

# Optimum Walnut Canopies: Spacing and Managing Orchards for Both Early and Mature Production

## Production

Bruce Lampinen



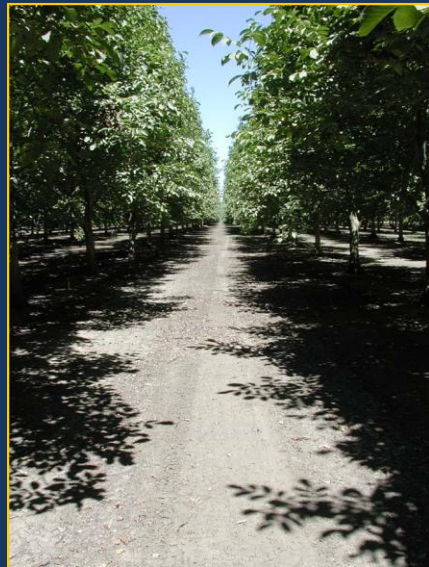
~10% midday light interception



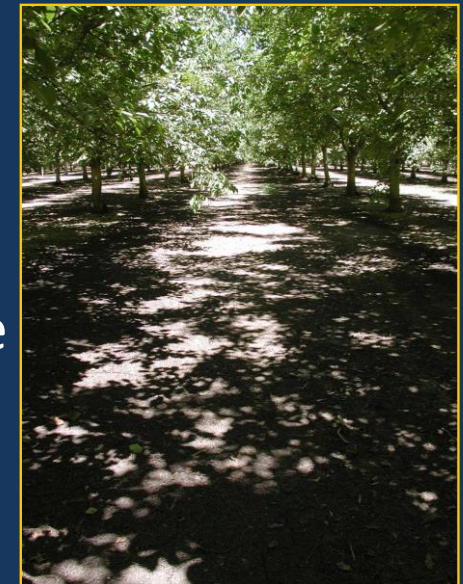
~30% midday light interception



~45% midday light interception



~70% midday light interception



~90% midday light interception

Quad County Walnut Institute  
March 6, 2014

Potential yield is limited by the percentage of the total incoming light that a canopy can intercept



Low yield potential (~2 tons/acre)

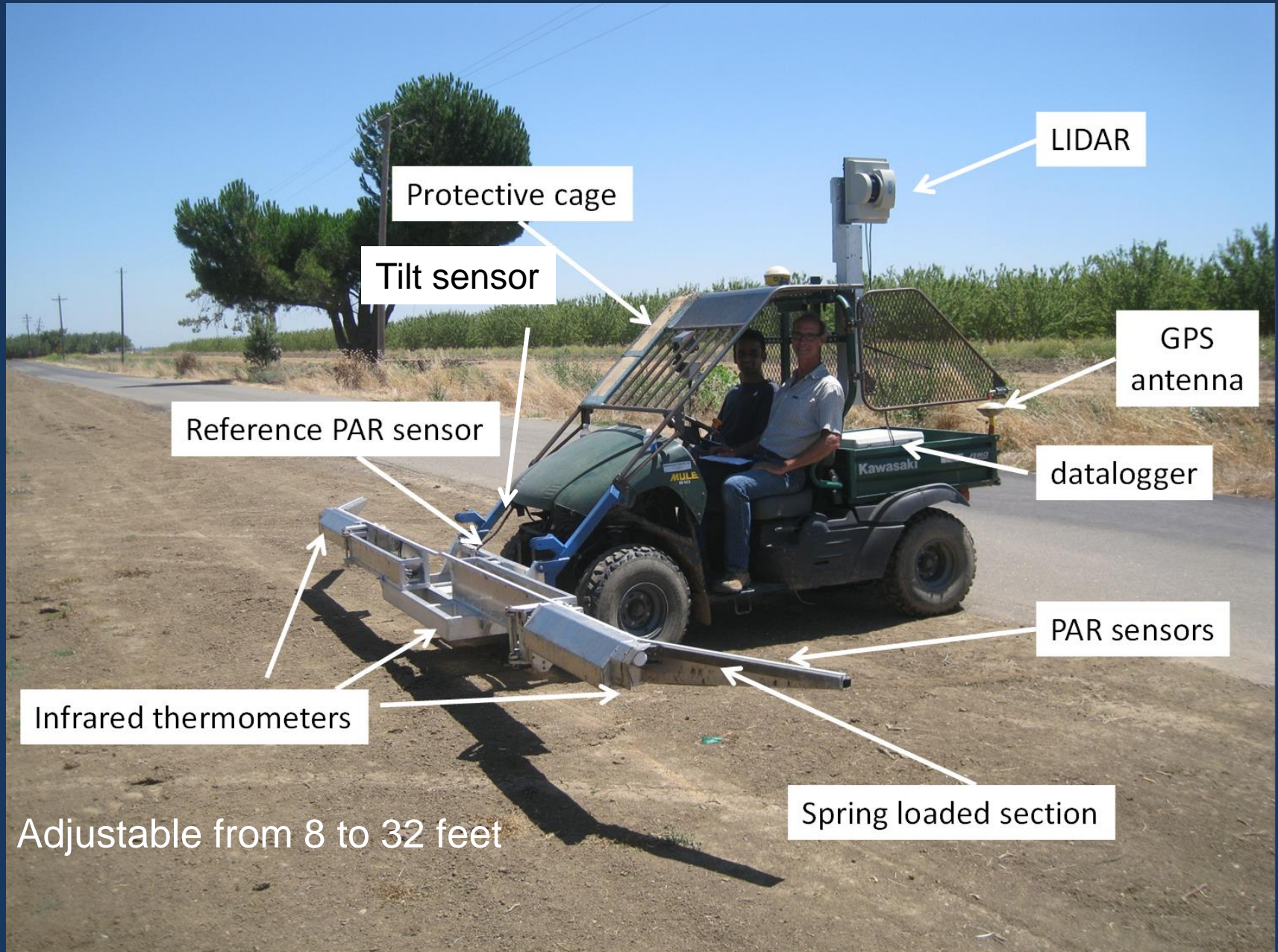


High yield potential (>4 tons/acre)

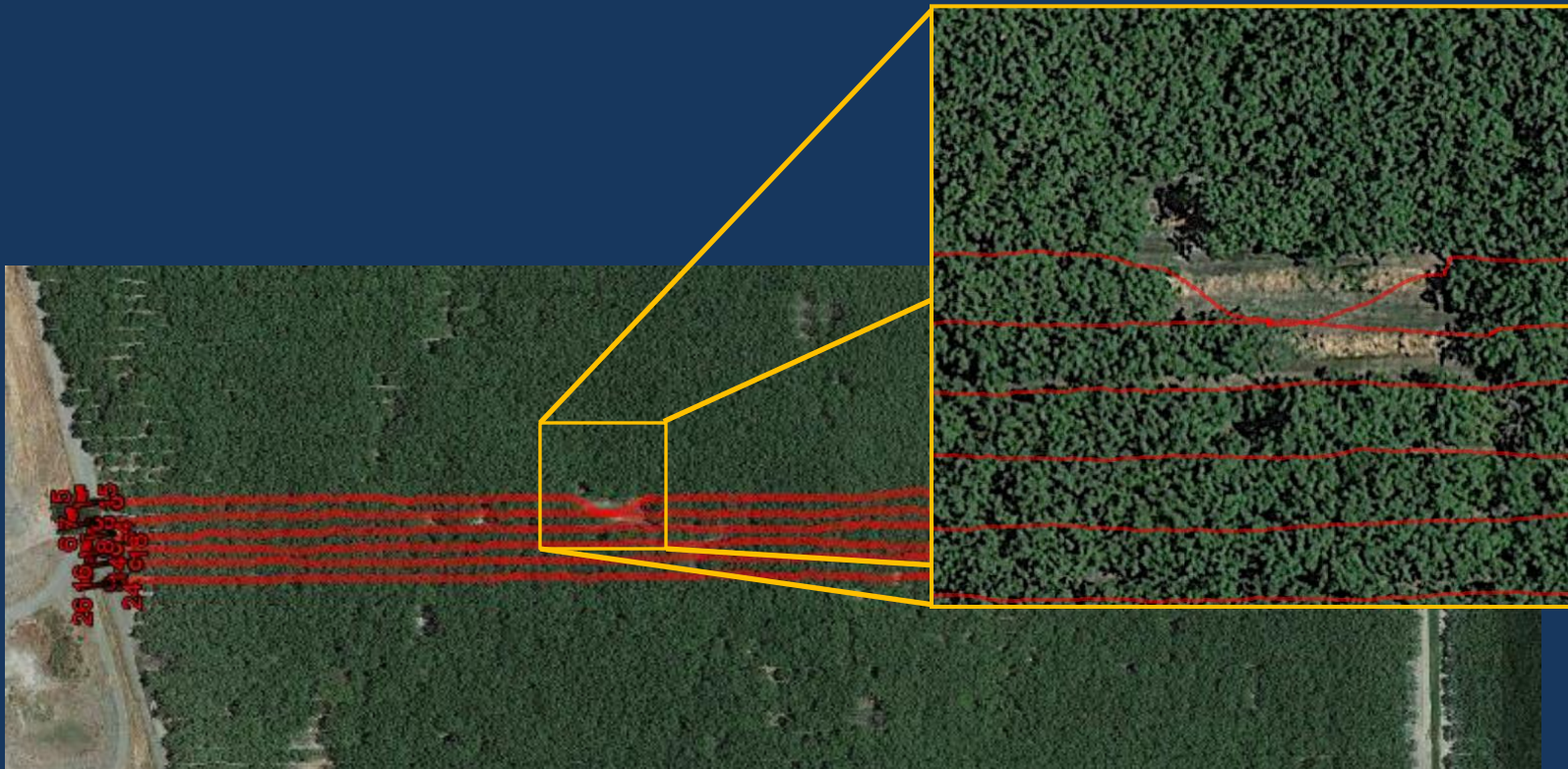
## What I will cover

- 1) How we quantify canopy light interception
- 2) How canopy light interception relates to yield
- 3) How tree spacing relates to canopy development and yield potential
- 4) How pruning/non-pruning influences canopy development and yield

# How we quantify canopy development



- Improvements with second generation Mule
  - Adjustable from 10-32 feet (versus 18-26 feet for first generation)
  - Soil surface temperature at much higher resolution
  - High resolution GoPro camera
  - New GPS that works much better in dense canopies



# How light interception relates to yield



Mid-summer, drive down rows with Mule light bar



At harvest, pick up and weigh all nuts from same area driven down with light bar

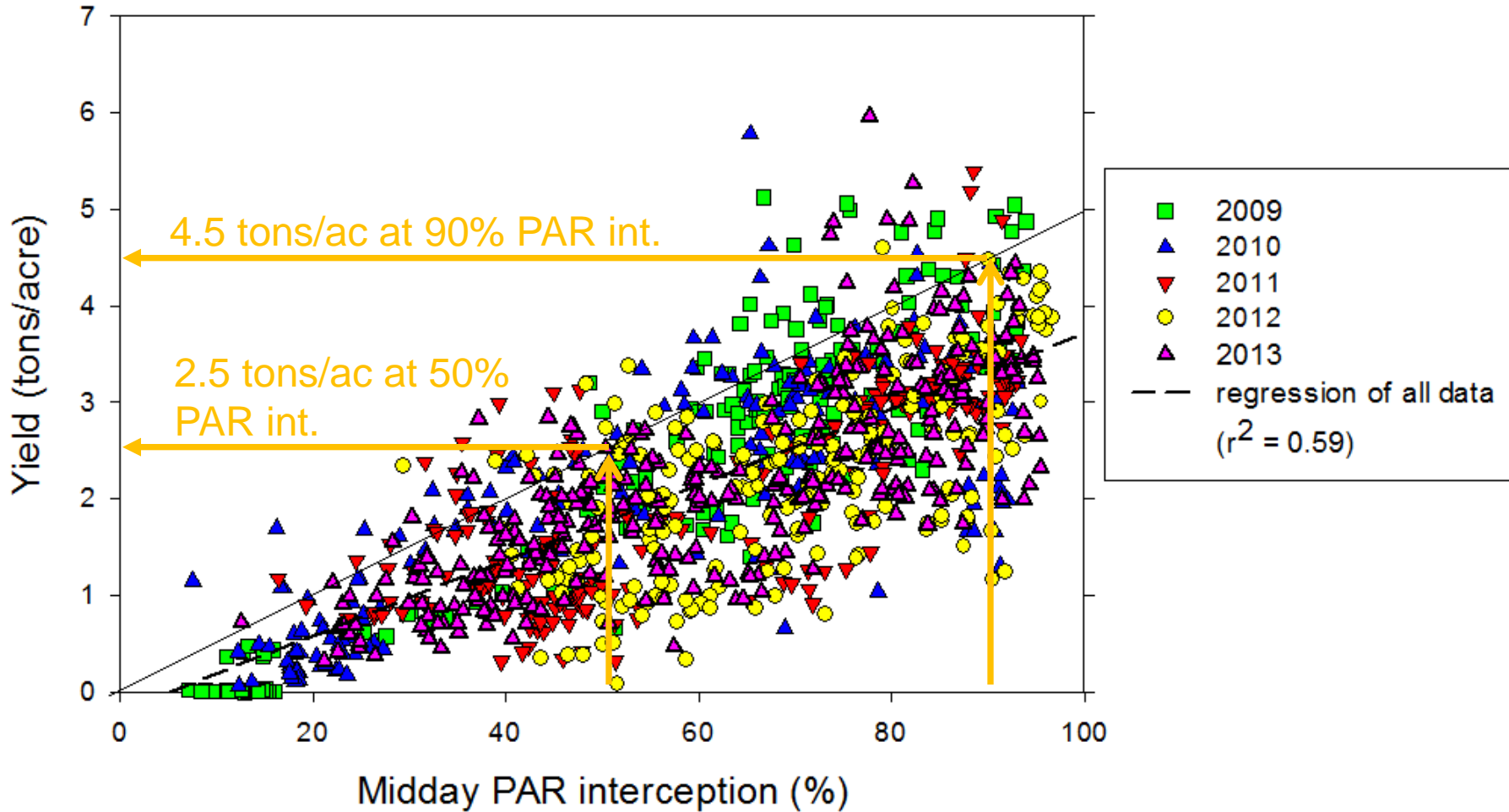


Hydraulically driven auger to deliver samples to rear



Samples are delivered to 5 gallon bucket at rear

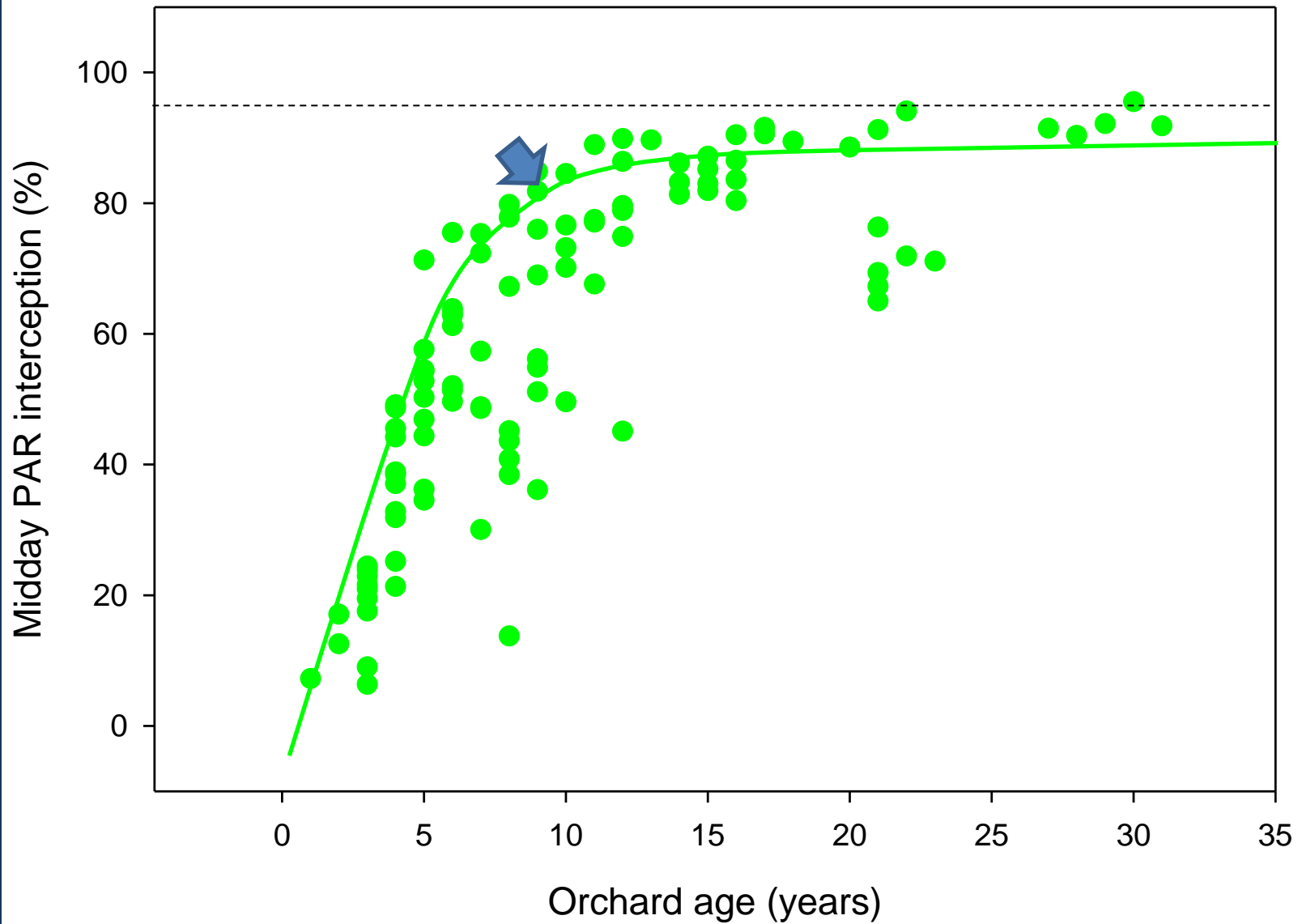
### All walnut data 2009-2013



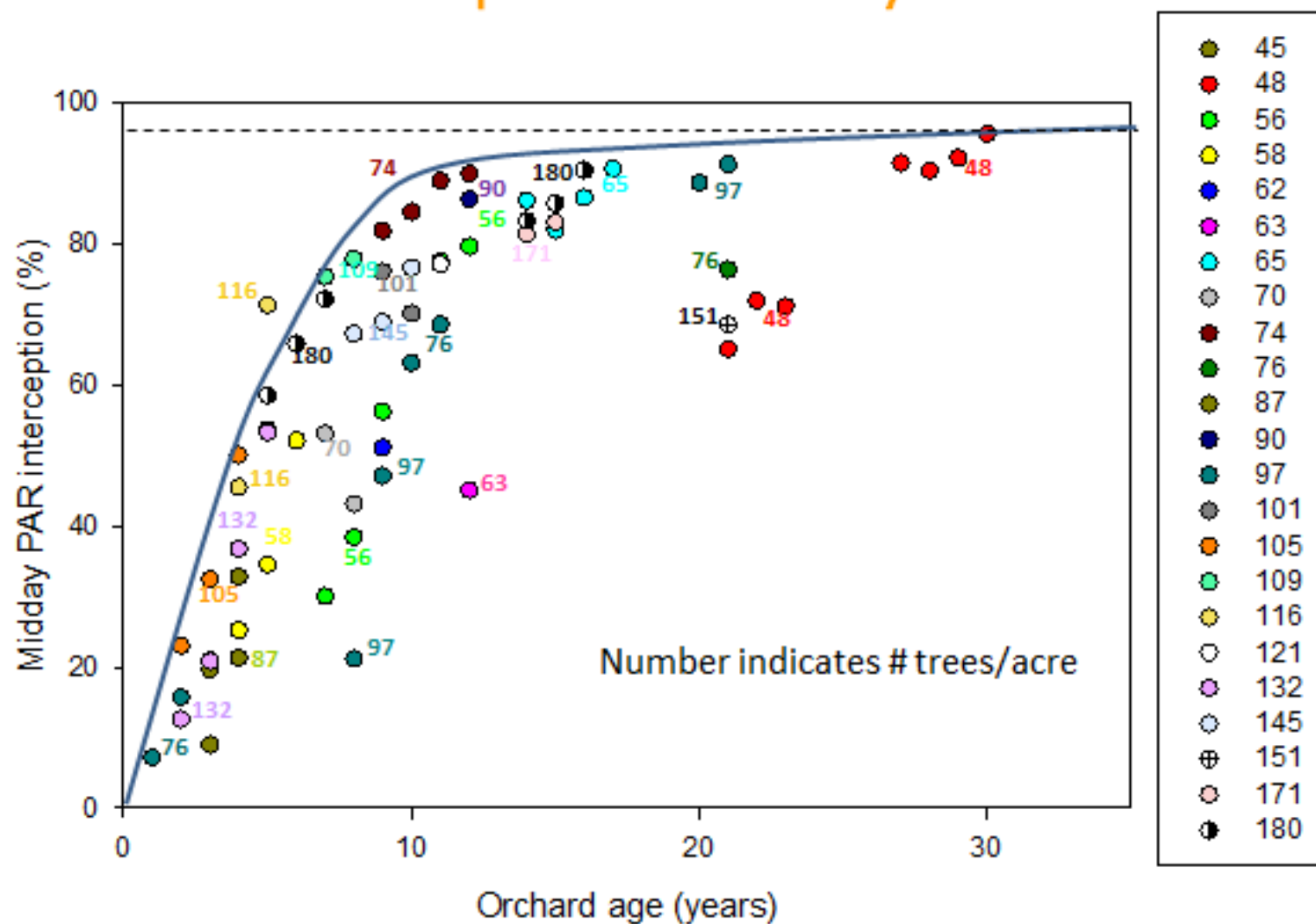
Best orchards can produce 0.05 tons/acre for each 1% of the PAR they intercept (solid black line in figure)  
(PAR = photosynthetically active radiation)

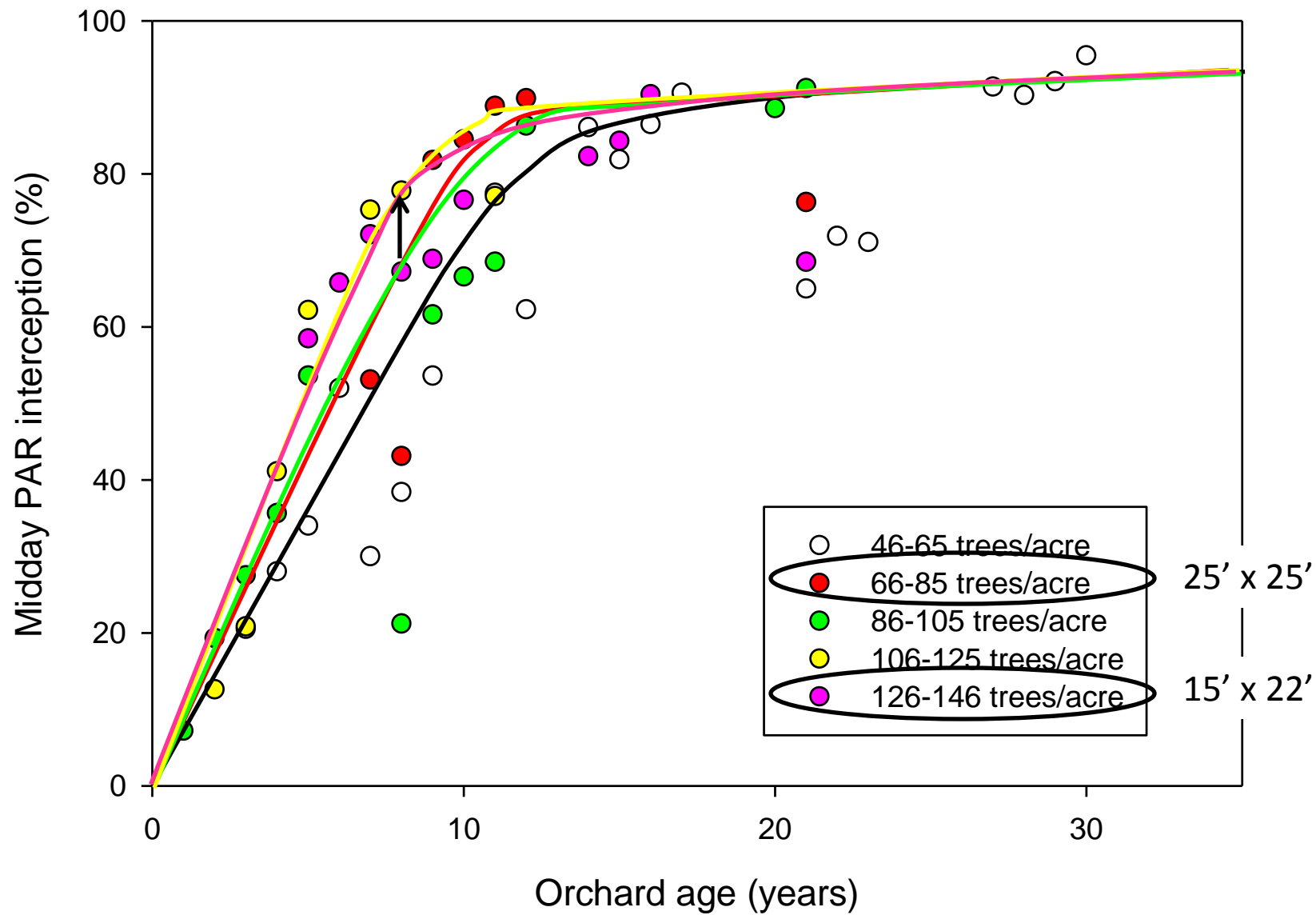


The fastest growing orchards can increase in light interception by 10% per year reaching about 90% cover by the 9<sup>th</sup> year



# How tree spacing influences canopy development and yield



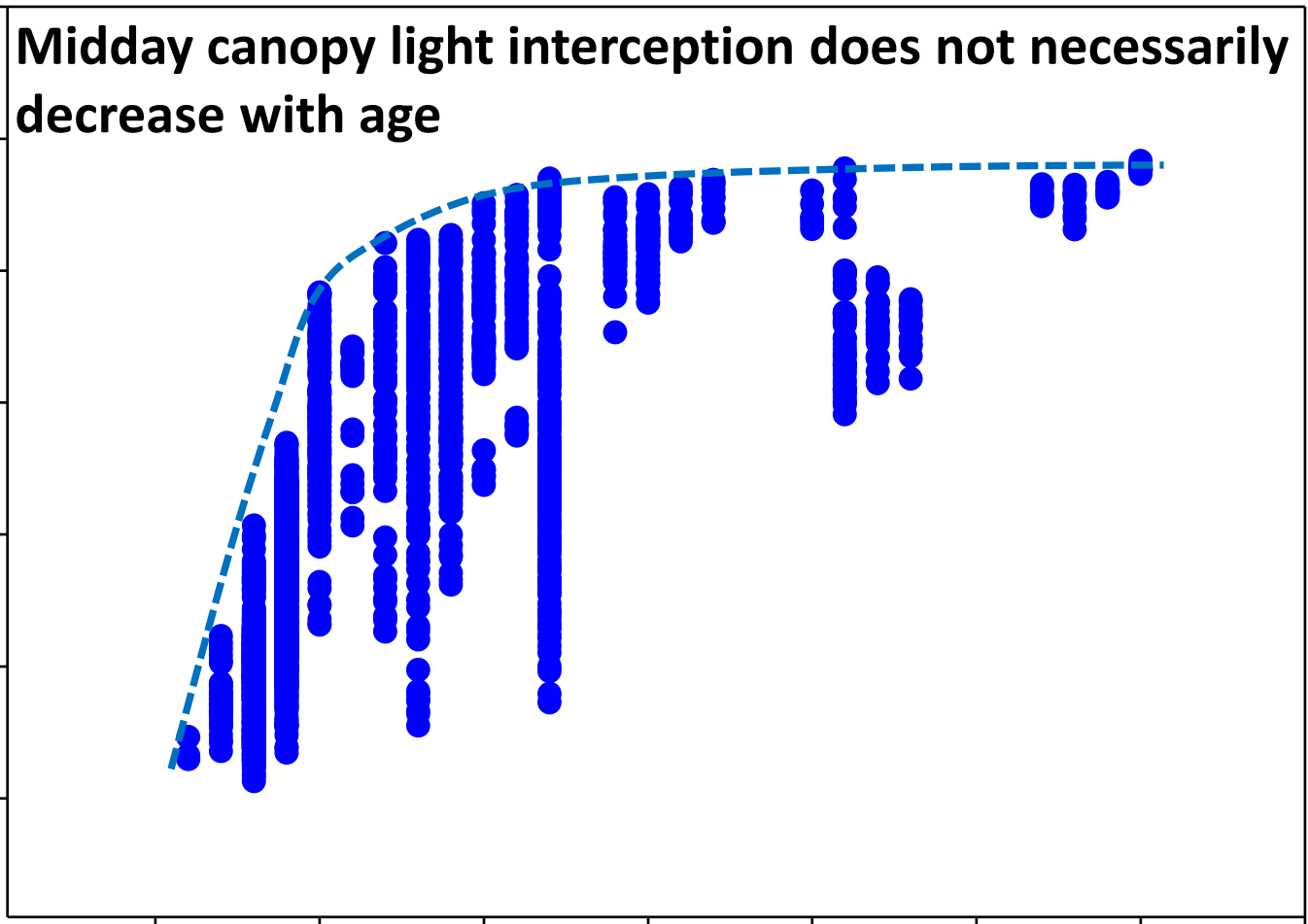


**Midday canopy light interception (%)**

120  
100  
80  
60  
40  
20  
0

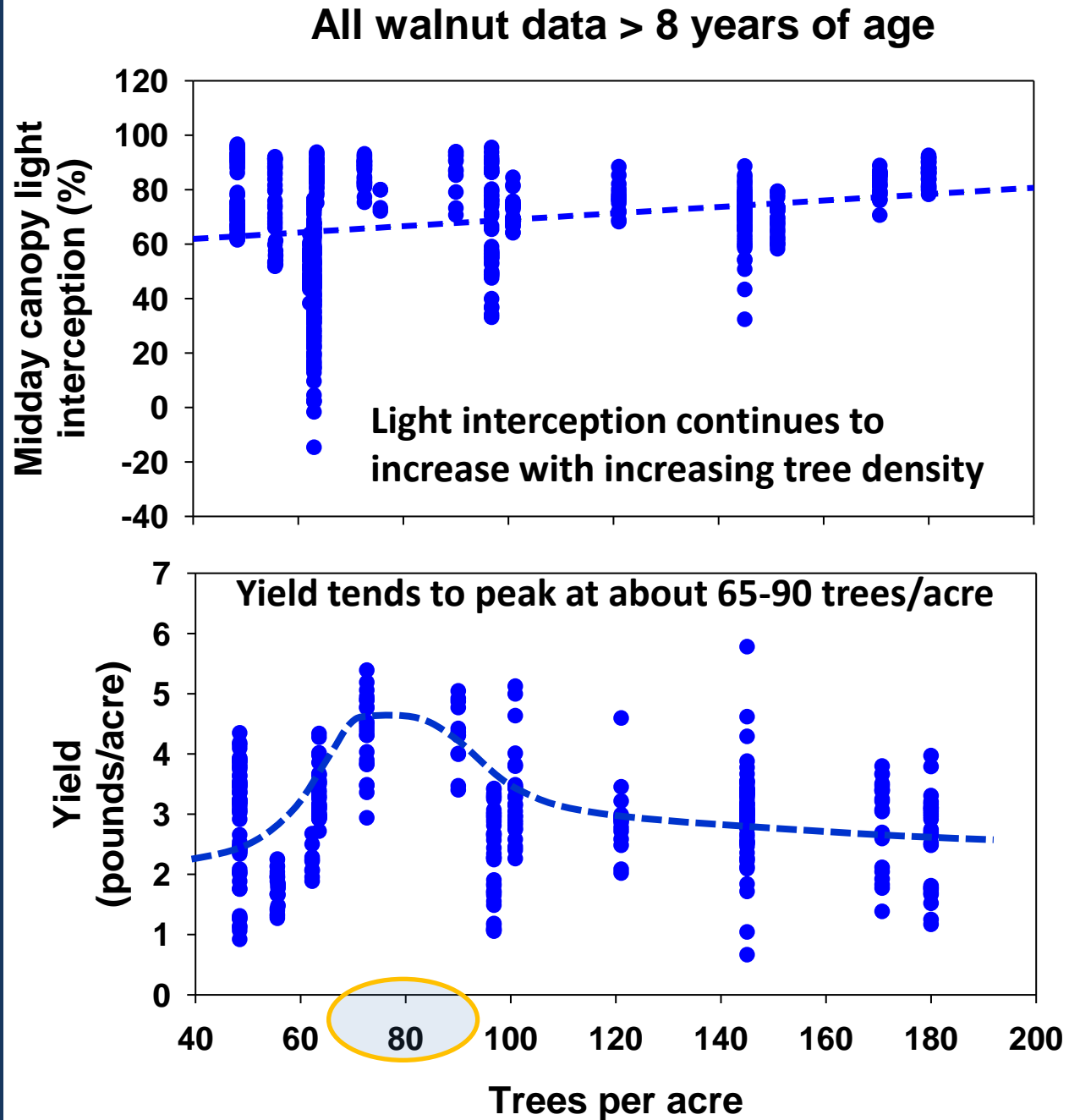
**Midday canopy light interception does not necessarily decrease with age**

0 5 10 15 20 25 30 35  
**Age (years)**



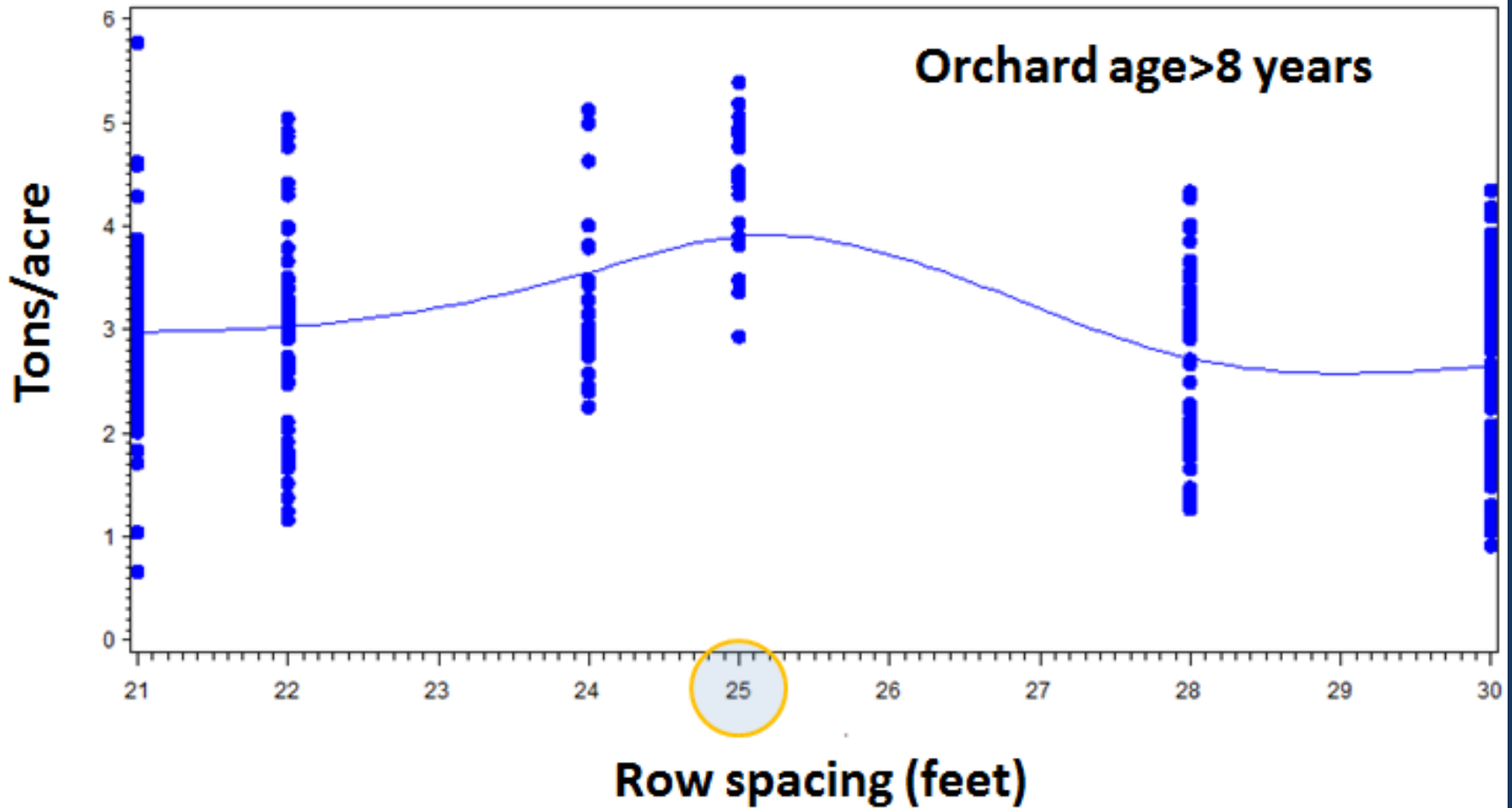


# Trees per acre



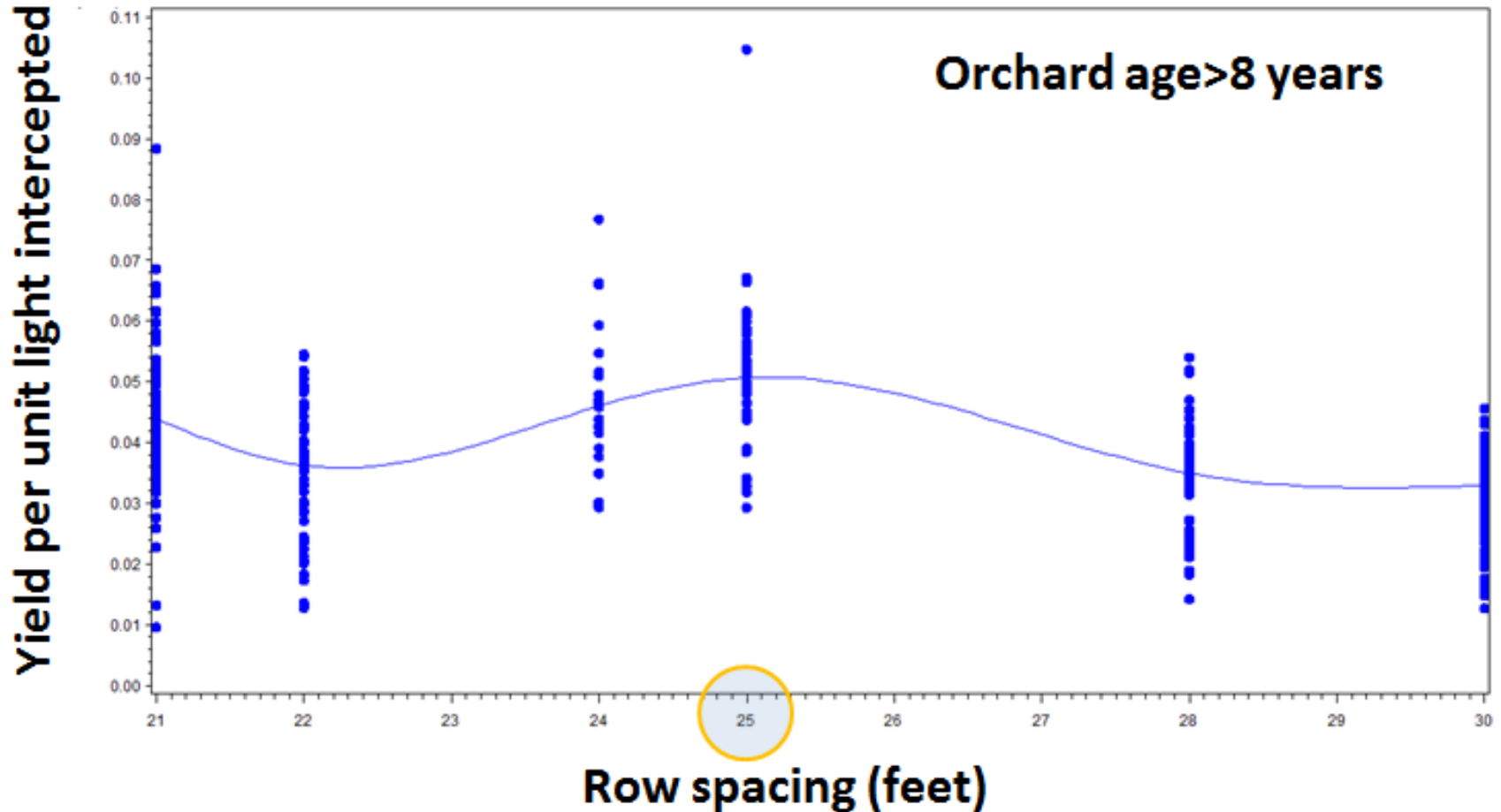
# Tons per acre versus row spacing

Highest yield occurred at a row spacing of ~25 feet



# Yield per unit light intercepted versus row spacing

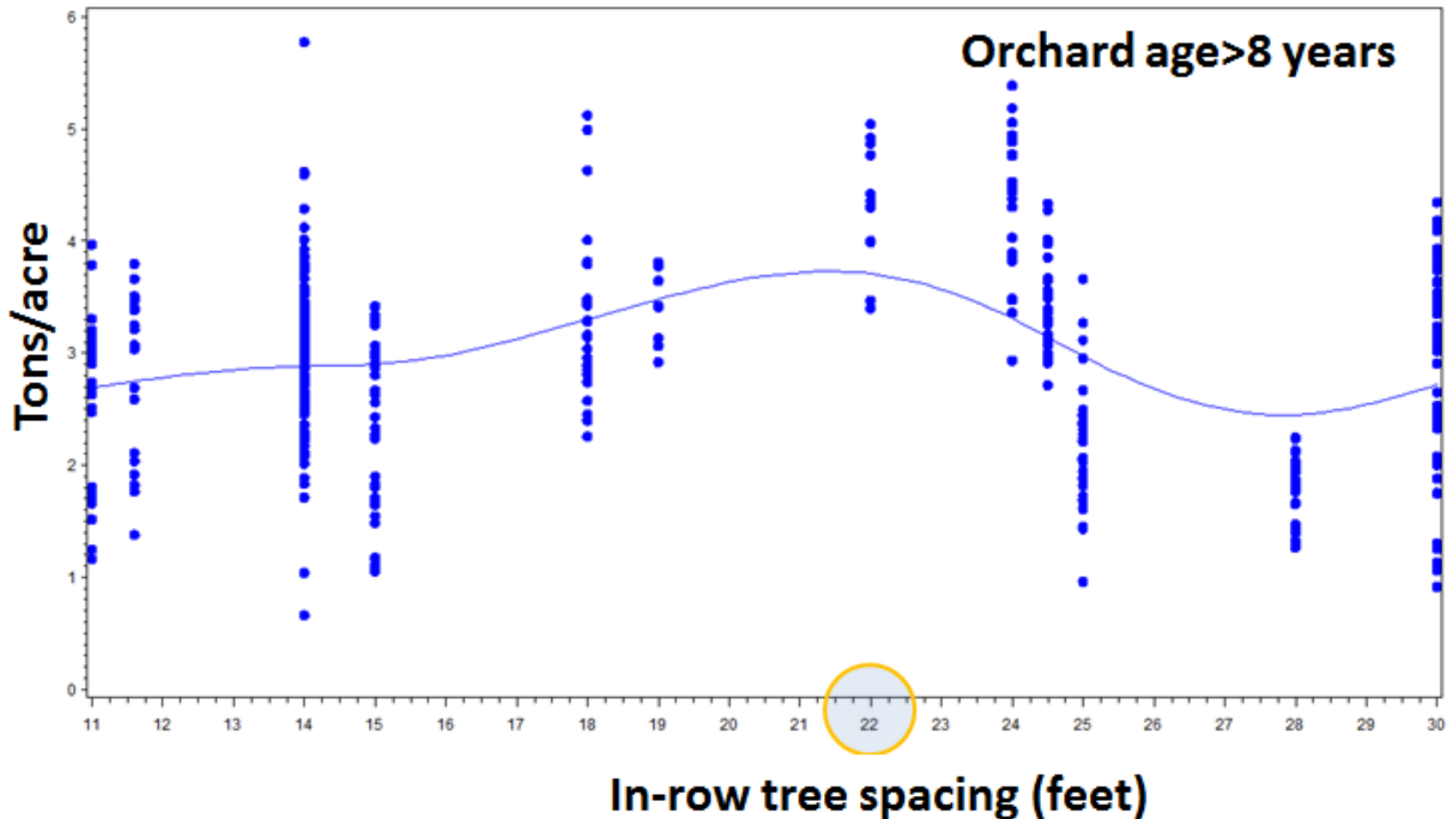
Highest yield per unit light intercepted occurred at a row spacing of 25 feet





# Tons per acres versus in-tree row spacing

Highest yield- within row tree spacing of 22 feet



**Optimum appears to be at about 22'-28' traditional square spacing and about 65-75 trees per acre. The highest yielding orchard in trial was 24' row spacing by 25' tree spacing**

Row spacing	Tree spacing	#trees/acre
20	20	109
21	21	99
22	22	90
23	23	82
24	24	76
25	25	70
26	26	64
27	27	60
28	28	56
29	29	52
30	30	48

\*This is dependent on soil type, rootstock, scion, management style, etc.

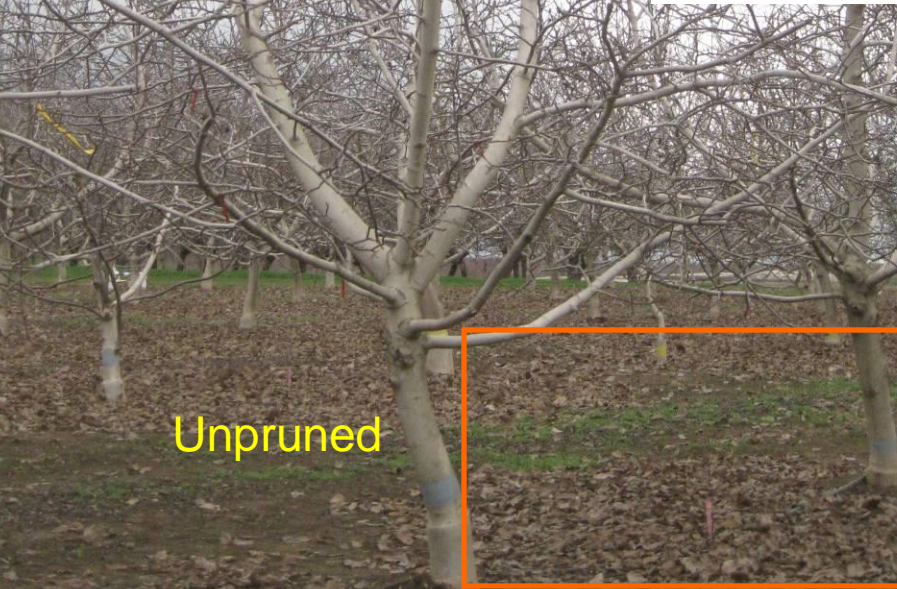
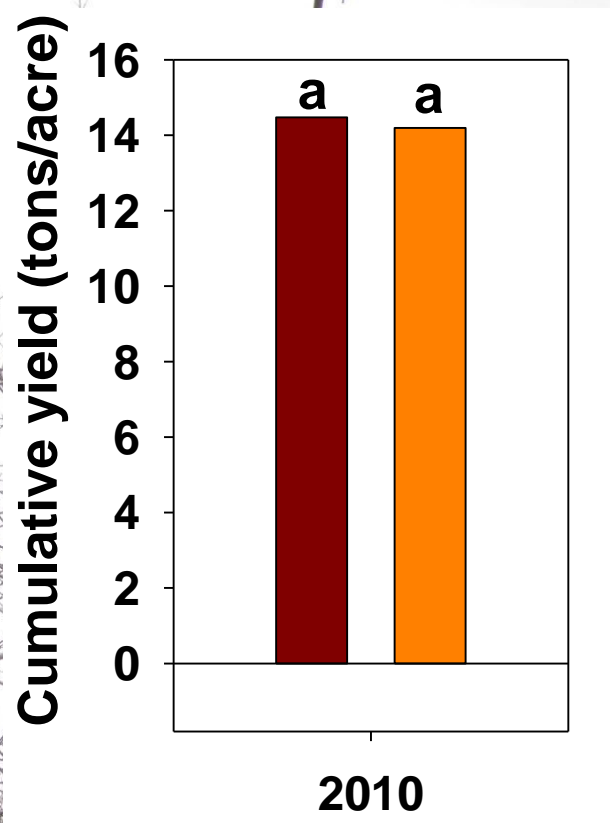
# How pruning/non-pruning influences canopy development and yield



# Howard pruning trial summary- results after 7 years of treatment

- Pruned versus unpruned- no significant differences in:
  - Tree size
  - Midday canopy light interception
  - Cumulative yield
  - Percent sunburn
  - Quality- except more large nuts in unpruned one year

Jan. 2010



Unpruned



Pruned

**March 2007**

elongation  
(neoformed  
growth)



**March 2008**

lateral  
branching  
(preformed  
growth  
only)



**Feb 2009**

elongation  
(neoformed  
growth)



Unpruned

Unpruned

Unpruned

# Chandler pruned versus unpruned trial

**Chandler orchard planted at 15 x 22 ft.**

**Planted 2008**

**Nursery budded on Paradox rootstock**

**March 2009 first pruning**

**Treatments**

- Heavily pruned**
- Minimally pruned**
- No heading/no pruning**

**Heavily pruned**



**Unpruned**

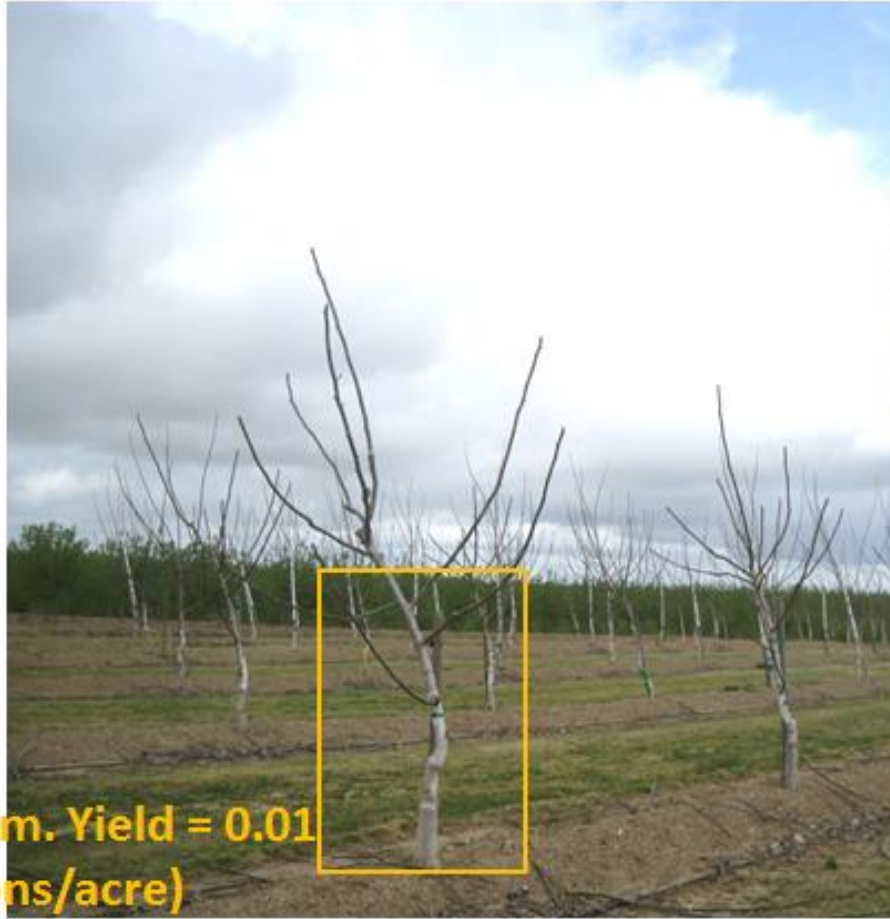


**3/25/09**



**Heavily pruned**

**Unpruned**



**Cum. Yield = 0.01  
(tons/acre)**



**0.02**

**3/29/10**

Heavily pruned



Cum. Yield = 0.15  
(tons/acre)

Unpruned



0.74

04/05/11

**Heavily pruned**



**Cum. Yield = 1.79  
(tons/acre)**

**Unpruned**



**2.98**

**01/05/12**



**Heavily pruned**

**Cum. Yield = 3.87  
(tons/acre)**



**Unpruned**

**4.84**

**01/01/13**



Heavily pruned

Cum. Yield = 5.20  
(tons/acre)

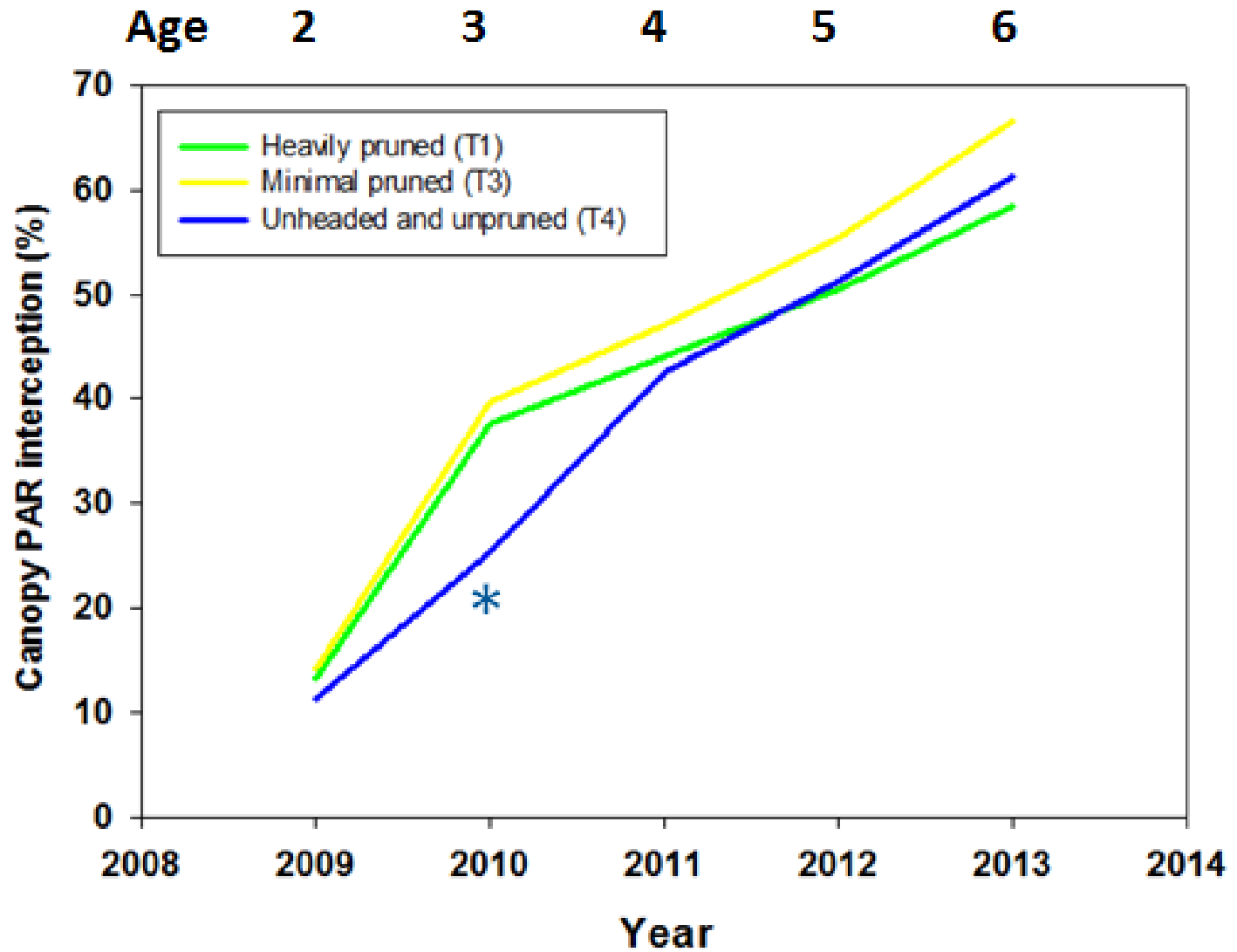


Unpruned

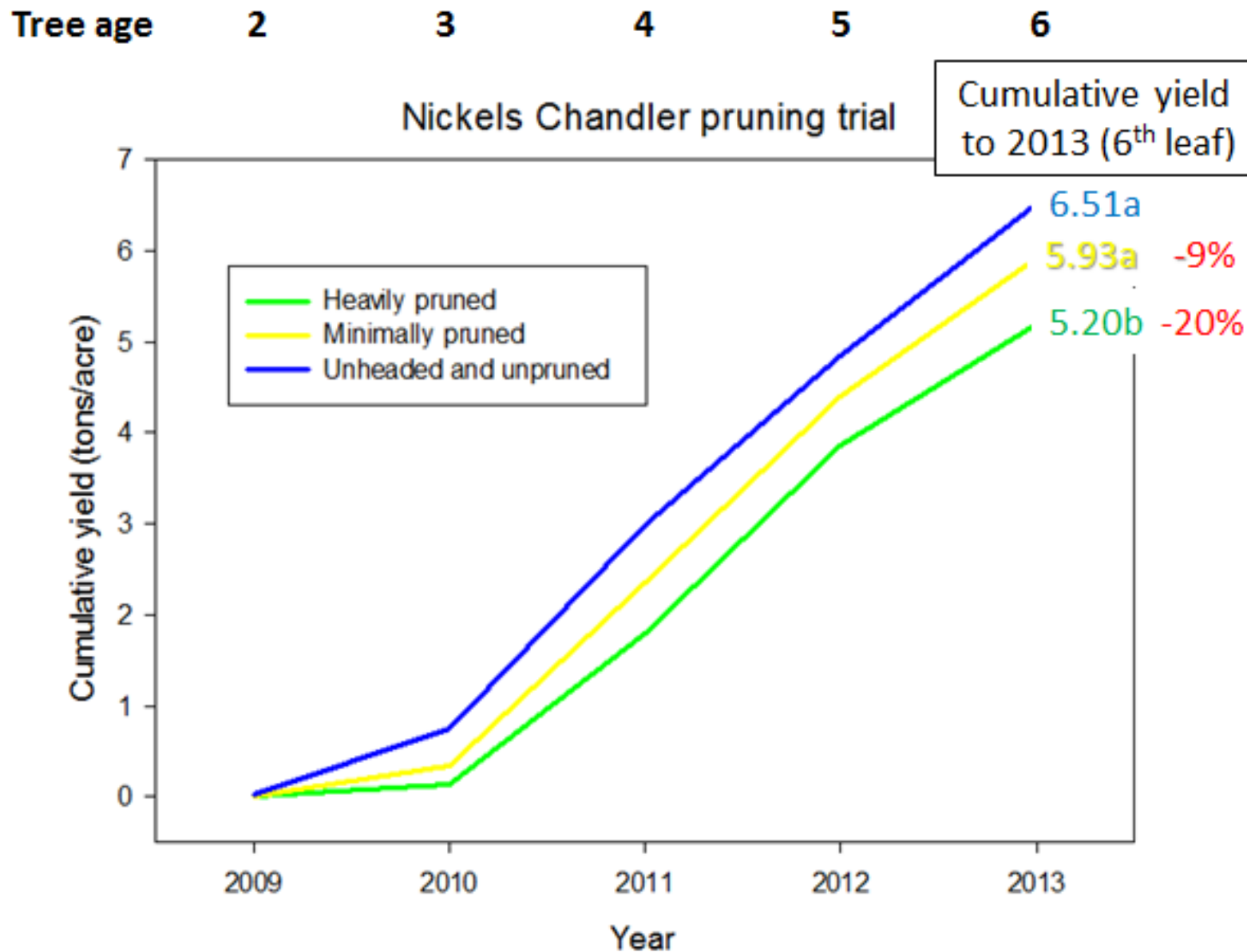
6.51

2/24/14

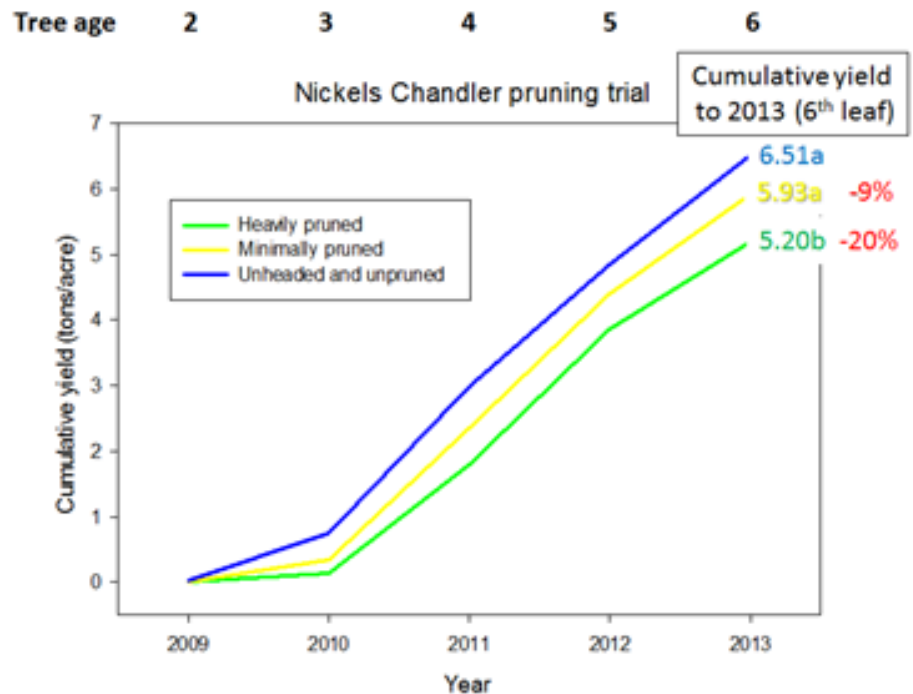
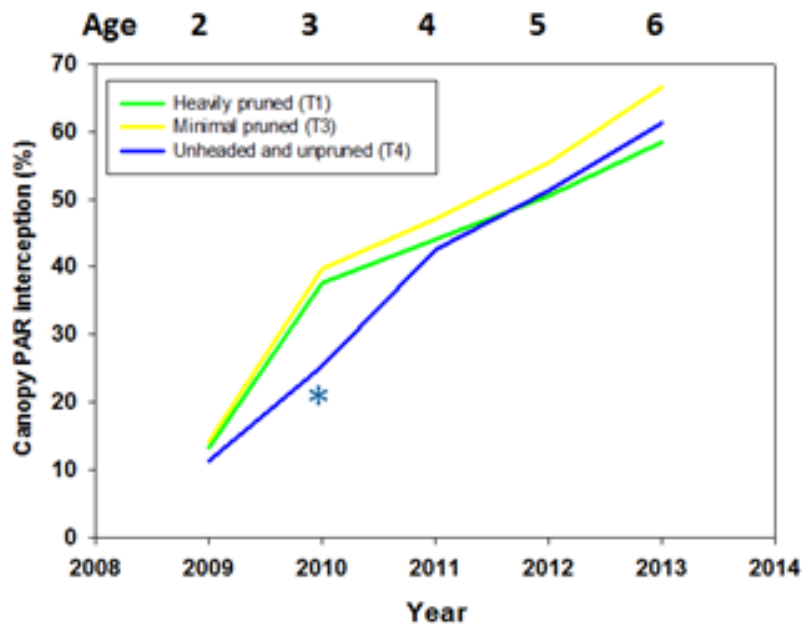
# Midday canopy light interception by treatment and year for Chandler



# Cumulative yield by treatment and year for Chandler



Higher midday canopy light interception combined with lower yield indicates lower water use efficiency for pruned treatments in years 2-6.





# Water needed to support canopy based on proportion of 42 inches needed at 60% canopy cover

Age

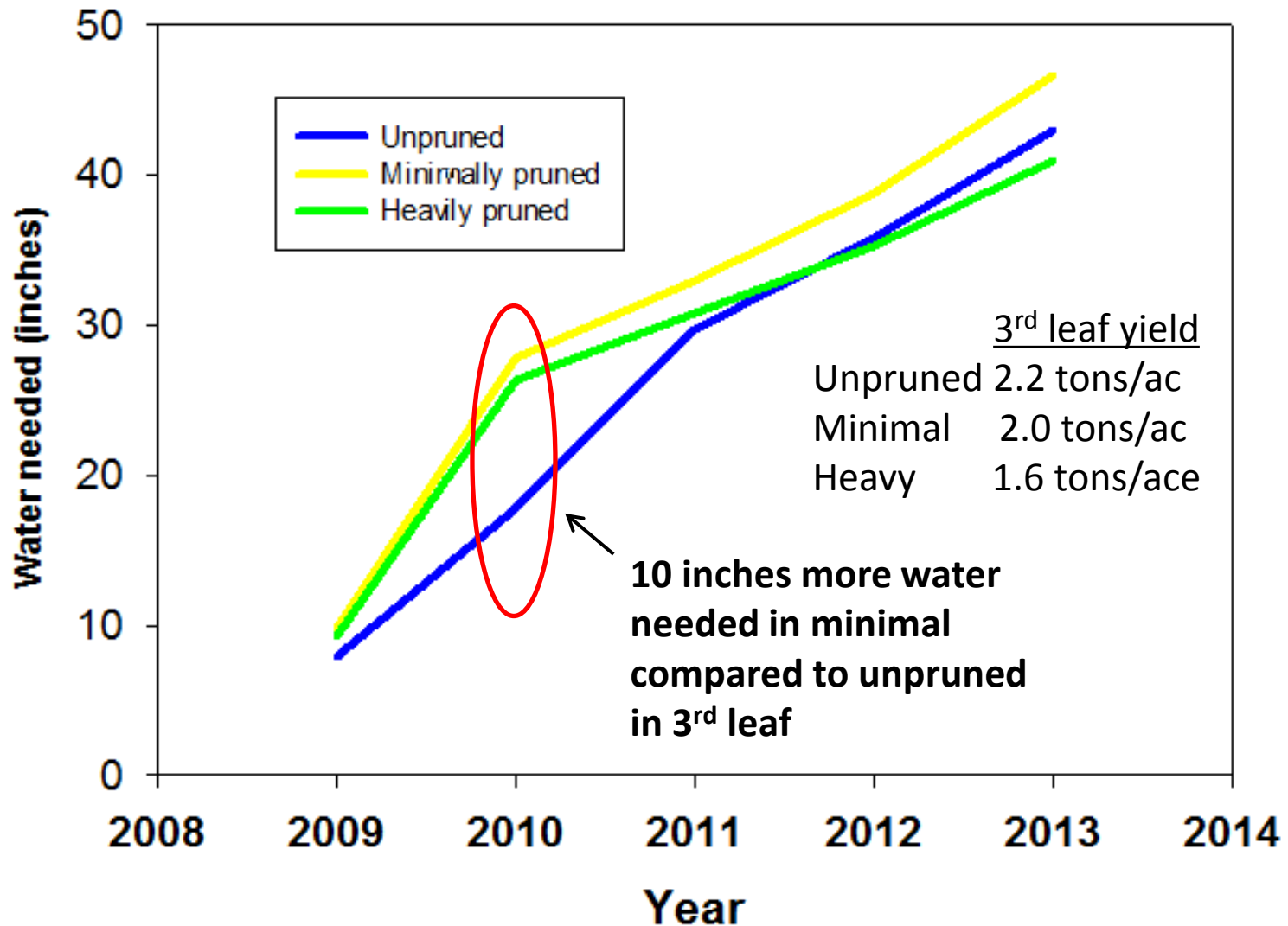
2

3

4

5

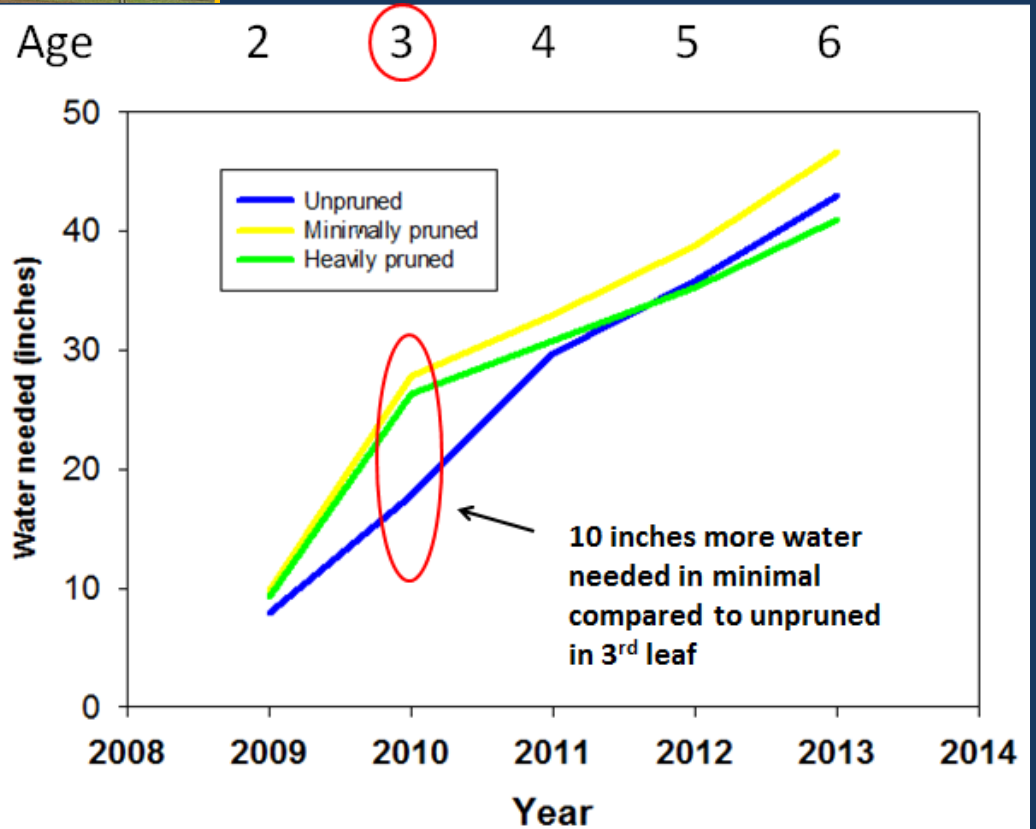
6





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 minimally pruned in 3<sup>rd</sup> leaf



10 inches more water needed in minimal compared to unpruned in 3<sup>rd</sup> leaf

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

<b>Treatment</b>	<b>Total water needed based on canopy size (years 2-6)</b>	<b>Cumulative yield (tons/acre)</b>	<b>Water use efficiency expressed as pounds of walnuts produced per inch of water applied</b>	<b>Water use efficiency (% of unpruned)</b>
Unpruned	134	6.51	97	100
Minimally pruned	156	5.93	76	78
Heavily pruned	142	5.20	73	75

# Chandler pruning trial summary

- Heavy pruning resulted in smaller trees and less yield in years 1-4
- After 6 years, cumulative yields are similar for unpruned and minimally pruned but significantly less for heavily pruned
- Water use efficiency higher in unpruned
- There were no benefits to either minimal or heavy pruning in this trial

The Howard and Chandler pruned versus unpruned trials do not support the common wisdom that you need to prune walnuts to get them to grow and be productive

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# Current pruned versus unpruned trials throughout California- designed to test concept under a variety of conditions and management styles

3<sup>rd</sup> Leaf Forde in Yolo County



3<sup>rd</sup> Leaf Howard in Butte County



3<sup>rd</sup> Leaf Chandler in Tulare County



3<sup>rd</sup> Leaf Chandler in Lake County

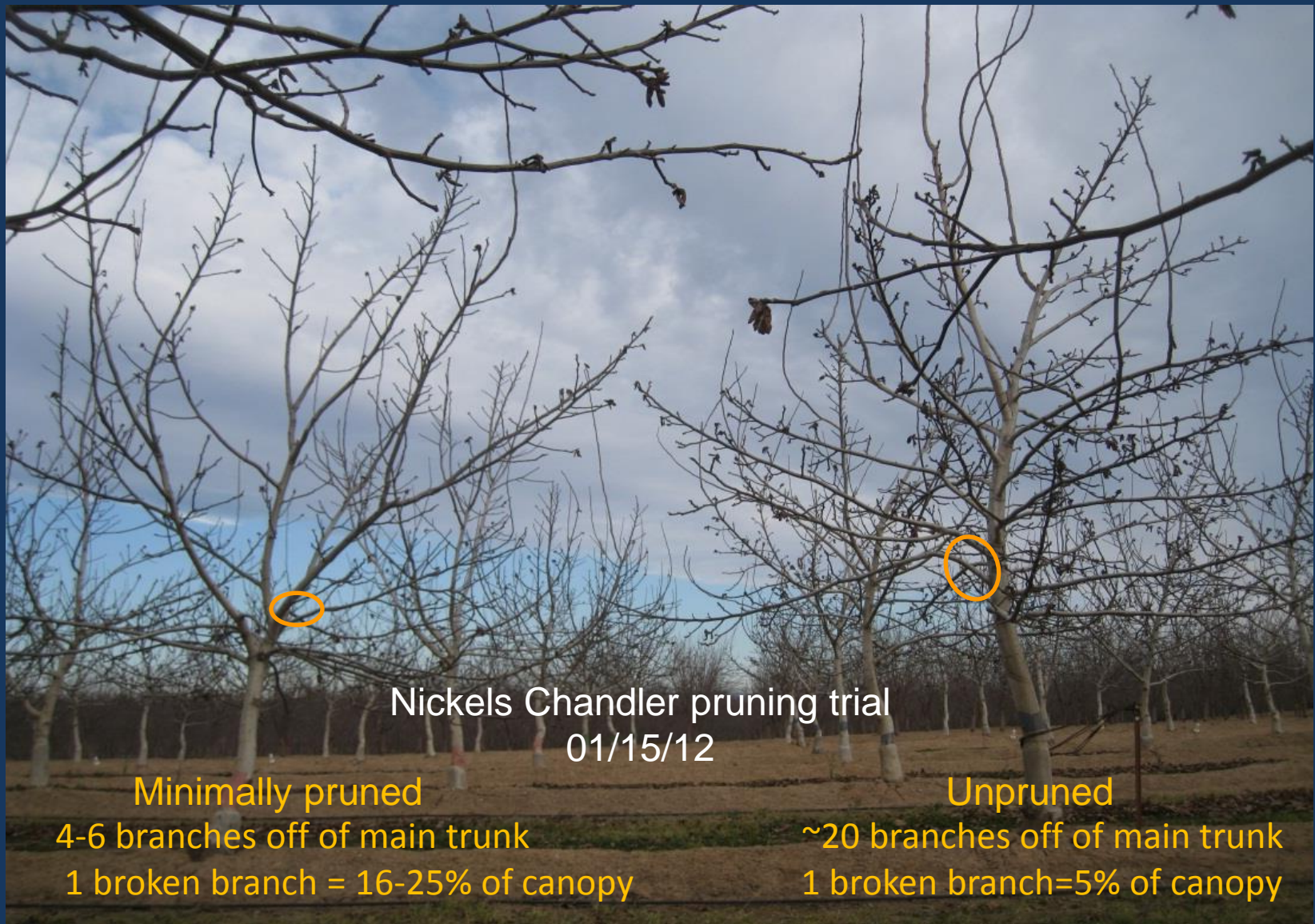


3<sup>rd</sup> Leaf Chandler in Merced County



4<sup>rd</sup> Leaf Forde in Butte County





Nickels Chandler pruning trial  
01/15/12

**Minimally pruned**  
4-6 branches off of main trunk  
1 broken branch = 16-25% of canopy

**Unpruned**  
~20 branches off of main trunk  
1 broken branch=5% of canopy



More open structure

Longer light path

Shorter light path

Flatter branch angles

Shading related dieback will occur earlier

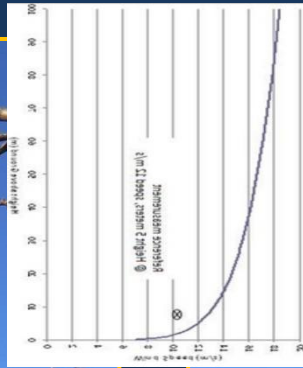
December 2012

Heavily pruned

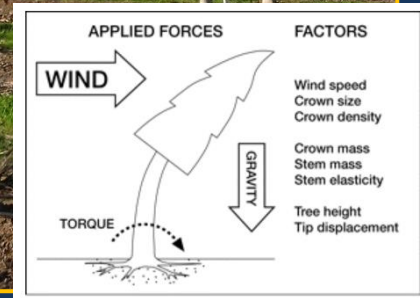
Unheaded/unpruned



Minimally pruned



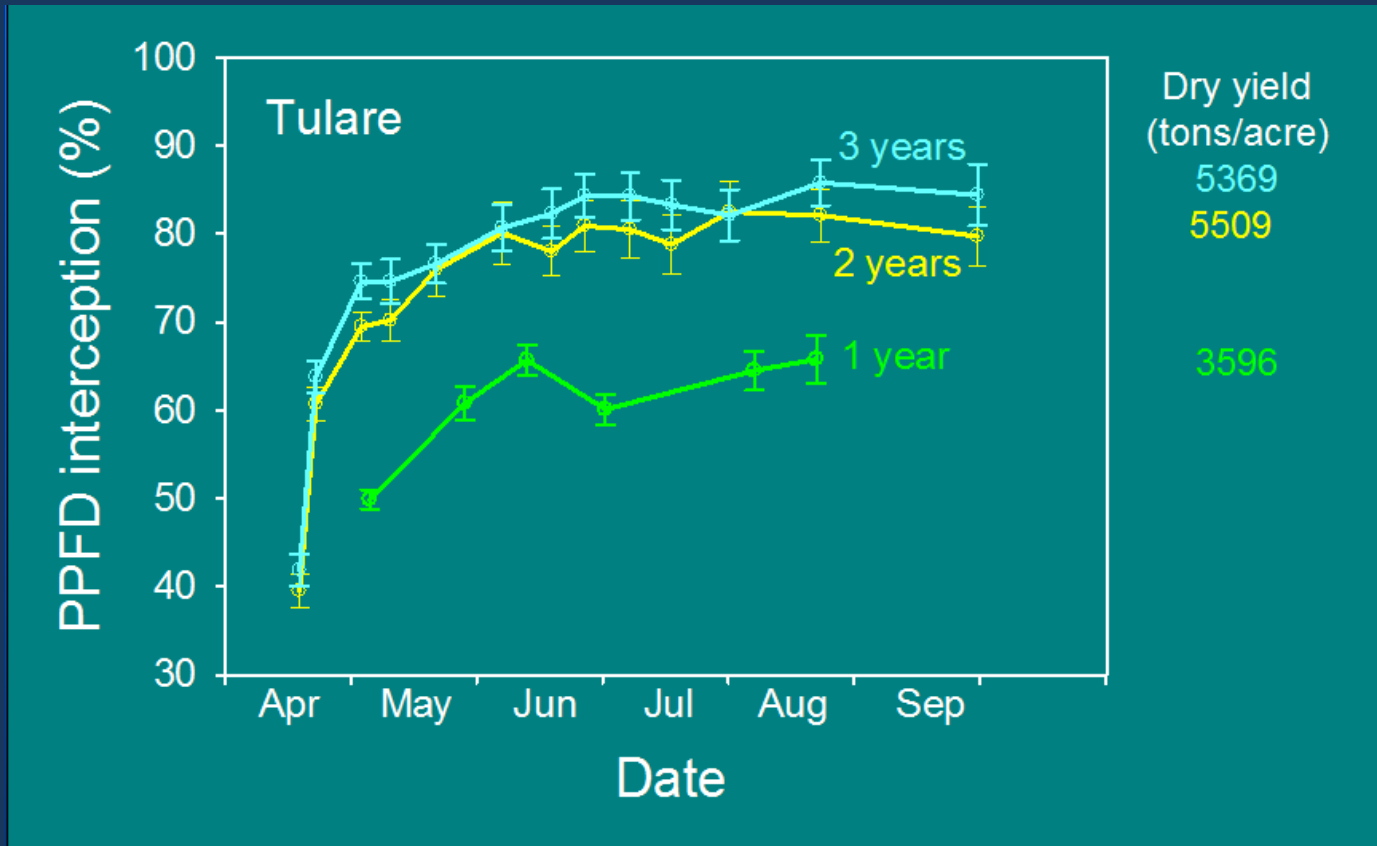
Unheaded/unpruned



# How hedging influences canopy development and yield



# Tulare growth and yield responses to mechanical hedging Solano County 2003



20% decrease in PAR interception = 1 ton/acre loss

#nuts

2

10

20

26

primary  
shoot



~3 to 6+ feet

cut

branching  
point

0

1

2

3

4

1

2

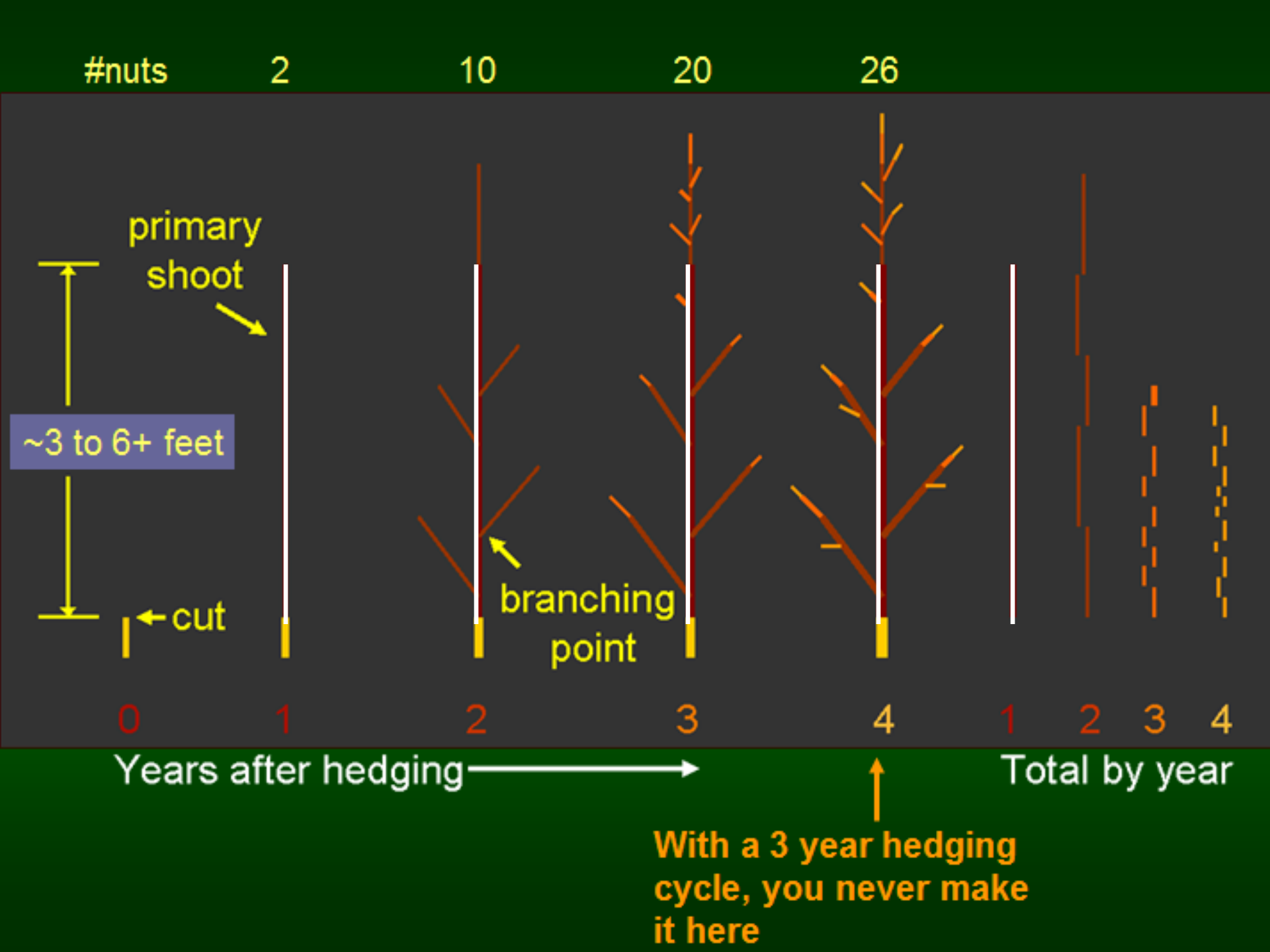
3

4

Years after hedging →

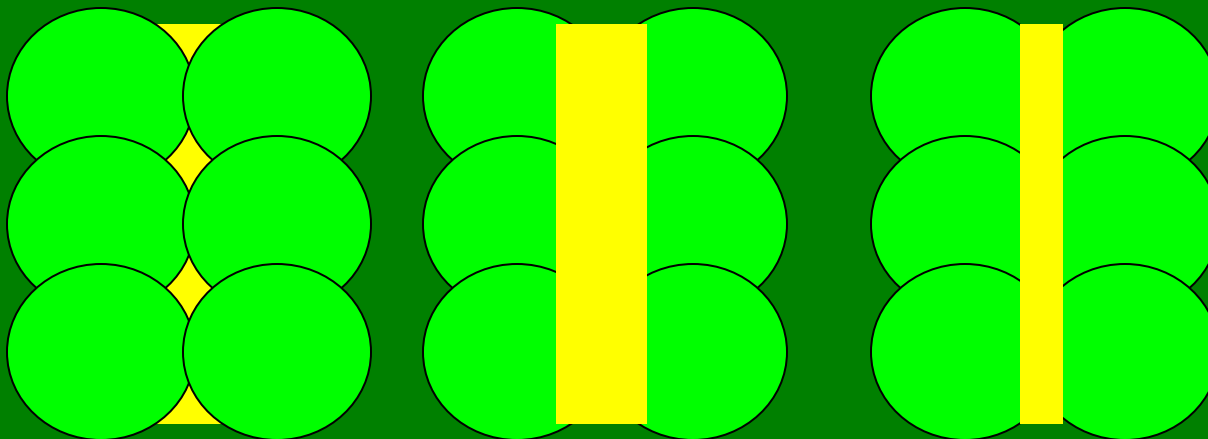
Total by year

With a 3 year hedging  
cycle, you never make  
it here

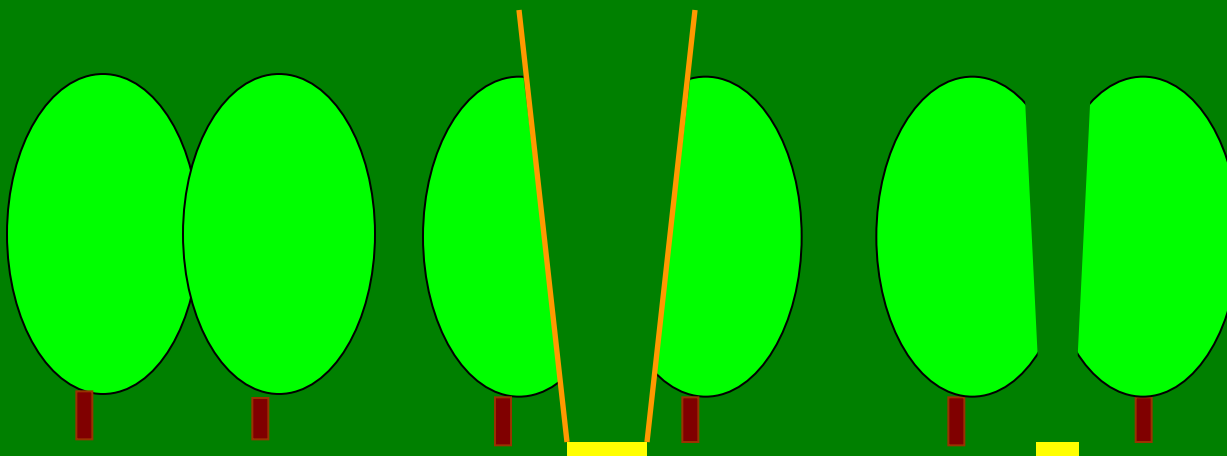


# High density

top view



side view



before hedging

after hedging

one year later

3 yr ave.

PAR int.

85%

70%

80%

83%

Yield potential ~~4.2 tons~~

~~3.2 tons/ac~~

~~4.0 tons/ac~~

~~3.8~~

3.6 tons/ac

2.4 tons/ac

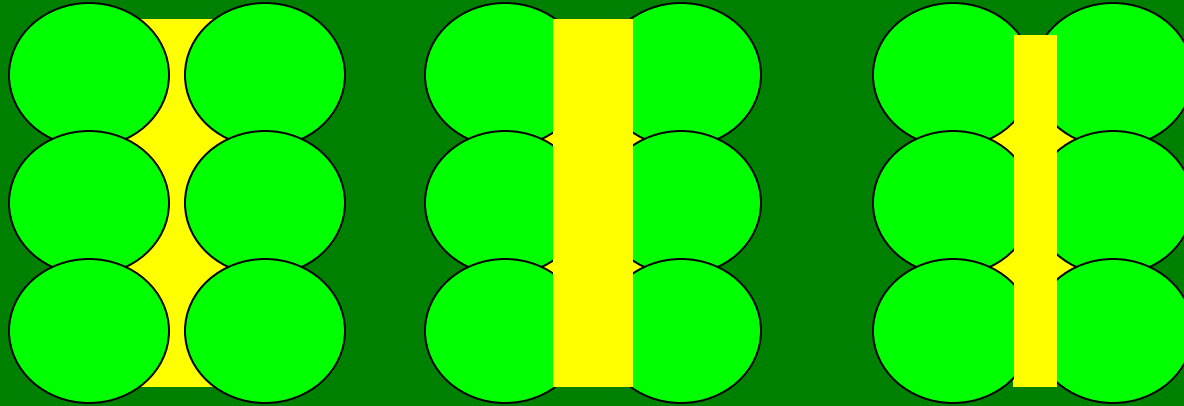
2.9 tons/ac

3.0

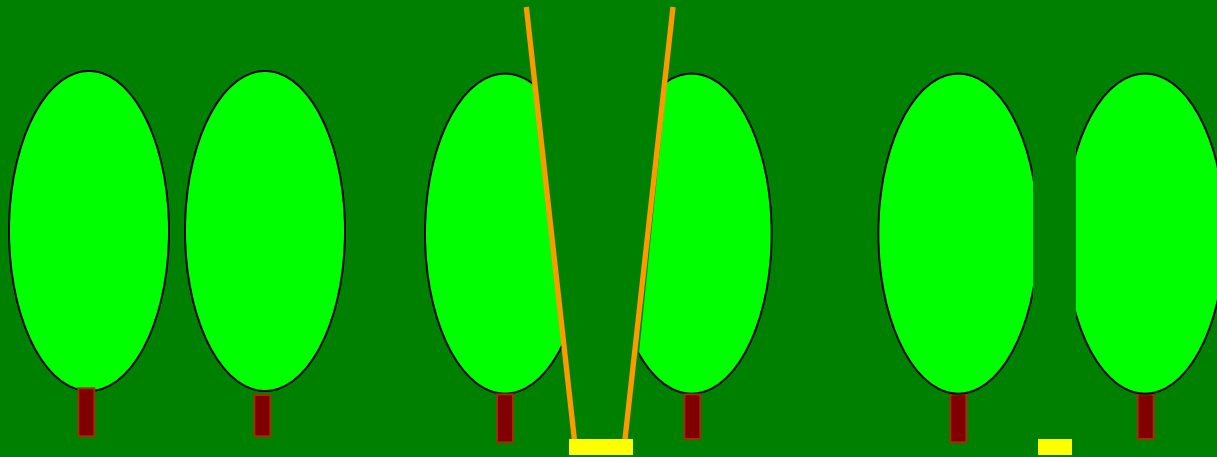


# Moderately high density

top view



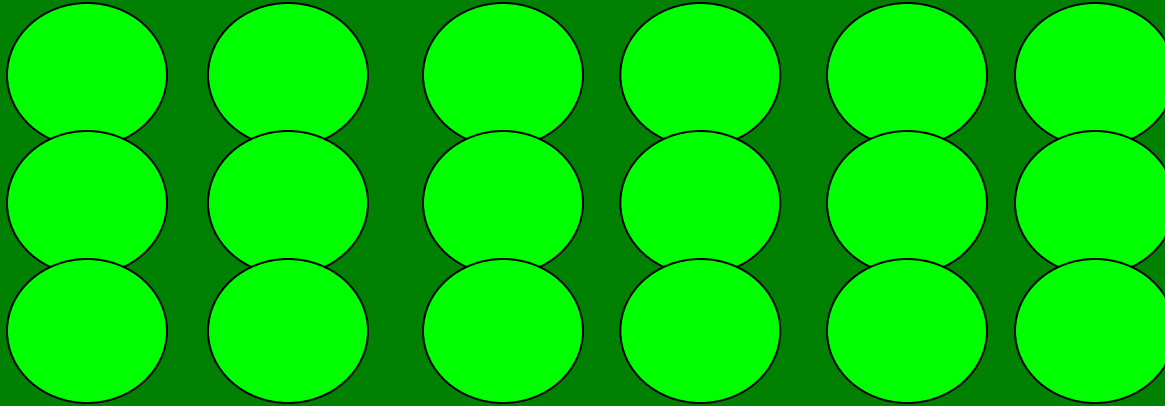
side view



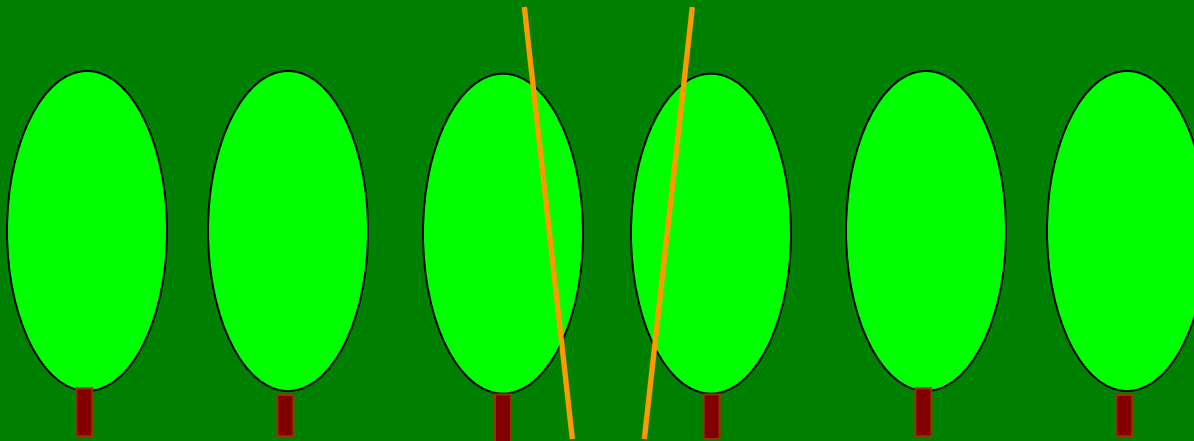
	before hedging	after hedging	one year later	3 yr ave.
PAR int.	80%	65%	75%	73%
Yield potential	<del>4.0 tons/ac</del> 3.4 tons/ac	<del>2.7 tons/ac</del> 2.5 tons/ac	<del>3.7 tons/ac</del> 2.8 tons/ac	<del>3.5 tons/ac</del> 2.9 tons/ac

# Lower density with no hedging

top  
view

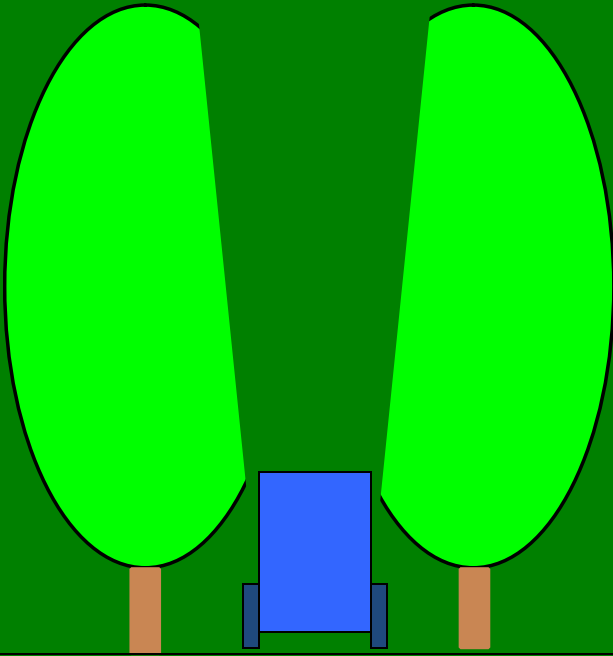


side  
view

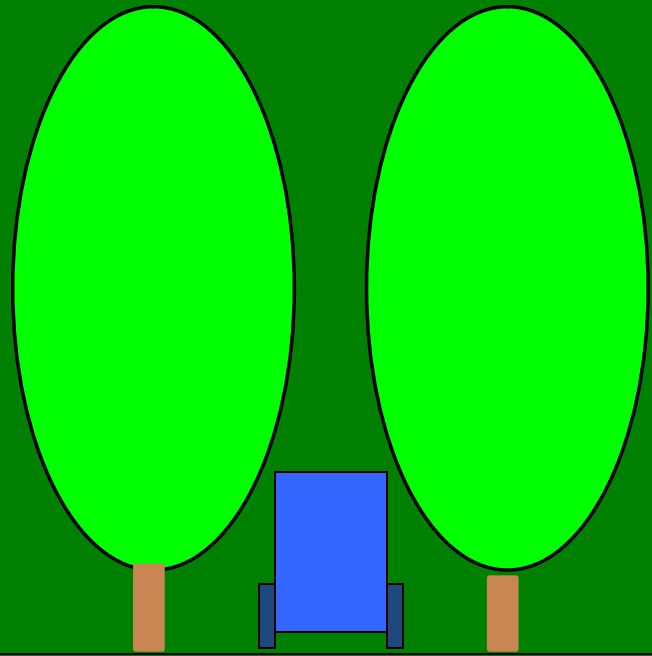


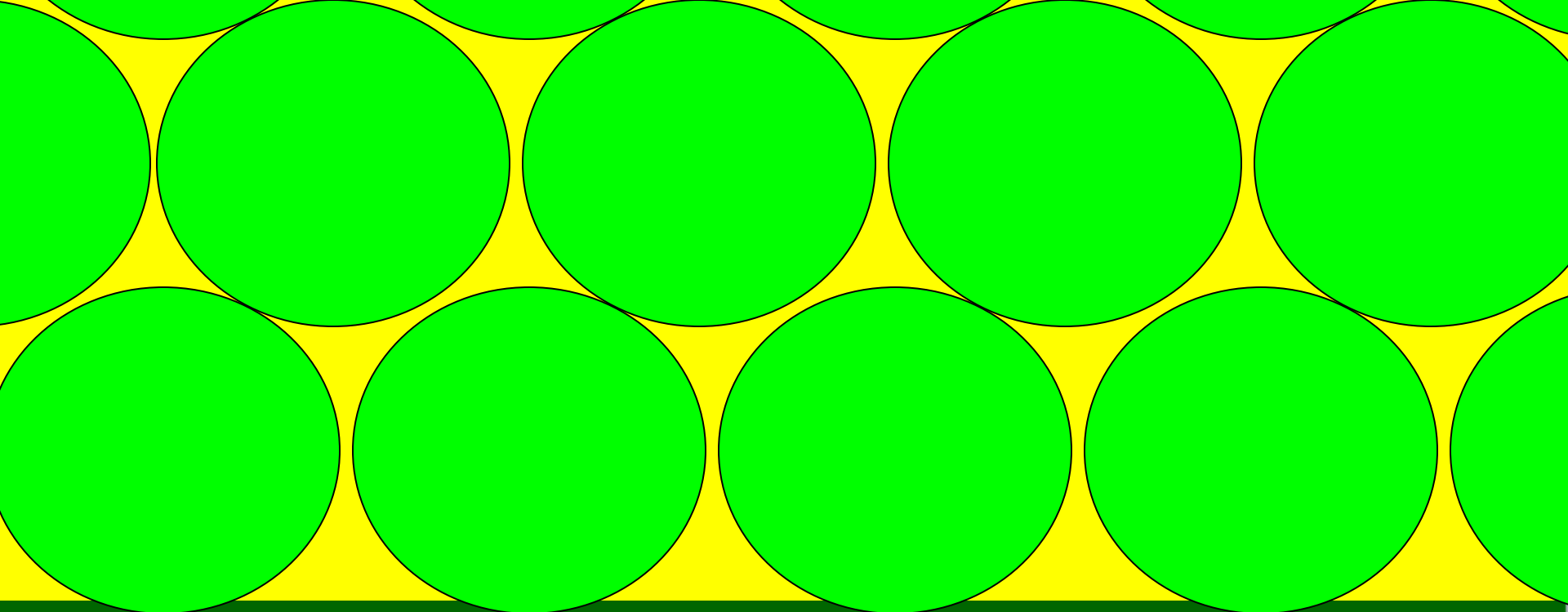
	unpruned	unpruned	unpruned	3 yr ave.
PAR int.	75%	76%	77%	76%
Yield potential	3.75 tons/ac	3.8 tons/ac	3.85 tons/ac	3.8 tons/ac

High density with hedging

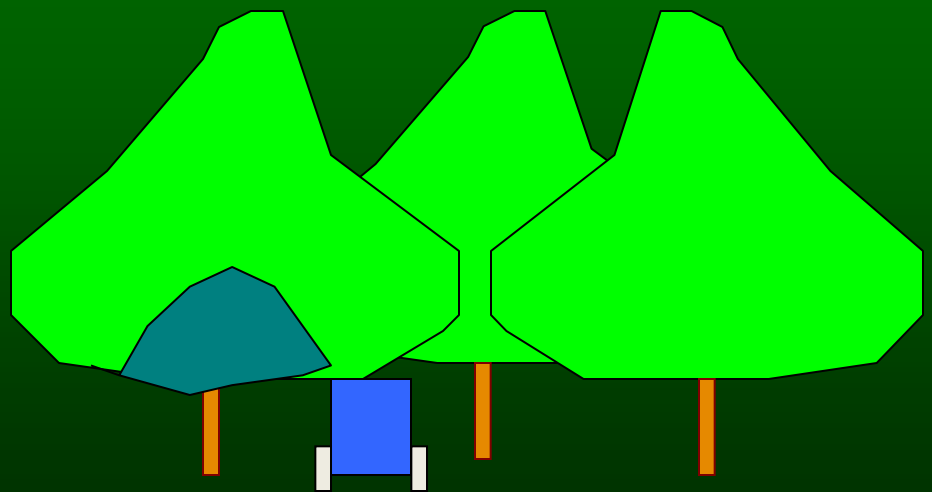
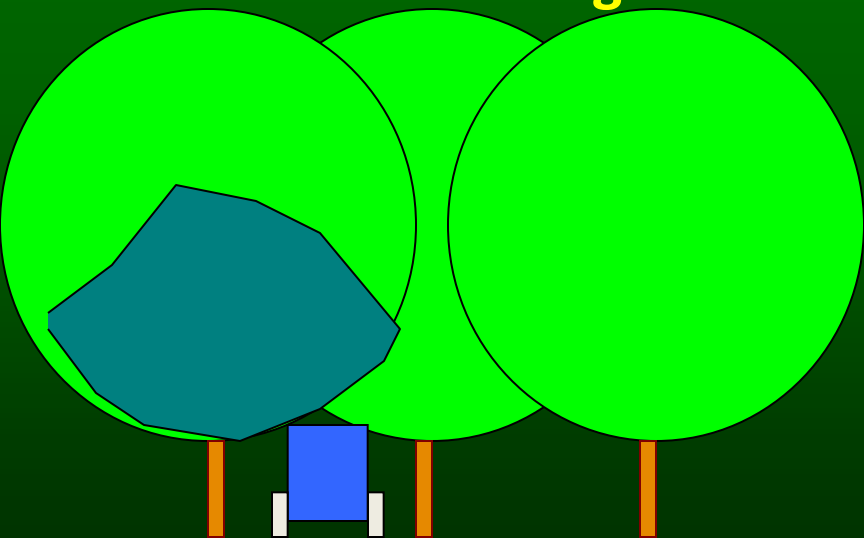


Lower density with no hedging





**~90% light interception (4.5 tons/acre potential)**

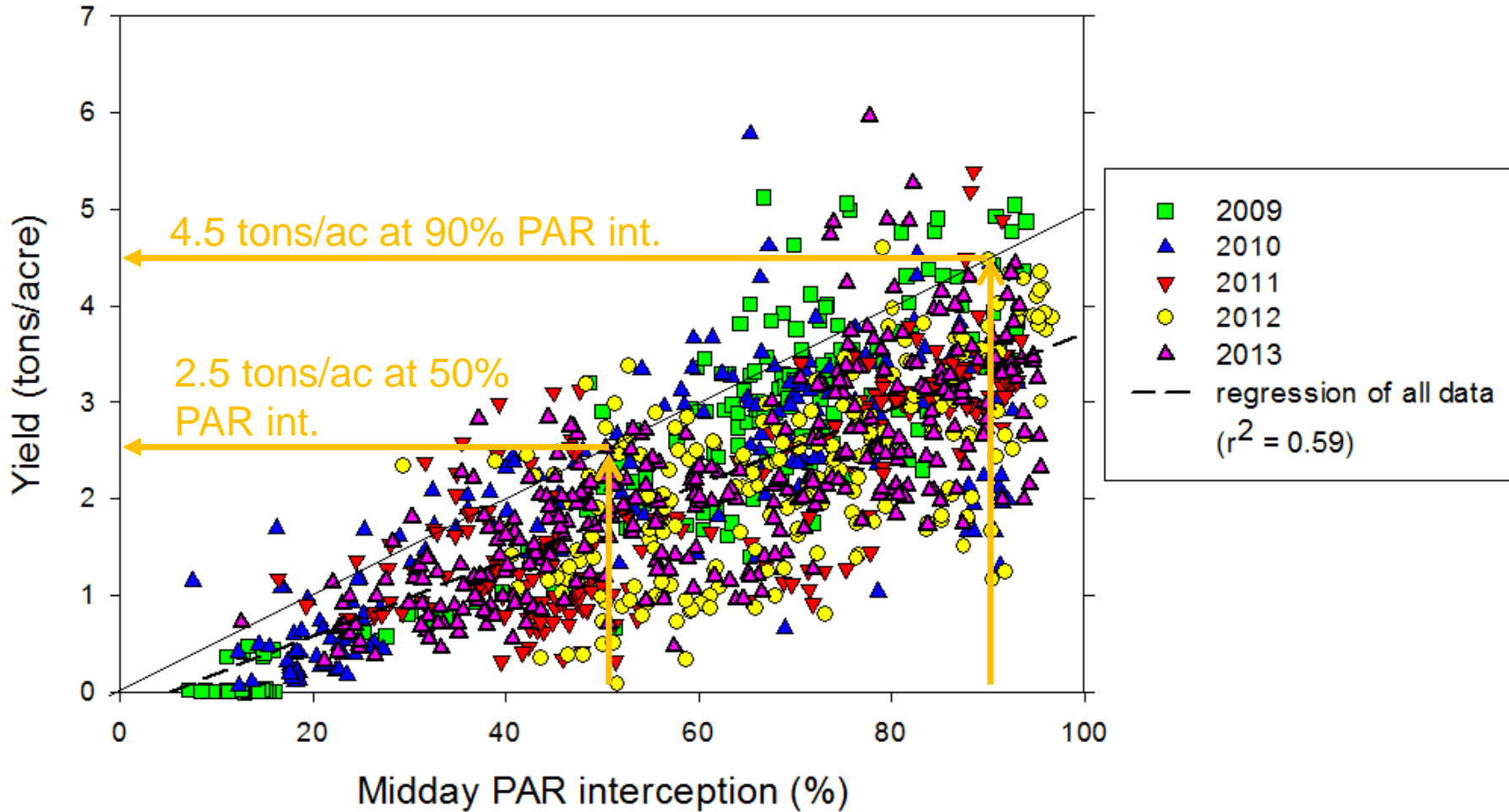


**Conventional spacing**

# Summary of 3 scenarios

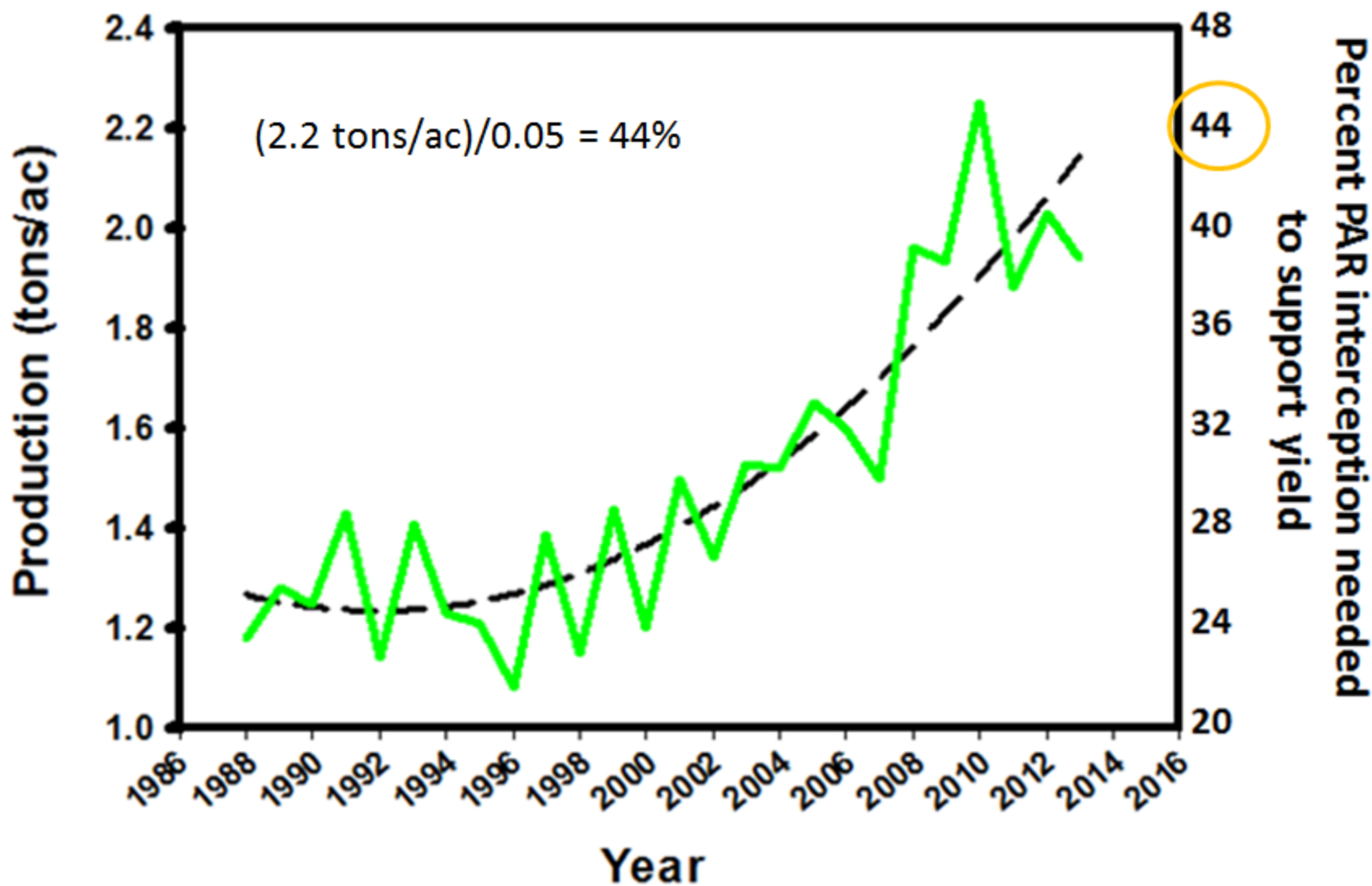
Scenario	Year 1	Year 2	Year 3	Average
High density	70%	80%	85%	83%(int.)
	<del>3.5</del>	<del>4.0</del>	<del>4.2</del>	<del>3.8</del> (potential)
	2.4	2.9	3.6	3.0 (actual)
Unpruned, slightly wider spacing	75% 3.75	76% 3.80	77% 3.85	76% 3.8
Conventional spacing	91% 4.55	92% 4.60	93% 4.65	91% 4.60

### All walnut data 2009-2013

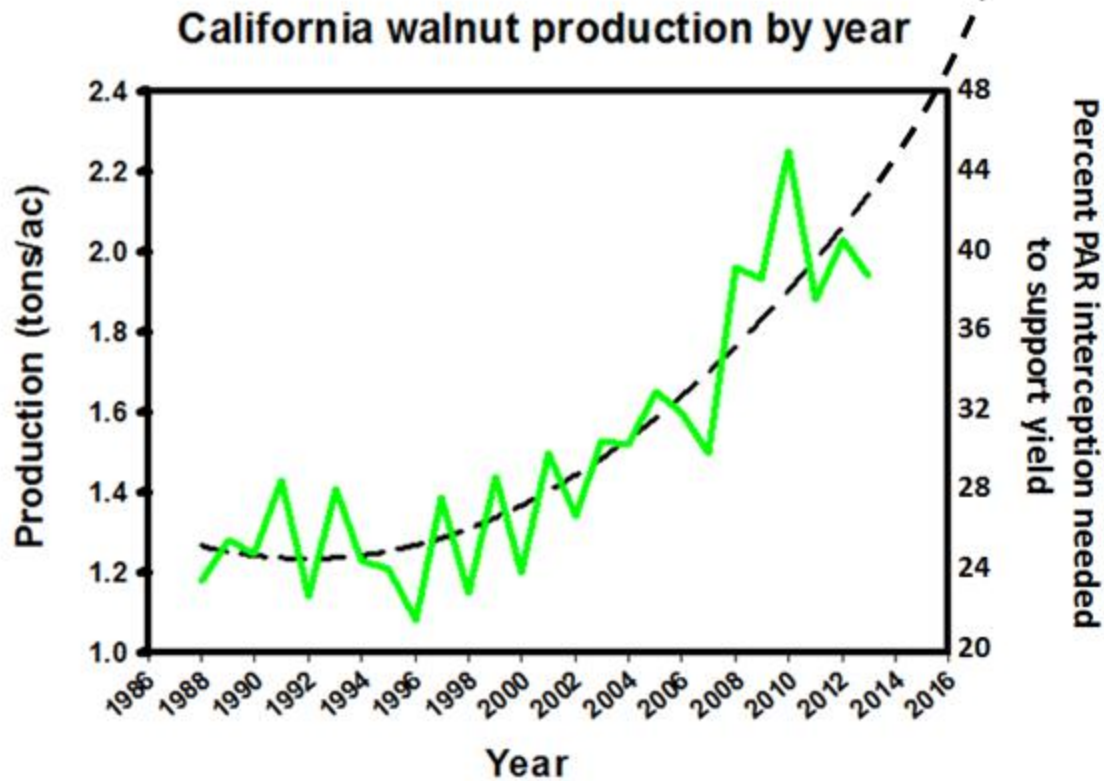


Best orchards can produce 0.05 tons/acre for each 1% of the PAR they intercept (solid black line in figure)

# California walnut production by year



4.0 tons/acre = ~80% PAR interception  
by approximately 2028





# Conclusions

- Although you can potentially get higher yields in years 3-8 with higher density plantings, ultimately the highest yields come from more traditional spacings (22' to 28' square planting)
- Yield per unit light intercepted will likely be lower when pruning or hedging takes place
- 7 year Howard pruning trial and 6 year Chandler pruning trial have shown no benefits to pruning/training in early years
- Pruning leads to decreased water use efficiency in years 2-6
- Each pruning cut tends to decrease yield and generate more work for the following 1-4 years
- Mechanical hedging can result in decent but not high yields and generally leads to increased quality problems

# Conclusions

- Although you can potentially get higher yields in years 3-8 with higher density plantings, ultimately the highest yields come from more traditional spacings (24' to 28' square planting)
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# Hedgerow spacing




13 year old hedgerow Howard  
planting (14' x 21')







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planting (14' x 21')



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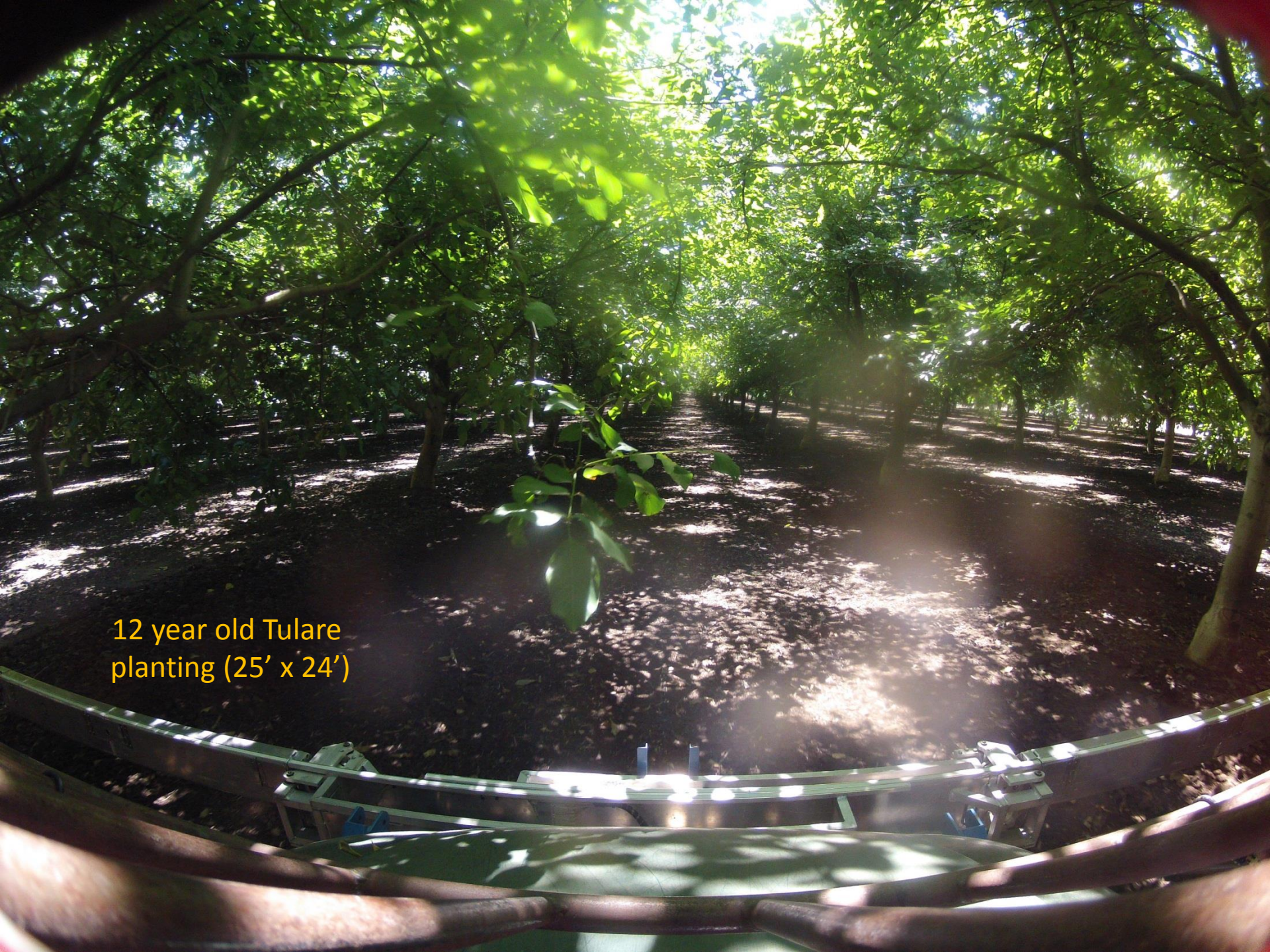


13 year old Tulare  
planting (25' x 24')







13 year old Tulare  
planting (25' x 24')

A wide-angle, fisheye photograph taken from the perspective of someone inside a tractor or similar agricultural vehicle. The view is looking down a long, straight row of mature tulare trees in an orchard. The trees are lush green and their branches are dense, creating a canopy overhead. Sunlight filters through the leaves, casting dappled shadows on the ground. In the foreground, a curved metal implement, likely a furrow opener or similar tool, is visible, mounted on the tractor. The ground is dark and appears to be covered in mulch or soil. The overall scene is a well-maintained agricultural setting.

12 year old Tulare  
planting (25' x 24')

A wide-angle, fisheye photograph taken from the perspective of someone sitting on a tractor in a mature orchard. The tractor's metal frame and a large, flat, light-colored surface (possibly a tray or a piece of equipment) are visible in the foreground. The orchard consists of numerous rows of trees with dense, vibrant green foliage. Sunlight filters through the leaves, creating a dappled pattern of light and shadow on the ground. The rows of trees recede into the distance, creating a sense of depth. The overall atmosphere is bright and natural.


13 year old Tulare  
planting (25' x 24')




13 year old Tulare  
planting (25' x 24')




13 year old Tulare  
planting (25' x 24')

A perspective view of a 13-year-old Tulare orchard. The image shows rows of trees with dense green foliage, creating a canopy overhead. Sunlight filters through the leaves, casting dappled shadows on the ground. In the foreground, a curved metal structure, likely part of a machine or irrigation system, is visible. The text "13 year old Tulare planting (25' x 24')" is overlaid in yellow on the left side of the image.

13 year old Tulare  
planting (25' x 24')


A wide-angle, fisheye view from the perspective of someone sitting on a tractor in a mature orchard. The tractor's green metal frame and a curved implement are visible in the foreground. The orchard consists of many rows of trees with dense green foliage. Sunlight filters through the leaves, creating a dappled light effect on the ground. The rows of trees recede into the distance, creating a sense of depth.

13 year old Tulare  
planting (25' x 24')

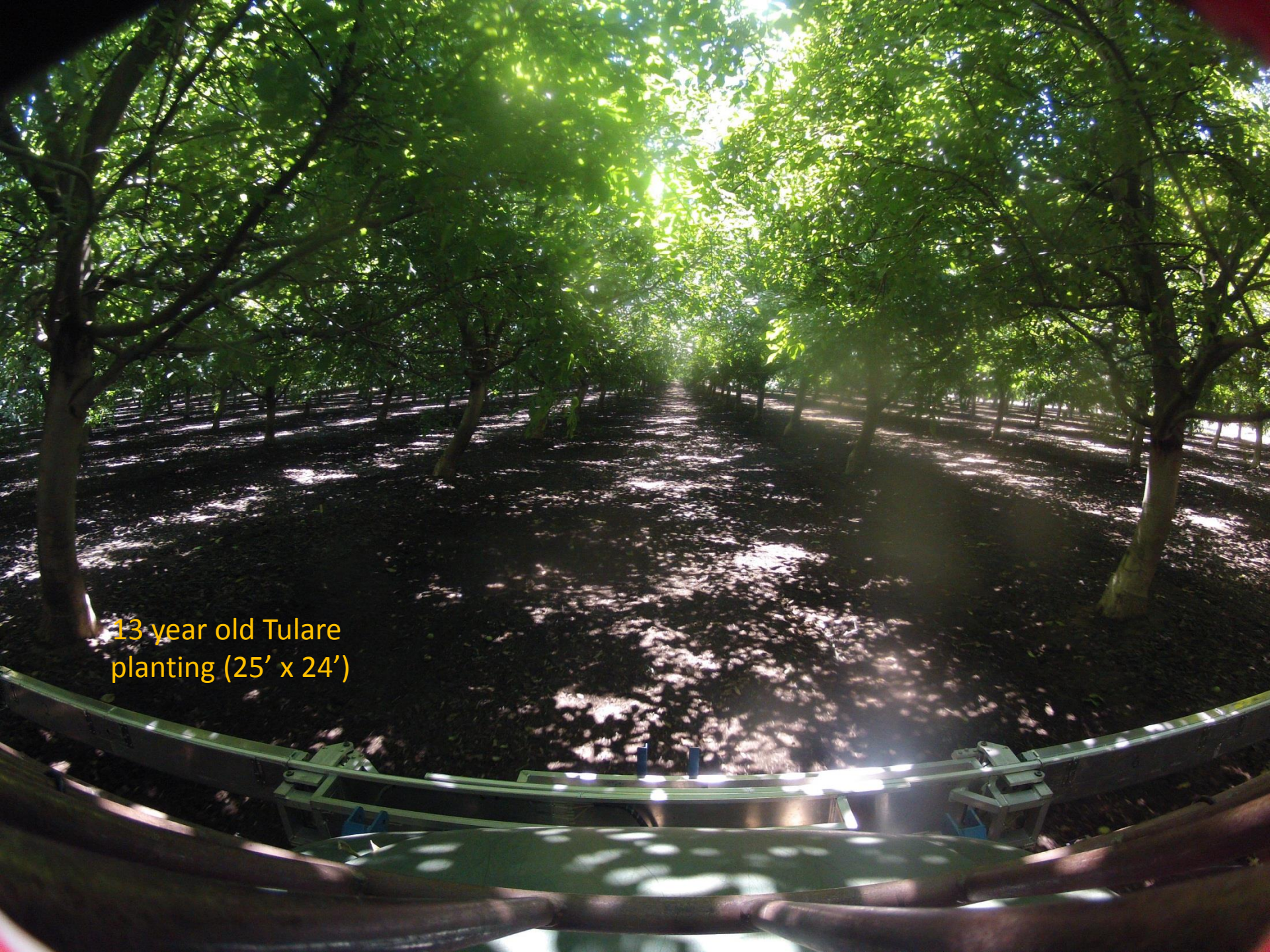


13 year old Tulare  
planting (25' x 24')




A wide-angle, fisheye photograph taken from the perspective of someone sitting in a tractor or similar agricultural vehicle. The view is looking down a long, straight row of mature Tulare trees in an orchard. The trees are densely packed and have thick, dark trunks and lush green foliage. Sunlight filters through the leaves, creating a dappled pattern of light and shadow on the dark, mulched ground. In the immediate foreground, the curved metal frame of the tractor is visible, including a horizontal bar and some mechanical components. The overall scene is a well-maintained, established agricultural landscape.

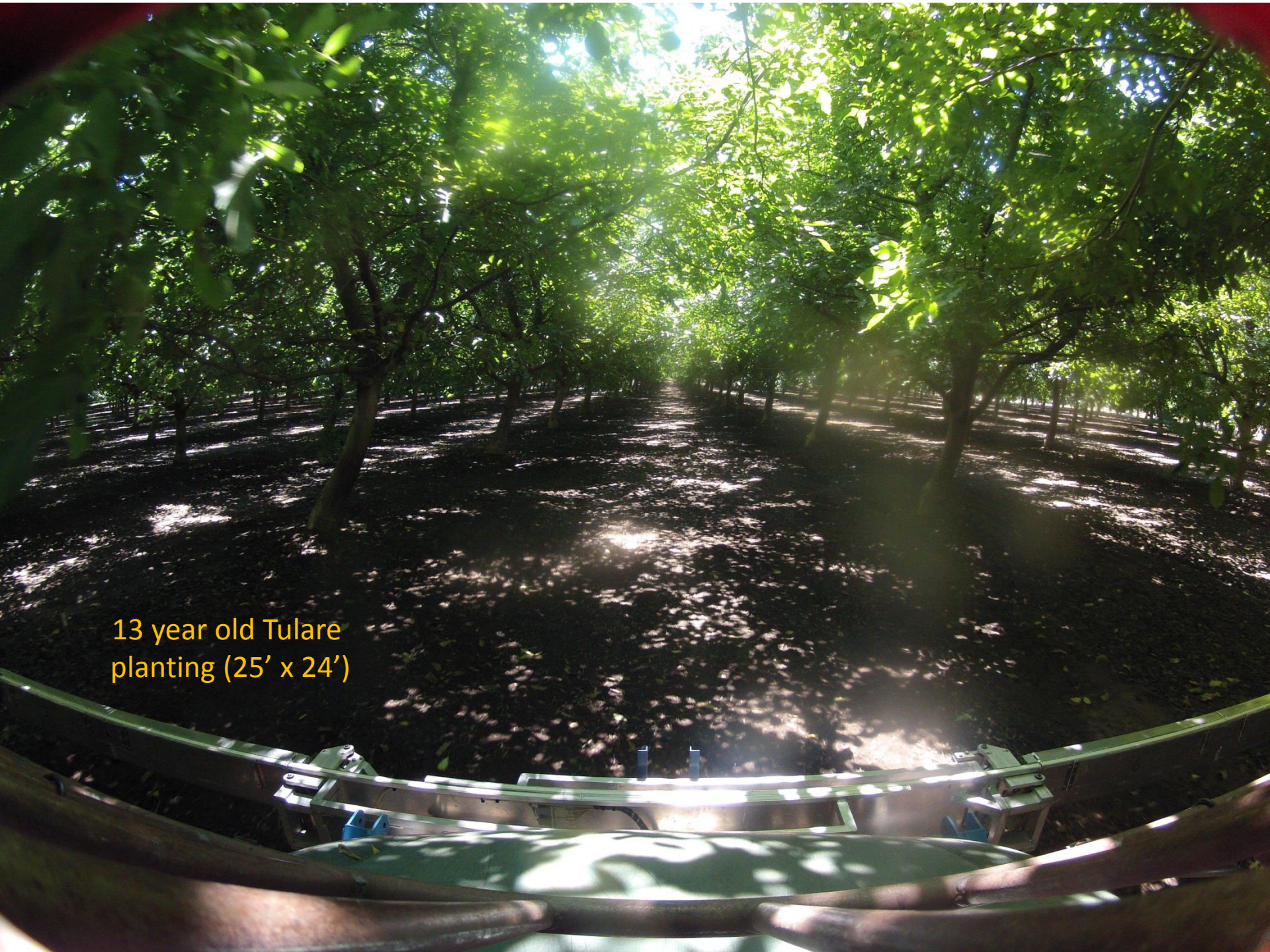
13 year old Tulare  
planting (25' x 24')

A perspective view of a 13-year-old Tulare orchard. The image shows rows of trees with dense green foliage, creating a canopy overhead. Sunlight filters through the leaves, casting dappled shadows on the ground. In the foreground, a curved metal structure, likely part of a machine or irrigation system, is visible. The text "13 year old Tulare planting (25' x 24')" is overlaid in yellow on the left side of the image.


13 year old Tulare  
planting (25' x 24')




13 year old Tulare  
planting (25' x 24')

A wide-angle, fisheye photograph of a mature orchard. The view is from a low perspective, looking down a long, straight row of trees that recede into the distance. The trees are lush green and their leaves create a dappled pattern of light and shadow on the ground. In the foreground, a curved metal structure, likely part of a machine or irrigation system, is visible, with some blue components. The overall scene is bright and sunlit, with a strong sense of depth and perspective.

13 year old Tulare  
planting (25' x 24')

A perspective view of a 13-year-old Tulare orchard. The image shows a long, straight row of trees stretching into the distance, creating a sense of depth. The trees are lush green, and the sunlight filters through the canopy, casting dappled shadows on the ground. In the foreground, a curved metal structure, likely part of a tractor or harrow, is visible, suggesting the orchard is being maintained or prepared for harvest. The overall scene is bright and vibrant, with a strong contrast between the dark shadows and the bright sunlight.

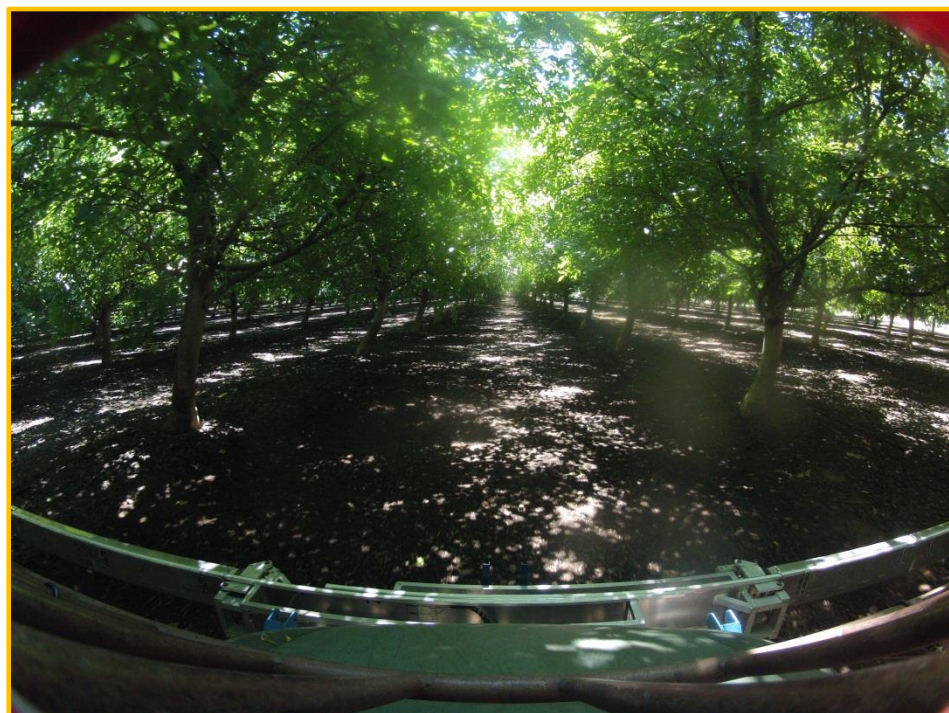
13 year old Tulare  
planting (25' x 24')

A perspective view of a 13-year-old Tulare orchard. The image shows a long, straight row of trees stretching into the distance, creating a sense of depth. The trees are lush green, and the ground is covered in dark mulch. Sunlight filters through the canopy, creating a dappled light effect on the ground. In the foreground, a curved metal structure, likely part of a machine or irrigation system, is visible. The overall scene is a well-maintained agricultural landscape.

13 year old Tulare  
planting (25' x 24')



**13 year old  
14' x 21' Howard hedgerow  
PAR interception ~70%  
Yield ~ 3.0 tons/acre over last 5  
years**



**13 year old  
25' x 24' Tulare planting  
PAR interception ~90%  
Yield ~ 4.2 tons/acre over last  
5 years**



Questions?

**Thanks to the California Walnut Board and the Federal SCRI program for funding this work**