Potential Impacts of Water Stress in Walnut on Yield and Quality

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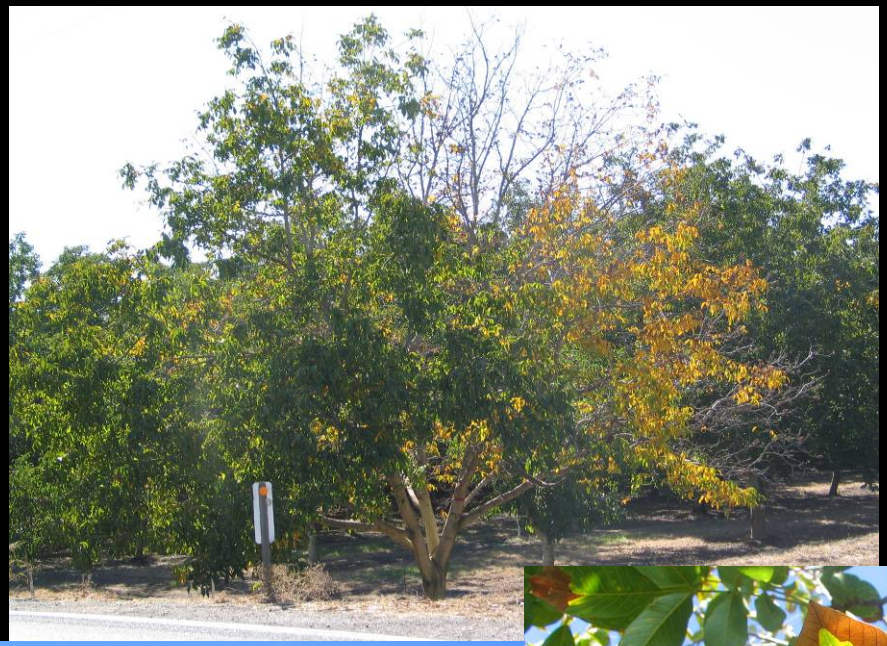
Topics I will cover

- Symptoms of over and under-irrigation in walnut
- Impacts of water management on canopy development
- Relationship between midday canopy light interception and yield
- Impacts of canopy light distribution and stress on quality

Typical appearance of a tree that was too wet in spring- likely will be water stressed later in summer due to compromised root system

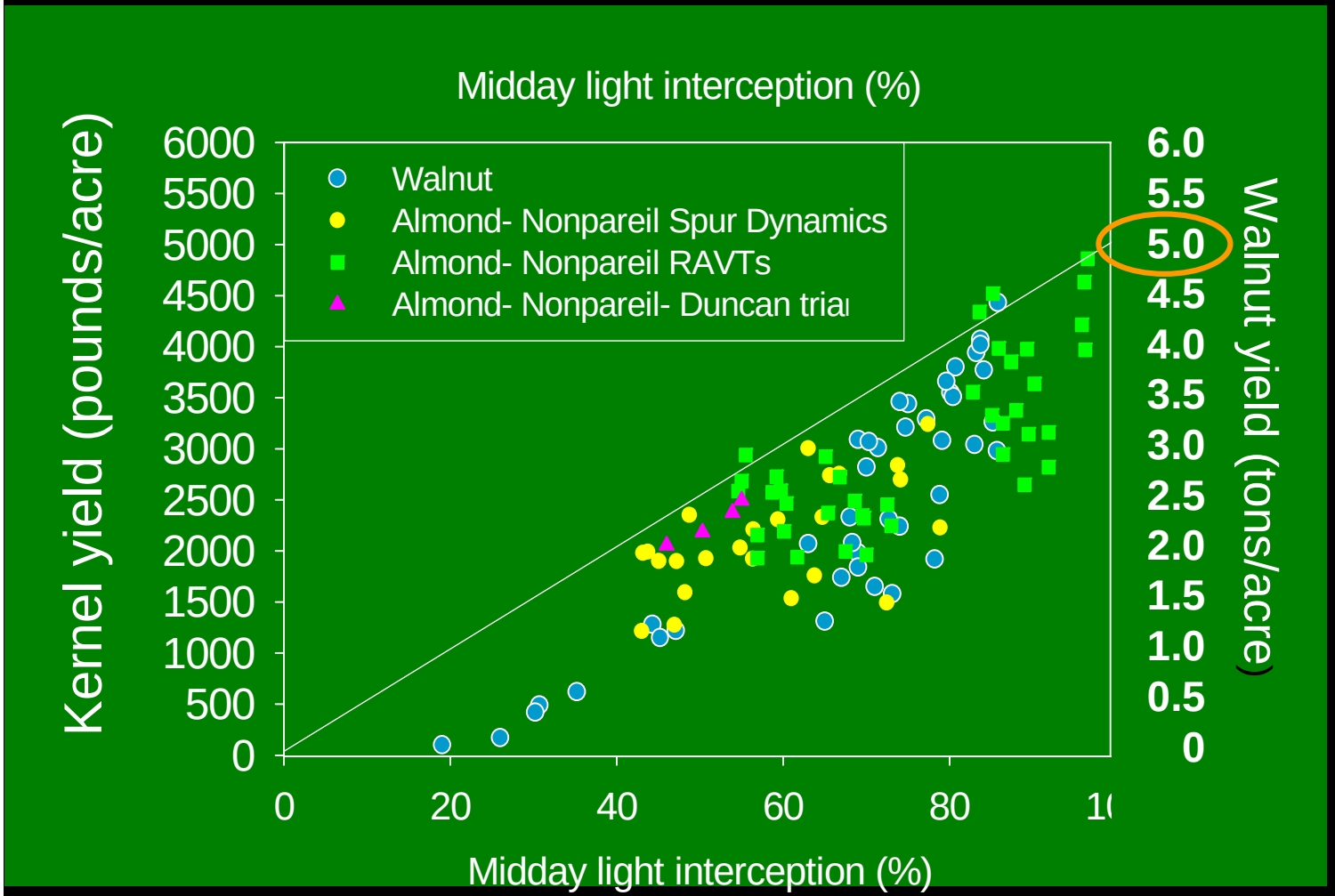


All of the examples on this slide were trees that we pressure bombed and were found to be overly wet.

Whenever you see any of these symptoms look at your water managment

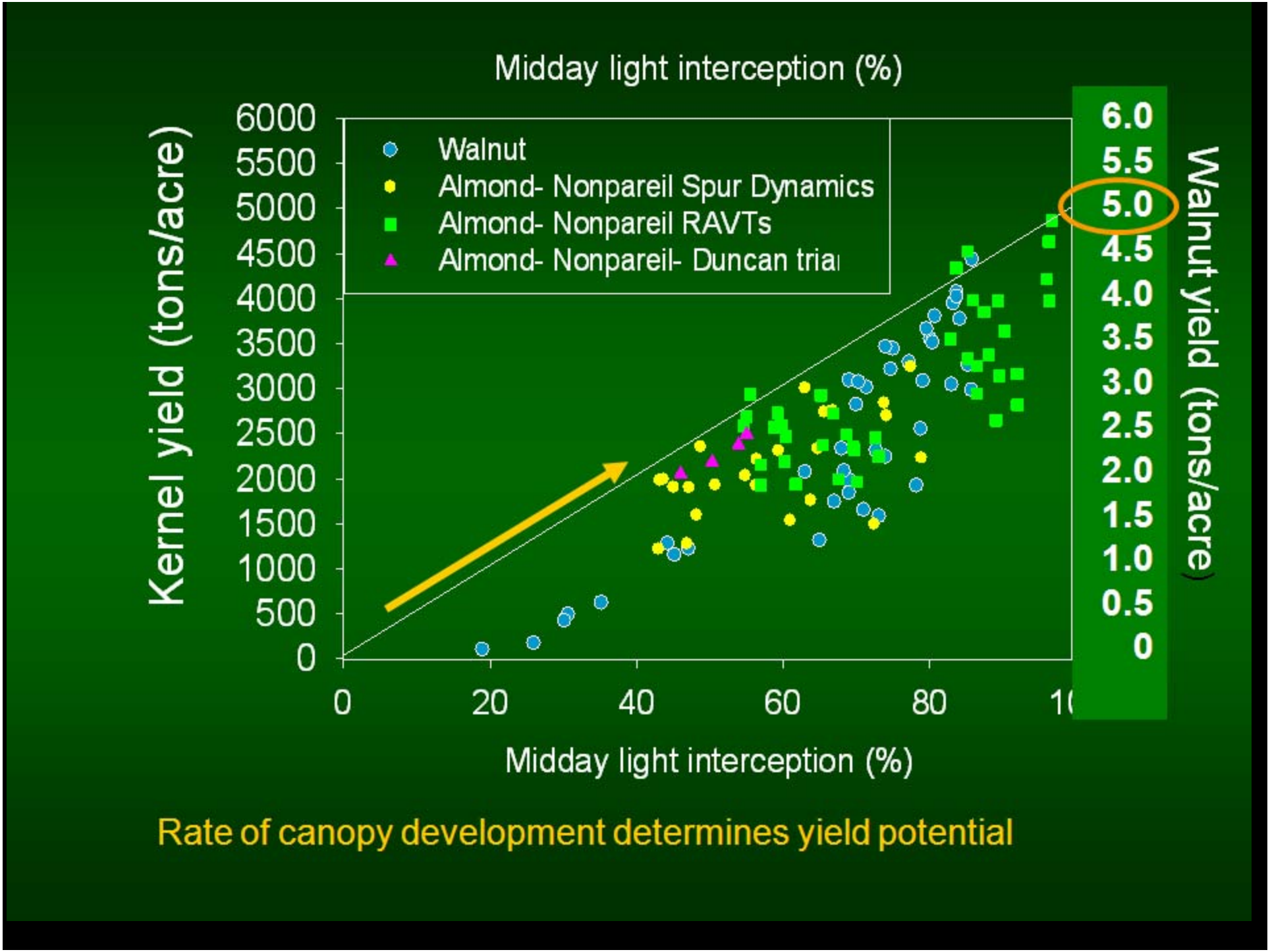
Leaf symptoms of over-irrigation in walnut- often on outer canopy leaves but can be anywhere

Leaf symptoms of under-irrigation in walnut- usually yellowing and drop of inner canopy shaded leaves

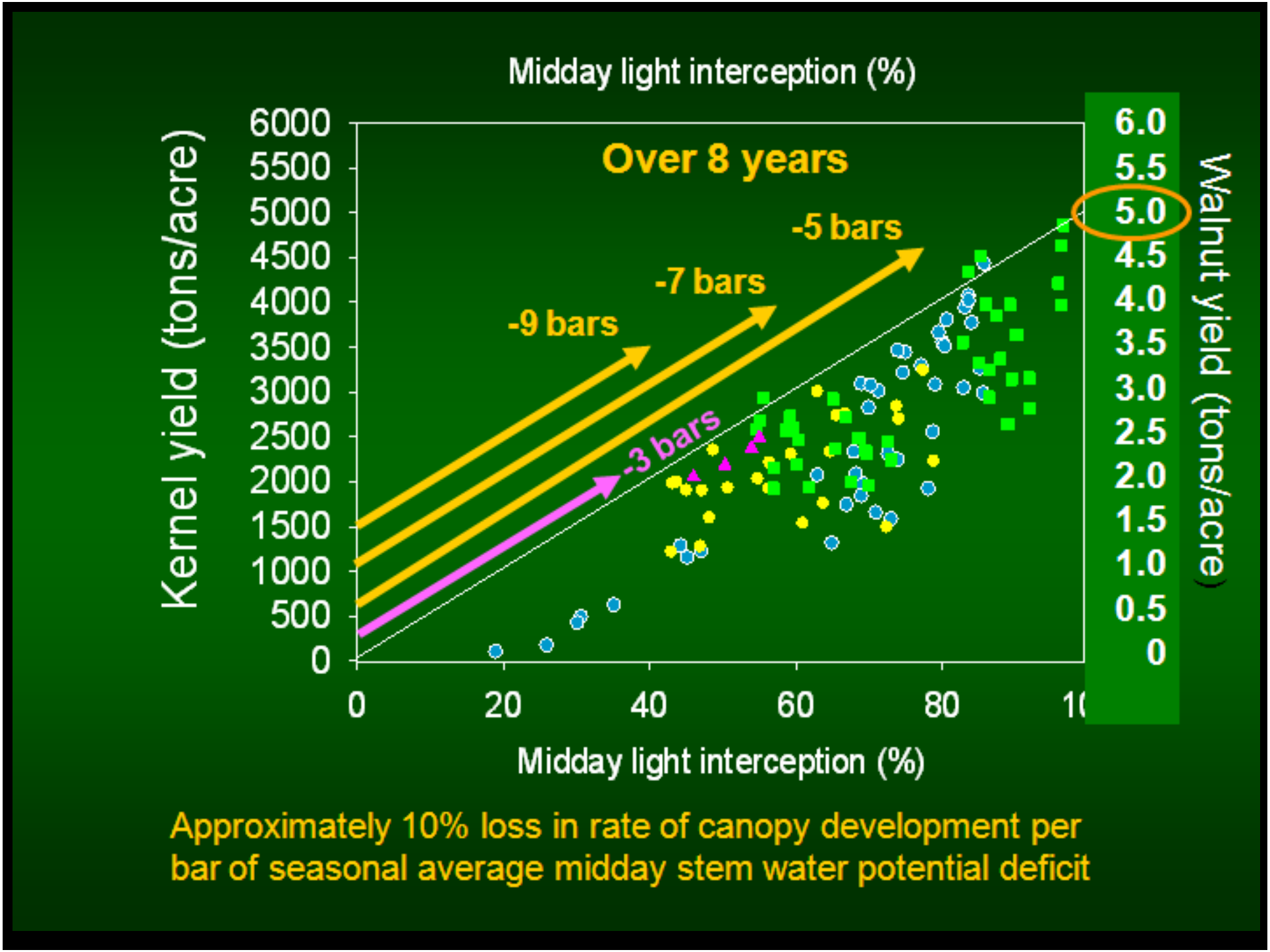


Production potential is about 0.5 t/ac for walnut or 500 kernel pounds/ac of almond for every 10% of incoming light intercepted

The white line is the maximum potential yield. Any number of factors can decrease your orchard yield relative to it's potential including water stress (excess or deficit), disease pressure, poor bloom weather, poor nutrient management etc.



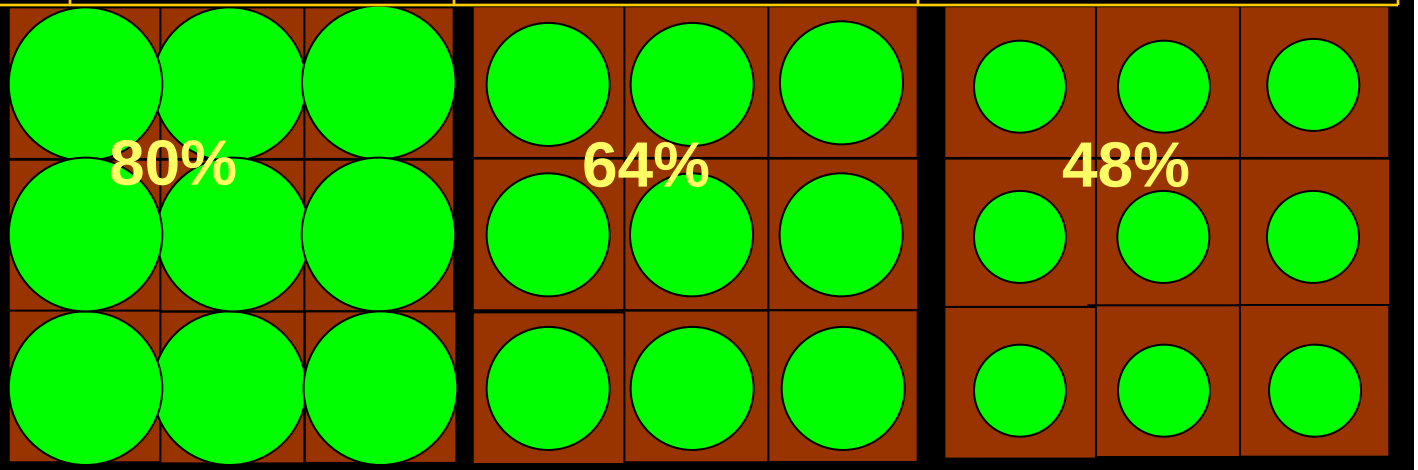
Rate of canopy development determines yield potential



Approximately 10% loss in rate of canopy development per bar of seasonal average midday stem water potential deficit

After nine years at a seasonal average midday stem water potential of:

	-5 bars	-7 bars	-9 bars
Yield (tons/ac)	4	3.2	2.4
Cum. yield	18.0	14.0	10.8
Cum. dollars	$36,000	$28,000	$21,600
Per acre loss		-$8,000	-$14,400



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

10/5/2007

Poor growth area

Good growth area

9/15/2008

Poor growth area

Good growth area

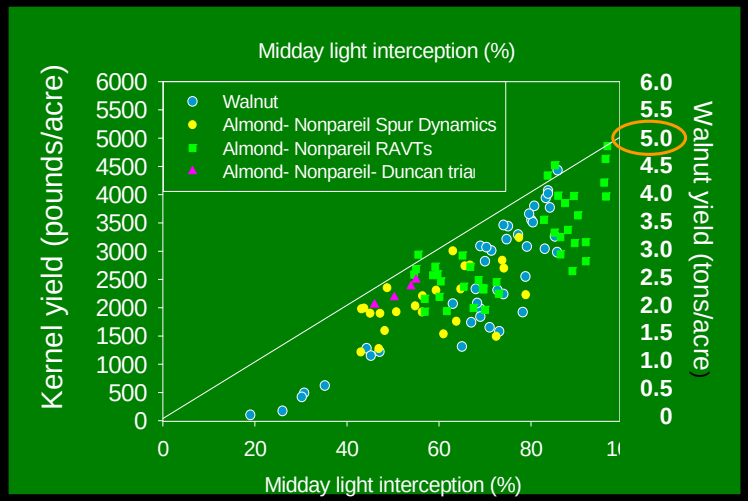
9/09/2009

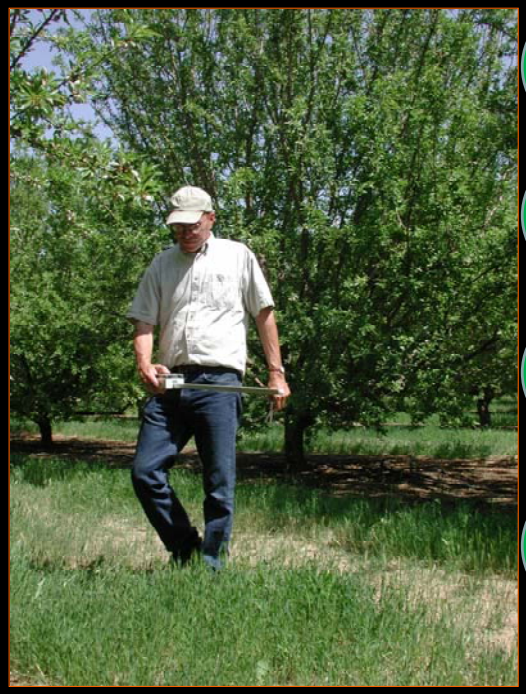
Poor growth area

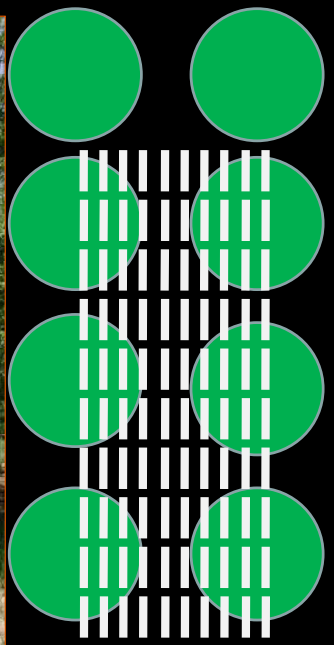
Good growth area

	Trunk circ (cm)	Tree height (ft)	Midday canopy light interception (%)
Poor growth area	31.3 b	16.21 b	11.1 b
Good growth area	51.8 a	24.97 a	24.2 a

- Data used to generate graph below was developed comparing light bar data and yield data from numerous trials
  - However, yield data and light data are usually covering the same area, hence there is a lot of variability in data
    - Limited in how much light bar data we can collect with hand method







Mule light bar

640 photodiodes active in PAR range
IR thermometers for soil surface temp
Sub meter GPS- used outside orchard
Radar used within orchard
Campbell Scientific CR3000
Display on dashboard
Adjustable to row widths from ~18-28 feet
Travel about 10km/hr- gives one scan about every 30 cm

Infrared thermometers for measuring soil surface temperature

Reference weather station set up on site

- PAR
- Temp/RH
- Wind speed/direction

Data logged at one minute intervals and used to calibrate Mule lightbar

County	Site	Variety	Date mapped
Colusa	Nickels Chandler pruning trial Arbuckle	Chandler	07/29/09 and 08/08/09
Colusa	Nickels Howard pruning trial Arbuckle	Howard	07/29/09 and 08/08/09
Kings	Kings County retain trial Hanford	Serr	07/25/09
Kings	Kings County PDS site Hanford	Tulare	07/25/09
Lake	Walnut lightbar site #1 Upper Lake	Chandler	06/25/09
Lake	Walnut lightbar site #2 Upper Lake	Chandler	06/25/09
Lake	Walnut lightbar site #3 Upper Lake	Chandler	06/25/09
San Joaquin	Walnut lightbar site Farmington	Tulare	08/11/09

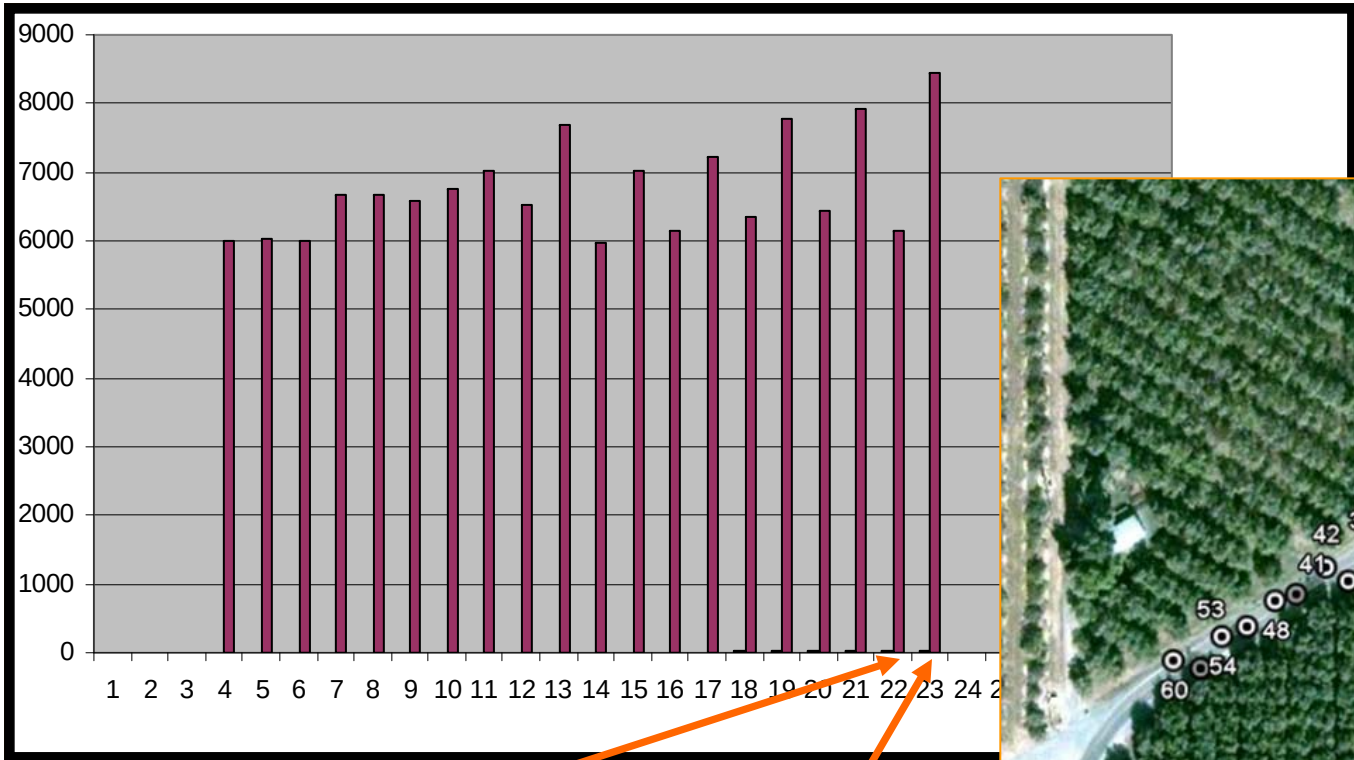
County	Site	Variety	Date mapped
Solano	Surround trial Winters	Tulare	06/02/09, 06/16/09, 06/17/09, 07/13/09
Stanislaus	Walnut lightbar site Modesto	Chandler	09/30/09
Sutter	Walnut lightbar site Rio Oso #1	Chandler	05/26/09 and 09/16/09
Sutter	Walnut lightbar site Rio Oso #2	Chandler	05/26/09 and 09/16/09
Sutter	Walnut lightbar site Rio Oso #3	Chandler	05/26/09 and 09/16/09
Sutter	Own-rooted trial Rio Oso	Chandler/ Vina	09/15/09
Yolo	Walnut lightbar site Madison	Chandler	08/10/09
Yuba	Tulare Surround trial Rio Oso	Tulare	09/24/09
Yuba	Howard Surround trial Rio Oso	Howard	07/14/09
Yuba	Chandler replant trial Rio Oso	Chandler	09/15/09

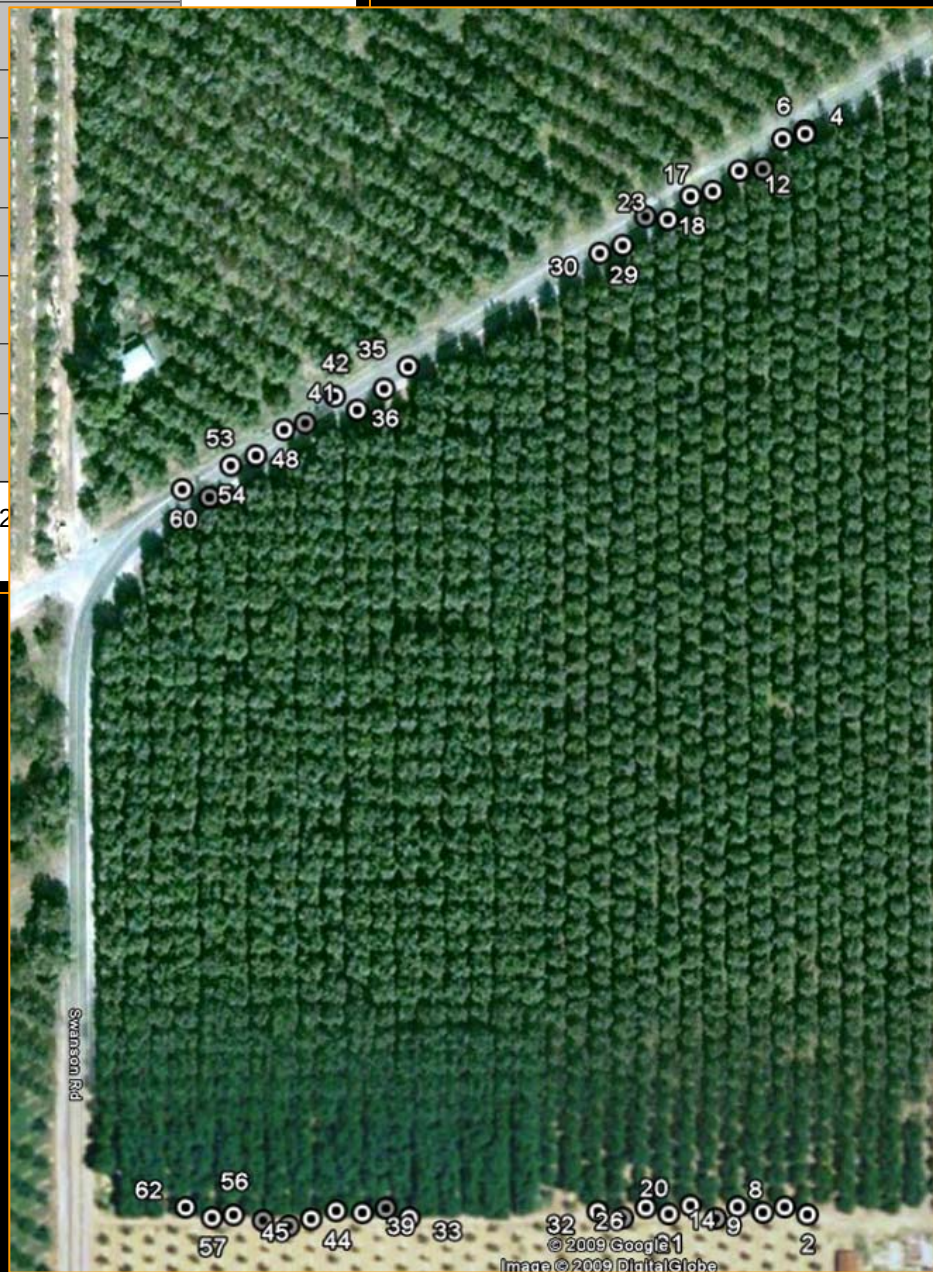
1	**Site:**	**Norene - Sutter County : Orchard 1**												
2	**Date:**	**5-26-09**												
3														
4	Test #	Start	Avg.Frac.PAR		Absorp.	FS PAR	Sun angle (deg)		Total Area (m^2) :			Distance	Heading	
5		Time	Left	Right	Both	µmol/m^2/s	Altitude	Azimuth	Left	Right	Both	(m)	(deg)	Direction
6	3	12:23	0.745	0.912	0.829	1946.9	70.2	-28.3	1710.7	1710.7	3421.4	407.3	181.0	N
7	7	12:27	0.830	0.587	0.708	1953.7	0.0	0.0	1683.9	1683.9	3367.9	400.9	1.0	S
8	10	12:31	0.772	0.915	0.843	1953.7	70.9	-23.0	1645.5	1645.5	3291.0	391.8	181.0	N
9	13	12:34	0.854	0.604	0.729	1962.8	0.0	0.0	1634.4	1634.4	3268.9	389.2	1.0	S
10	16	12:38	0.803	0.919	0.861	1961.2	71.3	-18.3	1615.5	1615.5	3230.9	384.6	181.0	N
11	19	12:41	0.832	0.602	0.717	1968.7	0.0	0.0	1599.3	1599.3	3198.7	380.8	1.0	S
12	22	12:44	0.771	0.920	0.846	1970.4	71.7	-13.6	1579.7	1579.7	3159.5	376.1	181.0	N
13	25	12:48	0.784	0.598	0.691	1973.7	0.0	0.0	1555.4	1555.4	3110.8	370.3	1.0	S
14	28	12:51	0.824	0.905	0.865	1973.7	71.9	-9.2	1535.6	1535.6	3071.2	365.6	181.0	N
15	31	12:54	0.807	0.576	0.692	1976.2	0.0	0.0	1497.7	1497.7	2995.3	356.6	1.0	S
16														
17														
18														
19														


Bear River Dr
Swanson Rd
© 2009 Tele Atlas
Image © 2009 DigitalGlobe
t 21, 2006
38°58'16.89" N
121°30'49.85" W
elev 52 ft

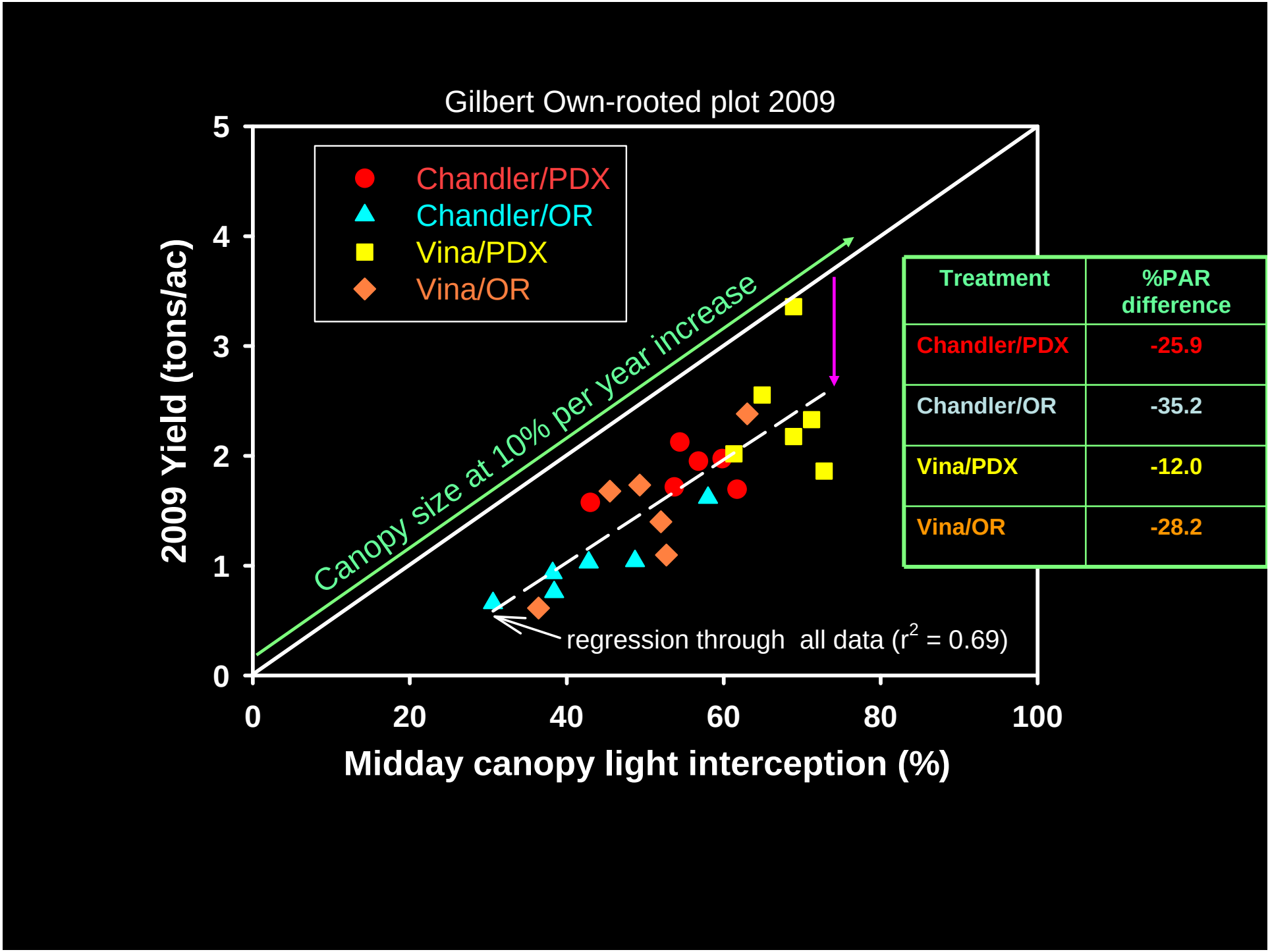

18
12
11
17
24
23
30
29

Rio Oso Walnut

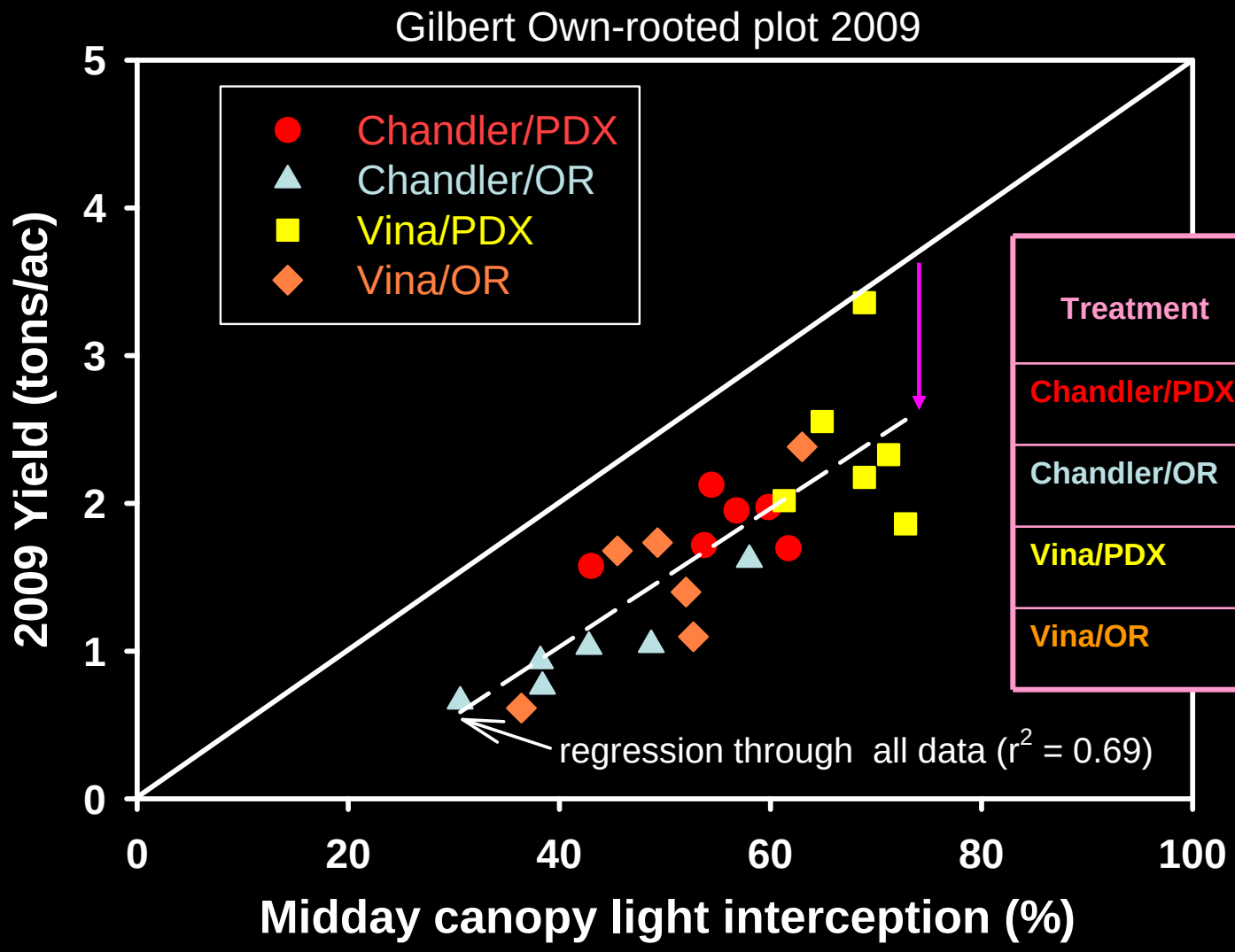





0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
7
13
19
20
25
26
31
32
37
38
43
44
49
50
55
56
61
Google
Imagery Date: Jun 25, 2007
38° 38.615' N 121° 59.525' W elev 192 ft
Eye alt 1548 ft



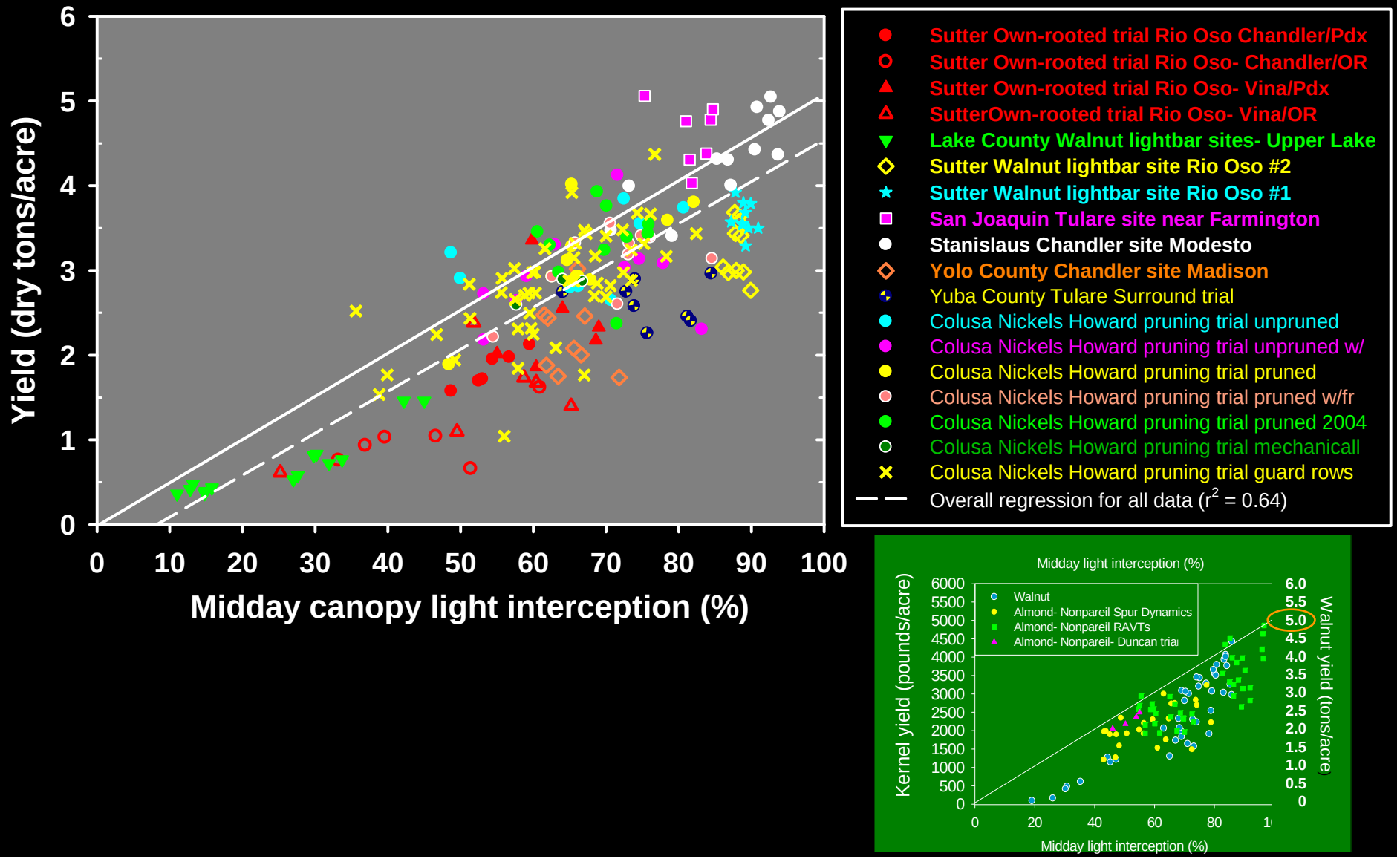
Treatment	%PAR difference
Chandler/PDX	-25.9
Chandler/OR	-35.2
Vina/PDX	-12.0
Vina/OR	-28.2



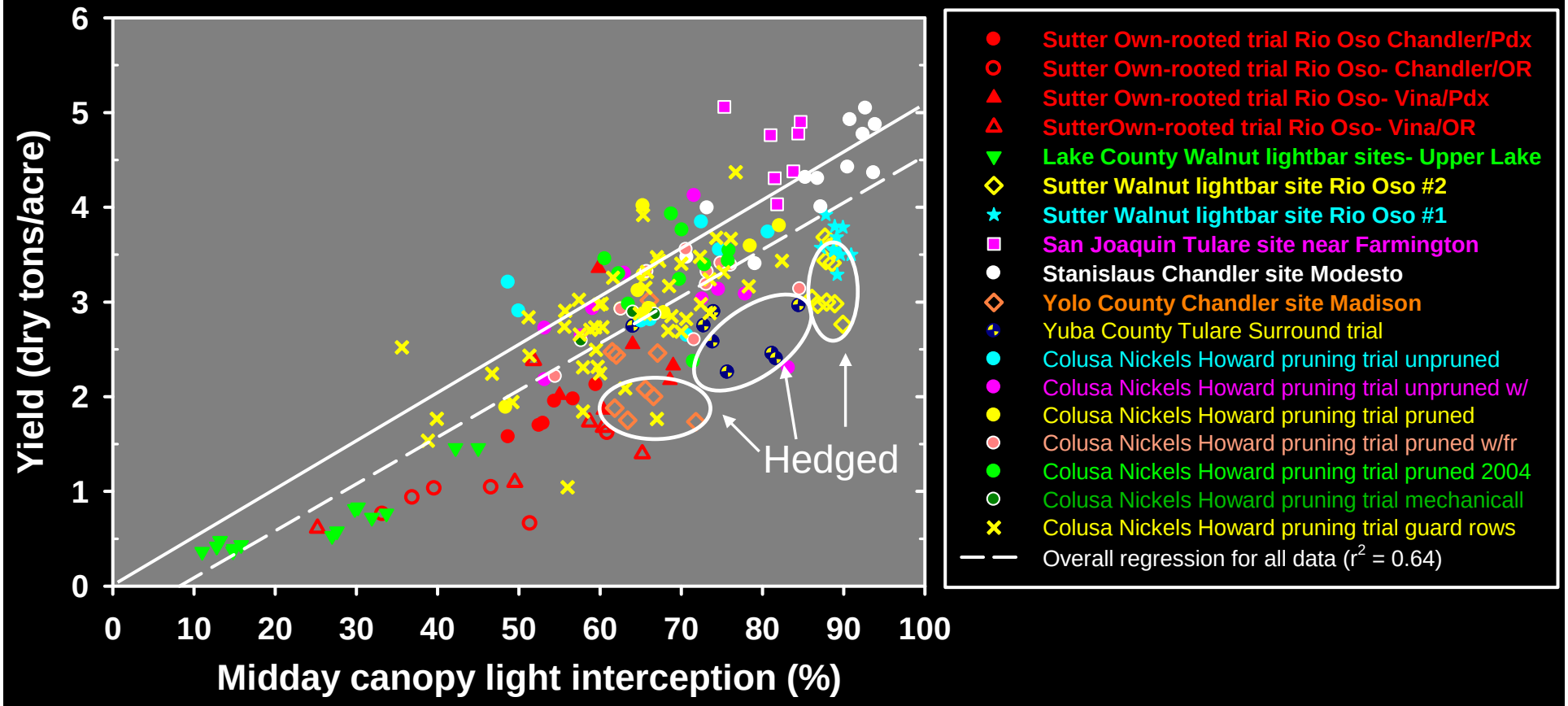
Treatment	Yield difference (tons/acre)
Chandler/PDX	-0.86
Chandler/OR	-1.24
Vina/PDX	-1.02
Vina/OR	-1.11

Can use this information to separate out effects of canopy size on productivity versus effect of productivity per unit canopy area

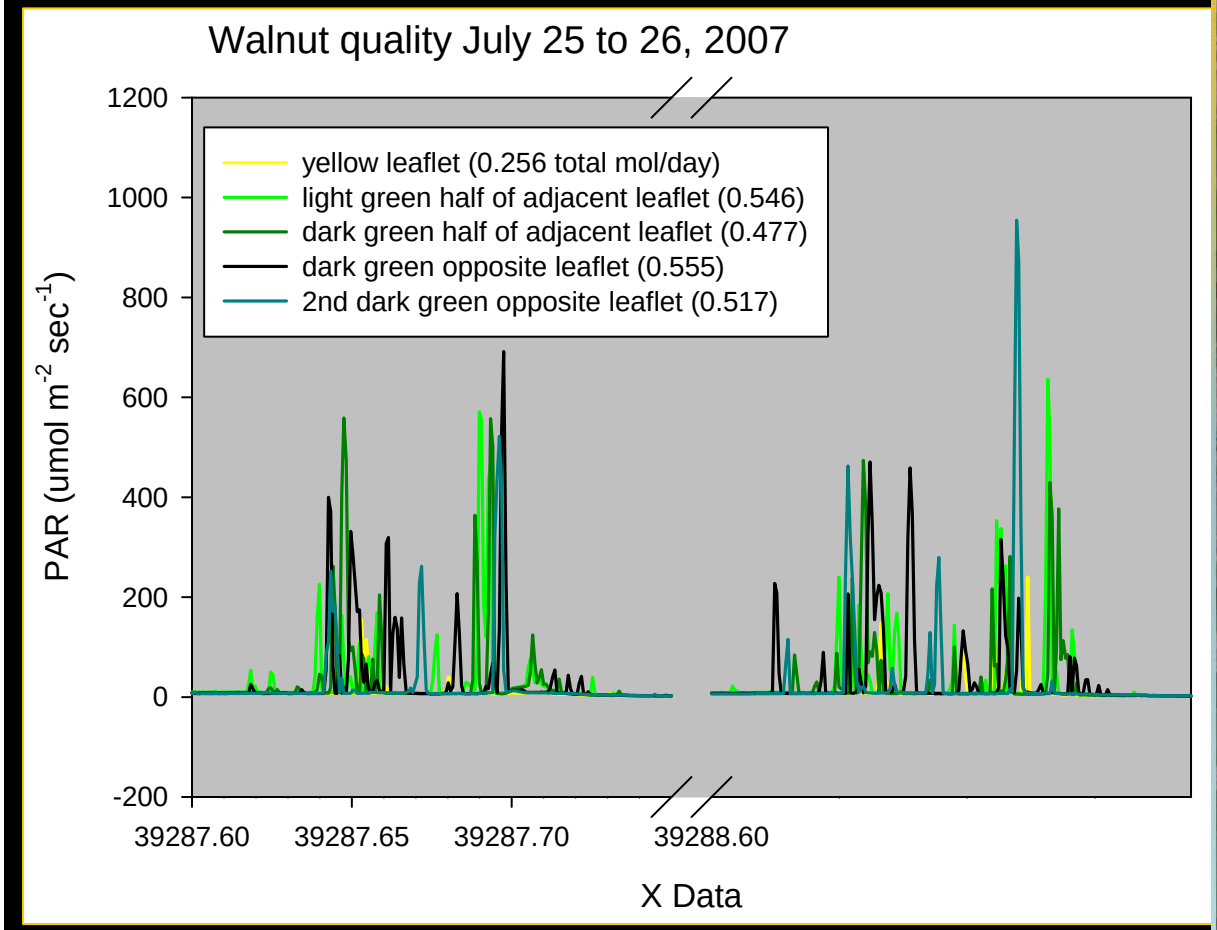
Walnut light interception sites 2009

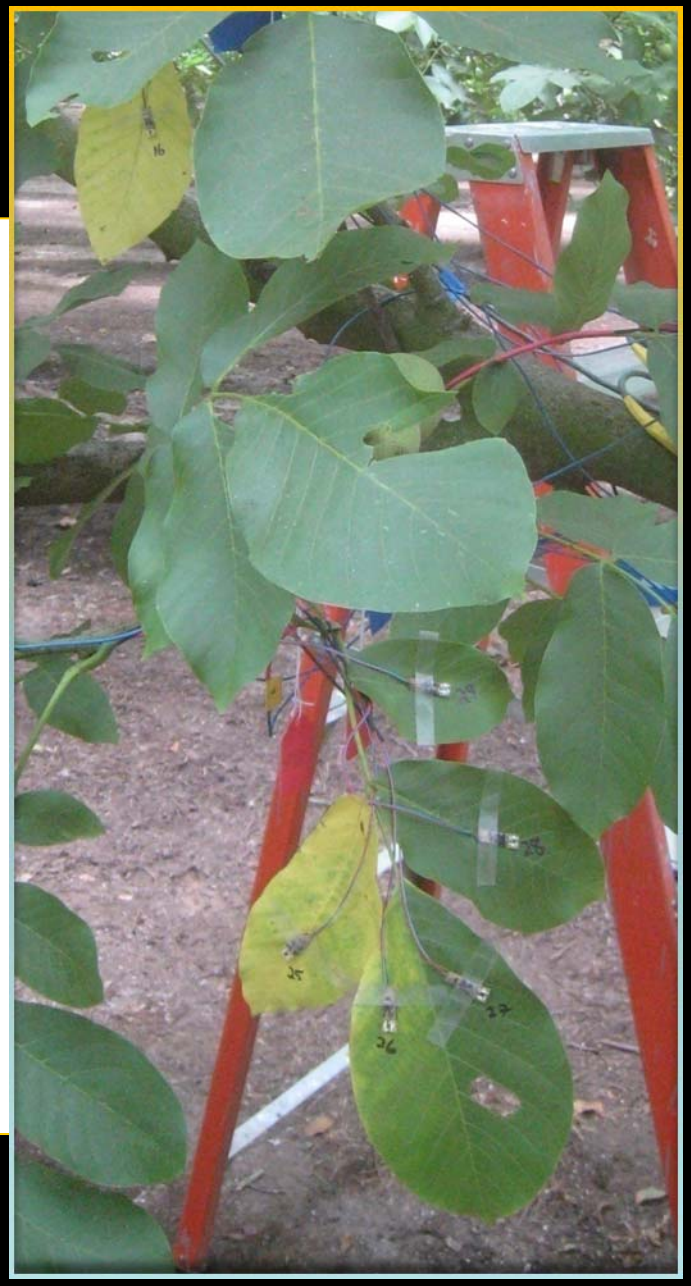


Walnut light interception sites 2009

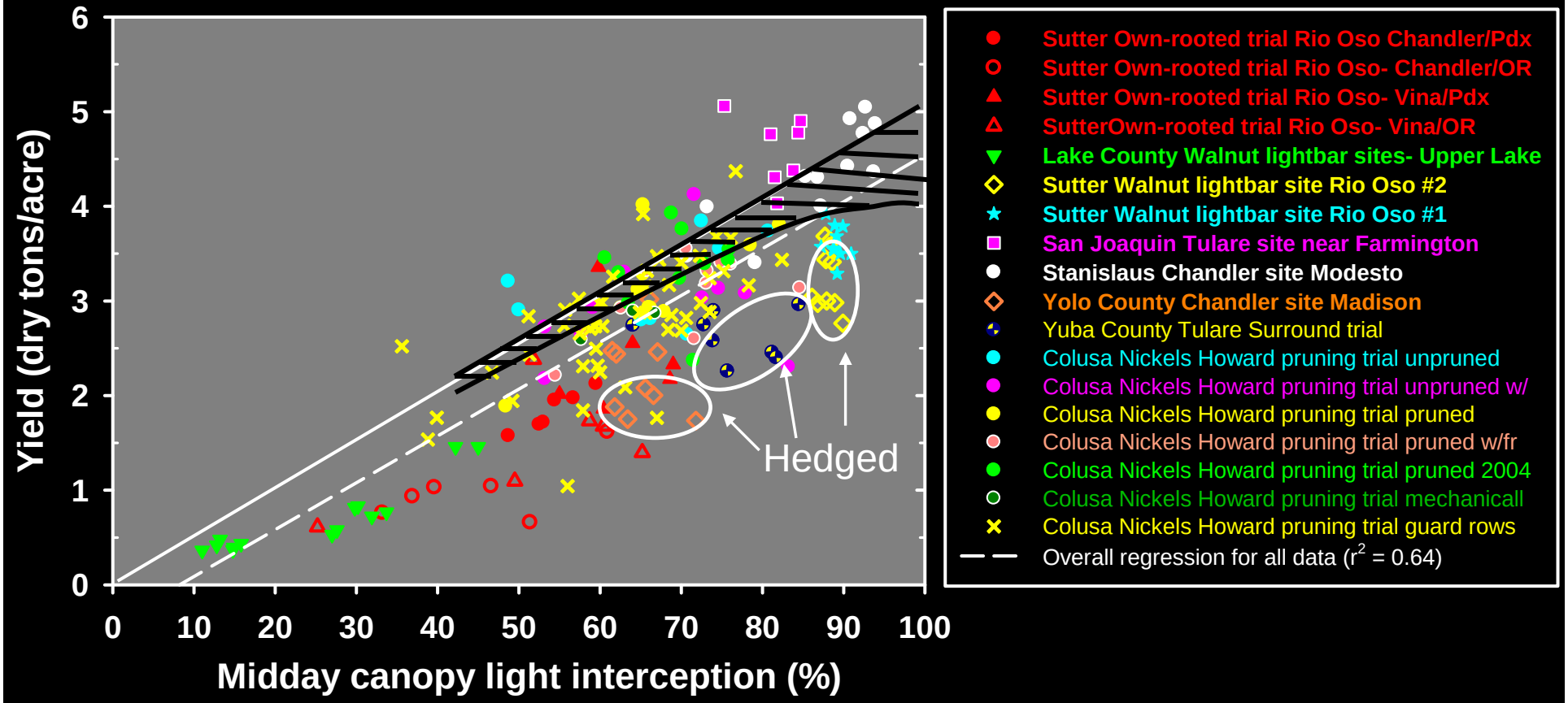


In order to keep lower canopy positions alive and productive, at least ½ hour of direct sunlight is required. In order to get this amount of light in these lower positions, you will have a certain amount of light falling on the orchard floor. Therefore, you should expect quality problems to increase as you approach yield potential.


Walnut quality July 25 to 26, 2007
1200
1000
800
600
400
200
0
-200
PAR (umol m-2 sec-1)
yellow leaflet (0.256 total mol/day)
light green half of adjacent leaflet (0.546)
dark green half of adjacent leaflet (0.477)
dark green opposite leaflet (0.555)
2nd dark green opposite leaflet (0.517)
39287.60
39287.65
39287.70
39288.60
X Data

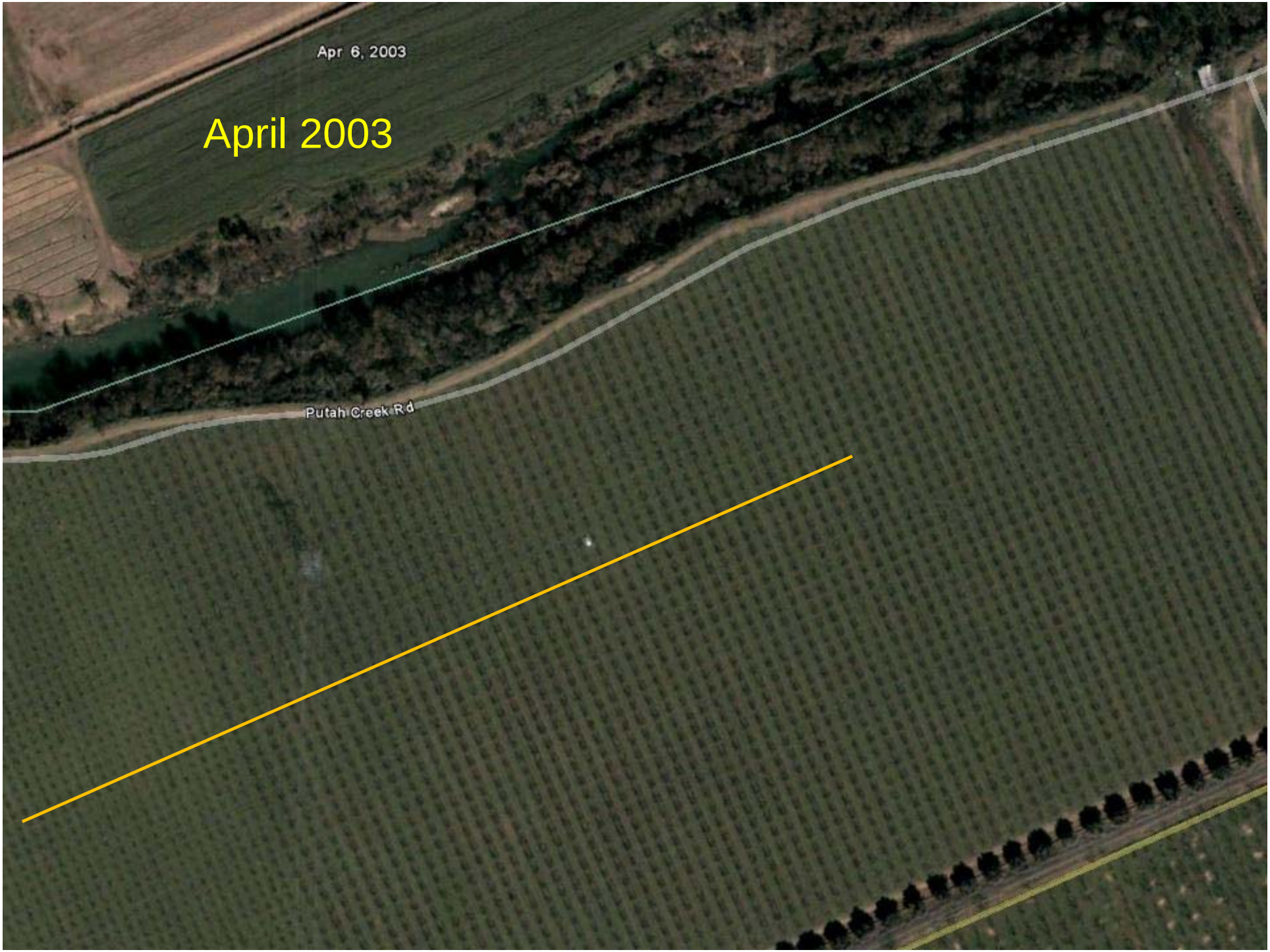


Walnut light interception sites 2009




September 2009
Putah Creek Rd

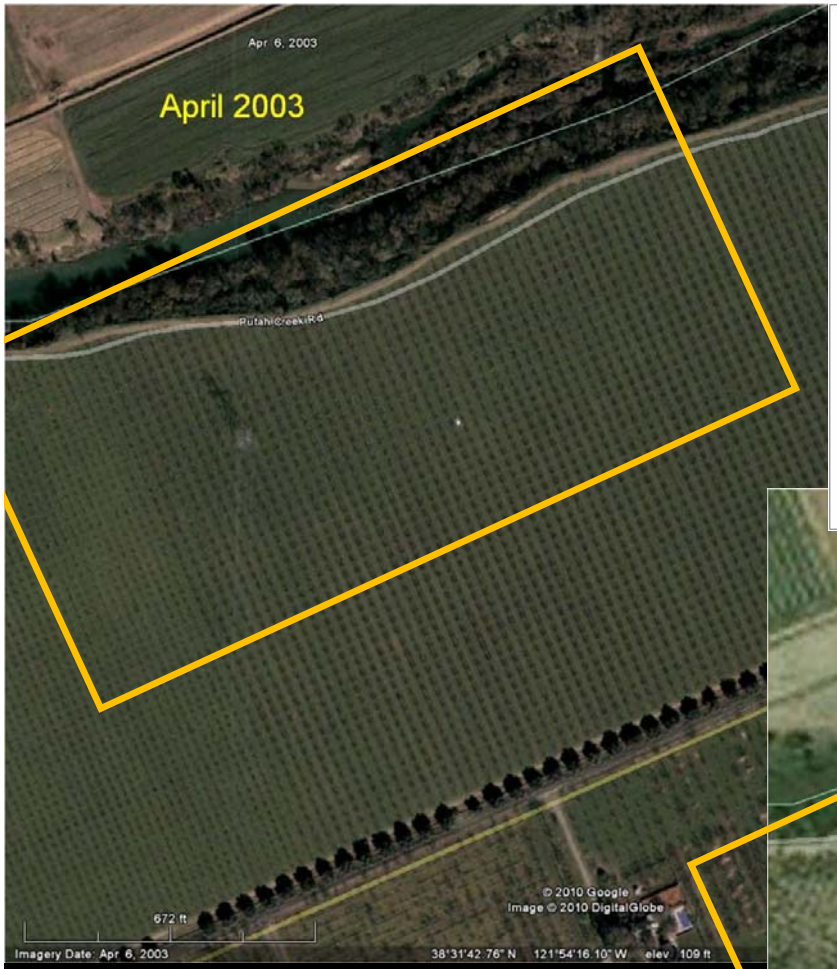

Jun 12, 1993
1993
2010
June 1993
Putah Creek Rd

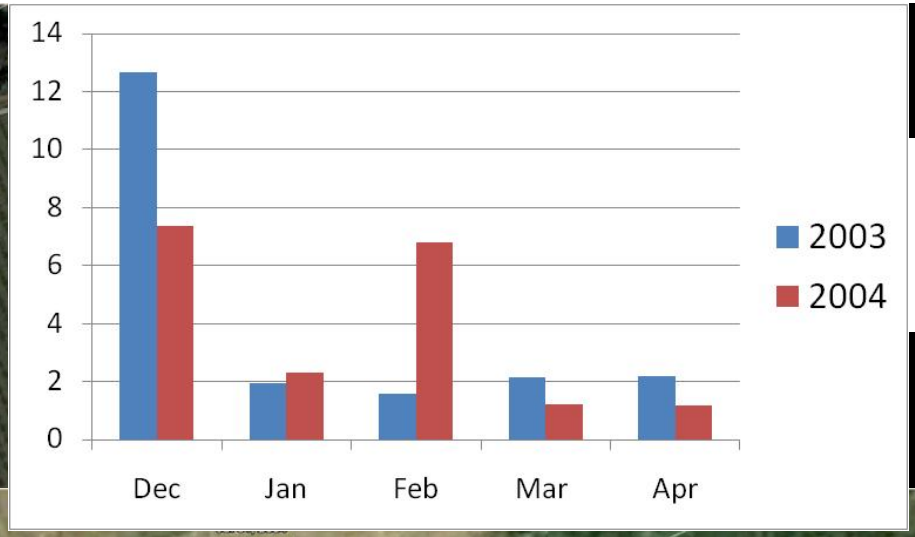

Apr 6, 2003
April 2003
Putah Creek Rd


Jul 31, 2004
July 2004
Putah Creek Rd

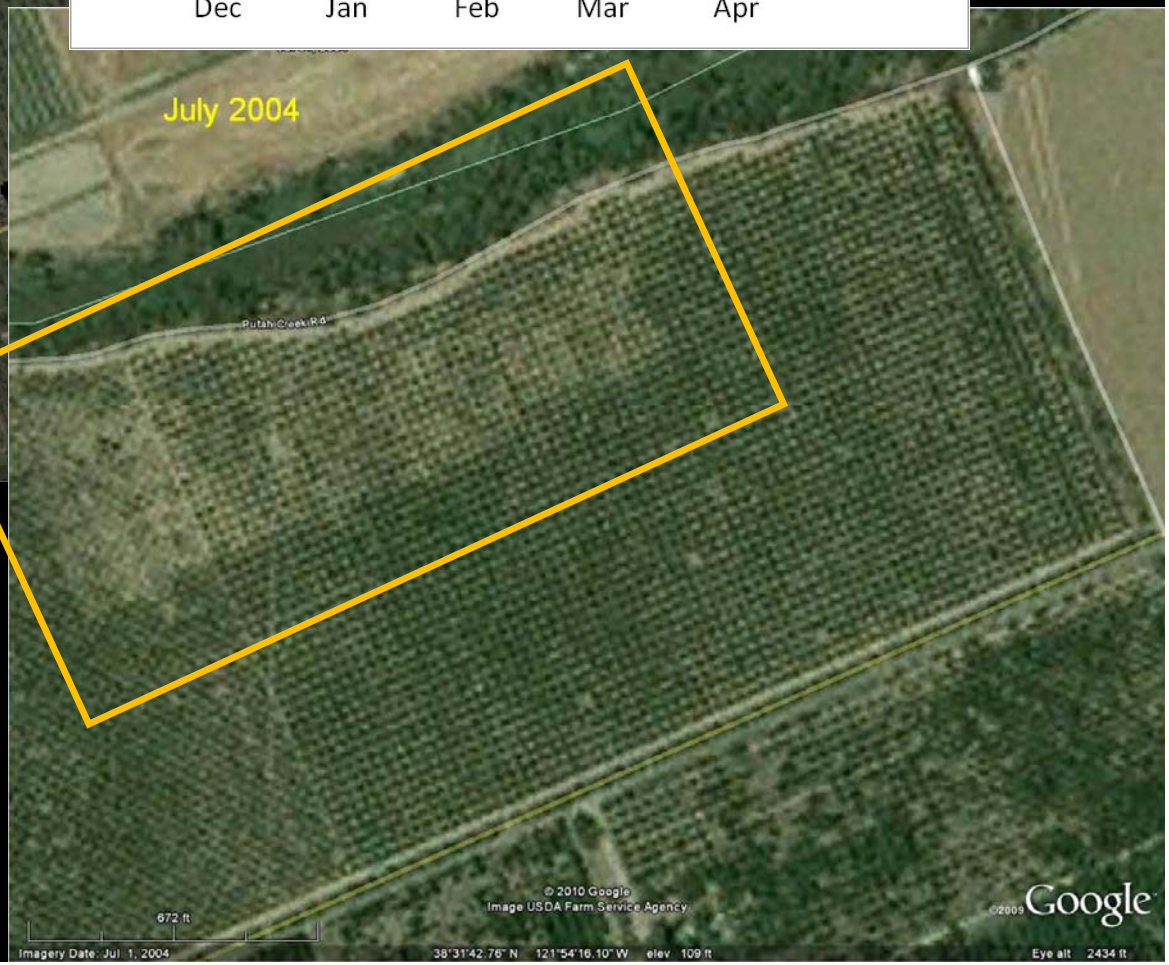

Dec 31, 2005
December 2005
Putah Creek Rd


Select date
September 2009
Putah Creek Rd

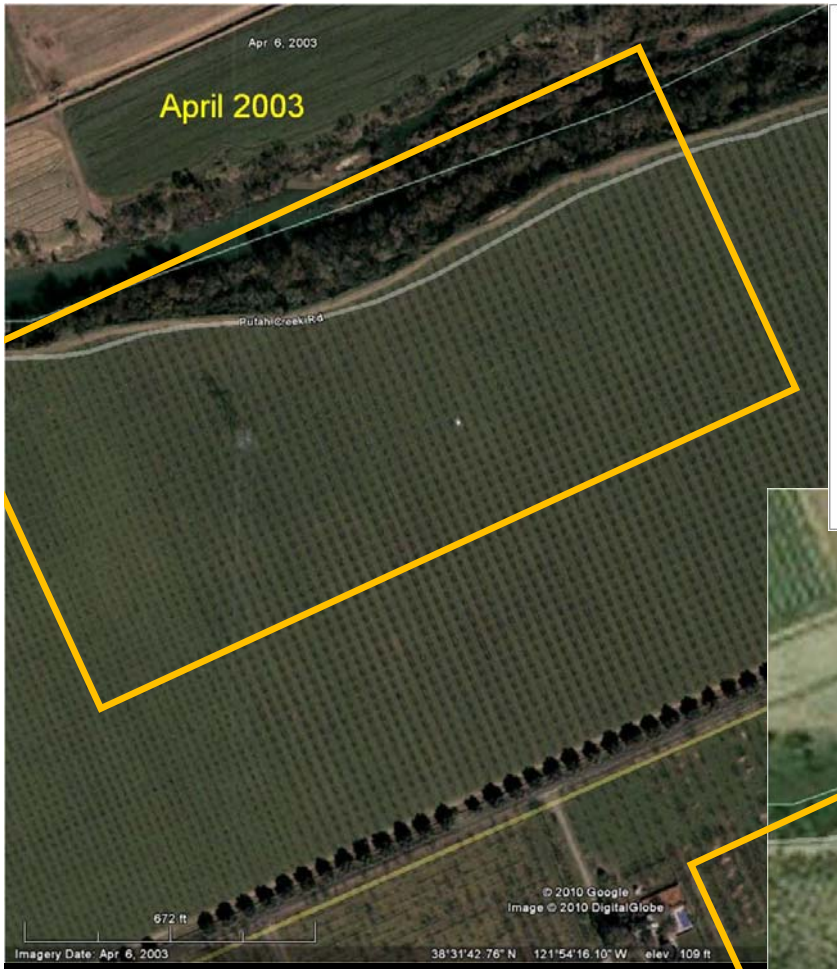


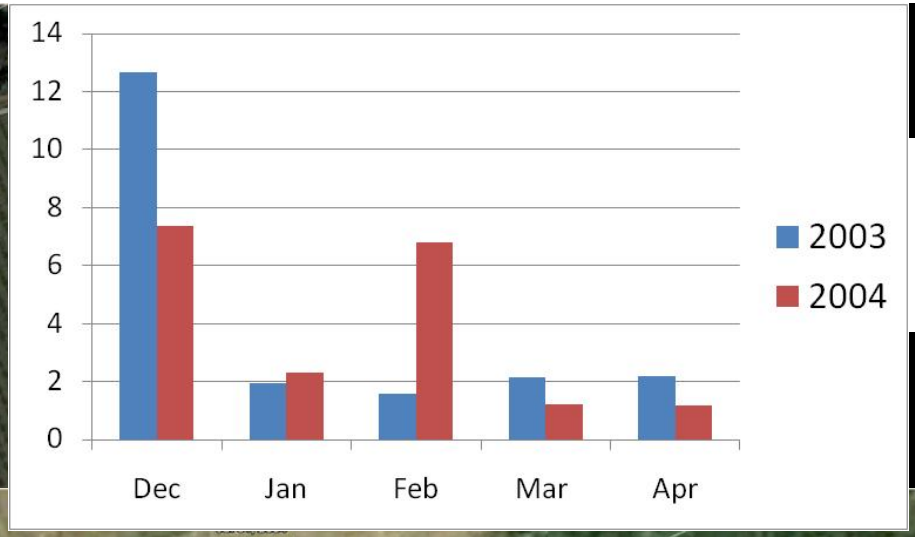


Total
25.7”
20.5”

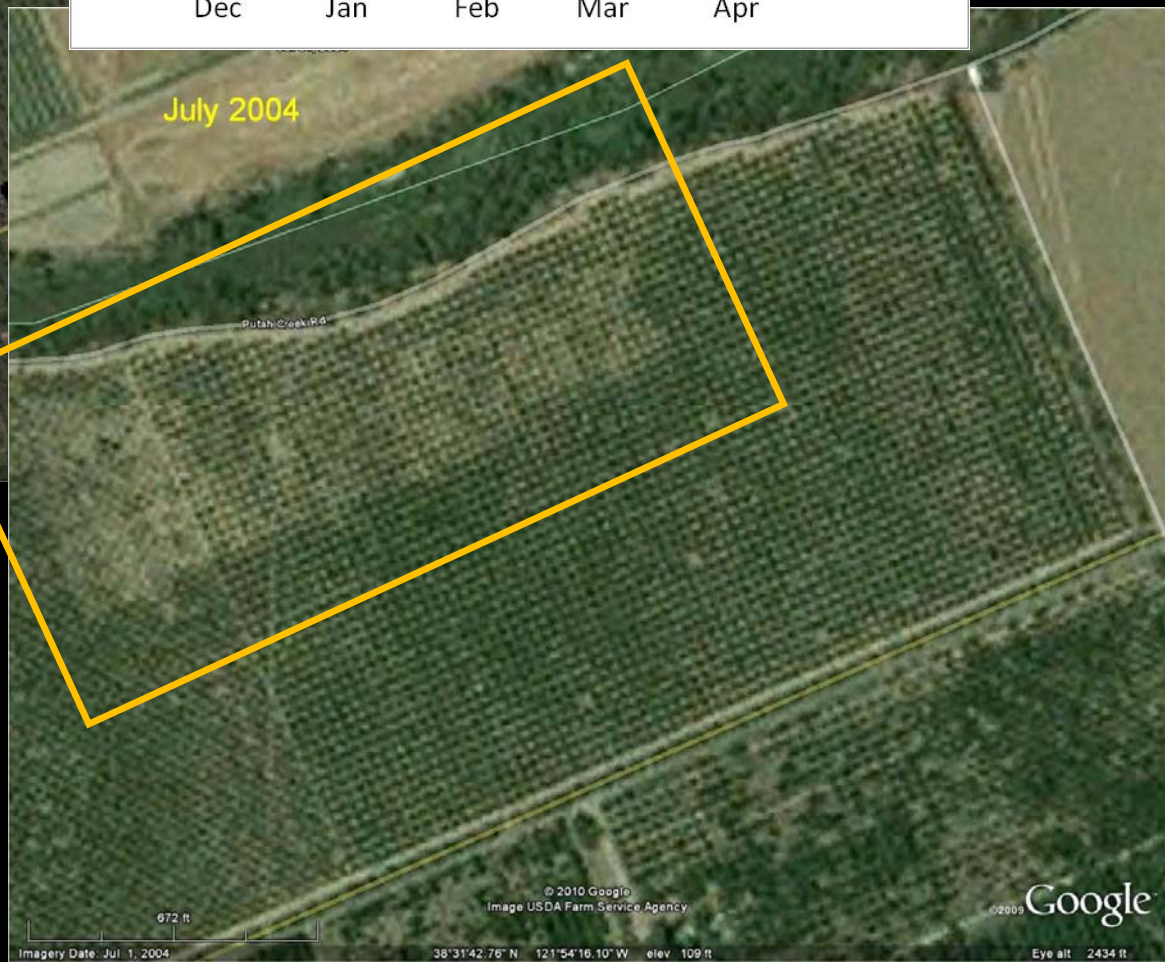


12 inches of rain in Dec. 2002,
9 inches of rain in Feb-April 2004

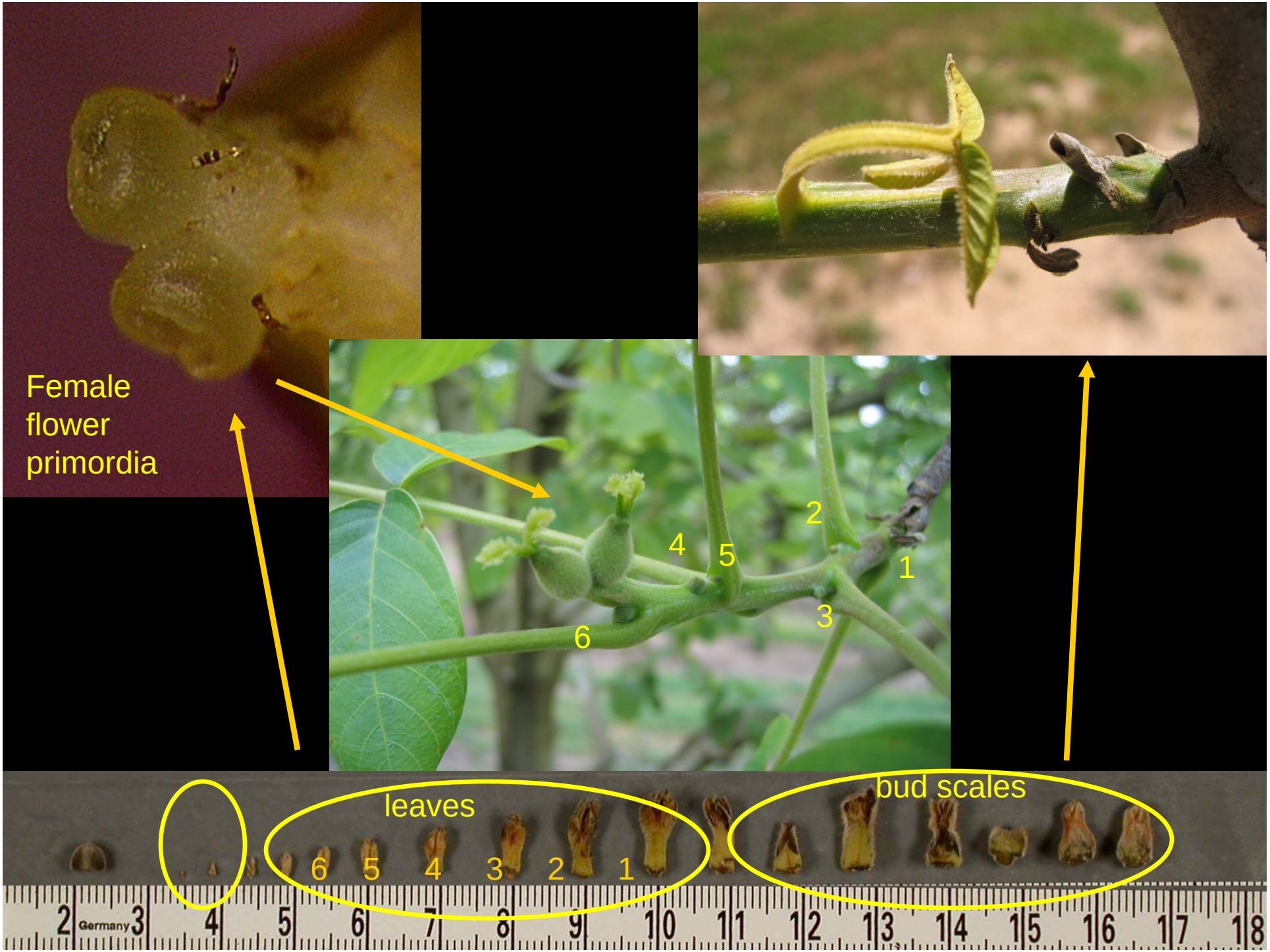




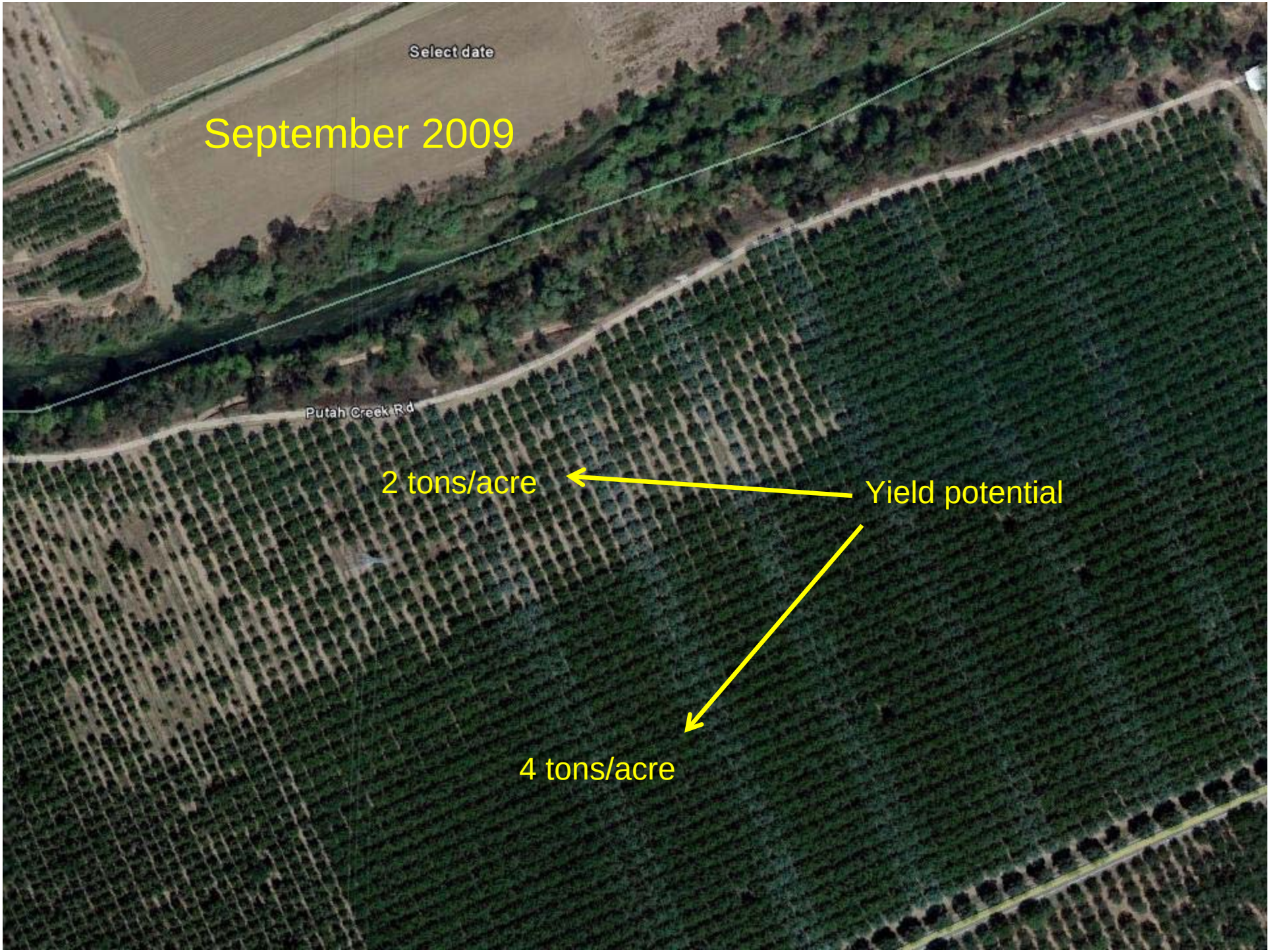
Total
25.7”
20.5”



Impact could be due to both wet periods since negative impacts would not yet be seen in April 2003

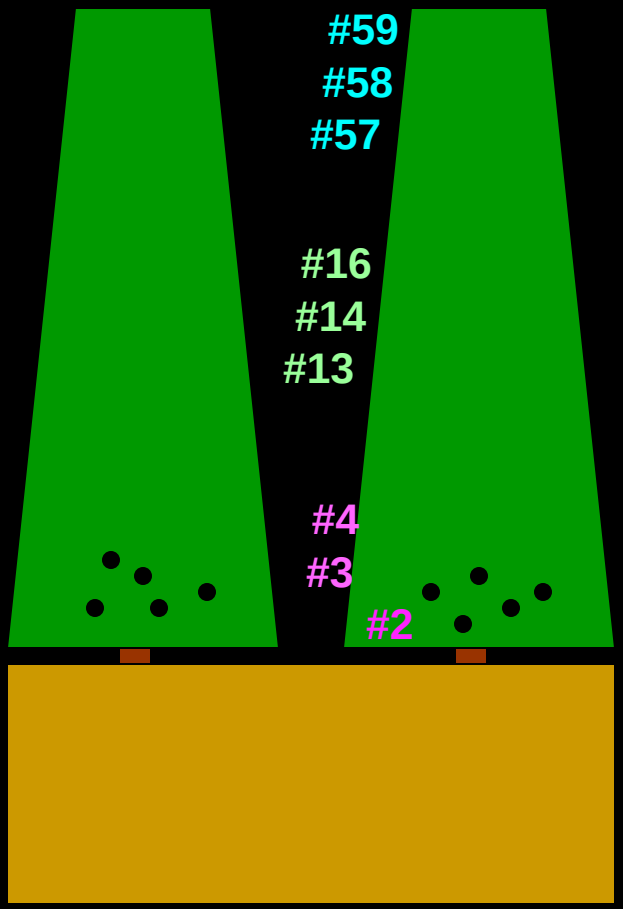

Female
flower
primordia
2
4
5
1
3
6
leaves
bud scales
6
5
4
3
2
1
Germany

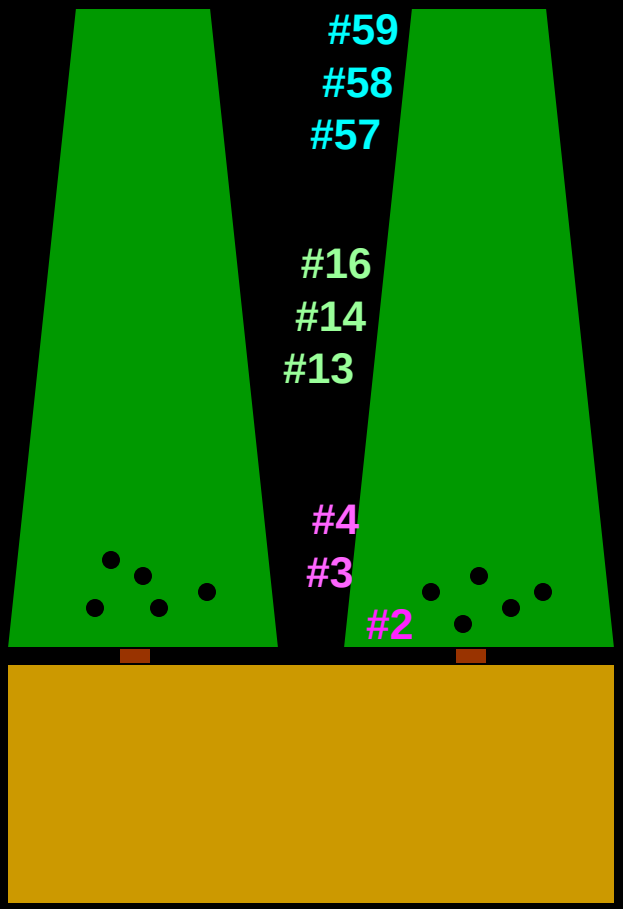
If secondary bud (composed of neoformed leaves formed in current season) does not grow it can be due to excessively dry or wet conditions. North of Sacramento it is usually due to excessively wet conditions but not necessarily so in Southern San Joaquin Valley

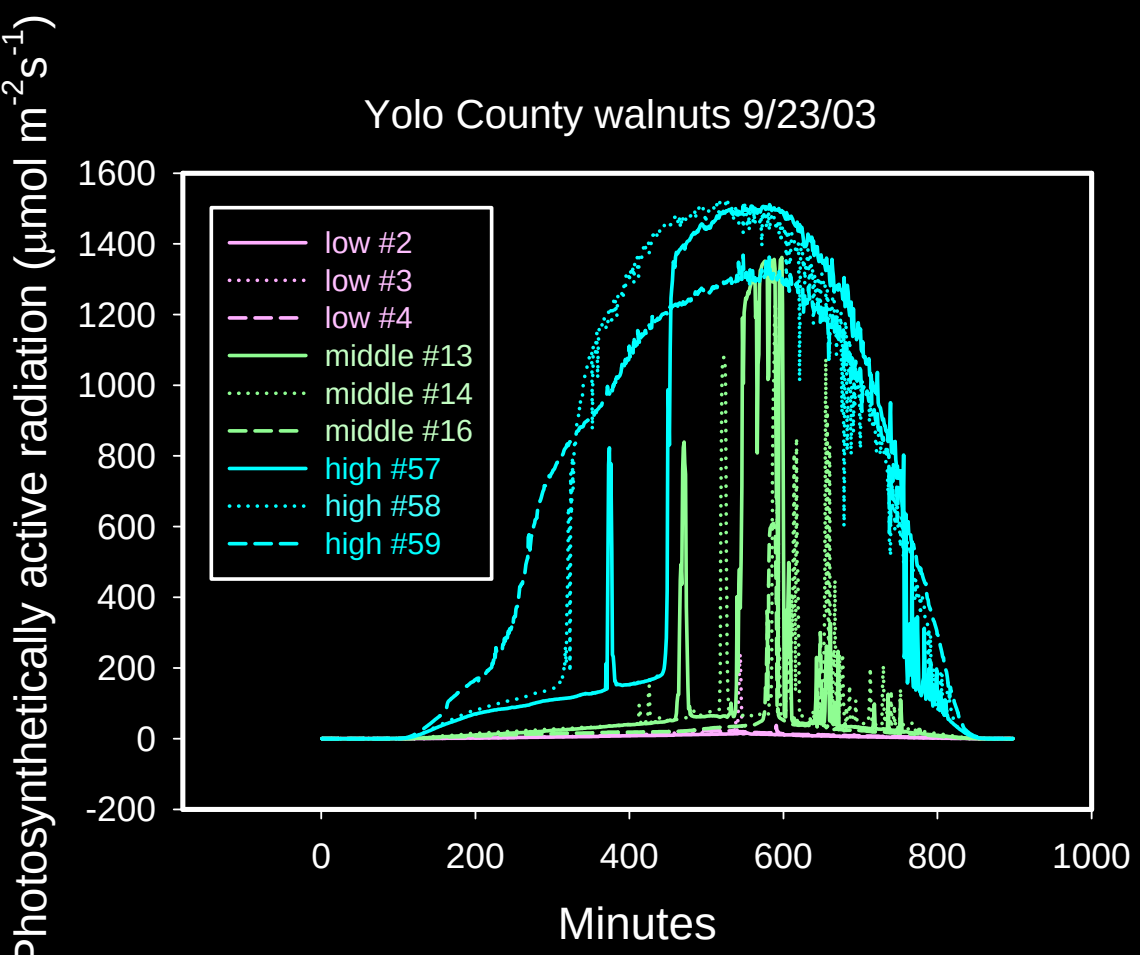

Select date
September 2009
Putah Creek Rd
2 tons/acre
Yield potential
4 tons/acre

Impacts of canopy light environment and stress on quality

Photodiodes attached to leaves throughout canopy







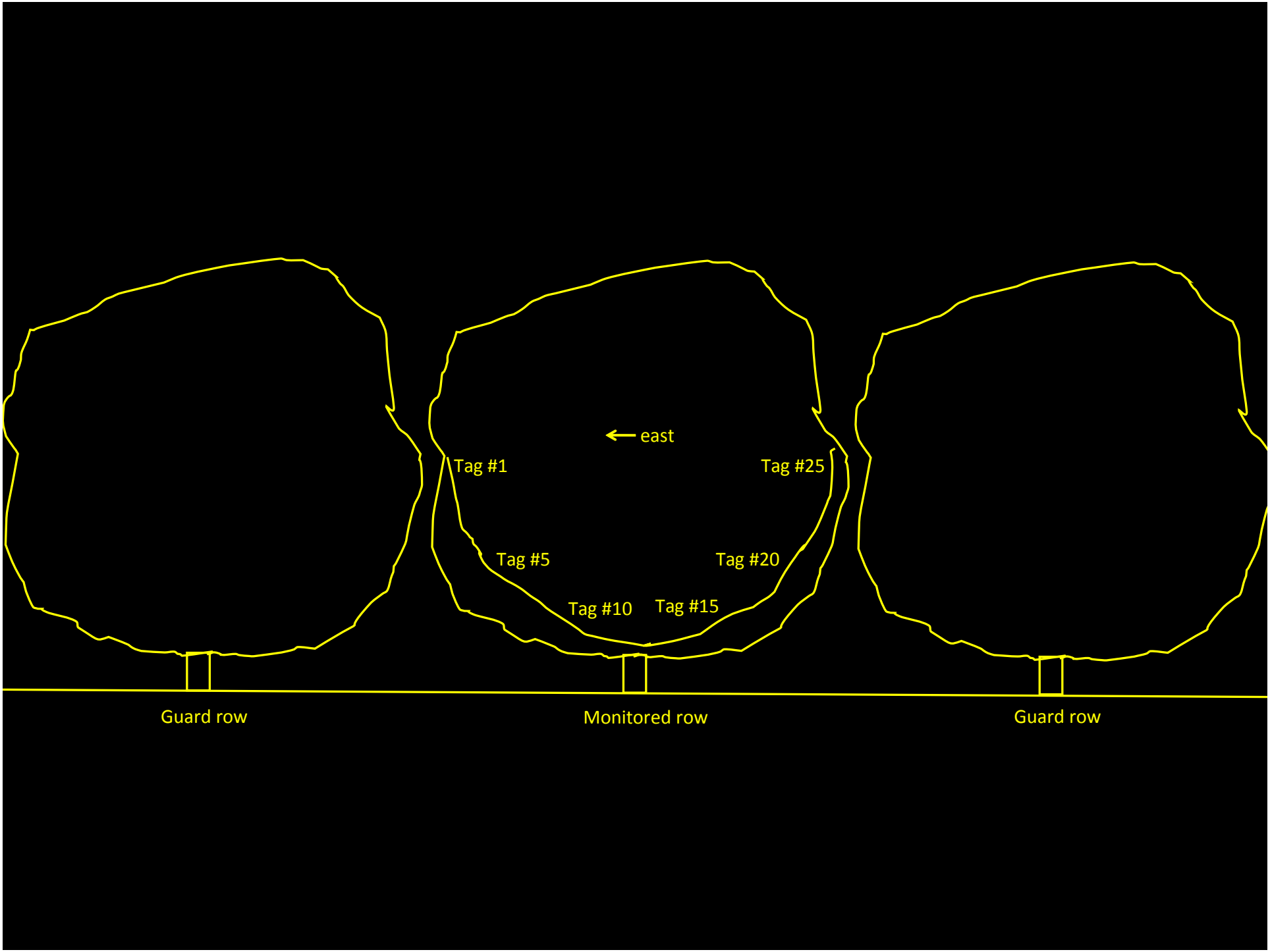
Nuts with quality problems (in this case mostly shrivel and bronze pellicles) came from spurs receiving less than about 30 minutes of direct light per day

Walnut quality studies initiated in 2007 and continued in 2008 and 2009

Replicated in adjacent 9 and 13 year old Chandler orchards

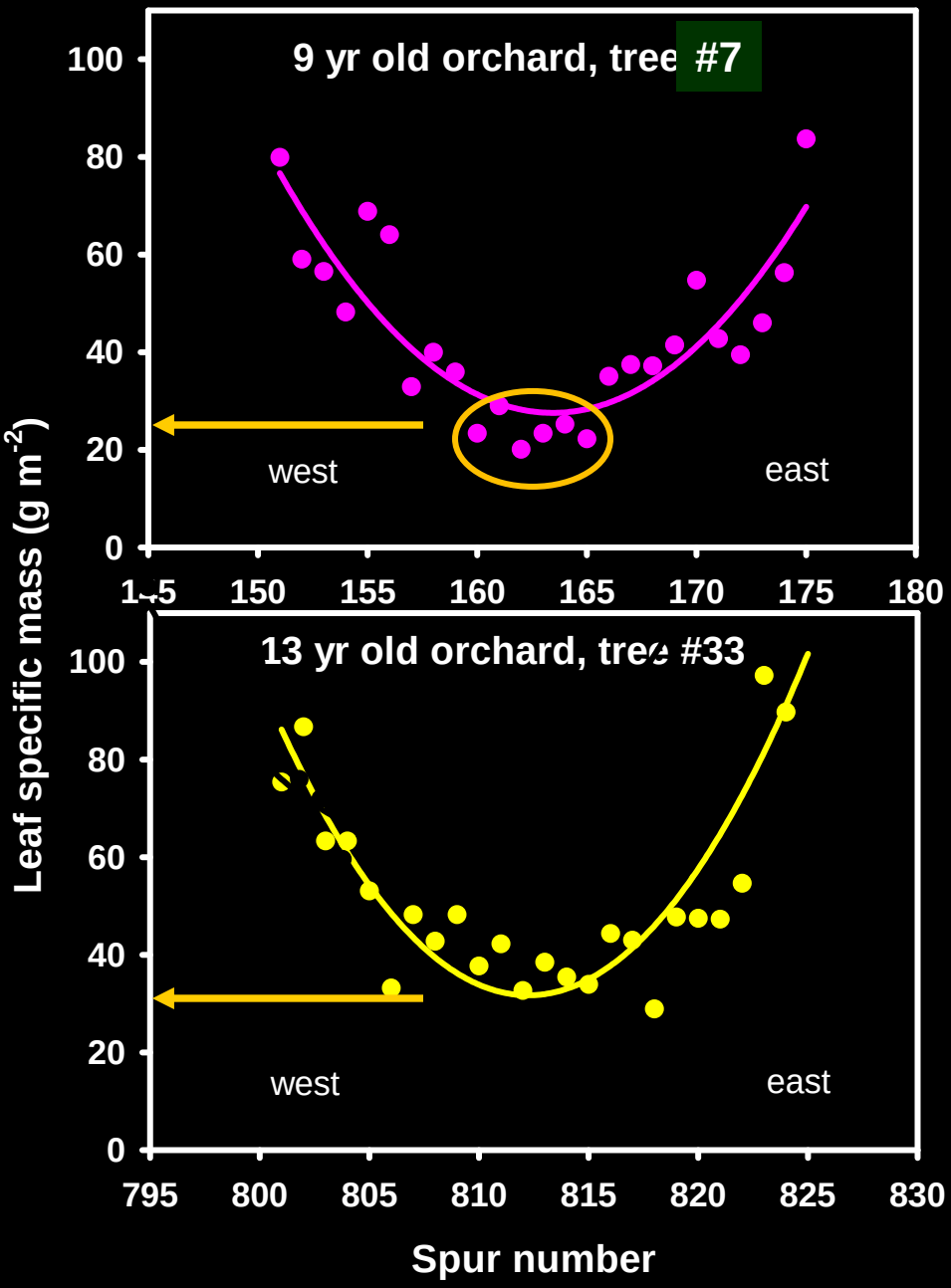
Both orchards have very high percentage of midday canopy light interception

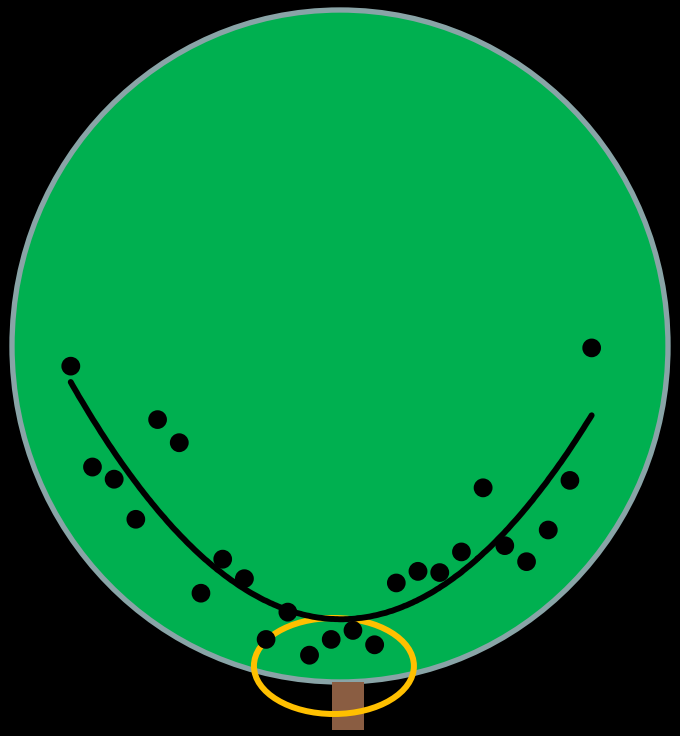
Both orchards have a history of producing nuts with yellow pellicles- according to the grower problem is worst at about 9 years of age and then improves as orchard ages after that


east
Tag #1
Tag #25
Tag #5
Tag #20
Tag #10
Tag #15
Guard row
Monitored row
Guard row

Normal husk split

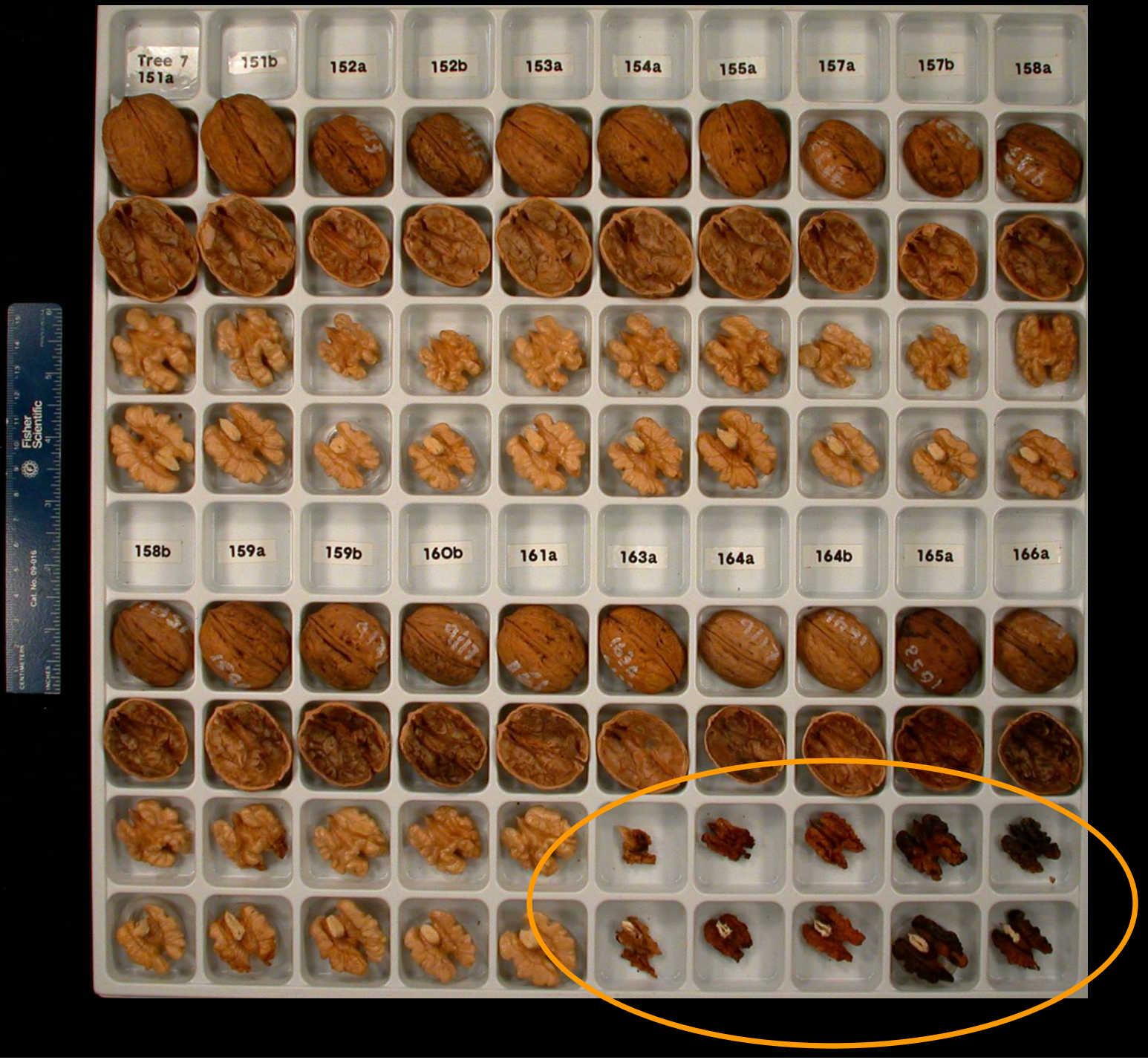
Nuts that sized fully in good light positions and then were shaded tended to lose leaves and the result was well formed nuts with a yellow pellicle (13% of nuts in 2006)- problem was very minor in 2007, 2008 and 2009 (less than 1 percent)

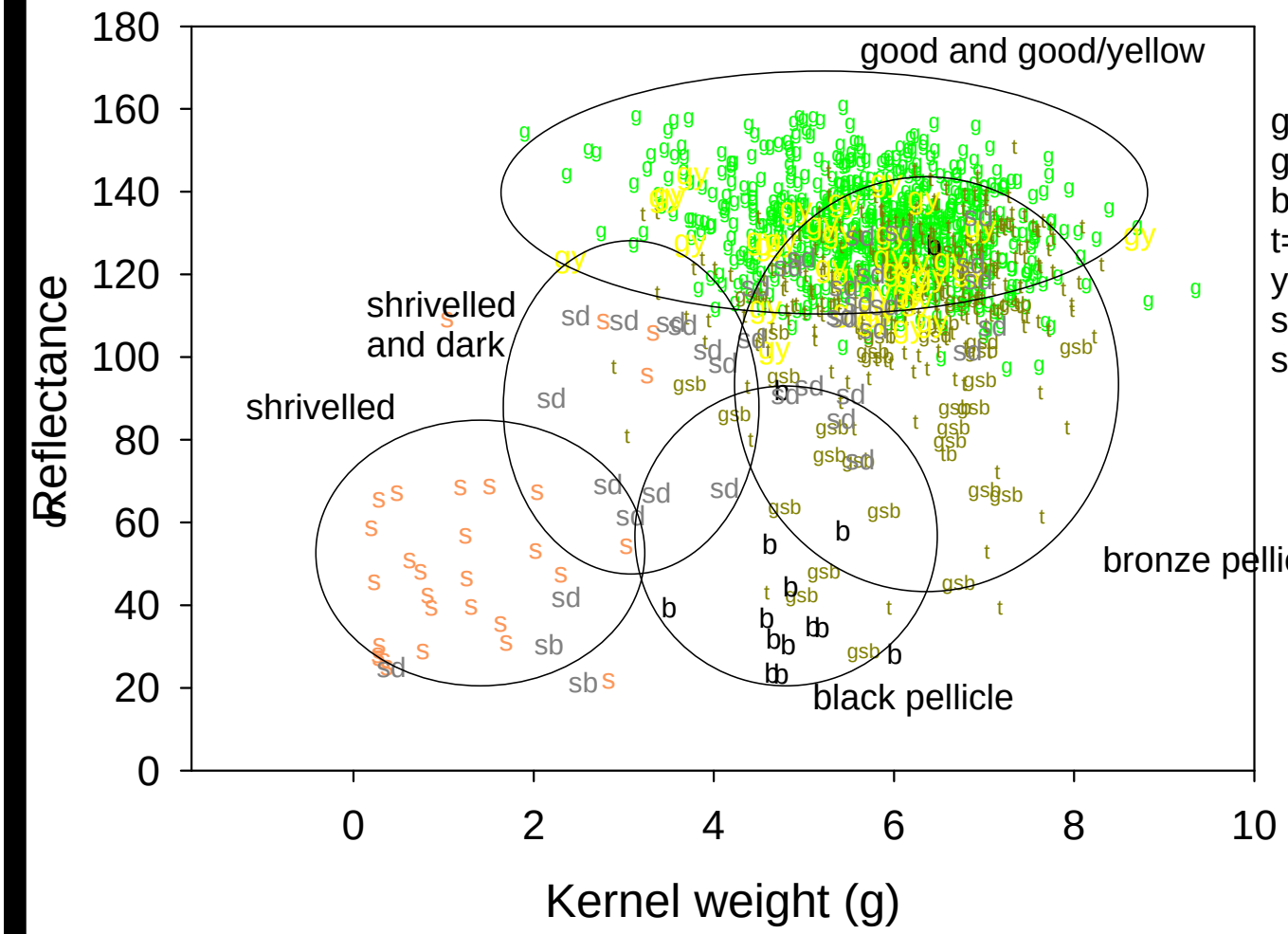




Most shrivel and pellicle color issues occurred in lower, shaded positions

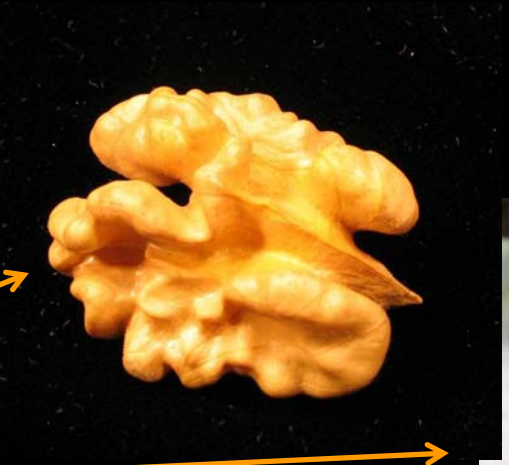
Tree #7-
9 yr old
orchard



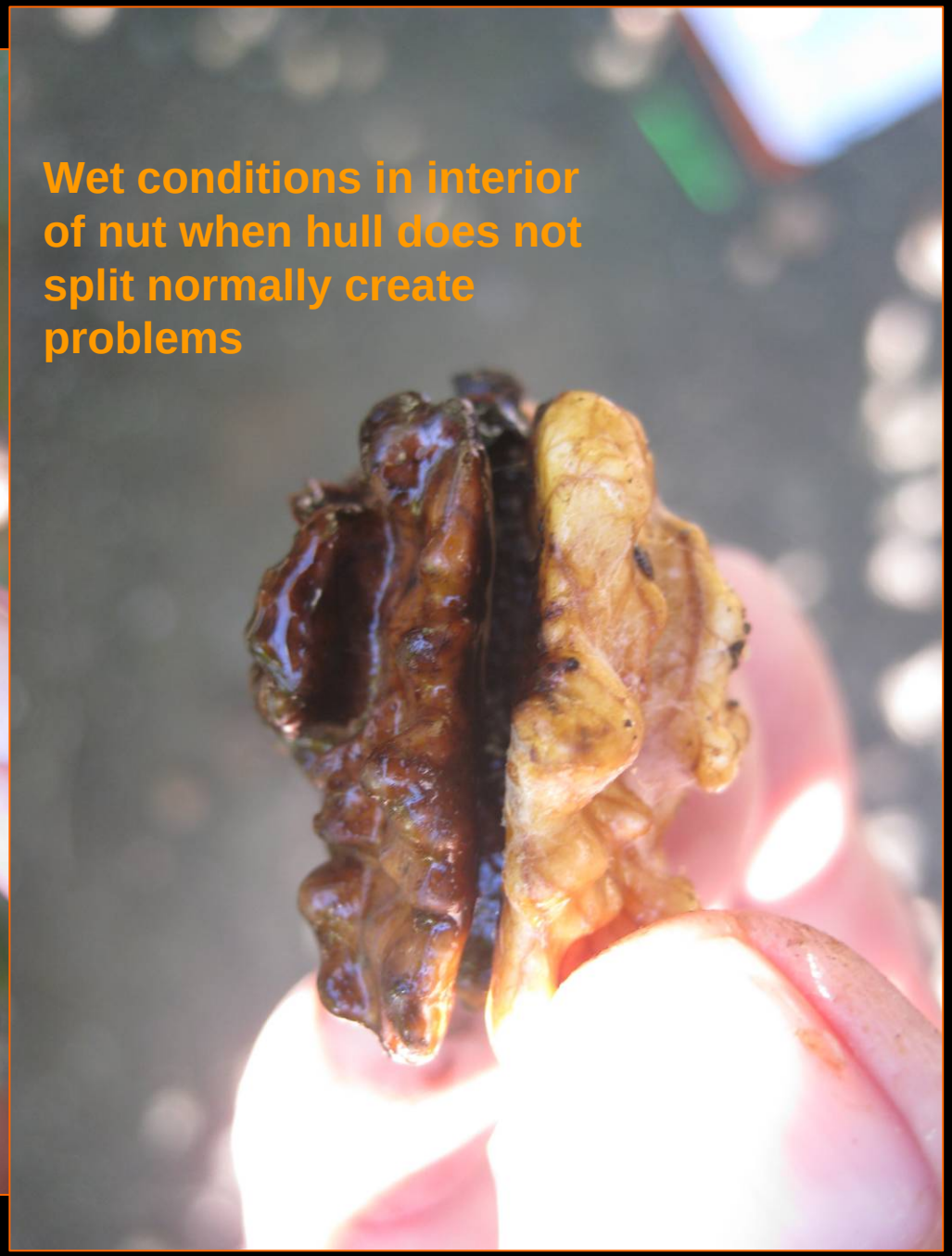


g= well filled nut with light pellicle
gsb= some bronzing of pellicle
b= black pellicle
t= bronze pellicle
y= yellow pellicle
s= shrivelled
sd= shrivelled and dark

Nuts that have hulls that do not split normally and maintain wet conditions around kernel cause quality problems

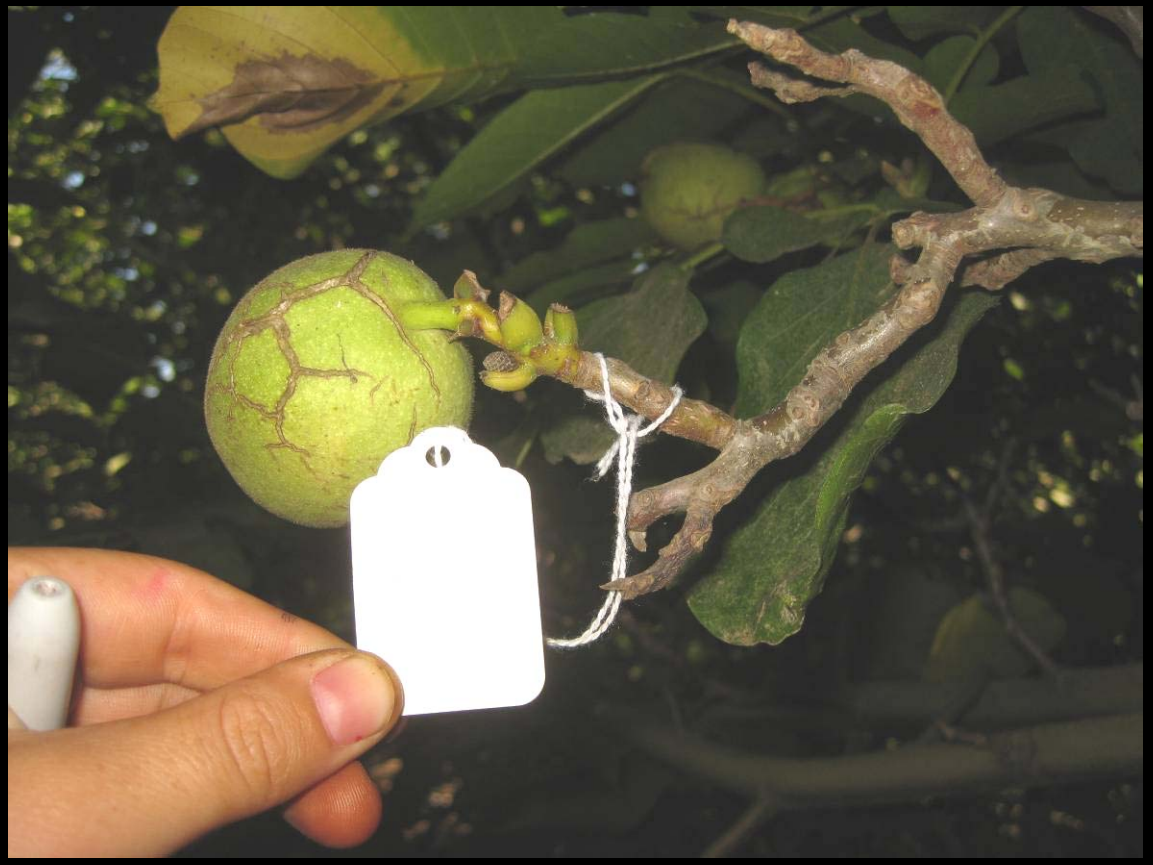


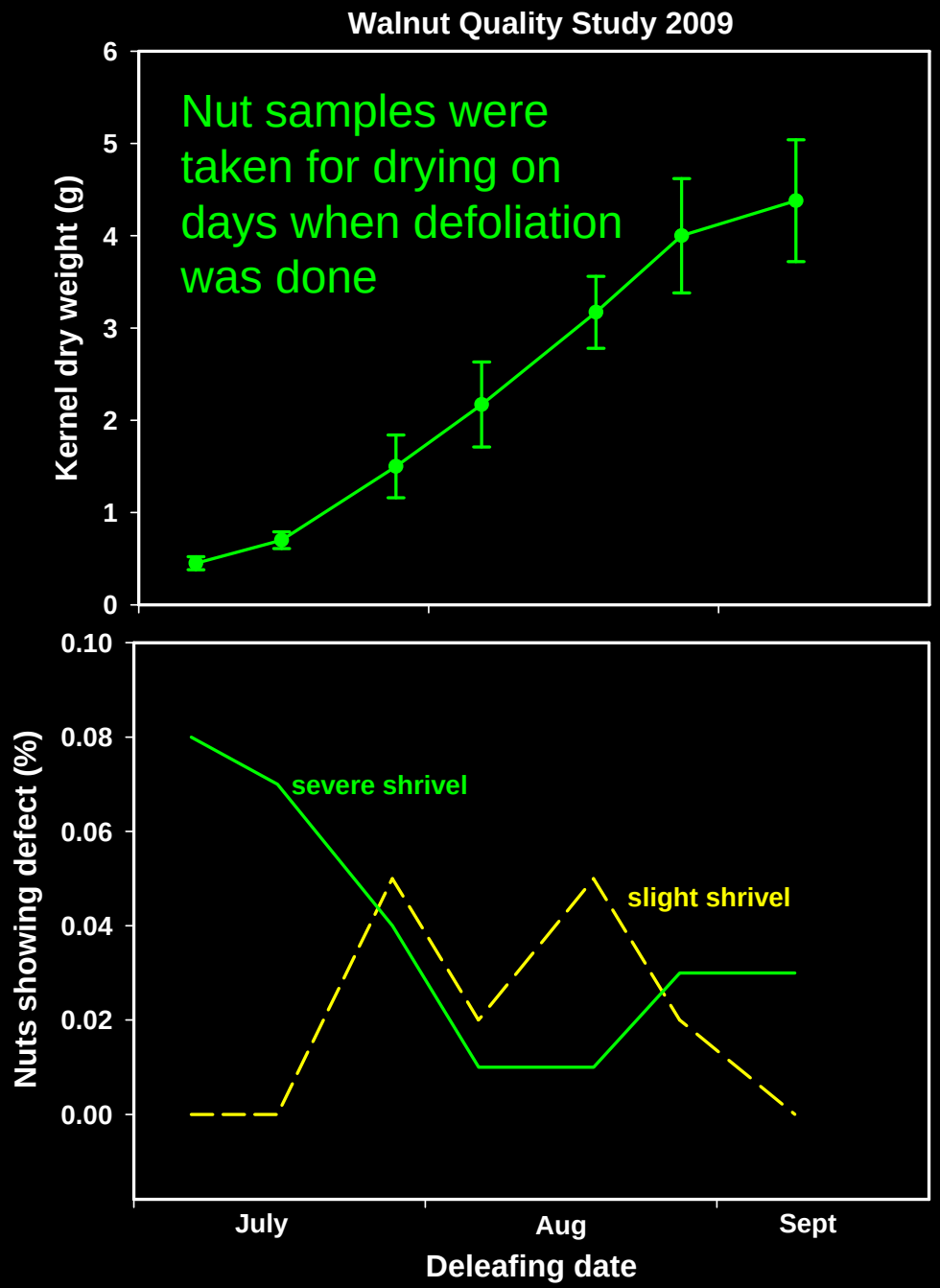
Nickels Soil Lab Howards 9/30/08



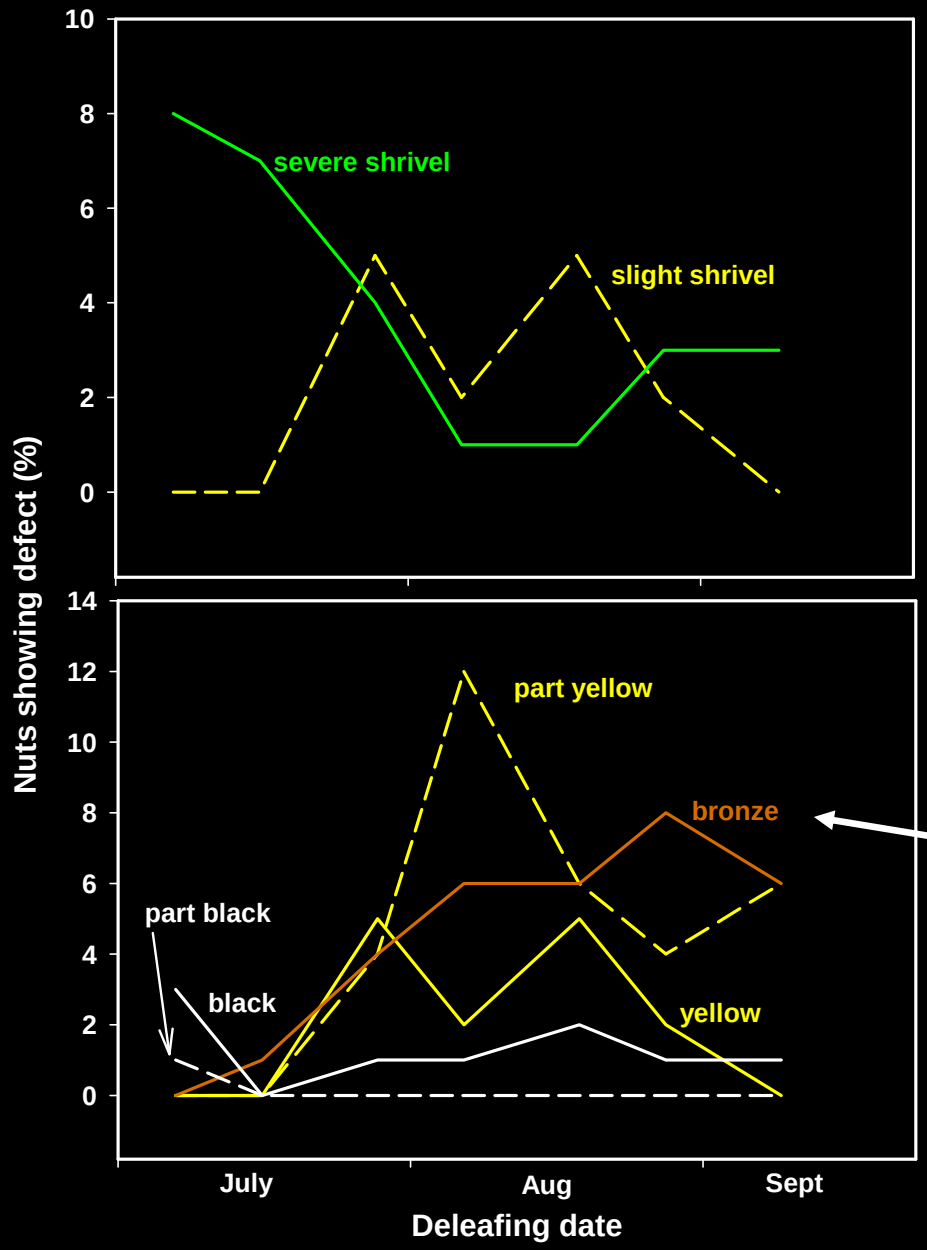
2009- artificially defoliated spurs in lower canopy positions at approximately 10 day intervals

July 7, July 16, July 28, Aug. 6, Aug. 18, Aug. 27 and Sept. 8





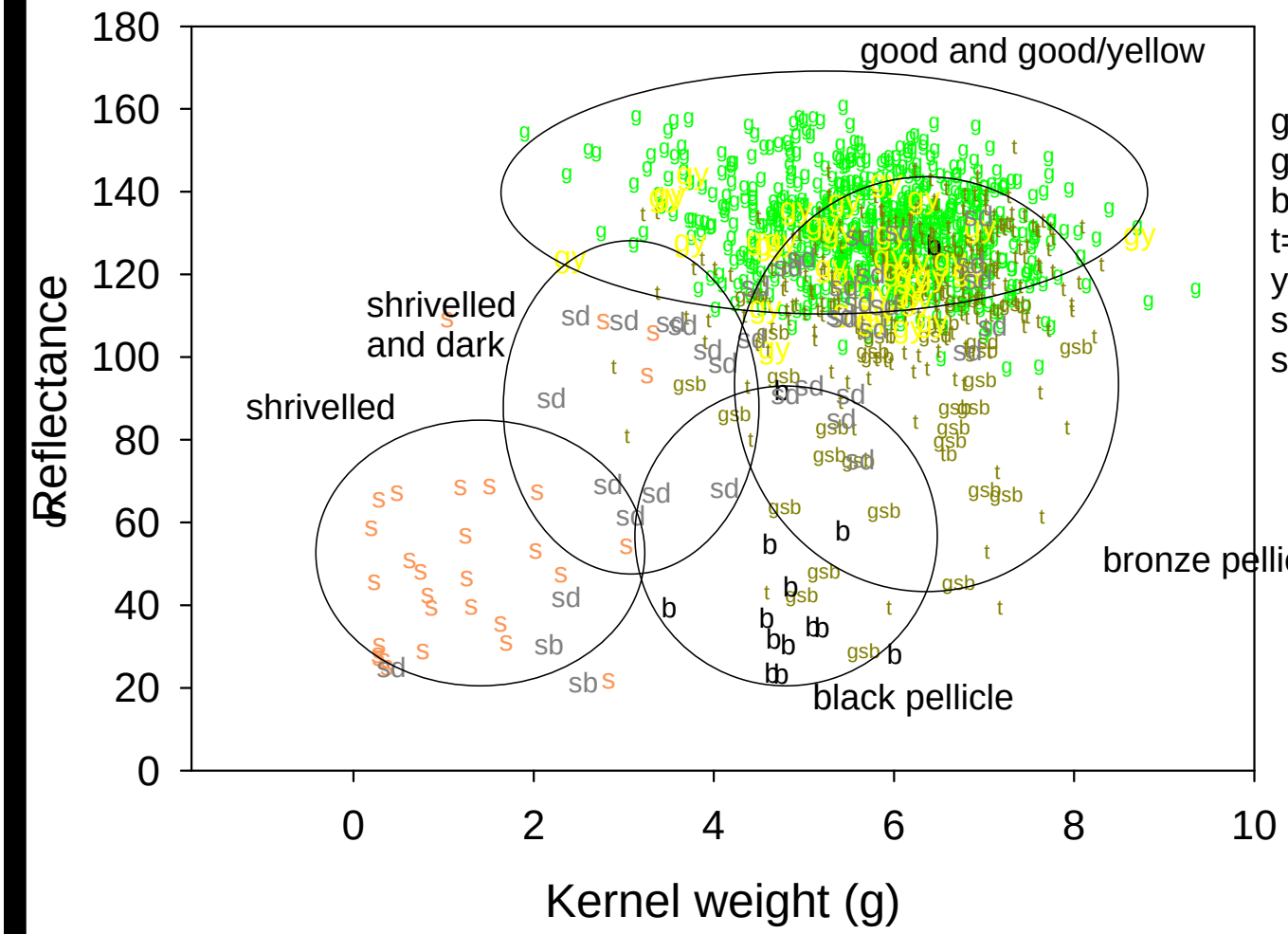
Chandler in
San Joaquin County



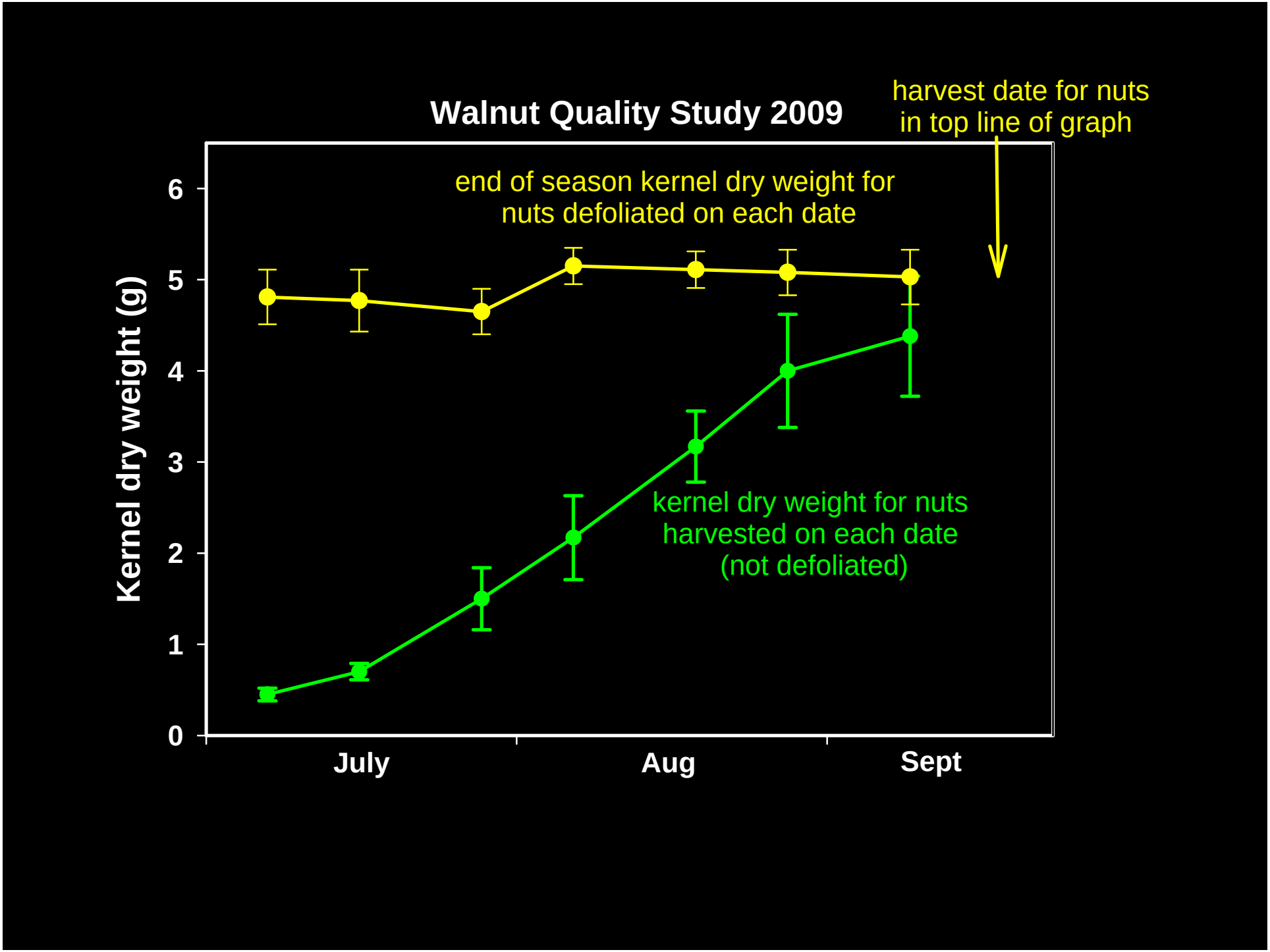
Chandler in
San Joaquin County

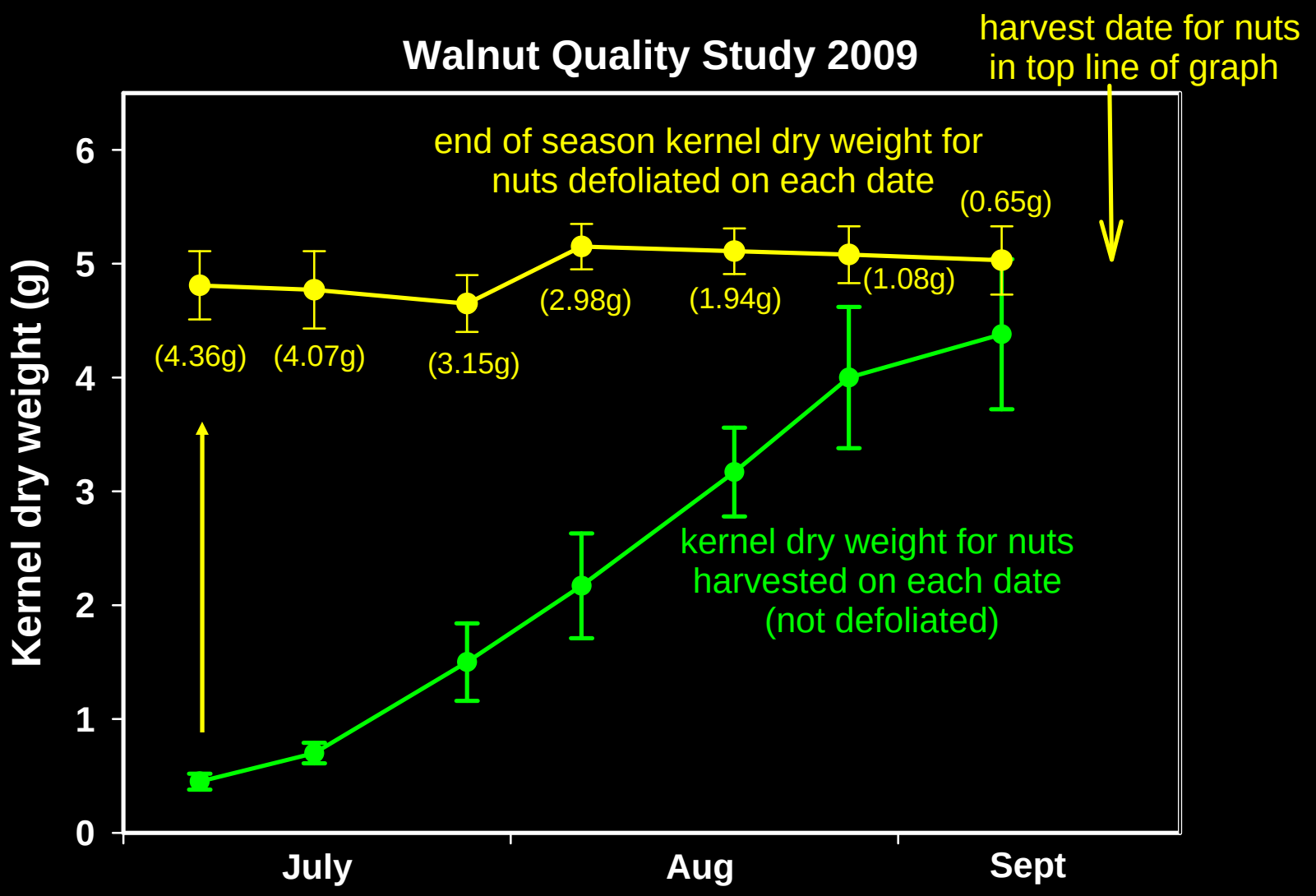
Condition	Peak
Severe shrivel	early July
Slight shrivel	early Aug
Black pellicle	early July, mid- Aug
Yellow pellicle	early Aug
Bronze pellicle	late Aug

oilless nuts

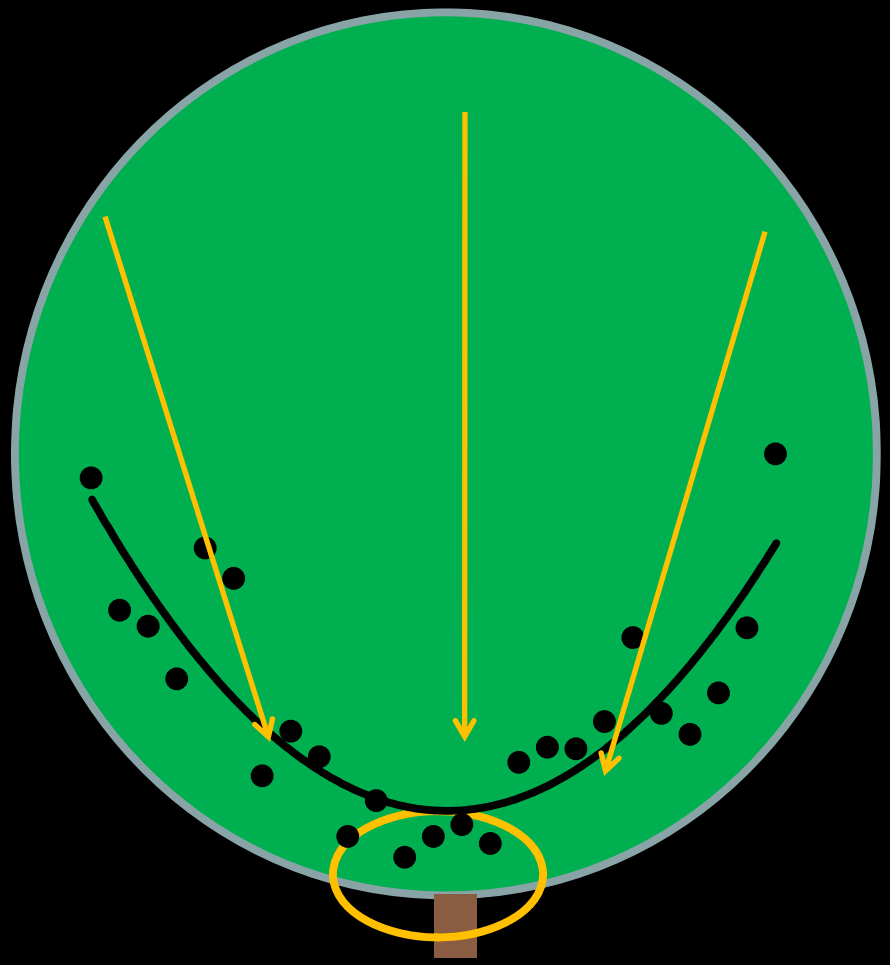


g= well filled nut with light pellicle
gsb= some bronzing of pellicle
b= black pellicle
t= bronze pellicle
y= yellow pellicle
s= shrivelled
sd= shrivelled and dark


Walnut Quality Study 2009
harvest date for nuts
in top line of graph
end of season kernel dry weight for
nuts defoliated on each date
kernel dry weight for nuts
harvested on each date
(not defoliated)
Kernel dry weight (g)
0
1
2
3
4
5
6
July
Aug
Sept



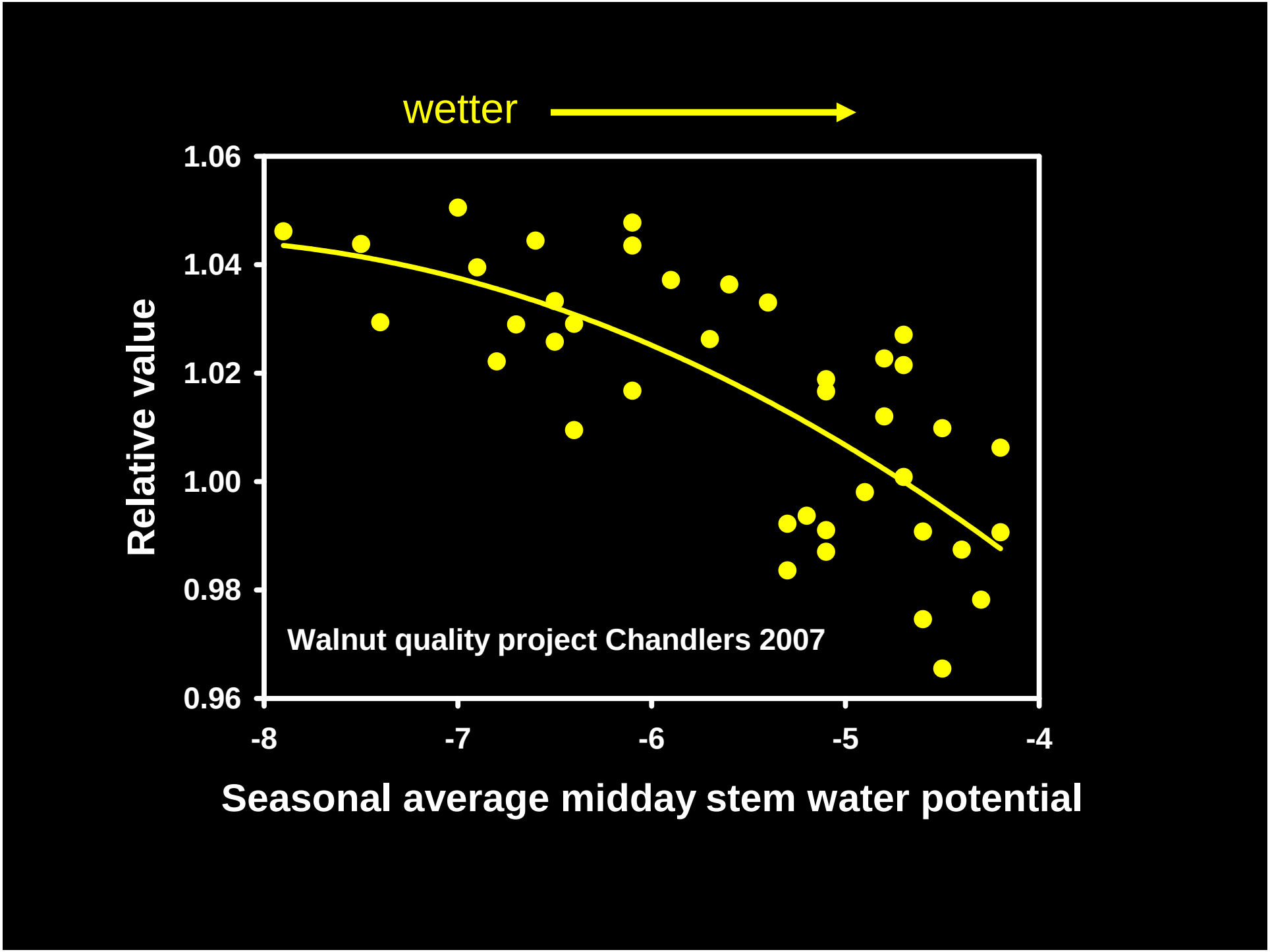
Number in parentheses indicates gain in weight after leaves were removed

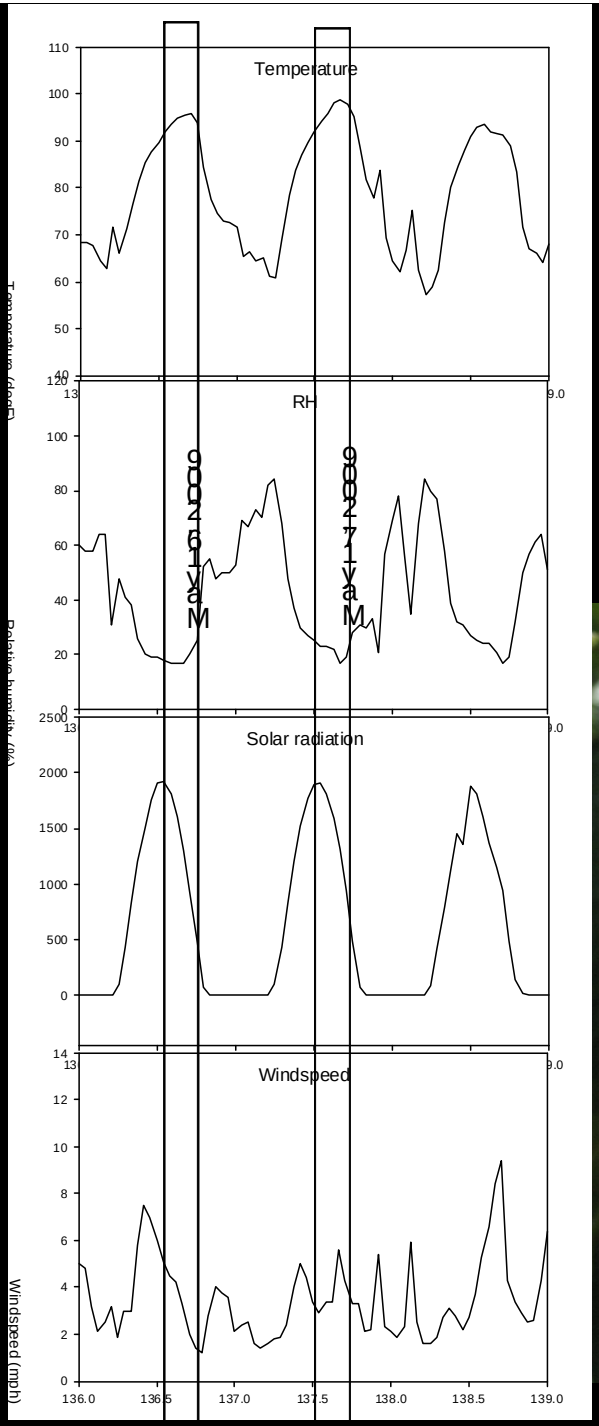


To some degree the walnut tree is able to move photosynthate from outer exposed positions to interior shaded positions

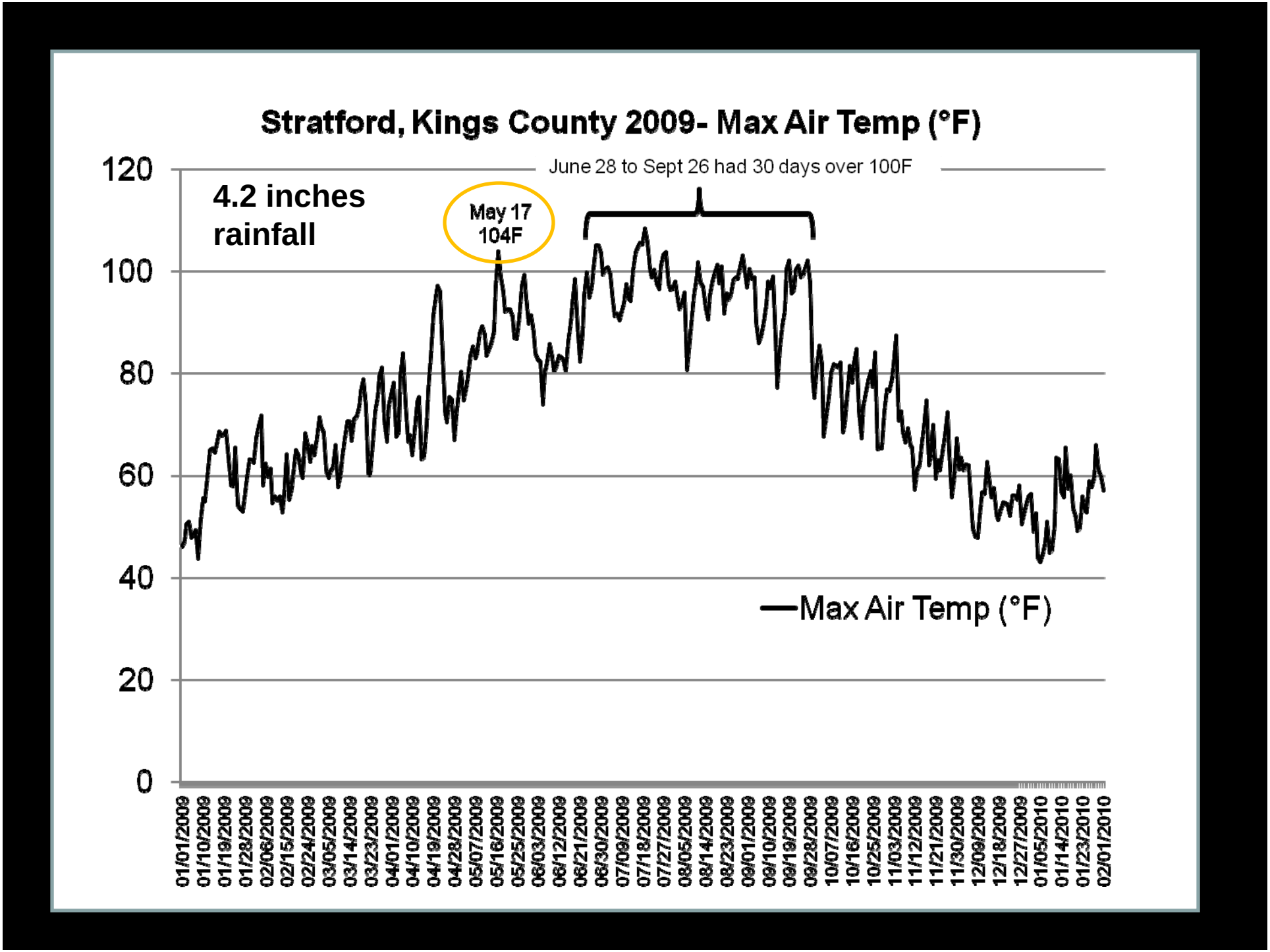
Under conditions of heavy crop load and/or stress, there would be less photosynthate available

We do not yet know how far photosynthate can be moved


wetter
1.06
1.04
1.02
1.00
0.98
0.96
Relative value
Walnut quality project Chandlers 2007
-8
-7
-6
-5
-4
Seasonal average midday stem water potential

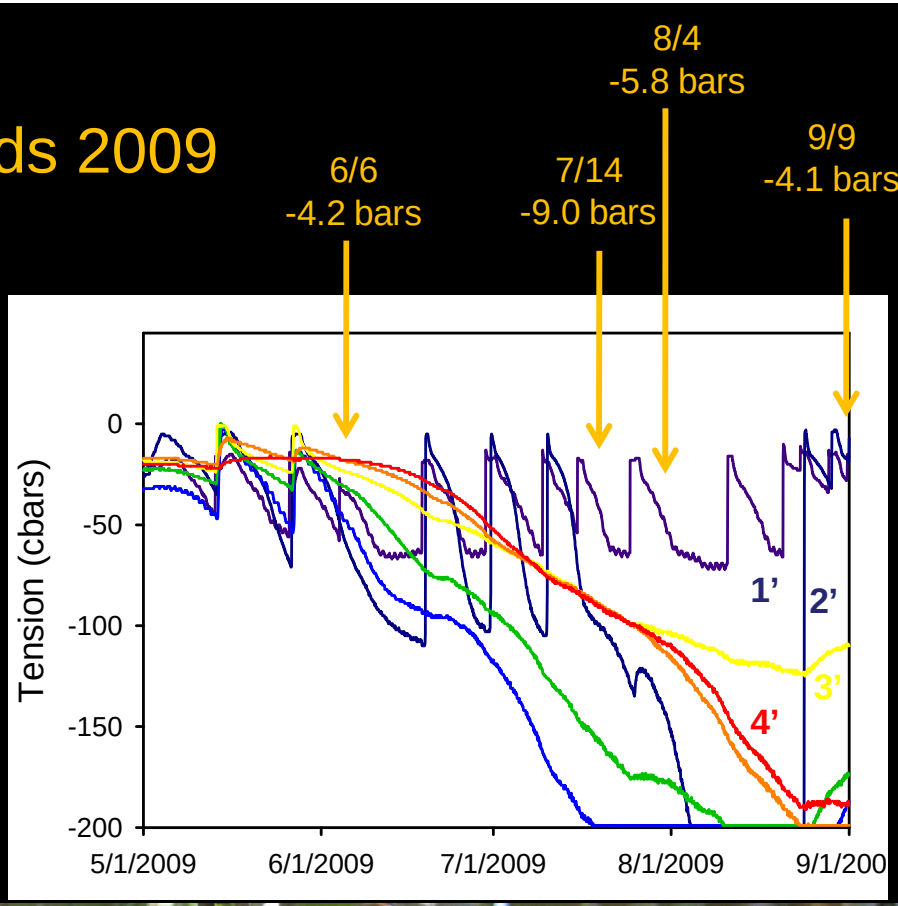


Yolo County Surround trial had sunburn before first Surround application was applied on June 14, 2009.


Stratford, Kings County 2009- Max Air Temp (°F)
June 28 to Sept 26 had 30 days over 100F
4.2 inches rainfall
May 17 104F
120
100
80
60
40
20
0
Max Air Temp (°F)
01/01/2009
01/10/2009
01/19/2009
01/28/2009
02/06/2009
02/15/2009
02/24/2009
03/05/2009
03/14/2009
03/23/2009
04/01/2009
04/10/2009
04/19/2009
04/28/2009
05/07/2009
05/16/2009
05/25/2009
06/03/2009
06/12/2009
06/21/2009
06/30/2009
07/09/2009
07/18/2009
07/27/2009
08/05/2009
08/14/2009
08/23/2009
09/01/2009
09/10/2009
09/19/2009
09/28/2009
10/07/2009
10/16/2009
10/25/2009
11/03/2009
11/12/2009
11/21/2009
11/30/2009
12/09/2009
12/18/2009
12/27/2009
01/05/2010
01/14/2010
01/23/2010
02/01/2010

Sutter County Howards 2009

Loss of many interior leaves
~10% severe shrivel
~5% mold
poor color



Conclusions

- Proper water management in years 1-8 when tree canopy is expanding is critical to avoid substantial losses in potential productivity
  - A short term stress event (excess or shortage of water) can have multi-year implications for yield
- Proper water management once an orchard has filled in it's allotted space is still critical to maximize yield and quality
  - If your orchard is approaching it's yield potential, some quality problems are likely to occur in lower canopy due to shading related issues
  - Quality problems can be greatly exacerbated by short term stress events


Thanks to the
Walnut Marketing
Board and Diamond
Foods, Inc. for
supporting this work