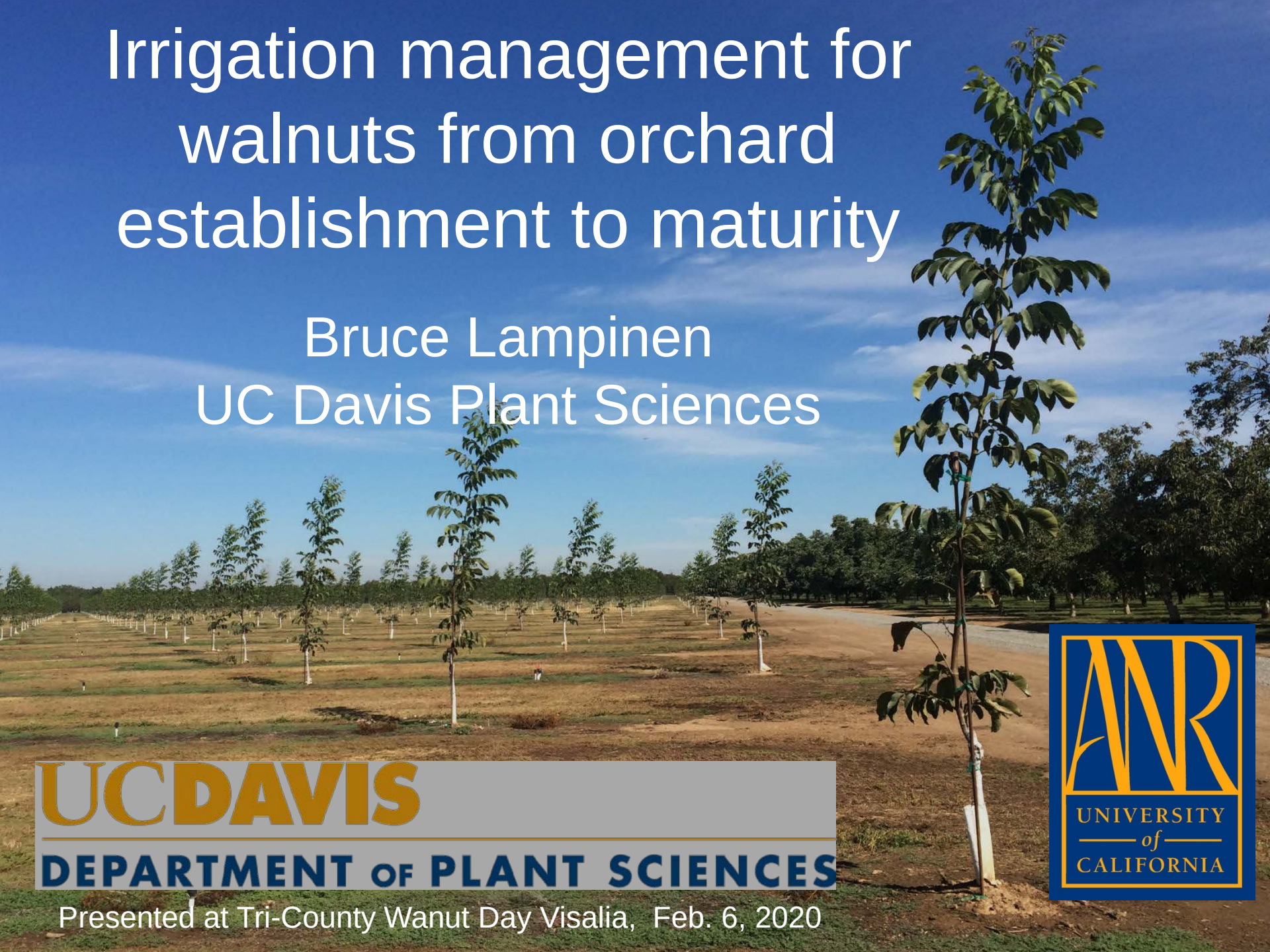
Irrigation management for walnuts from orchard establishment to maturity

Bruce Lampinen
UC Davis Plant Sciences



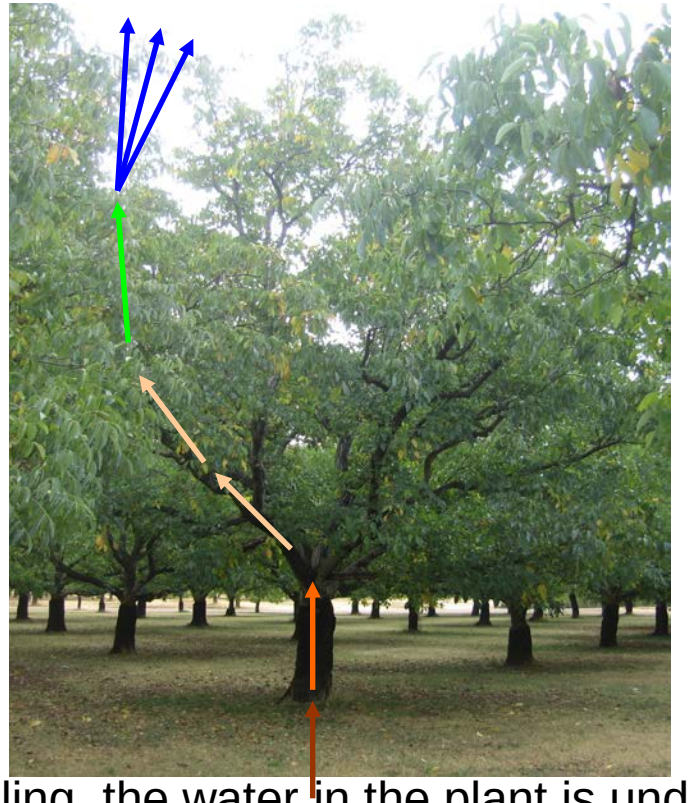
UCDAVIS
DEPARTMENT OF PLANT SCIENCES

UNIVERSITY of CALIFORNIA

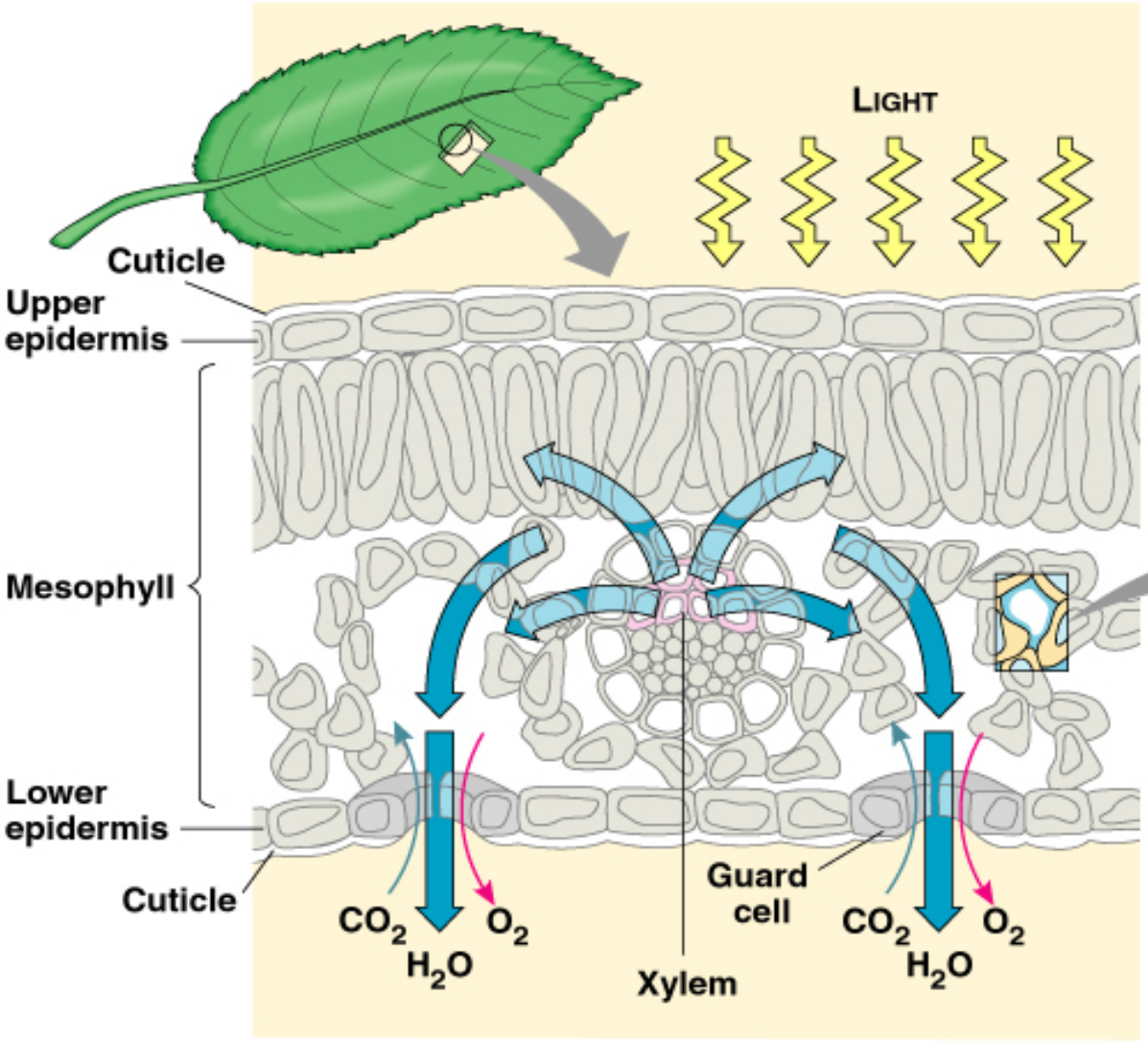
Presented at Tri-County Wanut Day Visalia, Feb. 6, 2020

Midday stem water potential

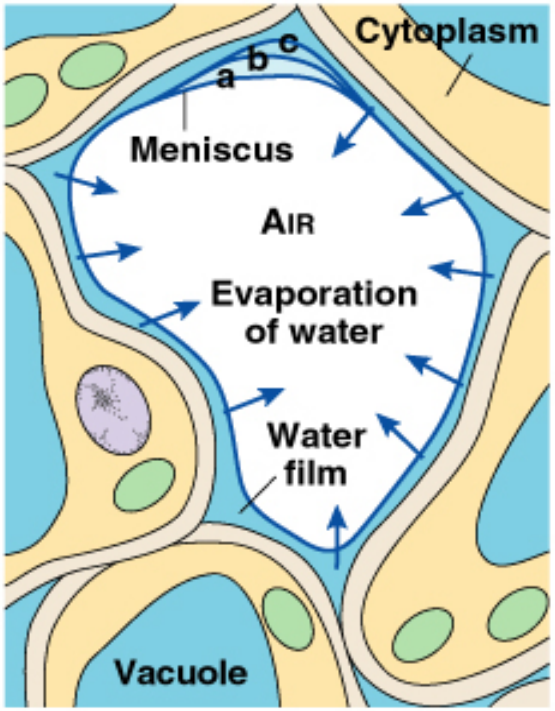
Water moves through plants in the xylem. There is a continuous column of water from the roots to the leaves. As water evaporates from the leaves, more water is pulled up through the plant.

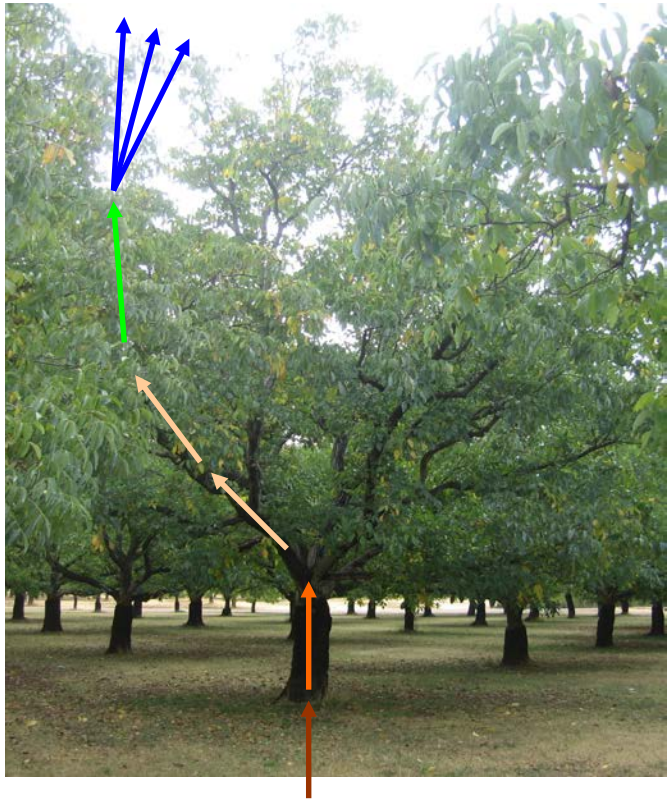


Because of this pulling, the water in the plant is under tension and it is this tension that we are measuring with a plant pressure chamber.



Radius of curvature (μm)	Hydrostatic pressure (MPa)
a = 1.00	a = −0.15
b = 0.10	b = −1.50
c = 0.01	c = −15.00

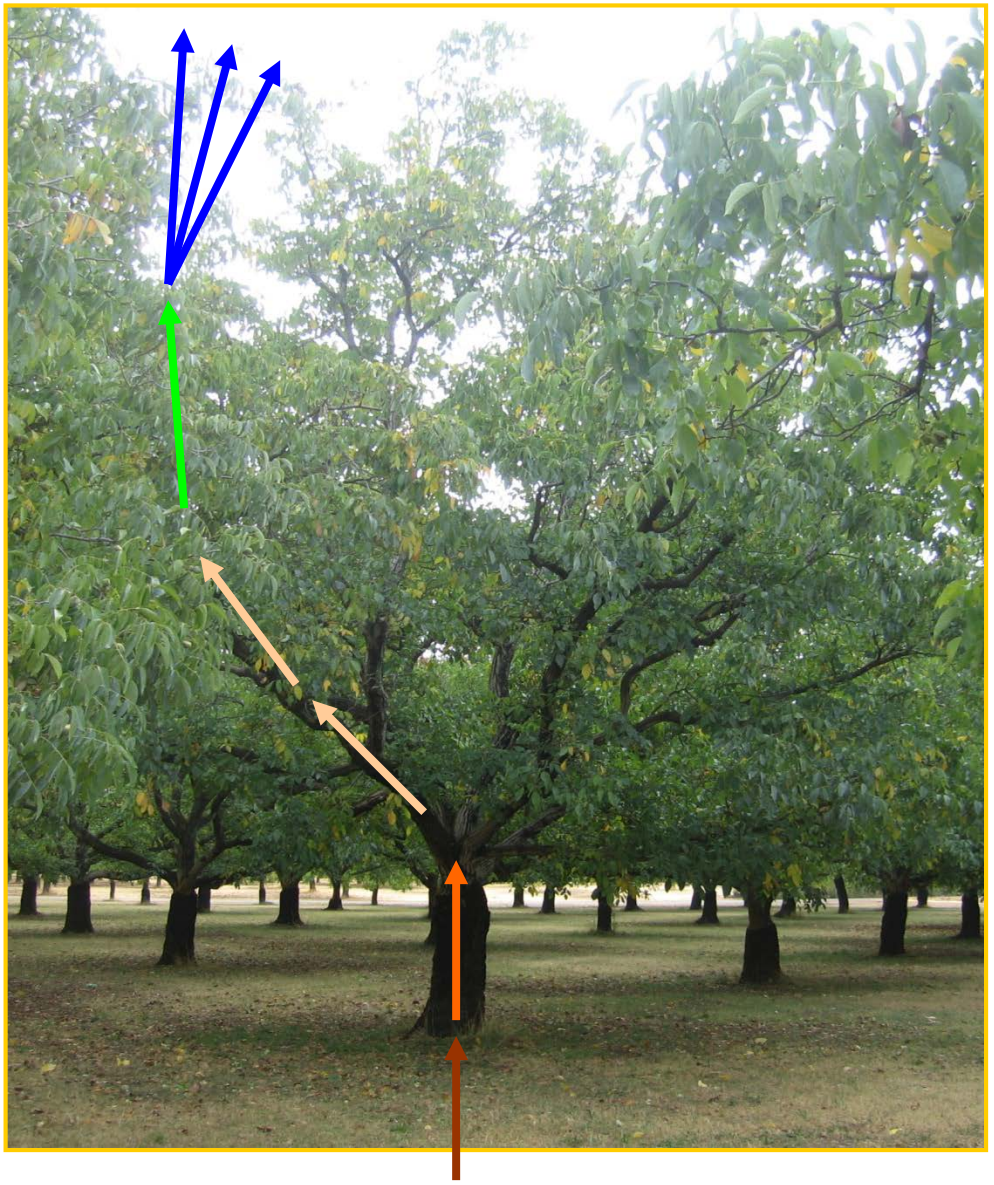




Because of this pulling, the water in the plant is under tension and it is this tension that we are measuring with a plant pressure chamber.

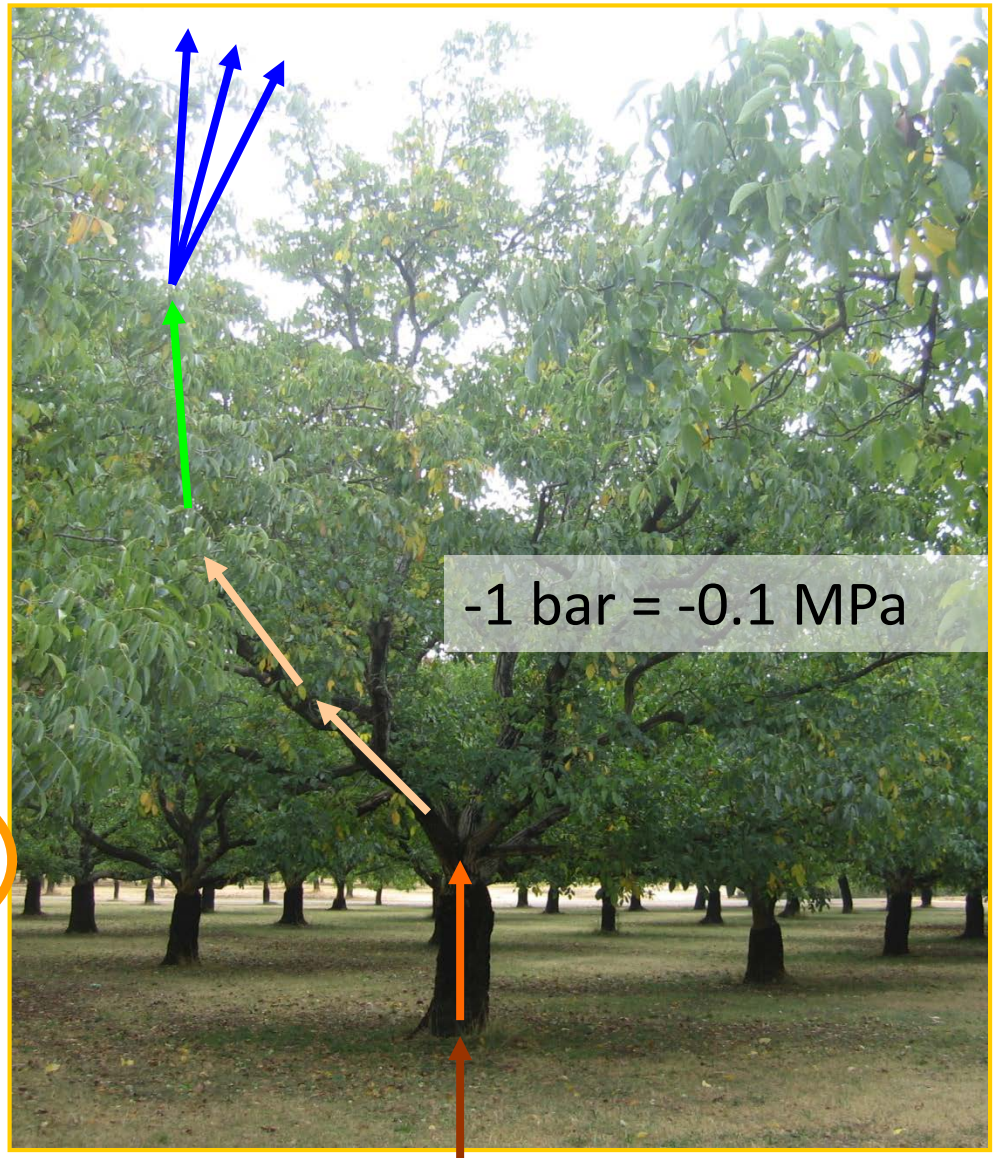
Water potential in the soil-plant-atmosphere continuum

Roots require oxygen to function. If the soil is too wet, soil oxygen can be depleted, leading to decreased root function and eventually death.



Water potential in the soil-plant-atmosphere continuum

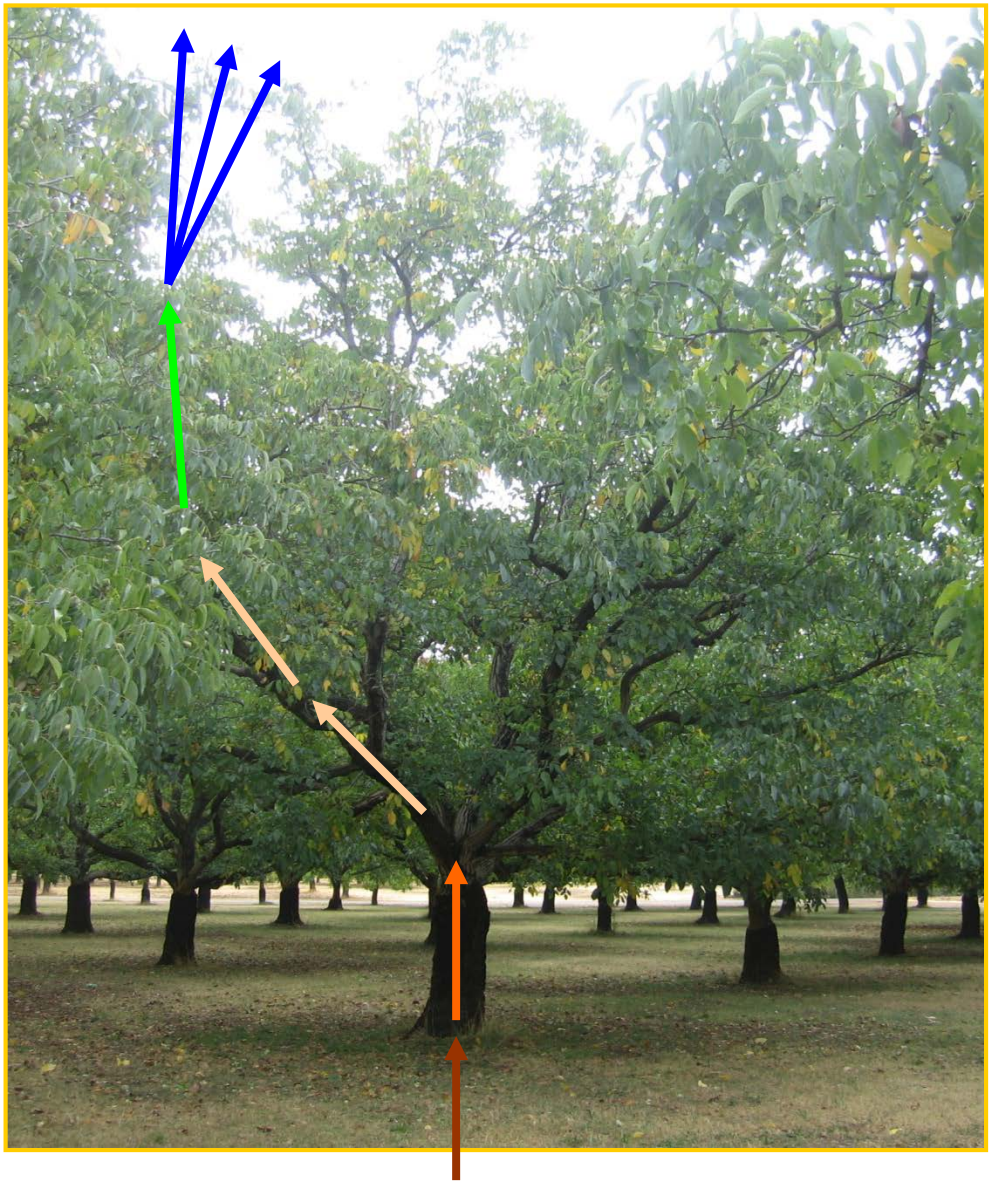
Location	(bars)
Air above tree	-95.0
Air near leaf	-70.0
Air in leaf	-6.9
Xylem in leaf (10m)	-4.5
Xylem in scaffold	-4.0
Xylem in trunk-	-3.5
Xylem in root	-0.6
Soil	-0.3



-0.3 bars equals -30 cbars

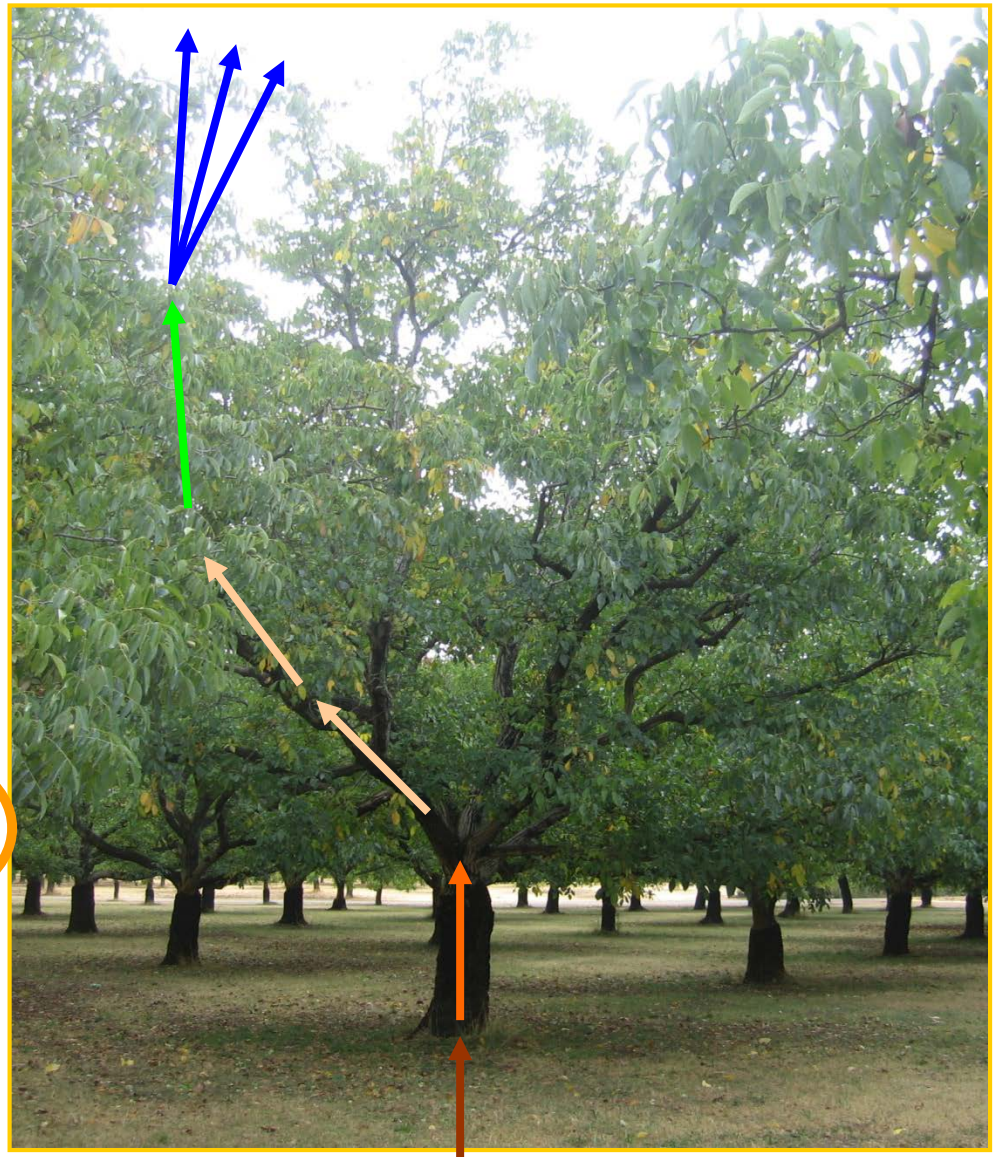
Water potential in the soil-plant-atmosphere continuum

As the soil dries, it becomes more difficult for the tree to “pull” the water up to the leaves



Water potential in the soil-plant-atmosphere continuum

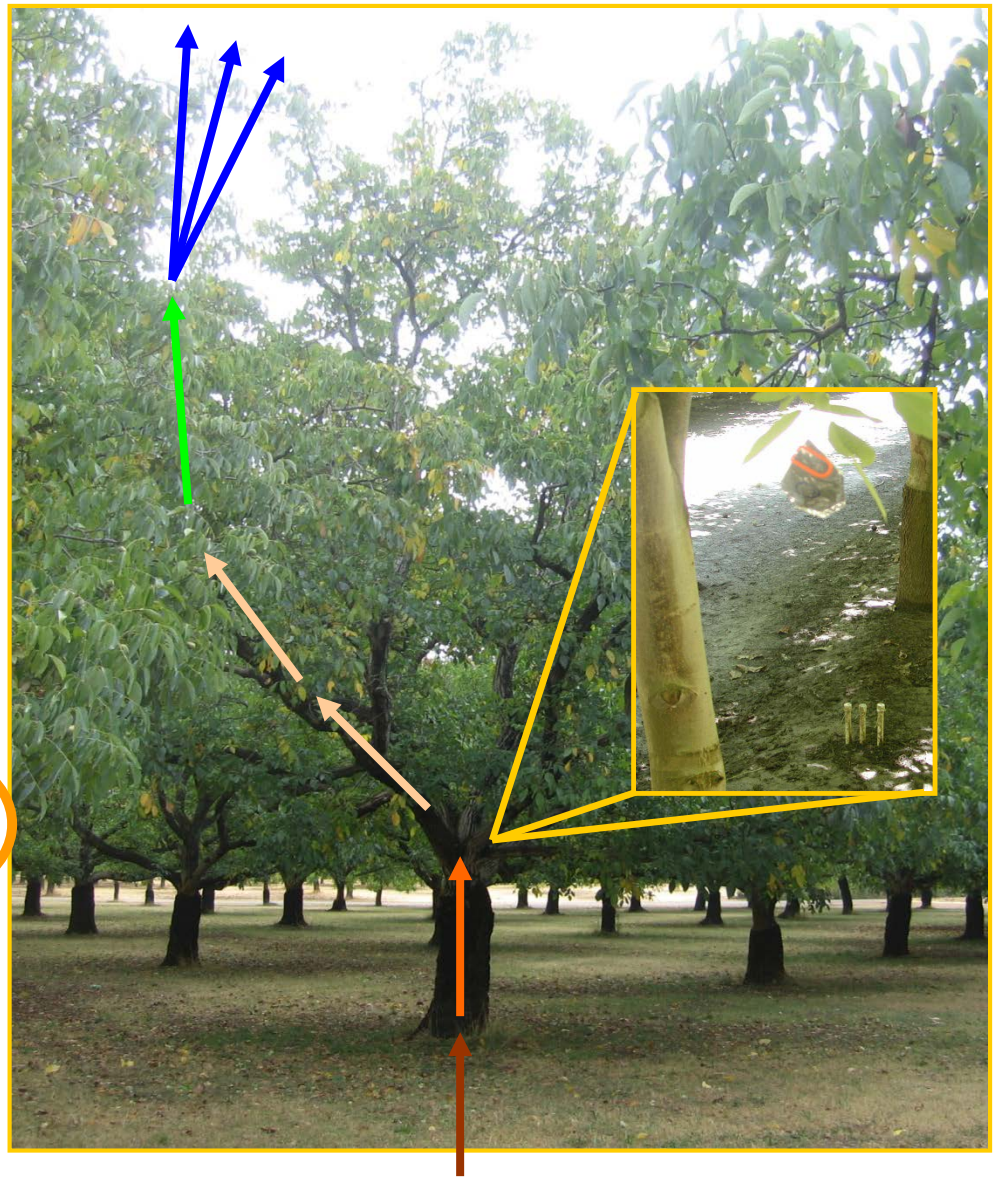
Location	(bars)
Air above tree	-95.0
Air near leaf	-70.0
Air in leaf	-14.0
Xylem in leaf (10m)	-12.0
Xylem in scaffold	-9.5
Xylem in trunk-	-8.5
Xylem in root	-1.8
Soil	-0.9



-0.9 bars equals -90 cbars

Water potential in the soil-plant-atmosphere continuum

Location	(bars)
Air above tree	-95.0
Air near leaf	-70.0
Air in leaf	-14.0
Xylem in leaf (10m)	-12.0
Xylem in scaffold	-9.5
Xylem in trunk	-8.5
Xylem in root	-1.8
Soil	-0.9

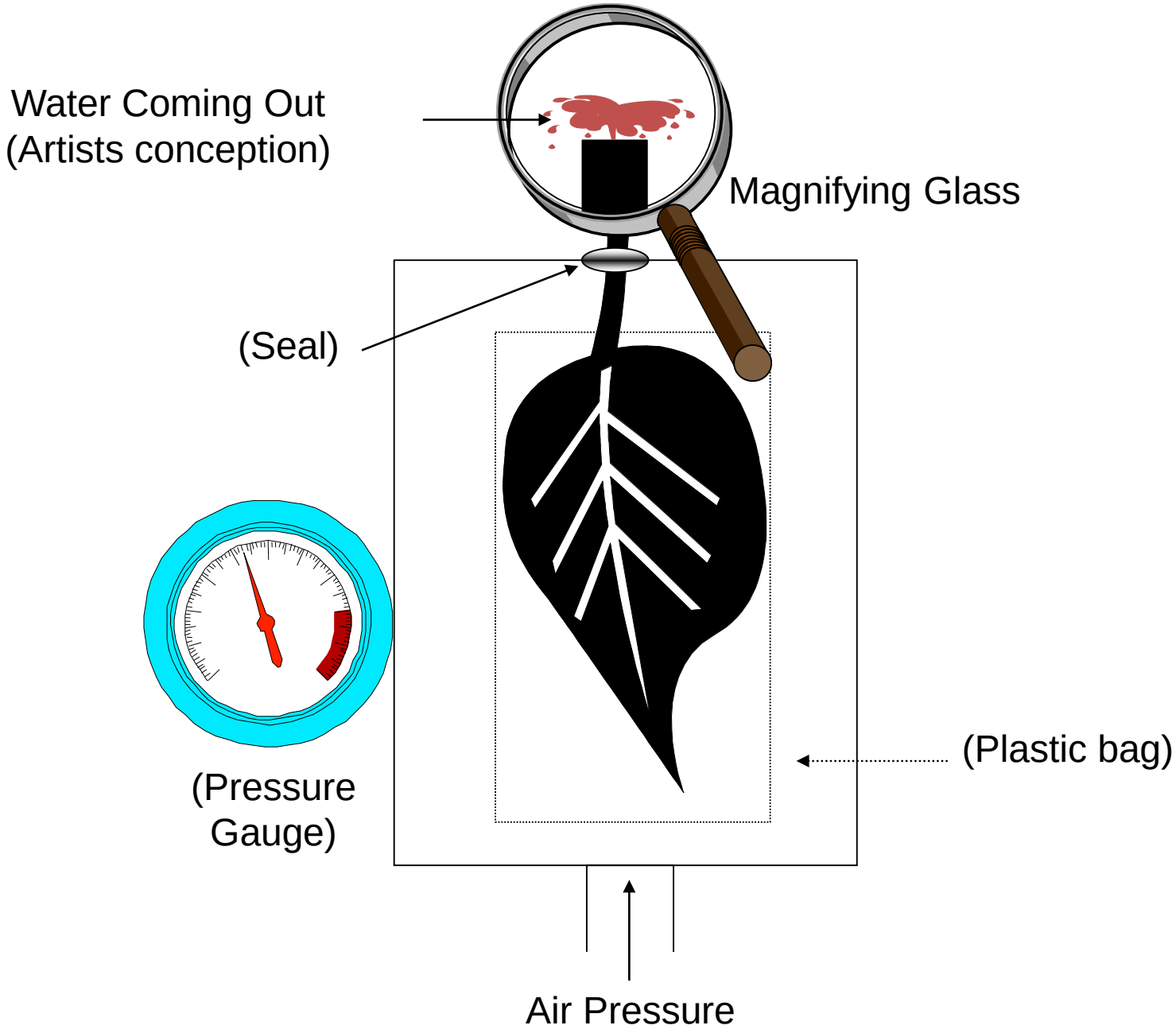


The plant pressure chamber- What is midday stem water potential?

- A plant pressure chamber is used to measure the tension in a leaf

- Midday stem water potential is normally expressed as negative value since you are measuring a tension in the xylem

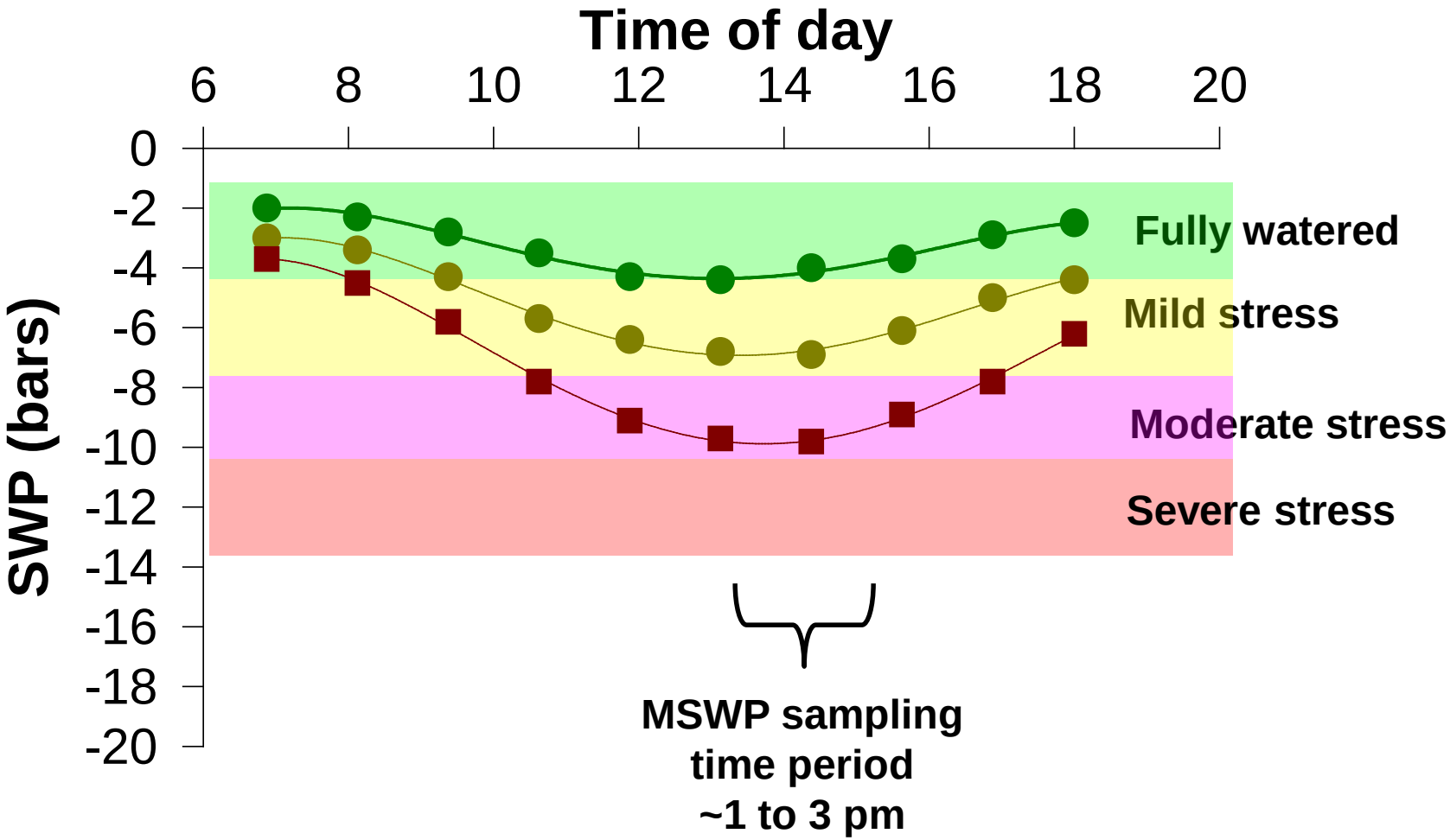
- Water potential readings done on a bagged leaf at midday are known as midday stem water potential (MSWP)- stem refers to the fact that you are letting the bagged leaf equilibrate with the water status of the trunk


Water Coming Out
(Artists conception)
Magnifying Glass
(Seal)
(Pressure
Gauge)
(Plastic bag)
Air Pressure

Before end point

At end point- take reading just as water reaches surface (xylem darkens)

Walnut stem water potential



Midday Stem Water Potential for a Fully Watered Walnut

Temperature (°F)	Air Relative Humidity (RH, %)						
	10	20	30	40	50	60	70
60	-3.8	-3.7	-3.6	-3.5	-3.3	-3.2	-3.1
65	-4.0	-3.9	-3.7	-3.6	-3.5	-3.3	-3.2
70	-4.2	-4.1	-3.9	-3.7	-3.6	-3.4	-3.3
75	-4.5	-4.3	-4.1	-3.9	-3.7	-3.5	-3.3
80	-4.8	-4.6	-4.3	-4.1	-3.9	-3.7	-3.5
85	-5.1	-4.9	-4.6	-4.4	-4.1	-3.8	-3.6
90	-5.6	-5.2	-4.9	-4.6	-4.3	-4.0	-3.7
95	-6.0	-5.7	-5.3	-4.9	-4.6	-4.2	-3.9
100	-6.5	-6.1	-5.7	-5.3	-4.9	-4.5	-4.0
105	-7.2	-6.7	-6.2	-5.7	-5.2	-4.7	-4.2
110	-7.8	-7.3	-6.7	-6.2	-5.6	-5.0	-4.5

MSWP irrigation thresholds

- **Young trees (1 to 6 years)- irrigate when trees reach 1.5 to 2 bars more negative than the fully watered baseline**

  If baseline is -5 bars, irrigate when trees get to -6.5 to -7.0 bars

- **Mature trees (7+ years)- irrigate when trees reach 2-3 bars more negative than the baseline**

  If baseline is -5 bars, irrigate when trees get to -7 to -8 bars

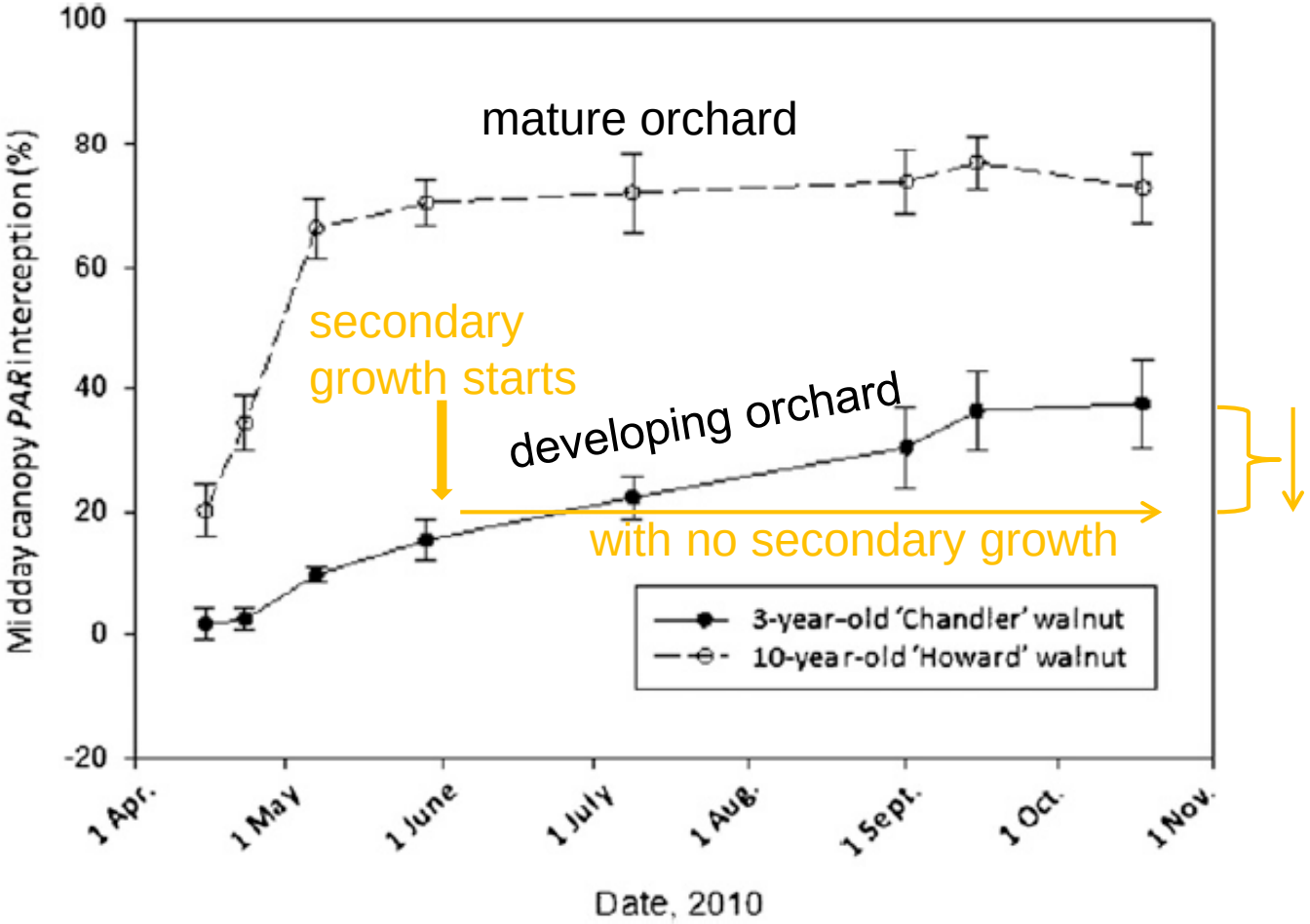


Fig. 6. Midday canopy photosynthetically active radiation (*PAR*) interception for a growing 3-year-old 'Chandler' walnut orchard and a mature 10-year-old 'Howard' walnut orchard in Colusa County, CA, over the 2010 season. Both datasets were for replicated trials with six replications for each data point. Bars indicate ±2 SE calculated using SAS Proc Means (SAS version 9.2; SAS Institute, Cary, NC).

From Lampinen et.al., 2012. A mobile platform for measuring photosynthetically active radiation interception in orchard systems. HortTechnology 22(2) 237-244.

Stress that impacts canopy development in early life of orchard can impact production for many years

	Fully watered	8%decrease in year 2
Year 3	30% (1.5 tons/ac)	22% (1.1 tons/ac)
Year 4	40% (2.0 tons/ac)	32% (1.6 tons/ac)
Year 5	50% (2.5 tons/ac)	42% (2.1 tons/ac)
Year 6	60% (3.0 tons/ac)	52% (2.6 tons/ac)
Year 7	70% (3.5 tons/ac)	62% (3.1 tons/ac)
Year 8	80% (4.0 tons/ac)	72% (3.6 tons/ac)
Year 9	90% (4.5 tons/ac)	82% (4.1 tons/ac)
Total	21 tons/ac	18.2 tons/ac

10% increase per year after year 2 in both

This is equal to a cumulative difference of 2.8 tons/ac from one time stress event in year 2

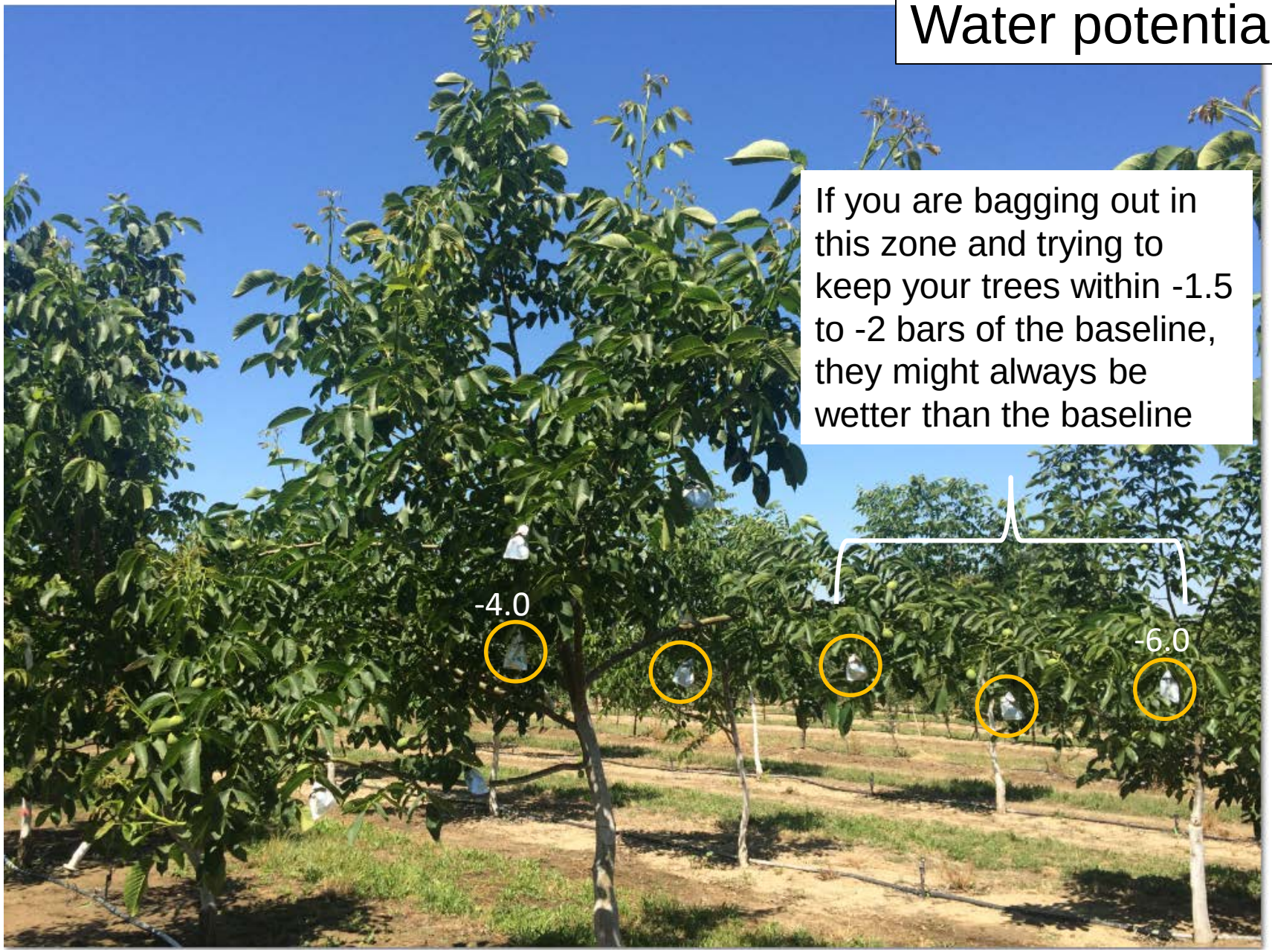
This is equal to 224 tons (448,000lbs) less yield over first 9 years for an 80 acre orchard- this would have paid for a lot of $5000 pressure chambers

Water potential

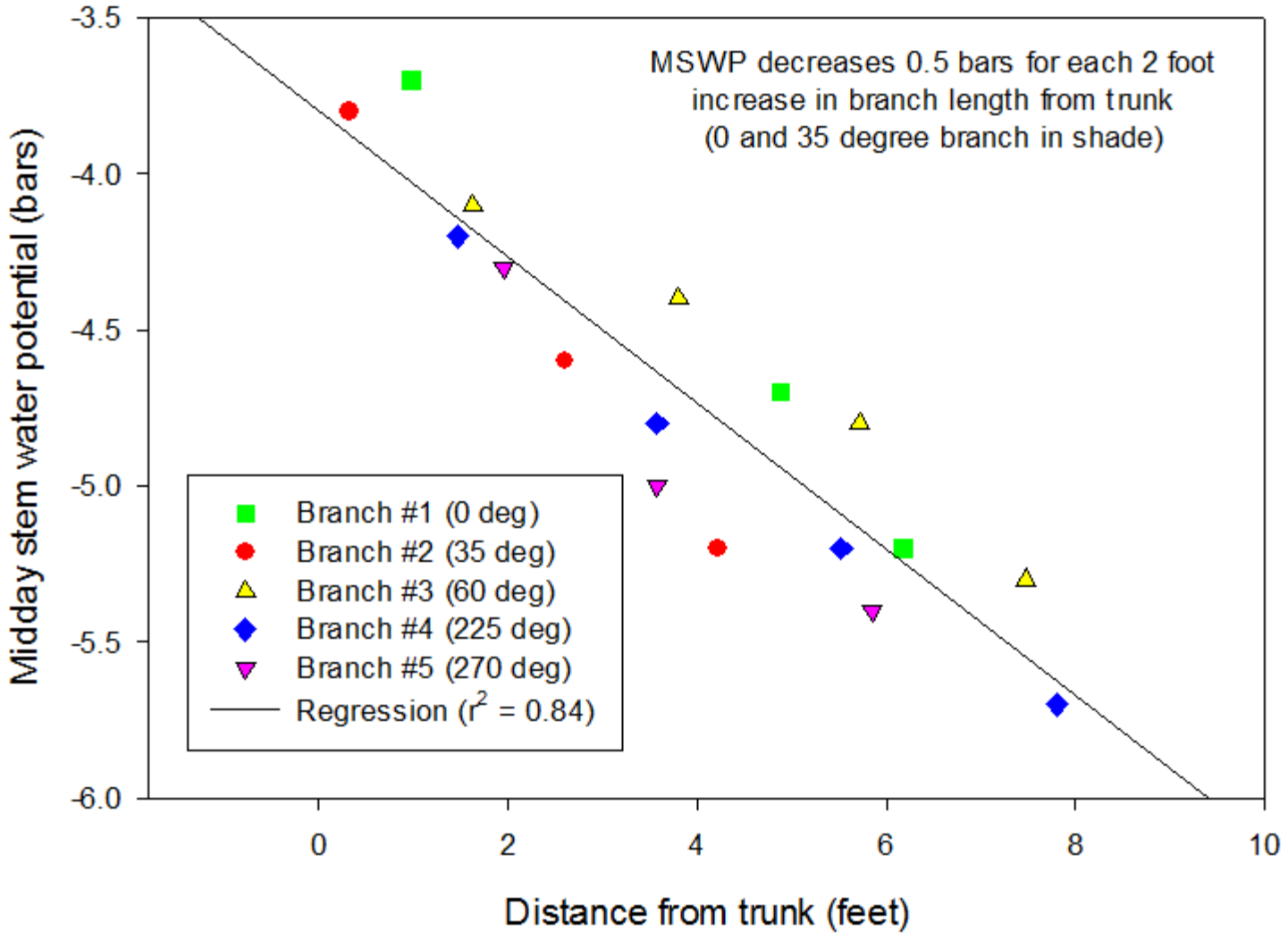
Does it matter where you hang your bags when doing MSWP?


Water potential

Water potential



Water potential



Trees that are too wet during the growing season will defoliate earlier in the fall

Irrigation issues

Fig. 9. Normal watered tree (left) and excess watered tree (right) on November 22, 2016. Note extensive defoliation on wet tree and healthy green leaves on normal watered tree.

Soil Moisture Equipment
Plant Pressure Chamber

ICT stem psychrometer

Phytec Dendrometer

Decagon D6 Dendrometer

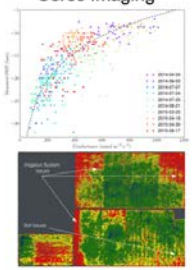
Zim Plant Technology
Magnetic Patch Clamp
Pressure Probe

ZIM-probe
plant microclimate
sensors

Decagon ECH2O 5TM FDR Sensor

Electrical resistance sensors

Ceres Imaging



Cermetek LeafMon

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.

Edaphic Scientific
Sap Flow Sensor

ICT Sap Flow Sensor

Dynamax Dynagage
Sap Flow Sensor

Irrometer Watermark

Soil Moisture Equipment
Plant Pressure Chamber

ICT stem psychrometer

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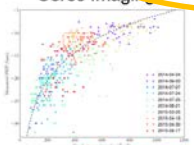

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Dynamax Dynagage
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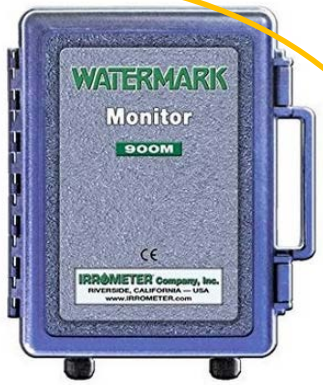
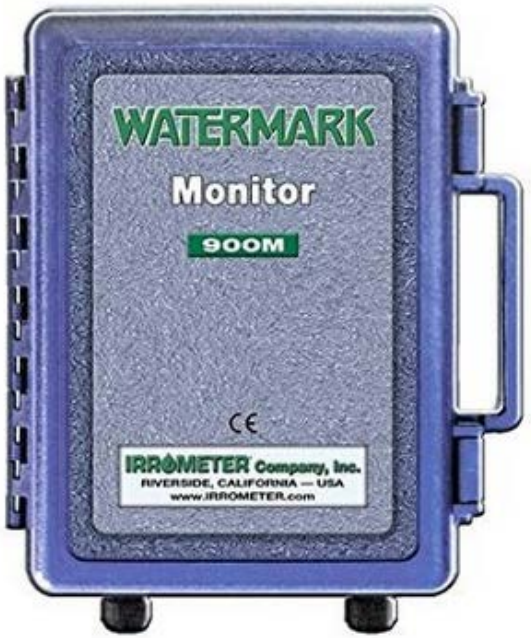


Irrometer Watermark

Watermark sensors for soil moisture monitoring- report in units of soil moisture tension



sensor hand reading meter datalogger

0 cbars = saturated soil
200 cbars = dry soil
Remember that 1 bar = 100 cbars
Normal range would be 20 cbars after irrigation and 70 cbars before irrigation

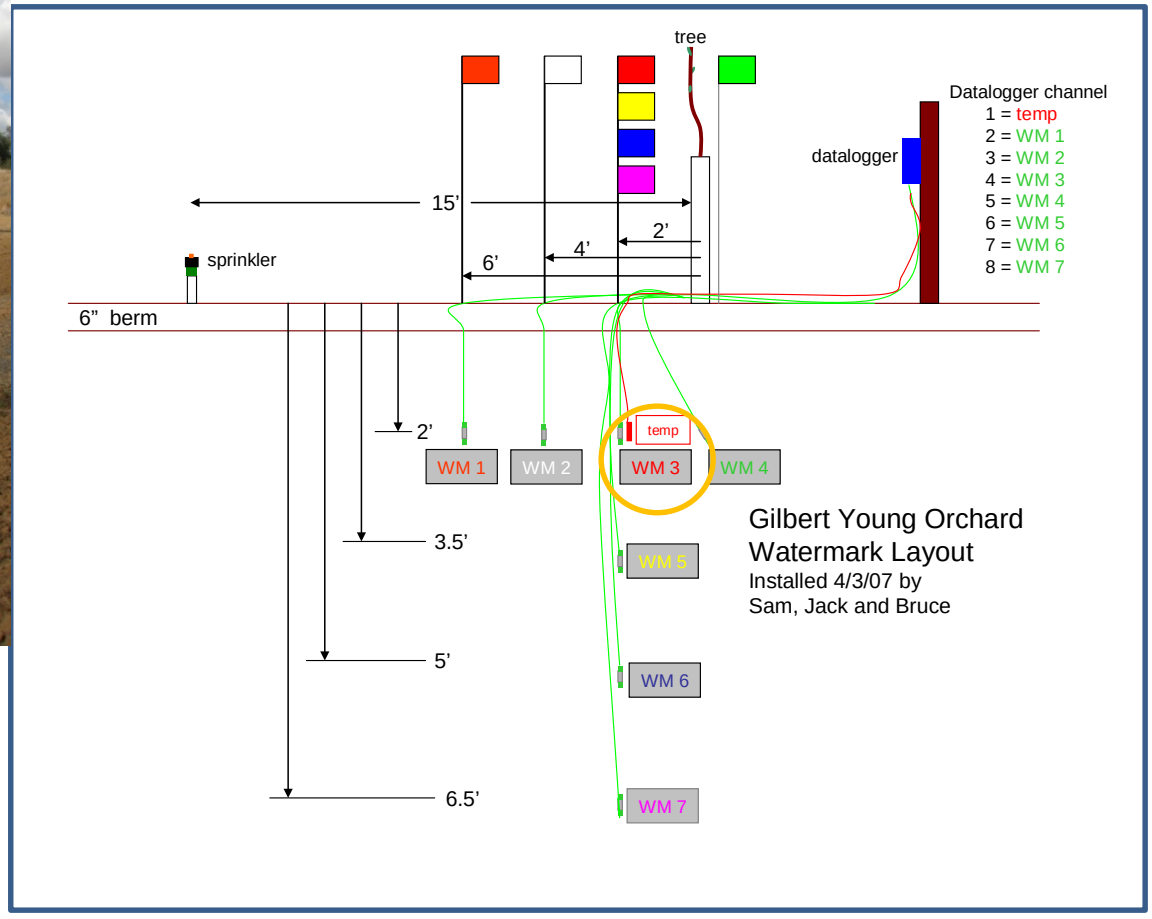
Coverage by type

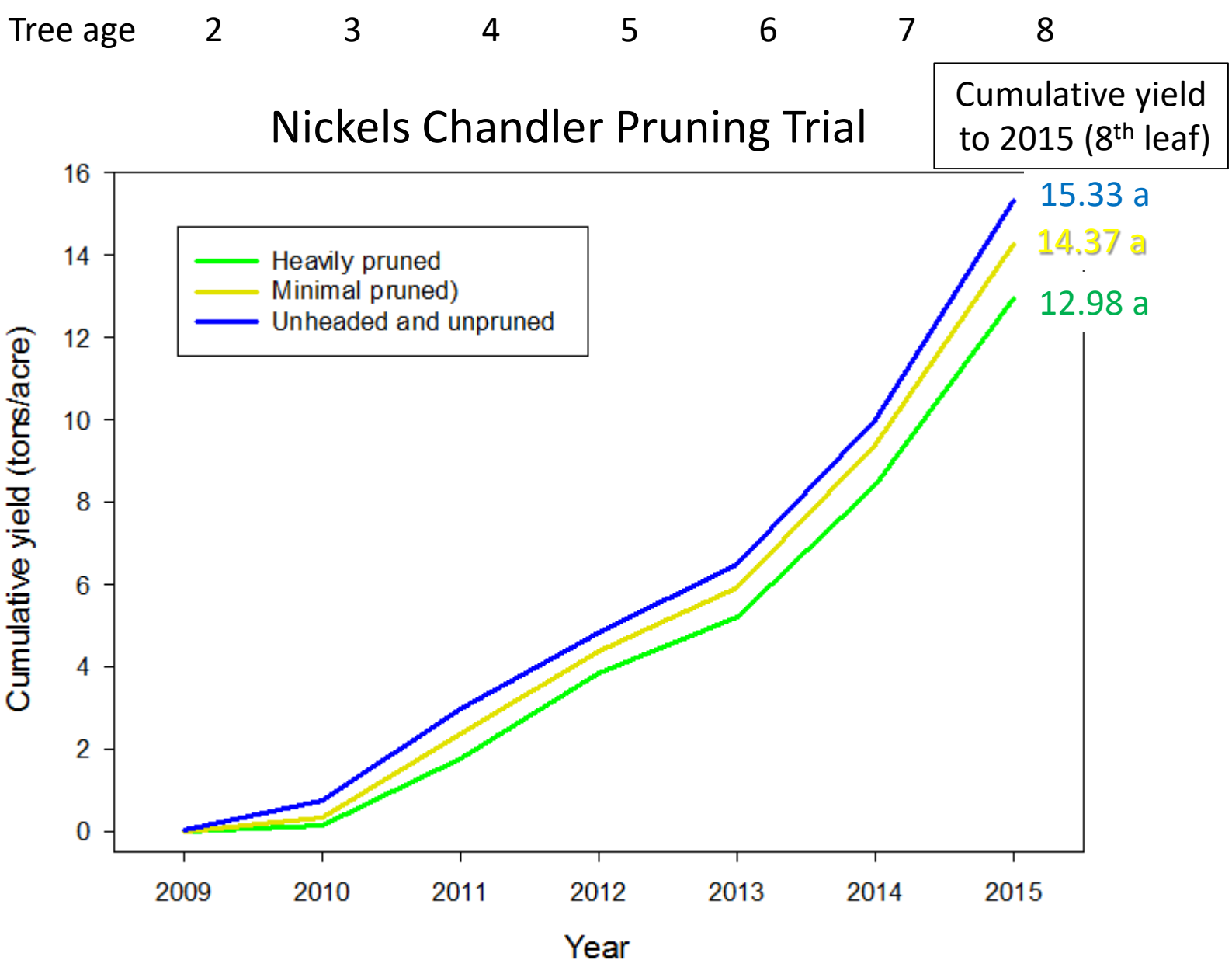
Irrigation type	Coverage
Flood	100
Solid set	80-100
Microsprinkler	~30-70
Double line drip	~20-40

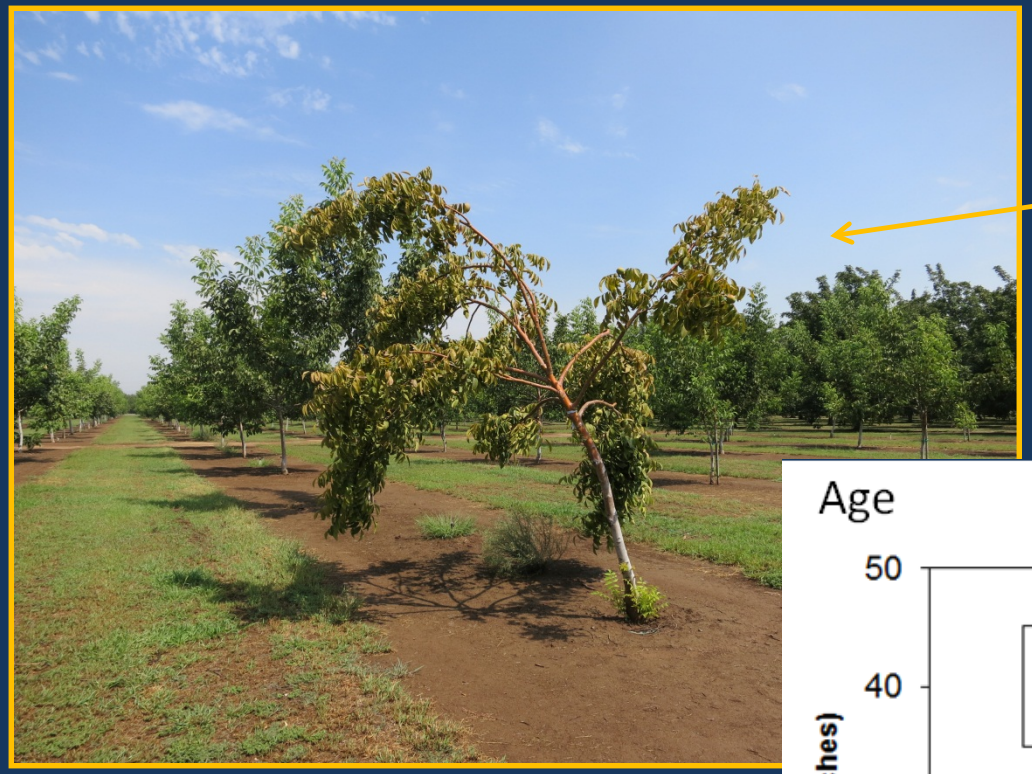
This makes it very difficult to use ET data to schedule irrigation since only a portion of water is within reach of roots when trees are young

Year 1- Watermark sensor at 2 feet in root zone agrees well with MSWP

With this full coverage system 80+% of the water is likely not available to the tree in year 1 so ET data not really useful

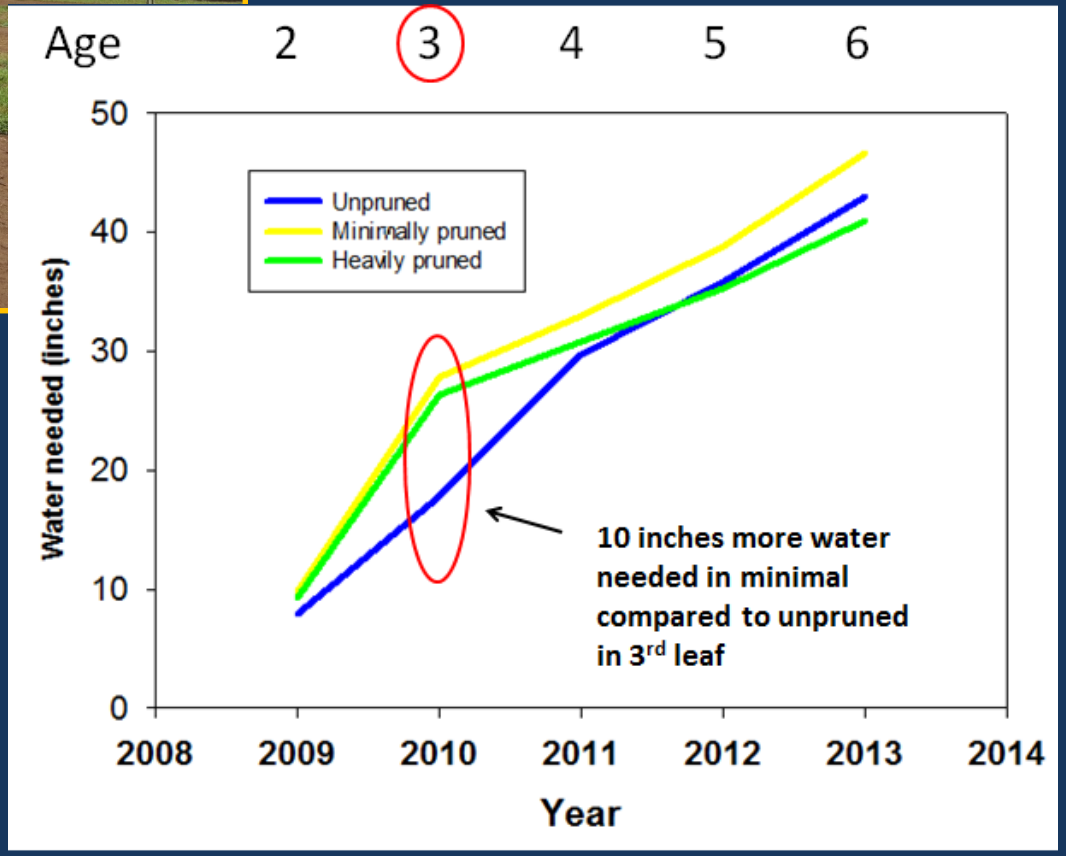



Tree age 2 3 4 5 6 7 8
Nickels Chandler Pruning Trial
Cumulative yield to 2015 (8th leaf)
15.33 a
14.37 a
12.98 a
Heavily pruned
Minimal pruned)
Unheaded and unpruned
Cumulative yield (tons/acre)
0
2
4
6
8
10
12
14
16
2009
2010
2011
2012
2013
2014
2015
Year



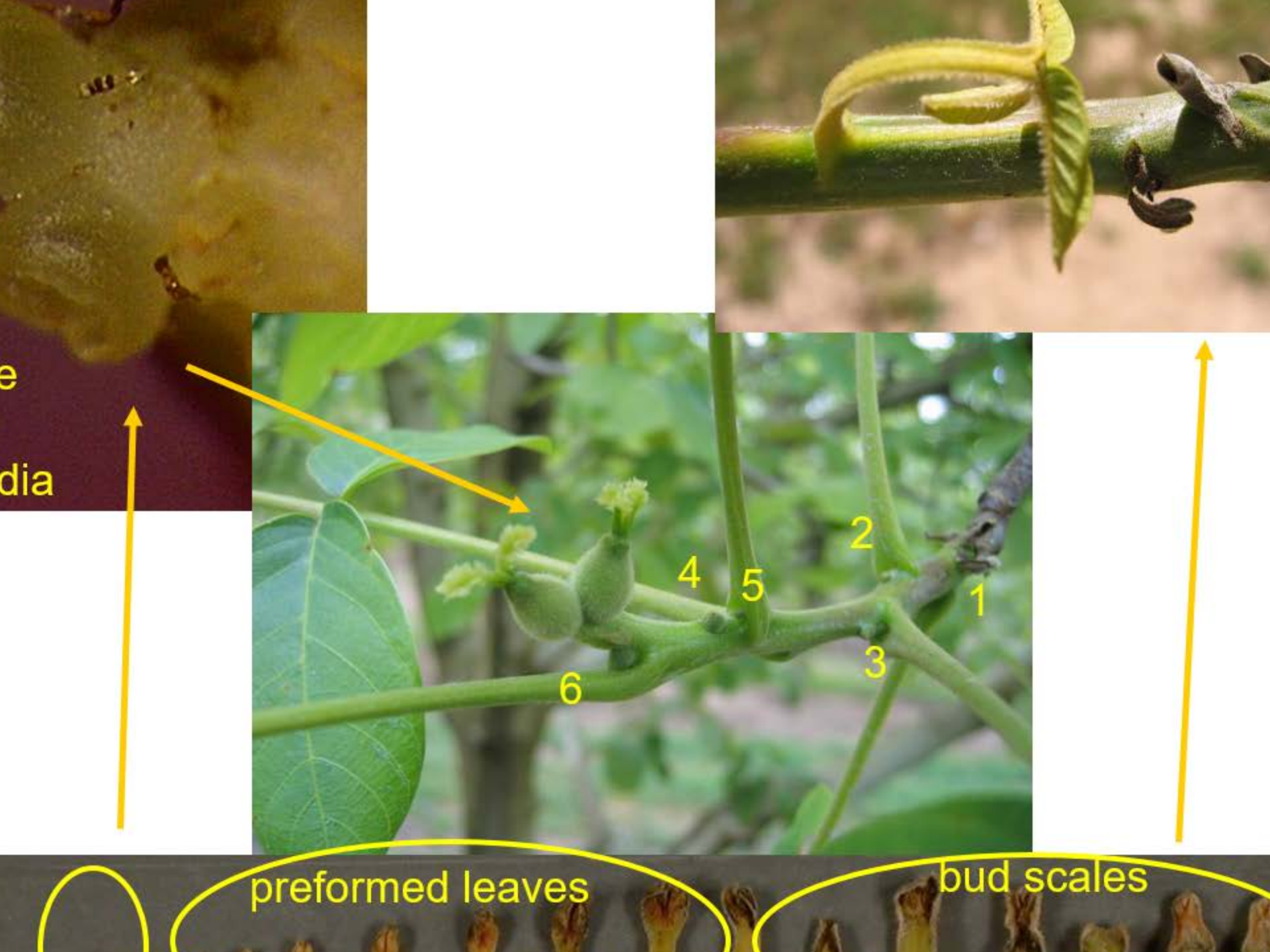
A tree that looks like this has stalled out from overwatering, not from lack of pruning

Based on canopy size, 10 inches more water needed for minimally pruned in 3rd leaf

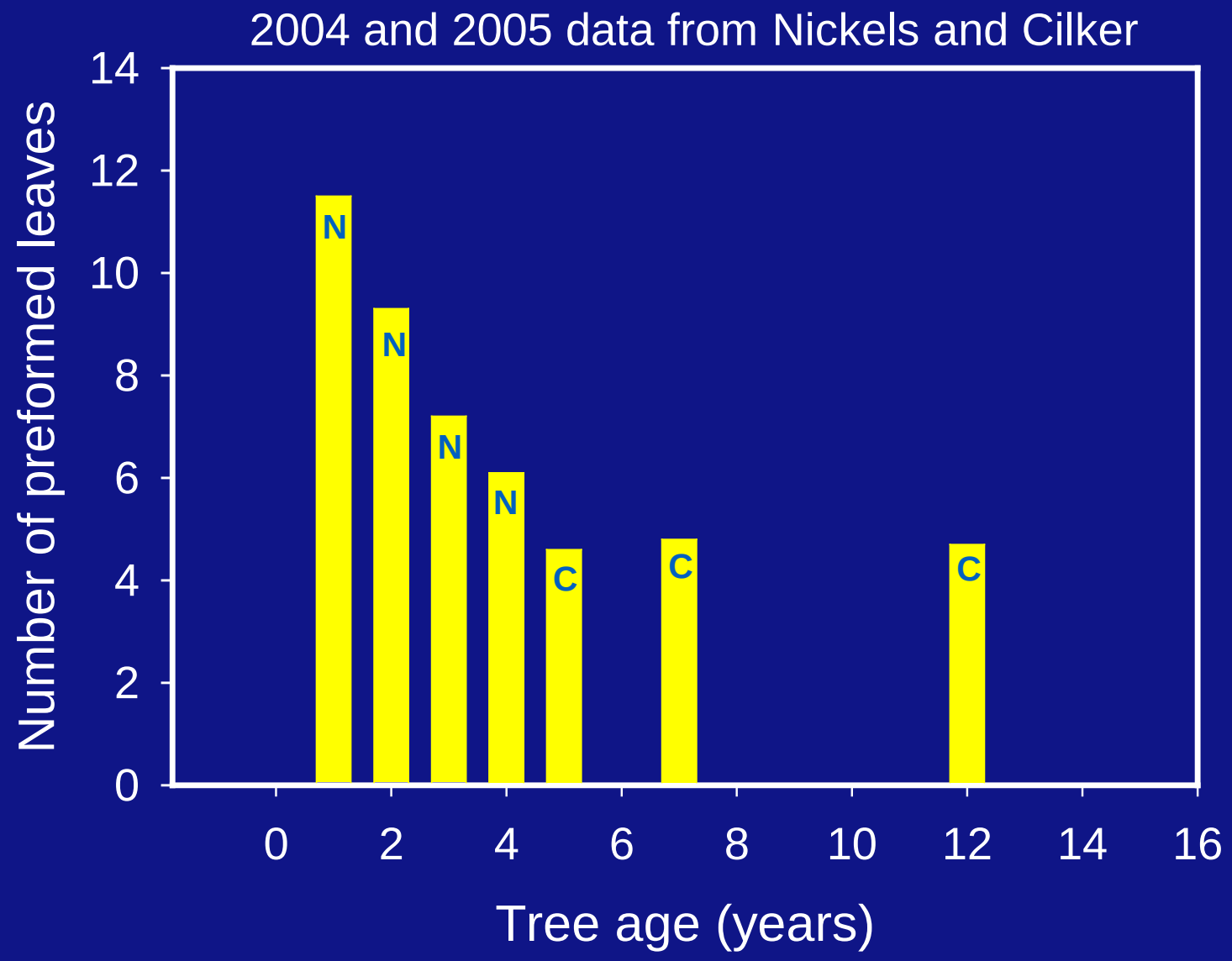


Water use efficiency for pruned versus unpruned treatments Years 2-6 summary

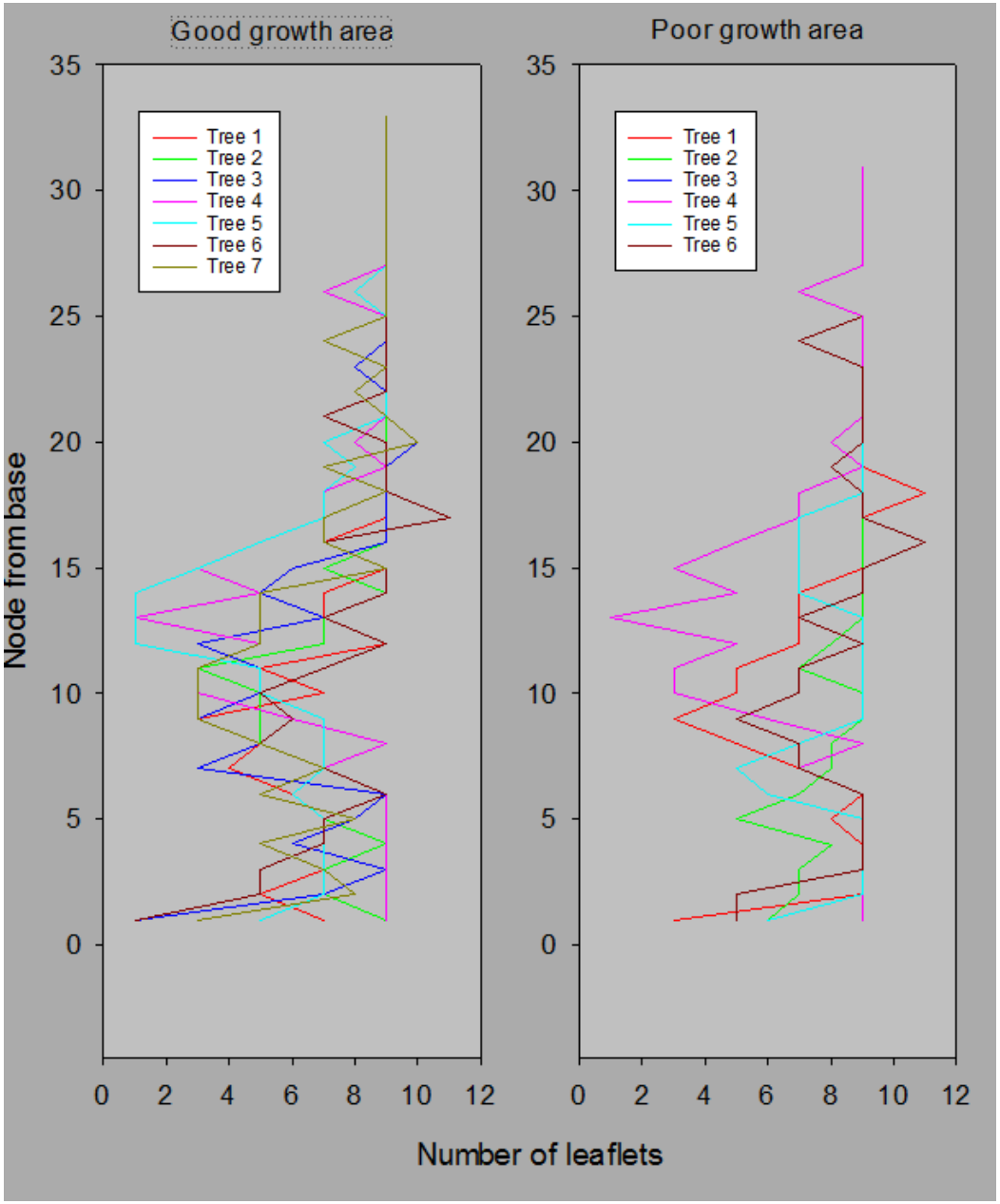
Treatment	Total water needed based on canopy size (years 2-6)	Cumulative yield (tons/acre)	Water use efficiency expressed as pounds of walnuts produced per inch of water applied	Water use efficiency (% of unpruned)
Unpruned	134	10.01	149	100
Minimally pruned	156	9.42	121	81
Heavily pruned	142	8.42	118	79


e
dia
2
4
5
1
3
6
preformed leaves
bud scales

Preformed leaves



Different numbers of preformed leaves can be formed due to environmental and physiological factors




Kaolin clay
Effect of kaolin spray
on
walnut gas exchange
Adolfo Rosati, Samuel Metcalf, Rick Buchner,
Lisa Zane, Allan Fulton, Ken Shackel, Bruce Lampinen

Why study kaolin?

Pest control

Sun burn

Water stress relief ?

In walnut: no information on the effects on water stress

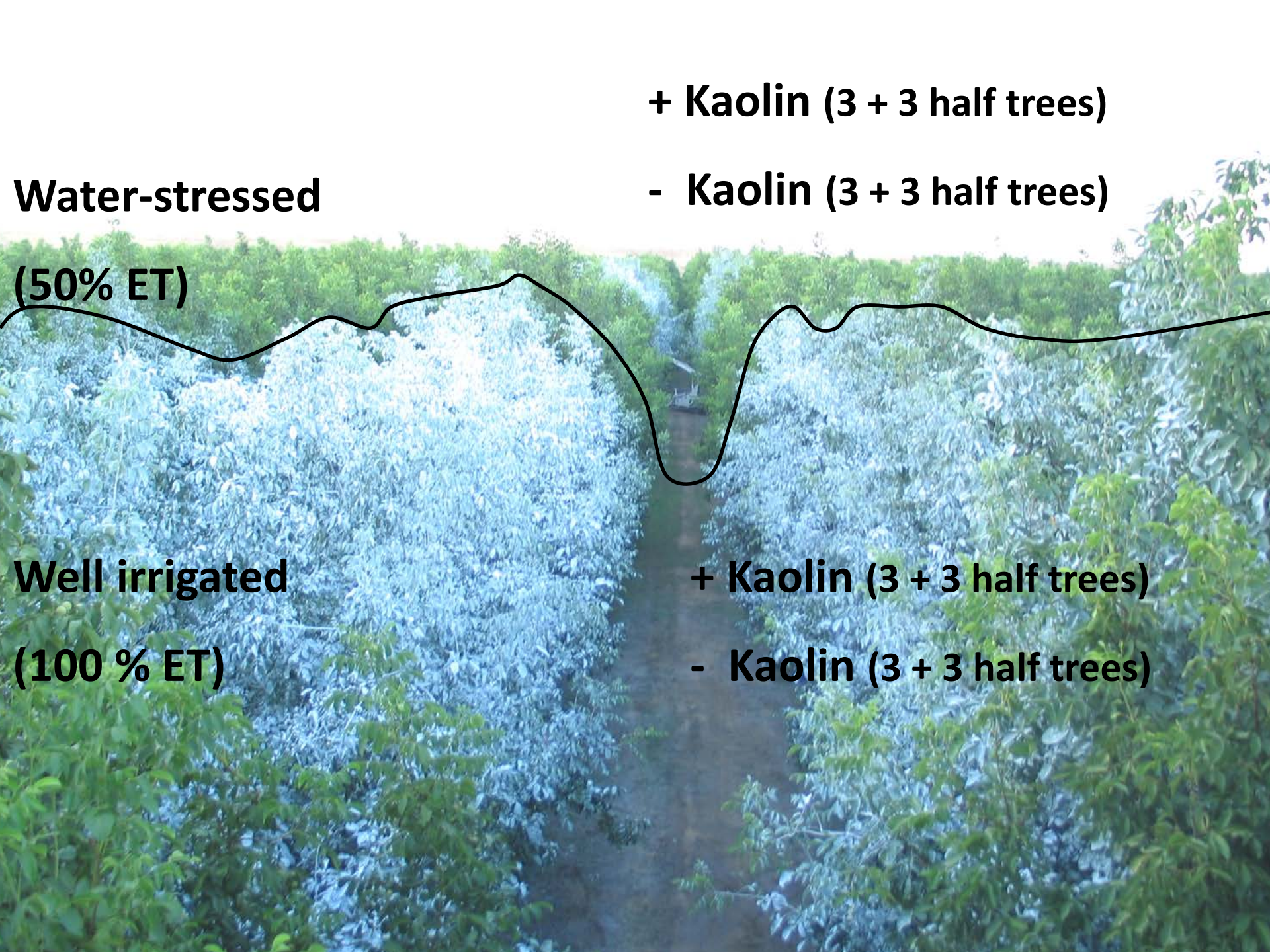
Objectives

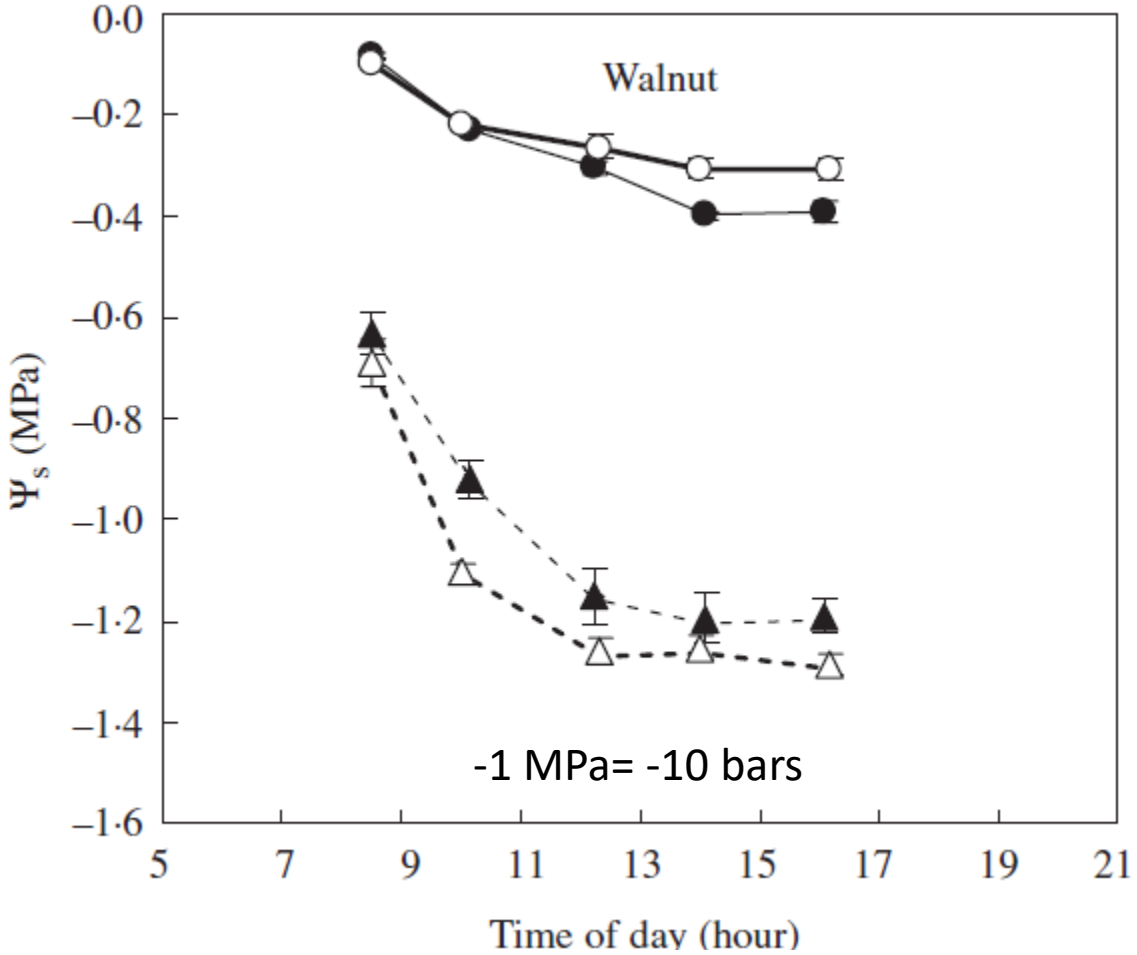
Effects of kaolin spray on

- Tree Water status (water potential)
- Gas exchange (Photosyn. Transp. etc.)
- Leaf temperature
- Light interception

In WELL-IRRIGATED and WATER-STRESSED walnut trees


What we did
We sprayed kaolin (6% Surround®) on the canopy, from above.


+ Kaolin (3 + 3 half trees)
- Kaolin (3 + 3 half trees)
Water-stressed
(50% ET)
Well irrigated
(100 % ET)
+ Kaolin (3 + 3 half trees)
- Kaolin (3 + 3 half trees)

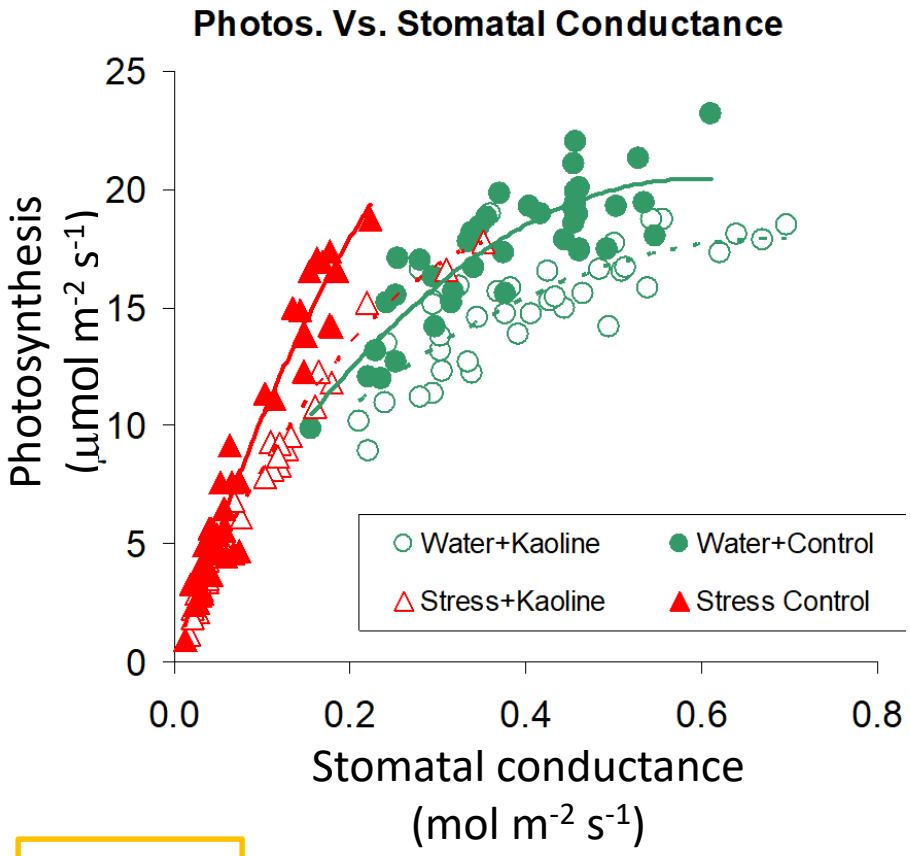


Annals of Botany **98**: 267–275, 2006
doi:10.1093/aob/mcl100, available online at www.aob.oxfordjournals.org

Physiological Effects of Kaolin Applications in Well-irrigated and Water-stressed Walnut and Almond Trees

A. ROSATI[1,*], S. G. METCALF[2], R. P. BUCHNER[3], A. E. FULTON[3] and B. D. LAMPINEN[2]

Kaolin clay



KAOLIN REDUCED (slightly) WATER-USE-EFFICIENCY

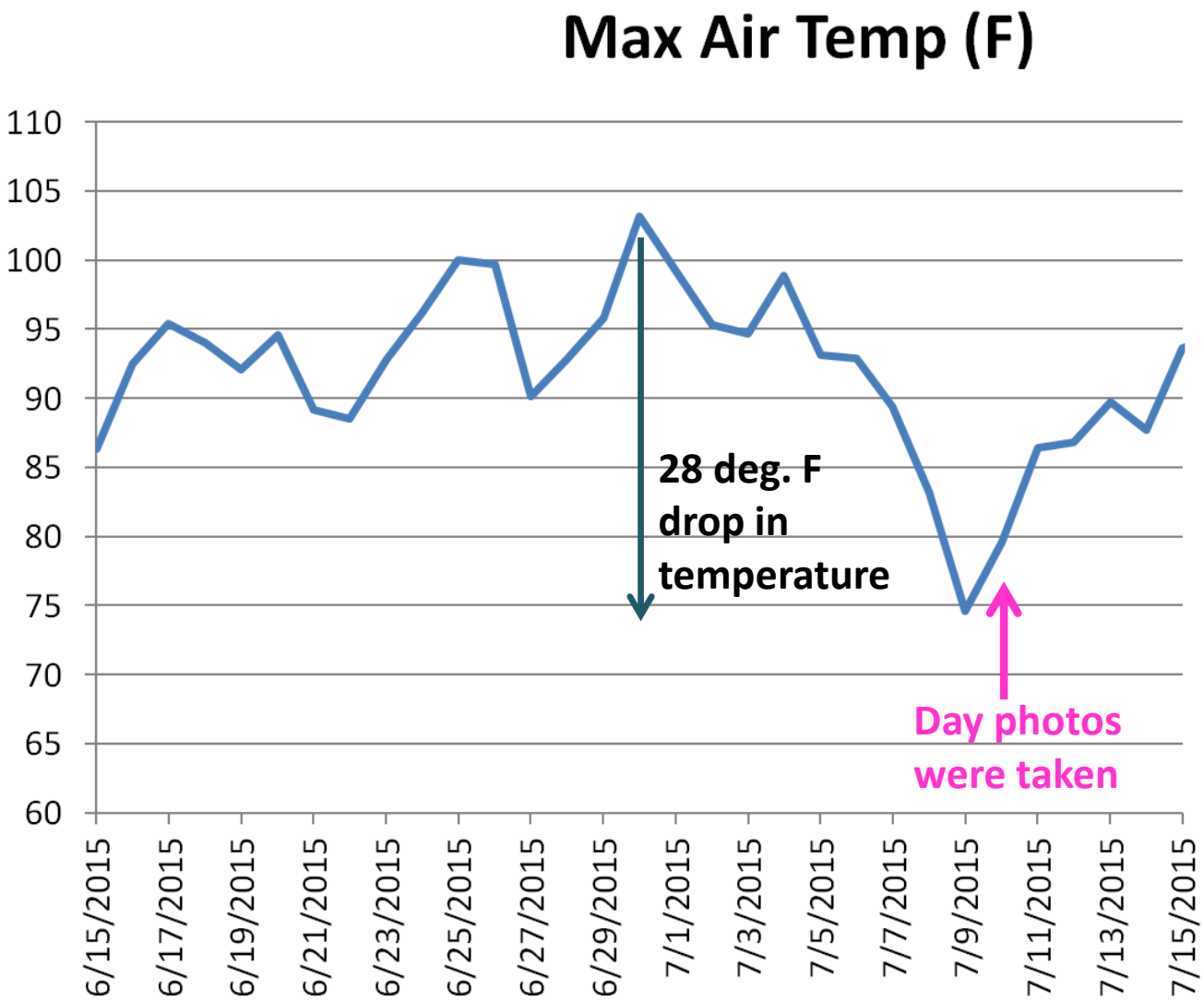
by reducing photosynthesis

without reducing

stomatal Conductance.

July 10, 2015 on Highway 45 south of Chico, almost all orchards had yellow neoformed shoots

July 10, 2015 on campus trial also had yellow neoformed shoots on excessively wet trees only

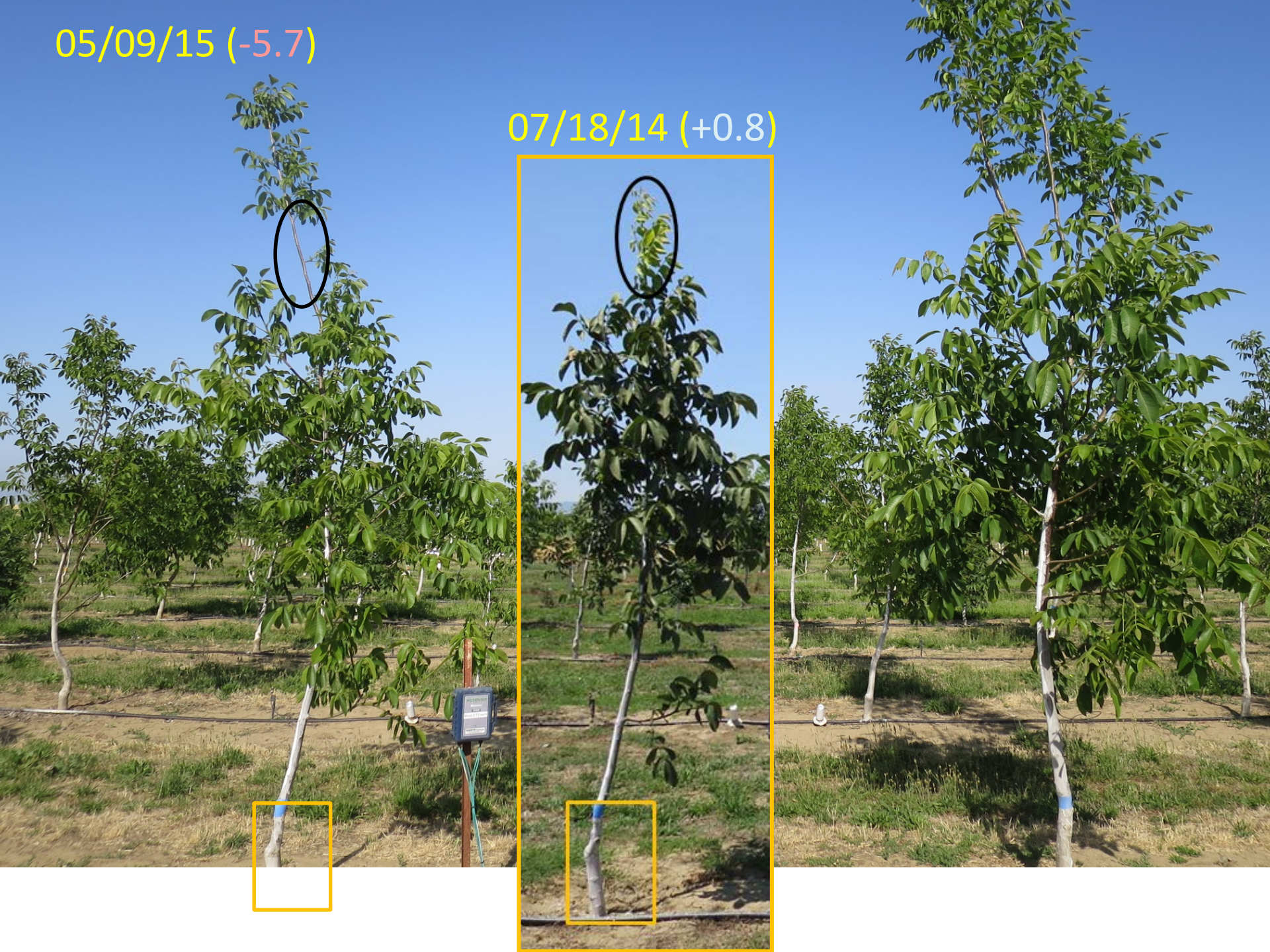

Max Air Temp (F)
110
105
100
95
90
85
80
75
70
65
60
6/15/2015
6/17/2015
6/19/2015
6/21/2015
6/23/2015
6/25/2015
6/27/2015
6/29/2015
7/1/2015
7/3/2015
7/5/2015
7/7/2015
7/9/2015
7/11/2015
7/13/2015
7/15/2015
28 deg. F drop in temperature
Day photos were taken

Summer 2016 on Highway 45 south of Chico, almost all orchards had poodletails

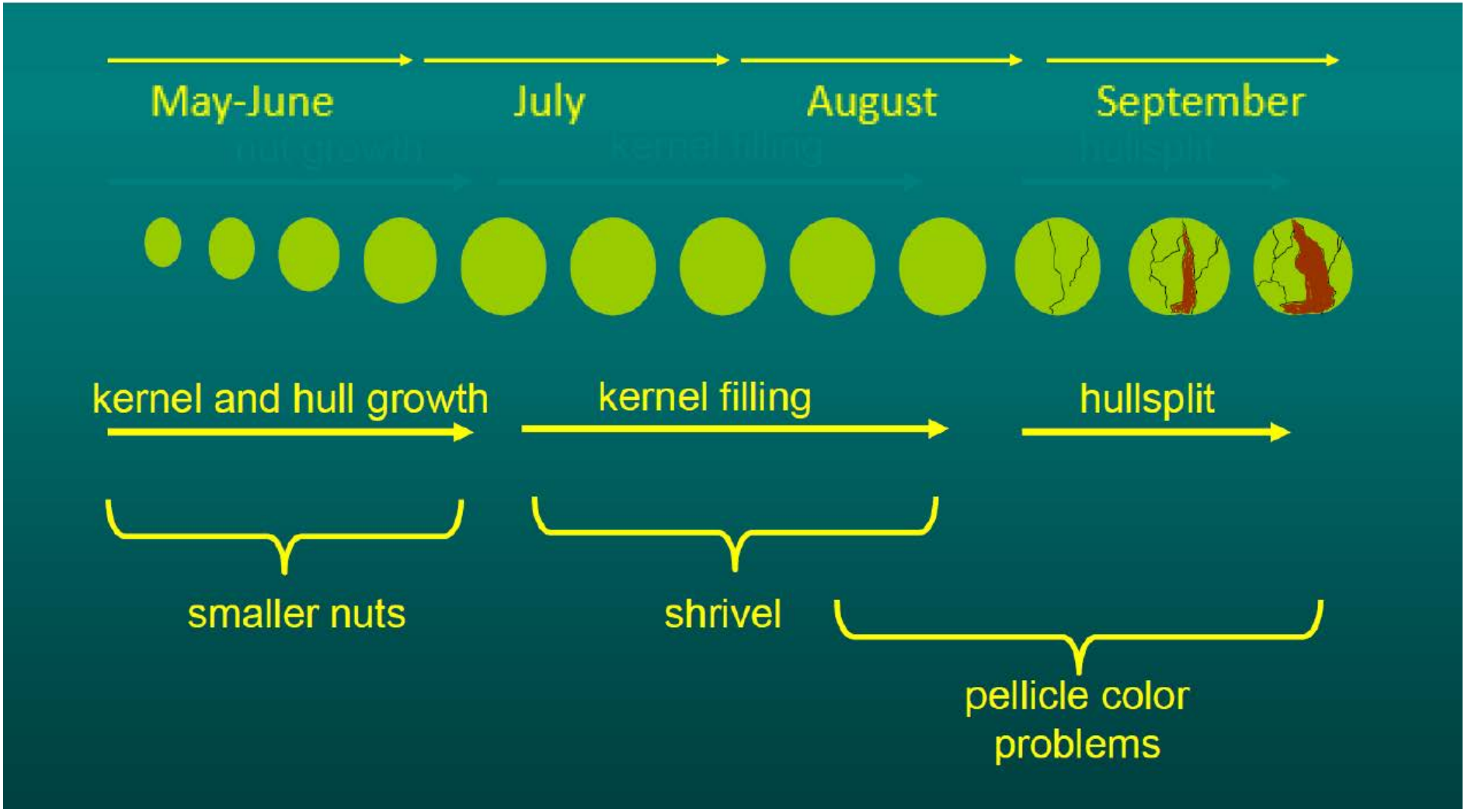

07/18/14 (+0.8)
If elongating shoots turn yellow during mid to late summer…


11/24/14
The areas that were yellow will defoliate earlier in the fall


05/09/15 (-5.7)
And the following spring these areas will be blank (poodletails)


05/09/15 (-5.7)
07/18/14 (+0.8)

Stress Impacts on quality



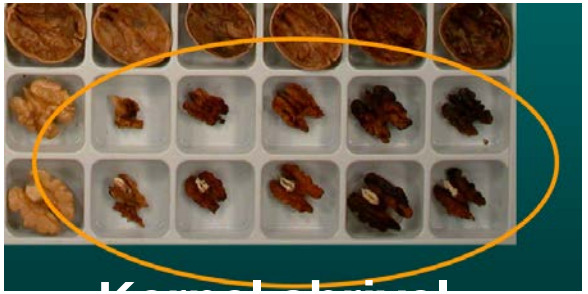
Nut quality problems can be associated with current year conditions or previous year conditions

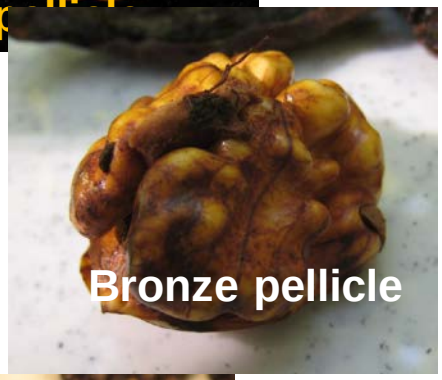
Current season carbohydrate deprivation resulting from water stress (lack or excess) and/or shading related leaf loss

Symptom	Timing
thin shell	early June
severe shrivel	early July
slight shrivel	early August
yellow pellicle	early August
black pellicle	mid-August
bronze pellicle	late Aug/early Sept

Previous season insufficient carbohydrate storage during bud formation resulting in small leaves and small nuts in current season. Likely associated with buds that developed in shaded positions the previous year.

- Very weak bud = pee wee nut
- Relatively weak bud = brown adhering hull





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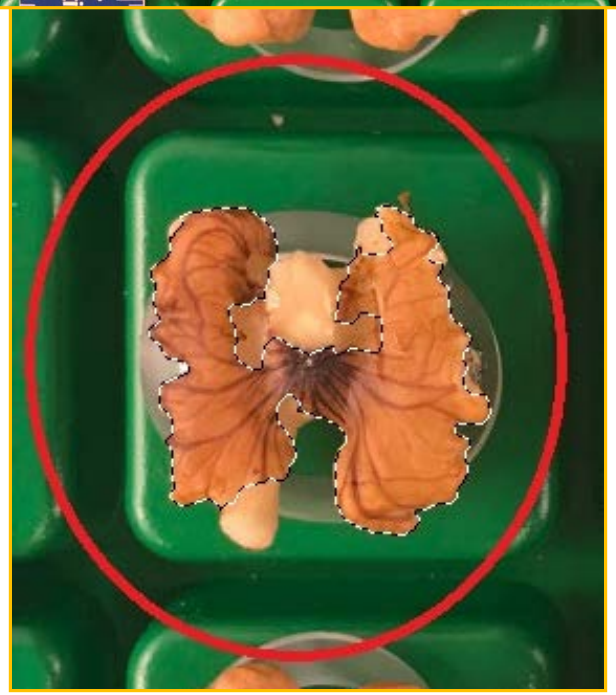
Maximizing walnut quality to improve value in a low-price year

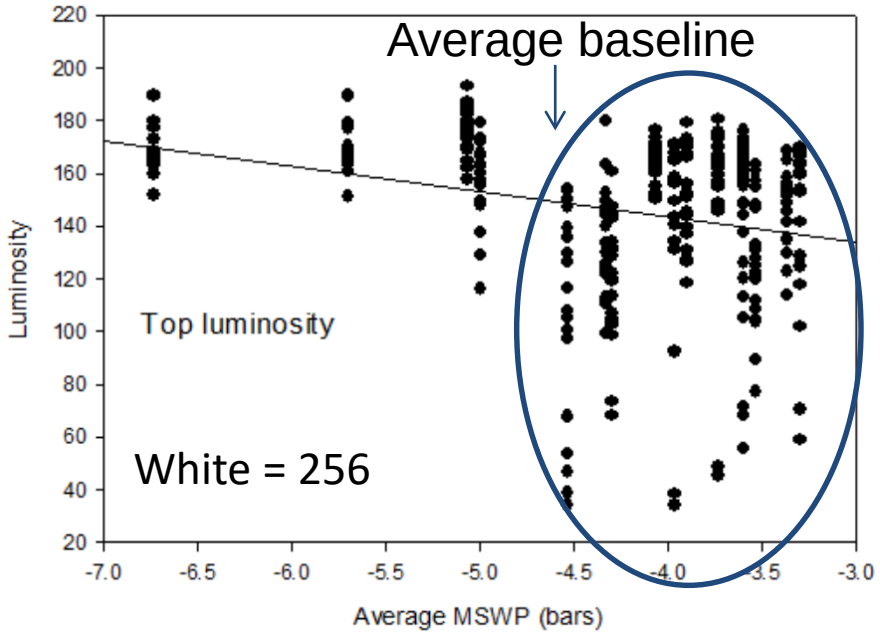
Home > Walnuts > Cost And Expense Considerations

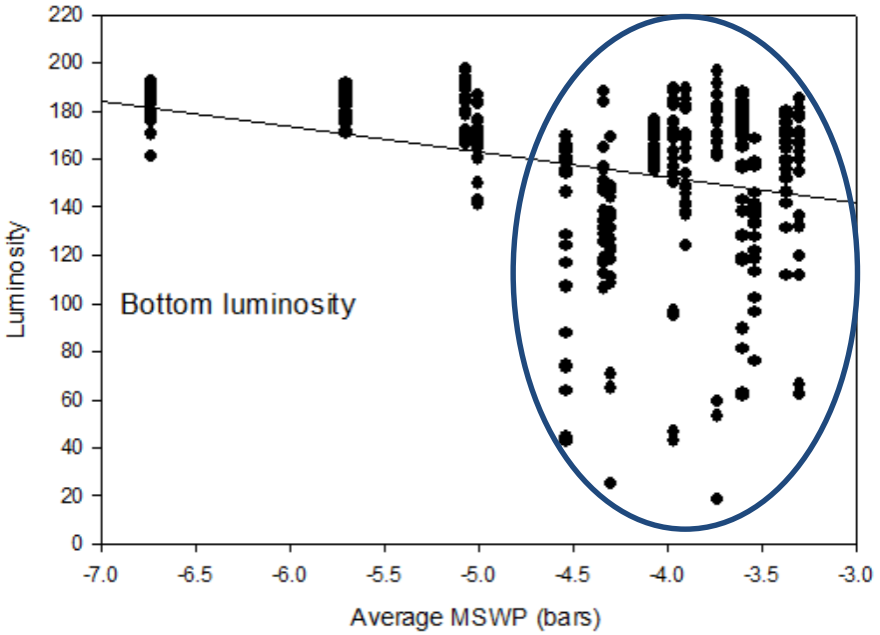
Posted on July 15 2019 by Sacramento Valley Orchards

Elizabeth Fichtner, UCCE Farm Advisor, Tulare County; Carlos Cristosto, CE Specialist, Postharvest Physiology; Bruce Lampinen, CE Specialist, Plant Sciences

We also did a study looking at variability in quality within trees for the most and least stressed trees



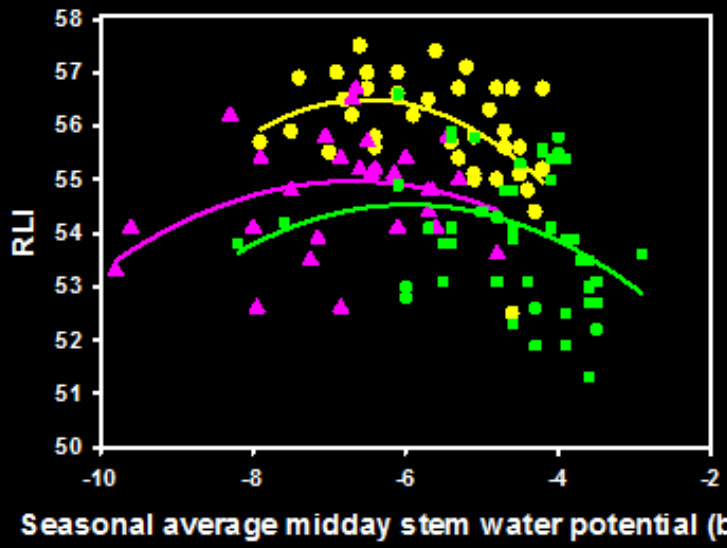


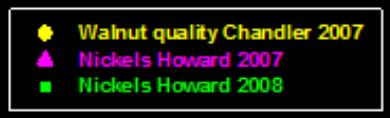


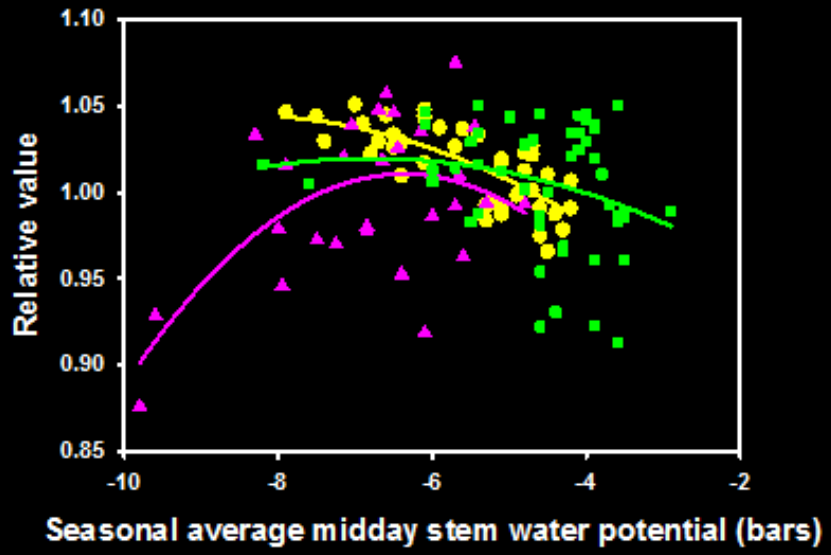
Darker pellicle

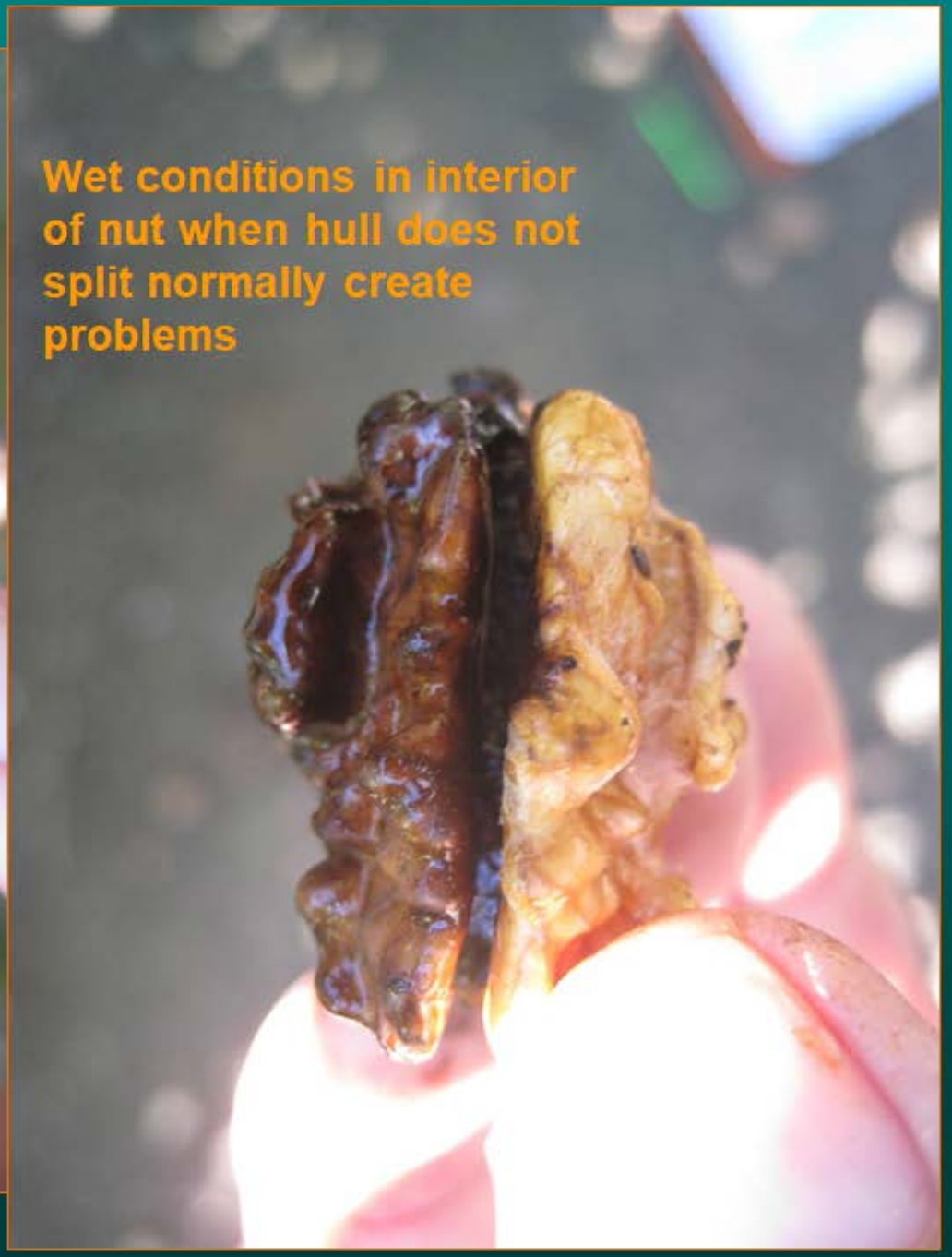
wetter

wetter →


RLI
58
57
56
55
54
53
52
51
50
-10
-8
-6
-4
-2
Seasonal average midday stem water potential (bars)


Walnut quality Chandler 2007
Nickels Howard 2007
Nickels Howard 2008


Relative value
1.10
1.05
1.00
0.95
0.90
0.85
-10
-8
-6
-4
-2
Seasonal average midday stem water potential (bars)



Nickels Soil Lab Howards 9/30/08

Healthy leaf

Leaf damage symptoms observed only on excessively wet trees

Damage symptoms from excessively wet conditions


Damage symptoms from excessively wet conditions


Damage symptoms from excessively wet conditions

Damage symptoms from excessively wet conditions

Damage symptoms from excessively wet conditions

Damage symptoms from excessively wet conditions

I like to use a combination of soil moisture and plant based data to manage water

- Year 1- Watermark in root zone plus MSWP
  - May be able to use Watermark once you establish relationship
- Years 2 on- Watermark plus MSWP can be used effectively
  - Which depth of sensor agrees best depends on previous year water management, winter rainfall, etc.
  - Following a dry winter, sensor at 3 foot might agree better with MSWP while after wet winter 1 to 2 foot depth might agree better
  - Once you figure out this relationship for season can use Watermark sensors as main data and check periodically with MSWP

What about evapotranspiration (ET) data?

- As data from Kari showed, ET can be quite misleading since a large part of tree water demand can be met from stored soil moisture in many years.
- ET data can be useful for estimating how much water should be applied since the last irrigation

In general, I prefer to use a combination of midday stem water potential (MSWP) and soil moisture (Watermark) data

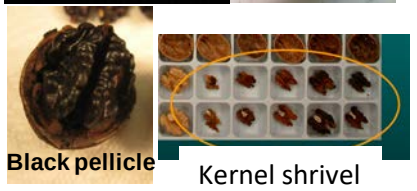
- Let MSWP fall about 1.5 to 3 bars below the fully watered baseline before initiating irrigation
- Make sure that trees are not wetter than the fully watered baseline after irrigating
- Make sure that lower soil moisture is drying out over the season

If you see these things…..

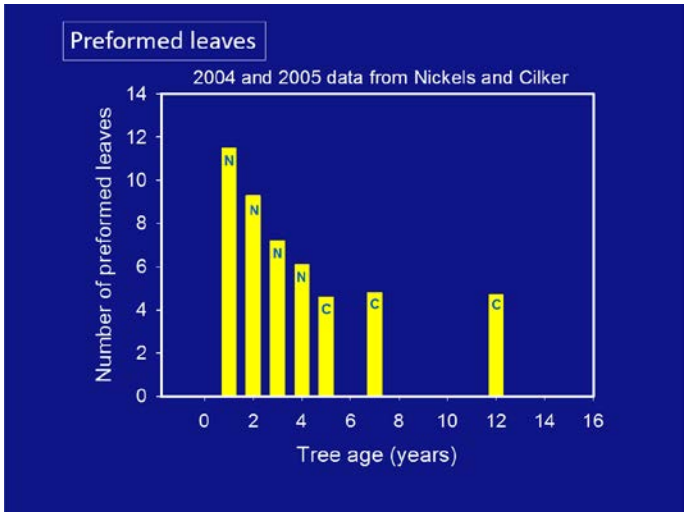
Distorted leaves, leathery leaves, purple veins, pellicle color problems, kernel shrivel, no neoformed growth, lots of black hulls in lower canopy- think water management problems in the current year







Poodletails, smaller number of preformed leaves than normal- think water management problems last year



Thanks to the California Walnut Board and Diamond Foods Inc. for funding this work

Questions?