Water Management Considerations for Tree Crops Under a Limited Water Supply

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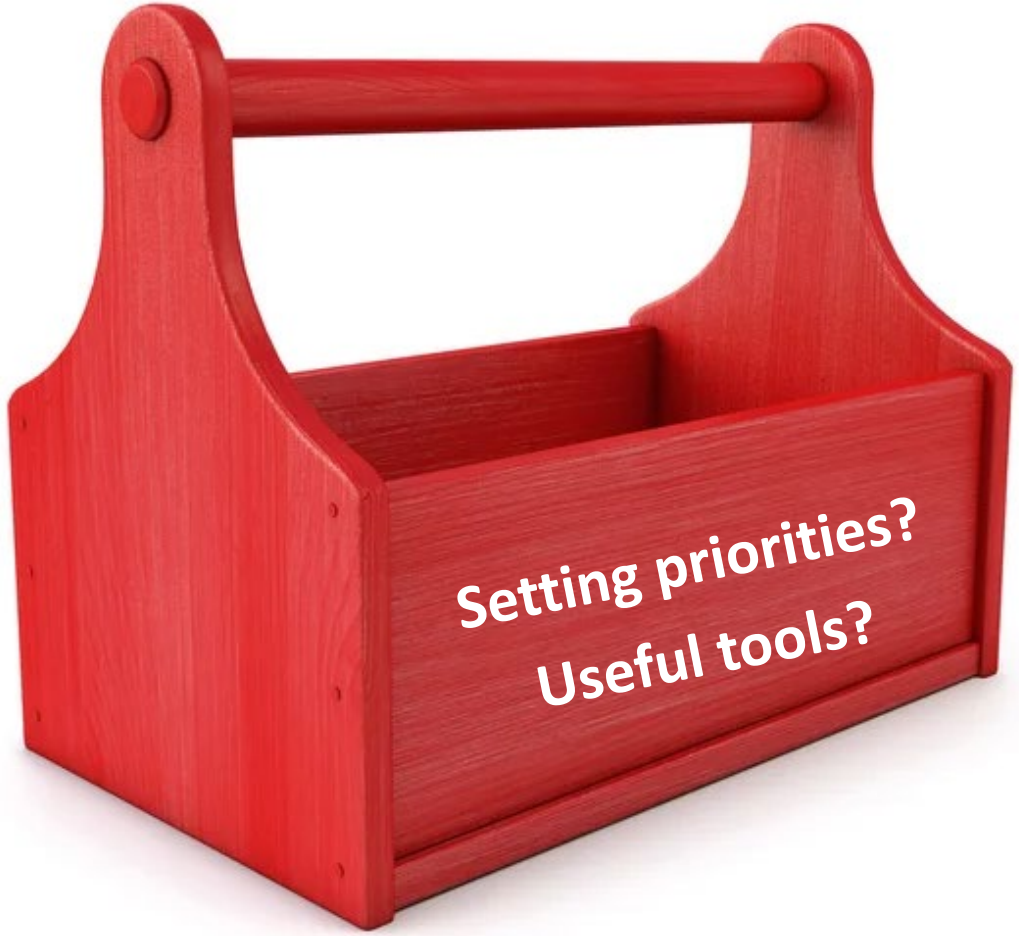
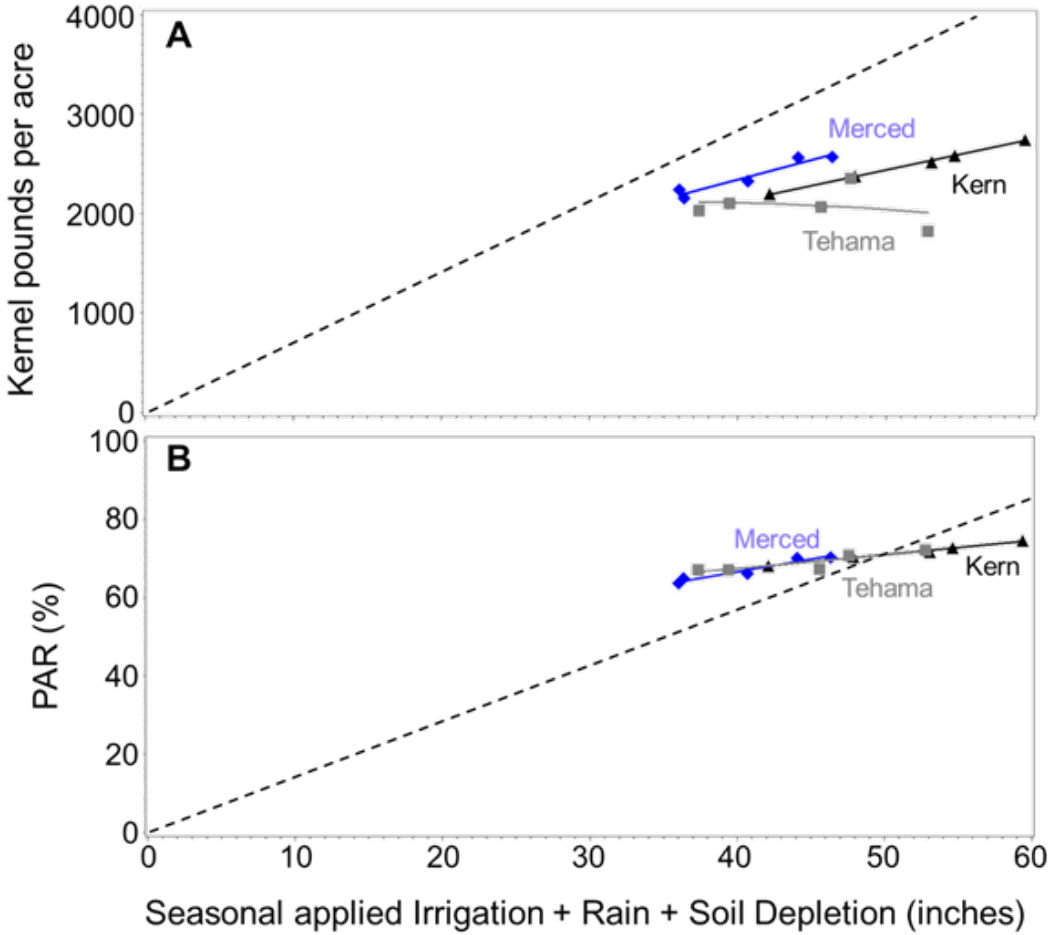
Information and tools to manage limited water supplies in orchards?



Will All Orchards Respond the Same to More Water? One Experience in Almond.

Source: Shackel, et. al., 2016/17. Almond Production Function. Almond Board Reports. Project No.: 15.HORT17.Shackel



- Despite wide range of 35 to 60 inches of seasonal water use, observed modest increases in yield at two of three orchards (about 35 kernel pounds of additional yield per acre for every additional inch of water). Expected increases of about 70 kernel pounds per inch. Third orchard did not respond to range in water use.
- Overall canopy growth (PAR), did not appear to limit yield at any of the three sites.
- Together, these results indicate that a factor/factors other than water stress may be preventing yields from reaching their potential at these sites

Figure 6. Comparison of the 2014-2016 average response of orchard yield (A) and PAR (B) to the sum of applied irrigation, rain, and soil water use (depletion), in each irrigation treatment (each point) of the 3 study sites. Dashed lines are the expected values of about 70 kernel pounds (A) and 1.4% PAR (B) per inch of water use, based on research of B. Lampinen.

Not all walnut orchards will reach maximum yield potential.

Source: Lampinen, et. al., 2016 Walnut Research Reports.

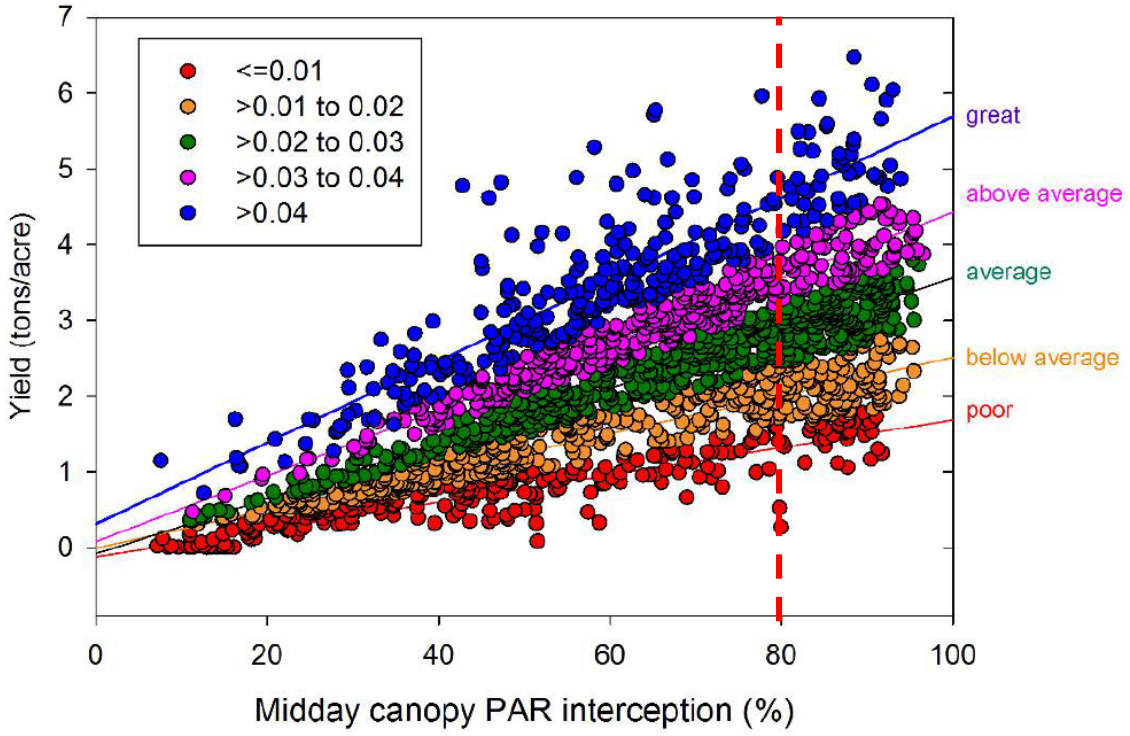


Fig. 8. Midday canopy PAR interception versus yield broken up into 4 categories (great, above average, average, below average and poor) based on the yield per unit PAR intercepted.

Some factors that can confound orchard growth and production responses to water

Horticultural variables:

- Underperforming rootstock/scion selections
- Canopy light management
  - Less than optimal tree spacing
  - Pruning practices – too much pruning or excess shading
- Poor conditions for pollination
- Foliar and root diseases
- Nutritional deficiencies
- Second generation orchards (plant back problems)
- Aging orchards

If tree crop production responses to total seasonal water are variable, then how should limited water supplies be used across a farm to maximize productivity and returns?

A couple of options*:

1. Proportional deficit irrigation (PDI)
   - Allocate water equally across all mature orchards on the farm independent of production histories
   - Simpler to implement

2. Prioritized allocation
   - Allocate "enough" water to the most productive orchards, implement cutbacks to the less responsive.
   - More work to implement

* Young, developing orchards are not good candidates for water cutbacks. It's important to manage irrigation water to promote tree growth and rapidly develop fruit bearing tree canopy.

How to identify orchards where production is more responsive to water from those less responsive?

Helpful and attainable information:

- Orchard production history
- Applied water measurements
- Midday canopy light interception
- Familiarity with orchards and other known limitations

Assess Water Productivity

- Pounds production per acre foot applied water
- Revenue per acre-foot applied water

- Example (multi-year average yield)
  - Orchard #1: 4500 lbs/ac dry inshell walnut @ 3.3 ac-ft/ac water
  - Orchard #2: 6100 lbs dry inshell walnut @2.9 ac-ft/ac water
  - Orchard #1: 1364 lbs dry inshell walnut per ac-ft water
  - Orchard #2: 2103 lbs dry inshell walnut per ac-ft water

  - Orchard #2 has history of higher water productivity and might be given higher priority for water

Evaluate midday canopy light interception and productivity (lbs crop production for each percent light interception).[1]

Yield Categories	Walnuts (dry in-shell yield for each % light interception or % PAR)	Almonds (kernel meat yield for each % light interception or % PAR)
Great	> 88 lbs	>44 lbs
Above Average	75 - 88 lbs	37.5 - 44 lbs
Average	50 - 75 lbs	25 - 37.5 lbs
Below Average	25 – 50 lbs	12.5 – 25 lbs
Poor	< 25 lbs	<12.5 lbs

[1] Table adapted from Lampinen et.al., 2016 Walnut Research Reports and recent Almond Research Reports.

Orchards with higher crop production per unit canopy light interception are likely to have higher water productivity.

Values calculated by dividing crop yield by measured canopy light interception.

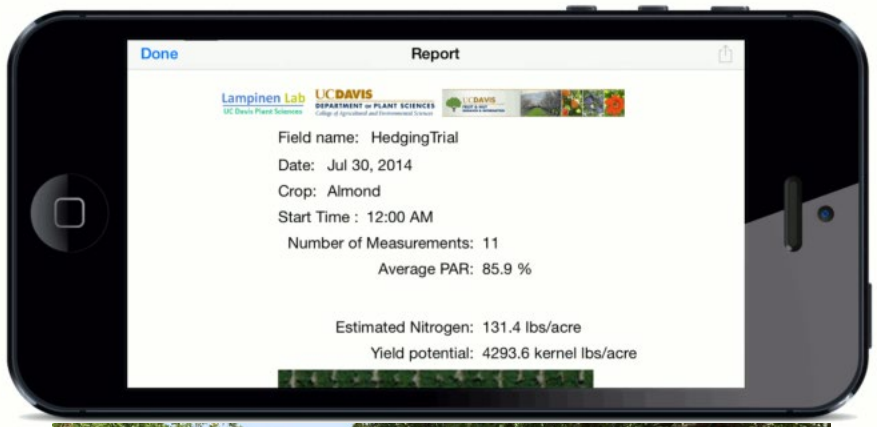
Ground techniques to assess canopy shading

Estimate midday canopy shading yourself (DIY)

Approximate canopy shading = 18/44 = 41 %

Use iPhone/iPad app

https://ucanr.edu/sites/LampinenLab/Canopy_Management/iPAR/



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Aerial imagery to estimate canopy shading

UAV's

Fixed Wing

Satellite

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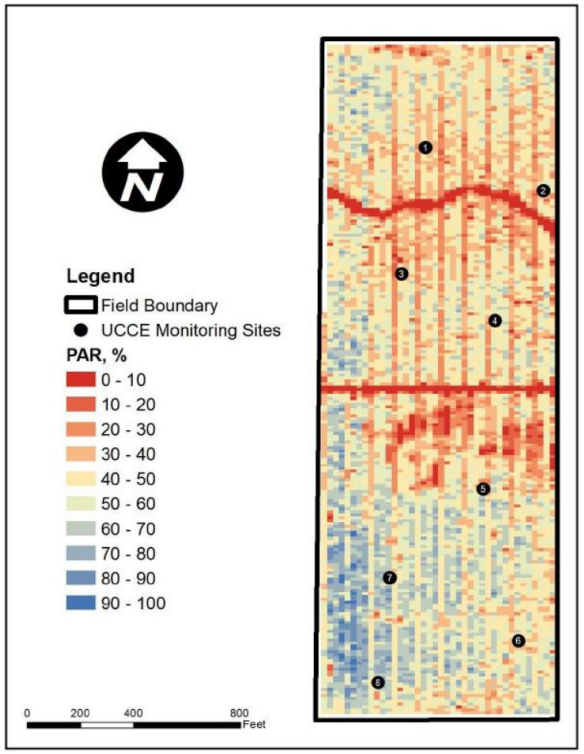
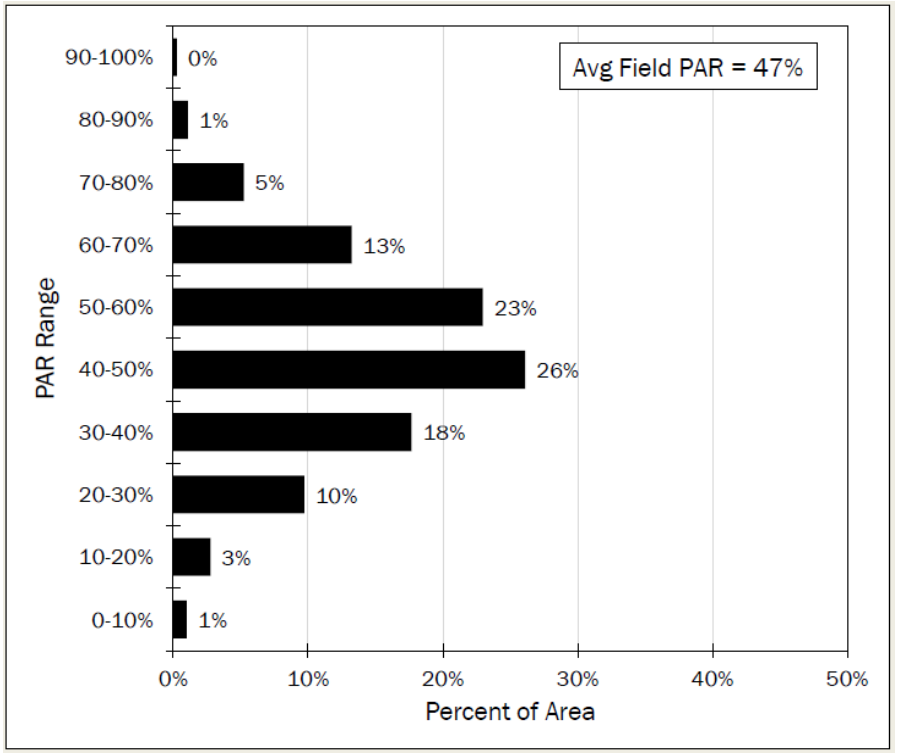
Example canopy assessment using aerial imagery

PAR = Photosynthetic Active Radiation = Percent canopy light interception or shading





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Monitoring groundwater pumping levels and having well design and construction information is useful.

Manual Measurement

Automated and measured remotely

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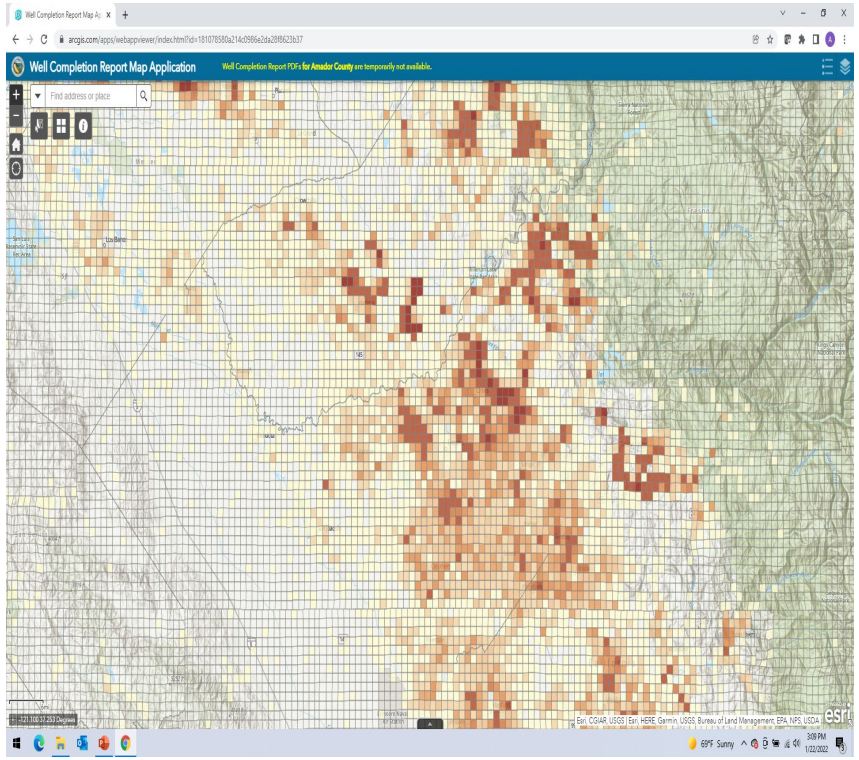
Discerning more from less reliable groundwater supplies and foreseeing potentially costly well improvements.

Useful Diagnostics:

- Pumping water table level versus depth of well perforations or screens
- Pumping water table level versus GSA management criteria
- Well(s) at risk of going dry or facing SGMA restrictions combined with orchard(s) of low water productivity represent more difficult circumstances to sustain through a severe or extreme drought

California DWR Well Completion Map Application



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GOOD INITIAL IRRIGATION SYSTEM DESIGN, STEADY MAINTENANCE, AND PERIODIC EVALUATION REMAIN IMPORTANT

- One data set in Sacramento Valley
- From about 2009 to present
- Over 1200 irrigation system evaluations
- Mostly micro irrigation systems in orchards
- Suggests about 1 in 4 or 5 systems have less than 70 percent distribution uniformity (DU)

One perspective on irrigation scheduling tools for drought management

From FAO Paper 66. Yield response to water of fruit trees and vines: Guidelines

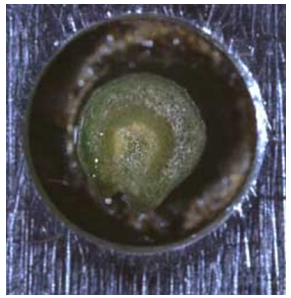
"Three technical approaches may be used for making scheduling decisions. They are based on: a) monitoring soil water status; b) monitoring plant water status; and c) computing a water budget of the tree root zone."

"While soil-based instruments give information of soil moisture levels in the plant root zone, the plant itself is the best indicator of its water status."

"It is not easy to define thresholds for practical use. Tree water status measurements need to be benchmarked against equivalent measurements representing fully irrigated plants in the same environment."

Conventional Measurement of Plant Water Status in Trees

Pressure Chamber & midday SWP



Refer to Sacramento Valley Orchard Blog “Stem Water Potential Series” for information.

https://www.sacvalleyorchards.com/manuals/

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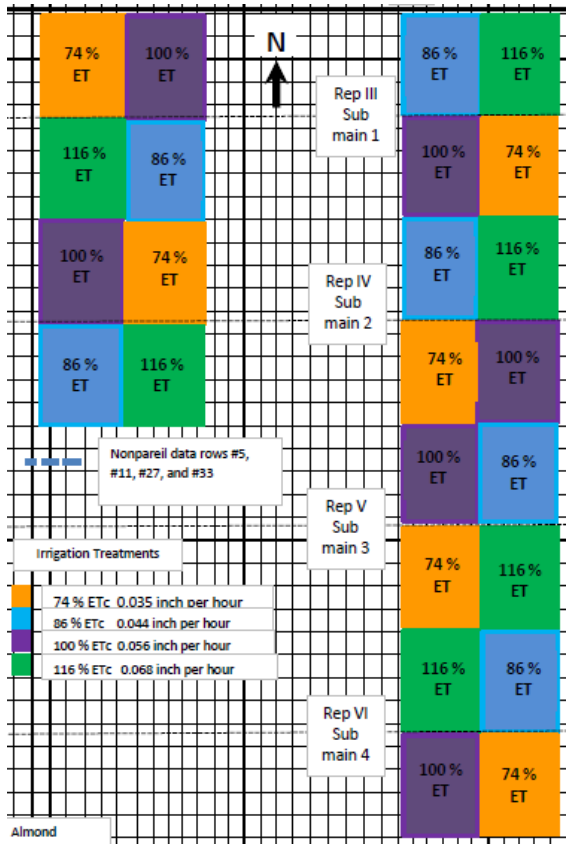
Advanced Ground-based, Direct and Indirect Tree Water Status Sensors

Water Potential Sensor

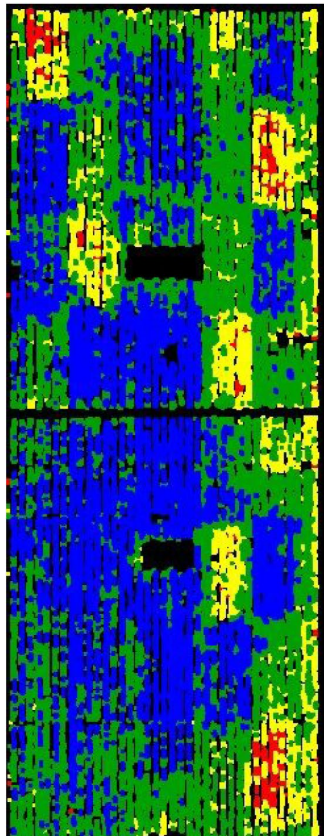
Dendrometer – measures trunk growth characteristics

Canopy Temperature Applications

Map of Tehama County Almond Irrigation Experiment



Aerial Image – Stomatal Conductance, 7/2/15



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One experience from northern California in walnut demonstrating potential value of tree water status as a drought management tool.

- California Walnut Board funding
- Began testing in 2014 near Red Bluff, CA
- 9-year old commercial Chandler/Paradox orchard located within 0.5 mile of Sacramento River
- Planted at 18 x 28 ft (86 trees per acre)
- Deep, well-drained silt-loam/fine sandy-loam
- Testing continued through 2019

- Used tree water status determined with a pressure chamber and SWP to guide when to begin irrigation at the start of the season.

- Test treatments included:
  - grower's typical starting date about 30 days after leafout and when tree water status was at or near the fully irrigated baseline.
  - Four other trigger levels allowing the trees to reach 1, 2, 3, or 4 bars drier than baseline SWP before starting irrigation.
  - Each treatment was replicated in five different, randomly placed plots in the orchard.
  - All total, the test consisted of 12.5 acres

Irrigation start dates, seasonal irrigation applied, and crop yield, for each of the irrigation treatments imposed in the first year of the study (2014).

2014 (ET – in-season rainfall = 38 inches)

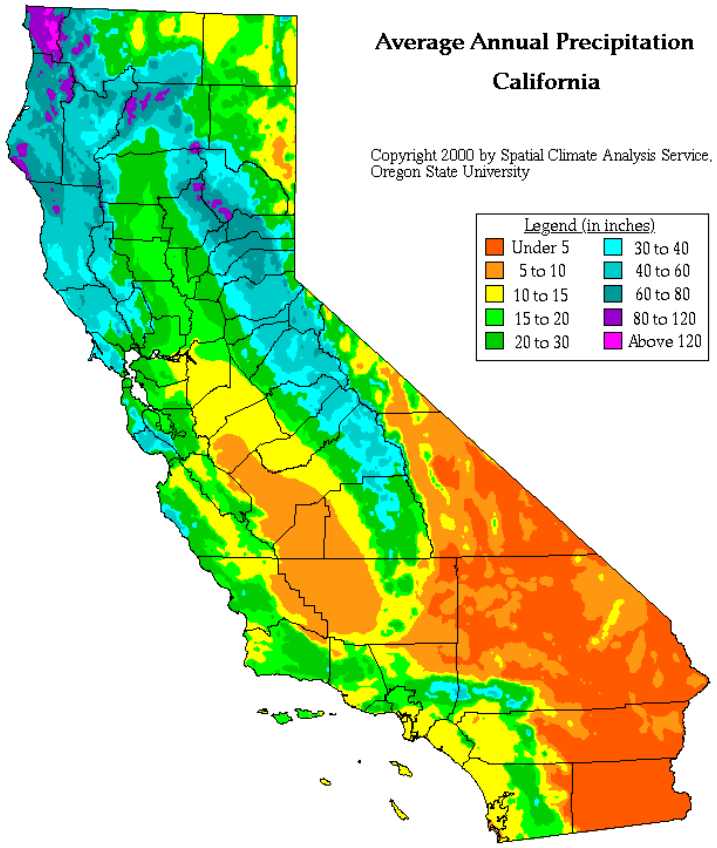
Treatment	Irrigation Start Date	Irrigation Applied	Percent of ET - Rain	Yield (lbs dry in-shell/ac)
Grower – at or above baseline	April 26	38”	100%	3690
1 bar drier	April 26	34”	89%	3700
2 bar drier	May 28 to June 18	30”	79%	3440
3 bar drier	June 2 to June 13	25”	66%	3420
4 bar drier	June 2 to June 13	25”	66%	3360

Average irrigation start date, seasonal irrigation applied, yield, percent edible yield, and crop relative value (2015-2018).

SWP Trigger for the first irrigation	Average 2015-2018 (ET-rain: 38.6")				
	Irrigation start date (days after leafout)	inches irrigation (% ET-R)	yield (pounds/acre dry inshell)	% edible yield	[1]Relative crop value (% of control)
At or near baseline (control)	Late April/Early May (25-35)	24.4 (63%)	5360	45.1	4840 (100%)
1 bar below baseline	Mid to late May (45-60)	22.5 (58%)	5230	45.5	4760 (98%)
2 bars below baseline	Early to mid June (60-75)	20.7 (54%)	5000	45.1	4540 (94%)
3 bars below baseline	Mid to late June (75-85)	16.9 (44%)	5080	45.9	4660 (96%)
4 bars below baseline	Late June to early July (85-95)	18.3 (47%)	4940	45.9	4530 (94%)

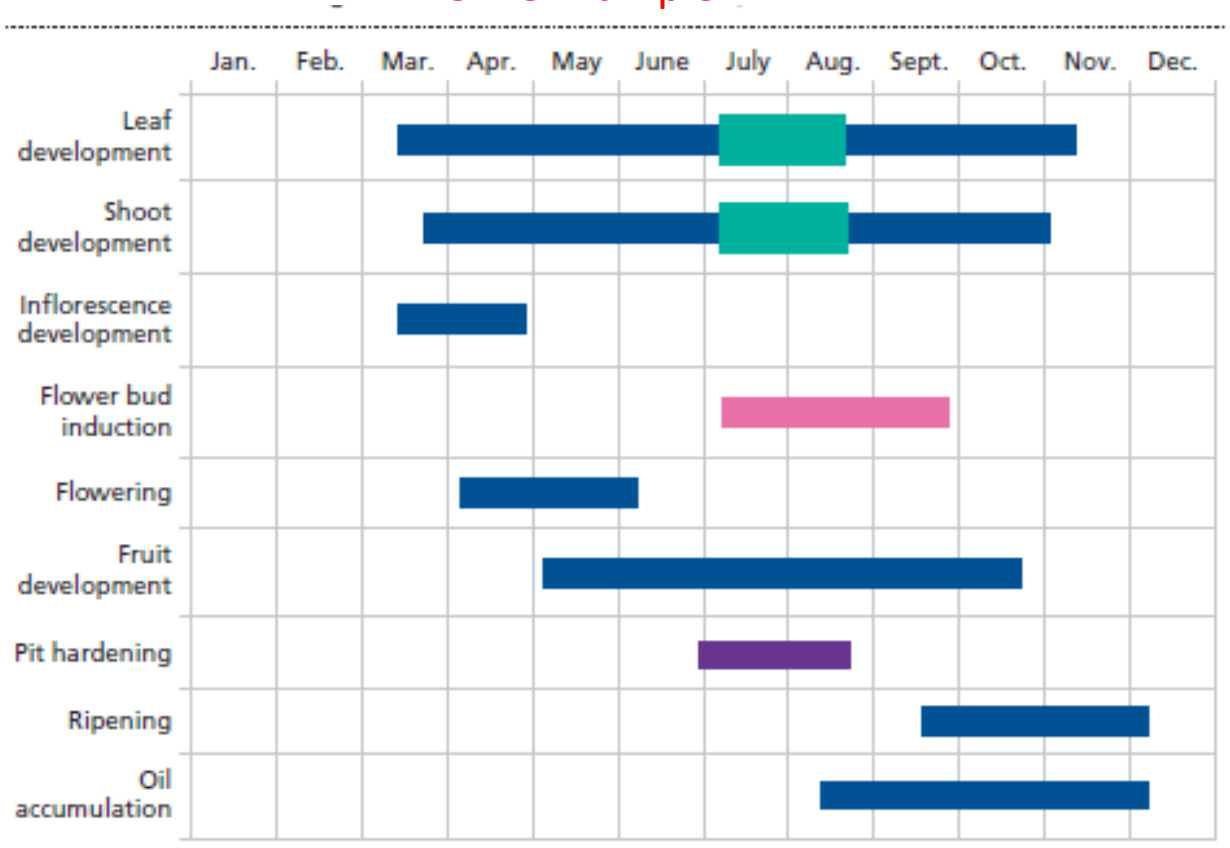
Orchard settings where tree water status is likely to be more effective at reducing irrigation and managing water shortages

- Medium to high rainfall regions
- Deep, uniform soils of fine sandy loam texture of finer
- Potential for capillary water movement into root zone
  - River or tributary influences
  - Orchards bordered by surface water canals or drains
  - Non-saline soils and water



Knowledge of crop phenology important to manage limited water supplies

Olive Example



Source: FAO Paper 66. Crop Yield Response to Water. Section 4.1. 2012.

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Summary of Suggested Strategic Deficit Irrigation Approaches for Selected California Tree Crops

Crop	Crop Stages Where Water Stress is Likely to Have Less Impact on Production and Revenue	Percent of ETc Supplied at Targeted Growth Stage	Potential Seasonal Water Savings*
Almond	Potential to delay start of irrigation from bloom to full canopy (March-April) and save water. Two weeks prior to hull split on heavy, deep soils only (June 15 – July 1). Two weeks after onset of hull split (early July) Approaching leaf drop (late Oct/Nov)	50 %	10 to 15 % Maybe more
Pistachio	Shell hardening (mid May through entire month of June) Post-harvest period (Oct. 1 – Nov. 15) Also, consider alternate bearing seasons	50 % 25 %	25 % or more
Walnut	Potential to delay irrigation and save water from bloom to full canopy and during shoot, hull, and shell expansion (April 1 – June 15).	50 %	20 – 30 % or more

* Potential water savings expressed as a percent of seasonal evapotranspiration for non-stressed crops and represent reductions in applied water that minimize impacts to production and revenue. Employing more extreme RDI regimes to cope with greater water shortages may result in more extreme impacts on production. The greater the water shortage the larger the impacts on production and revenue.

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Table Olive	Early stages of fruit sizing and pit hardening (June – Aug 15). Under severe water shortages, may extend deficit irrigation into mid stages of fruit sizing (mid Aug – early Sept)	50 %	20 % Maybe more
Olive Oil	Olive fruit size is not as critical for oil production, so extended and steeper deficits can be tolerated targeting the same tolerant fruit and pit hardening stages (June – mid September). A proportional deficit across the whole season works well too.	40 – 50 %	40-60 %
Prune	Potential to delay irrigation to save water after pollination through canopy development (April-early May) to save water. End of fruit sizing (mid to late August) fosters sugar accumulation and fruit drying. Post harvest cutbacks.	50 %	20 – 50 %

* Potential water savings expressed as a percent of seasonal evapotranspiration for non-stressed crops and represent reductions in applied water that minimize impacts to production and revenue. Employing more extreme RDI regimes to cope with greater water shortages may result in more extreme impacts on production. The greater the water shortage the larger the impacts on production and revenue.

Information Resources to Learn More about Strategic Deficit Irrigation

- FAO Paper 66. Yield response to water of fruit trees and vines: Guidelines (Sections 4.0 and 4.1). https://www.fao.org/3/i2800e/i2800e00.htm
- UC Drought Management Website https://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/
- UC ANR Drought Tips https://ucanr.edu/sites/ucanr/News/Drought/Drought_tips/

Suggested Information and Tools to Consider for Your Drought Management Tool Box

Real-time Crop ET Information

Understand stages of tree and crop development and sensitivity to water stress

Weekly and Seasonal Applied Water Measurements

Capabilities of monitoring tree water status

Measure of mid-summer canopy shading

Good Irrigation System Design, Steady Maintenance, and Periodic Evaluation

Orchard Yield History

Well Sounding Capabilities and Well Completion Reports


THANK YOU!