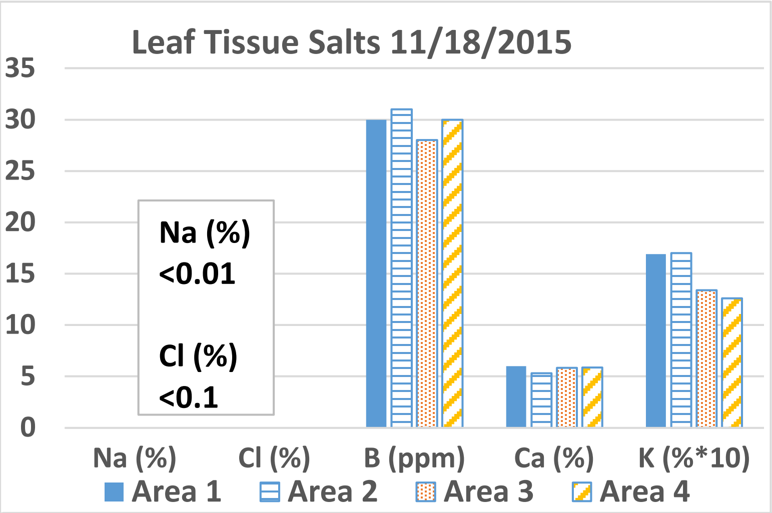


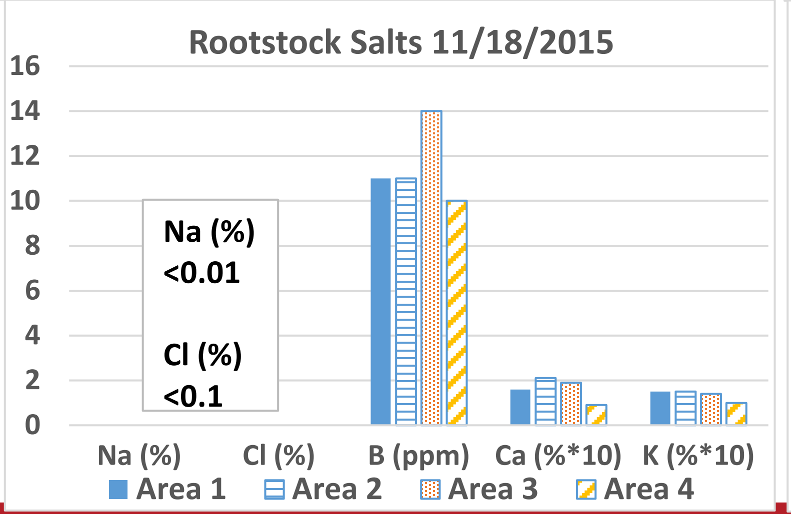
There was no significant benefit as of 9/22/2015 from any of the surtfactant amendments to reduce water stress. Nor was there any yield benefit or differences in tissue salt concentration.

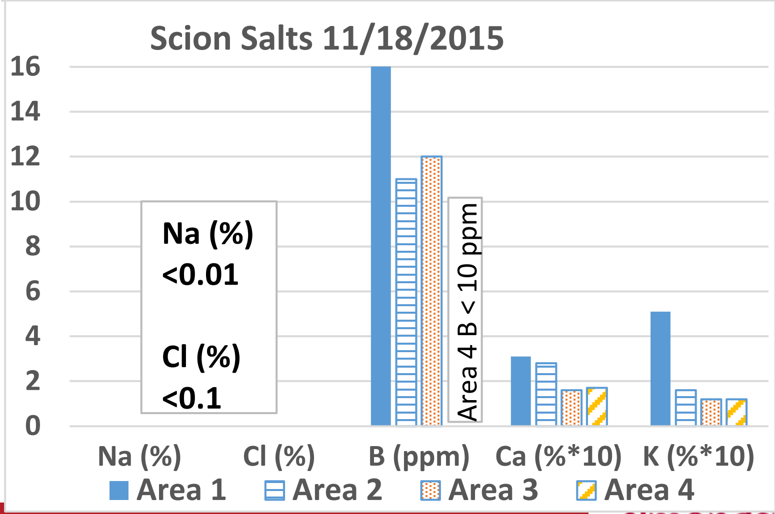


Various leaf and wood tissue samples showed no real correlation to soil salinity, except scion and leaf K decreased as Na increased.









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Patrick Brown,
University of California, Davis

growing ADVANTAGE
The Almond Conference

Physiology of Salinity Stress in Almond

Umit Baris Kutman, Francisco Acevedo, Patrick Brown

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Introduction

- Main experiments on grafted trees grown outdoors in 7-gal pots with Turface as growth medium
  - 3 salinity levels: control (~1 dS/m), low (~3 dS/m), high (~5 dS/m)
  - 1st season data in 2014 and 2nd season data in 2015
  - Rootstock experiment: Nemaguard, Hansen536, Empyrean-1, Viking
  - Cultivar experiment: Nonpareil, Mission, Monterey, Fritz
  - Salt type experiment: NaCl, KCl, Na_2SO_4
  - Double-grafting experiment: Nonpareil & Mission on Nemaguard
- Recovery experiment (2015) on grafted trees grown outdoors in 2.5–gal pots with Turface
  - 3 salinity levels: control (~1 dS/m), low (~3 dS/m), high (~5 dS/m)
  - Rootstock: Nemaguard; Cultivars: Nonpareil, Monterey
  - 9 weeks of salinity treatment followed by 5 weeks of recovery treatment
- Split-root experiment (2015) on non-grafted rootstock cuttings grown hydroponically in greenhouse
  - Effects of non-uniform vs. uniform salinity on water uptake and tissue salt accumulation
  - Rootstocks: Nemaguard, Hansen536, Empyrean-1, Viking

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Summary of 1st Season Results

- The main component of salinity stress for well-watered almond trees is Na and Cl toxicity.

- While both Na and Cl are potentially toxic, Cl accumulates much faster than Na and is the dominant toxic ion when NaCl is used as the salinizing agent.

- There is wide variation among Prunus rootstocks and almond cultivars with respect to salinity tolerance.
  - Rootstocks: Na and Cl exclusion capabilities seem to correlate for rootstocks.

    Nemaguard < Hansen536 < Empyrean-1 ≈ Viking
  - Cultivars: Nonpareil is the best at excluding Na from leaves while Mission is the best at excluding Cl.

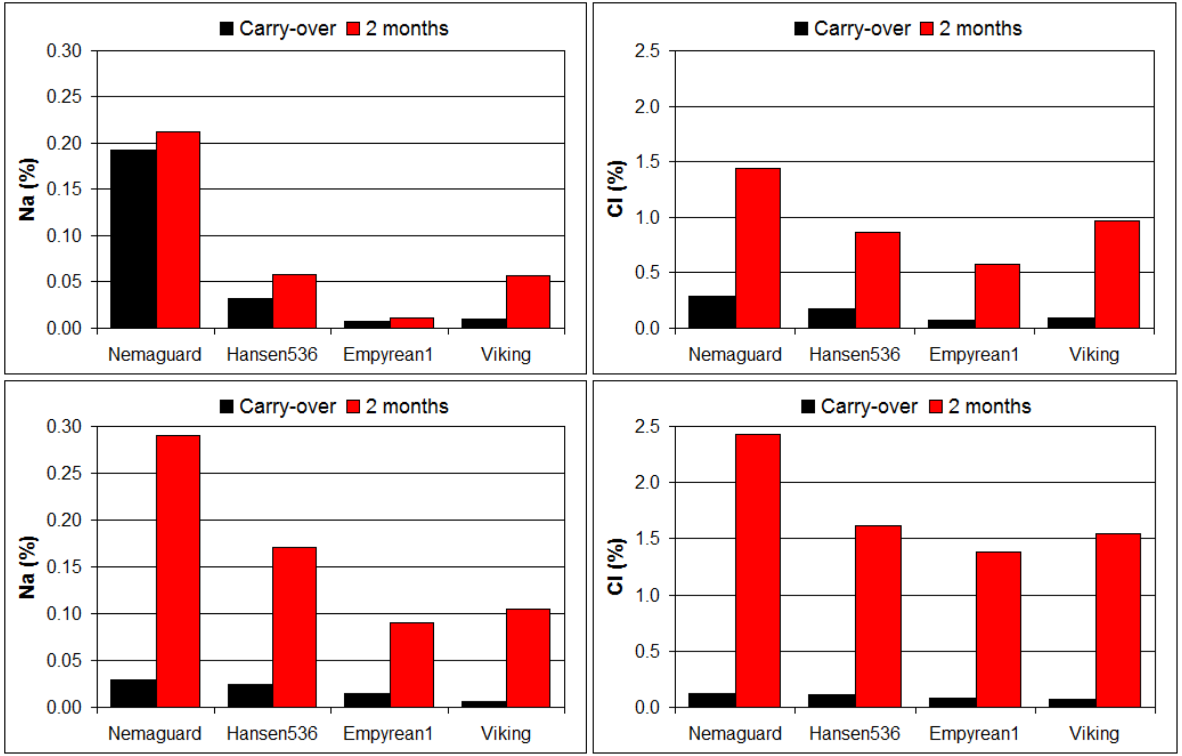
- Na can be stored in woody tissues, and this contributes to the Na tolerance of Nonpareil.

Rootstock Experiment –2nd Season

Leaf Na Concentrations | Leaf Cl Concentrations

Low Salinity
(20 mM NaCl)
(No Recovery Treatment)

High Salinity
(40 mM NaCl)
(With Recovery Treatment)



Na and Cl levels due to last years salt

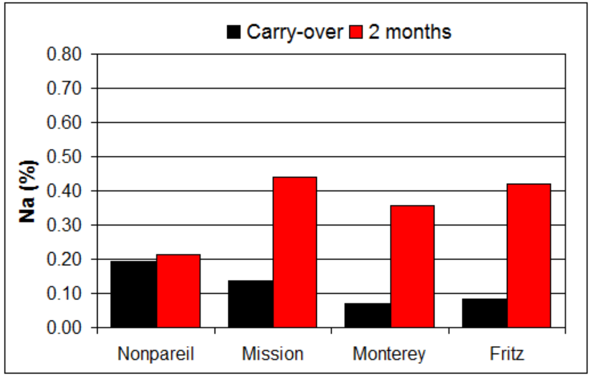
Following 2 months of salt in 2015

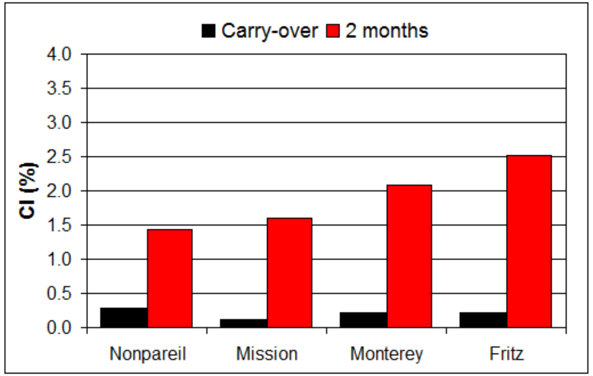
Na and Cl levels are low because we removed trees to no salt in Oct 2014

Cultivar Experiment – 2nd Season

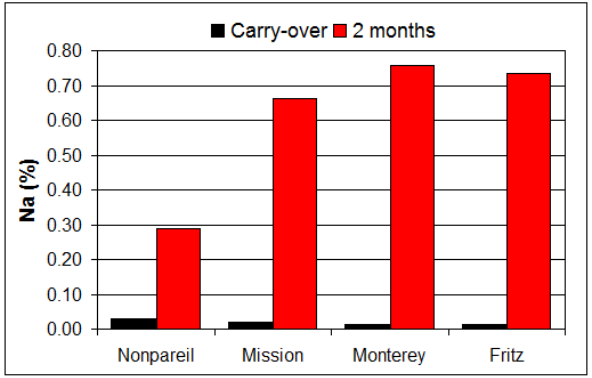
Leaf Na Concentrations | Leaf Cl Concentrations

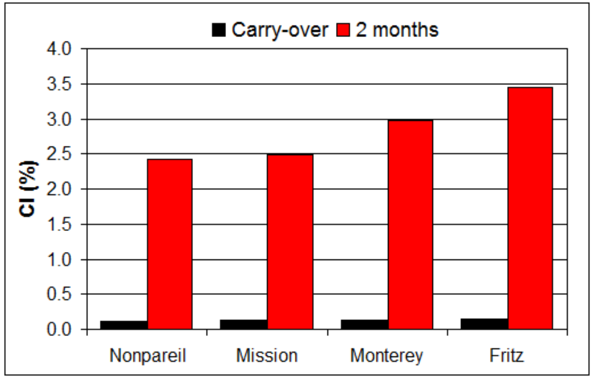
Low Salinity
(20 mM NaCl)
(No Recovery Treatment)



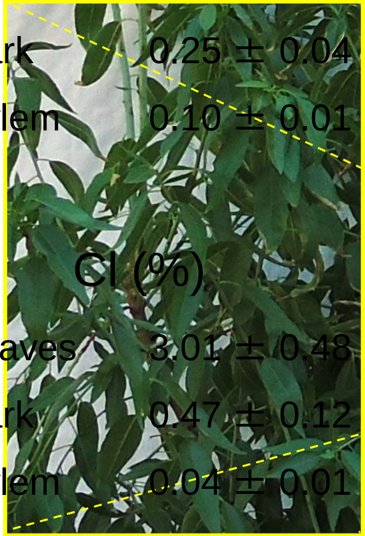


High Salinity
(40 mM NaCl)
(With Recovery Treatment)





Double-Grafting Experiment: Nonpareil vs. Mission on Nemaguard



Nonpareil

Na (%)	
Leaves	0.72 ± 0.07
Bark	0.25 ± 0.04
Xylem	0.10 ± 0.01

Cl (%)	
Leaves	3.01 ± 0.48
Bark	0.47 ± 0.12
Xylem	0.04 ± 0.01

Graft Union

Mission

Na (%)	
Leaves	1.70 ± 0.07
Bark	0.02 ± 0.01
Xylem	0.02 ± 0.00

Cl (%)	
Leaves	3.92 ± 0.39
Bark	0.41 ± 0.10
Xylem	0.04 ± 0.02

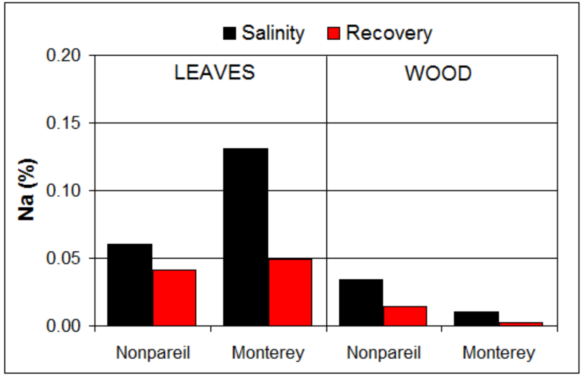
Recovery Experiment

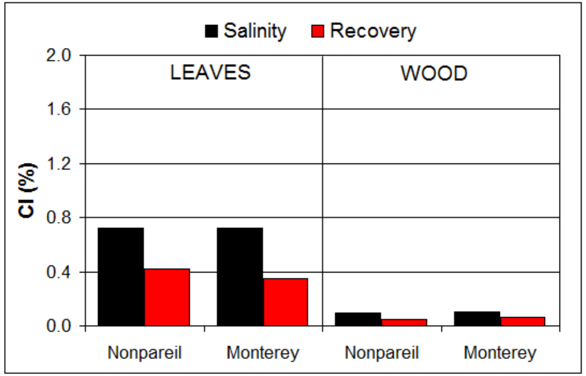
9 weeks salinity treatment followed by 5 weeks recovery with no added salt.

Na Concentrations

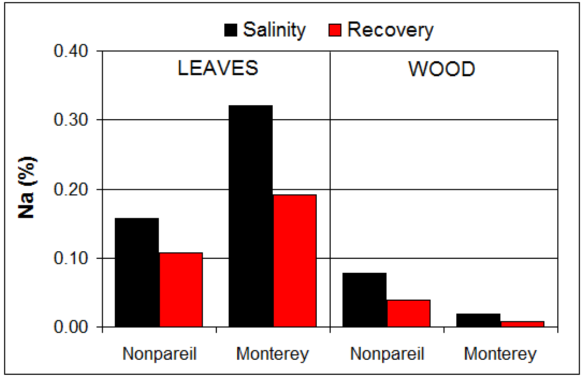
Cl Concentrations

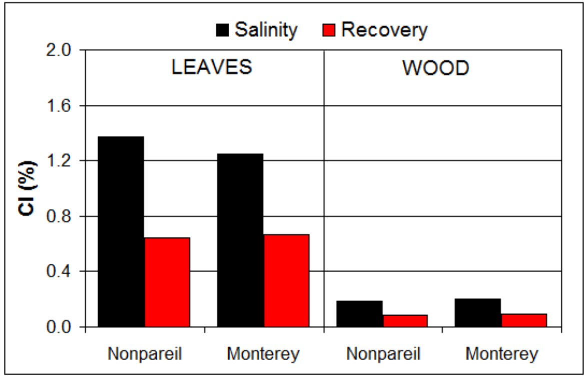
Low Salinity
(20 mM NaCl)





High Salinity
(40 mM NaCl)





Summary of Findings & Poster Information

- In general, 2nd season data are consistent with 1st season data for the main rootstock experiment.
  - In order of decreasing leaf salt load: Nemaguard > Hansen536 > Empyrean-1≈ Viking
  - BUT: Leaf Cl differences between Hansen536, Empyrean-1 and Viking disappeared in season 2.
- Among tested cultivars, Nonpareil is the best one in excluding Na from leaves, while Nonpareil and Mission are the best two in excluding Cl from leaves.
- Na allocation to woody tissues plays a critical role in Na exclusion from leaves and contributes majorly to Na tolerance in Nonpareil.
- When found at equal concentrations, Cl accumulates faster to toxic levels in leaves than Na, and KCl is even more toxic than NaCl (counter-ion effect).
- In-season recovery treatment effectively reduces leaf and wood Na and Cl concentrations.
- Under non-uniform salinity, all rootstocks preferentially absorb water from the less-saline side.
- Partial root access to good-quality water significantly lowers the Na and Cl levels in shoot tissues.
- For further information and discussion, please visit Poster 45.

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Georgia Drakakaki,
University of California, Davis

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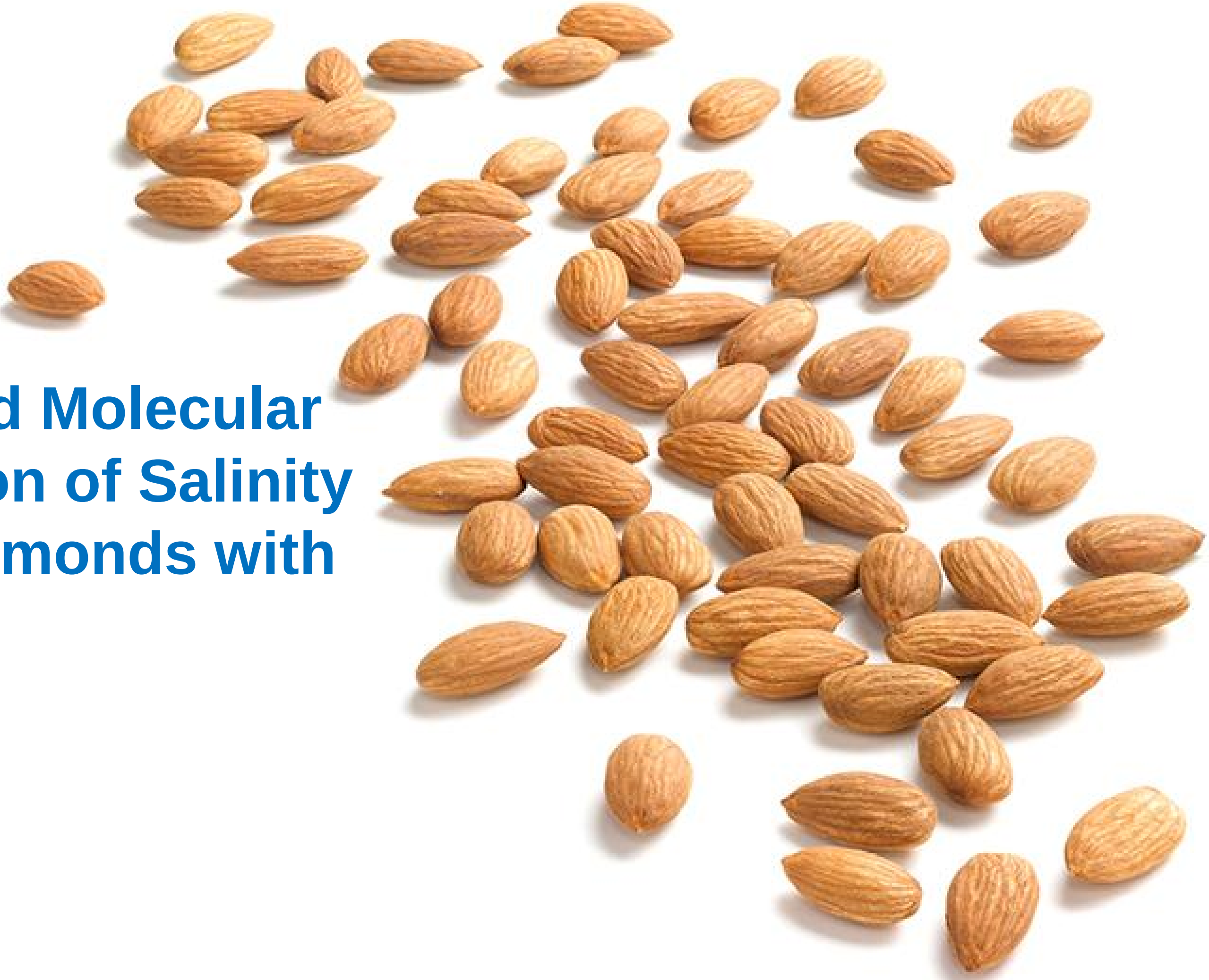
Subcellular and Molecular Characterization of Salinity Tolerance in Almonds with Novel Tools



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Subcellular and Molecular Characterization of Salinity Tolerance in Almonds with Novel Tools

Georgia Drakakaki

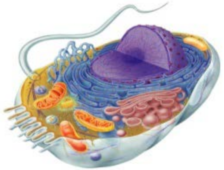
Department of Plant Sciences, University of California, Davis

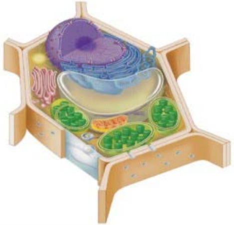
Collaborators: Thomas Wilkop, John Preece, Malli Aradhya, Bruce Lampinen, Patrick Brown, Tom Gradziel, Roger Duncan

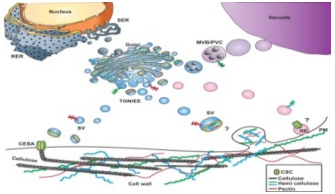
Outline

- Our research interests and expertise
- Preliminary studies of sodium subcellular accumulation
- Our future work

Plants Can’t Move!!







Shindo et al. (2006) Genes and Development

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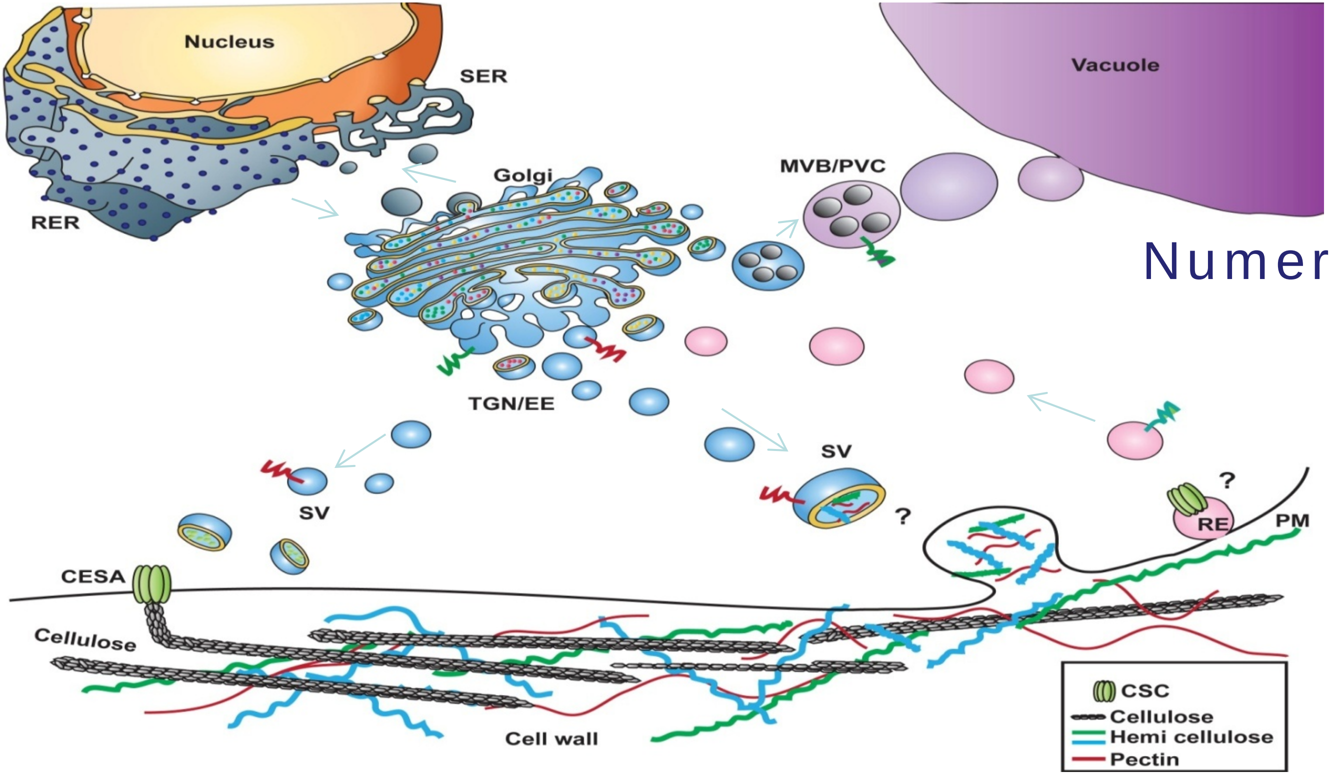
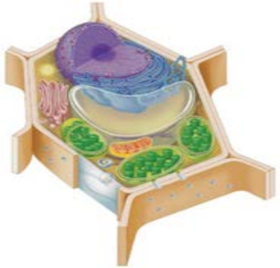
The Endomembrane System Consists of:



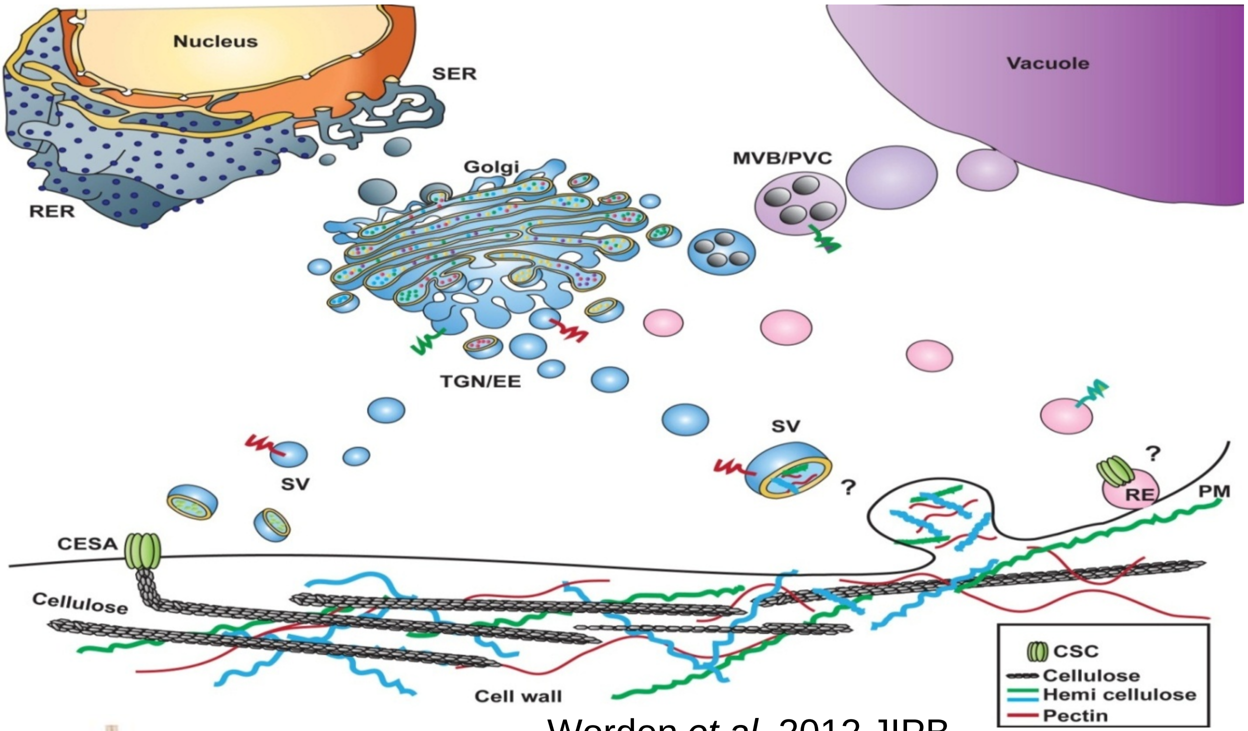
Worden *et al*. 2012 JIPB



Numerous Compartments

- **Abiotic stress response**
- Plant development and cell wall biosynthesis [cell pattern formation, senescence, flowering]
- Signal transduction
- Hormonal responses
- Plant pathogen resistance

Questions in my Research Group:

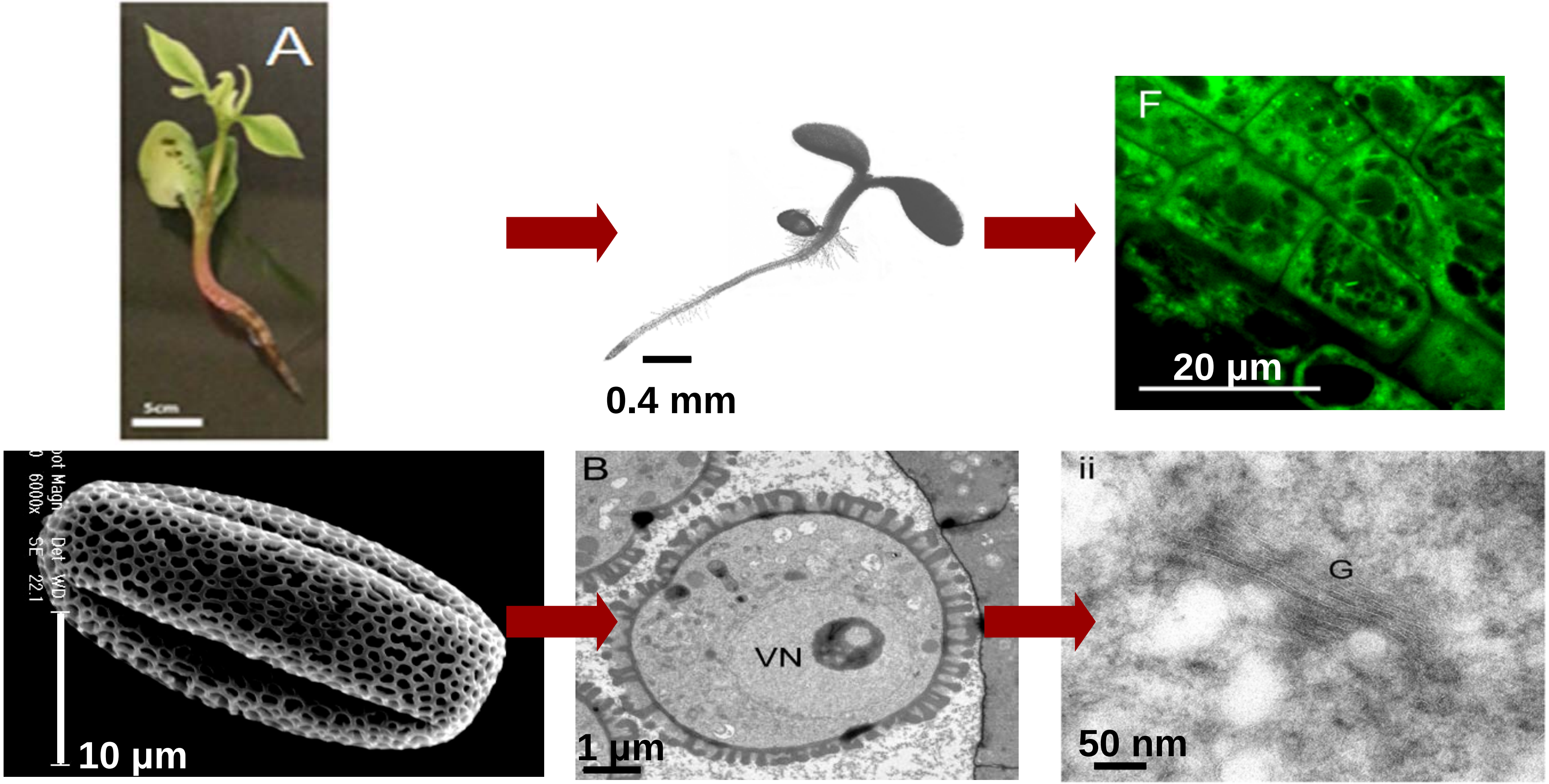


Worden *et al*. 2012 JIPB

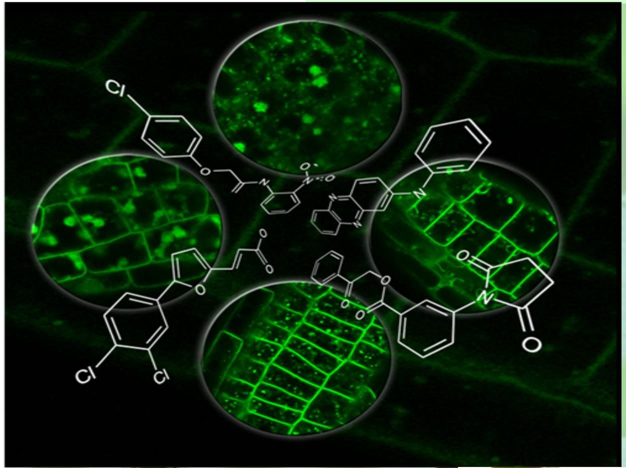
- ❑ **How does this membrane network controls response to biotic an abiotic stress?**
- ❑ **How do cell wall components reach their destination?**

Wall polysaccharides and enzymes travel along the endomembrane system to the wall

We Investigate Plant Cellular Processes



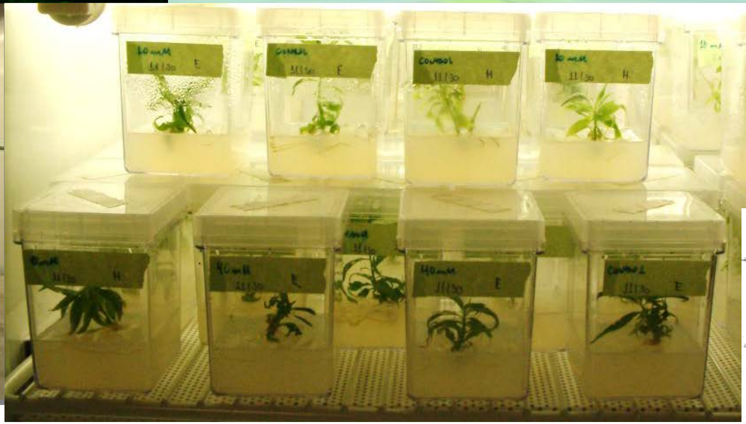
Approaches Used in Our Lab

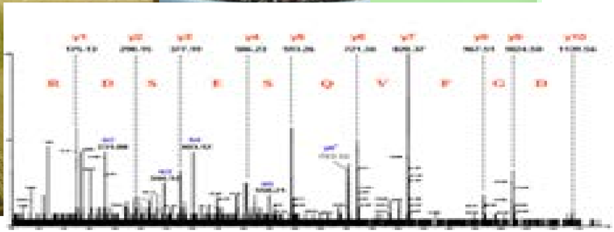


Proteomics

Chemical Genomics

Genetics





Outline

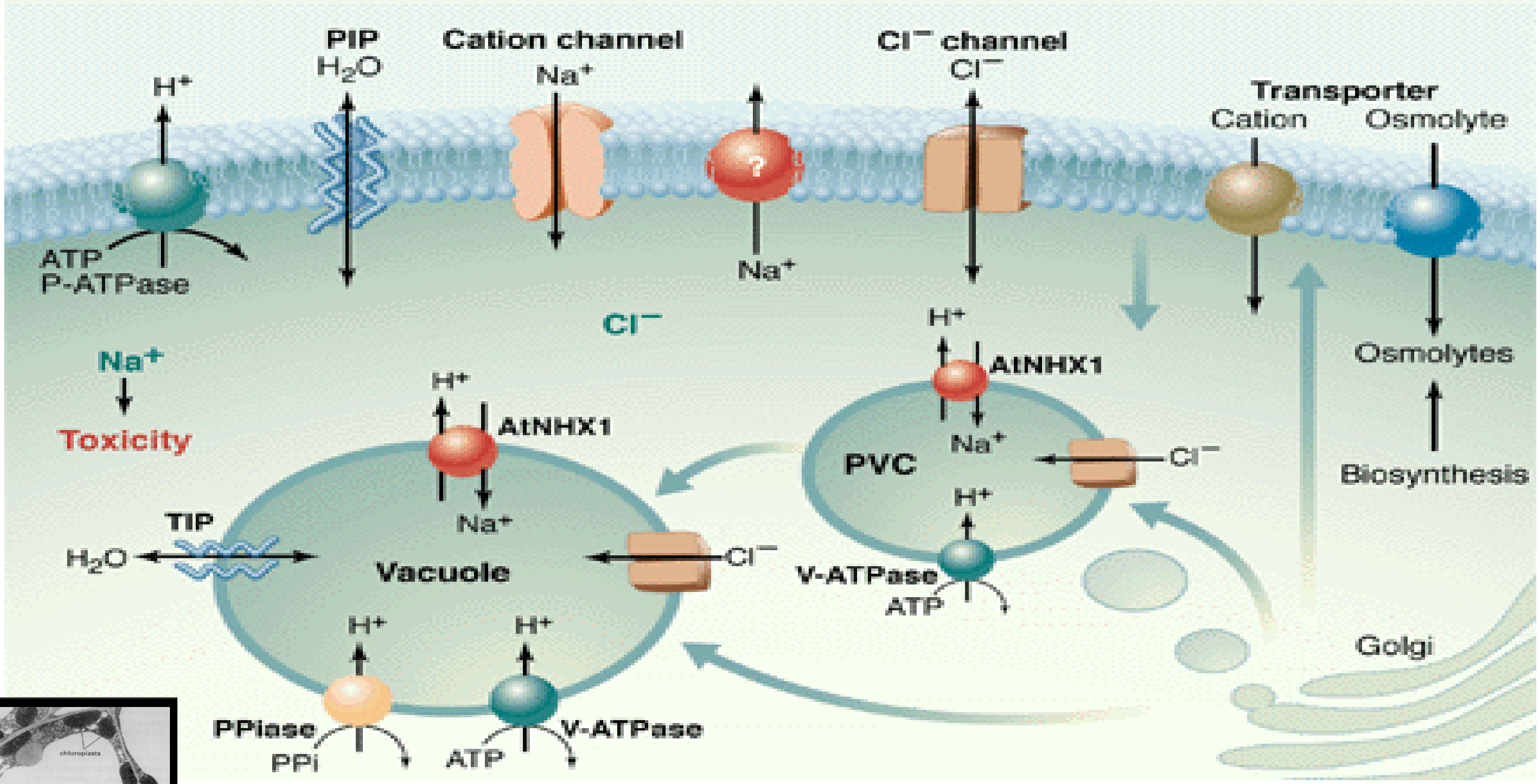
- Our research interests and expertise
- Preliminary studies of sodium subcellular accumulation
- Our future work

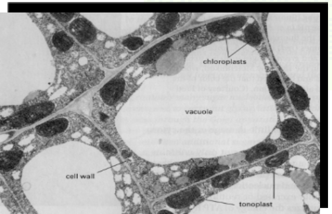
Motivation

Almond plants are relatively sensitive to salinity stress

Need for robust tools to screen for elite genotypes on salinity tolerance

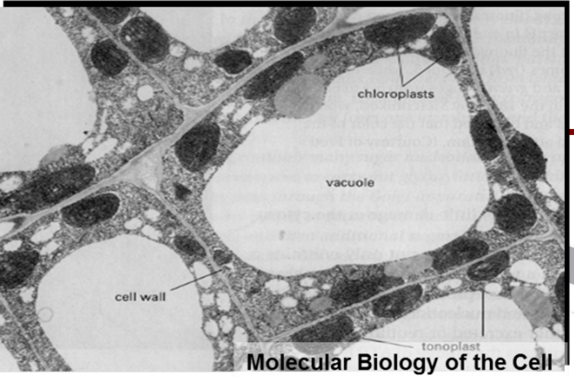
Plant Vacuole and Ion Transport

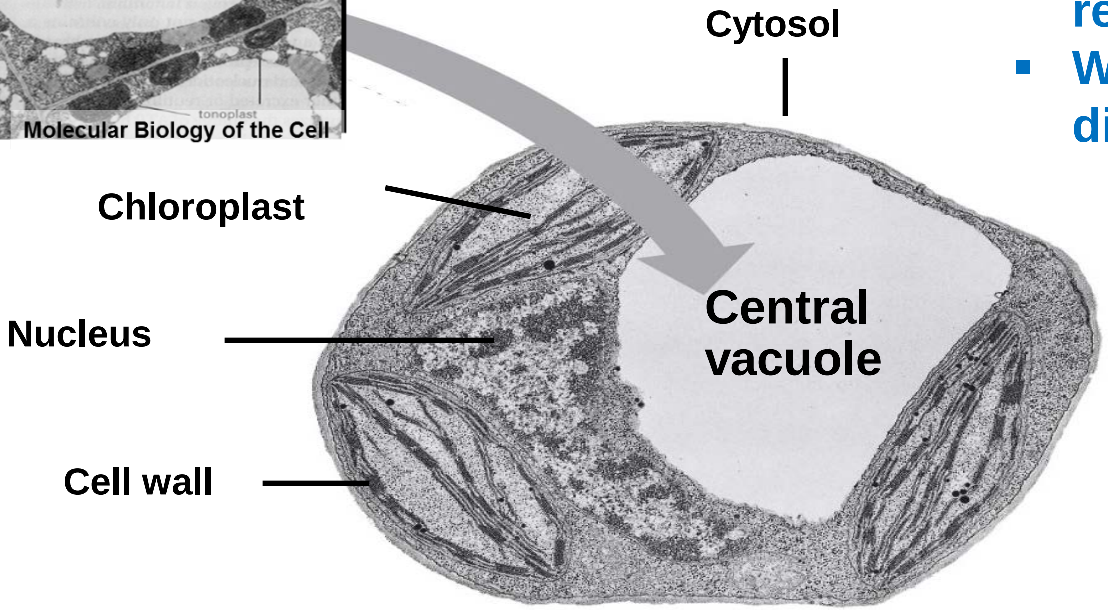




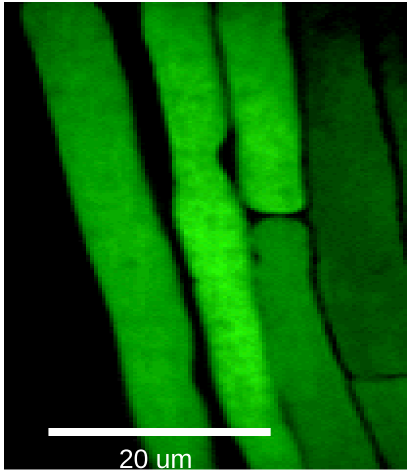
Science 1999: vol. 285 no. 5431 1222-1223

Importance of The Plant Vacuole





- **How different rootstocks respond ?**
- **What happens after different treatments?**

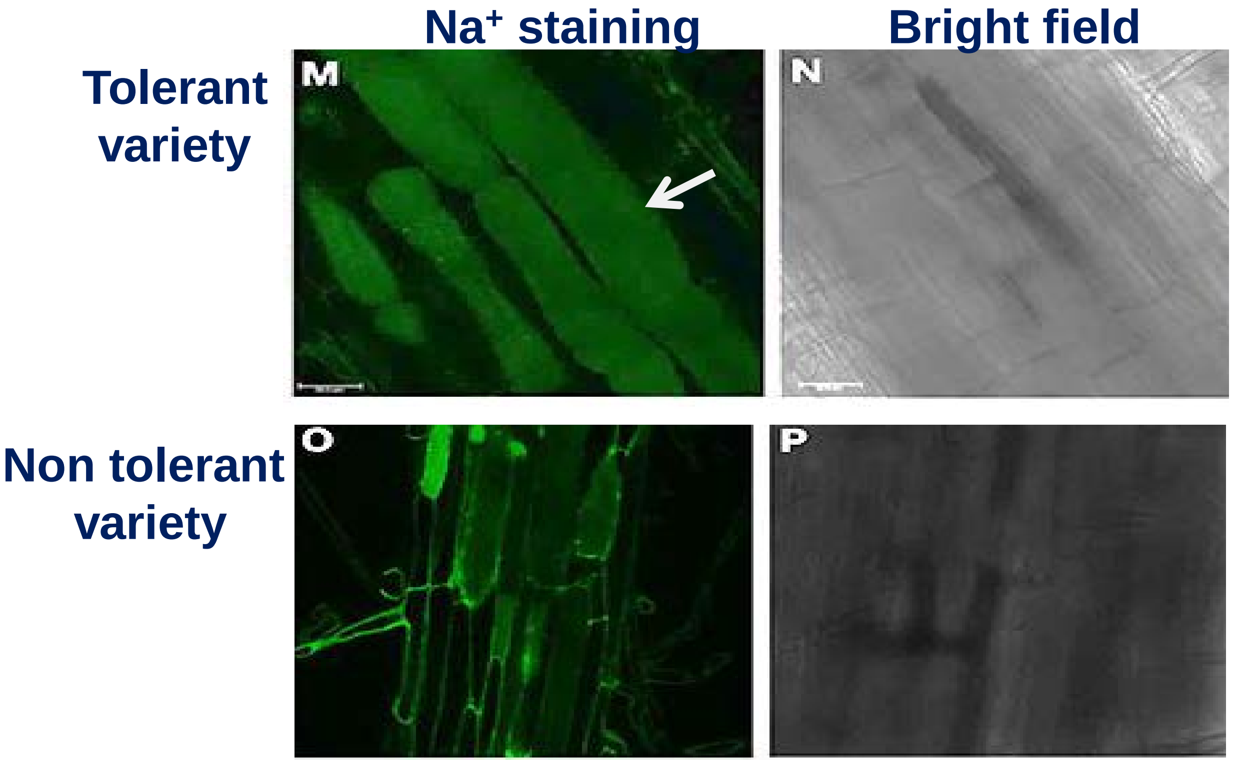


Tamura et al. (2003) Plant J.

Mature plants carry a central vacuole:

- **Detoxification- accumulation waste products**
- **Occupy up to 95% volume**

Na^+ Accumulation in the Vacuole of Bread Wheat



Front. Plant Sci., 20 February 2015 | doi: 10.3389/fpls.2015.00071

Salinity tolerance associated with sodium accumulation in the vacuole

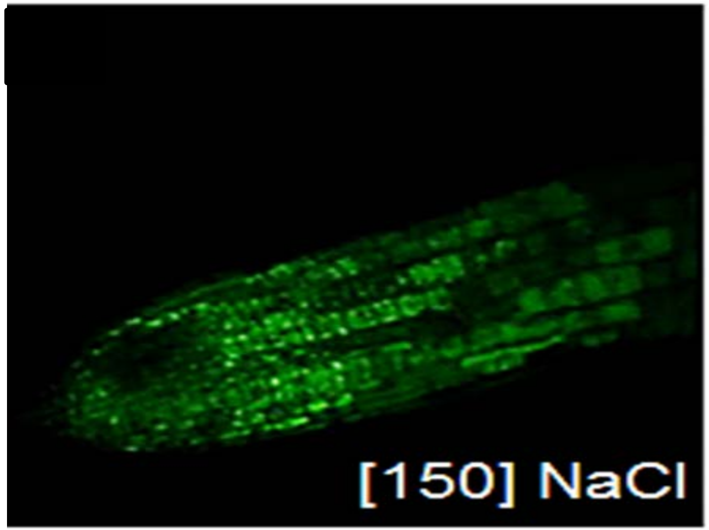
Similar studies have been reported in citrus and pepper

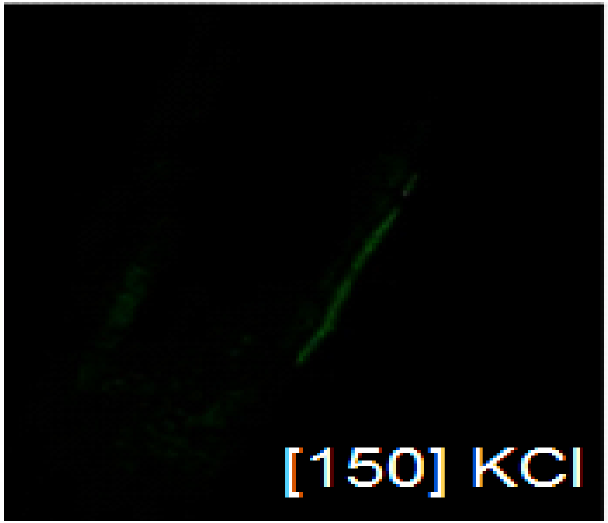
Our Pistachio Research...

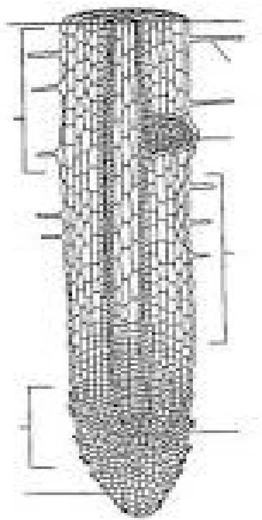
- **Establish a method of sodium localization in pistachio plant tissues.**

- **Characterize sodium localization in various rootstock seedlings tissues treated with NaCl.**

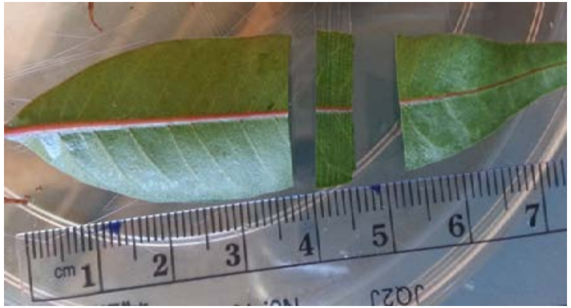
Selectivity of CoroNa-Green with Sodium



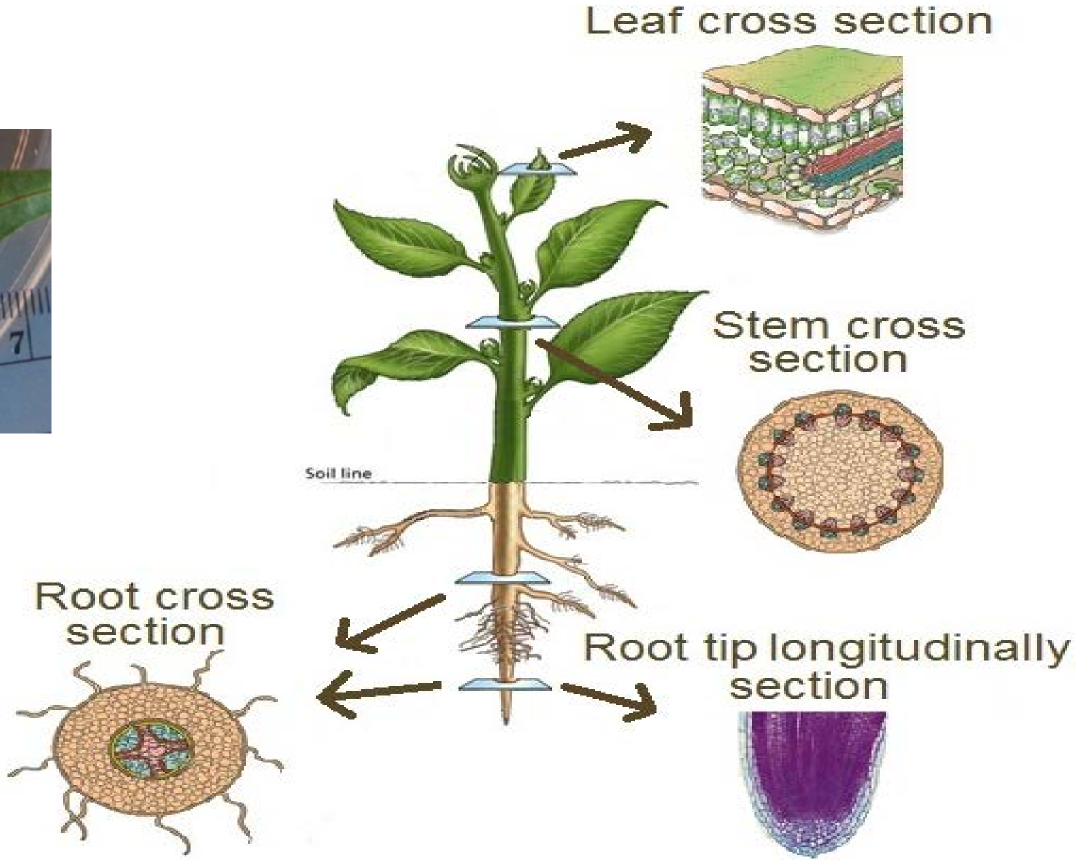




Tissues Tested

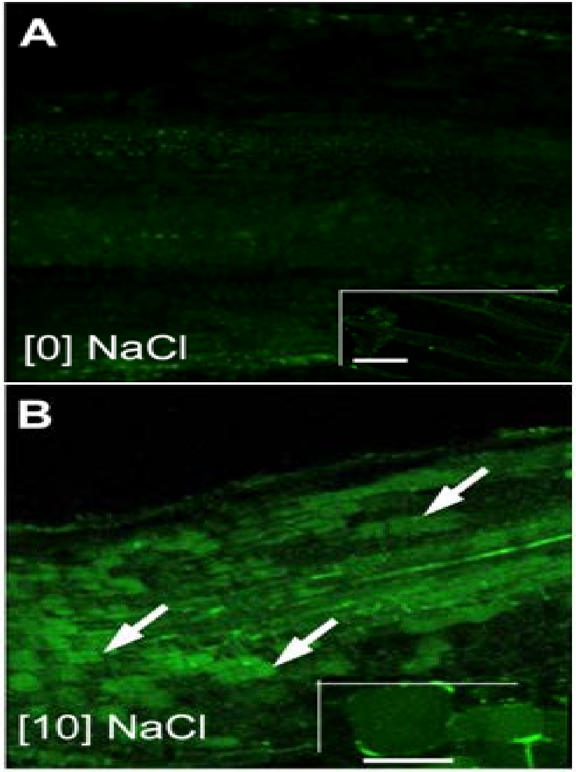


Roots, leaves and stems were sectioned transversely and/or longitudinally into 1-2 mm sections.



Sodium Localization of in Pistachio Roots after NaCl Treatment

Root tip longitudinally section



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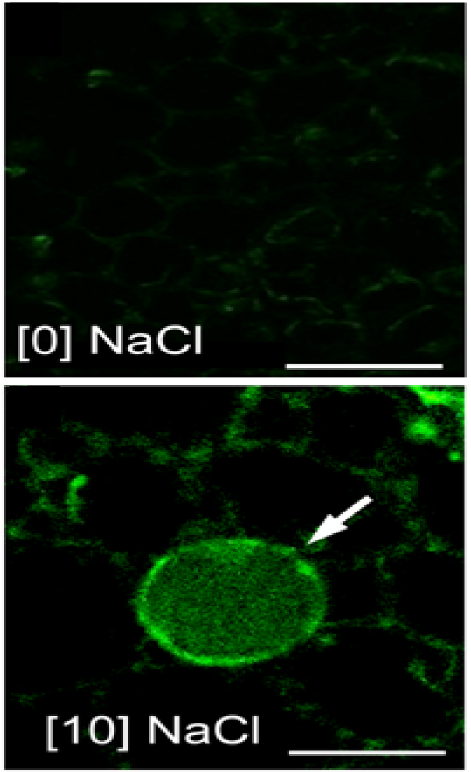
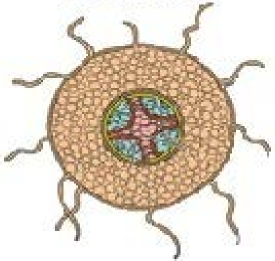
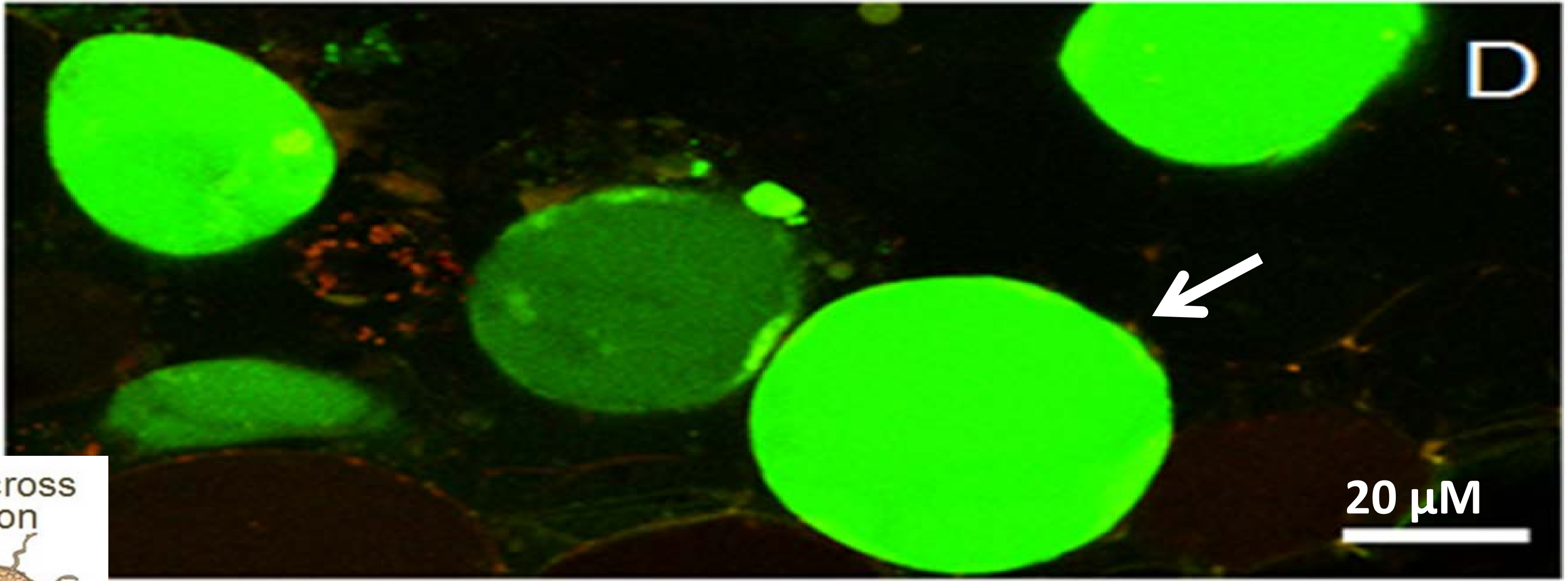


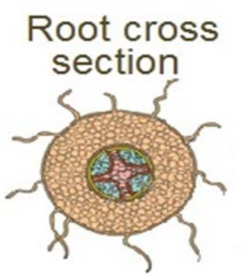
3 week treatment

Root cross section



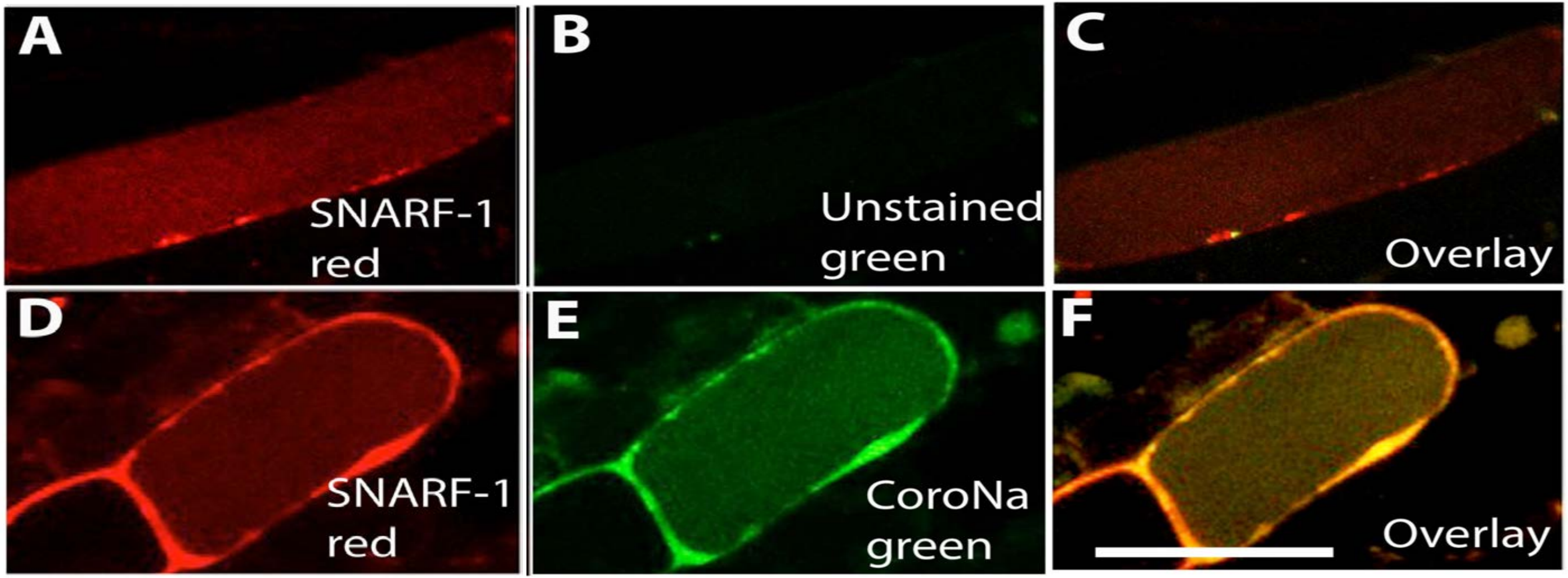
Sodium Accumulation in Root Vacuole Upon NaCl Stress



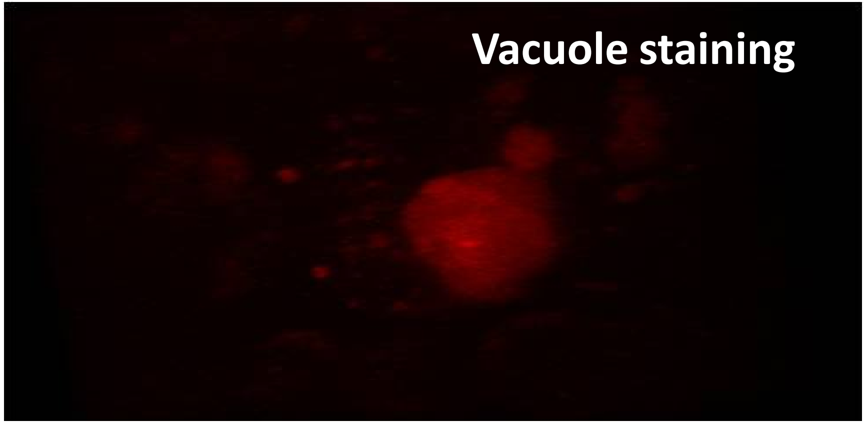


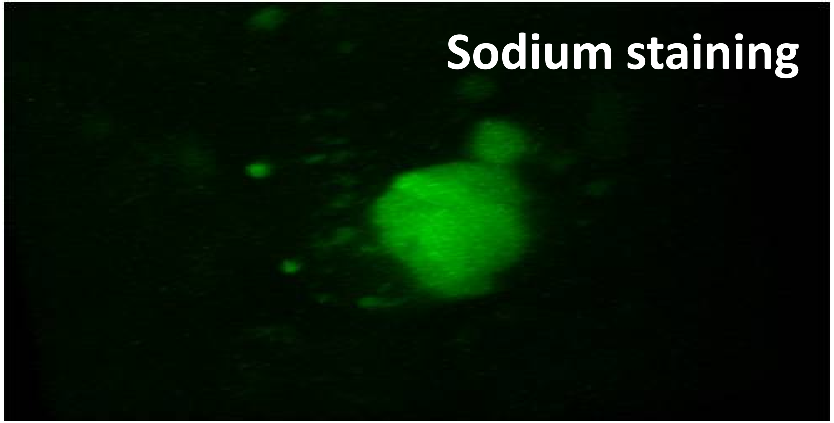
This approach allows us to screen several genotypes under different treatments

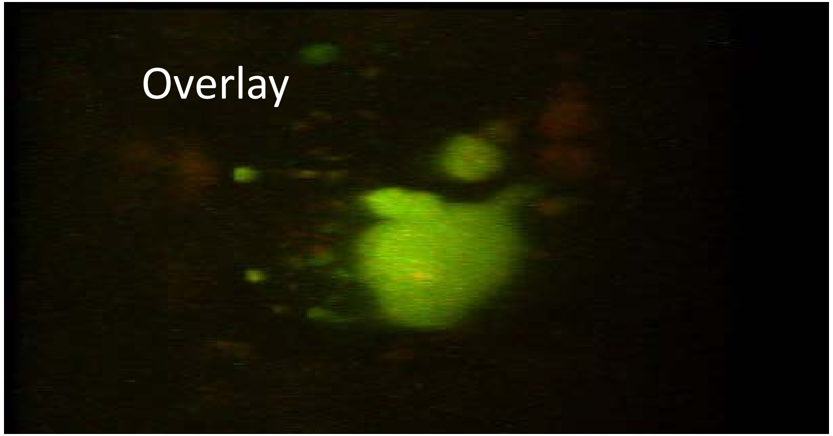
Sodium Localization in the Vacuole of Pistachio cells

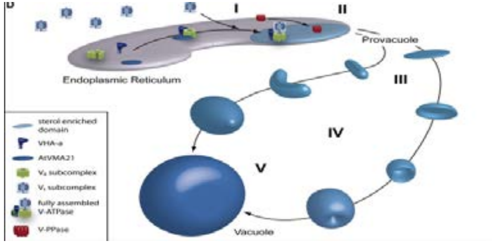


Vacuolar Localization of Sodium in Developing Vacuole



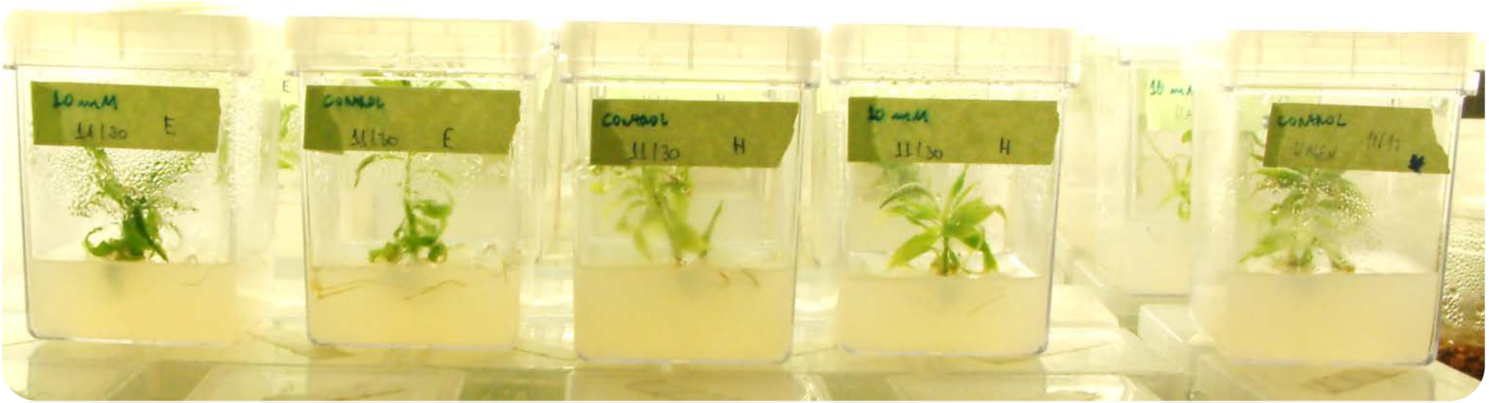






Viotti C et al. Plant Cell 2013

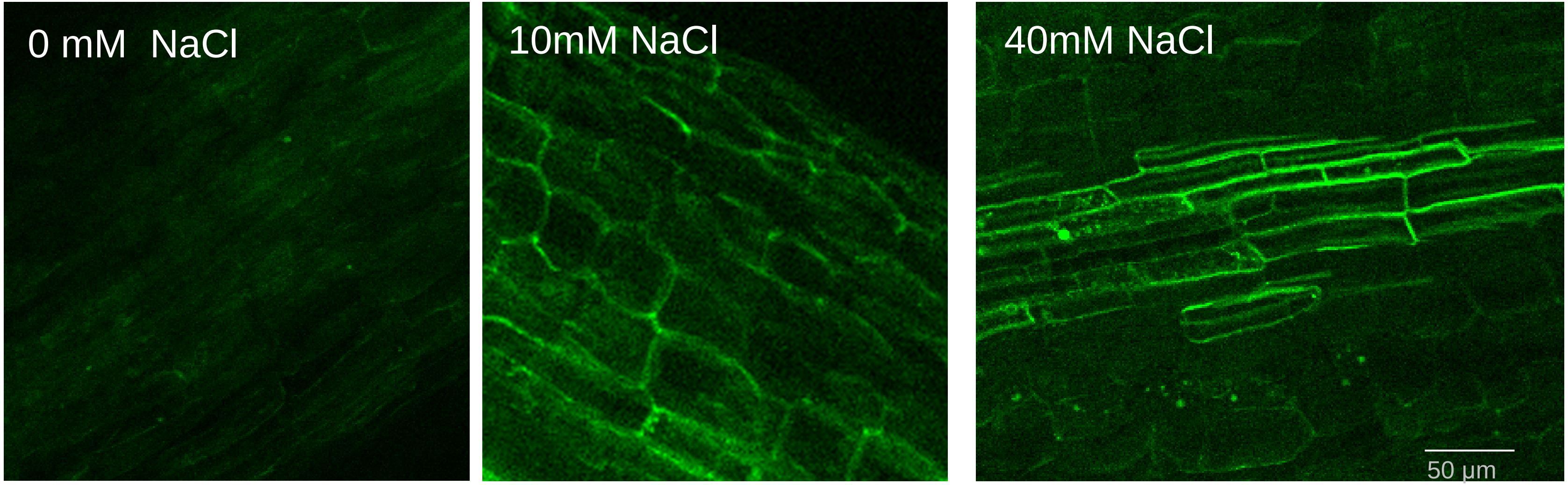
Screen of Selected Almond Rootstocks



Hansen 0, 20, 40 mM NaCl

Sodium Localization in Almond Roots after NaCl Treatment

Sodium Staining Corona Green



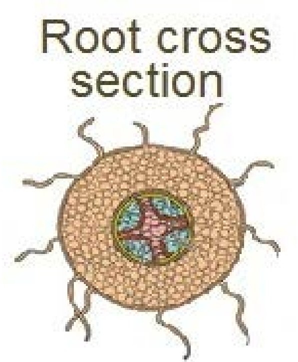
Hansen rootstock, 2 weeks treatment

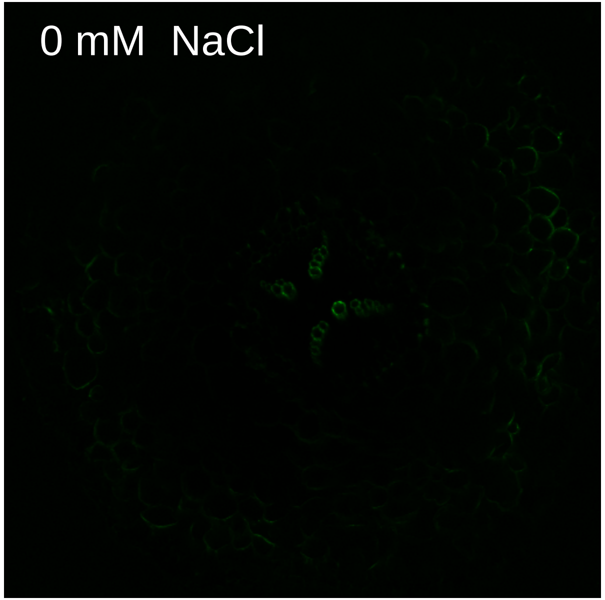
Root tip longitudinally section

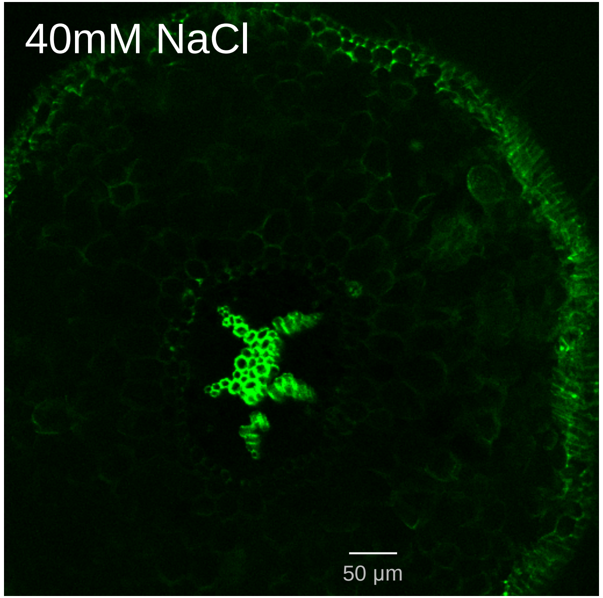
Increased cellular accumulation of sodium is observed

Sodium Localization in Almond Roots after NaCl Treatment

Sodium Staining CoroNa-Green





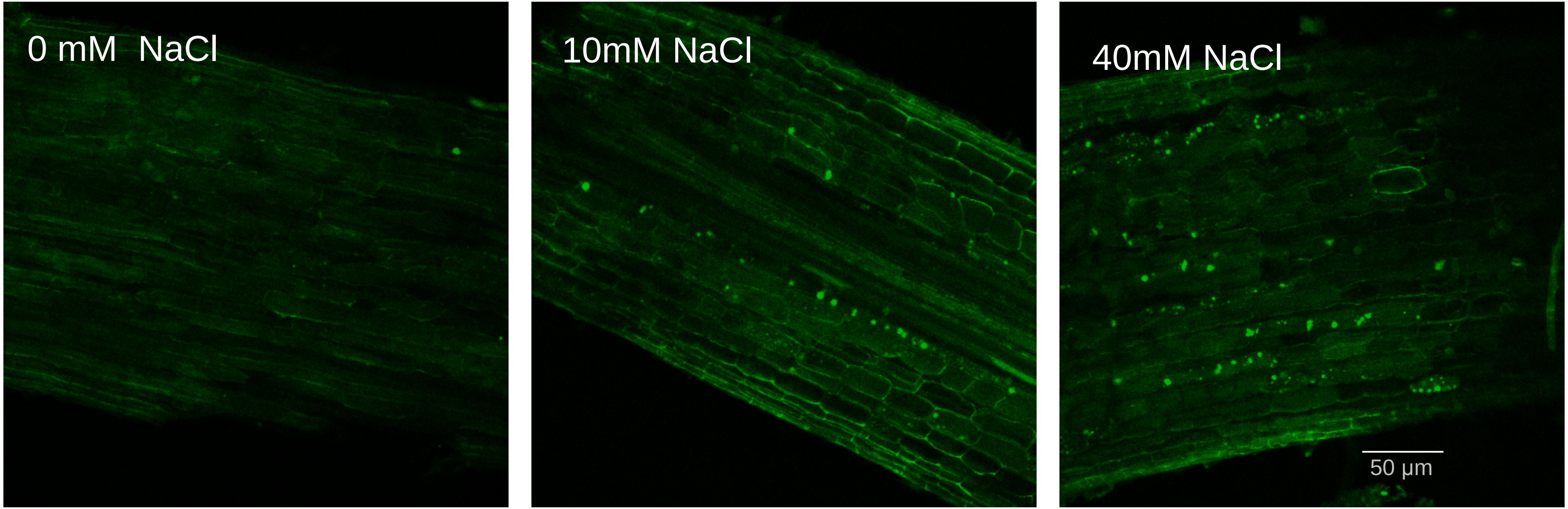


Hansen rootstock, 2 weeks treatment

Altered cellular accumulation of sodium is observed

Potassium Localization in Almond Roots after NaCl Treatment

Potassium Staining Asante Potassium-Green



Hansen rootstock, 2 weeks treatment

Root tip longitudinally section

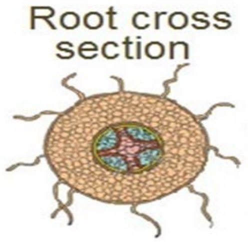
Altered localization pattern of potassium is observed

Summary

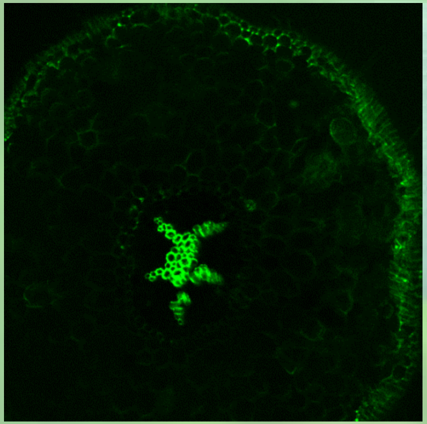
The methodology for quantitative potassium and sodium localization in almond root cells has been established

Increased cellular accumulation of sodium and altered potassium localization patterns were observed in salt treated rootstock seedlings

Continuing Work :



- Establish a methodology for chloride detection
- Extend screen of almond rootstocks
- Mapping the structural morphology of almond roots in order to establish a reference



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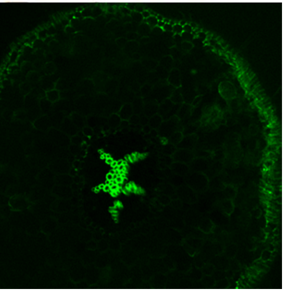
Longer Term Aims



- **Incorporate the subcellular characterization of ion sequestration in currently developing genotypes that are undergoing phenotypic screening at the National Germplasm Repository**

- **On the genetic level, identify molecular markers for halotolerance in combination to other desired traits**

Acknowledgements

Almond Project:

Thomas Wilkop

Angelo Herringer

Collaborators:

John Preece,

Malli Aradhya,

Bruce Lampinen,

Patrick Brown,

Tom Gradziel,

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Sierra Gold Nurseries

Pistachio project:
Thu Le
Victor Esteva
Juvenal Quezada
Thomas Wilkop

Collaborators:
Jessie Godfrey
Louise Ferguson
Maciej Zwieniecki

Daniel Schellenberg,
University of California, Davis

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Nutrient Availability and Food Safety of Organic Matter Amendments

Daniel Schellenberg[1], Stephen Hart[2],
Jeffery McGarvey[3] and Patrick Brown[1]
[1]Department of Plant Sciences University of California Davis
[2]School of Natural Sciences University of California Merced
[3]USDA ARS Food Toxin Detection and Prevention Unit Albany

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Project Objectives

- Compare sources of organic matter amendments
- Demonstrate food safe integrated nutrient management
- Estimate decomposition rates
- Evaluate potential soil moisture savings
- Contrast availability of nutrients (NPK)

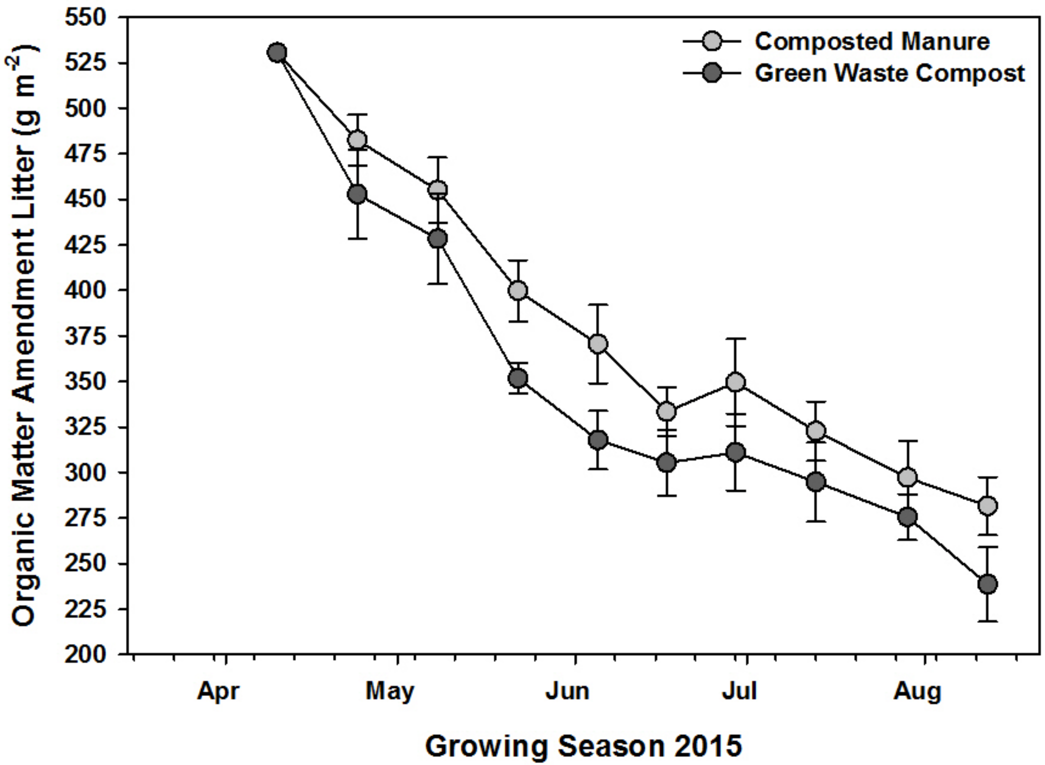
Sources of Organic Matter Amendments

- Composted Dairy Manure
  - pH 8.0
  - EC 29 dS/m
  - C:N 12
- Green Waste Compost
  - pH 5.0
  - EC 23 dS/m
  - C:N 19
- Both Sources Free of Human Pathogens

Food Safe Approaches

- Composted Materials
- Testing for Human Pathogens
- Trials with Non-bearing Trees
- Application 120 days before Harvest
- Mulched on Tree Berm
- Placed in Wetted Zone

Decomposition Rate



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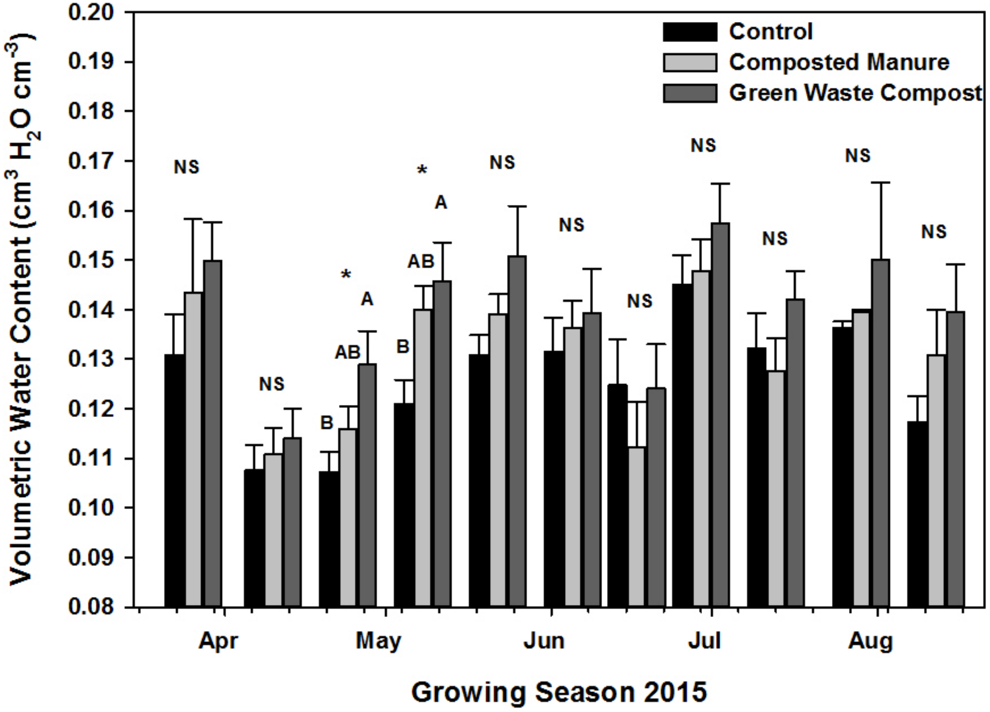
Soil Moisture Savings



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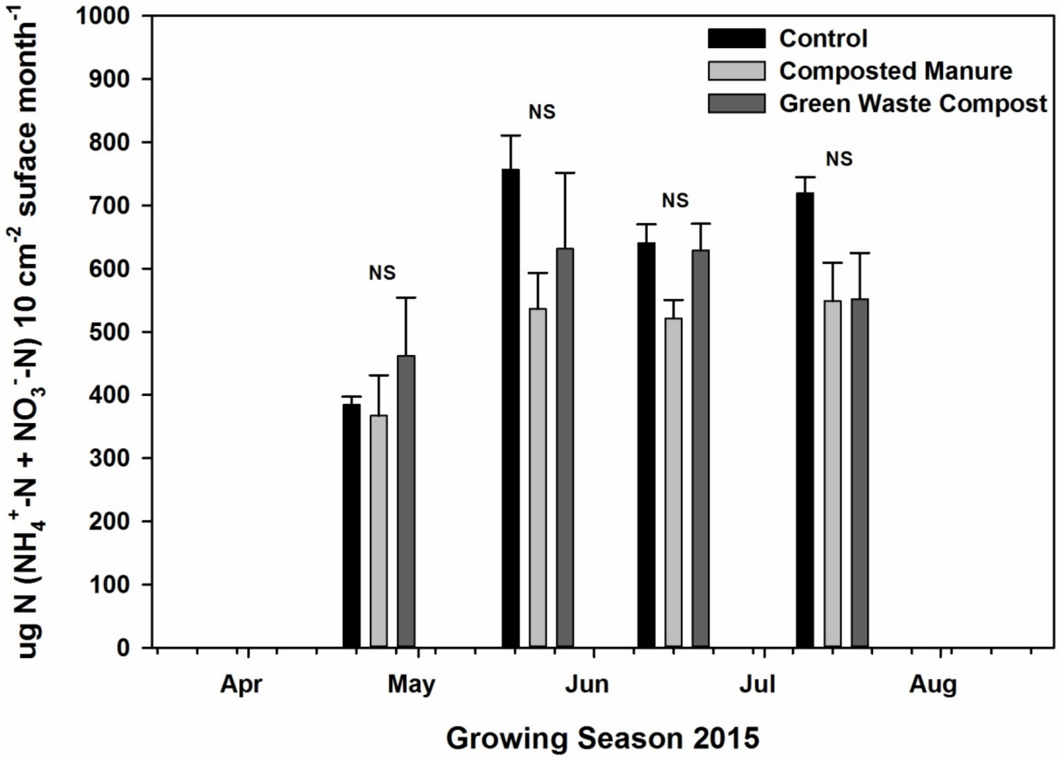
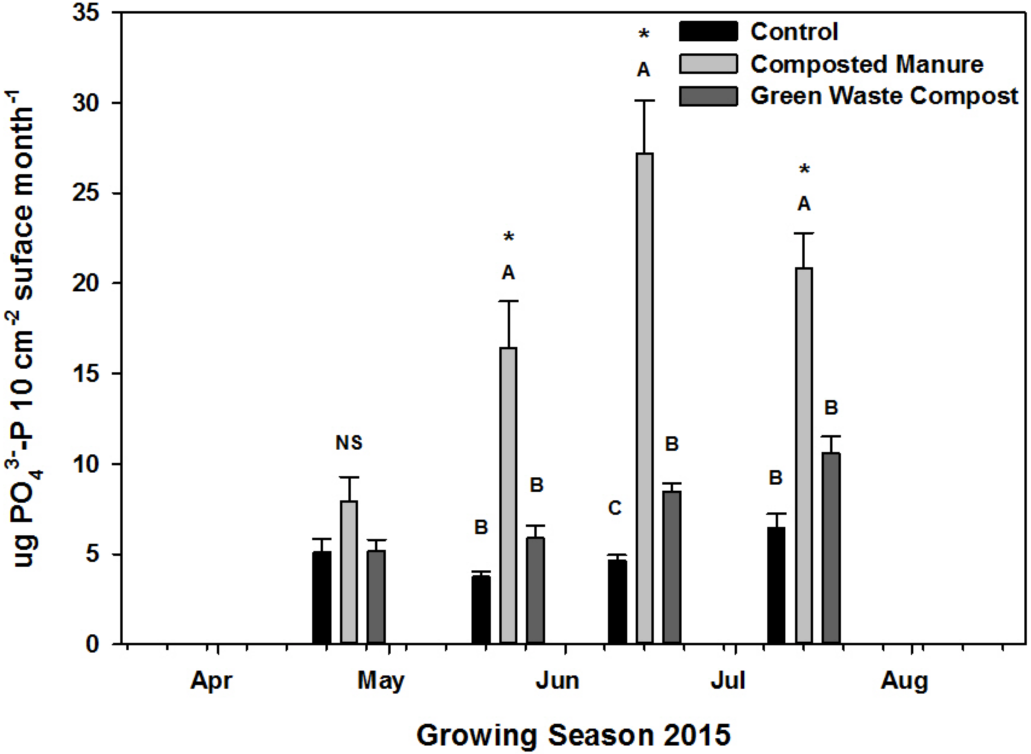
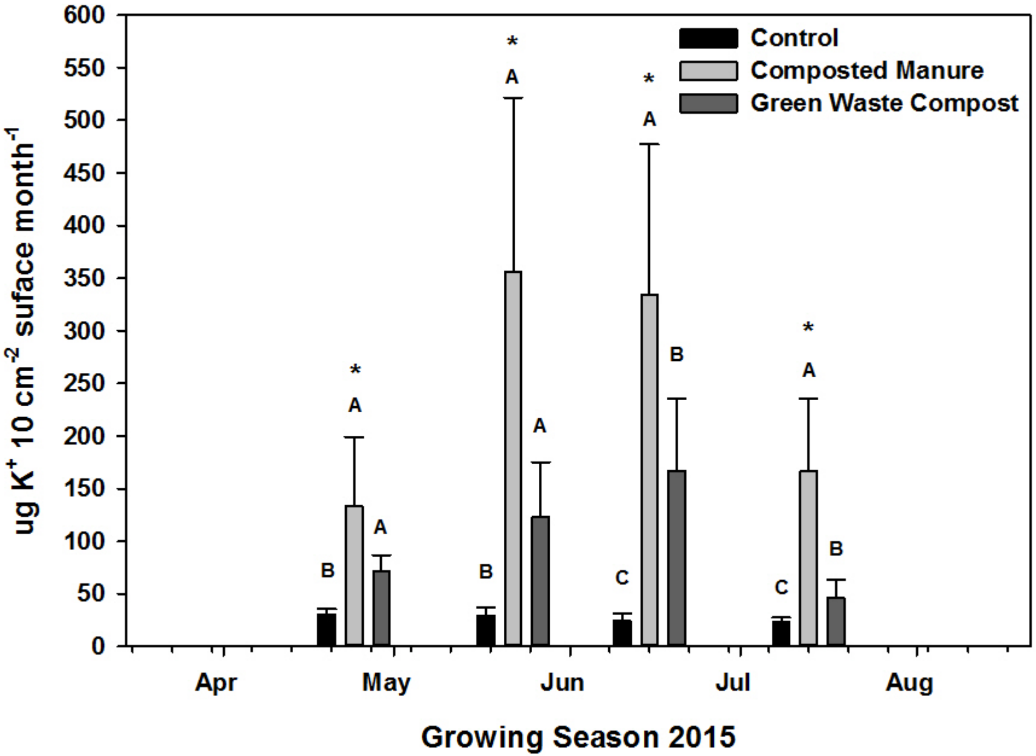
Nutrient Availability – Nitrogen



Nutrient Availability – Phosphorus



Nutrient Availability – Potassium



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Conclusions

- Viable option for partial substitution of fertilizers
- Decomposition of ~7-9 lb/acre/day during growing season
- Early season soil moisture savings
- Potential role of N storage
- Effective source for P and K fertilizer

Future Work

- Trial on 3rd leaf at Escalon site in San Joaquin County
- Join our Soil Health Network
  - –Participate in Satellite trials
  - –Use of Organic Matter Amendments
  - –Trees on 1st to 5th leaf or older
  - –Microirrigation system
  - –Contact me by email dschel@ucdavis.edu

David Smart,
University of California, Davis

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N_2O Emissions From Almond

David R. Smart, Sharon Dabach, Rebekah Davis, Maria del Mar Alsina and Daniel Schellenberg

University of California, Davis

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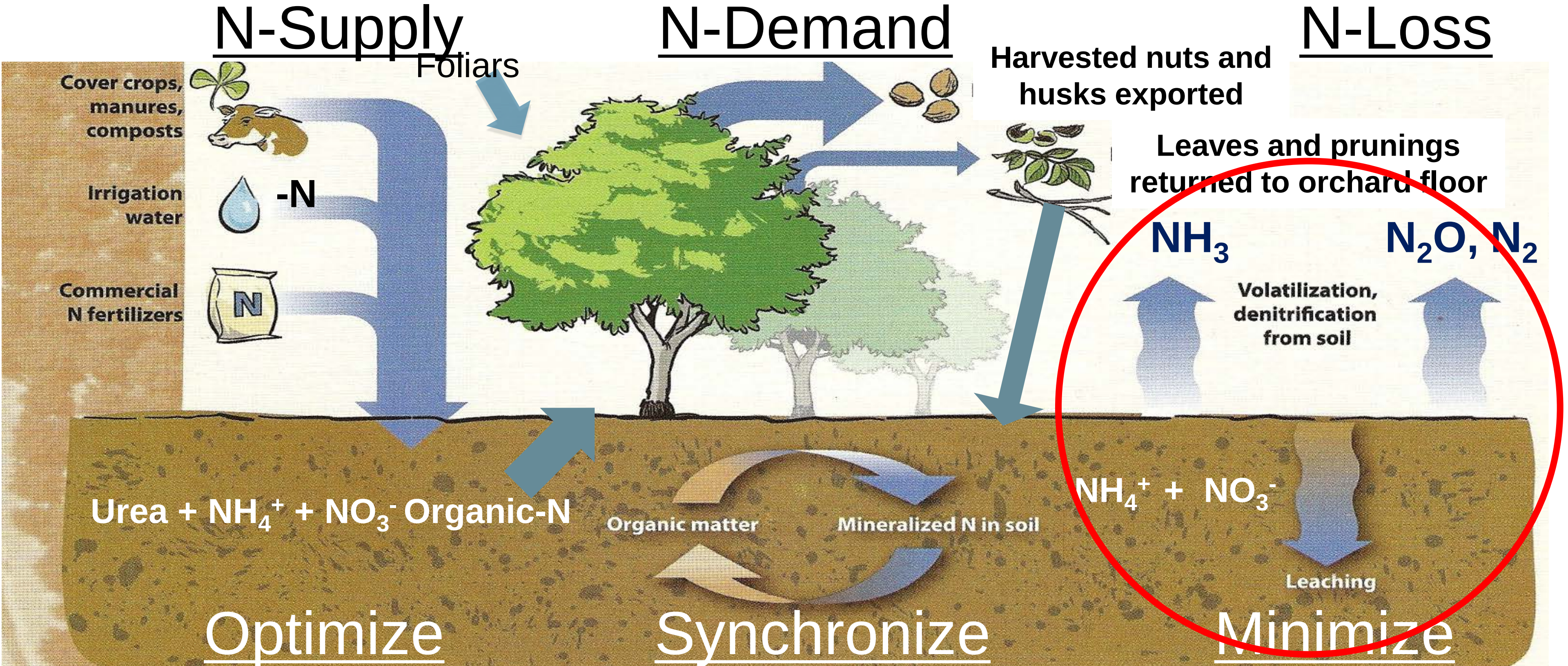

BMP Treatments:

Advanced Grower Practice (AGP)
(split applications targeted to N demand)

High Frequency Low [N] (HFLC)
(spoon feed, 20 split apps of 5-15 lbs $acre^{-1}$)

Pump and Fertilize (P&F)
(AGP, compensating for well water N loads)

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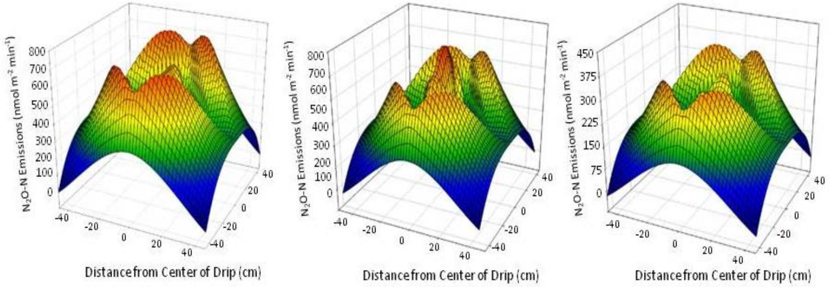
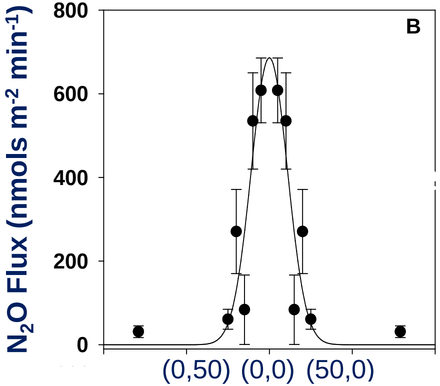
Spatially Modeling N_2O Emissions





$$\iint_A f(x,y)dxdy \cong \sum_{x=-0.5}^{x=+0.5}\sum_{y=-0.5}^{y=+0.5} y_o + y^{a \cdot e^{\frac{1}{2}\left[\frac{(x-x_0)^2}{b^2}+\frac{(y-y_0)^2}{c^2}\right]}}$$

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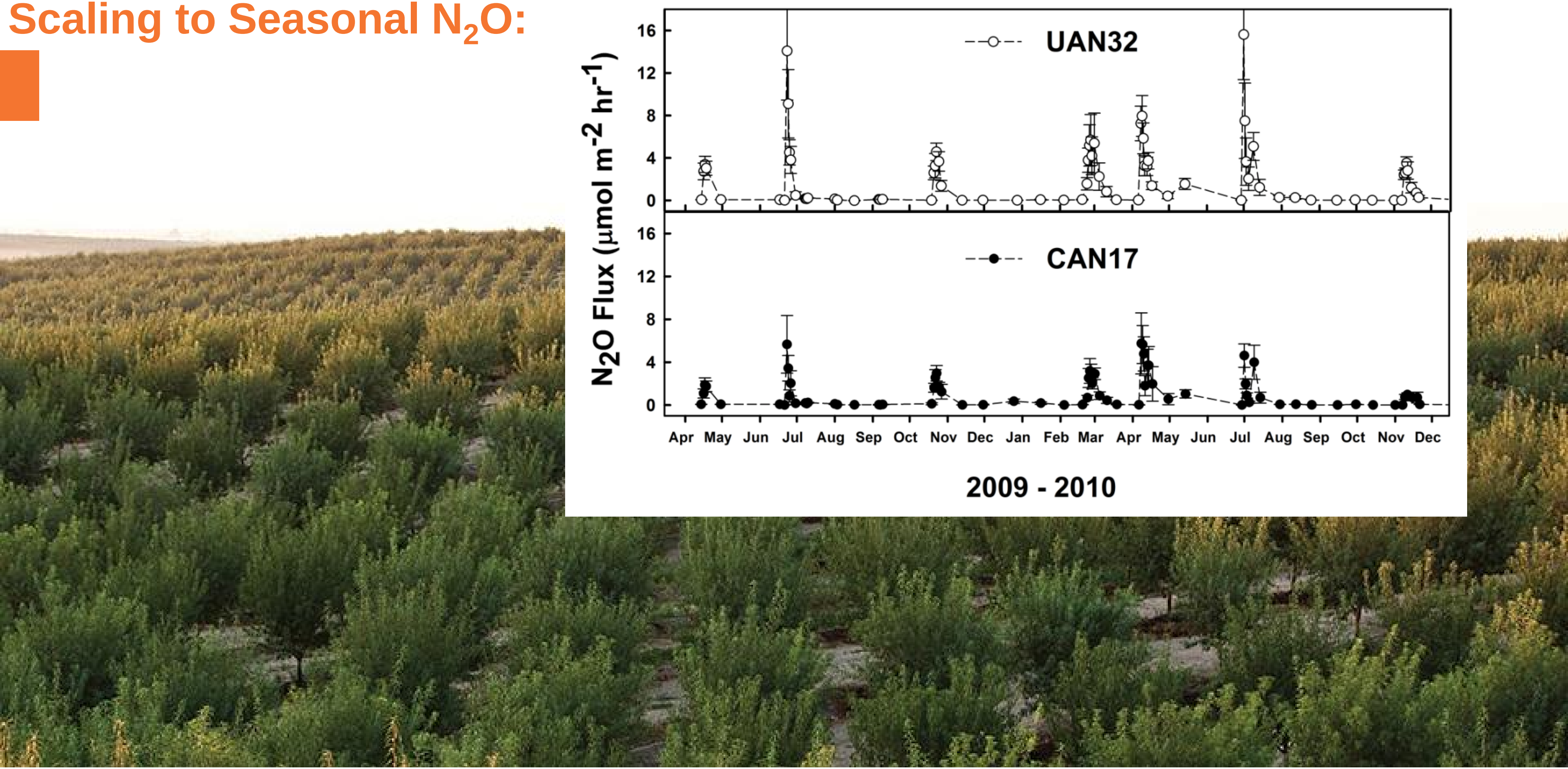
Scaling to Seasonal N_2O:



	Almond (lb/acre)			Pistachio (lb/acre)		
	AGP	HFLC	P&F	AGP	HFLC	P&F
Yield (kernels)	2699	2869	2695	2837	2869	2668
Groundwater-N	73.8	73.8	73.8	14.3	14.3	14.3
Fertilizer-N	215	215	186	174	166	161
Compost-N*	2	2	2	2	2	2
Kernel-N	119	130	112	79	80	75
Storage-N (wood)	25	25	25	25	25	25
N in Hulls	67	72	67	5	5	5
N_2O-N Loss	0.65	0.29	0.54	na	na	na
NUE	0.72	0.78	0.77	0.57	0.61	0.59

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Compost-N*	2	2	2	2	2	2
Kernel-N	119	130	112	79	80	75
Storage-N (wood)	25	25	25	25	25	25
N in Hulls	67	72	67	5	5	5
N_2O-N loss (CO_2 eq)	62.1	27.9	51.2	62.1	27.9	51.2
NUE	0.51	0.69	0.59	0.25	0.45	0.30

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Conclusions:

- In general, N_2O emissions from almond and pistachio orchards in the arid West are much lower than for other crops.
- Only the HFLC N, “spoonfeed”, N application treatment lowered emissions of the greenhouse gas N_2O. When factored into NUE calculations, showed slightly superior CA emission factor.
- In terms of lowering carbon offsets, we still have some work to do in terms of identifying Best Management Practices.

Optimizing Use of Groundwater Nitrogen for Nut Crops

David R. Smart, Patrick H. Brown, Thomas Harter & Jan Hopmans

University of California

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Acknowledgements

Fertilizer Research and Education Program
California Pistachio Research Board
Almond Board of California

Dept of Viticulture & Enology

Dept of Plant Sciences

Dept of Land, Air & Water Resources

University of California, Davis

Climate Change ● Sustainable Farming
Environmental Quality ● Remote Sensing

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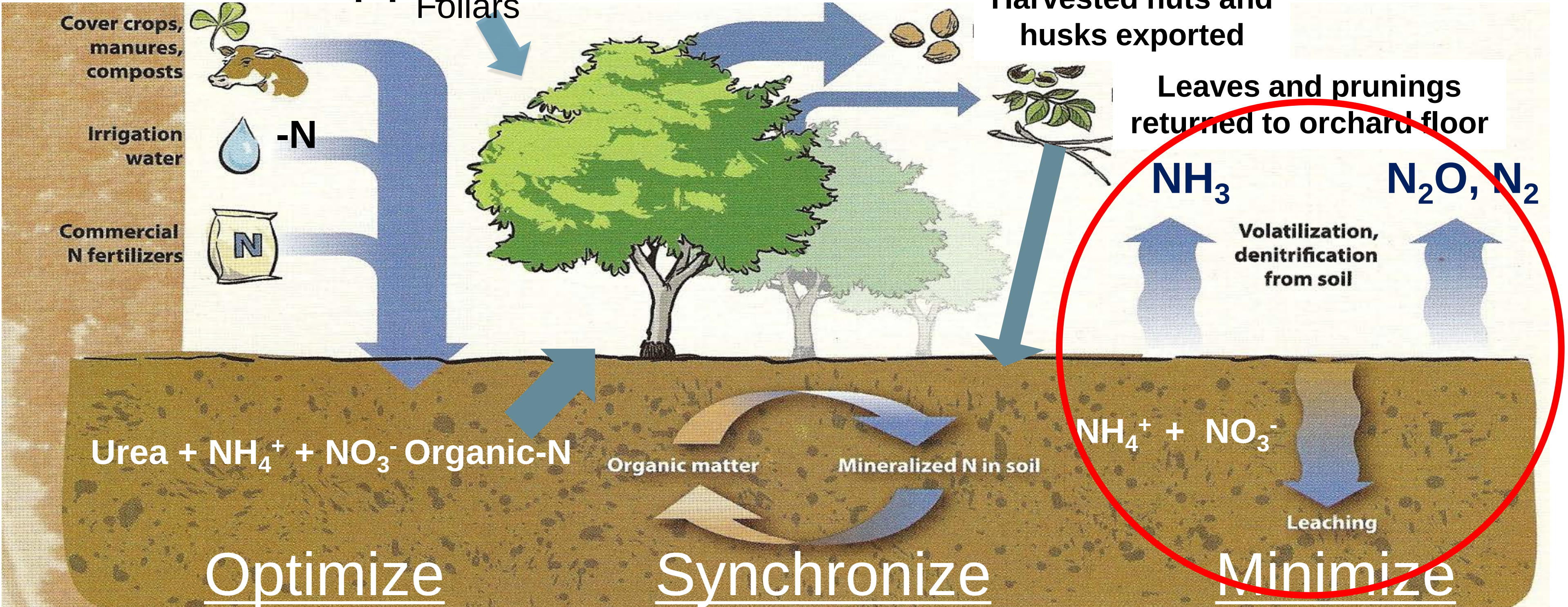
N-Supply N-Demand N-Loss



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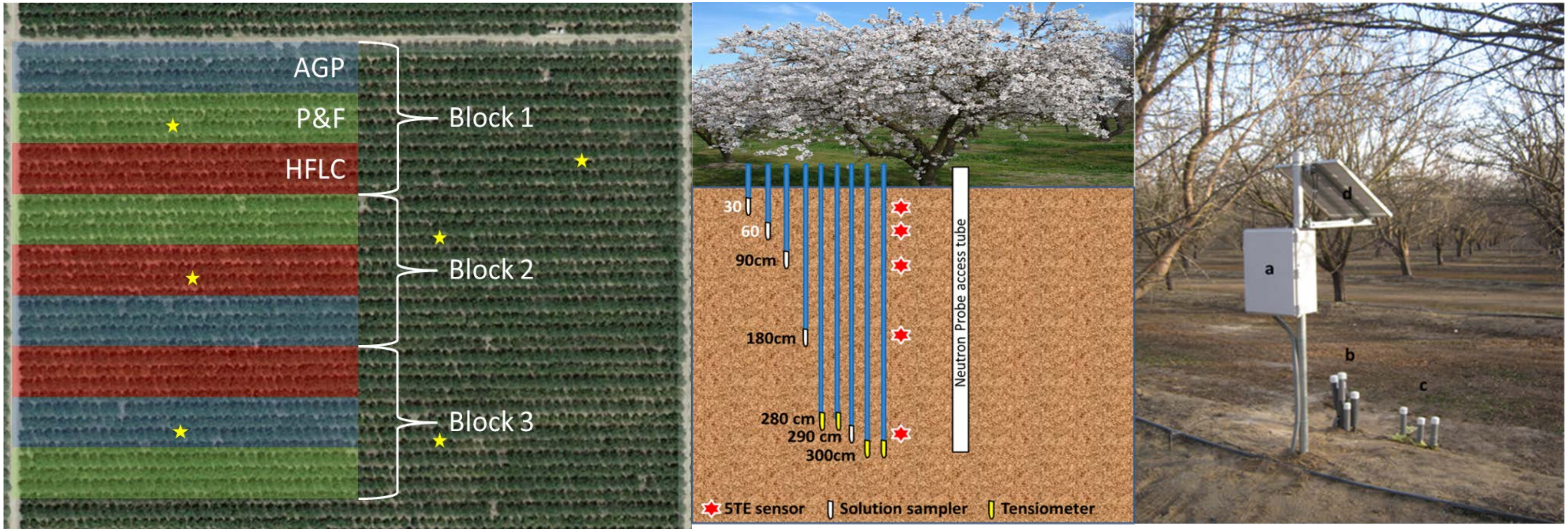

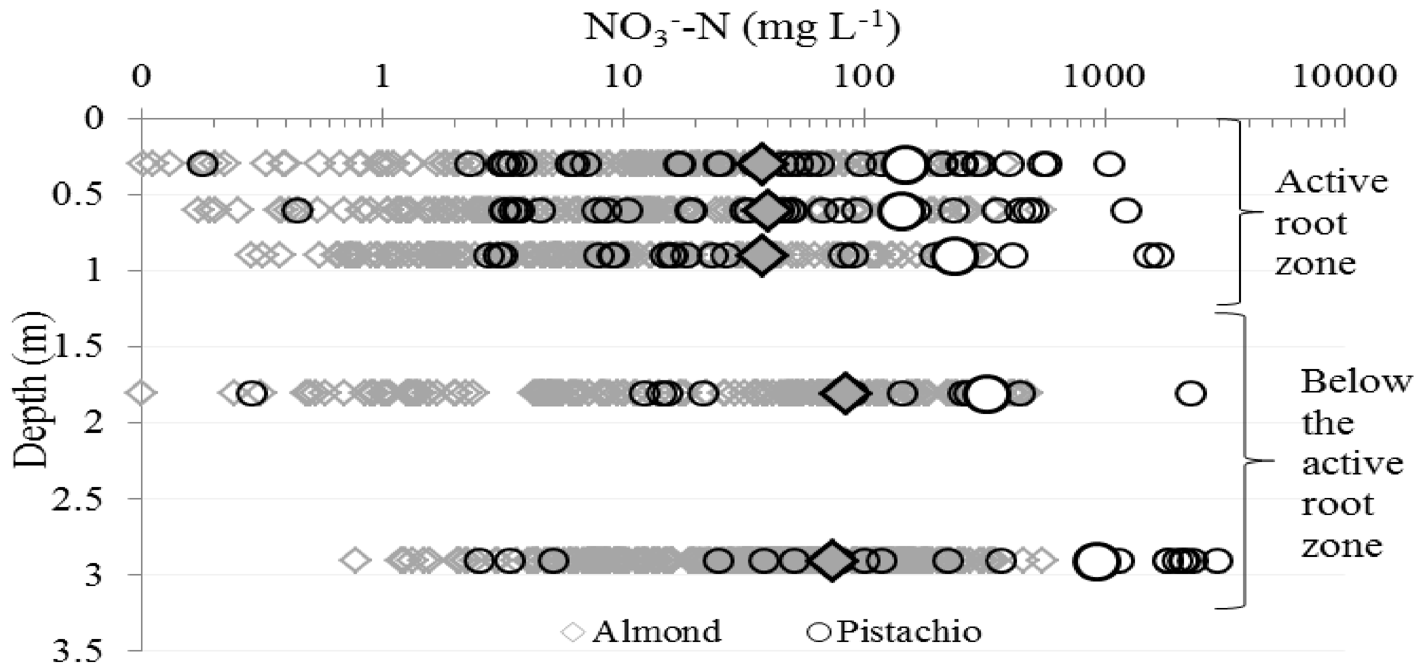
NO_3^--N (mg L^{-1})
0
1
10
100
1000
10000
0
0.5
1
1.5
2
2.5
3
3.5
Depth (m)
Active root zone
Below the active root zone
Almond
Pistachio

	Almond (lb/acre)			Pistachio (lb/acre)		
	AGP	**HFLC**	**P&F**	**AGP**	**HFLC**	**P&F**
Kernel Yield	2699	2869	2695	2837	2869	2668
Groundwater-N	73.8	73.8	73.8	14.3	14.3	14.3
Fertilizer-N	215	215	186	174	166	161
Compost-N	2	2	2	2	2	2
Kernel-N	119	130	112	79	80	75
Storage-N (wood)	25	25	25	25	25	25
N in Hulls	67	72	67	5	5	5
NO_3^--N (1.3-3.0 m)	197.3	144.3	56.7	na	na	na

Conclusions:

1) There were no detectable effects on production between AGP, HFLC and P&F and therefore supports the hypothesis that a lb of N in well water acts like a lb of synthetic N fertilizer.
2) The P&F treatment seemed to lower potential leachable NO_3^--N below the rooting zone but this result will require further scrutiny because of extreme heterogeneity in soil NO_3^- concentrations.

Fraser Shilling,
University of California, Davis

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California Almond Water Footprint

Fraser Shilling & Julian Fulton
UC Davis

Almond Board of California

What is Water Footprint?

Blue Water refers to applied water, whether from surface or ground sources, that is utilized in orchard development.

Green Water refers to rainwater and residual soil moisture that is utilized in orchard development.

Gray Water refers to contamination and is expressed as the volume of water needed to dilute non-utilized nutrients and other pollutants to acceptable levels.

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Objectives

- Calculate an accurate water footprint for California almonds
- Compare almond water footprint to economic benefits gained from almond production and sales
- Compare water footprint to food value
- Analyze the effects of variation in evapo-transpiration rates
- Compare the water footprint to other types of footprint and life cycle analysis to improve management

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Denominator is important

$$Water\ Footprint = \frac{Consumptive\ Water\ Use}{Yield}$$

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What are we finding?

- Average (10-year) values for California are:
  - $$Blue\ water = \frac{4.3\ acre-feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre-feet} = 610\ \frac{gallons}{lb_{kernels}}$$
  - $$Green\ water = \frac{0.6\ acre-feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre-feet} = 87\ \frac{gallons}{lb_{kernels}}$$
  - $$Grey\ water = \frac{3.2\ acre-feet/acre}{1.2\ tons_{kernels}/acre} \times \frac{1\ ton}{2{,}000\ lbs} \times \frac{325{,}851\ gallons}{1\ acre-feet} = 464\ \frac{gallons}{lb_{kernels}}$$

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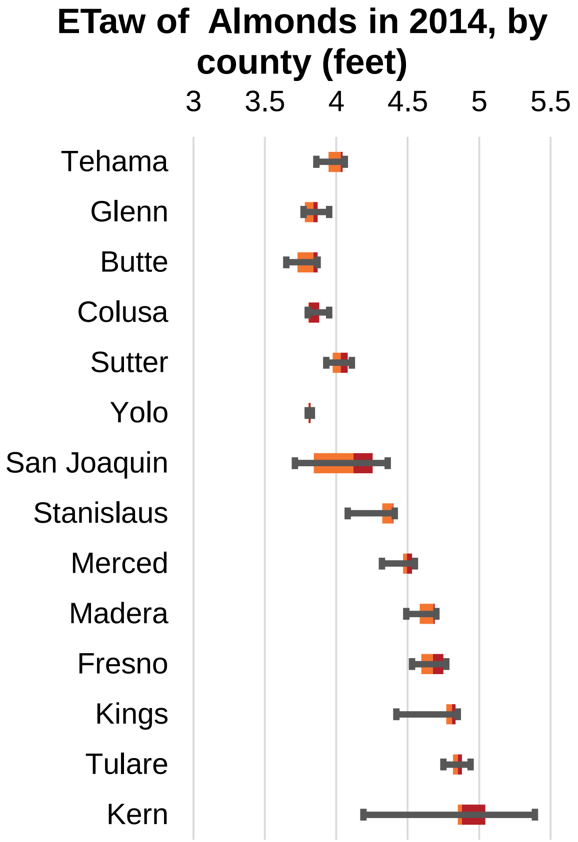
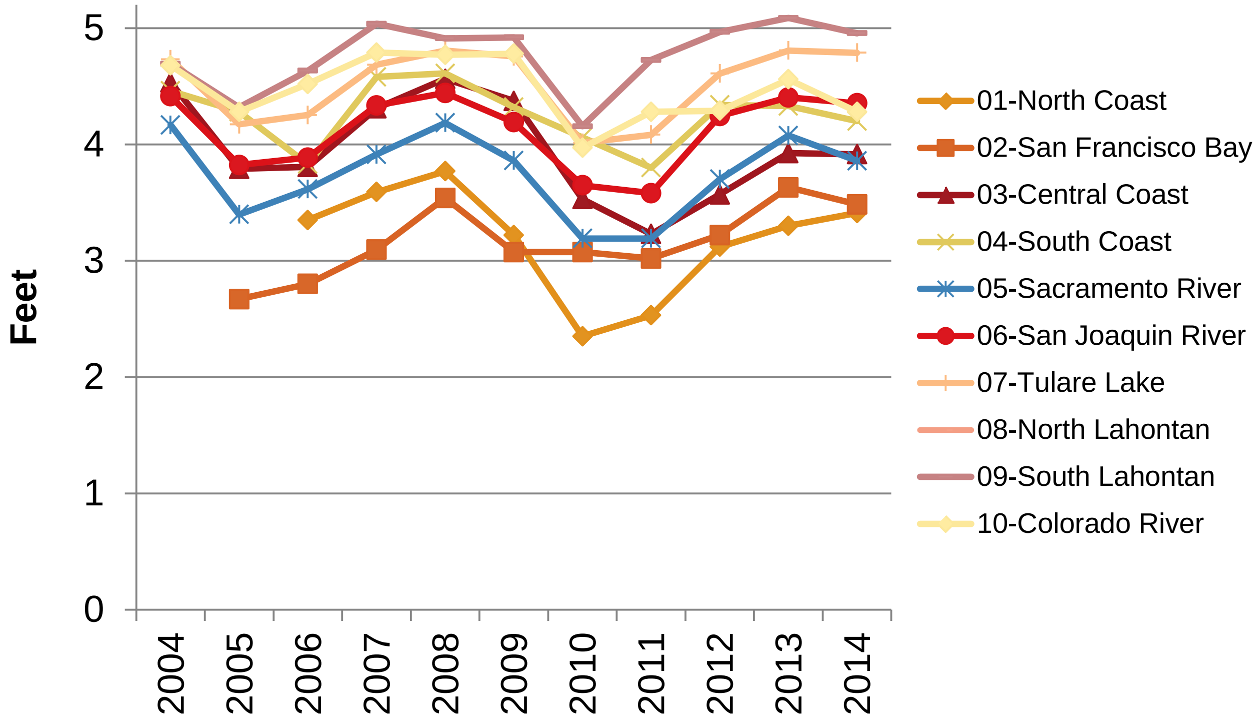
Almond irrigation water use varies by county

- Evapo-transpiration of irrigation water, modeled by DWR (CalSIMETAW)



Almond ETc varies by region



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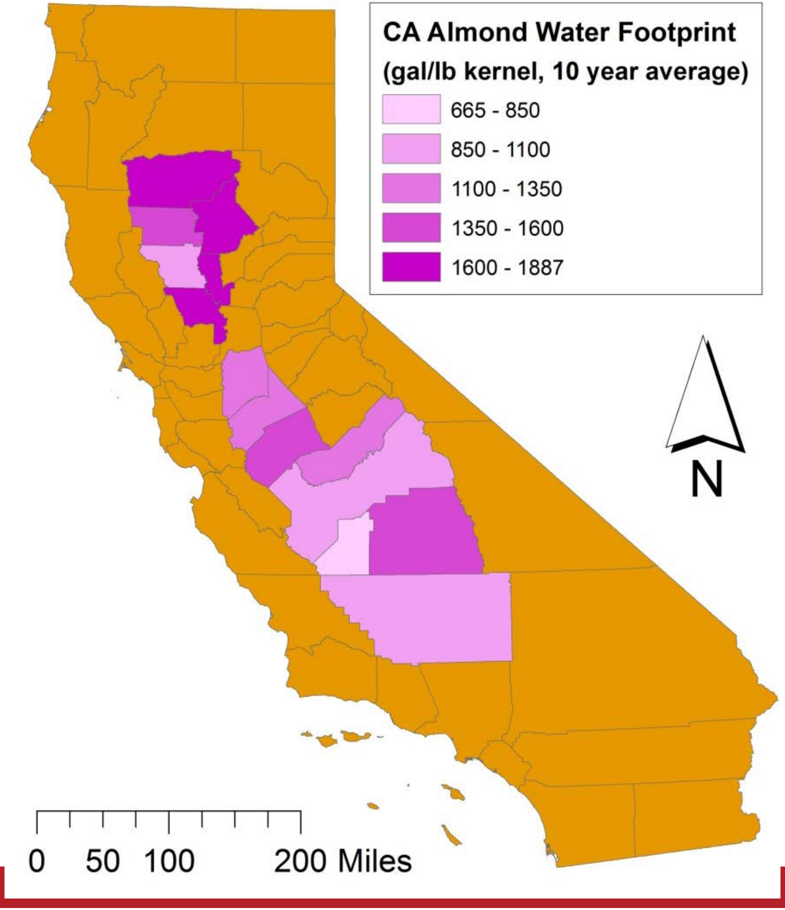
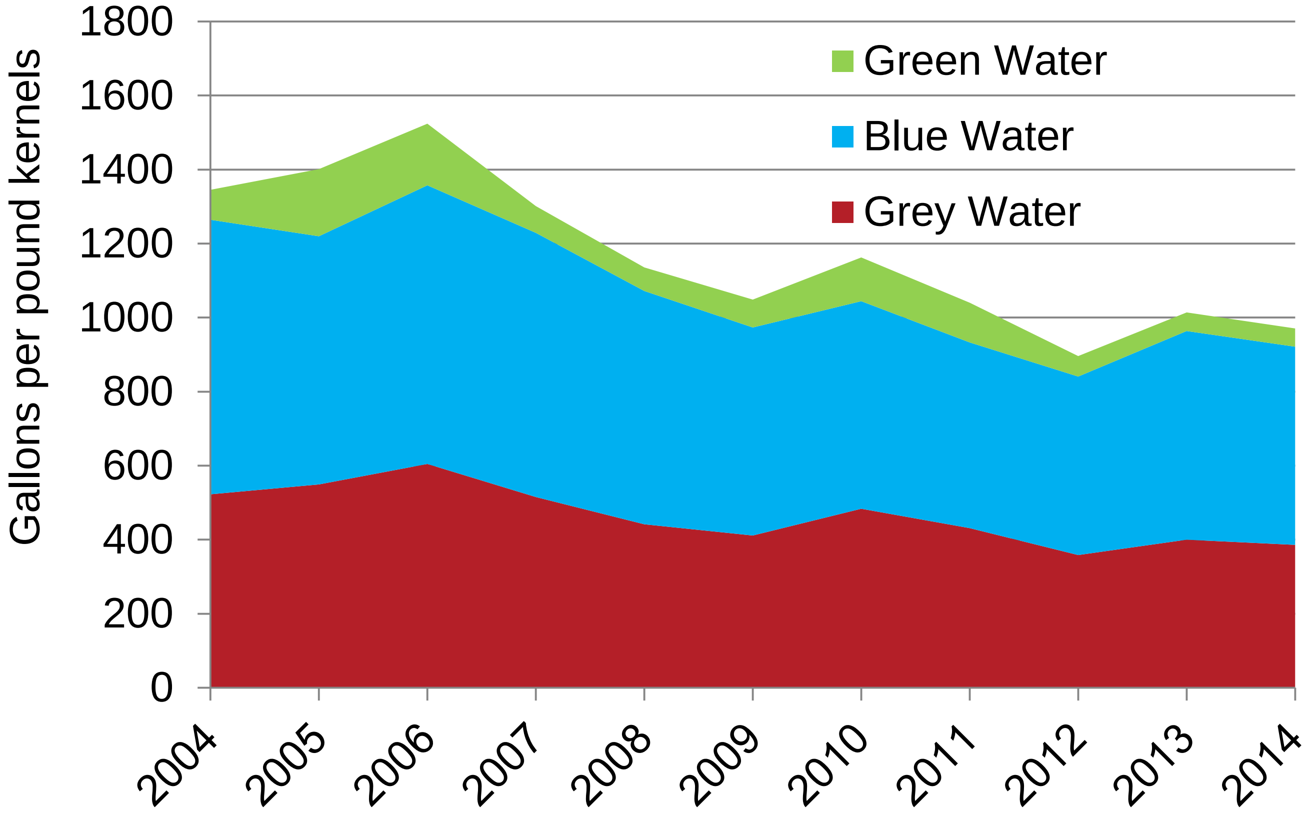
Water Footprint varies by county



Water footprint is declining



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Contacts

Julian Fulton (julianfulton@gmail.com)

Fraser Shilling (fmshilling@ucdavis.edu)

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Tom Gradziel,
University of California, Davis

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Almond Variety Development

Tom Gradziel, UC Davis

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Is this the future for California almonds?

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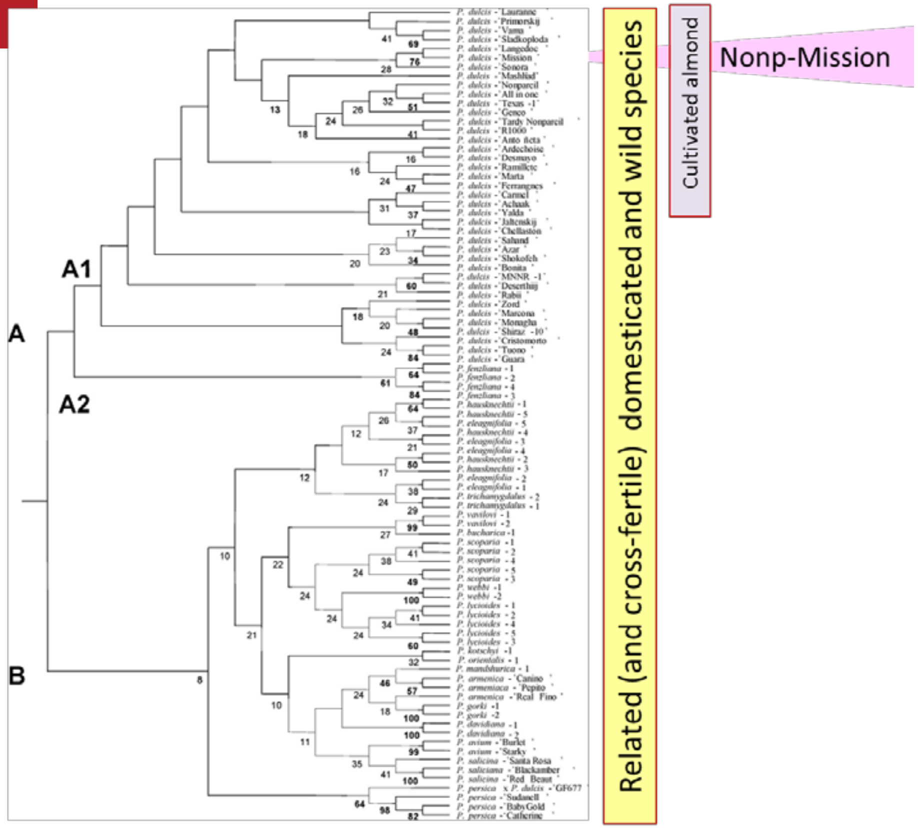
Cultivated almonds is very adaptive; its wild relatives even more so.



Genetic variability in almond & species relatives

New germplasm = New traits = New solutions

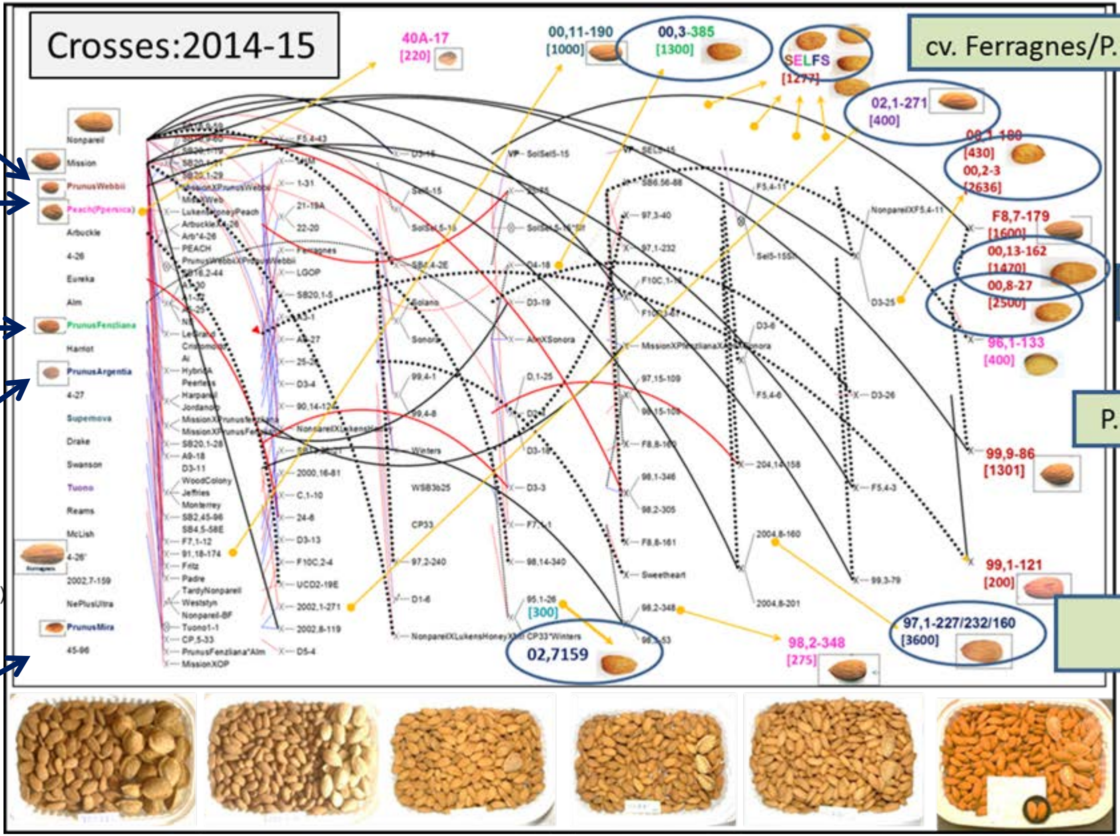
P, webbii (Iran)

P. persica (Korea)

P. fenzliana (Syria)

P. argentea (Turkey)

P. mira



cv. Ferragnes/P. webbii

P. webbii/ P. persica

P. fenzliana/P. webbii

P. mira

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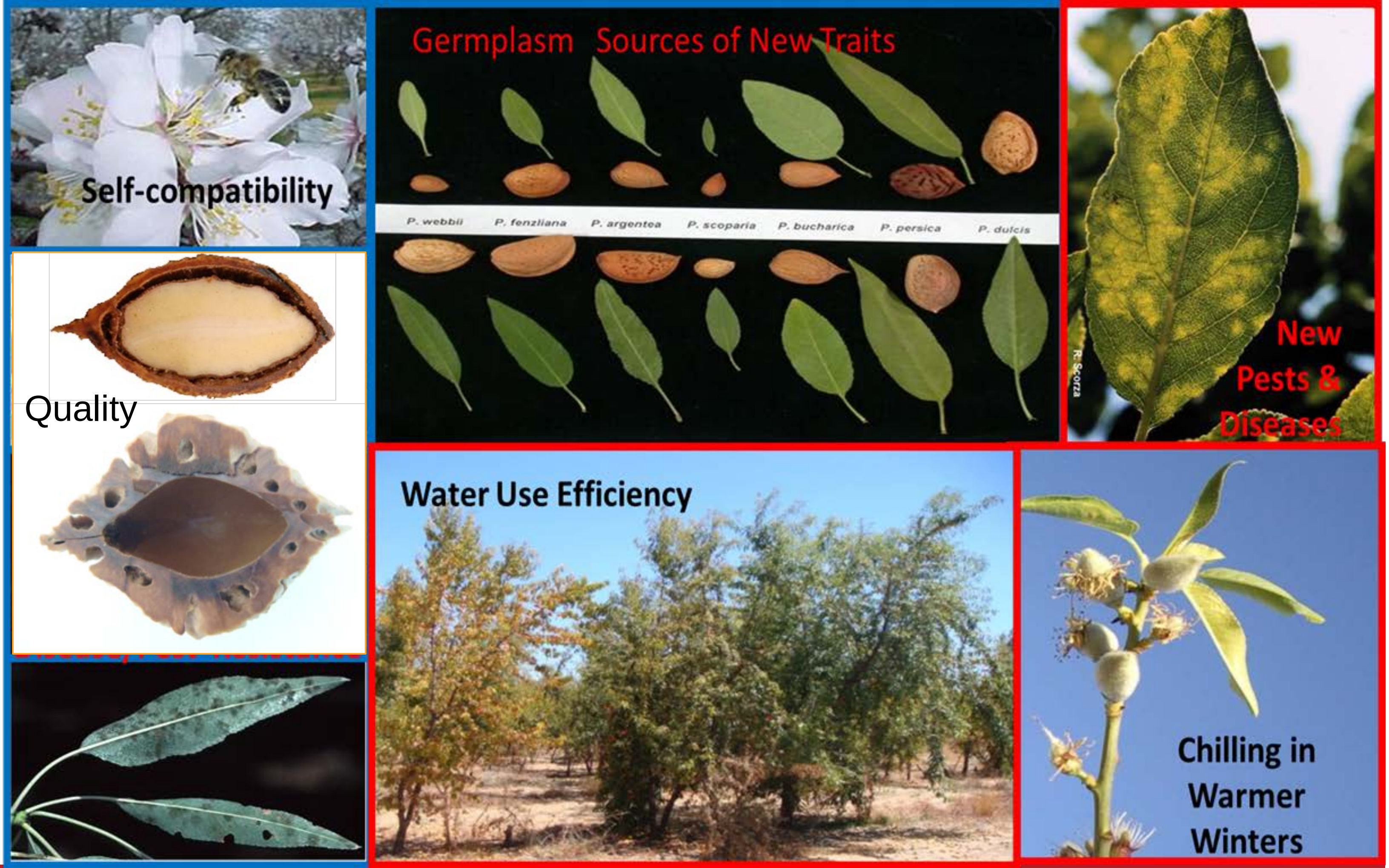
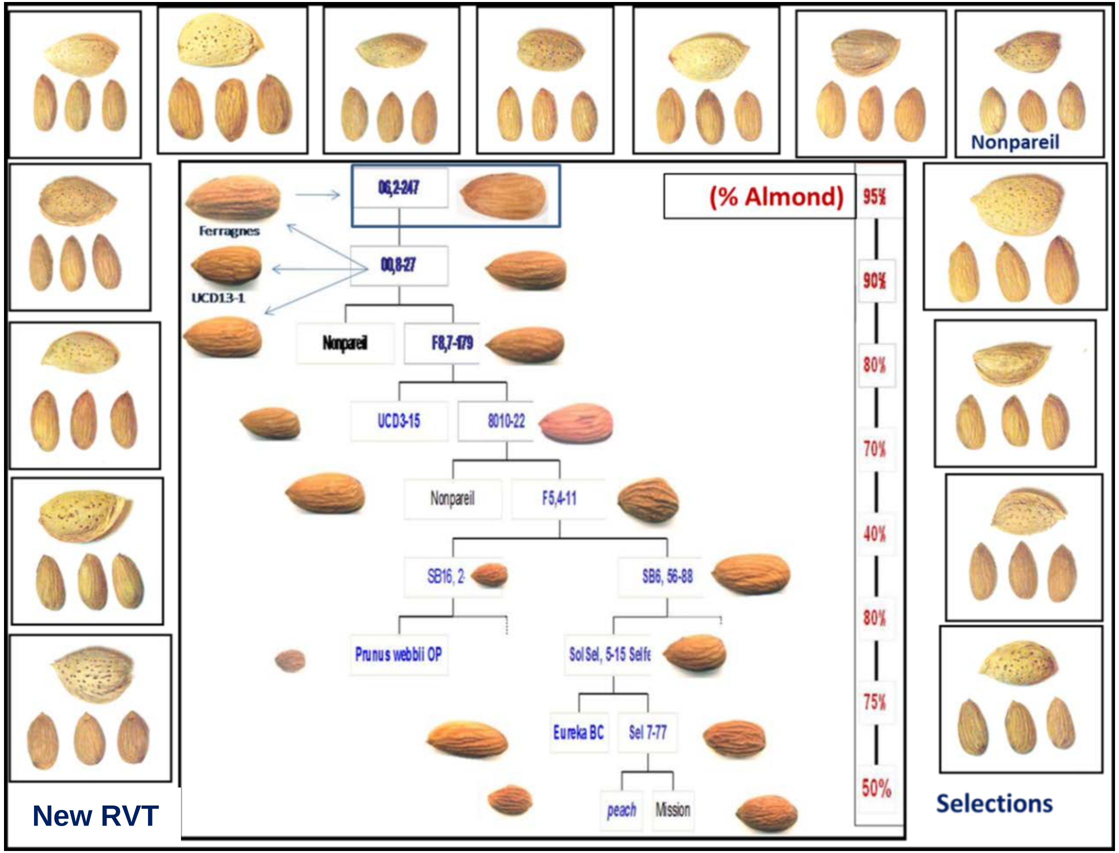
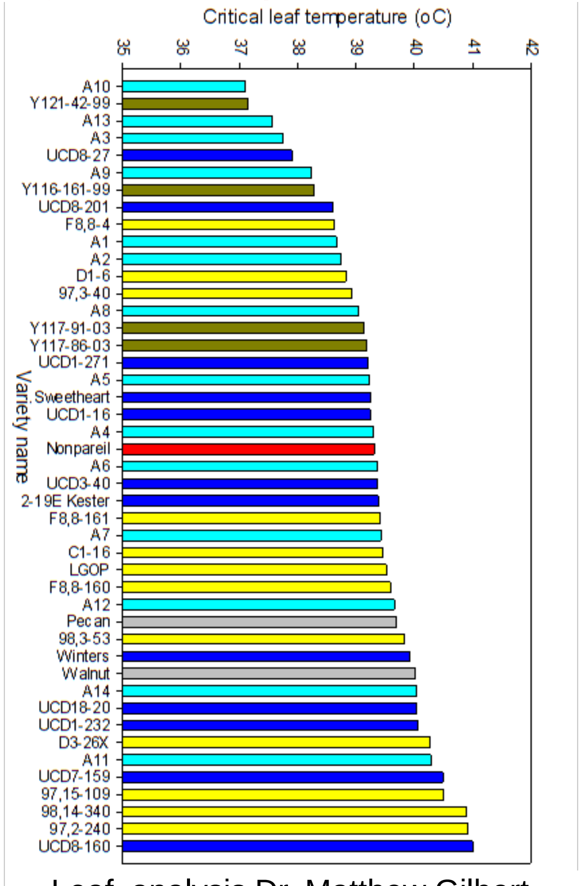

Self-compatibility
Quality
Germplasm Sources of New Traits
P. webbii
P. fenzliana
P. argentea
P. scoparia
P. bucharica
P. persica
P. dulcis
R. Scorza
New Pests & Diseases
Water Use Efficiency
Chilling in Warmer Winters

Breeding objectives: focused improvement yet maintain diversity (future options)

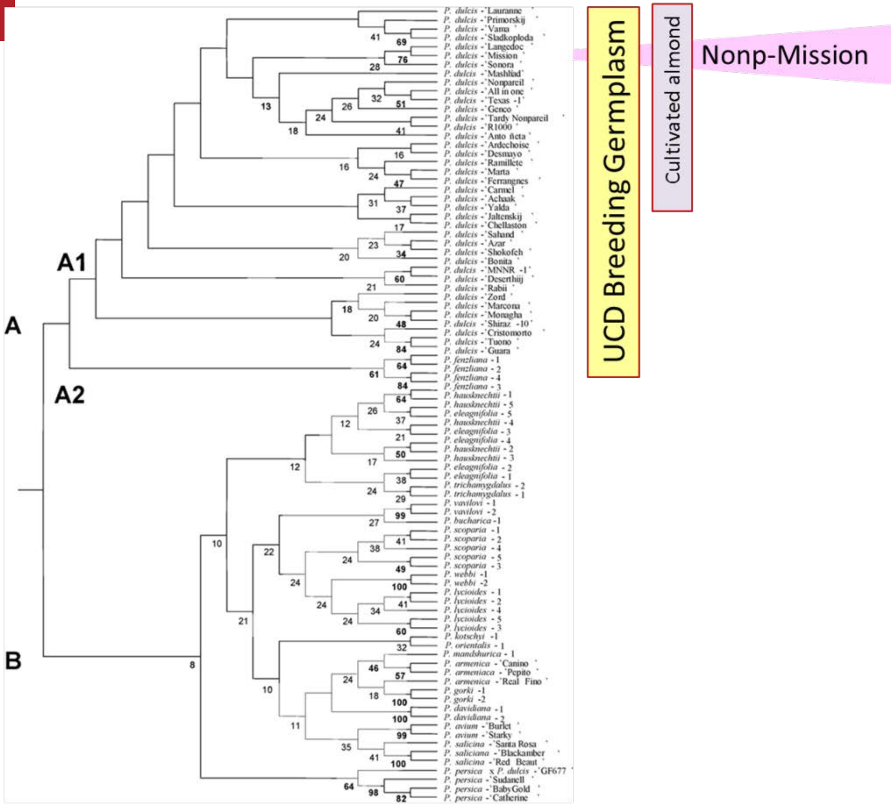
Self-fertile almonds now in Regional Testing.





Leaf. analysis Dr. Matthew Gilbert

Captured germplasm



New germplasm incorporated into UCD Breeding

Kester almond: new UCD release.

New germplasm = new risks (14+yrs reg. testing).

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Thank you

Almond Variety Development

-

Cooperators:

B. Lampinen, S. Metcalf, M. Billings,

S. Marchand, J. Adaskaveg, J. Connell,

F. Niederholzer, J. Fresnedo, M. Viveros,
R. Duncan, M. Gilbert & M. González.

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Rootstock Germplasm

Tom Gradziel, UC Davis

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This is the Future (and present) for California Almond Rootstocks

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Wild *P. fenzliana* thriving in Syrian desert.

New almond rootstocks are species-hybrids to complex species multi-crosses.

Name	Genetic background
Adefuel	P. dulcis x P. persica
Atlas	peach, alomd, plum, apricot interspecific
Bright Hybrid-1	P. persica x P.dulcis
Cadaman	P. persica x P. davidiana
Citation	OP Red Beaut Plum-OR- Siberian C x (plum x almond)
Cornerstone	P. persica x P.dulcis
Empyrean#1 (Barrier 1)	P. persica x P. davidiana
Empyrean#2 (Penta)	O.P. P. domestica
GxN 15(Garnem)	P. dulcis x P. persica (Nemared)
Hansen 536	[Okinawa x (P. davidiana x peach PI 6582)] x almond
Ishtara	(P. cerasifera x P. saliciana) x (P. persica x P. cerasifera)
Krymsk #1 (VVA 1)	P. tomentosa x P. cerasifera
Krymsk 2	P. incana x P. tomentosa
Krymsk#86 (Kuban 86)	P. persica x P. cerasifera
Marianna 2624	P.munsoniana x P. cerasifera (Kester: ceracsifera
Nemaguard	P. persica x P. davidiana
Nickels	P. dulcis x P. persica
Paramount (=GF677)	P. persica x P.dulcis
Titan	Nemaguard x pollen sterile Titan almond
Viking	peach, alomd, plum, apricot interspecific

Most wild germplasm remains untested and so under-utilized

P. scoparia in Iran

P. bucharica in Turkey

P. webbii in Iran

P. tangutica in Tibet (?)

From drought tolerance to cold & rain tolerance.

P. nana in Central Asia

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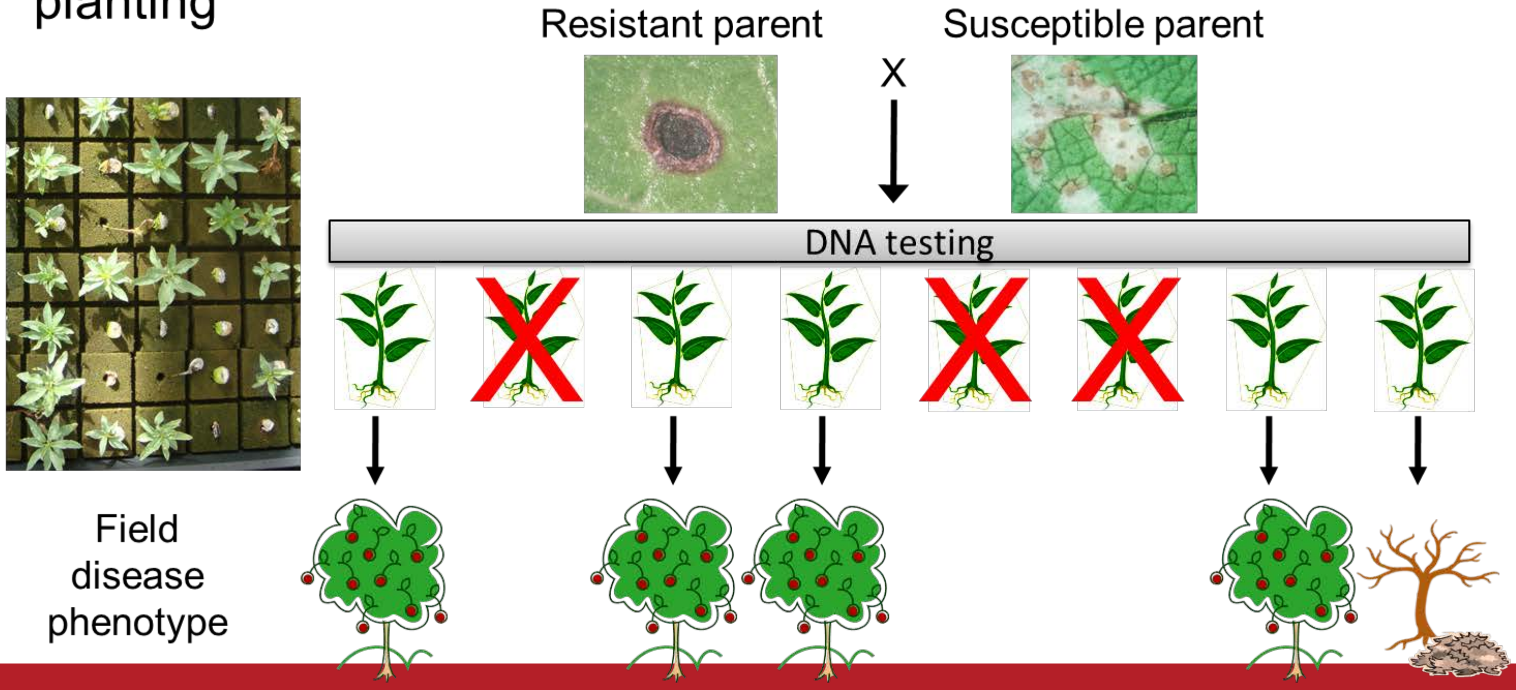
Resistance Screening: DNA Marker-Based Approach

DNA test outcomes identify resistant seedlings before field planting



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Multiple Resistance/Tolerance Alleles Pyramided using DNA Tests

DNA tests used to monitor inheritance both disease resistance and quality from the donor parent

Donor parent with pyramided alleles

resistance

tolerance

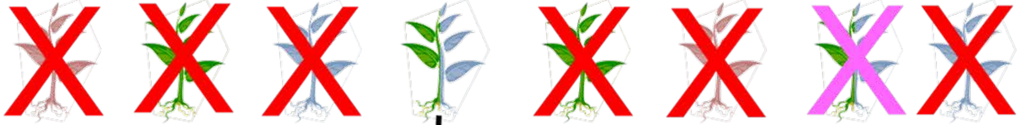
X

Elite parent e.g. 'Nemaguard'

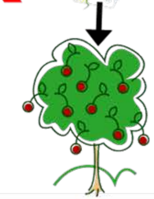
susceptibility

Desirable alleles for fruit quality & productivity

DNA testing for both resistance and tolerance ...and quality, productivity



Field disease phenotype

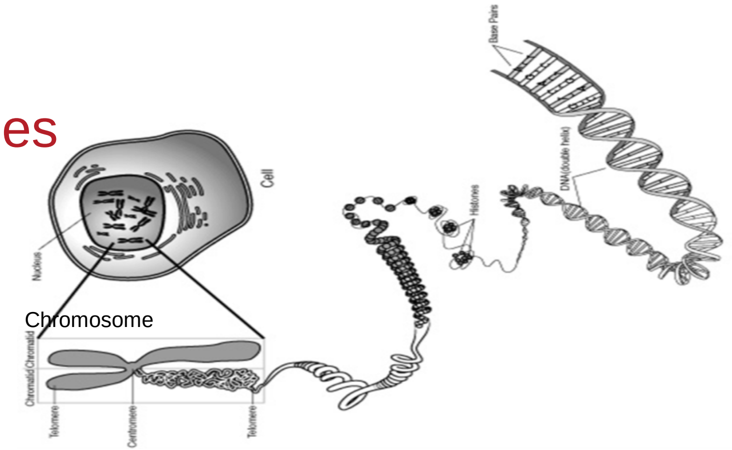


durable resistance!

...and superior horticultural quality

Accuracy of molecular markers in wide crosses

- Generally effective in closely related crosses
- Lose accuracy as crosses become wider.
  - Useful for specific trait tagging & paternity



Parents	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira	Peach / P. mira
	TT / TC	CC / CC	TT / TC	AA / AG	AA / AC	AG / AG	CC / AC	AA / AG	GG / GG	CC / TC	AC / AC	AG / AG	GG / AG	GG / GG	AG / AG	GG / GG	GG / GG	GG / GG	AA / AG	CC / CC	AC / AC	BB / AB	BB / BB	BB / BB	AA / AB
Progeny-1	TT	CC	TT	AA	AA	AA	CC	AA	GG	TC	AC	AA	GG	GG	AA	GG	GG	GG	AA	CC	AA	BB	BB	BB	AA
Progeny-2	TC	CC	TT	AA	AA	AG	CC	AA	GG	CC	AC	AG	GG	GG	AG	GG	GG	GG	AA	CC	AA	BB	BB	BB	AA
Progeny-3	TC	CC	TT	AA	AC	AA	CC	AA	AG	CC	AA	AG	AG	GG	AG	AG	GG	GG	AA	CC	AB	BB	BB	BB	AG
Progeny-4	TC	CC	TT	AA	AA	AG	CC	AA	GG	CC	AC	AG	GG	GG	AA	GG	GG	GG	AA	CC	AA	BB	BB	BB	AA
Progeny-5	TT	CC	TT	AA	AA	AA	CC	AA	GG	CC	AA	AG	AG	GG	AA	GG	GG	GG	AA	CC	AA	AB	BB	BB	AA
Progeny-6	TT	CC	TC	AA	AC	AA	AC	AG	GG	TC	AA	GG	GG	GG	AG	GG	TG	TG	AG	CC	AC	AB	AB	AB	AB
Progeny-7	TC	CC	TC	AG	AC	AA	AC	AA	GG	TC	AC	AG	AA	GG	AG	GG	GG	GG	AG	CC	CC	BB	BB	BB	AB
Progeny-8	TC	CC	TC	AG	AC	AA	AC	AA	GG	TC	AC	AG	AA	GG	AG	GG	GG	GG	AG	CC	AC	BB	BB	BB	AB
Progeny-9	TT	CC	TC	AG	AC	AA	CC	AG	GG	TC	AA	AG	GG	GG	AA	GG	GG	GG	AG	CC	CC	BB	BB	BB	AB
Progeny-10	TC	CC	TC	AG	AC	AA	CC	AG	GG	TC	AC	AG	AA	GG	AG	GG	GG	GG	AG	CC	CC	BB	BB	BB	AB
Progeny-11	TC	CC	TC	AG	AC	AA	AC	AG	GG	TC	AC	AA	GG	GG	AG	GG	GG	GG	AG	CC	CC	AB	BB	BB	AB
Progeny-12	TC	CC	TC	AG	AC	AA	AC	AG	GG	TC	AC	AG	AA	GG	AA	GG	GG	GG	AG	CC	AC	AB	BB	BB	AB
Progeny-13	TC	CC	TC	AG	AC	AA	AC	AG	GG	CC	AC	AA	AA	GG	AA	GG	GG	GG	AG	CC	AC	AB	BB	BB	AA
Progeny-14	TC	CC	TC	AG	AC	AA	AC	AG	GG	CC	AC	AG	GG	GG	AG	GG	GG	GG	AG	CC	AC	AB	BB	BB	AB

Problem: Traits complex (Hybrid vigor)
Genetic control -complex

Drought tolerance

Novel traits: modify Nonpareil shape or size

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Thank you

Rootstock Germplasm

Cooperating Personnel:

J. Preece, T. Michailides, M. Aradhya,
C. Ledbetter, G. Browne, J. Adaskaveg,
S. Marchand, D. Kluepfel & J. Slaughter.

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Almond Board of California

Roger Duncan,
UCCE – Stanislaus County

growing ADVANTAGE
The Almond Conference

Field Evaluation of Almond Rootstocks

Roger Duncan, UCCE Farm Advisor, Stanislaus County

Joe Connell, UCCE Farm Advisor Emeritus, Butte County

David Doll , UCCE Farm Advisor, Merced County

Katherine Pope, UCCE, Yolo, Solano, Sacramento

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High Boron Rootstock Trial

Katherine Pope, UCCE Yolo, Solano, Sacramento Counties

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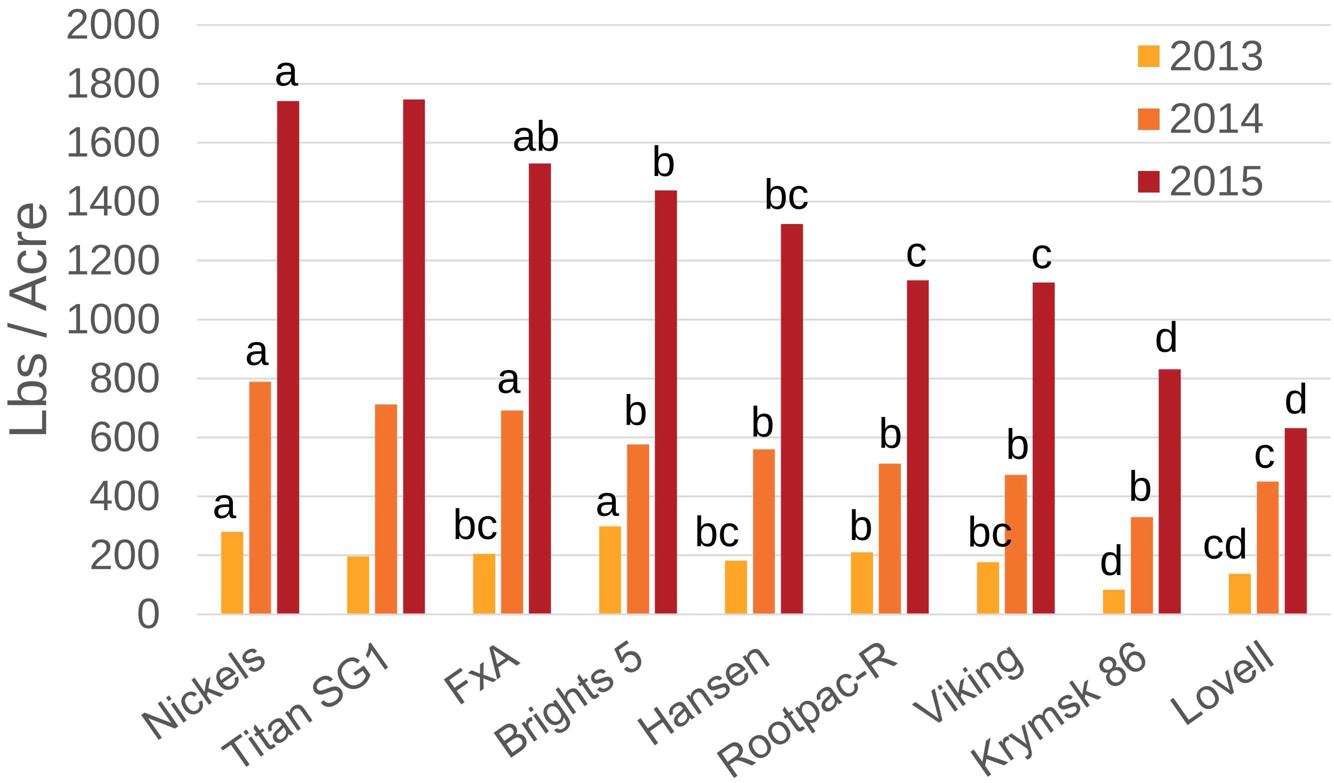
Boron Rootstock Trial – Yield Highly Correlated with Rootstock



Marvin silty clay loam
Water: <1 - 3.1 mg/l B
Soil: 1.3-2.2 mg/l B

cv. Nonpareil
Nursery grafted
Planted: Feb, 2011
(Titan Apr 2011 not rep'd)
Spacing: 22' x 18'

Different letters indicate statistical diff. values when compared in same year.

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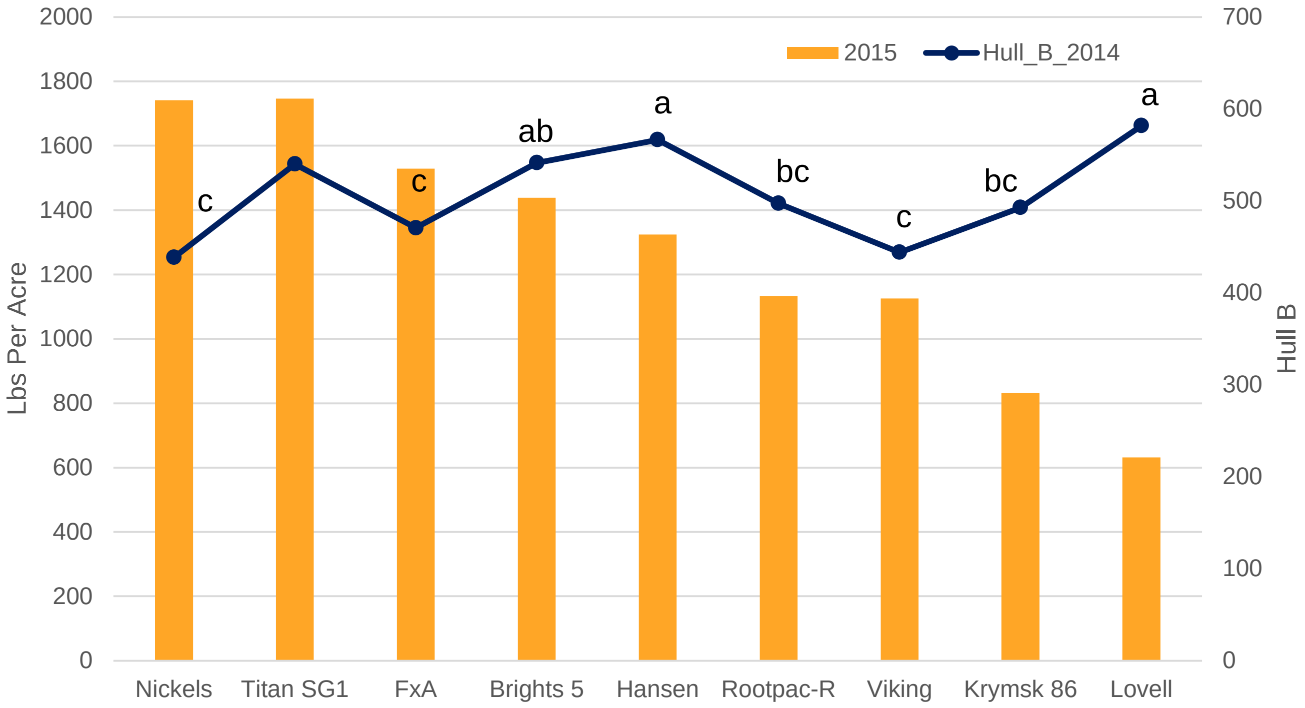
Boron Rootstock Trial – Hull B Content Highly Correlated with Rootstock

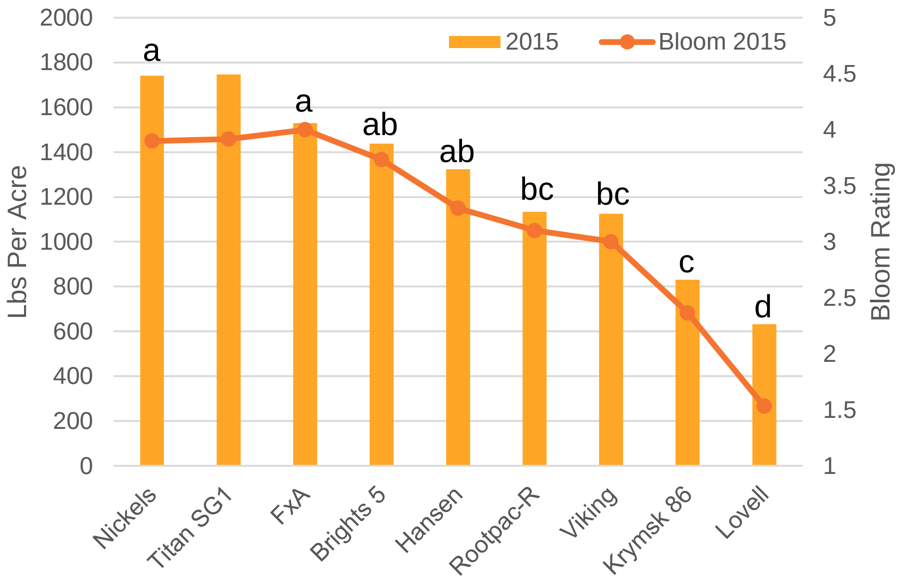


Boron Rootstock Trial – Bloom Vigor Highly Correlated with Rootstock

Bloom Vigor was rated (1-5 scale) based on flowers per unit canopy, not flowers in whole canopy. In other words, a large canopy didn't necessarily mean a higher bloom rating.

Bloom Vigor = 1
(Lovell)

Bloom Vigor = 5
(Nickels)



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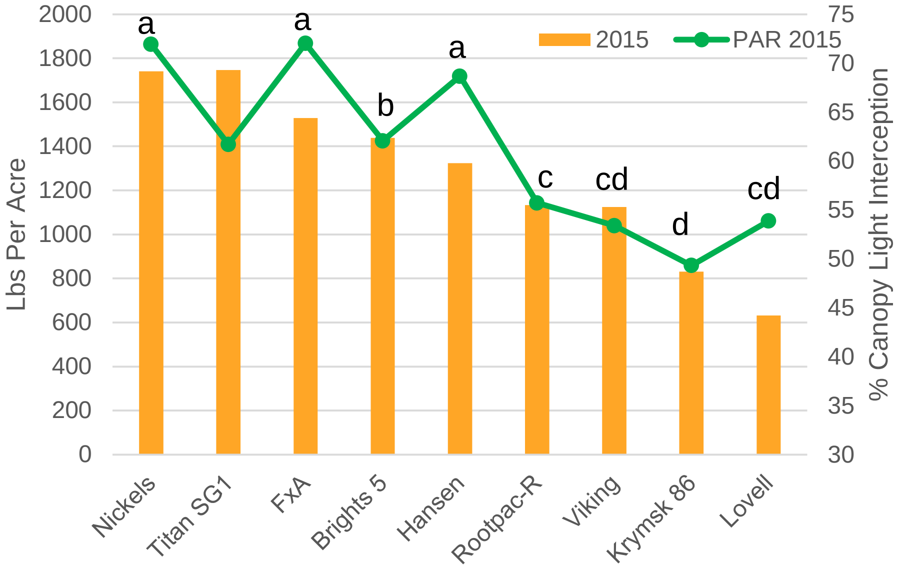
Boron Rootstock Trial – Canopy Size Highly Correlated with Rootstock



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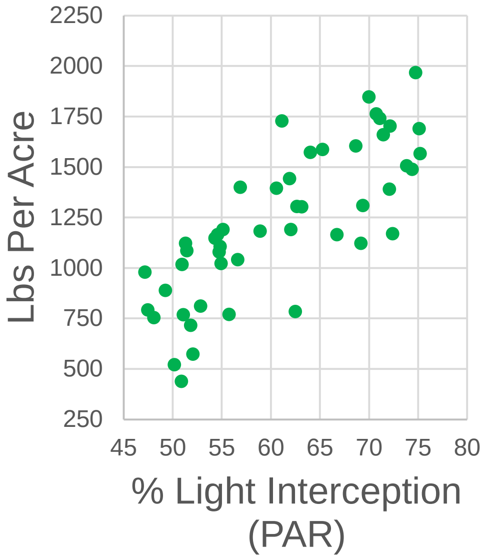
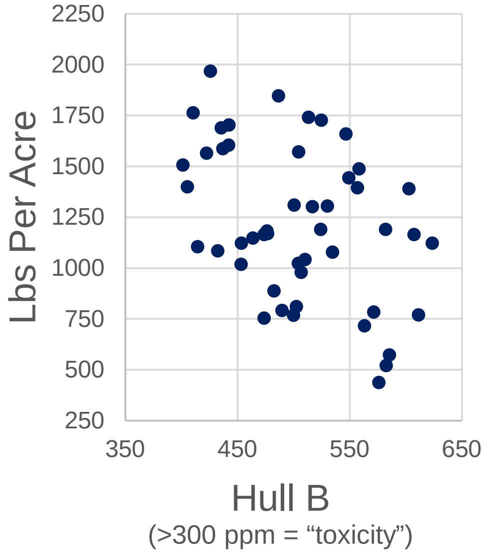
Are Higher Yields *Just* Result of Vigorous Rootstocks → Larger Trees? ***No.***

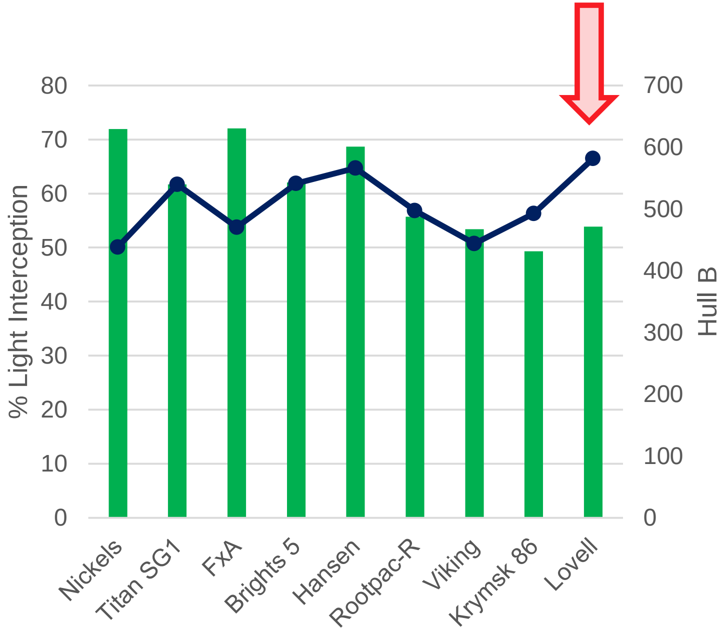
- True, larger trees → higher yield ($p < 0.001$). PAR alone predicts 60% of the variability in yield.



- But, Hull B content explains 14% of the yield variability that PAR does not explain ($p < 0.01$)*.



- Worst combination is low vigor + high hull B: Lovell (& Krymsk)



* R^2 contribution averaged over orderings among regressors. **R** relaimpo, lmg

Boron Rootstock Trial – Summary (So Far)

- **Poor Yield** related to **Canopy Size**, **Bloom Vigor**, **Hull Boron**. Points to two potential rootstock effects:
  - Vigorous rootstocks → Larger Trees
  - Boron tolerant rootstocks decrease B to scion → Decrease B at growing points (flowers, nuts) where it can do damage.
- **Nickels, Titan and FxA** continue to perform **better** than other rootstocks under high boron conditions
- **Lovell, Krymsk 86** continue to perform **poorly** under high boron conditions
- Looks like Lovell combines worst combination: Low vigor with high B

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Evaluation of Rootstocks for the Westside

Roger Duncan, UCCE, Stanislaus County

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Challenge: Heavy, high pH soil with sodium, chloride and boron in water

Soil:

- Zacharias clay loam soil
- Soil pH 7.6
- Boron 0.5 ppm
- EC 2.96 dS/m
- Na 12.1 meq/l
- Cl 14.1 meq/l
- Following decades of tomatoes, melons, row crops

Water:

- EC: 1.86
- Adj. SAR: 8.80
- Chloride: 8.90 meq / L
- Boron: 0.84 mg / L

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2014 Trunk Circumference – 3rd Leaf

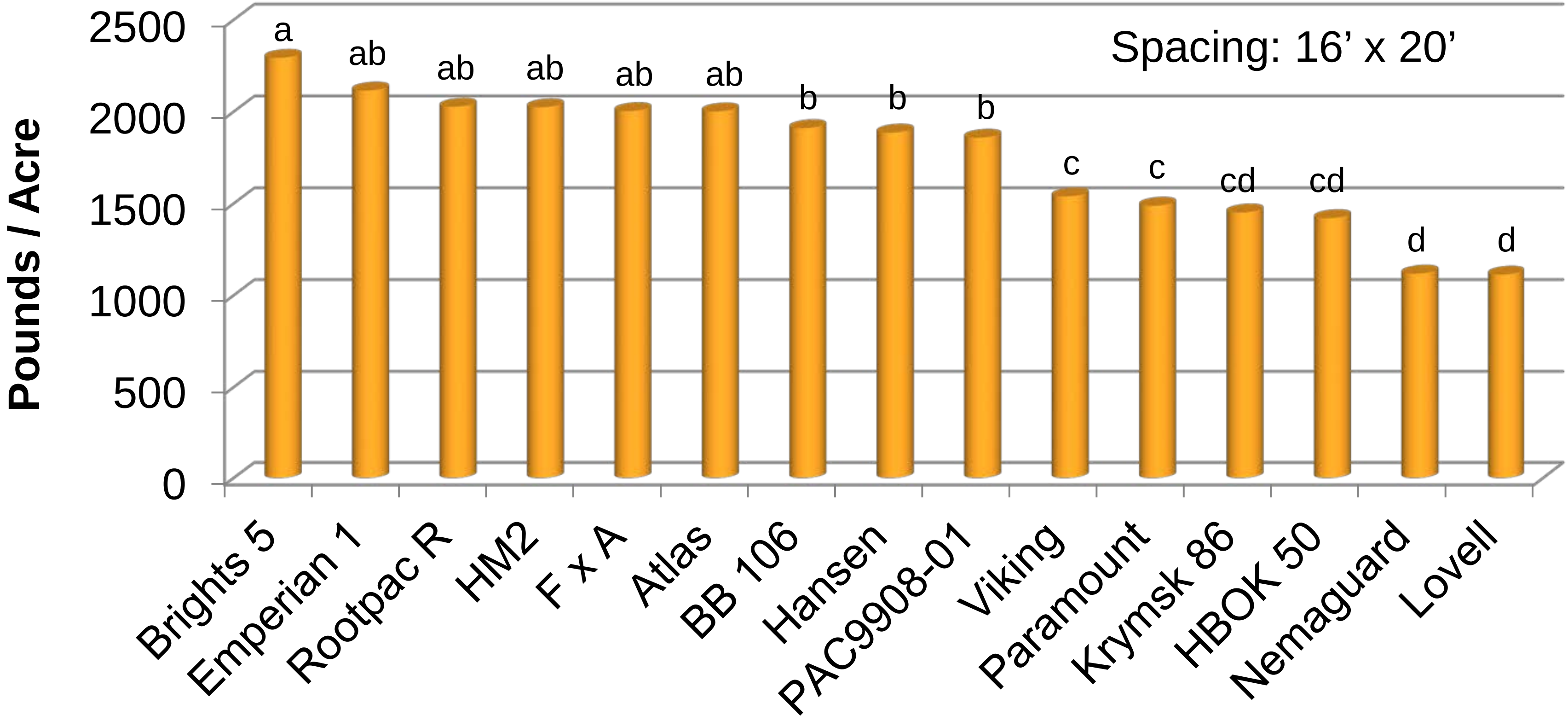
	Trunk Circumference (cm)
PAC9908-02	37.7 a
Empyrean 1	36.8 a
Flordaguard X Alnem (FxA)	36.3 a
Rootpac R	36.1 a
Hansen x Monegro (HM2)	35.8 a
BB 106	35.8 a
Hansen	35.7 a
Brights 5*	33.2 b
Nemaguard	33.1 b
Atlas	32.9 b
Viking	32.8 b
HBOK 50*	32.6 b
Paramount	32.9 bc
Krymsk 86	31.8 bc
Lovell	31.5 bc
Cadaman*	30.2 c

*Indicates planted as potted trees which are younger and smaller than bare root

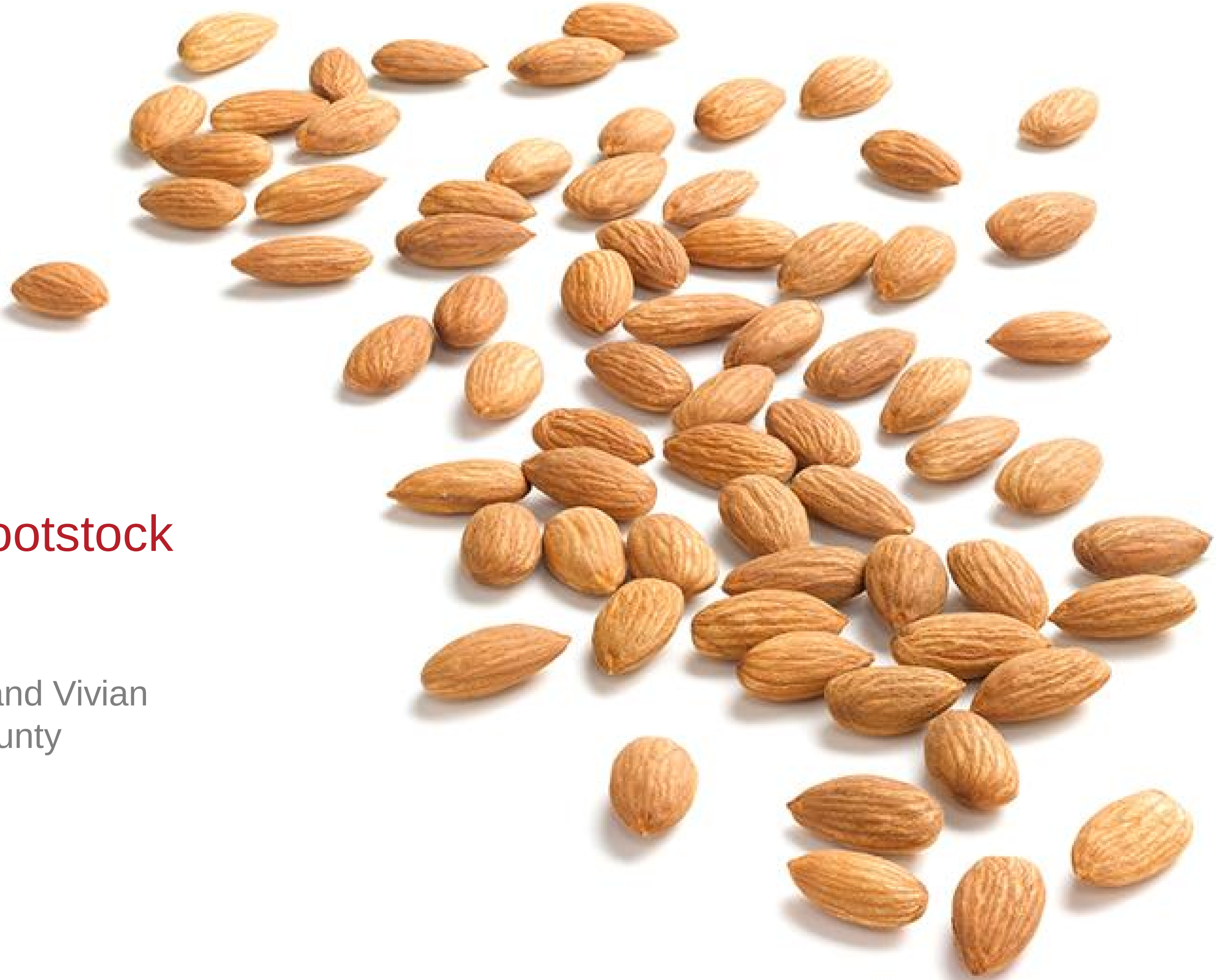
Rootstock Effect of Sodium, Chloride & Boron in Leaf and Hull Tissue

	% Cl	% Na	B (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	0.05 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

2015 Nonpareil Yield: 4th Leaf



HM2 (Hansen x Monegro) not acceptable – poor anchorage



Merced County Rootstock Trial

David Doll, Andrew Ray, and Vivian Lopez; UCCE Merced County

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Merced County Rootstock Trial

Background:
Planted in January 2011, trial currently in fifth leaf (third harvest).
Spacing 22' x 18'
13 rootstocks tested on 'Nonpareil.'
7 rootstocks tested on varieties 'Monterey,' and 'Fritz.'

Challenges:
Sandy soil near Atwater, CA, low cation exchange capacity, history of nematodes
Irrigated with groundwater with high nitrates and moderate sodium

'Nonpareil,' 'Monterey,' and 'Fritz'	'Nonpareil' only
Atlas	BB106
BH5	Cadaman*
Empyrean-1	Cornerstone*
Hansen 536	Floridaguard x Alnem
Nemaguard	Krymsk-86
Red Titan	RootPacR
Viking	TemproPac

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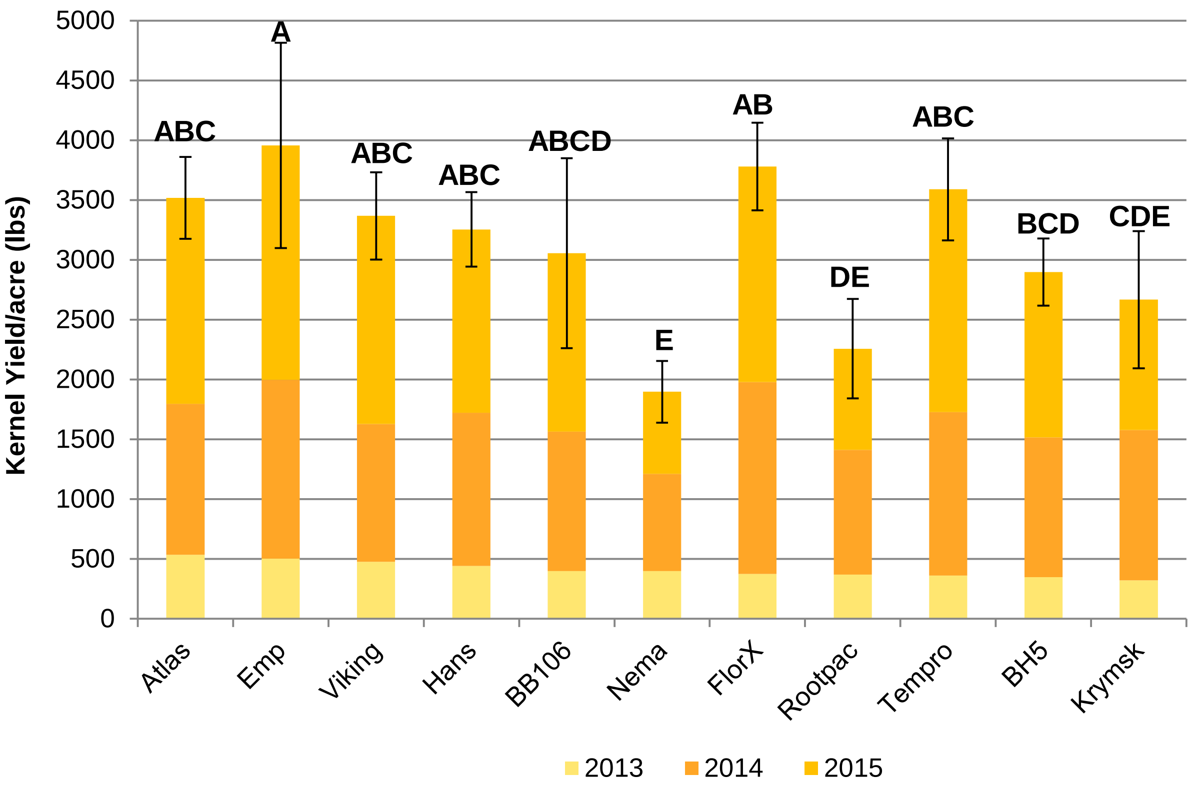
Merced County Rootstock Trial

Yields:

- Harvested annually since third leaf
- With the exception of Nemaguard, trees perform in respect to canopy size
- Significant branch losses within vigorous trees from crop-load and tree structure



Merced County Rootstock Trial

Nematode Susceptibility:

- Prior to planting, soil had detectable levels of Rootknot, Ring, and Lesion (*P. vulnus)* and grower strip fumigated with Telone-II
- Populations have been increasing over time within some rootstocks:
  - White: None Detected (Good thing!)
  - Green: Low (<25 per 500 g of soil)
  - Yellow: Medium (25-100 per 500 g of soil)
  - Red: High (100-250 per 500 g of soil)
  - Black: Very High (> 250 per 500 g of soil)
- Results suggest Krymsk-86 is susceptible to all plant parasitic nematodes, some P/A hybrids susceptible to Ring (e.g. Hansen, BH5)

Rootstock	Rootknot	Ring	Lesion
Atlas			
BB106			
BH5			
Cadaman			
Empyrean-1			
Cornerstone			
Hansen 536		Very High	
FloridaguardxAlnem			
Nemaguard			
Krymsk-86			
Red Titan			
RootPacR			
TemproPac			
Viking			

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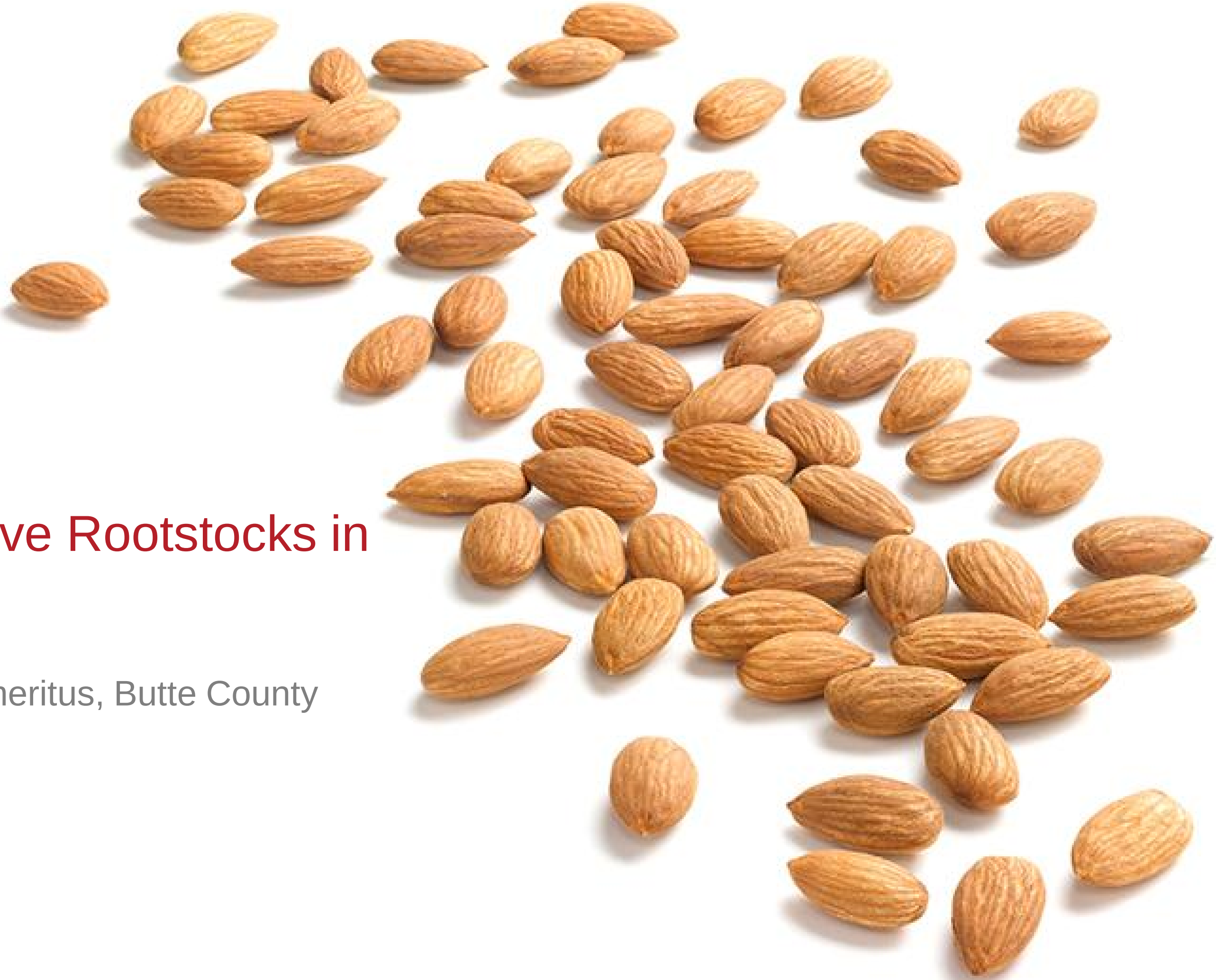
Exploring Alternative Rootstocks in Butte County



Joe Connell, UC Farm Emeritus, Butte County

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Nonpareil on Six Rootstocks

- Lovell
- Atlas
- Empyrean 1
- Rootpac R
- Krymsk 86
- Nickels

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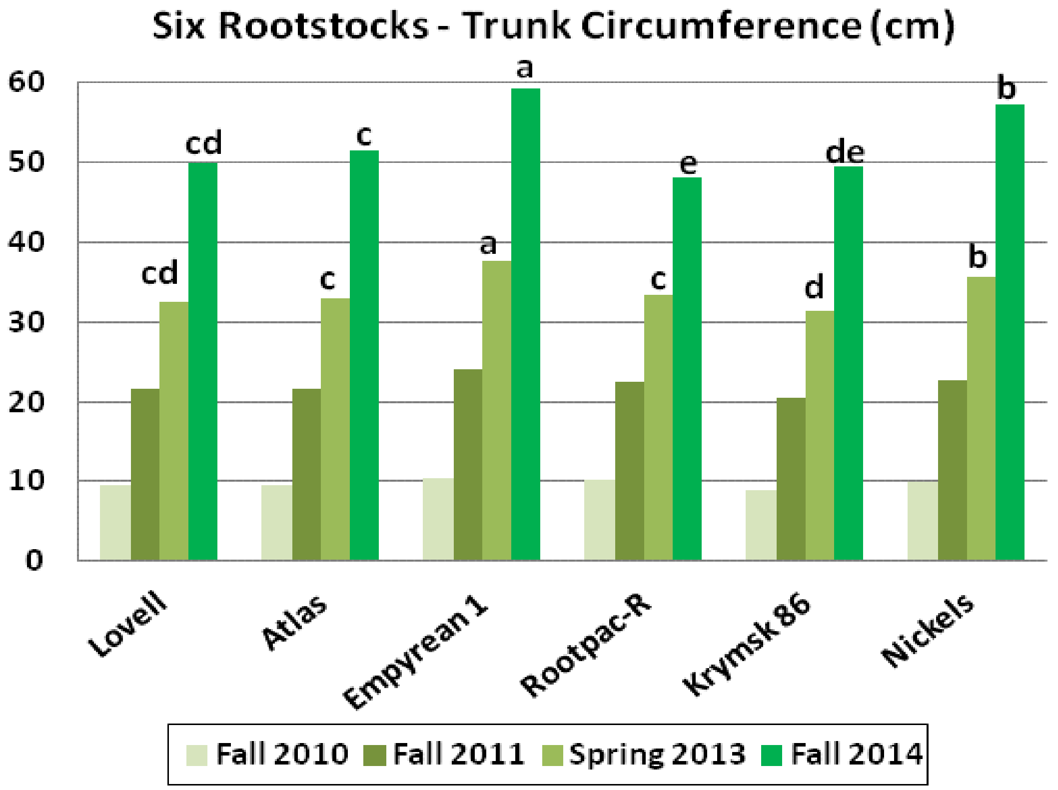
Tree Size as Measured by Trunk Circumference



- **'Empyrean 1' is the largest, followed by those on 'Nickels'.**
- **Trees on 'Lovell' and 'Krymsk 86' are similar in trunk circumference.**
- **'Rootpac-R' rooted trees are numerically smallest but statistically similar to trees on 'Krymsk 86'.**

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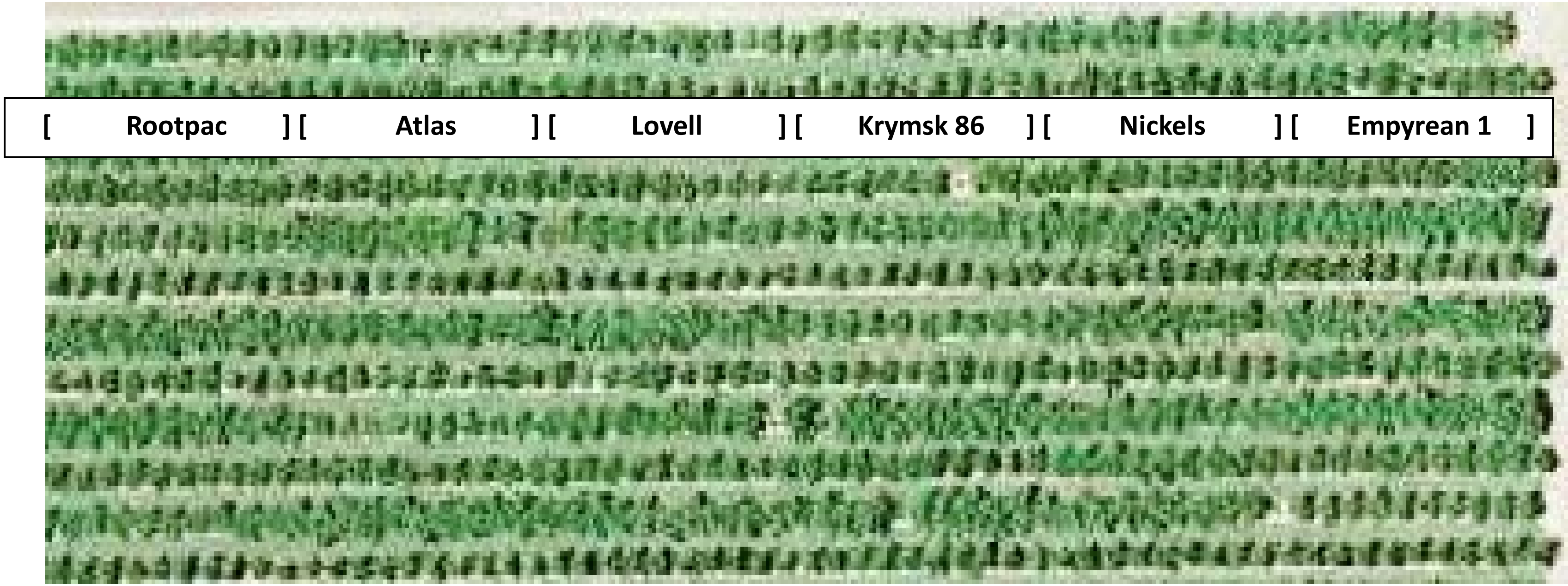
Lovell, Krymsk 86 & Rootpac R are noticeably smaller after 5 seasons



Google Earth Photo of April 14, 2015.

	Pounds of kernel per tree		
Rootstock	3rd Leaf	4th Leaf	5th Leaf
Lovell	0.65 cd	9.22 cd	12.62 b
Atlas	1.00 a	10.53 ab	18.23 a
Empyrean 1	0.61 d	11.69 a	19.32 a
Rootpac-R	0.79 bcd	9.07 d	13.74 b
Krymsk 86	0.93 ab	9.00 d	13.49 b
Nickels Hybrid	0.85 abc	10.28 bc	19.08 a

Values followed by the same letters are not significantly different from one another at P< 0.05 using Fisher's least significant difference (LSD) procedure.

- 5th leaf yield is mainly related to tree canopy size based on rootstock vigor (tree spacing is 24’x16’ or 113 trees per acre).
- ‘Nonpareil’ yields are heaviest on the largest trees, ‘Empyrean 1’, ‘Nickels’, and ‘Atlas’ and lightest on the smaller trees ‘Rootpac-R’, ‘Krymsk 86’, and ‘Lovell’.

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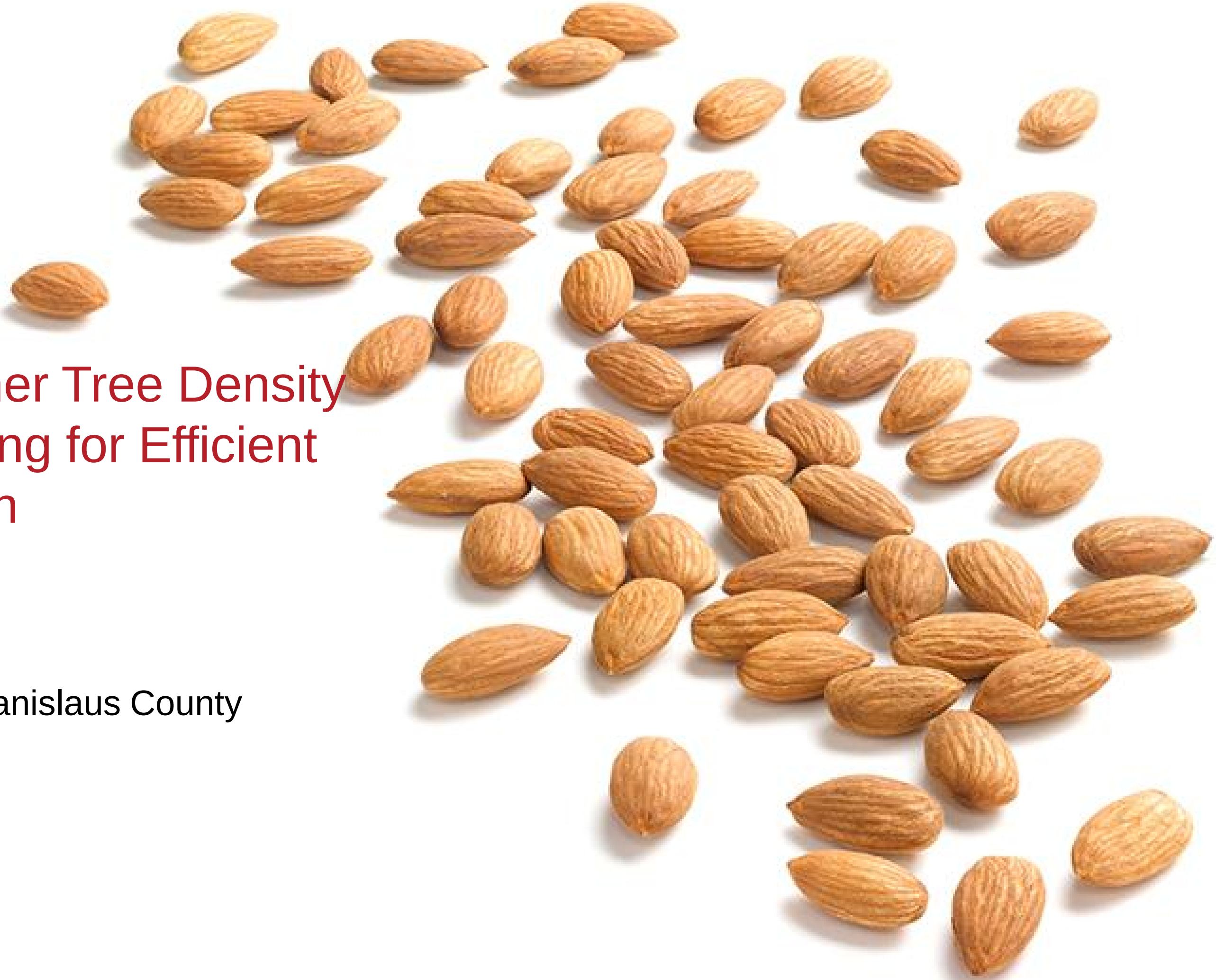

Integration of Higher Tree Density and Minimal Pruning for Efficient Almond Production

Roger Duncan, UCCE, Stanislaus County

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Goal when designing an almond orchard – maximize yield potential by maximizing light capture:

- Capture as much sunlight as early and for as long as possible.
- Each 1% of intercepted sunlight = 50 pounds of yield potential.

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Almond Spacing & Pruning Trial

- Planted fall, 1999
- 37 acres
- Four tree densities
  - –10’ x 22’ (198 trees / acre)
  - –14’ x 22’ (141 trees / acre)
  - –18’ x 22’ (110 trees / acre)
  - –22’ x 22’ (90 trees per acre)

- Overlaid with four pruning strategies and two rootstocks (Nemaguard & Hansen)

1) Standard trained, standard annual pruning

2) Standard trained, unpruned after 2nd dormant

3) Minimal training & pruning, topped 1rst summer

4) Untrained, unpruned

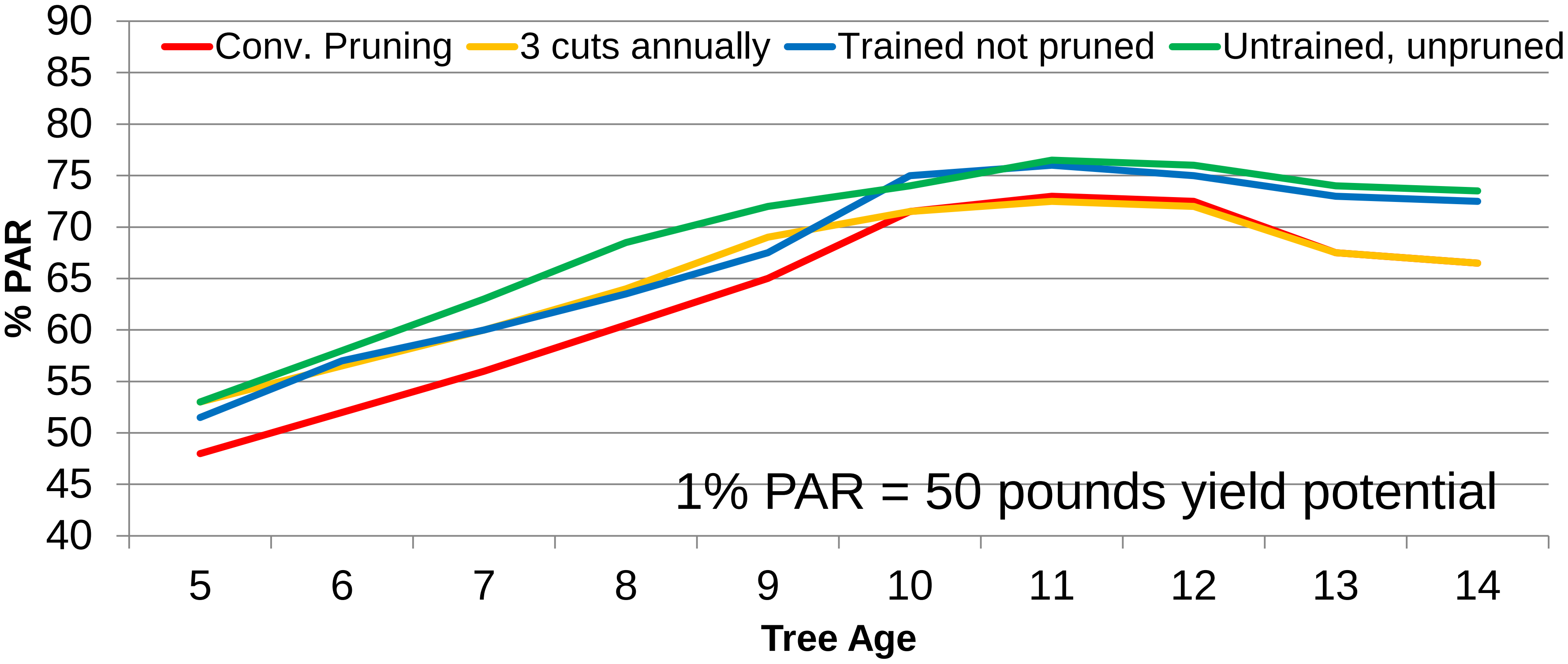
Standard trained & pruned vs. Untrained & unpruned.

End of 3rd Season.

The Effect of Pruning on 2015 (16th Leaf) & Cumulative Yield

	Nonpareil		Carmel	
	2015 Yield (lb. / a)	Cumulative	2015 Yield (lb. / a)	Cumulative
Training & Pruning Strategy				
Trained to 3 scaffolds; Annual, moderate pruning	1691 a	34,228	1548 a	32,230
Trained to 3 scaffolds; Unpruned after 2nd year	1597 a	35,359	1646 a	34,576
Trained to multiple scaffolds; Three annual pruning cuts	1538 a	33,400	1536 a	33,984
No scaffold selection; No annual pruning	1542 a	35,167	1685 a	35,971

Light Interception Dynamics of Different Pruning Methods



Effect of Pruning on Yield to Date

- Pruning has not increased or sustained yield. Conventional annual pruning has reduced yield in most years so far.

- 15 years x $150 pruning costs = $2250

- Decrease in yield by about 1000 to 3500 pounds = loss of ~$2000 - $7000 / acre
  - Cumulative loss from annual pruning likely $5,000 - $9,000 / acre

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Effect of Pruning on Yield to Date

- Sometimes pruning is needed for safety, equipment access, removing limb cankers, etc.

- Reason to prune should justify expense and yield loss

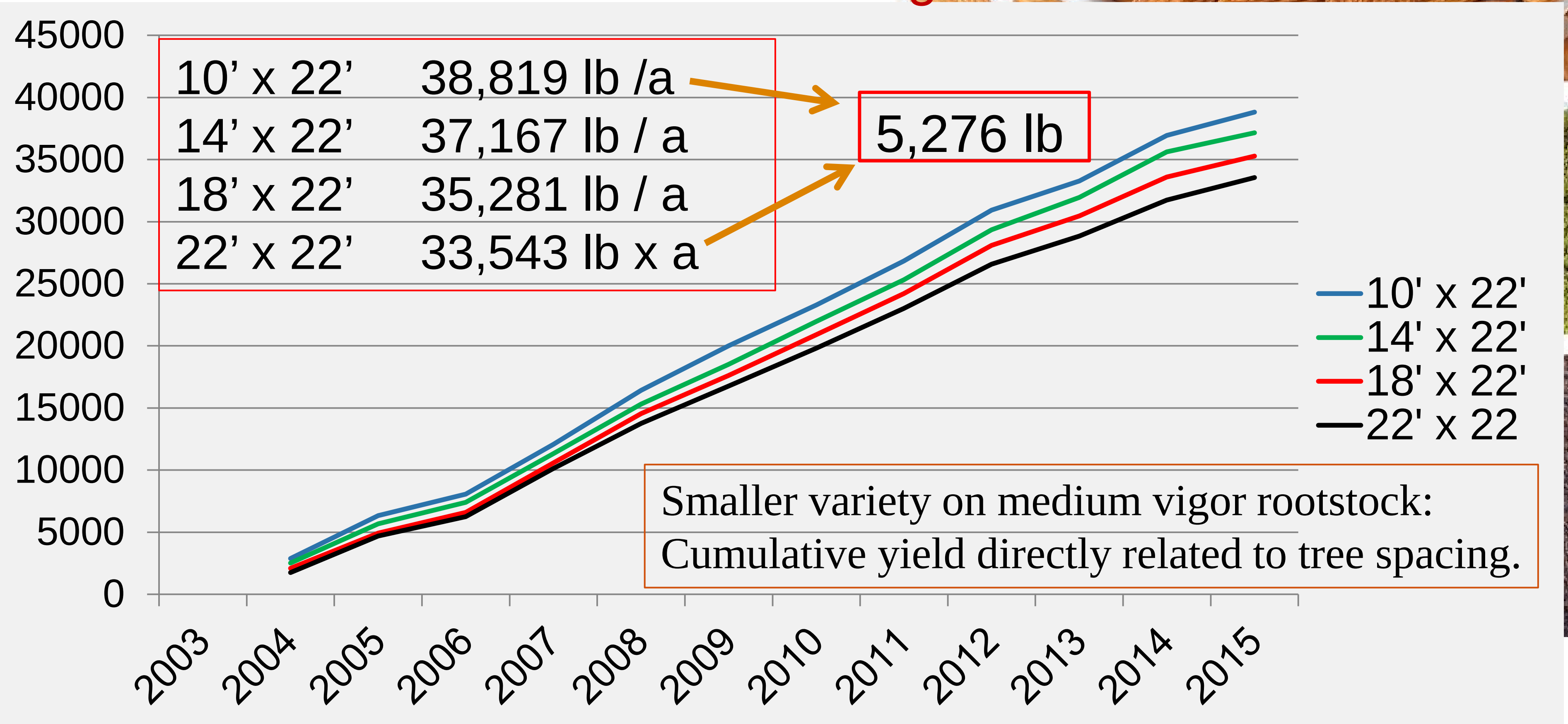

10’ x 22’
22’ x 22’

22’ x 22’   6th season

10’ x 22’ 6th season

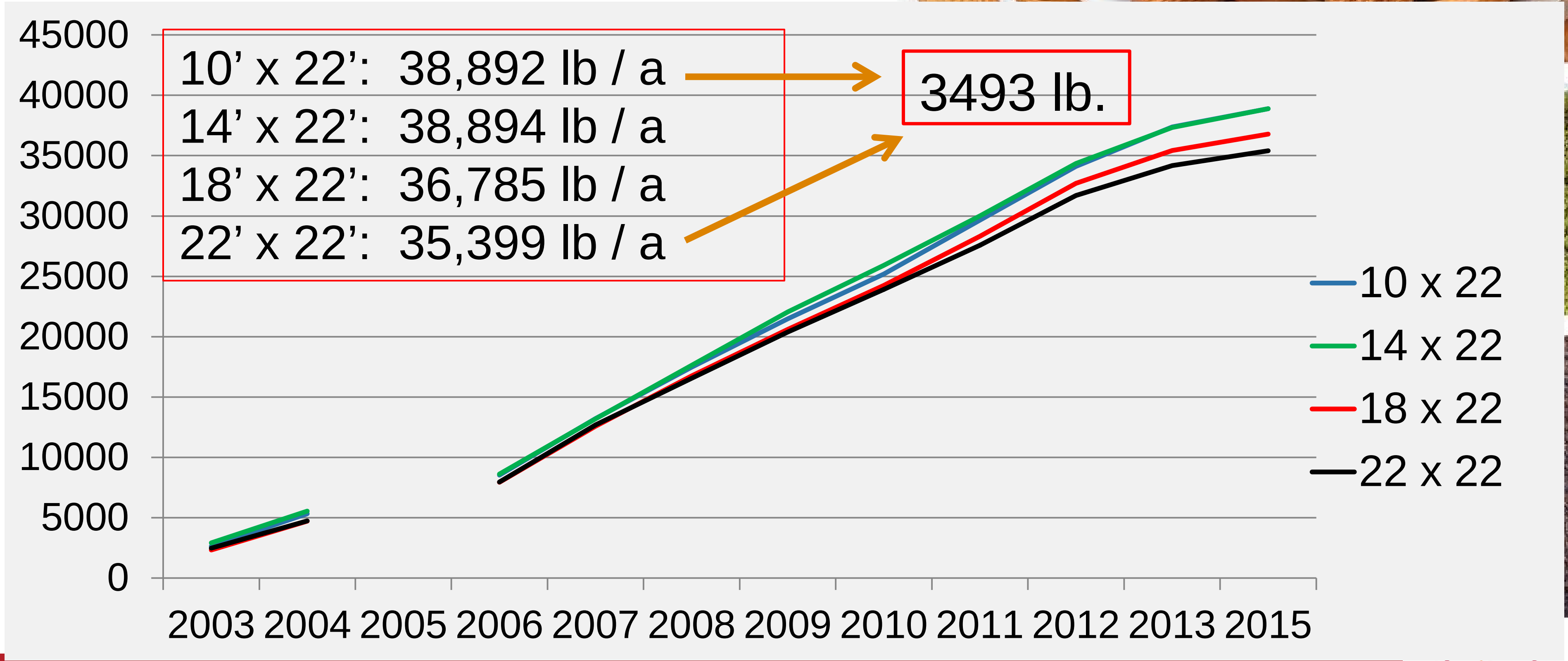
The Effect of Tree Spacing on Cumulative Yield

Carmel on Nemaguard

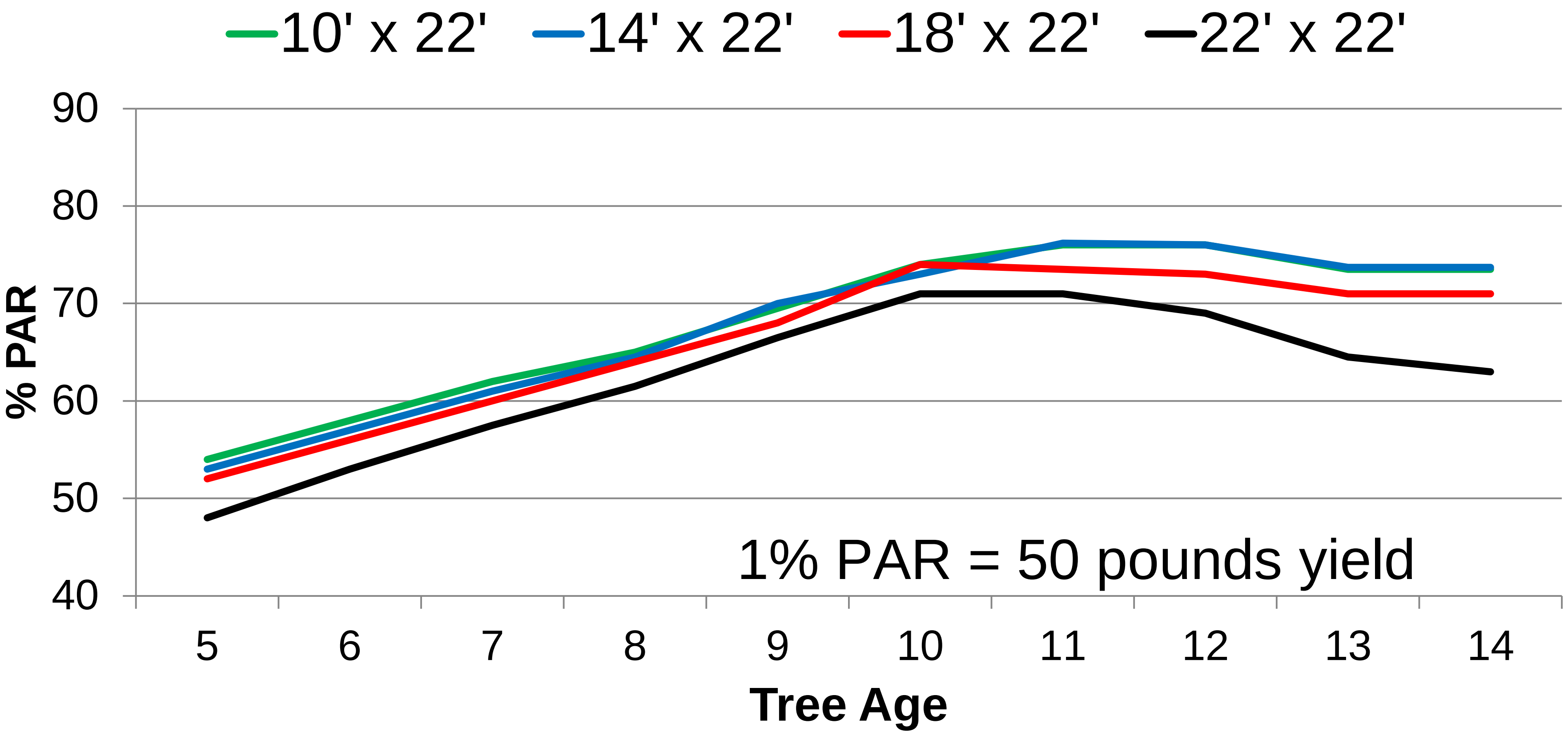


The Effect of Tree Spacing on Cumulative Yield Through 16th Season

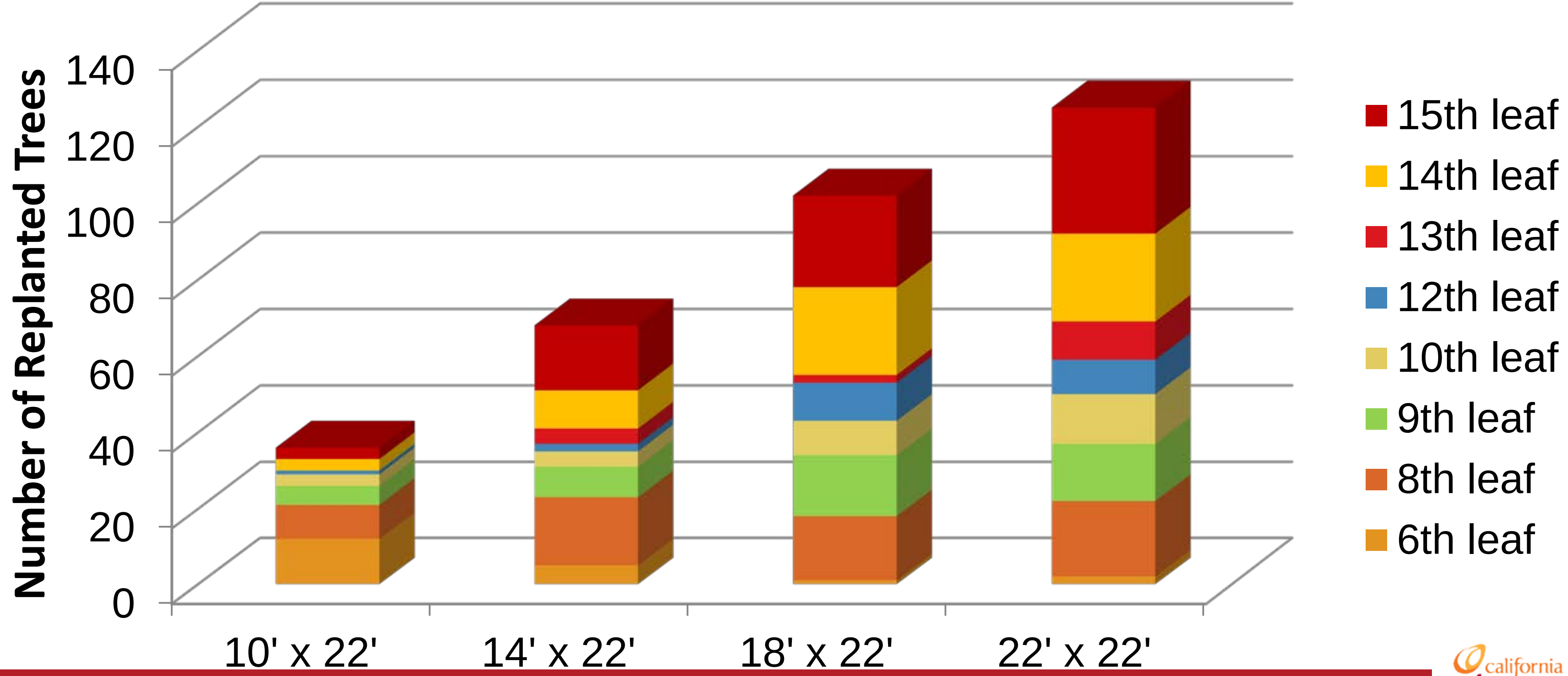
Nonpareil on Nemaguard



Light Interception Dynamics of Differently Spaced Trees



The Influence of Tree Spacing on the Number of Replanted Trees (on all 37 acres)



The Influence of Tree Spacing on Missing Canopy

	Cumulative Number of Replants	Square Footage of Missing Canopy
10' x 22'	35	7,700
14' x 22'	62	19,096
18' x 22'	98	38,808
22' x 22'	120	58,080

Effect of Tree Density on Yield to Date:

- Yield advantage to tighter spacing is highly dependent on inherent tree vigor
  - Smaller trees (varieties, rootstocks, etc.) will benefit most from tight spacing
  - Benefit may persist throughout orchard’s life
  - Large, vigorous trees may not have substantially higher yields at higher density.
- Advantages other than yield (smaller trees, easier to shake, fewer structural problems, fewer mummies, etc.)
- No disadvantage to close spacing yet (other than planting costs)

Mechanical Topping of Nonbearing Almond Trees

Roger Duncan, UCCE Stanislaus County

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Why mechanically top young trees? The assumptions are:

- Reduce training costs
- Create a shorter, bushier, higher (earlier?) yielding tree

Stanislaus County Trial Training Strategies:

1. Mechanically topped 1rst “dormant” (Nov. 2014) + minimal scaffold selection (by hand)
2. Mechanically topped 1rst & 2nd dormant + scaffold selection (by hand)
3. Mechanically topped 1rst & 2nd dormant, no scaffold selection
4. Standard “medium-long pruned” training by hand
5. “Short pruned” by hand
6. No scaffold selection / pruning

The test orchard:

- Nonpareil / Monterey / Fritz on Titan P/A Hybrid
- Spacing: 16’ x 20’
- Near Westley, CA (Westside)

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After topping, November 2014

8-9’

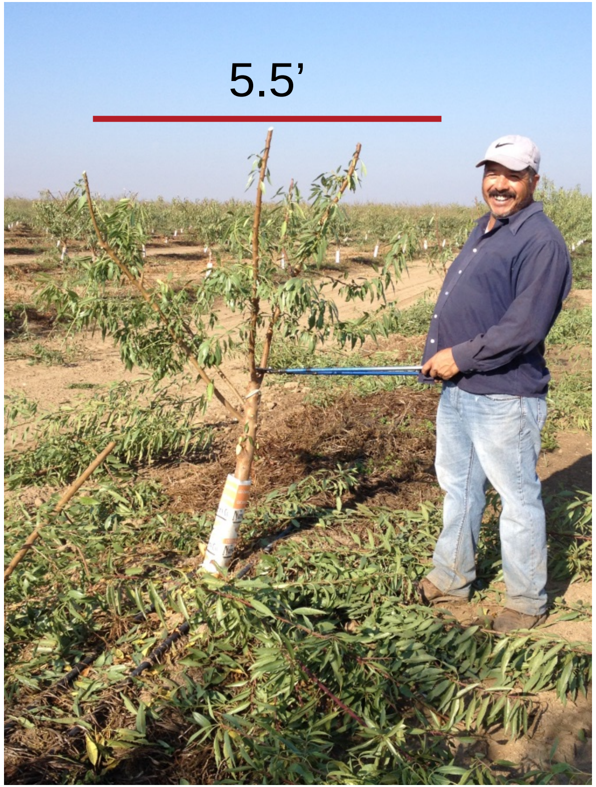
6’

Not Topped

Topped

Untrained

“Standard” long pruning



Butcher job

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Cost per Acre for Various Training Strategies

$18

$71

$66

$30 + $18 = $48
$30 + $53 = $83

*Labor valued at $12 / hour. Does not include cost of stacking and shredding brush

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Parameters to Measure:

- Pruning time / costs
- Tree height
- Trunk circumference
- Canopy light interception
- Tree failure / leaning / falling over, etc.
- Yield (3rd & 4th leaf)

End of 2nd Leaf; Nov., 2015

Effect of Training Techniques on Tree Size (End of 2nd Leaf)

	Tree Height (ft)		Trunk Circumference (cm)	
	Nonpareil	Monterey	Nonpareil	Monterey
Untrained	12.9 A	13.9 A	36.5 A	32.8 A
Topped no scaffold selection	12.7 A	13.5 AB	34.6 B	31.3 BC
Topped with scaffold selection	12.5 A	13.6 AB	35.2 AB	31.5 B
Hand trained (“long” pruned)	12.5 AB	13.5 AB	35.6 AB	30.3 CD
Hand trained (“short” pruned)	11.9 B	13.1 B	33.2 C	30.1 D

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Conclusions (and concerns):

- Mechanically topped trees were not shorter than standard hand trained or unpruned trees at the end of one year.

- Mechanical topping plus follow up scaffold selection was the most expensive treatment.

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Conclusions (and concerns):

- Mechanically topped trees were not shorter than standard hand trained or unpruned trees at the end of one year.

- Mechanical topping plus follow up scaffold selection was the most expensive treatment.

- Will heading cuts all at same height be a problem?