Precision Irrigation Management: What's Now and What's New (Part 1)

December 7, 2016

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Precision Irrigation Management: What's Now and What's New (Part 1)

Bob Curtis, Almond Board of California (Moderator)

Bruce Lampinen, UC Davis

Shrini Upadhyaya, UC Davis

Ken Shackel, UC Davis

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Bob Curtis,
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Bruce Lampinen, UC Davis

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Plant Water Status- Overview of Existing Tools

Bruce Lampinen, UC Davis Plant Sciences

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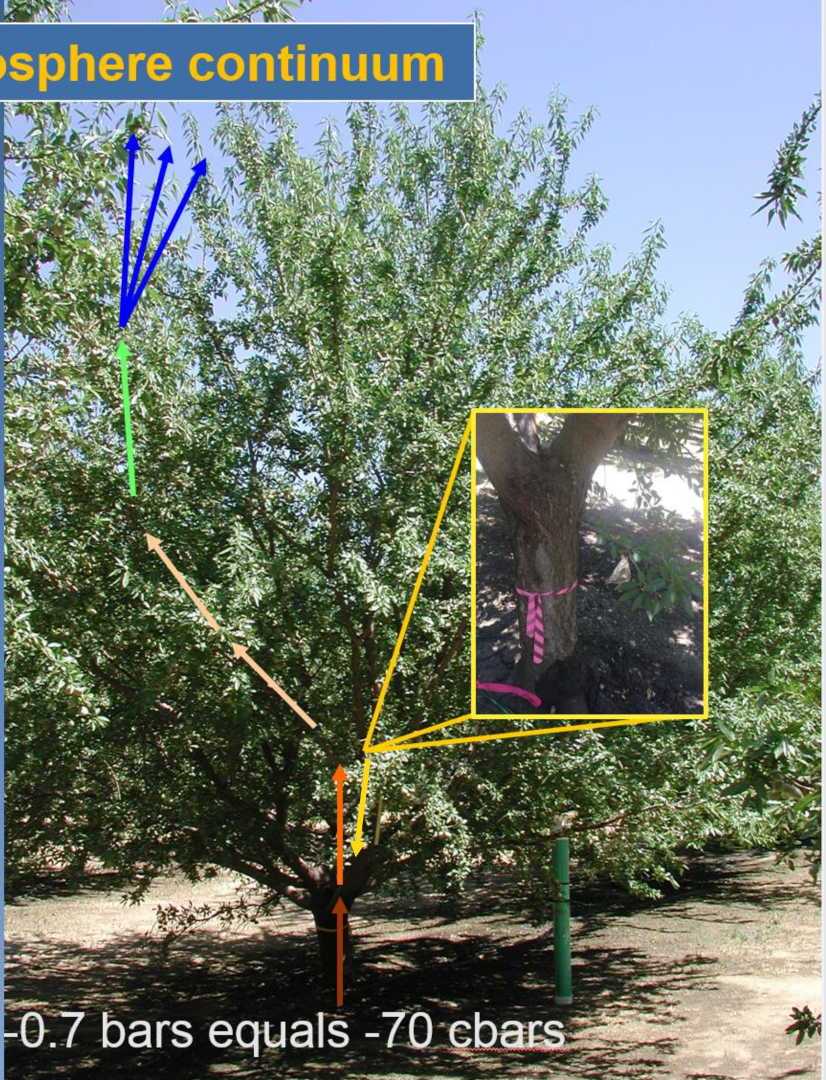
Water potential in the soil-plant-atmosphere continuum

Location	Fully watered bars	Stressed bars
Air above tree	-95	-95
Air near leaf	-70	-80
Air in leaf	-12	-18
Xylem in leaf (6m)	-10	-16
Xylem in scaffold	-8.0	-14
Xylem in trunk-	-7.5	-12
Xylem in root	-1.2	-3.0
Soil	-0.3	-0.7



As an almond tree become stressed from lack of water, several things happen

- Stem water potential becomes more negative
- Leaf temperature increases
- Increased shrinking of trunk at midday
- Water flow in xylem slows
- Leaf characteristics change

These are the characteristics that can be used to estimate plant water status

Stem water potential becomes more negative

Leaf temperature increases

Increased shrinking of trunk at midday

Water flow in xylem slows

Leaf characteristics change

Soil Moisture Equipment
Plant Pressure Chamber

ICT stem psychrometer

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Water flow in xylem slows

Leaf characteristics change

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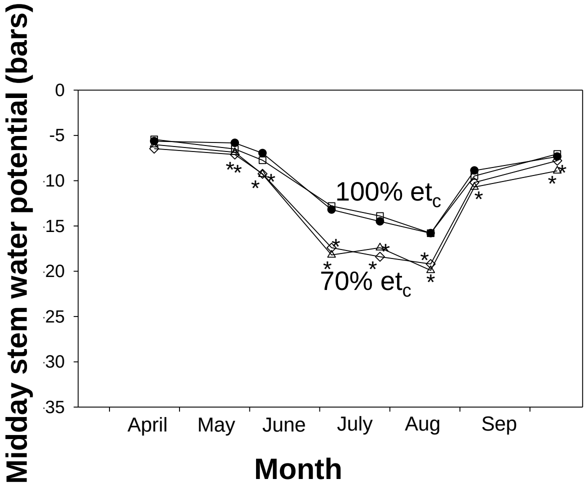
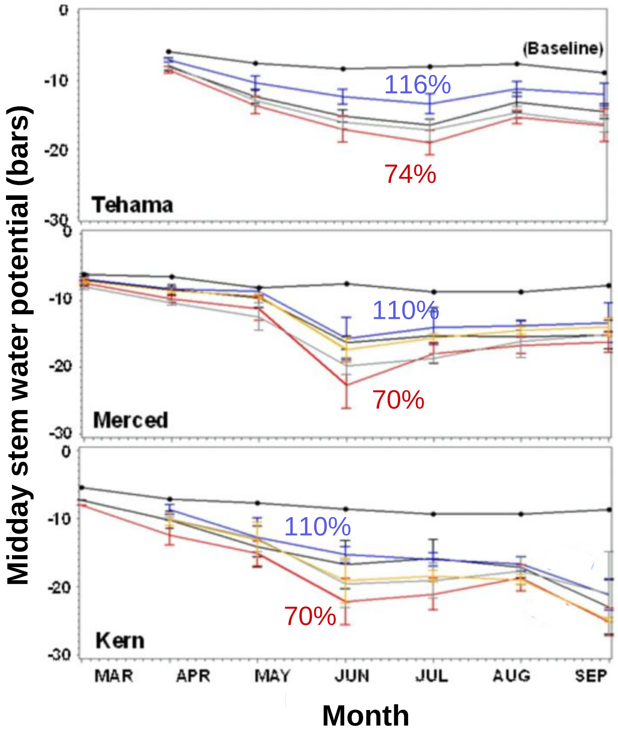




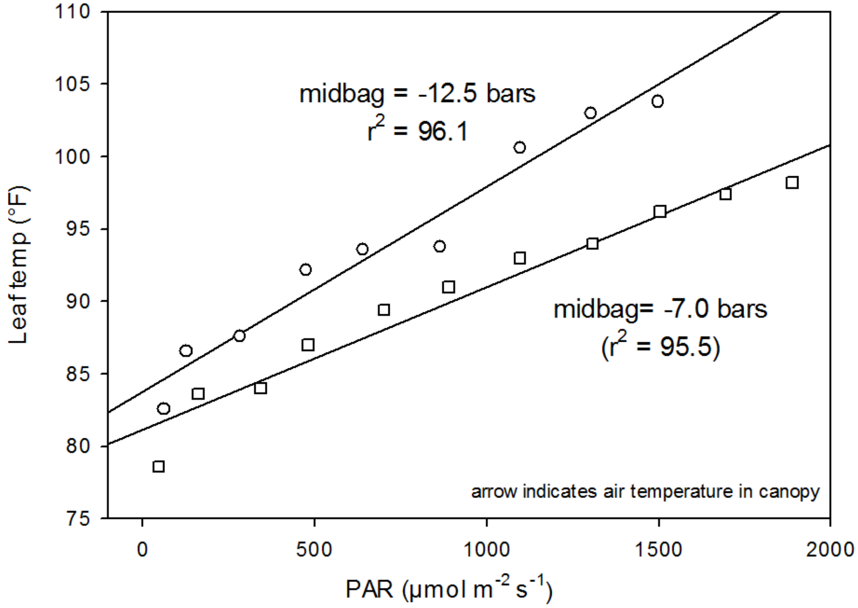
Stem water potential becomes more negative

Leaf temperature increases

Increased shrinking of trunk at midday

Water flow in xylem slows

Leaf characteristics change



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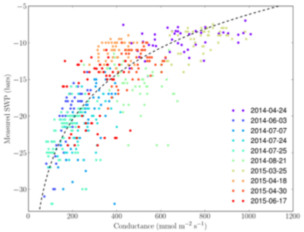
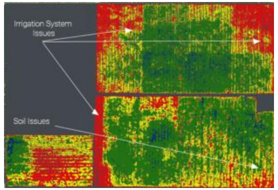
Ceres Imaging





Cermetek LeafMon

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SmartCrop® System

The SmartCrop® System has been used in many different environments across the U.S. and many countries around the world. The Standard SmartCrop® sensor measures continuous crop canopy temperature using an infrared thermometer and relays the information back to the Smartfield™ Base Station.

Research has shown canopy temperature to be a significant measurement of crop stress. If the temperature of the plant is above optimal temperature for an extended period of time, the metabolic processes become less efficient; the plant does not show as much growth, therefore, causing detriment to the yield.

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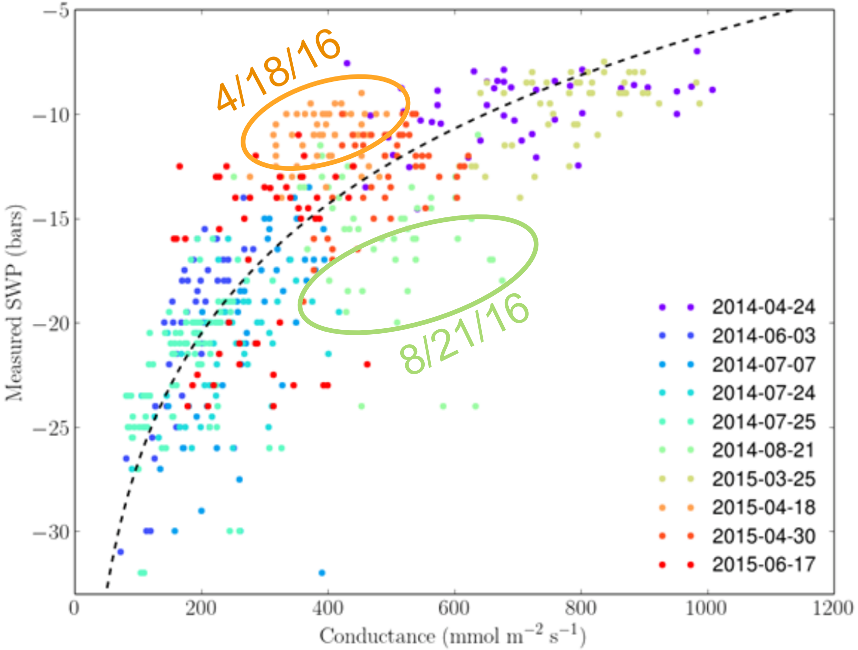
Leaf temperature increases

Increased shrinking of trunk at midday

Water flow in xylem slows

Leaf characteristics change



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Leaf temperature increases

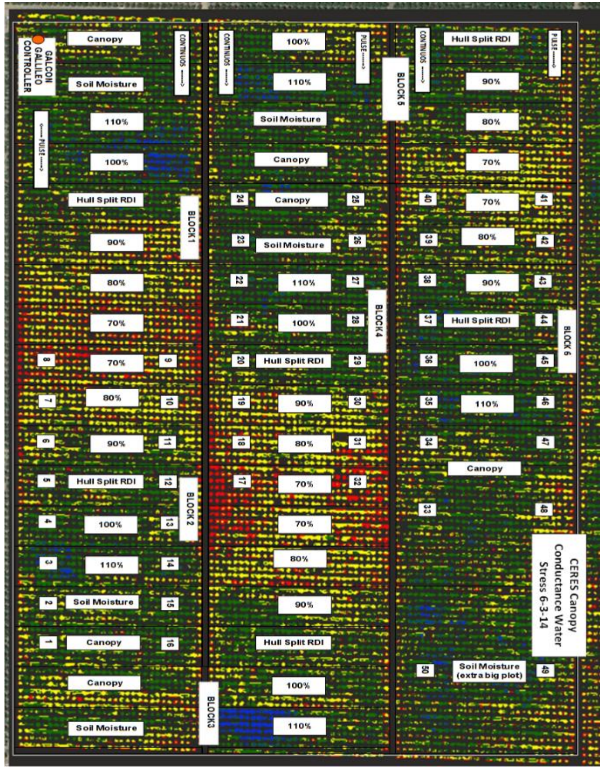
Increased shrinking of trunk at midday

Water flow in xylem slows

Leaf characteristics change

Kern Almond Water Production Trial (blue least stressed, red most stressed)

On any given day can show variability across orchard but calibration varies over season



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Stem water potential becomes more negative
Leaf temperature increases
Increased shrinking of trunk (or leaf?) at midday
Water flow in xylem slows
Leaf characteristics change

Phytec Dendrometer

Decagon D6 Dendrometer

Zim Plant Technology
Magnetic Patch Clamp
Pressure Probe

ZIM-probe
plant microclimate
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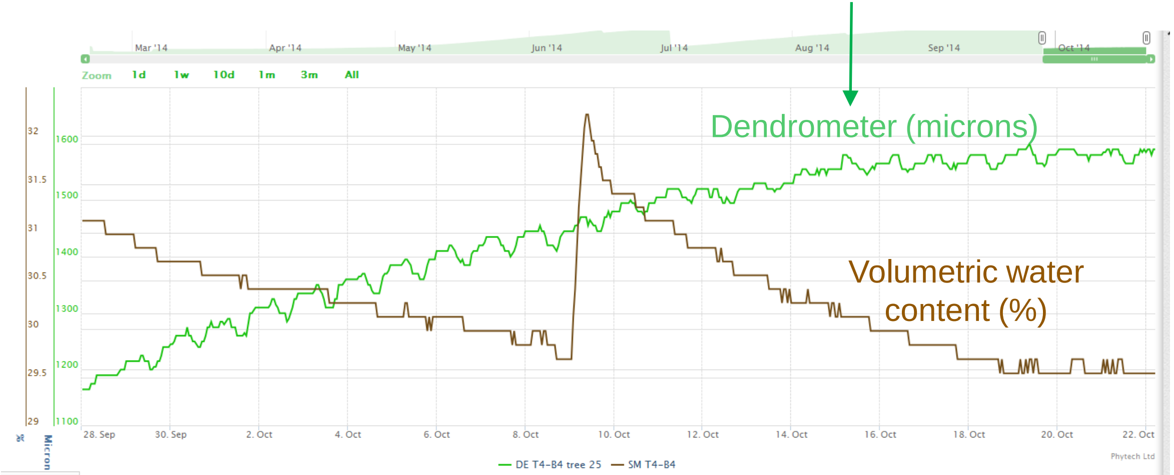

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Edaphic Scientific
Sap Flow Sensor

ICT Sap Flow Sensor

Dynamax Dynagage
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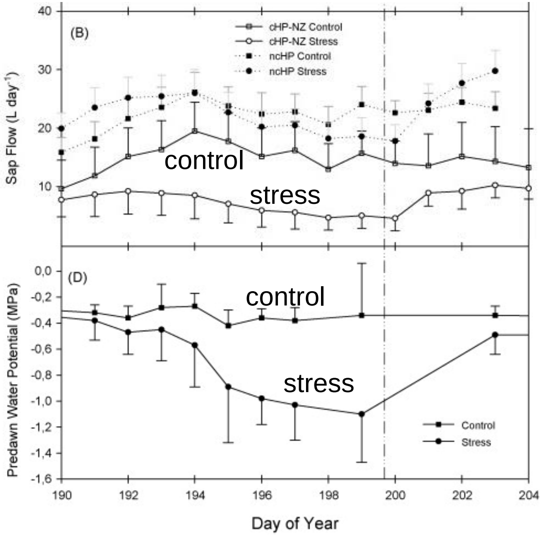

Fig. 2.

Evolution of (A) ETo; (B) daily total sap flow in control and stress treatment of ncHP and cHP–NZ systems; (C) relative sap flow of stress treatment respect to control measured with all systems and (D) predawn water potential (Ψp) in stress and control trees (*n* = 12, mean ± S.E.). The drying cycle was initiated on DOY 190 and it lasted till DOY 199 (the vertical dash-dot-dot line indicates re-watering of the stressed trees).

ELSEVIER

Agricultural Water Management

Volume 95, Issue 5, May 2008, Pages 503–515

Comparative assessment of five methods of determining sap flow in peach trees

P. González-Altozano[a], E.W. Pavel[b], J.A. Oncins[c], J. Doltra[d], M. Cohen[e], T. Paço[f], R. Massai[g], J.R. Castel[h]

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Stem water potential becomes more negative

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Increased shrinking of trunk at midday

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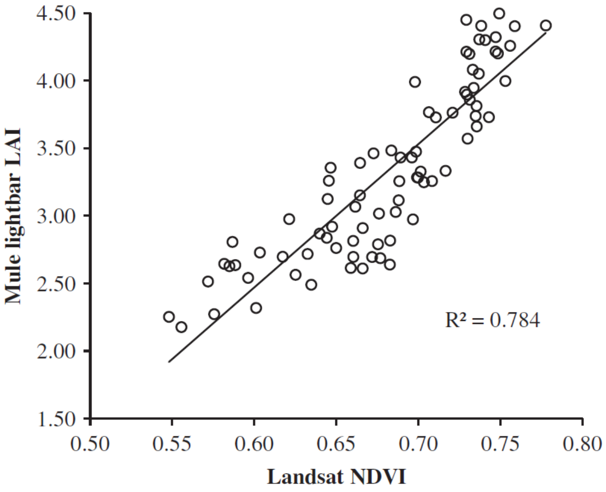
Leaf characteristics change- normalized difference vegetation index (NDVI)



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Computers and Electronics in Agriculture

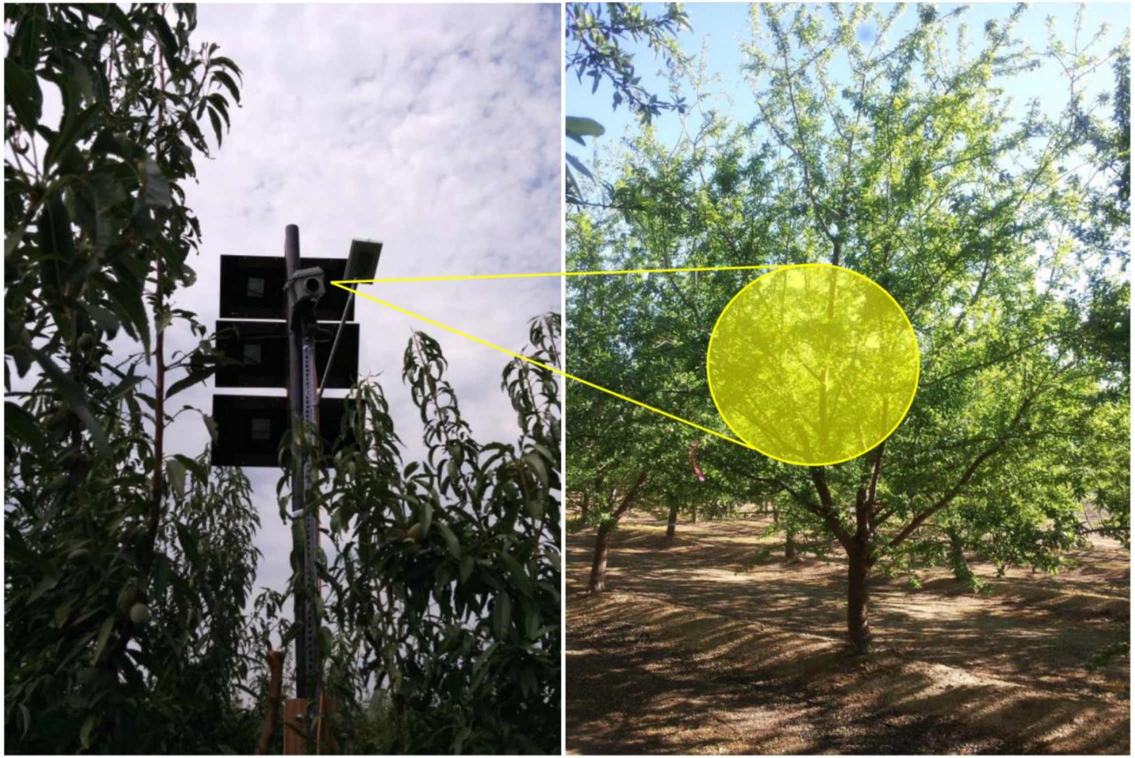
journal homepage: www.elsevier.com/locate/compag

Prediction of leaf area index in almonds by vegetation indexes

Jose L. Zarate-Valdez [a,b,*], Michael L. Whiting [b], Bruce D. Lampinen [c], Samuel Metcalf [c], Susan L. Ustin [b], Patrick H. Brown [c]

[a] Centro Regional Universitario del Noroeste, Universidad Autonoma Chapingo, Colima 163 Norte, Cd. Obregon, Sonora, Mexico
[b] Center for Spatial Technologies and Remote Sensing (CSTARS), Department of Land, Air, and Water Resources, University of California, Davis, CA 95616, USA
[c] Department of Plant Sciences, University of California, Davis, CA 95616, USA

Set up NDVI cameras aimed at individual trees



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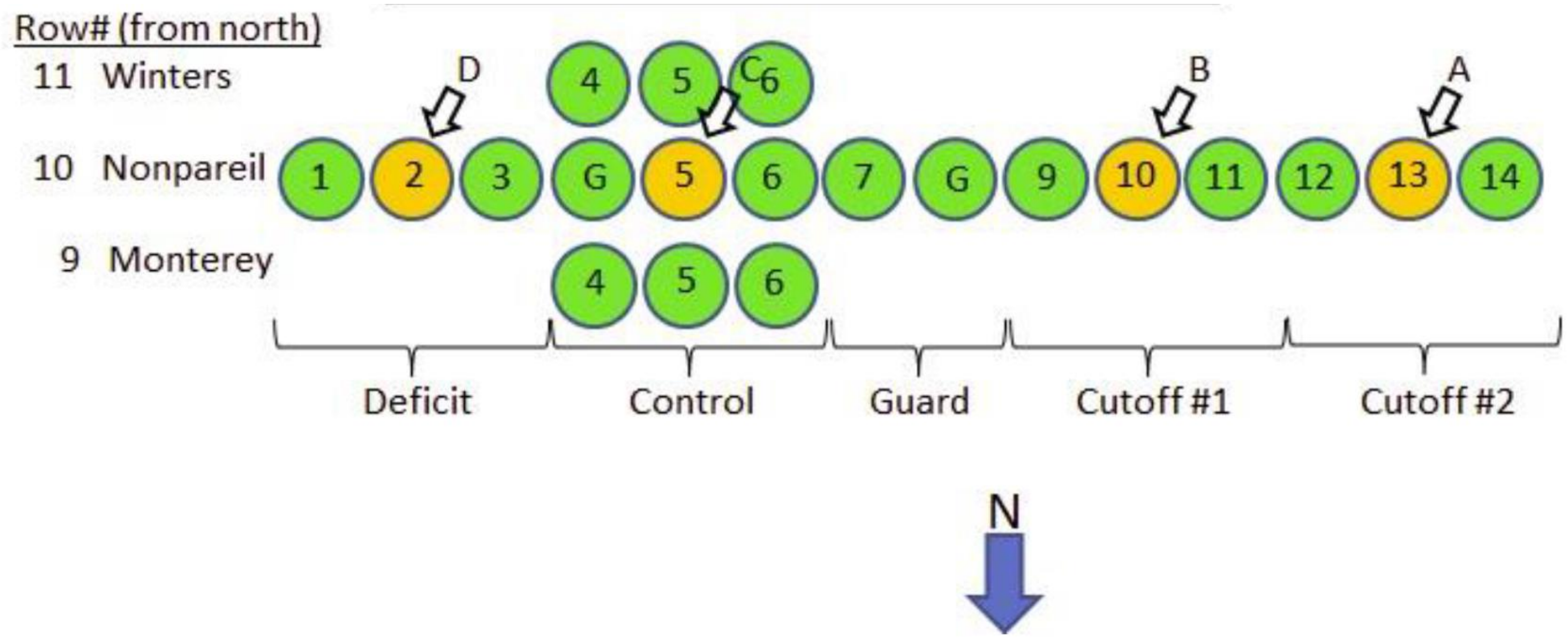

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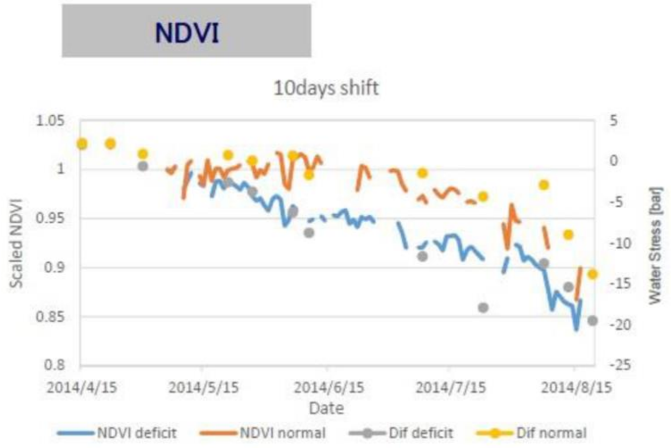


Coefficient correlation R2	0.85 (High Correlation)
Standard Error	1.36 bar
Delay from Water Stress	10 days

NDVI tracked changes in MSWP with a 10 day delay

In other words, NDVI told you what MSWP was 10 days ago

Usefulness of these techniques

- Leaf temperature increases
  - Varies with wind, air to leaf temp differences, etc.
- Increased shrinking of trunk at midday
  - Can be useful but need a fully watered tree to calibrate
  - Difficult (expensive) to monitor large number of trees
- Water flow in xylem slows
  - Can be useful but need a fully watered tree to calibrate
  - Difficult (expensive) to monitor large number of trees
- Leaf characteristics change (NDVI)
  - Can show orchard variability
  - Different calibration through season
  - Lags behind tree water status by about 10 days

Usefulness of these techniques

Whichever of these techniques you use, be sure to calibrate it against stem water potential

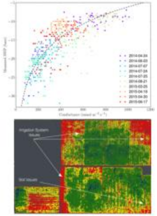
Soil Moisture Equipment
Plant Pressure Chamber

Thank you!

Soil Moisture Equipment
Plant Pressure Chamber

ICT stem psychrometer

Ceres Imaging



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Thanks to the Almond Board of California for funding various aspects of this work

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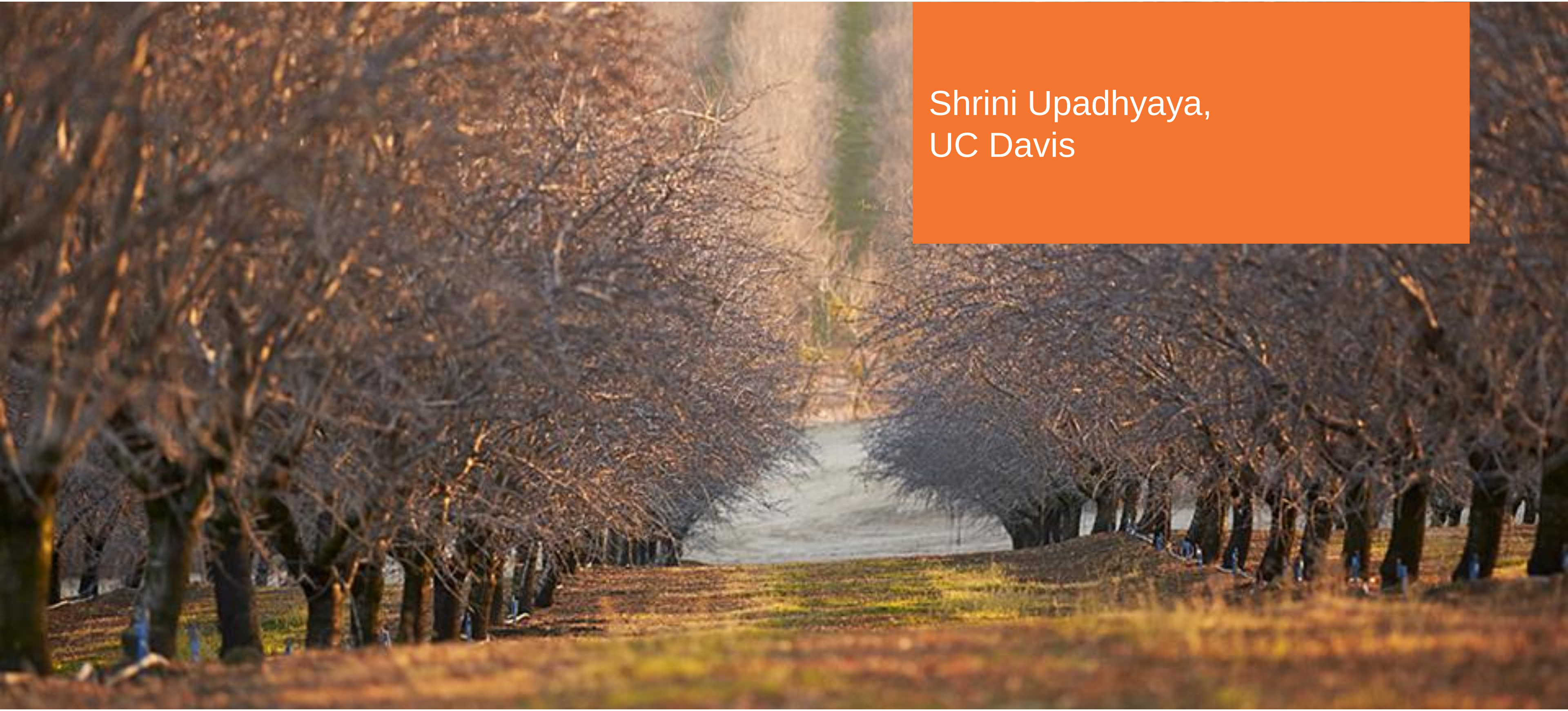

Shrini Upadhyaya,
UC Davis

Precision Irrigation Management: What's Now and What's New (Part I)

A Leaf Monitor to Continuously Monitor Plant Water Status

Shrini K Upadhyaya

Professor

Bio. and Agr. Eng. Dept.

UC Davis

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Acknowledgements

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Mr. Alexander Schramm, Junior Specialist
Ms. Julie Meyers, Undergraduate Researcher
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Ms. Chunxia Jiang, Visiting PhD Scholar China
Dr. Selcuk Ozmen, Visiting Scholar, Turkey
Dr. Changjie Han, Visiting Scholar, China
Dr. Bruce Lampinen, Plant Sciences
Dr. Ken Shackel, Plant Sciences
Dr. Mike Delwiche, Bio. and Agr. Eng
Dr. Franz Niederholzer

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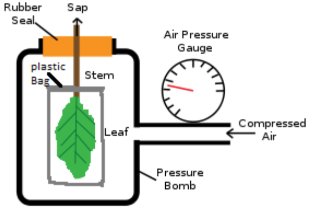
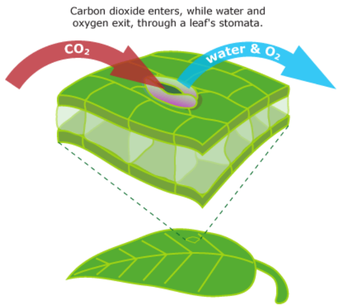
What Plant Physiologists recommend -

- For almonds it is important to manage plant water status
  - Between 12 to 14 bars pre- and post-hull split period, and
  - Between 14 to 18 bars during the hull split period
  - ➔ To achieve good quality, water use efficiency, and disease resistance



Stomatal Conductance and Leaf Temperature

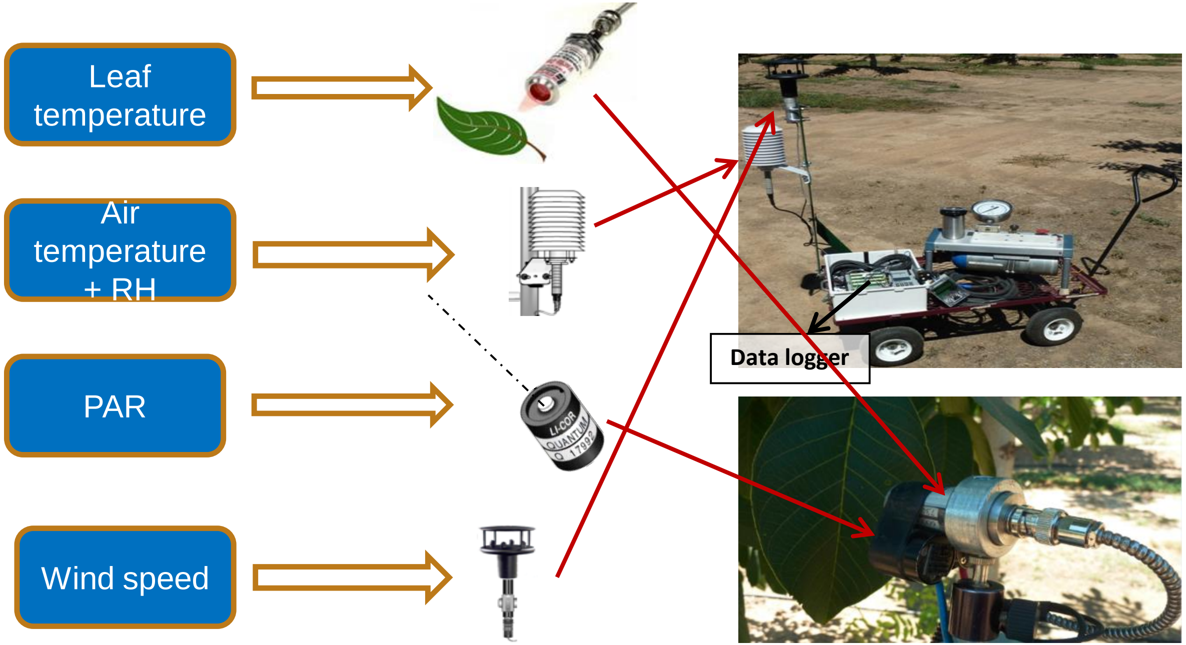
Plant has enough water → Opens stomata → More CO_2 for Photo-synthesis → More water vapor loss - transpiration → More cooling of leaf → Cooler leaf temperature



Leaf temp. less than air temp. → **Plant is under no water stress**

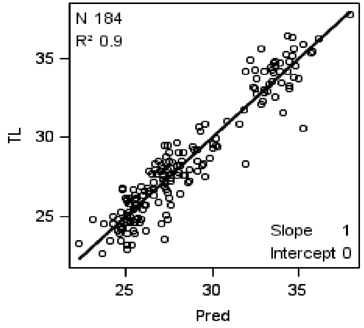
Is it that simple?

Sensor Suite System



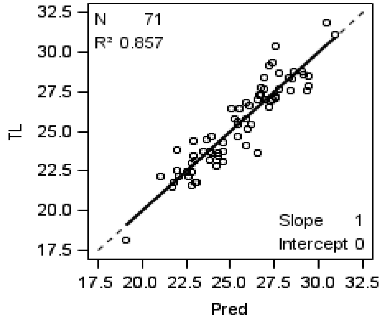
Multiple Linear Regression Results of Extensive Field Tests during 2010 and 2011

Almonds



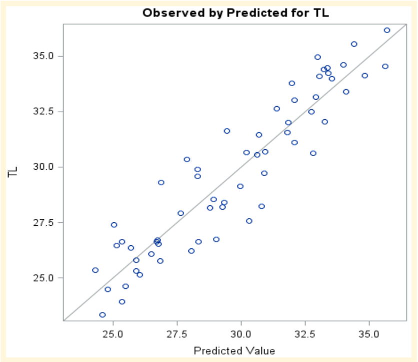
T_L= - 2.619+0.809T_a - 2.487 SWP + 0.044RH
R^2=0.90

Walnuts



T_L= - 3.028+0.817T_a - 2.424 SWP + 0.050RH
R^2=086

Grapes

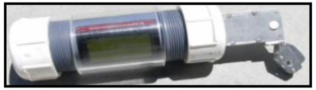


T_L= - 15.92 + 1.38T_a - 3.81 SWP + 0.029PAR
R^2=0.86

Further Developments

Leaf Temperature

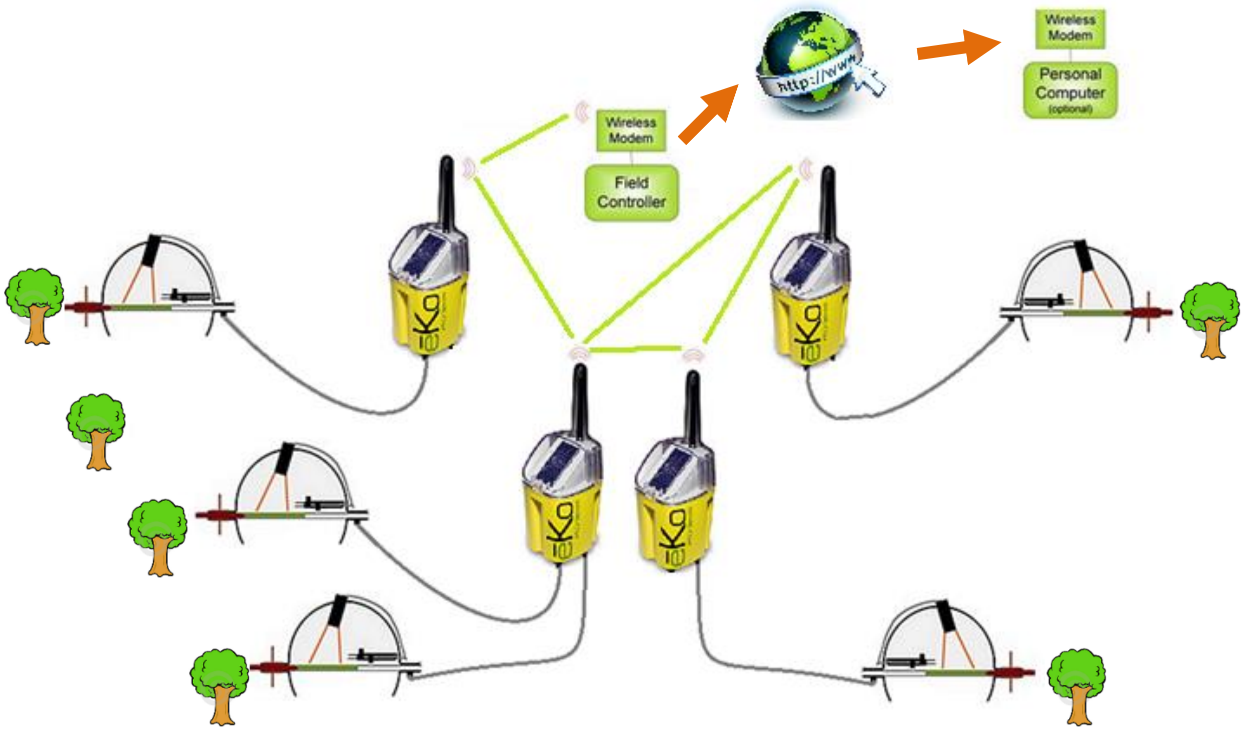
PAR



Air Temp. and Relative humidity

Wind speed

Wireless Mesh Network of leaf monitors

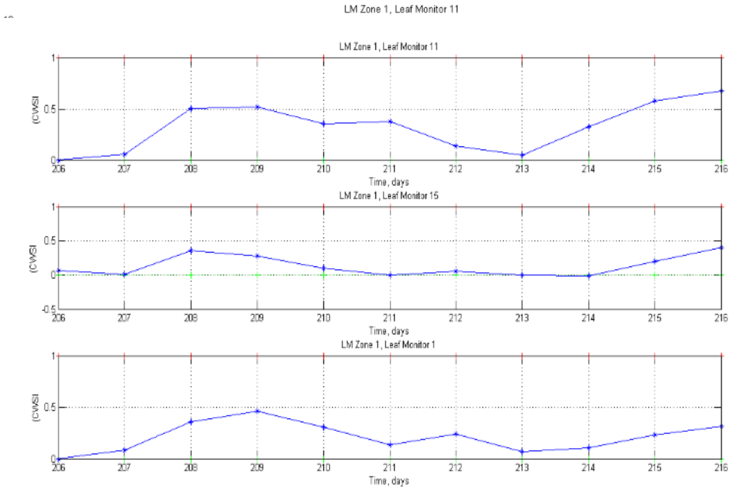


Status of a Plant

- A fully saturated tree/vine:

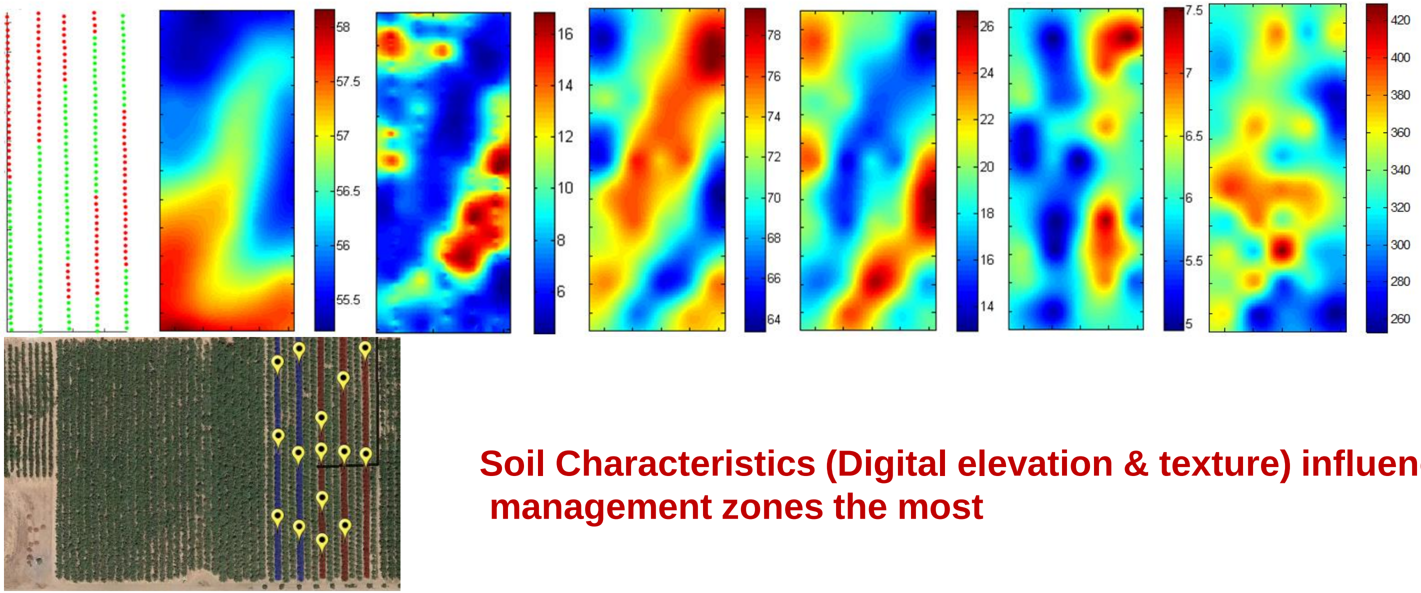
- A not so happy tree/vine:

- Representative tree/vine:



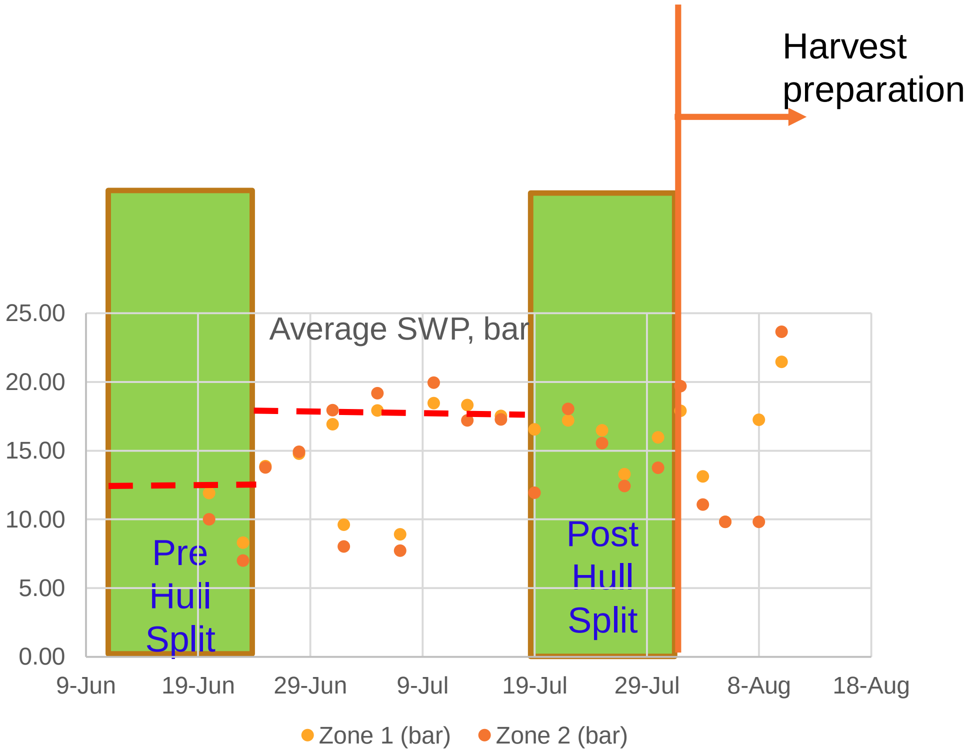
$$CWSI = \frac{(T_L - T_A) - (T_L - T_A)_{Sat}}{(T_L - T_A)_{Dry} - (T_L - T_A)_{Sat}}$$

Management Zone based Precision Irrigation in Almond Crop

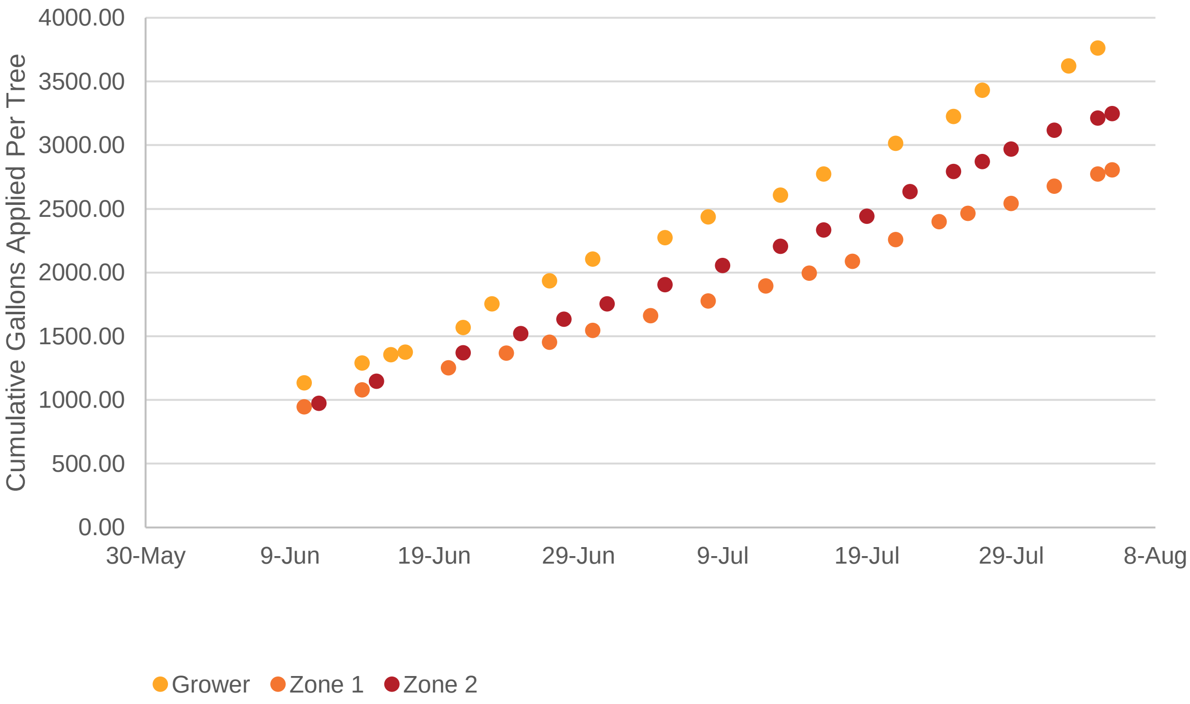


Soil Characteristics (Digital elevation & texture) influenced management zones the most

Plant water Status



Cumulative water applied per tree



Inches of water applied:

- Grower: 21.6 (94.0% of ET)
- Zone 1: 16.1 (70.0% of ET)
- Zone 2: 18.6 (81.0% of ET)

Overall water application:
Zone #1: 74.6%
Zone #2: 86.3%

Cumulative ET corrected for rainfall starting May 1st = 23.0 in

Yield and Quality

Treatment	Yield, lb/acre	Mass, g/50	Length/Width/Height, mm
Zone 1 - Grower	2643	64.8	23.8/13.7/8.5
Zone 1 - Stress	2551	65.0	24.0/13.5/8.5
Zone 2 - Grower	2869	65.1	24.3/13.7/8.4
Zone 2 - Stress	2496	65.8	23.9/13.6/8.5

- Mold percentages were also not significant.

100 YEARS UC DAVIS BIOLOGICAL AND AGRICULTURAL ENGINEERING

Nickels Soil Lab

cdfa

Thank You

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UC Davis

Precision Irrigation Management: What's Now and What's New (Part 1)

Ken Shackel

Water production function research

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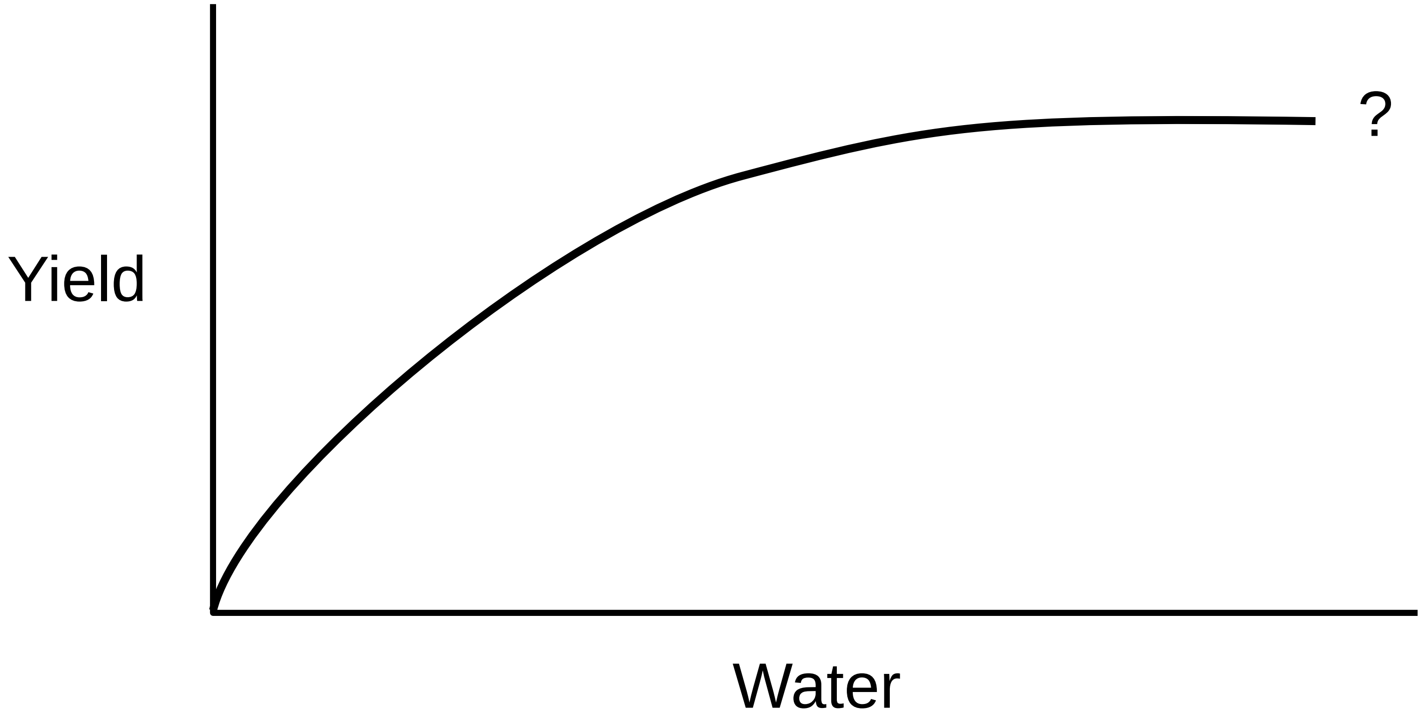
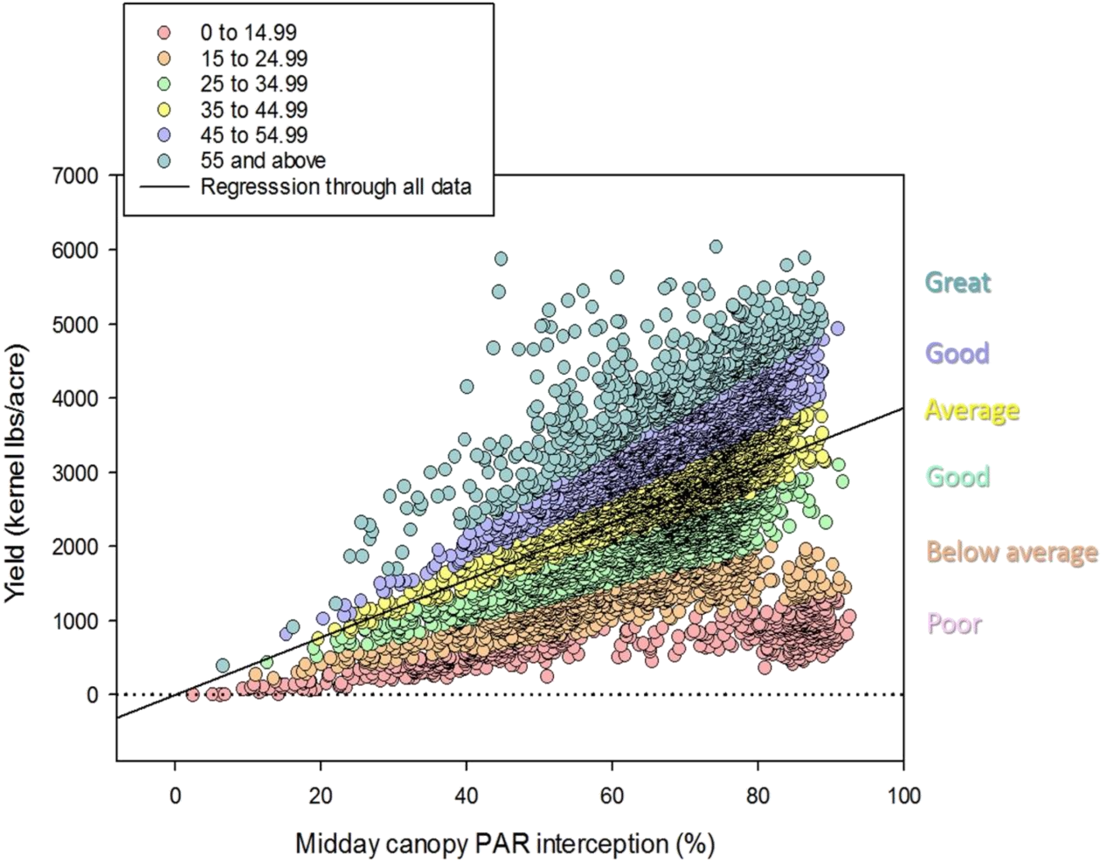
Question: how does almond yield respond to water?



Summary (c/o B. Lampinen) of Previous Almond Research Relating Yield to PAR and Applied Irrigation Water

PAR (shade):

- More shade on the ground means that trees are collecting and using more sunlight to grow the crop.
- Good orchards can achieve about 50 kernel pounds for every 1% of ground shaded (PAR).
- Average orchards are around 38 kernel pounds per 1% PAR



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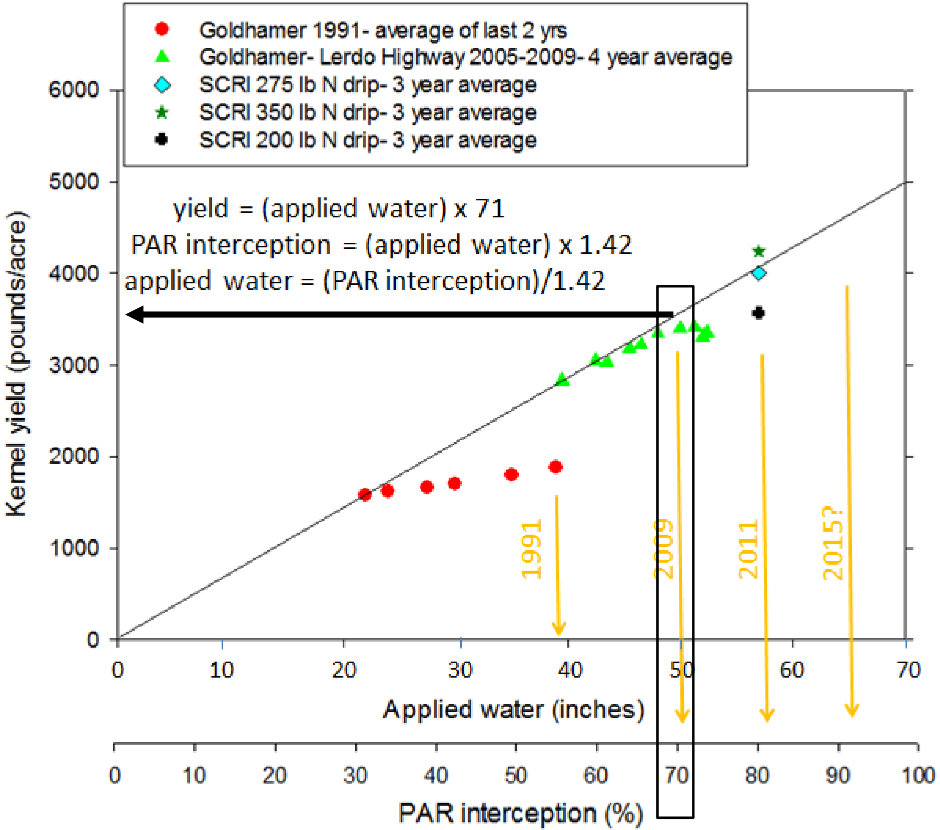
Applied Water:

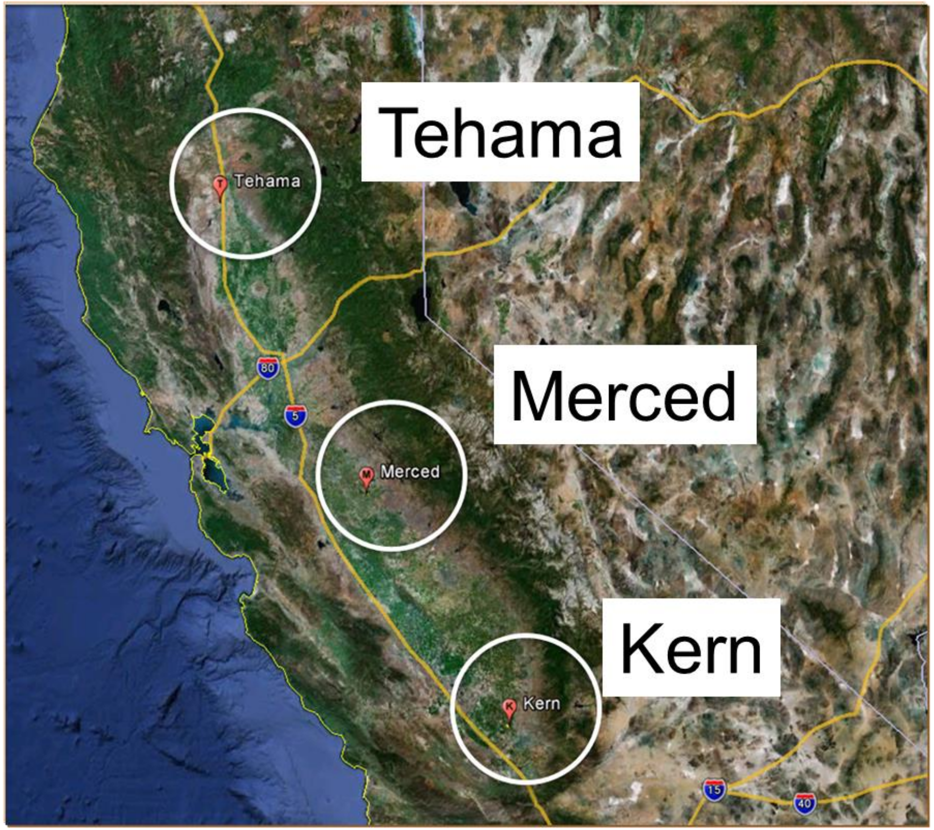
- Yield and PAR both increase more-or-less in a straight line as irrigation increases.
- Example: 50” of water should give about 70% PAR and about 3,500 kernel pounds.
- At some point, too much irrigation should cause problems and reduce yield, not to mention environmental issues, but the ‘too much’ water point has yet to be determined.

If we consider the three trials that have 2-4 year average yield versus applied water data



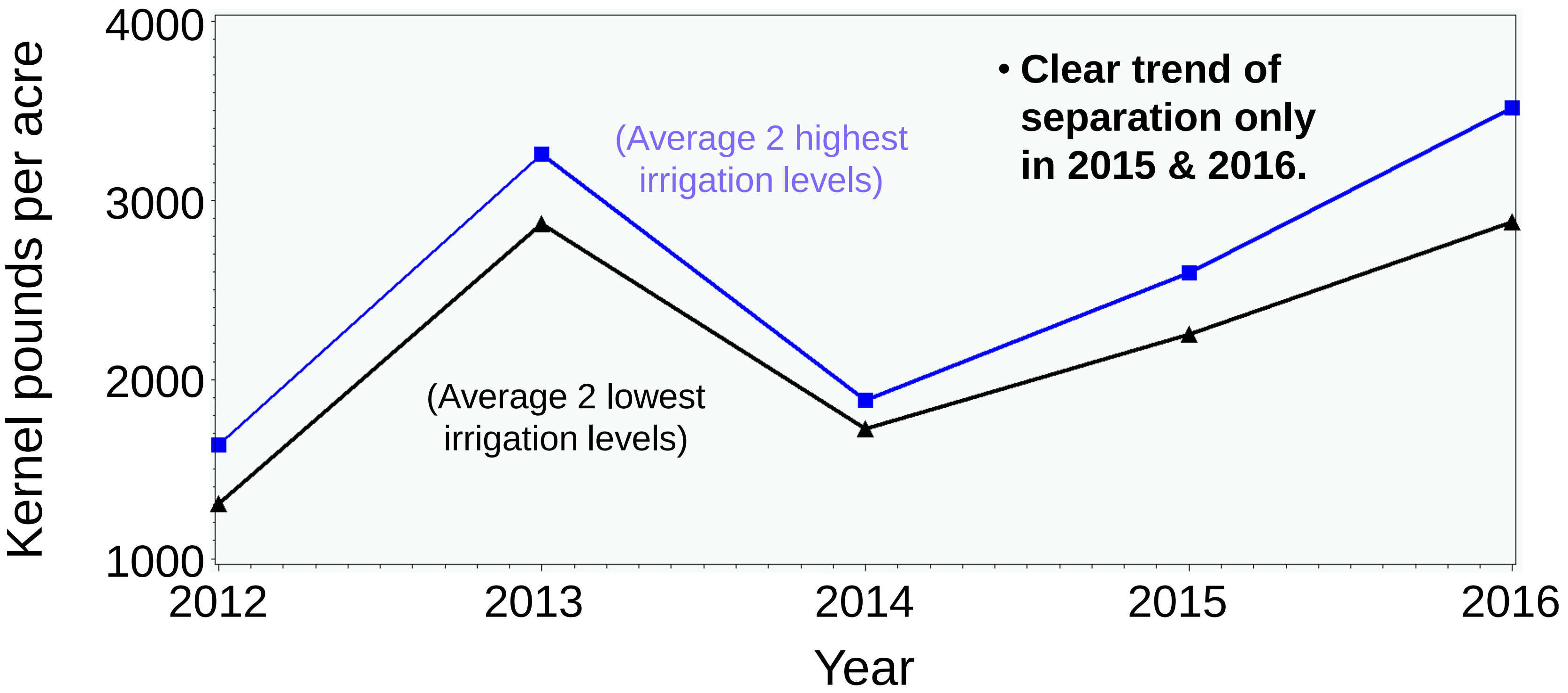
Almond Water Production Function Project

- 3 sites.
- 3-4 irrigation levels per site, range: 70% to 110% ET.
- Irrigation treatments since 2013.
- Yield since 2012 (pre-treatment).



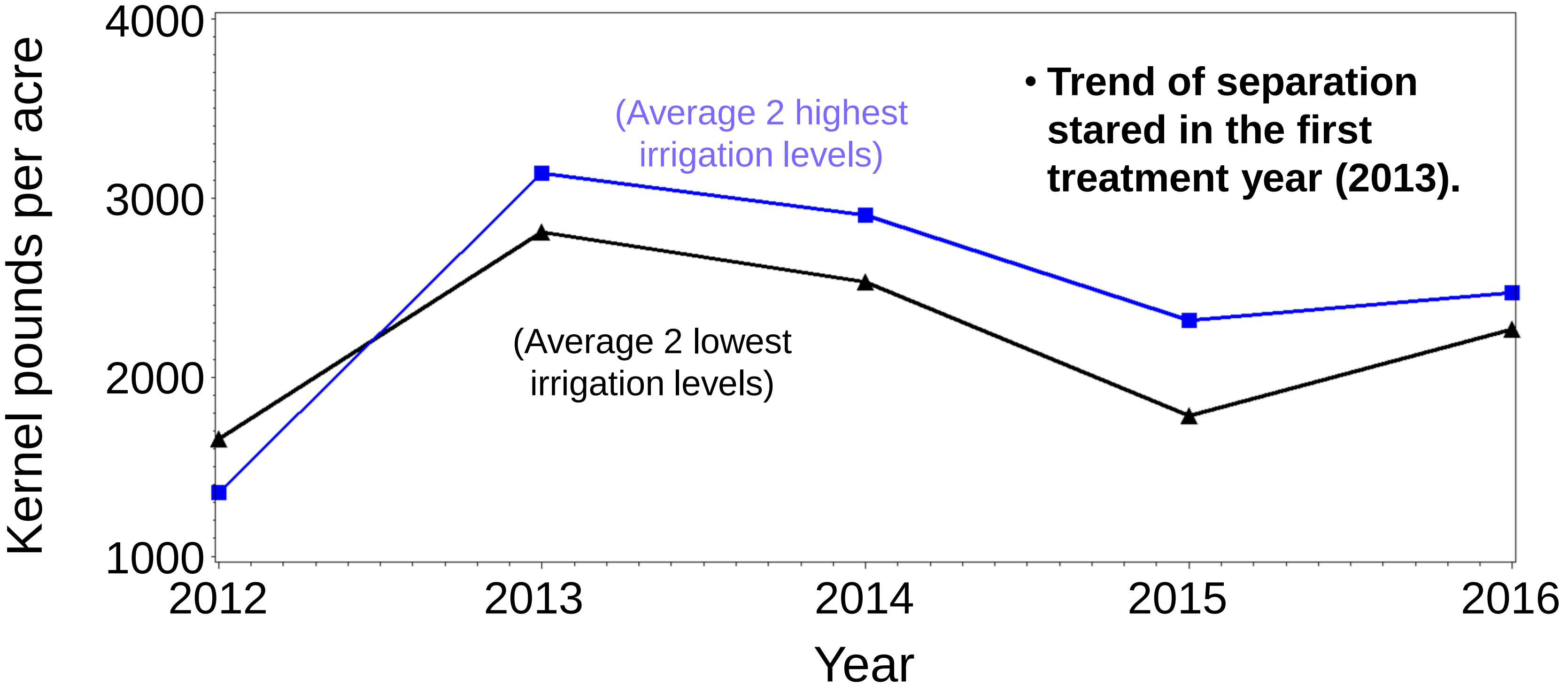
Almond yields from 2012 to 2016 at the **Kern** site

2 highest irrigation treatments (around 45”) compared to 2 lowest (around 28”)



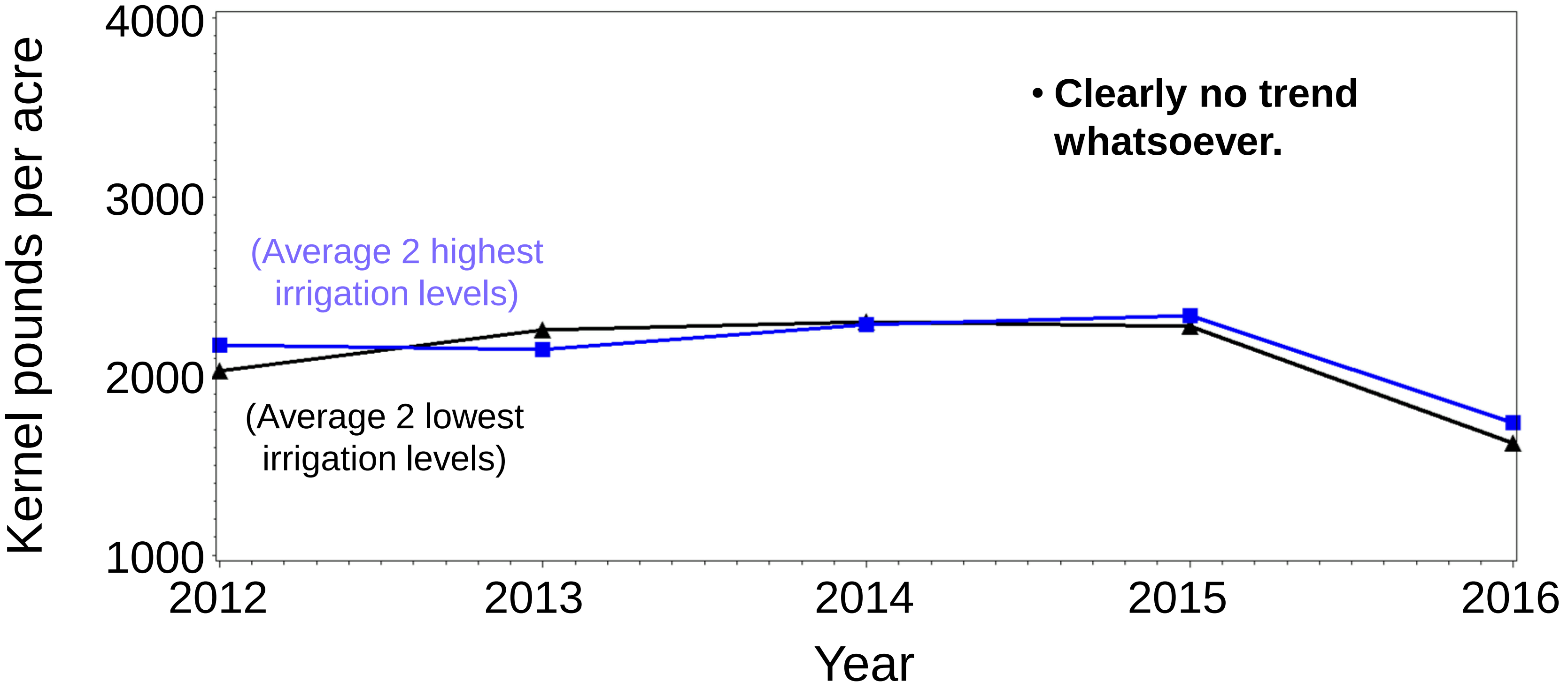
Almond yields from 2012 to 2016 at the **Merced** site

2 highest irrigation treatments (around 45”) compared to 2 lowest (around 28”)

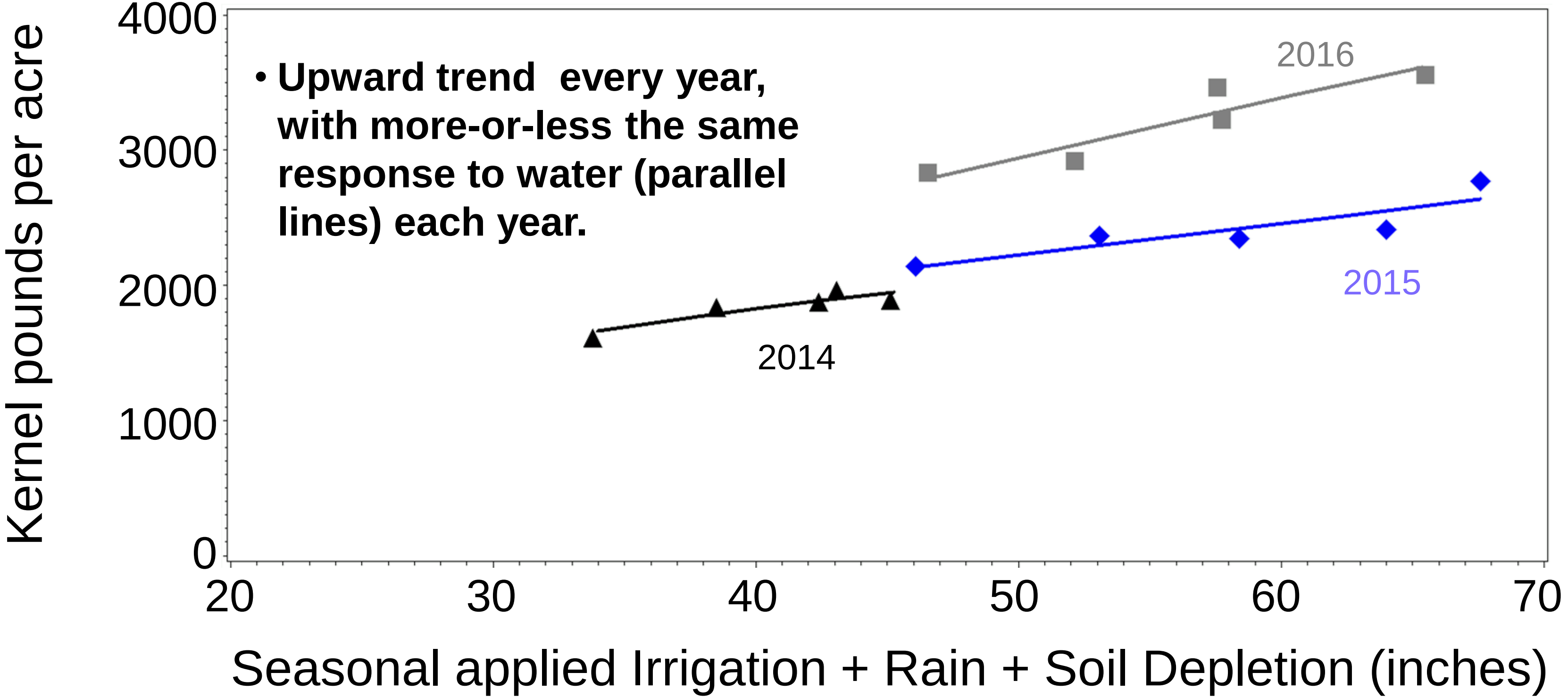


Almond yields from 2012 to 2016 at the **Tehama** site

2 highest irrigation treatments (around 45”) compared to 2 lowest (around 28”)



Almond yield response to water at the **Kern** site
(2014-2016)



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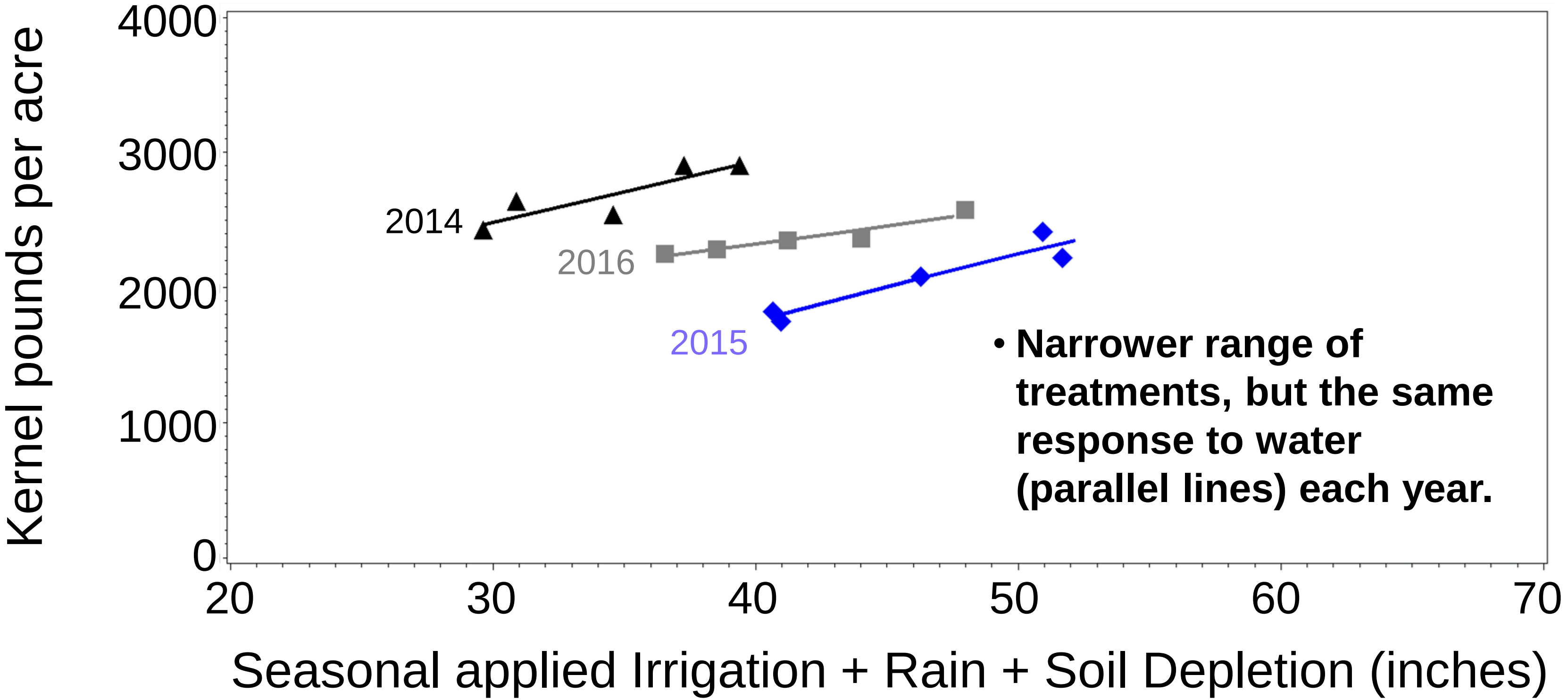
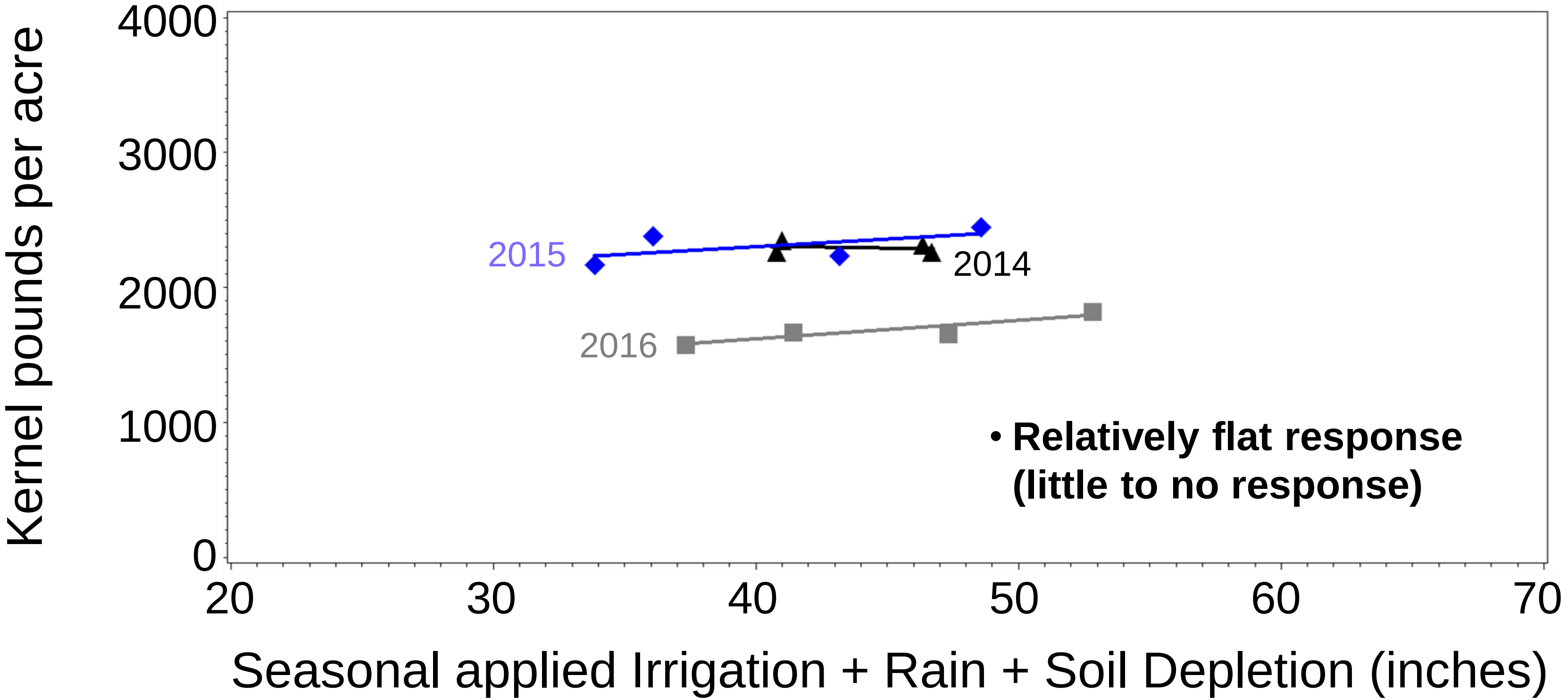
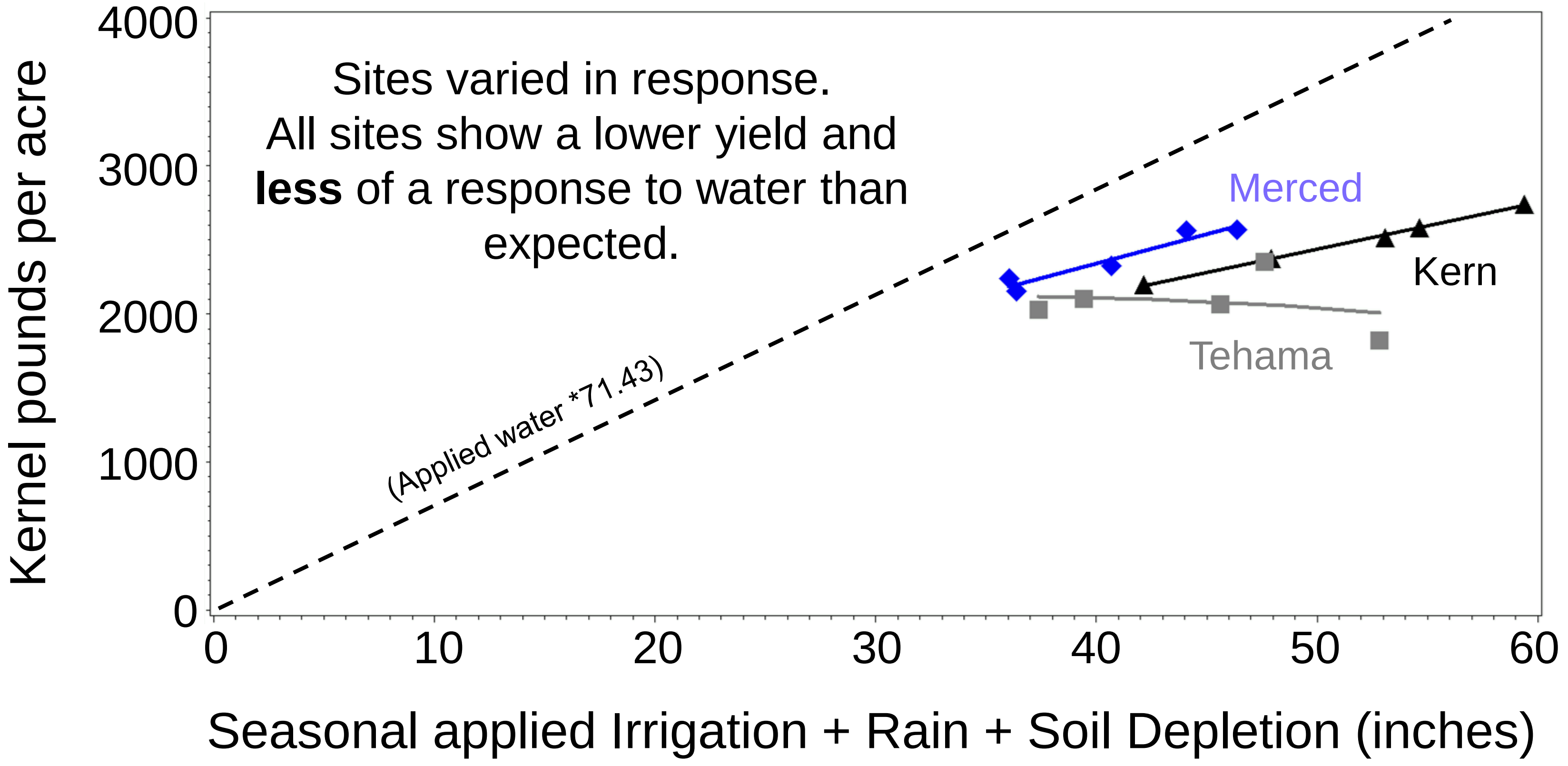


Almond yield response to water at the **Tehama** site
(2014-2016)



Comparison of average almond yield response to water across all sites



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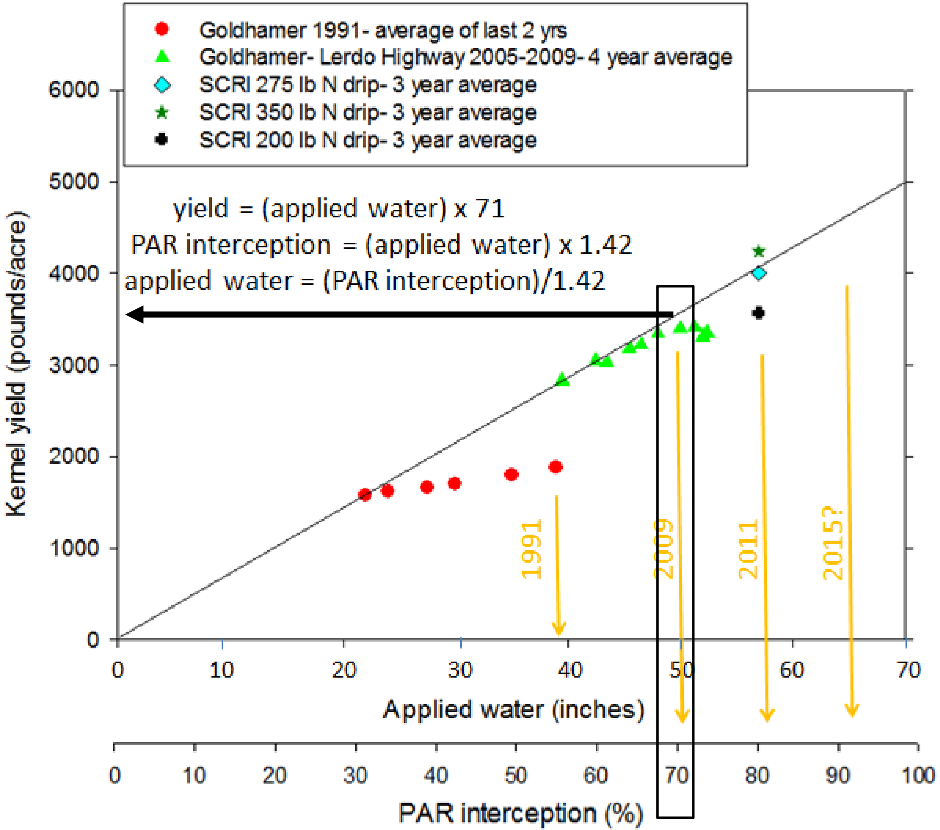
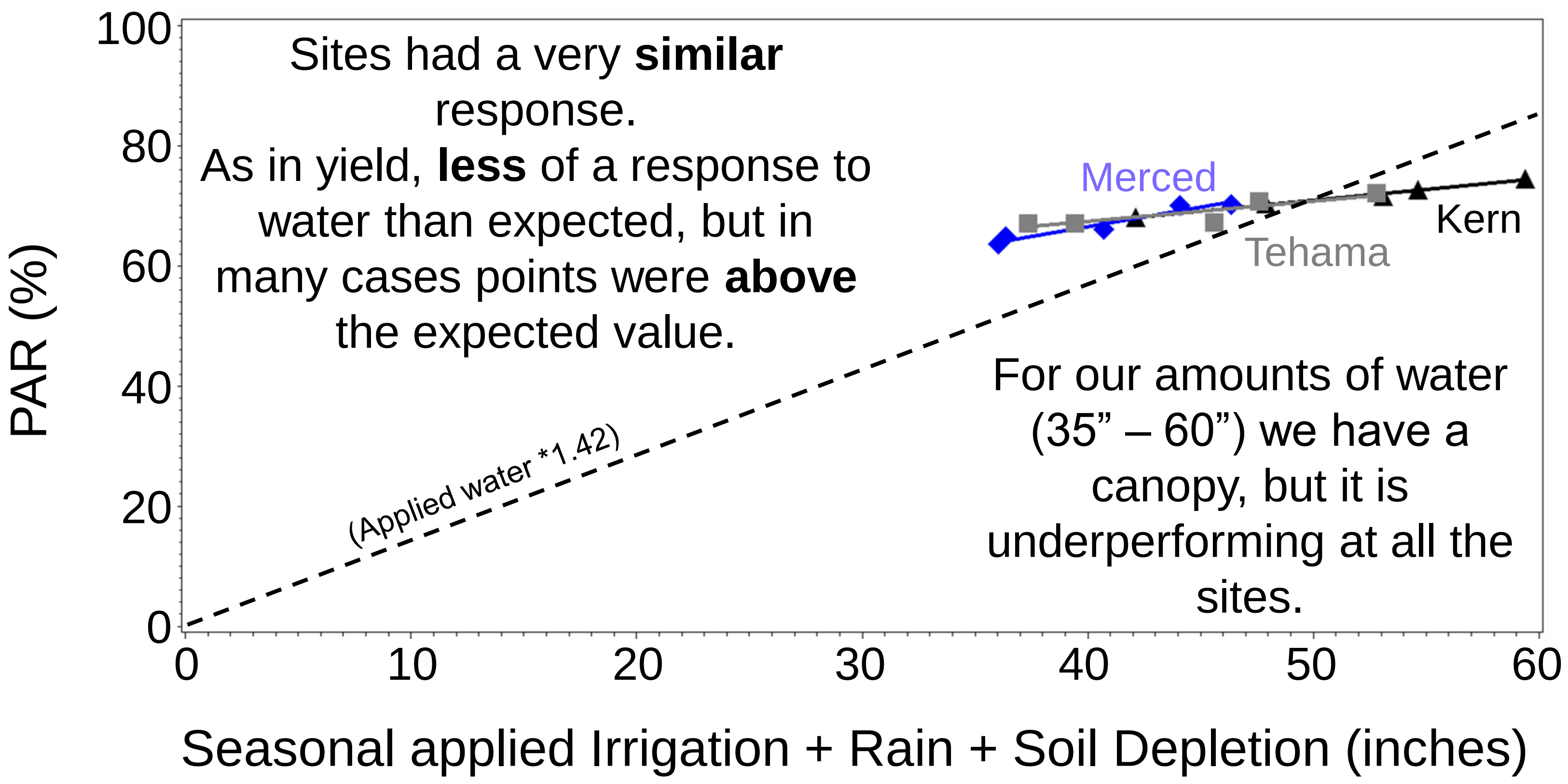
- At some point, too much irrigation should cause problems and reduce yield, not to mention environmental issues.

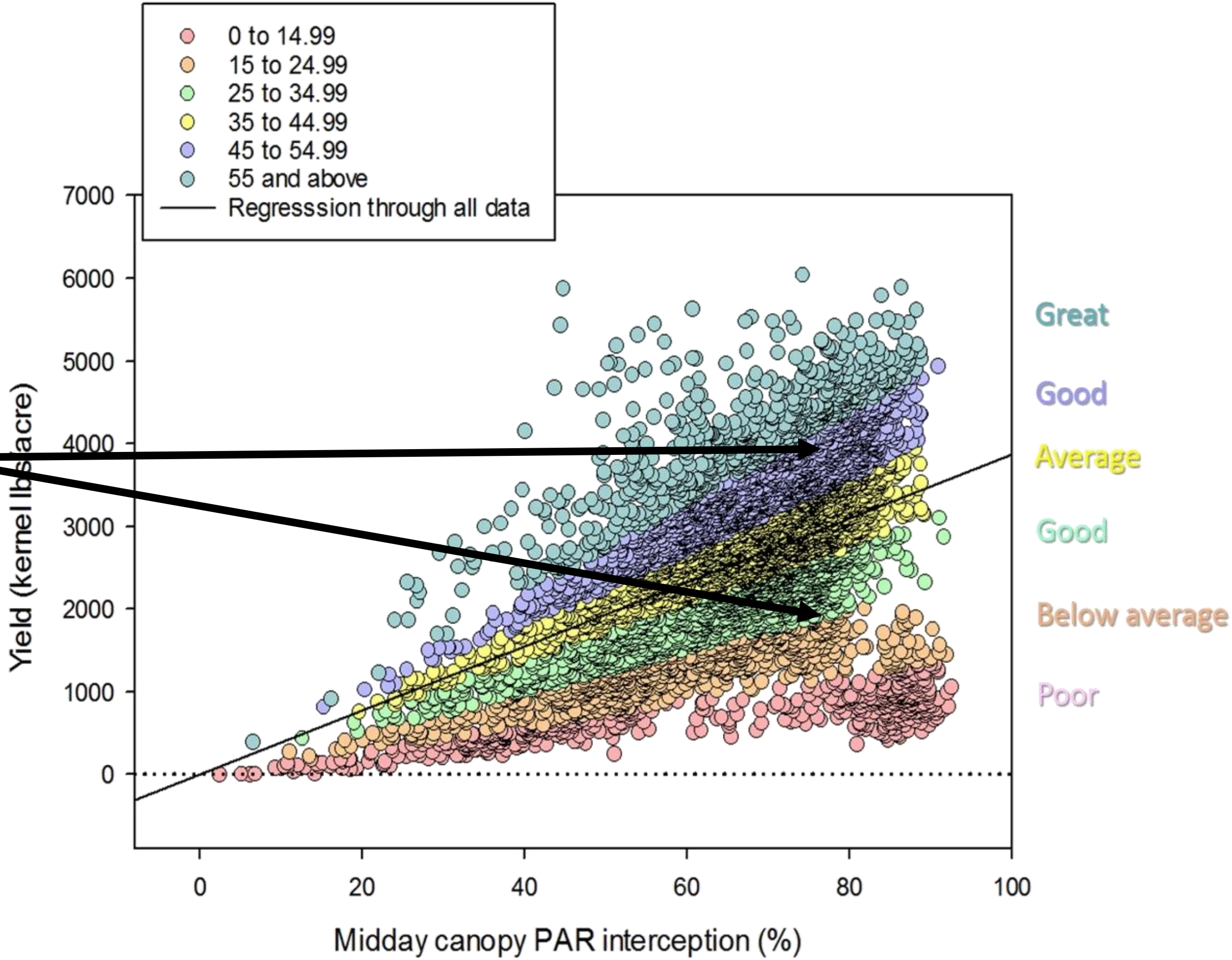
If we consider the three trials that have 2-4 year average yield versus applied water data



Comparison of average almond PAR response to water across all sites



- Orchards with the same PAR should require about the same amount of irrigation.
- These data indicate that yields for the same PAR can be substantially different.
- Making gains in water productivity will probably require us to determine why orchards with a sufficient canopy are not generating high yields.



Conclusions

- **At all sites, the trees have consistently responded to irrigation in terms of their physiological water stress levels starting on the first year of irrigation treatments.**
- **Despite this, across a relatively wide range of seasonal water regimes (35" to 60") we have only seen modest increases in yield, on average giving <u>about 35 kernel pounds of additional yield per acre for every additional inch of water</u>.**
- **Nonpareil yield at the Tehama site has been largely unresponsive to water, but the Monterey yield at that location has shown a similar response to Nonpareil at the other sites.**
- **Together, these indicate that a factor/s other than water stress may be preventing yields from reaching their potential.**

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Questions?

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