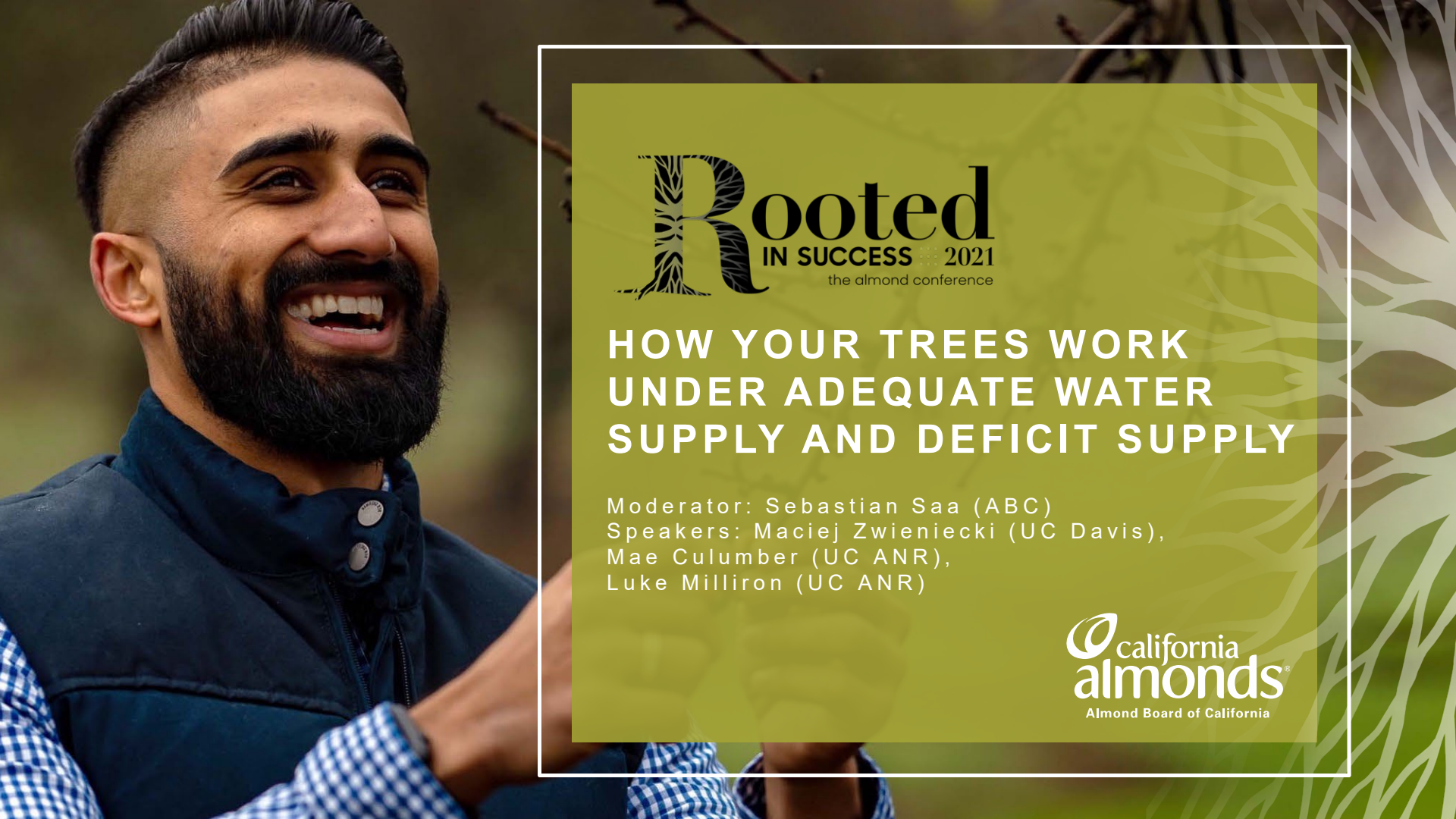

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HOW YOUR TREES WORK UNDER ADEQUATE WATER SUPPLY AND DEFICIT SUPPLY

Moderator: Sebastian Saa (ABC)
Speakers: Maciej Zwieniecki (UC Davis),
Mae Culumber (UC ANR),
Luke Milliron (UC ANR)

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Understanding Sustainable Yields

Sebastian Saa, Associate Director Ag. Research, ABC

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What are the factors that define almond yield in a given season?

- Nº of flowers
- % of fruit set
- Kernel weight

$$Yield\ potential = No.of\ flowers \times \%\ of\ fruit\ set \times kernel\ weight$$

4,000 lbs/acre = _____ x 0.0022lbs per kernel

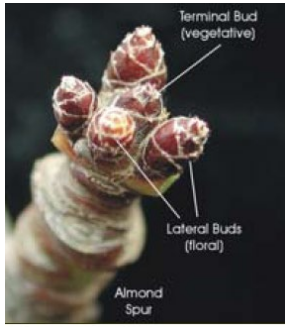
Number of flowers: A game of numbers and quality

- A game of numbers: The more the better!

- A game of quality: Healthy and fertile flowers are more likely to set fruit!

How do we play and win the game? -Number of Flowers-

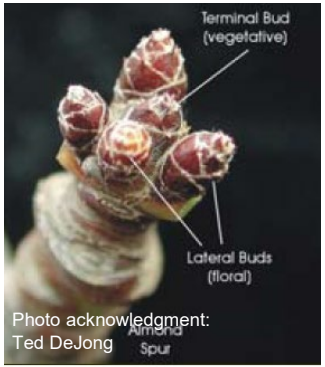
Almond spurs are the fundamental bearing unit in almonds



- **Spurs are compacted shoots no longer than 2-3 inches.**
- **Mature trees produce >80% of their total yield on spurs.**
- **Flowers depend on spurs that are at least two-year-old.**

How to play and win the game? -Number of Flowers-

Ideally, we would like to have as many spurs as possible, and as many of them flowering and bearing fruit.



<u>However, a significant amount of these spurs will die or not bloom from one season to another.</u>

Almond spurs are alternate bearing structures:

2021 season

2022 season

Almond spurs are likely to die after bearing multiple fruit (“the black widow phenomenon”):

The key for abundance is to maintain the balancing act between different spur types

Walk your orchards and learn how to identify the difference populations of spurs:

- The rate of spurs being formed needs to overcome the rate of spurs that are dying (check for new growth).
- Your current yield largely depends on the spurs with fruit.
- Your next year yield will largely depend on the spurs without fruit.

Drivers that affect the size and performance of spur populations: **Nutrients**

Nutrient deficiency

Reduced shoot growth and/or leaf area

Zinc deficiency: Small pale leaves, short internodes, rosette leaves.

Nutrients in excess

Increased susceptibility to diseases such as Hull Rot

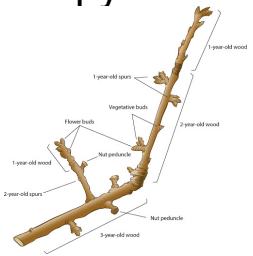
Excess of nitrogen results in higher hull rot susceptibility.

Adequate nutrient management by following the 4Rs of plant nutrition: Apply at the Right Rate, Right Time, Right Source and Right Place. Check the CASP Nitrogen budget calculator for more info.

Drivers that affect the size and performance of spur populations: **Irrigation management**

In Spring

Canopy size



In early Summer

Kernel size

20% reduction in kernel size

In late Summer

Formation of flower buds

In early Fall

Leaf senescence

Irrigation management is key all year round. Check the CASP irrigation calculator for more info.

Percentage of fruit set

Begins during flowering…. But ends….

Percentage of fruit set

…By the end of April

Percentage of Fruit Set is affected during bloom and after bloom

- During bloom percentage of fruit set is largely affected by:
  - Flower quality ~CHO and nutrients such as Boron and Zinc
  - Adequate crosspollination between the variety and pollinizer
  - Number of healthy and strong hives
  - Weather conditions

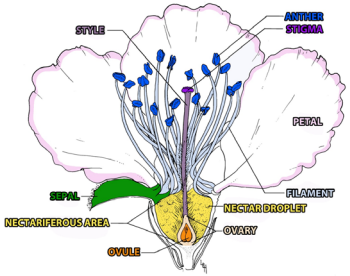


Photo acknowledgment: Joe Connell and Fruit and Nut Research and Information Center

Percentage of Fruit Set is affected during bloom and after bloom

- After bloom keep in mind the following:

Fruit drop happens in three distinct stages, the first of which is shortly after bloom when defective flowers fall from the tree. The second drop occurs about a month later when pea-sized flowers, mostly unpollinated, fall. The third and final drop occurs six to seven weeks after bloom - the load adjustment for almonds-.

A combination of factors affect the third fruit drop. Some of them we can control. Others not so much (weather).

Observational data shows that the following management factors affect the third drop:

- Poor fertigation
- Water applied in excess
- Correlated with fruit set: Low fruit set = low fruit drop

Tip: Walk your orchards, shake some branches with your hand in late April and observe how much fruit falls

Kernel weight

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As the season progresses the game is a function of # of fruit left on the tree x size of the individual kernels

- Your efforts in Spring start to pay off:

Adequate management results in a strong light harvesting machine

Photo acknowledgment: Bruce Lampinen

Energy

Provide the right amount of water and nutrients combined with an integrated pest management approach to maximize kernel size

Drivers that affect the yield equation: **Overall Horticultural Management**

The highest yield potential is observed in orchards whose trees produce a total shade of 80%- 85% in the middle of the summer at midday.

Summary

$$\textbf{Yield potential} = \textbf{No. of flowers} \times \% \textbf{ of fruit set} \times \textbf{kernel weight}$$

No. of flowers:

- A game of number and quality: Identify your spur populations and aim for a balancing approach. Keep in mind that flowers are formed during the previous summer and that their quality largely depend on the pest, nutrient and irrigation management.

% of fruit set:

- Bloom is just the beginning.
- We have little control on the weather once we establish an orchard. However, we still have a big influence on fruit set by promoting tree health and reducing fruit drop.

Kernel weight:

- Help the tree to do its job: Harvesting light and producing CHO. Supply the horticultural inputs (nutrient, water, IPM) at the right time and at the right amount for the tree to perform at its highest efficiency.

Acknowledgements

- Especial thanks to the following UC Davis Team:
  - Bruce Lampinen
  - Ted DeJong
  - Patrick Brown
  - Emilio Laca
  - Maciej Zwieniecki

- And to my former international collaborators:
  - Sergio Tombesi
  - Daniela Valdebenito
  - Eduardo Fernandez
  - And many more!

Thank You

Inner work of Almond tree

12/08/21 / Maciej Zwieniecki and Paula Guzman Delgado

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TABLE OF CONTENTS

01. Photosynthesis

02. Carbohydrates (NSC)

03. NSC and phenology

04. NSC and yield

05. Conclusions

>99% of plant material is built from three main elements.



Carbon C Hydrogen H Oxygen O

$(CH_2O)_n$- carbohydrates (sugars)

Where does all that CH_2O come from?

PHOTOSYNTHESIS

Photosynthesis is the process by which plants capture the energy in sunlight and convert it to a biologically usable form.

The energy is stored in carbon bonds created during photosynthesis and liberated during respiration.

Solar energy absorbed by chlorophyll

Photosynthesis →

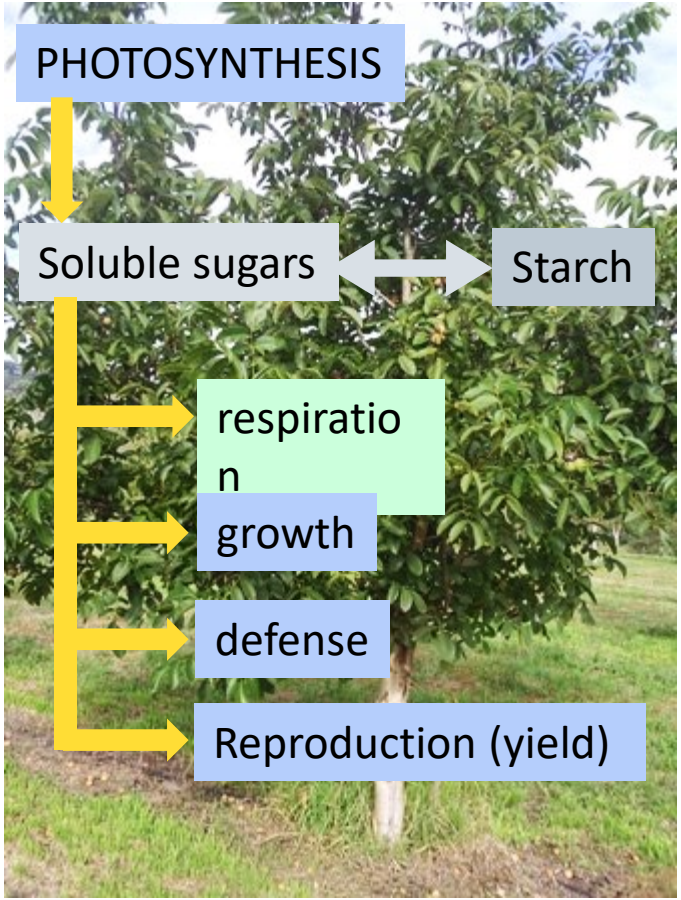
Water (H_2O) + Carbon dioxide (CO_2) ⇌ Carbohydrates (CH_2O) + Oxygen (O_2)

Respiration $_n$

Chemical energy To build and repair

Physiology of carbohydrates management in nut trees

- Carbohydrates provides energy for maintenance, growth, defense, and reproduction (yield)
- Carbohydrates are only being produced during day (sunlight) and only when leaves are on the trees but used 24 hour a day and 365 days a year.
- Non-Structural Carbohydrates (NSC) are the tree's liquid assets - 'currency' they are in two forms (1) soluble sugars and (2) starches.
- Soluble carbohydrates can be considered as 'cash' that flows around the tree. Starch is the 'currency' saving account.
- Trees continuously measure soluble sugar levels (measure cash in hand), and supplement it from starch (savings) or recharge savings if it has overflow of sugar (cash).
- **NSC level has to be maintained to allow trees to survive and recover after non-photosynthetic periods: daily (night) and seasonally (dormancy)**



Orchard management focus is on facilitating photosynthetic activity:

- irrigation
- Fertilization

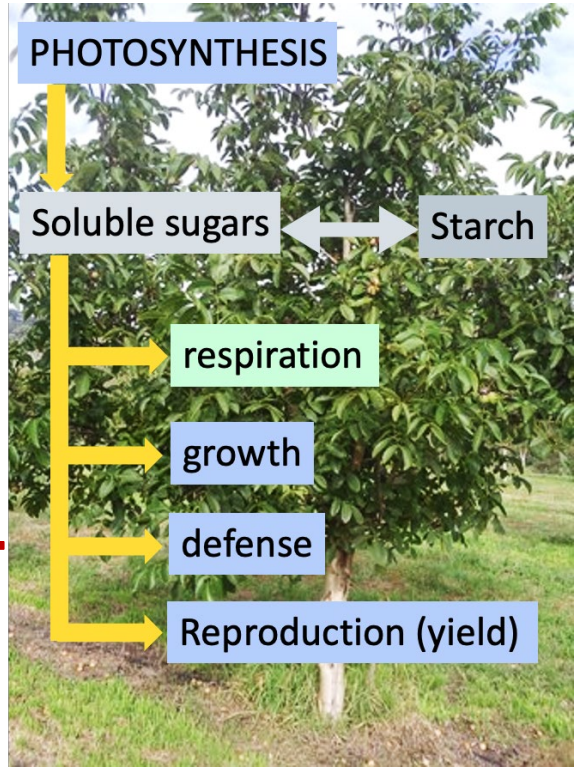
Boosting amount of carbohydrates

and protection from:

- insects
- pathogens
- Diseases

Reducing cost of defense

We hope that our effort will increase available NSC and they will be used to increase yield.



But,

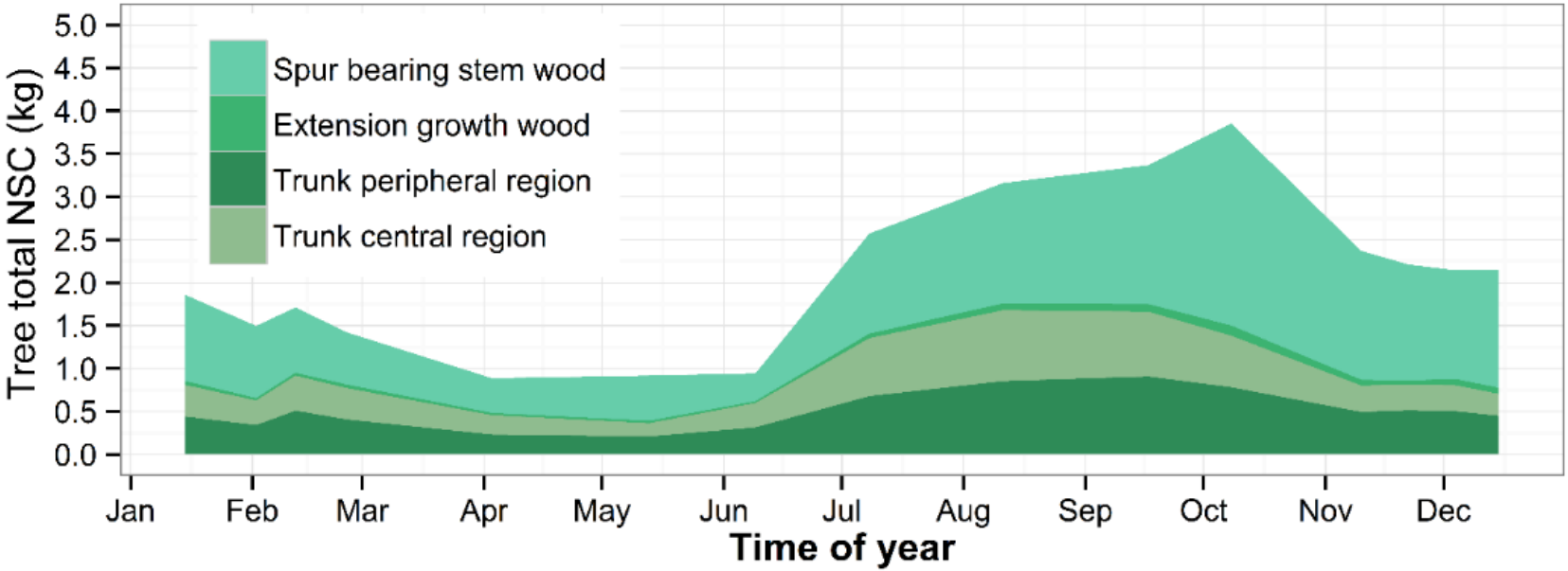
Respiration is temperature dependent – We can not do much about it

Growth is the function available NSC, space, physiological needs
- Usually, we can not tell plant how to grow - yet

Investment in reproduction is a function of initiated embryos, NSC availability and evolved redistribution function – Again, we have very little impact on forcing plant to change its evolved behavior - yet

Knowing when and how plant makes decision on its NSC investment can provide means to increase orchards productivity

So, what we know so far – WHERE - most NSC is in the spur bearing twigs



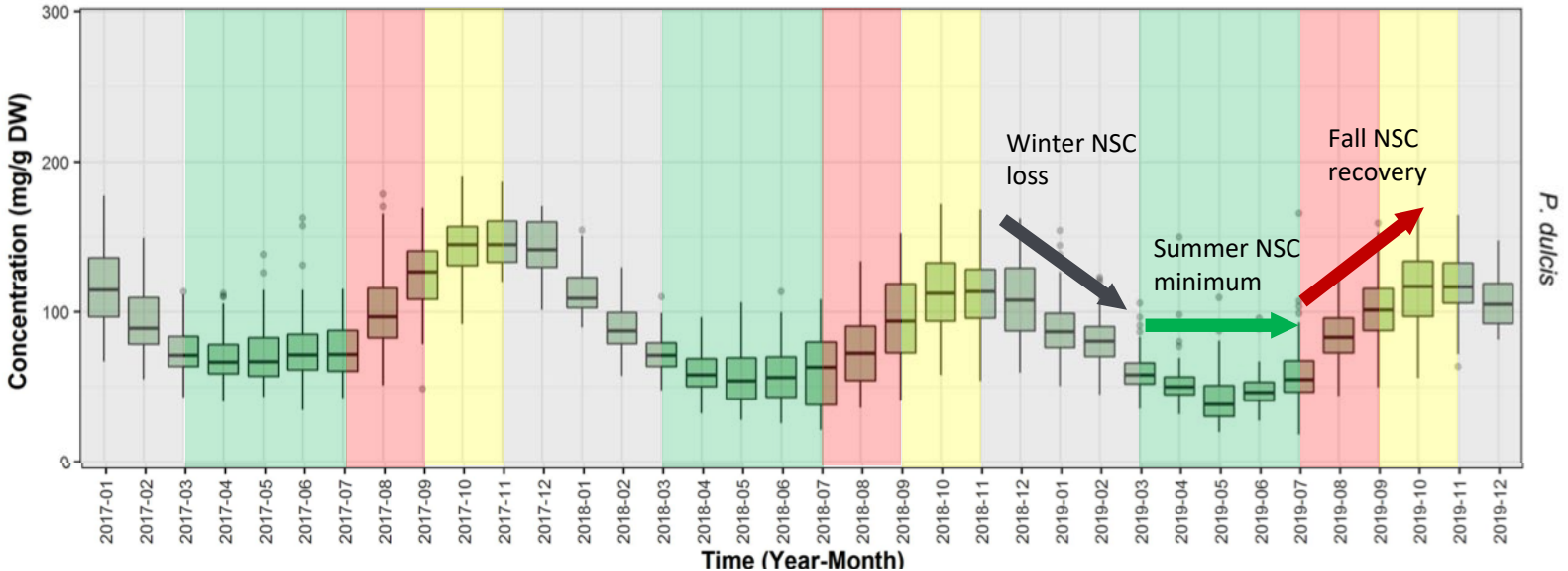
So, what we know so far – WHEN – NSC content varies seasonally

Growth and fruit development

Postharvest

Fruit maturation

Dormancy



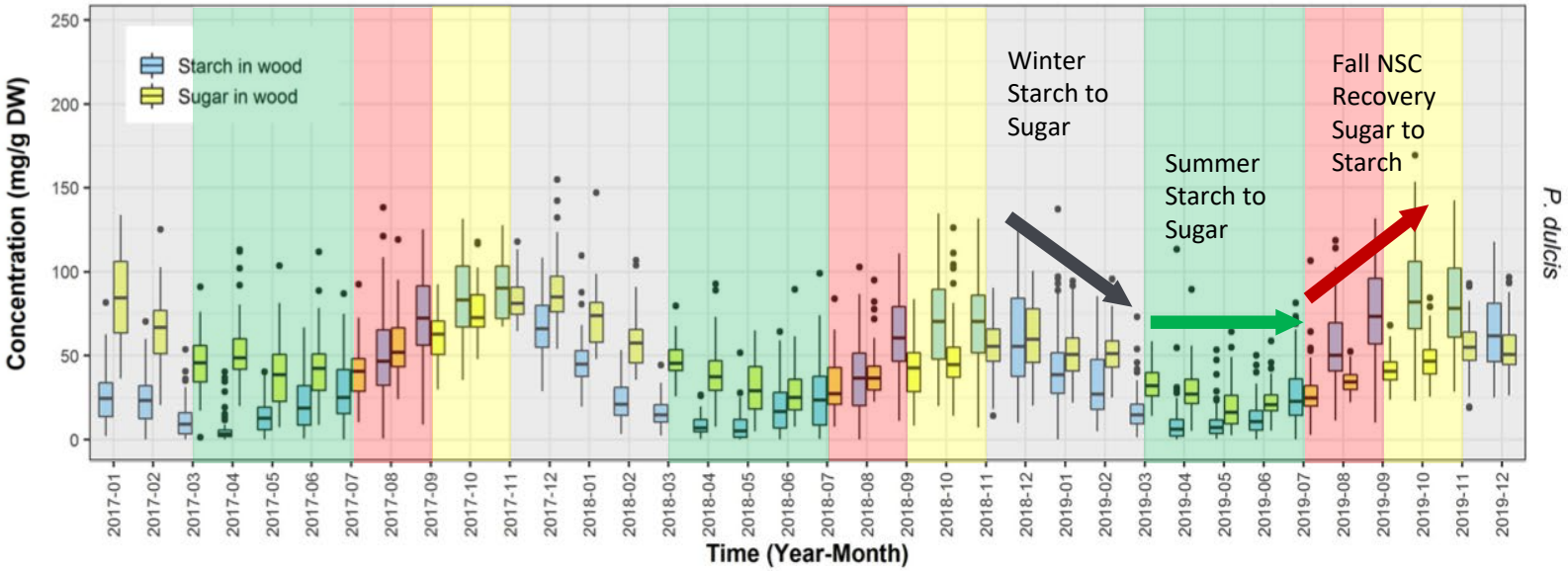
So, what we know so far – inner works – Starch to sugar conversion

Growth and fruit development

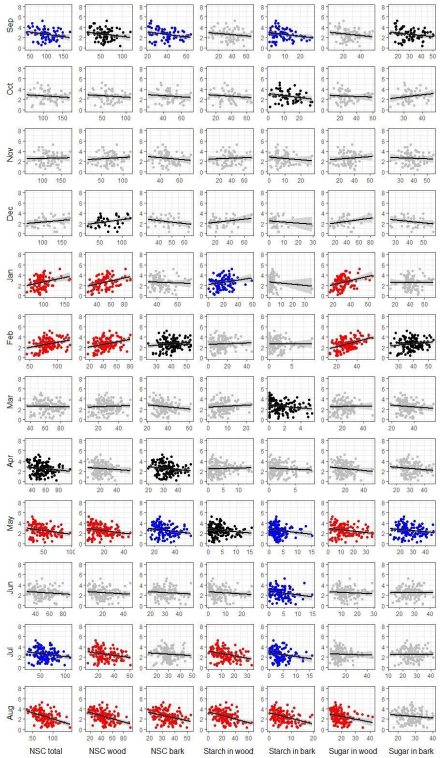
Postharvest

Fruit maturation

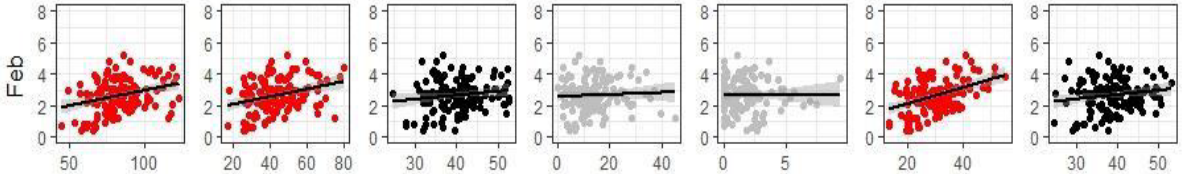
Dormancy



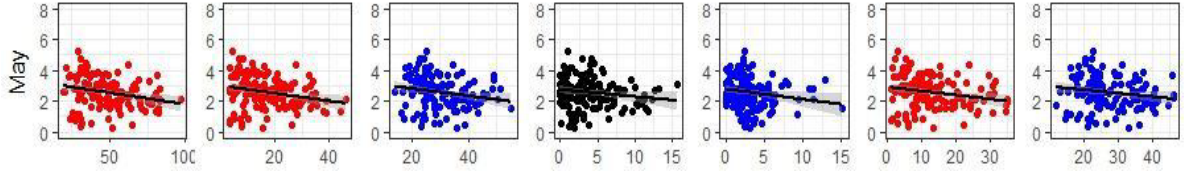
So, what we know so far – DO NSC MATTER? – YES



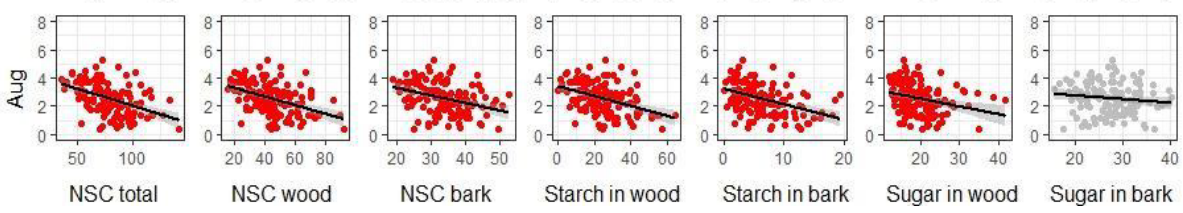
High levels in February are associated with higher yield – healthy bloom



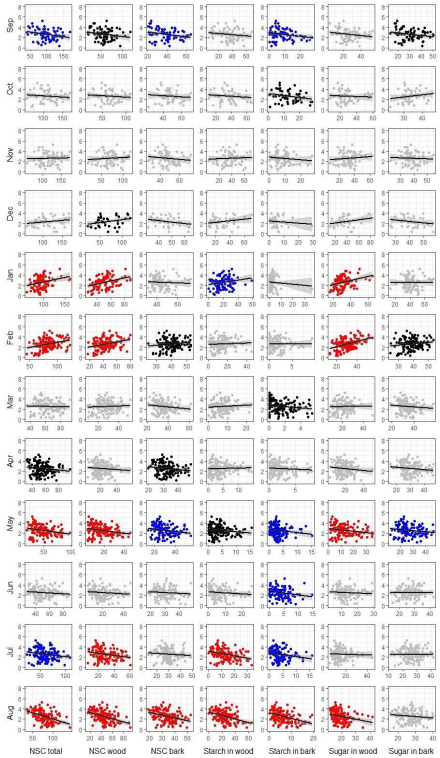
Low levels in May are associated with higher yield - use of NSC to avoid 'drop'

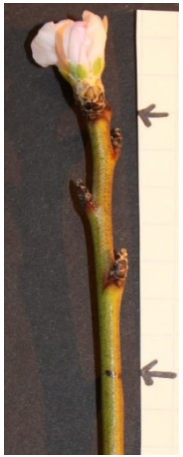


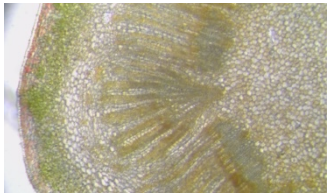
Low levels in August are associated with higher yield - use of NSC to fill

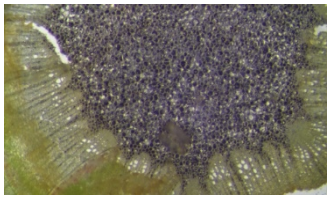


So, what we know so far – DO NSC MATTER? – YES









January

High level of sugars in January is correlated with high level of nectar in flowers in February and high yield

February

Total cost of flower = dry weight + respiration = 16-20 mg of sugars

NSC storage per cm ~10 mg or 80 mg per 1g of DW

~2-3 cm of twig is need for for each flower

High NSC = high yield

May

Low levels of sugar – **risk taking = high yield** – potentially investing in growth and reproduction with low reserves for defense

August

Low levels of sugar = high yield – investment in structure and yield while risk taking.

So, what we know so far – NSC and bloom

NSC and specifically soluble sugars respond temperature during winter – temperature change the respiration rates and affects transformation rates between sugar and starch. Together NSC can form an internal clock of dormancy progression and be used to asses the rediness of trees to bloom.
A beta (research) version of the clock is available at: https://zlab-budbreak-model.herokuapp.com/

How does it work – working hypothesis for high yield

Winter - Bloom

High initial reserves
Low loss during winter (chill)
High sugar in wood

What can we do?
Management
Treatments reducing respiration?
- water stress in the fall?
- whitening of the bark?
- chemicals?

Selection for high reserve?
- high amount of parenchyma cells?
- slow end of summer growth?

Summer

Risk taking - Very low reserves level

What can we do?
Management
- Reduce stress – under stress tree generate reserves in lieu of growth and reproduction
- Maintain high photosynthetic capacity

Selection for risk taking?
- no formation of reserves

Post-harvest

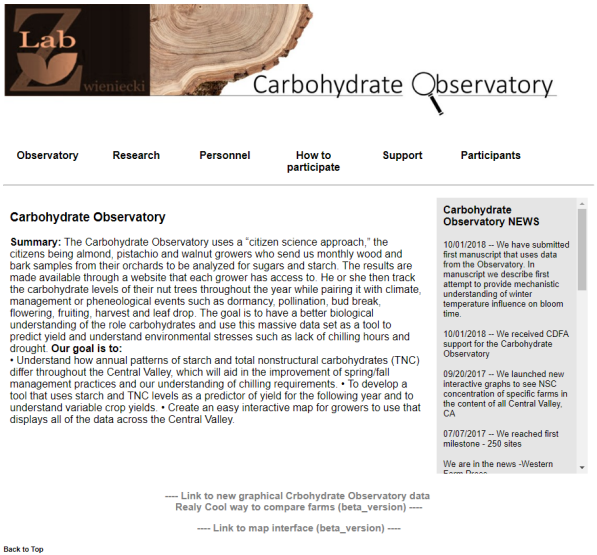
Recovery of reserves

What can we do?
Management
- Allow for reserves recovery
- Maintain photosynthetic capacity
- Enforce low stress to stop growth and stimulate reserves formation

Selection for risk taking?
- select for early growth stop?

To learn more or help in research by providing almond samples Please visit Carbohydrate Observatory website

https://psfaculty.plantsciences.ucdavis.edu/plantsciences_faculty/zwieniecki/CR/cr.html



Science

- Determination of management practices on carbohydrate metabolism and physiology
- Characterization of thermal/drought/biotic stresses on tree carbohydrate management/storage
- How to manage orchard for NSC?
- Modeling yield, and bloom time for orchards in specific locations for current weather

Applications

- Characterizing specific varieties of NSC based performance (yield) in relation to environment, management, salinity etc.
- Near real-time information on NSC orchard status to assist in management especially during postharvest and dormancy periods
- Provide information for precision physiology based agriculture

Thank You

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How Your Trees Work Under Adequate Water Supply and Deficit Supply

December 8th, 2021

Mae Culumber

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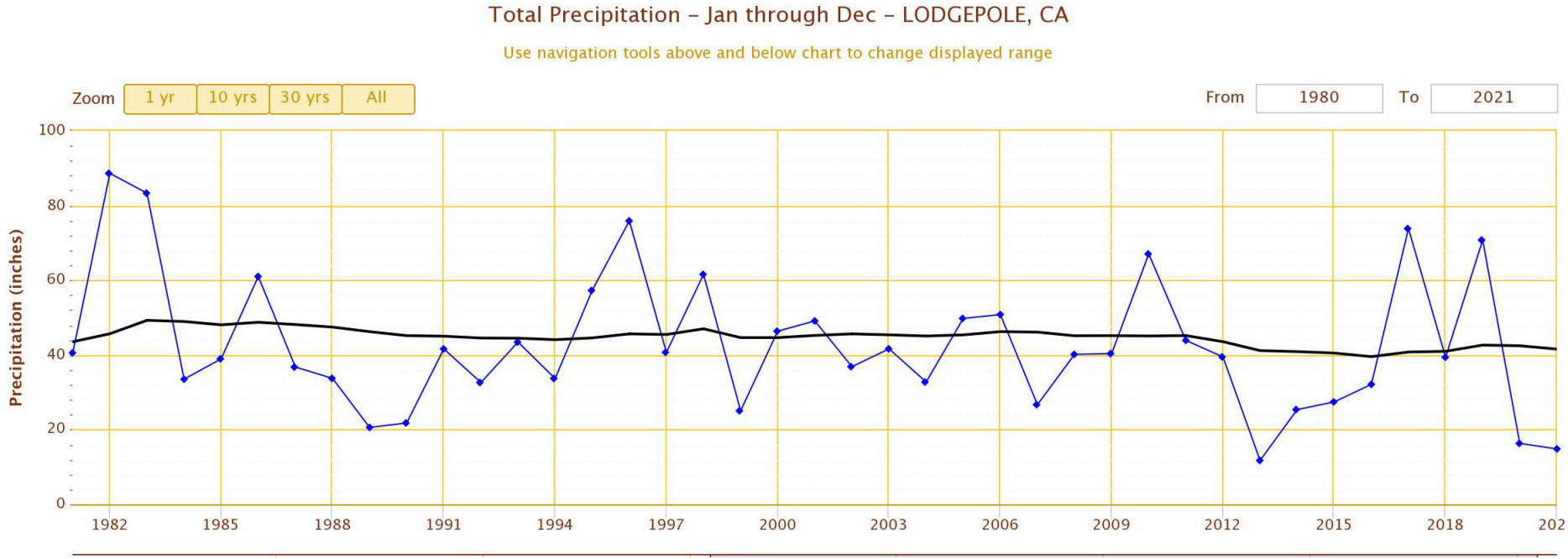
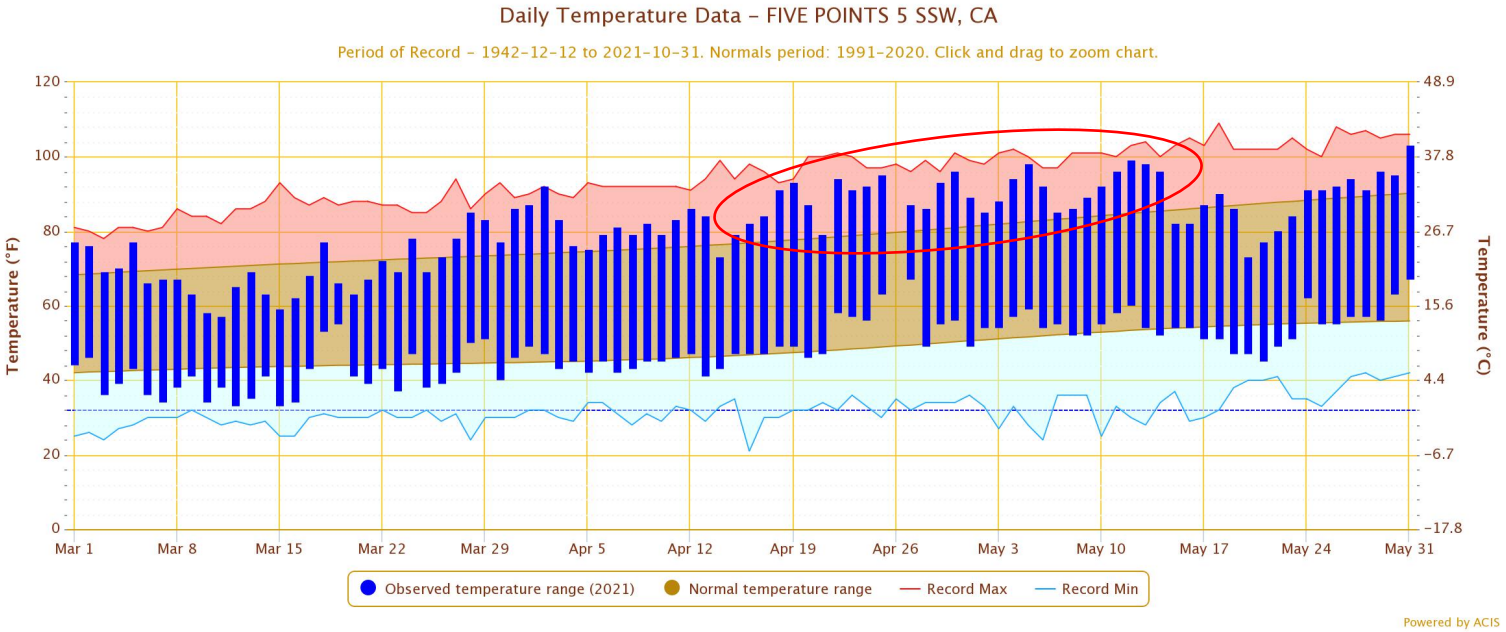
Low precipitation levels in 2020-2021

Precipitation above the San Joaquin river drainage 1981-2021



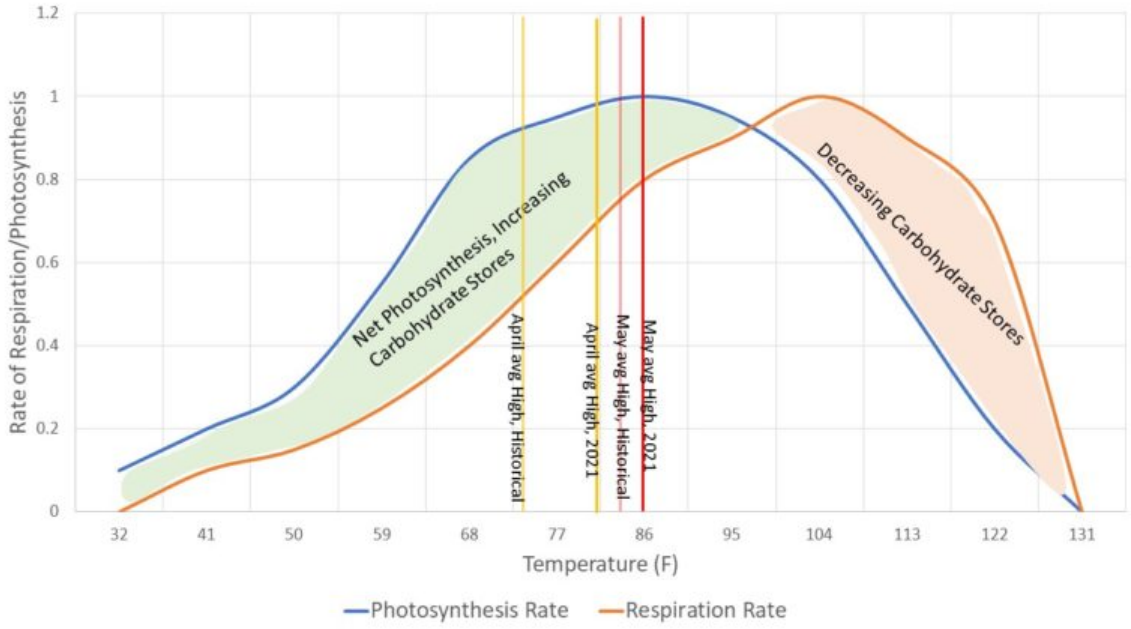
Drought and heat impacts fruit quality and yield

Some growers reported lower kernel weights in 2021



Association with above average temperatures in spring and summer?

Drought and heat impacts fruit quality and yield



- Heat induced plant stress reduces photosynthesis and carbohydrate production
- Carbohydrates are needed for plant growth and fruit development
- Some growers reporting low kernel weights, 28-30/ounce in 2021 despite adequate water

The Almond Doctor

https://thealmonddoctor.com/reduced-kernel-size-2021-harvest/

Frequent calls in early summer

- Yellowing leaves and dropping leaves in the lower canopy, some limbs dying back
- Likely cause a combination of factors related to heat and water stress, canopy shading, and humid conditions in the lower canopy
- orchards often have problems with ponded water at the surface

Drought impacts water supply

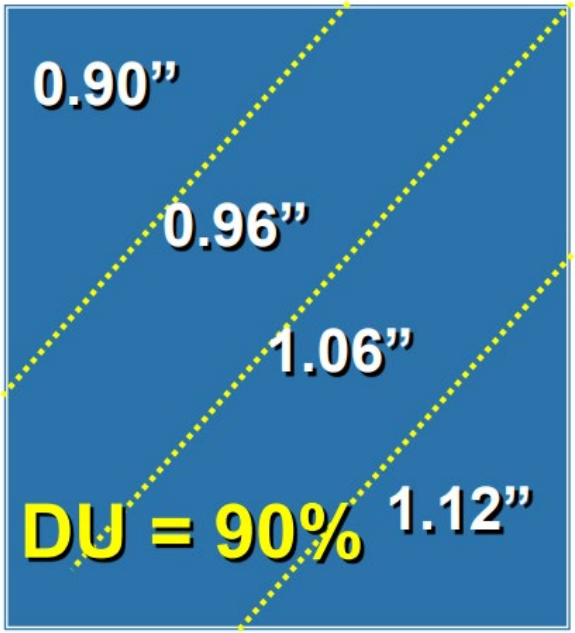
- Drought decreases surface water availability and increases demand on groundwater
- Decreased flow rates raises water temperature, elevates salt concentrations and other chemical and biological characteristics of the water
- May impact application rate and distribution uniformity as well as soil salinity levels and infiltration

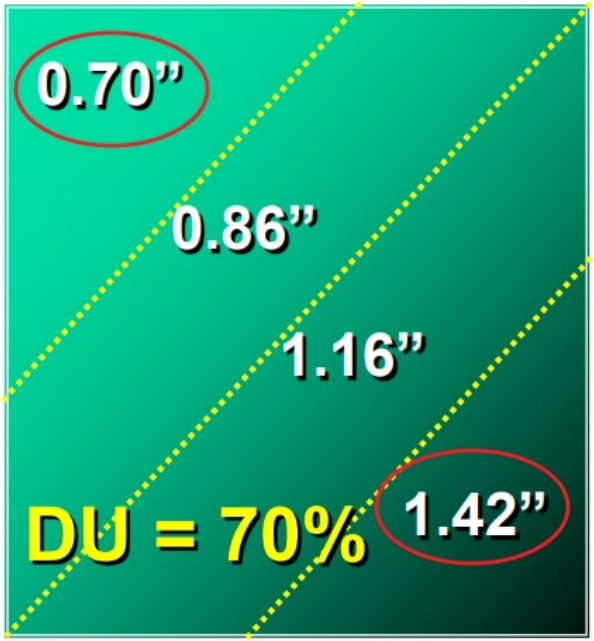
Irrigation system problems

- Small micro-emitters openings highly susceptible to clogging and leaks
- Routine inspection and maintenance is essential

Irrigation System Evaluation and Maintenance

Photo: D. Zaccaria



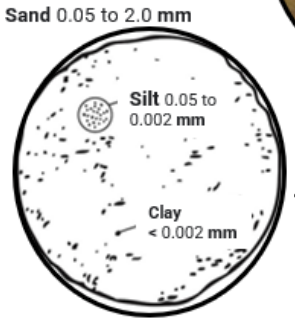


- Micro irrigation systems are highly efficient but almost all will have varying distribution uniformity (DU) across the block
- Untreated water quality problems will make things worse
- Professional system evaluation recommended every 2-3 years

Cumulative differences in application within a block

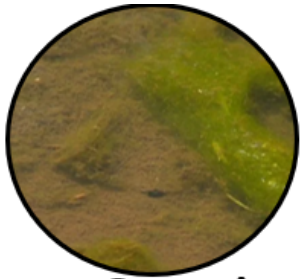
DU	Water Applied High ¼ of orchard	Water Applied Low ¼ of orchard	Difference across orchard one irrigation	Difference thirty irrigation cycles
	---------- Inches applied ----------			
90	1.12	0.90	0.22	6.6
80	1.27	0.80	0.47	14.1
70	1.42	0.70	0.72	21.6

Evaluating Irrigation Water Quality



Particulates

sand, silt, clay



Organic contaminants

algae, bacteria

Chemical precipitates

Calcium and magnesium carbonates, iron and manganese sulfides, injected fertilizers

Salinity & toxic ion levels

Total dissolved salts, EC, sodium, chloride, boron, bicarbonates

A typical well water analysis for eastside SSJV

- High pH and bicarbonate(alkalinity)
- Low EC
- High Ca (hardness)
- Low Na and Cl

Company: Simplot Water Logic
Submitted By:
Grower:
Sample Desc:

Water Source: Well
Sample ID#: 72304
Date Sampled: 7/23/21
Date Submitted: 7/23/21
Analysis Comments:

Cations	mg/L	meq/L	Lbs/Ac/Ft	Target Limits
Calcium	57.5	2.87	156.4	41 - 80
Magnesium	14.0	1.15	38.0	9 - 16
Sodium	26.2	1.14	71.3	30 - 35
Potassium	3.5	0.09	9.6	4.6 - 6
Iron	<0.1			<0.20
Manganese	<0.1			<0.10

Anions	mg/L	meq/L	Lbs/Ac/Ft	Target Limits
Hydroxide	<0.1			Varies on pH
Carbonate	<0.1			3.0 - 4.0
Bicarbonate	222.3	3.64	604.6	120 - 180
Sulfate	38.6	0.80	105.1	25 - 50
Chloride	33.9	0.96	92.1	70 - 140
Nitrate-N	6.6	0.47	18.1	3 - 7
Boron	<0.01			0.3 - 0.6

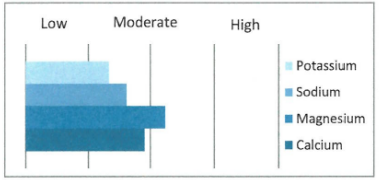

Bacteria

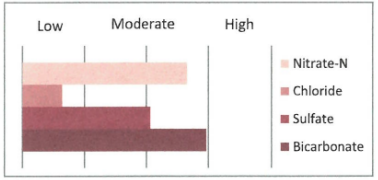

Fungi

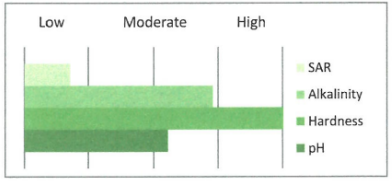
Bacteria & Fungi	CFU/mL	Target Limits
Bacteria, cfu/mL	<100	<100
Fungus, cfu/mL	<10	<10

Coliform	Presence/Absence
Coliform	
E. Coli	

Other	Lbs/Ac/Ft	Target Limits
Total Dissolved Solids, mg/L	849.9	<450
Electrical Conductivity, dS/m	0.549	<0.450
pH	7.93	6.8 - 7.5
Hardness, mg/L as CaCO3	201	546.9	60 - 120
Alkalinity, mg/L as CaCO3	182	496.0	100 - 150
Langelier Saturation Index	0.6		-0.2
Sodium Adsorption Ratio, adj.	1.1		2 - 4



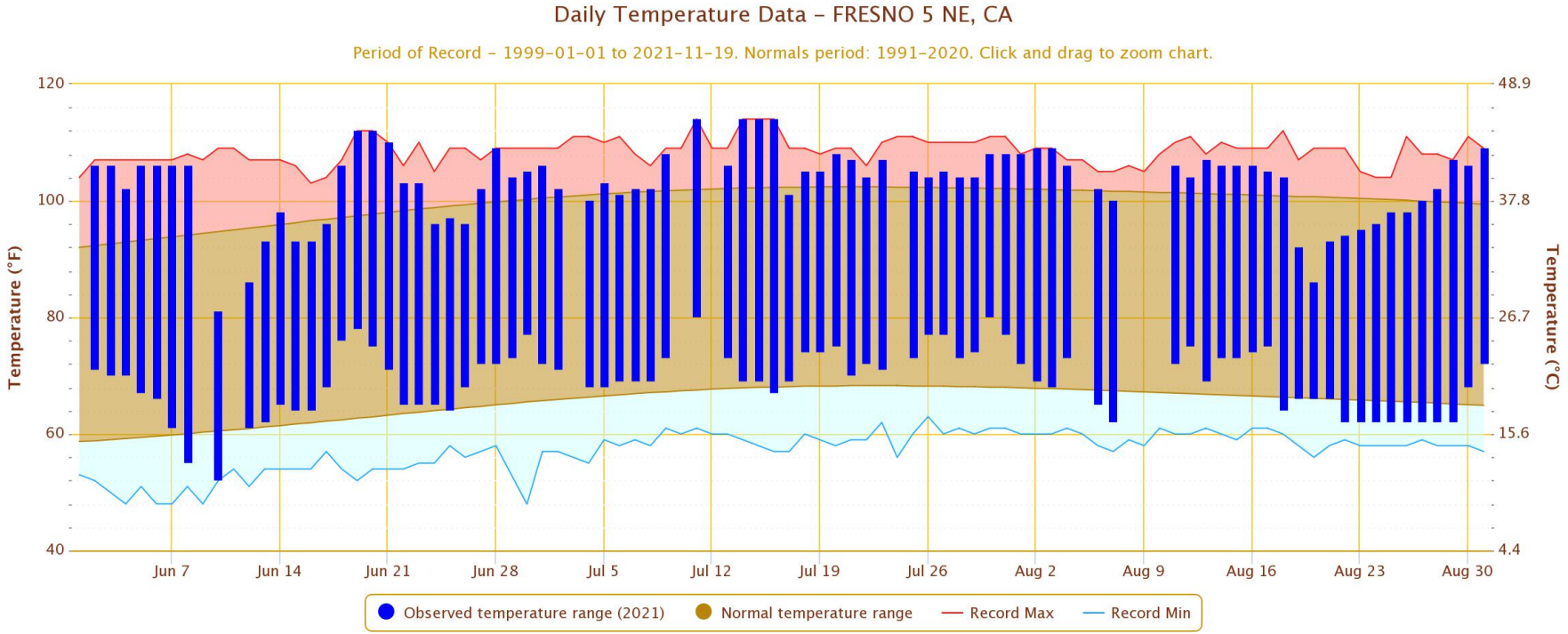




Water has low EC and low sodium but visible salt damage and elevated levels in tissue analysis

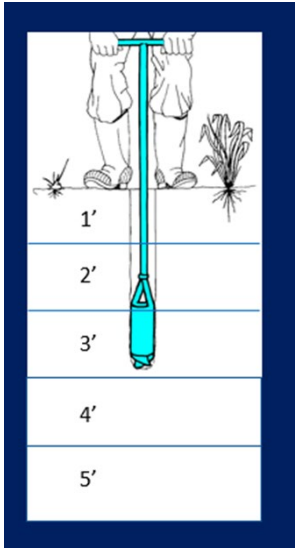
	Total Nitrogen (%)	Nitrate-Nitrogen (ppm)	Calcium (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Manganese (ppm)	Zinc (ppm)	Boron (ppm)	Sodium (%)	Chloride (%)	Iron (ppm)	Copper (ppm)
Ranch (Weak)	2.10		4.5	1.29	0.09	0.5	67	40	33	0.26	0.60	97	9
	2.4 - 3.0		1.0 - 4.0	0.25 - 0.70	0.12 - 0.30	1.5 - 2.0	25 - 80	25 - 100	40 - 80	0.01 - 0.20	0.01 - 0.6	70 - 250	6 - 20

High temperatures = high evapotranspiration and accumulation of salts



Salinity Reclamation Timeline

November:
Sample irrigation water and soil from 1’ to 5’ Determine EC, pH, Na^+ (SAR), B
Calculate and apply soil and/or water amendments if needed
Calculate depth of reclamation: Determine depth of water (inches per foot depth soil) needed to achieve desired salinity
Determine timeline for completing leaching program
November to February:
Leach in dormant season
1st fill profile to field capacity (3-6 inches over 3-4 days), then 2-4 days drainage…..then begin leaching applications
February:
Re-sample irrigation water and soil from 1’ to 5’ to determine effectiveness of applied leaching and starting point for growing season



Adaptive approaches to water shortage

- Water budgeting
- Soil moisture and plant water status monitoring
- Regulated deficit irrigation
- Improved distribution uniformity with routine maintenance
- Winter reclamation for salts in the rootzone

Thank You

Rooted IN SUCCESS 2021
the almond conference

One Sacramento Valley Perspective

Dec. 12, 2021: How Your Trees Work Under Adequate Water Supply and Deficit Supply

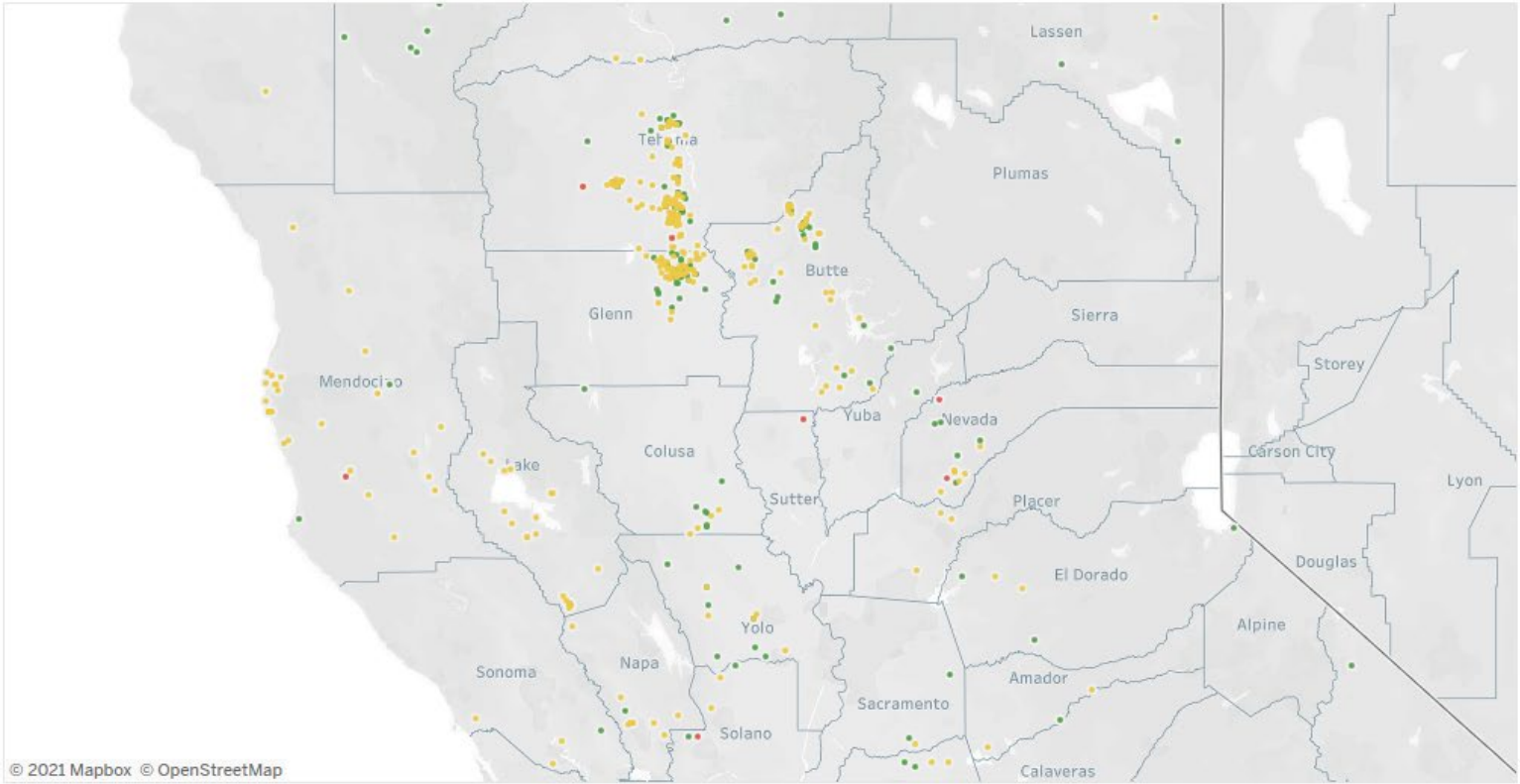
Luke Milliron

california almonds
Almond Board of California

Statewide Distribution of Reported Household Water Supply Shortages

The interactive map below illustrates the relative statewide distribution of reported household water supply shortages.

(Last updated 11/18/2021 4:11:04 AM) https://tableau.cnra.ca.gov/t/DWR_SGM/views/mydrywatersupply/Map.pdf

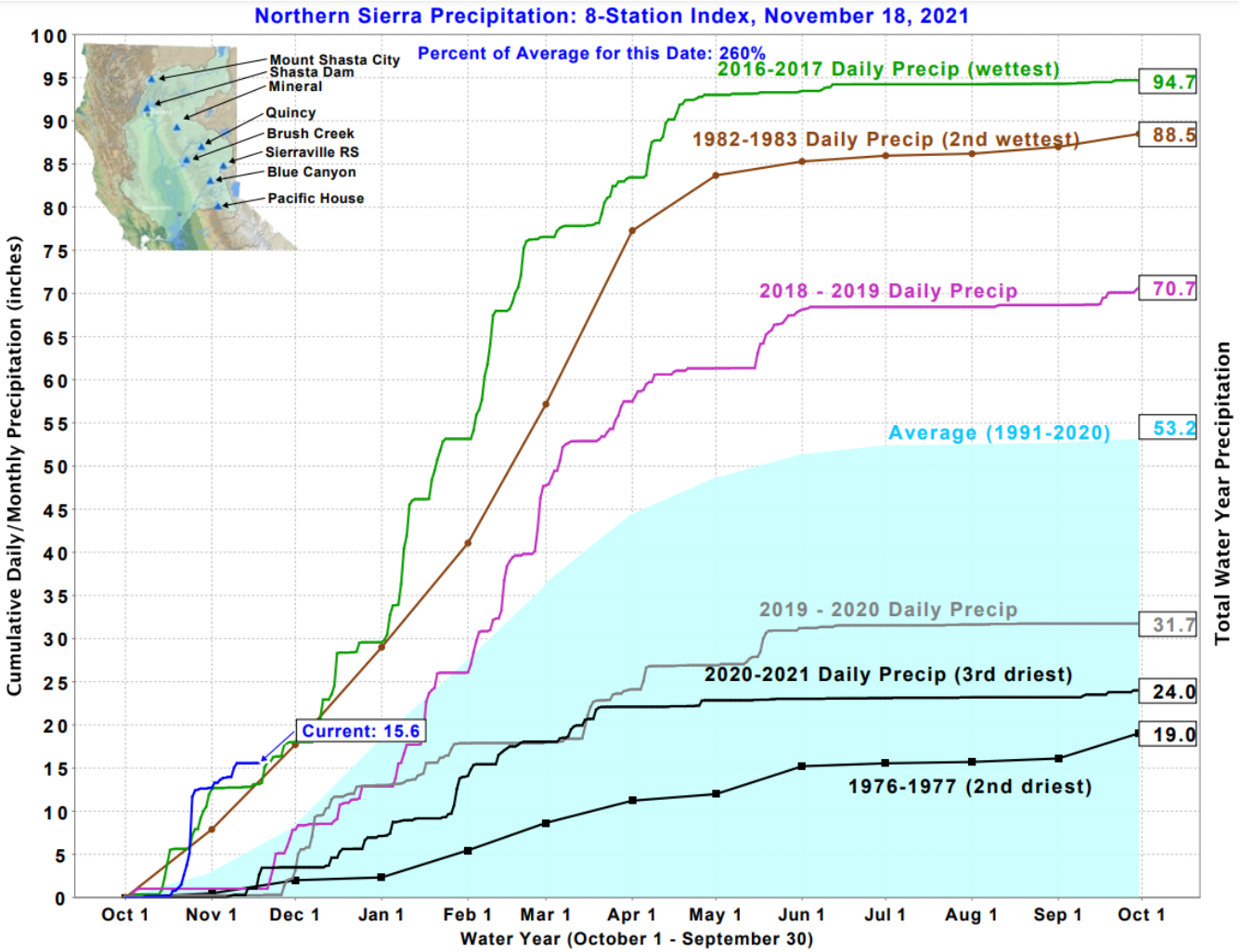


Primary Use

- [x] (All)
- [x] Ag/Irrigation
- [x] Combination of Household/Agriculture
- [x] Household
- [x] Other

Reported

- Last 30 days
- 31-365 days
- >365 days


Northern Sierra Precipitation: 8-Station Index, November 18, 2021
Percent of Average for this Date: 260%
Mount Shasta City
Shasta Dam
Mineral
Quincy
Brush Creek
Sierraville RS
Blue Canyon
Pacific House
2016-2017 Daily Precip (wettest)
94.7
1982-1983 Daily Precip (2nd wettest)
88.5
2018 - 2019 Daily Precip
70.7
Average (1991-2020)
53.2
2019 - 2020 Daily Precip
31.7
2020-2021 Daily Precip (3rd driest)
24.0
1976-1977 (2nd driest)
19.0
Current: 15.6
Cumulative Daily/Monthly Precipitation (inches)
Total Water Year Precipitation
Water Year (October 1 - September 30)
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1

West Side Problems

- You may have water, but how clean is it?
- Trees exceeding toxicity levels for Cl
  - Has the shoe dropped yet?

- Runoff instead of infiltration
  - Refilling the soil profile: Long road to go…

Winter Irrigation: Month by Month

- Track rainfall and compare with average
- Substitute irrigation for rainfall shortages on a monthly basis

Table 1. Red Bluff (Gerber CIMIS #222) Winter Rainfall (In)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
Avg. Monthly	**1.2**	**2.8**	**4.2**	**5.0**	**4.1**	**3.2**	**20.5**
2019 / 2020	0.0	0.1	2.7	1.3 (K)	0.0*	?	4.1*

Continuum: Plant Water Status

1.0
Fundamental

Visual plant cues

Pre-irrigation or biweekly

95%

30%

27%

almonds.com/irrigation

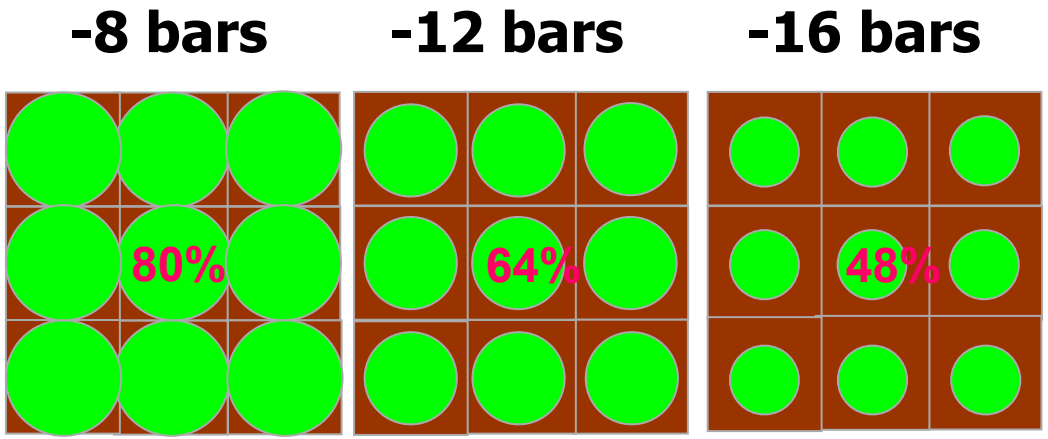
Water status has huge growth, yield, and tree health consequences!

$$$

Growers report $10-20 per acre cost annually

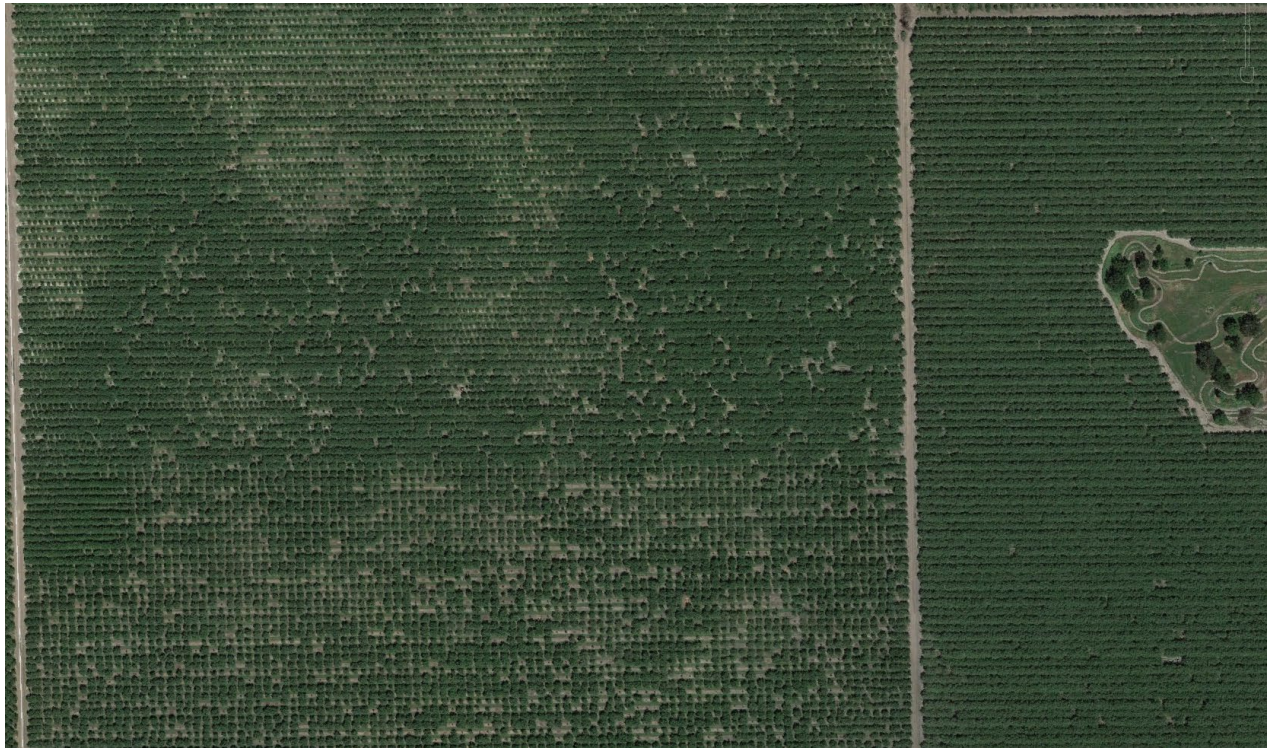
Potential revenue loss from stress during canopy development

Time period	Loss on 80 acres for each 1 bar of stress	Loss on 80 acres for 4 bars of stress
1 year	$13,860	$55,440
8 years	$110,880	$443,520



More variation in tree size when over-irrigating

- Small trees suffer
- If you under irrigate slightly, larger trees grow more slowly, and orchard becomes more uniform



Automated Water Potential

e.g. FloraPulse

- Good agreement with pressure chamber
- Representative tree?
- Unknown cost efficacy vs. pressure chamber

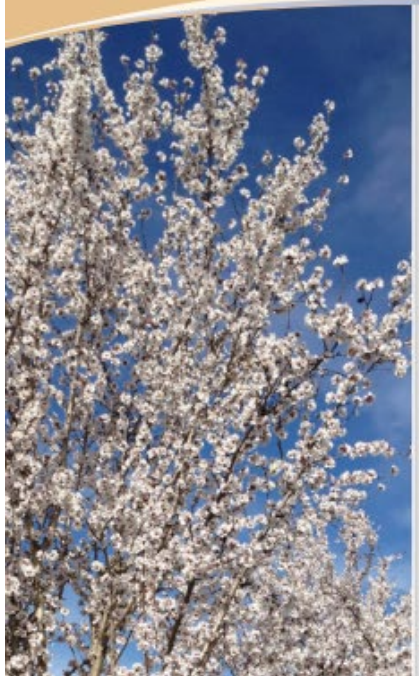
Soil Moisture

For more information:

University of California
Agriculture and Natural Resources

ANR Publication 8515 | February 2015
http://anrcatalog.ucanr.edu

UC PEER REVIEWED



DROUGHT TIP

Drought Management for California Almonds

Impacts of Stress on Almond Growth and Yield

Almond trees are tolerant to drought conditions and respond to water availability with increasing yields. Research has shown that trees are able to survive on as little as 7.6 inches of water (Shackel et al. 2011), but they produce maximally with 54 to 58 inches in many areas of California (Sanden 2007). Minimizing water stress increases growth and yield due to increased rates of photosynthesis and respiration.

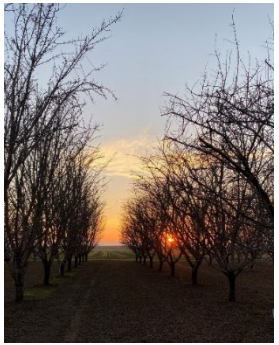
DAVID DOLL, University of California Cooperative Extension Farm Advisor, Merced County
KENNETH SHACKEL, Professor, Department of Plant Science, University of California, Davis

For more information:

- Contact your local orchard or irrigation advisor
- SacValleyOrchards.com & SJVTandV.com
- GrowingTheValleyPodcast.com

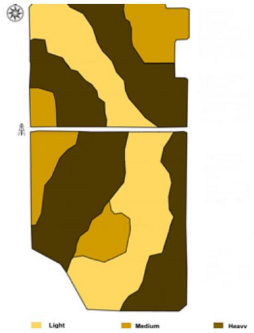
Craig Ledbetter on the USDA breeding program

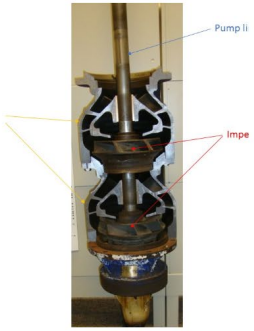
Irrigation Management with David Doll

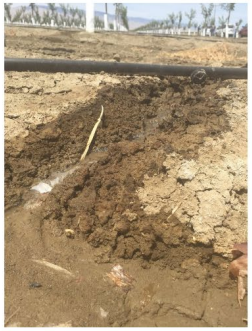


Field Evaluation of Almond Varieties

The Dangers of Irrigation Leaks







Available for CDFA CEU credit

Google: “CDFA Continuing Education”

Aug 19

Irrigation Part 5. Evapotranspiration with Allan Fulton

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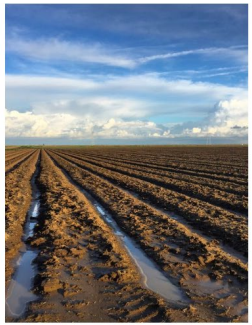

Aug 19

Irrigation Part 4. Soil Moisture Monitoring with Allan Fulton

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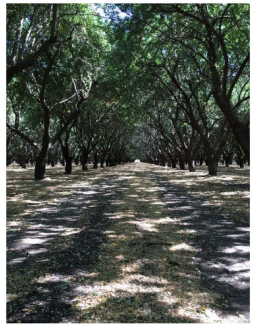
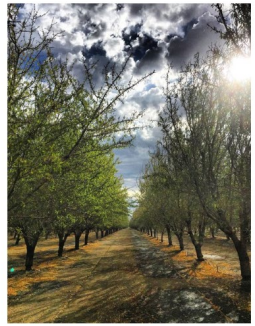
Aug 19

Irrigation Part 3. Water Potential and the Soil-Plant-Atmosphere Continuum with Phoebe Gordon



Aug 19

Irrigation Part 2: Basic Irrigation Technologies With Spencer Cooper



Aug 19

Irrigation Part 1: Management with David Doll

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For more information:

University of California
Agriculture and Natural Resources

ANR Publication 8515 | February 2015
http://anrcatalog.ucanr.edu

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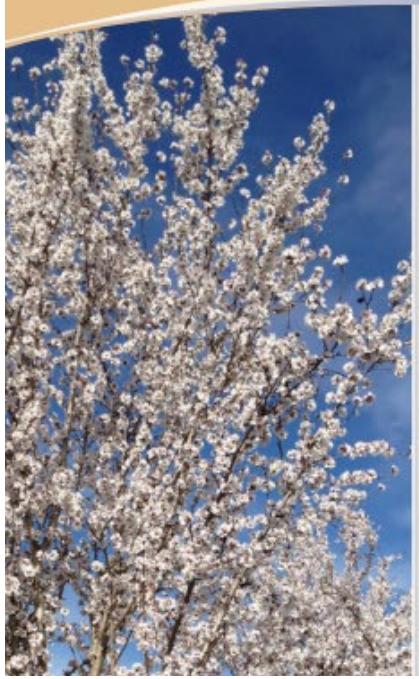

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ALMOND
IRRIGATION
IMPROVEMENT
CONTINUUM
almonds.com/irrigation

Action Steps vs. Flying Blind

1. Winter: Pray for gentle rains…
2. Winter: Substitute irrigation for rainfall shortages
3. Pressure chamber for…
   - starting season, weekly trigger, regulated deficit
4. Not going to use the pressure chamber?
   - automated water potential, or at least use soil moisture
5. Test water quality and take leaf samples (including Cl)

Thank You