

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

Production

Bruce Lampinen



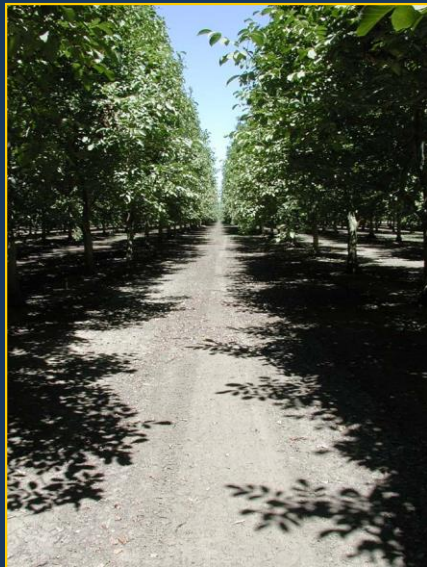
~10% midday light interception



~45% midday light interception

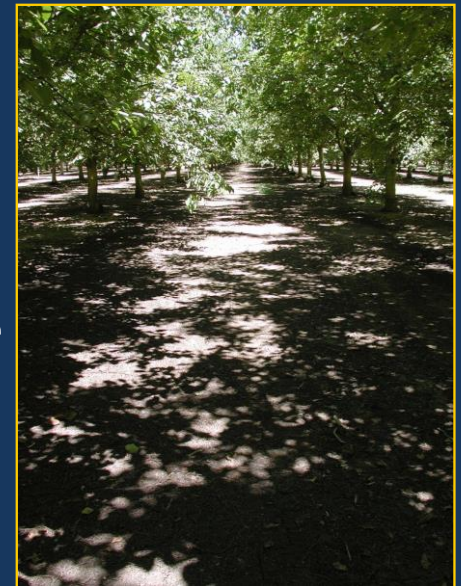


~30% midday light interception



~70% midday light interception

Quad County Walnut Institute
March 6, 2014



~90% midday light interception

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



Low yield potential (~2 tons/acre)

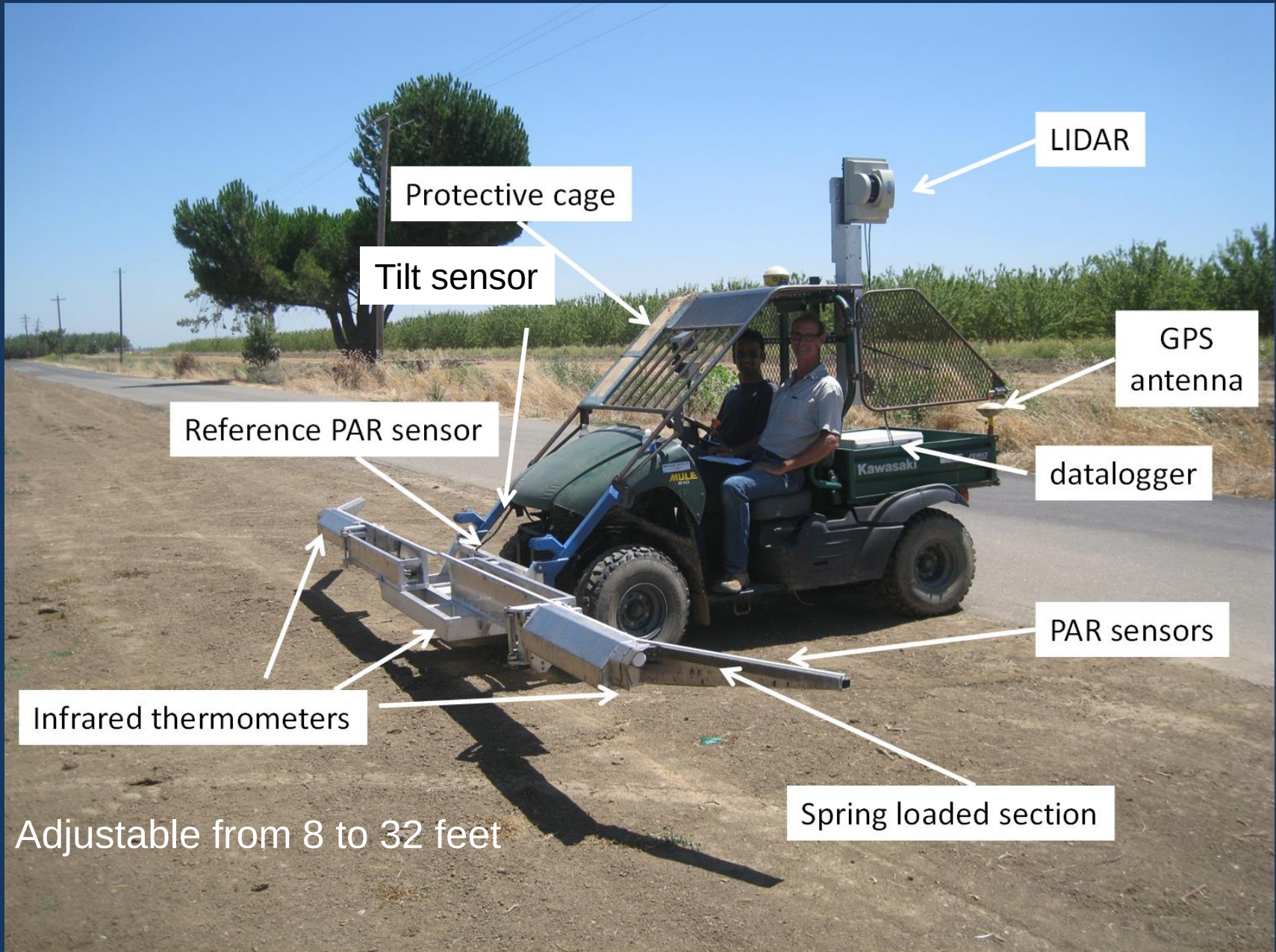


High yield potential (>4 tons/acre)

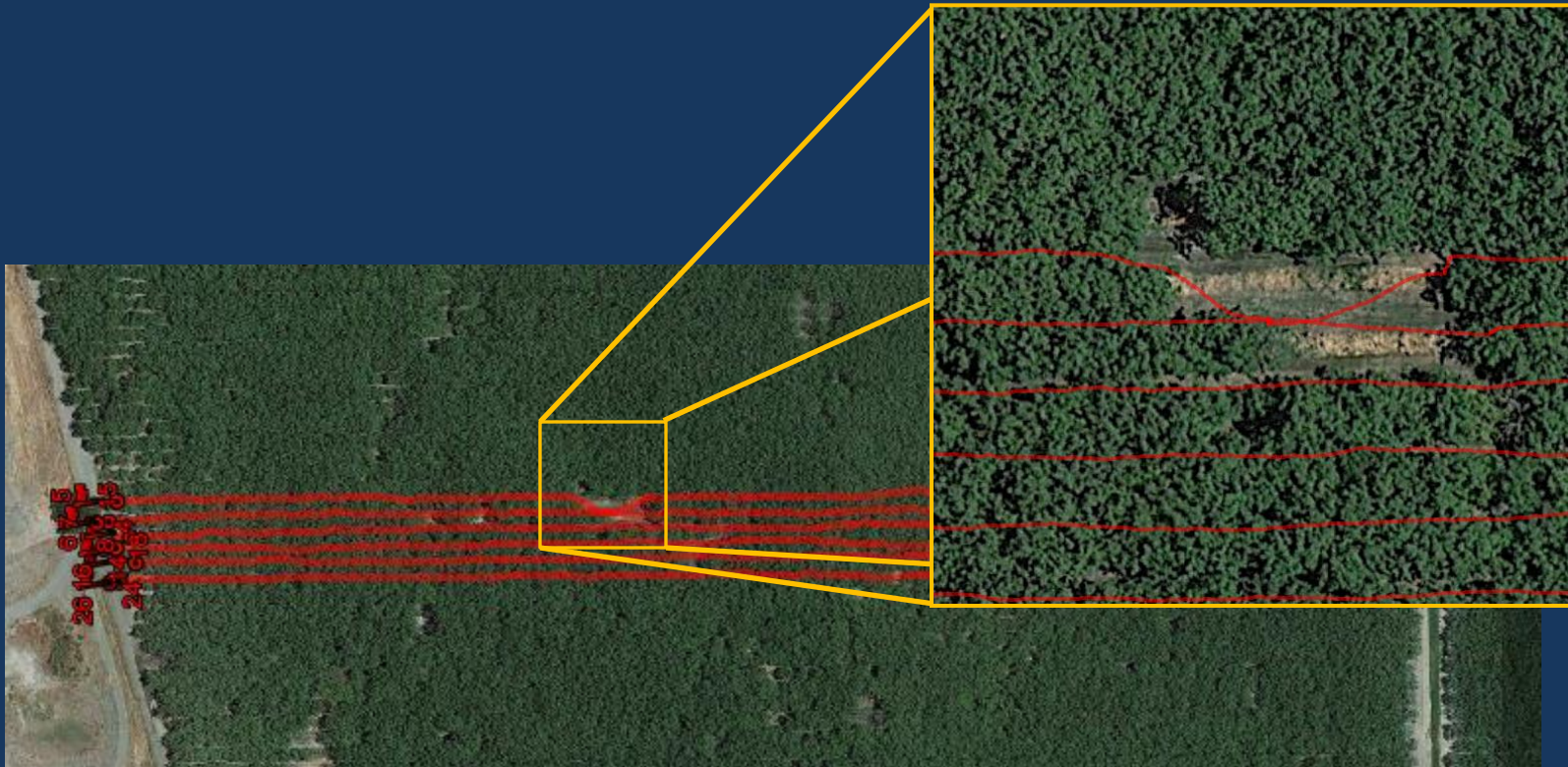
What I will cover

- 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

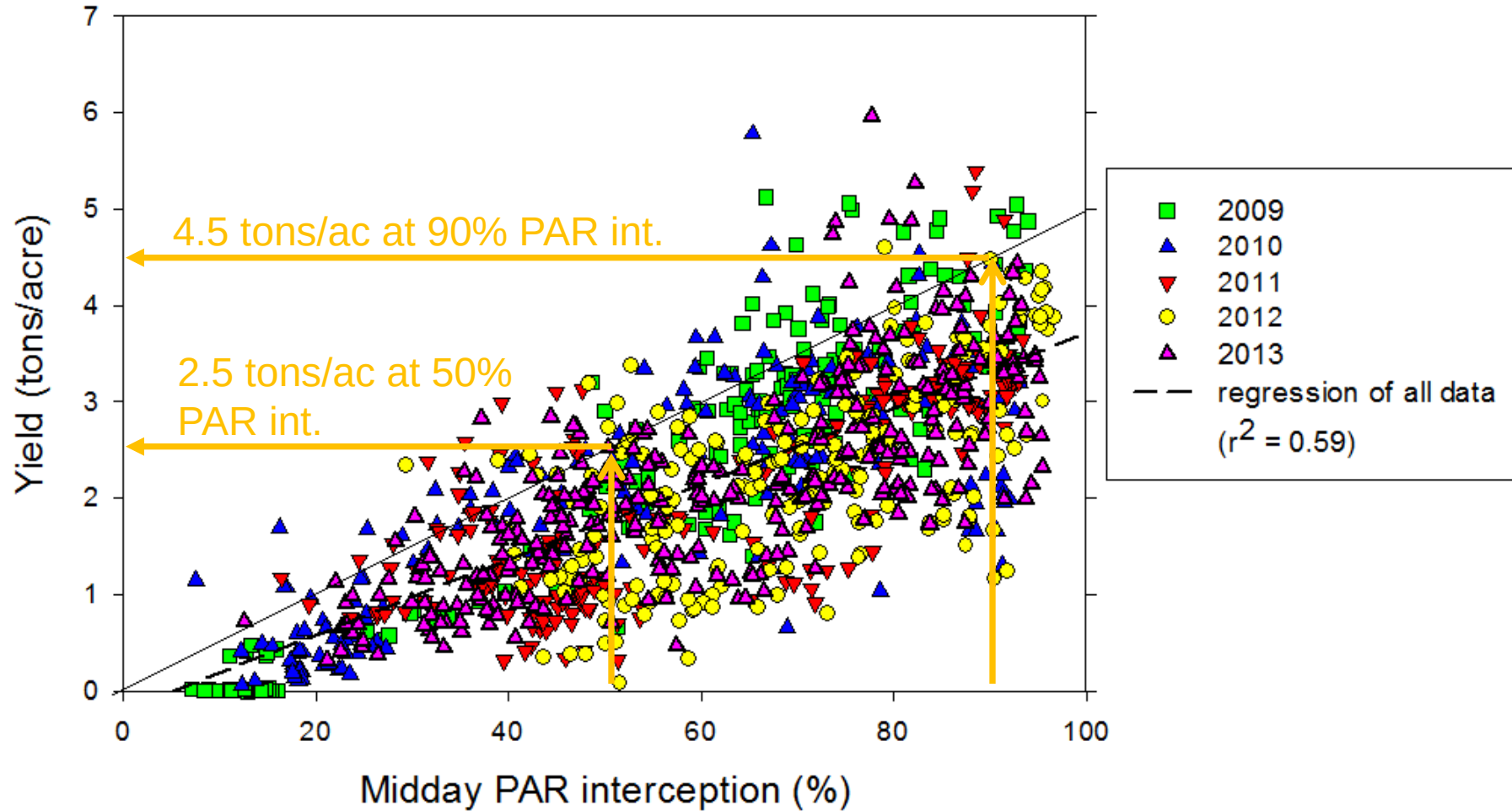


Hydraulically driven auger to deliver samples to rear



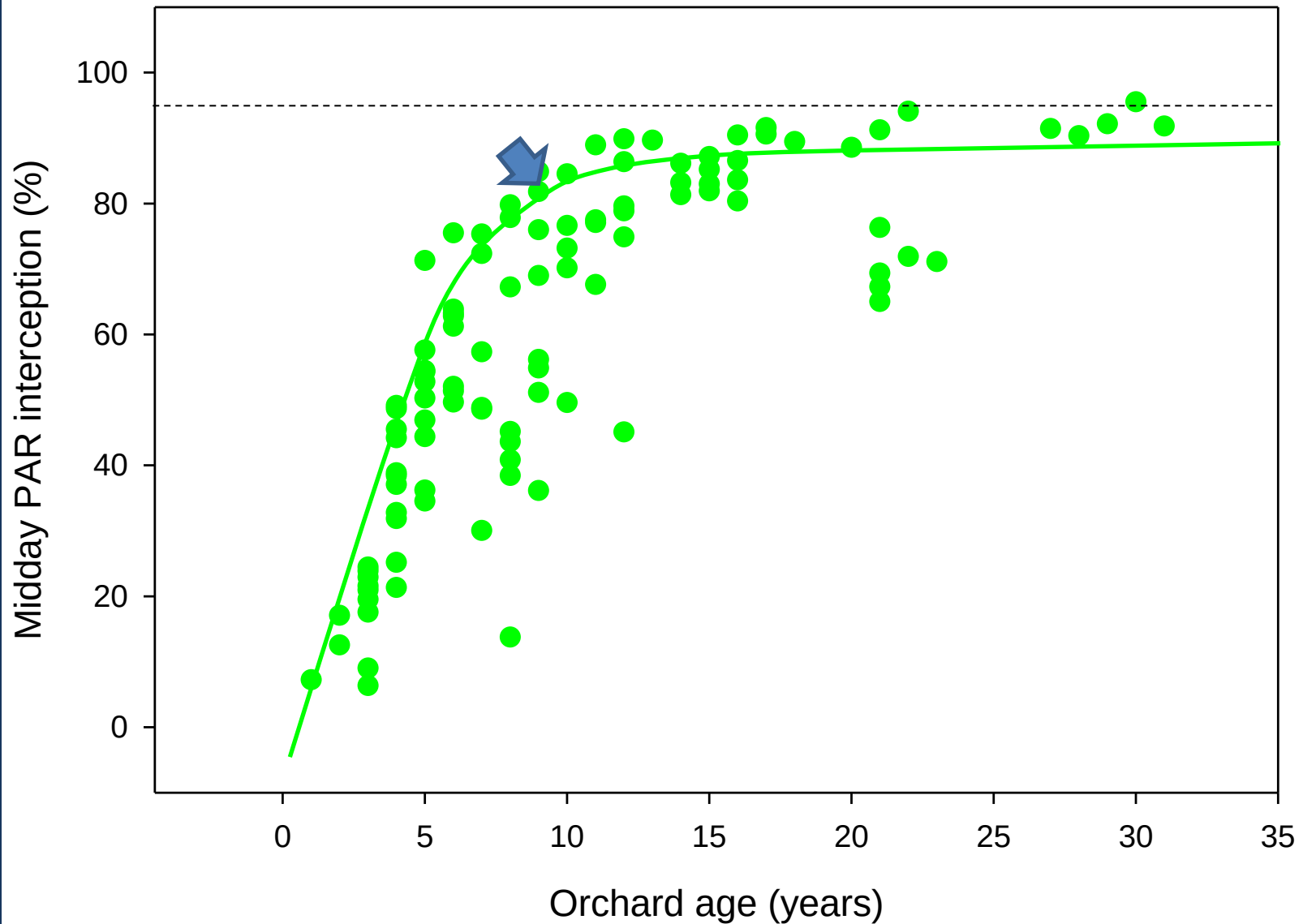
Samples are delivered to 5 gallon bucket at rear

All walnut data 2009-2013

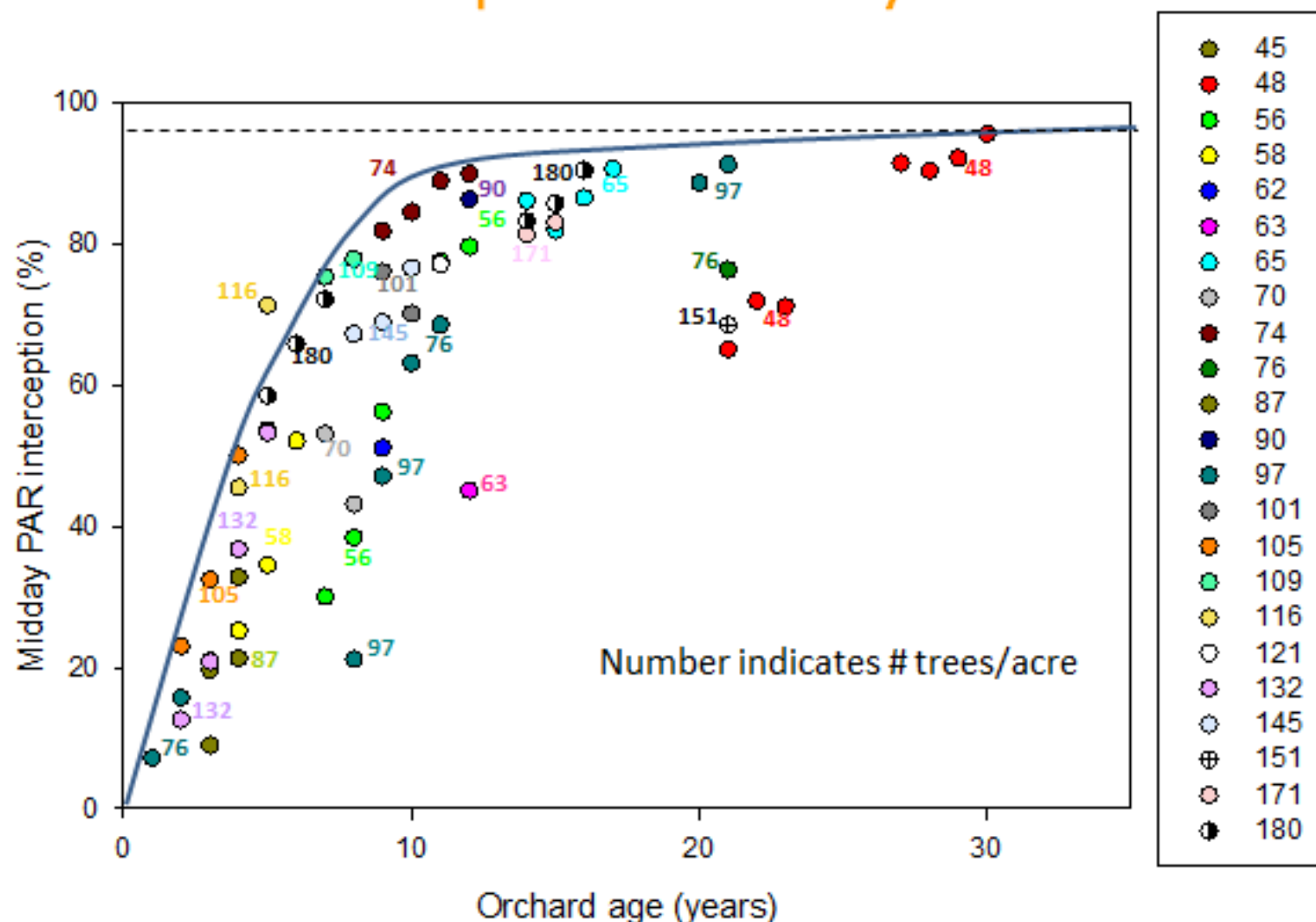


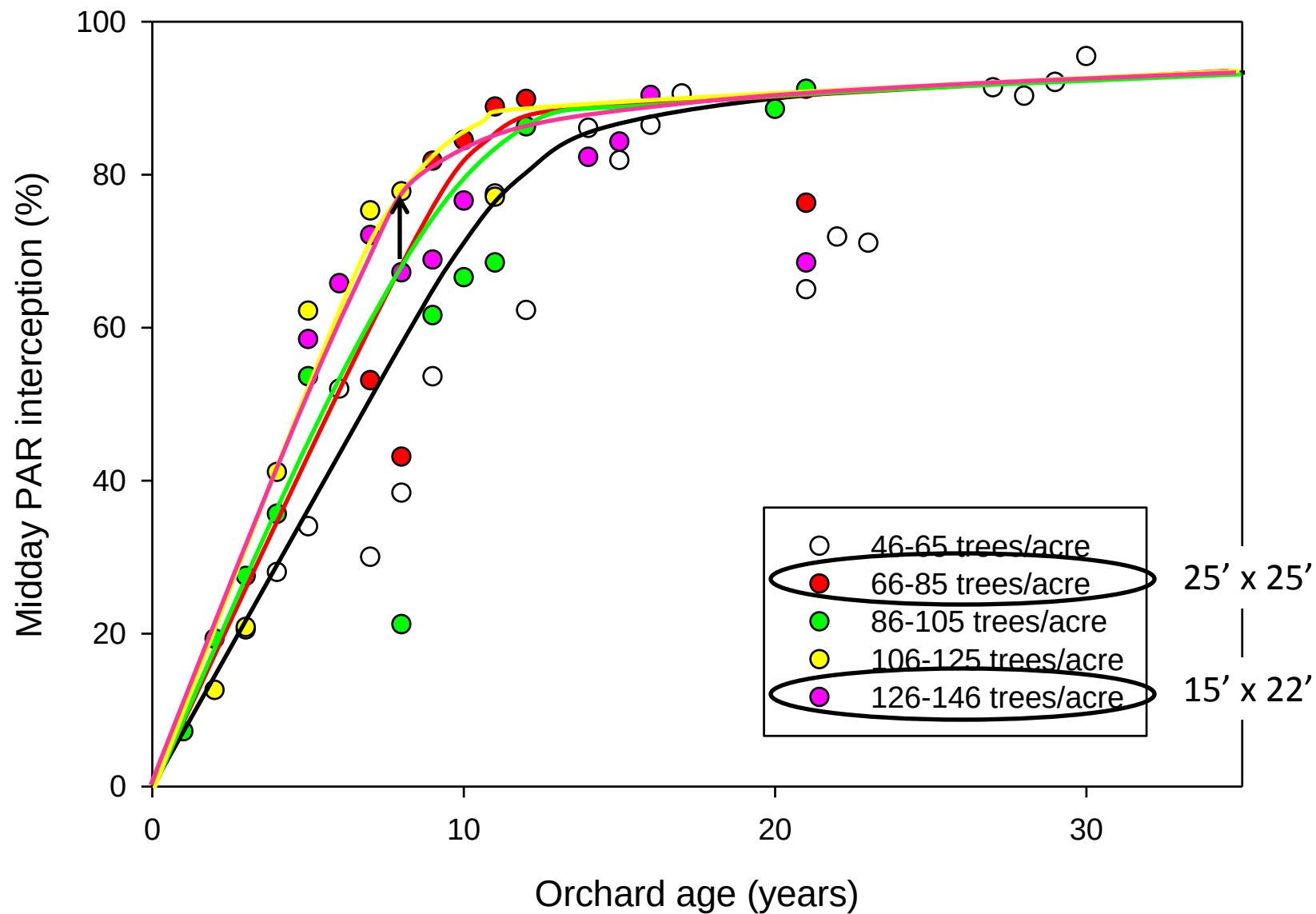
Best orchards can produce 0.05 tons/acre for each 1% of the PAR they intercept (solid black line in figure)
 (PAR = photosynthetically active radiation)

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

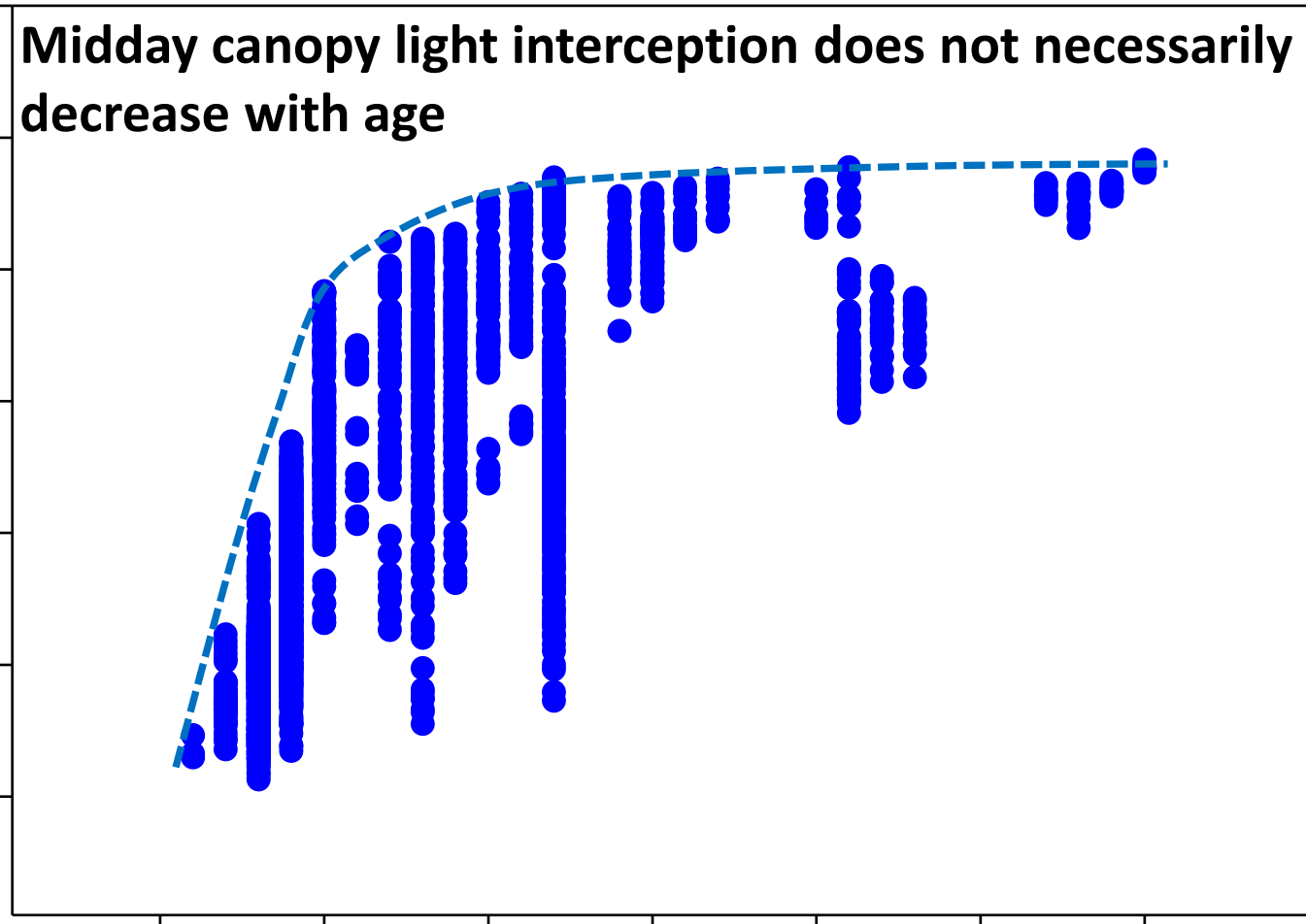
20

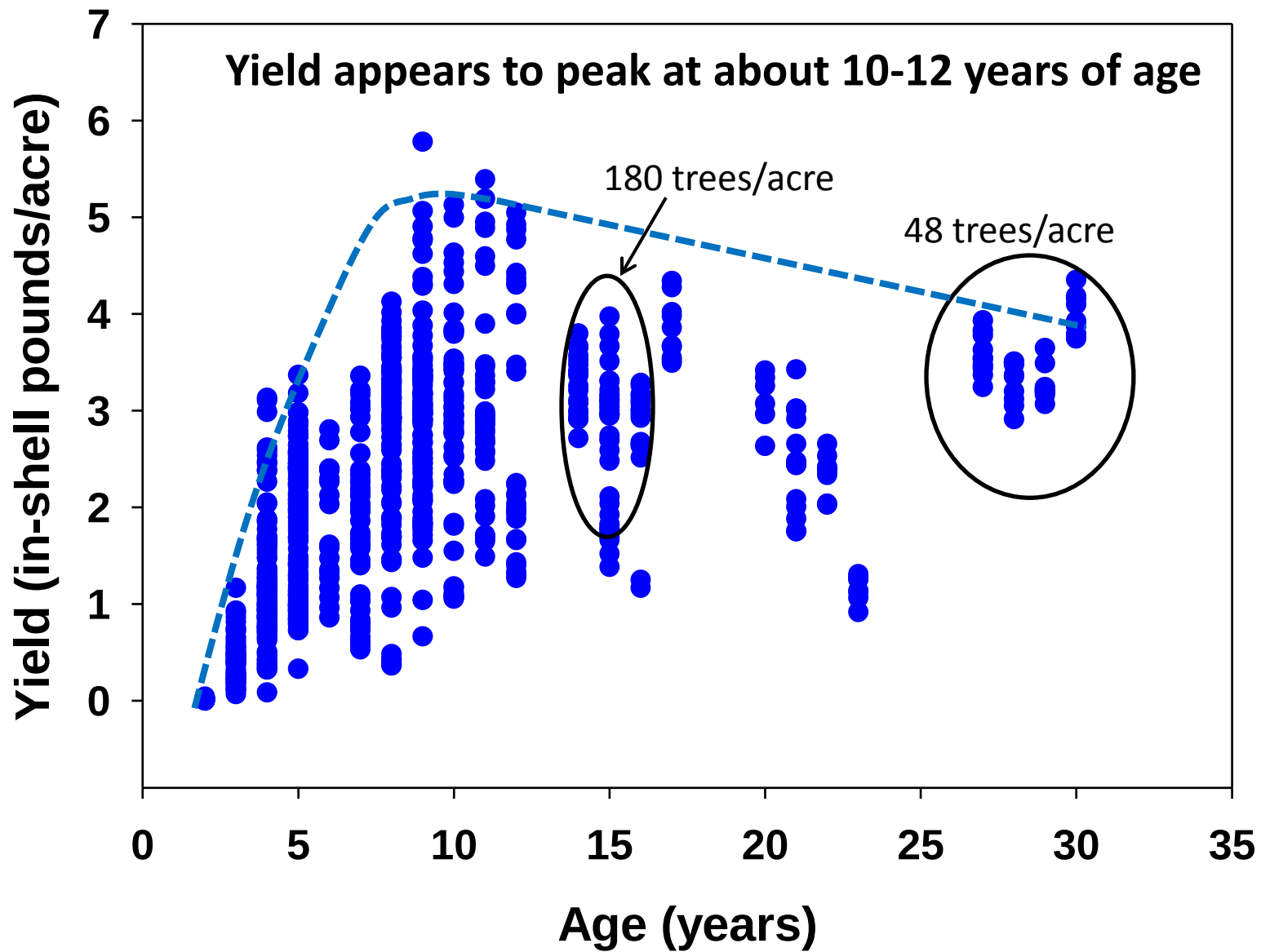
25

30

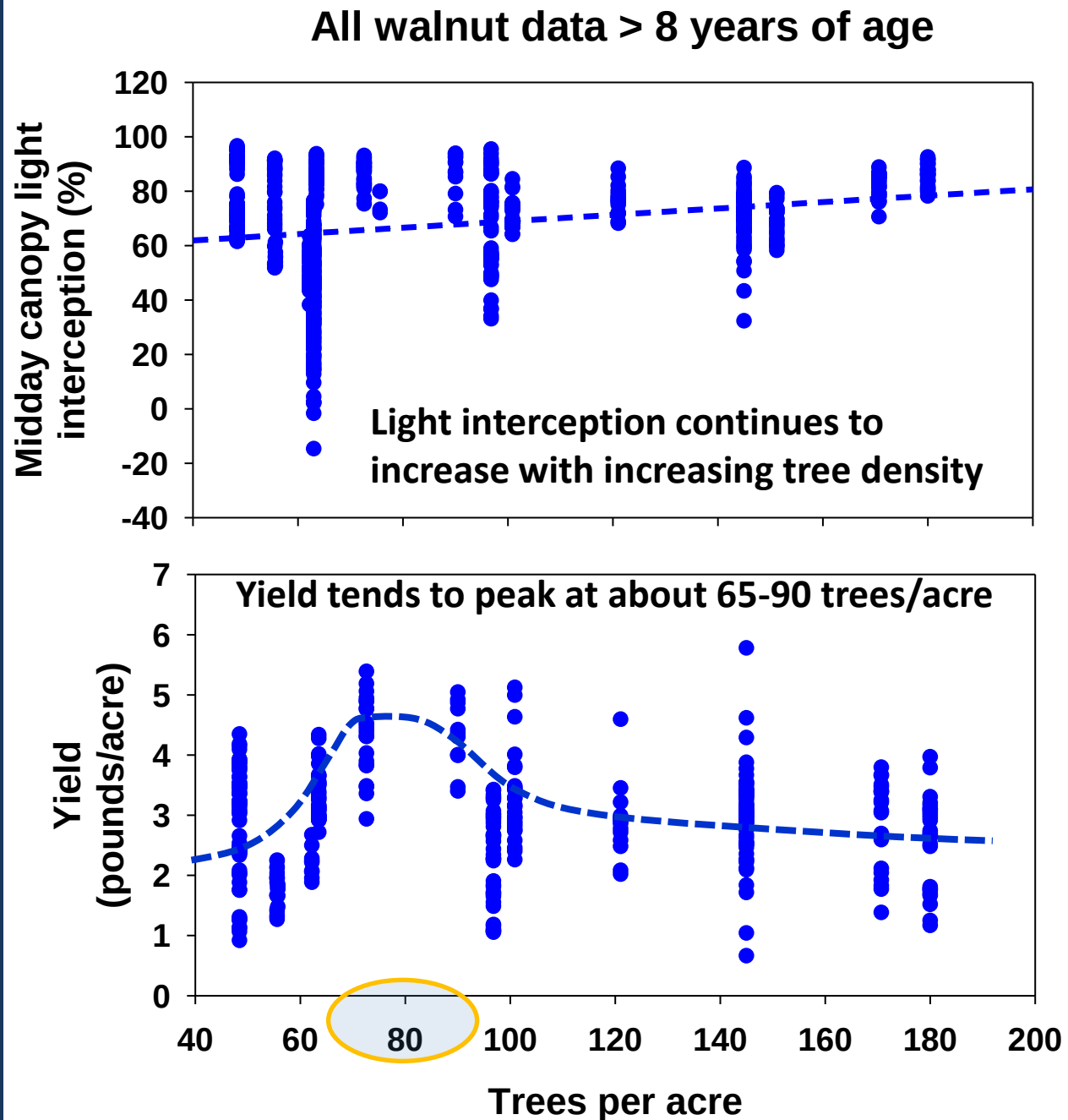
35

Age (years)



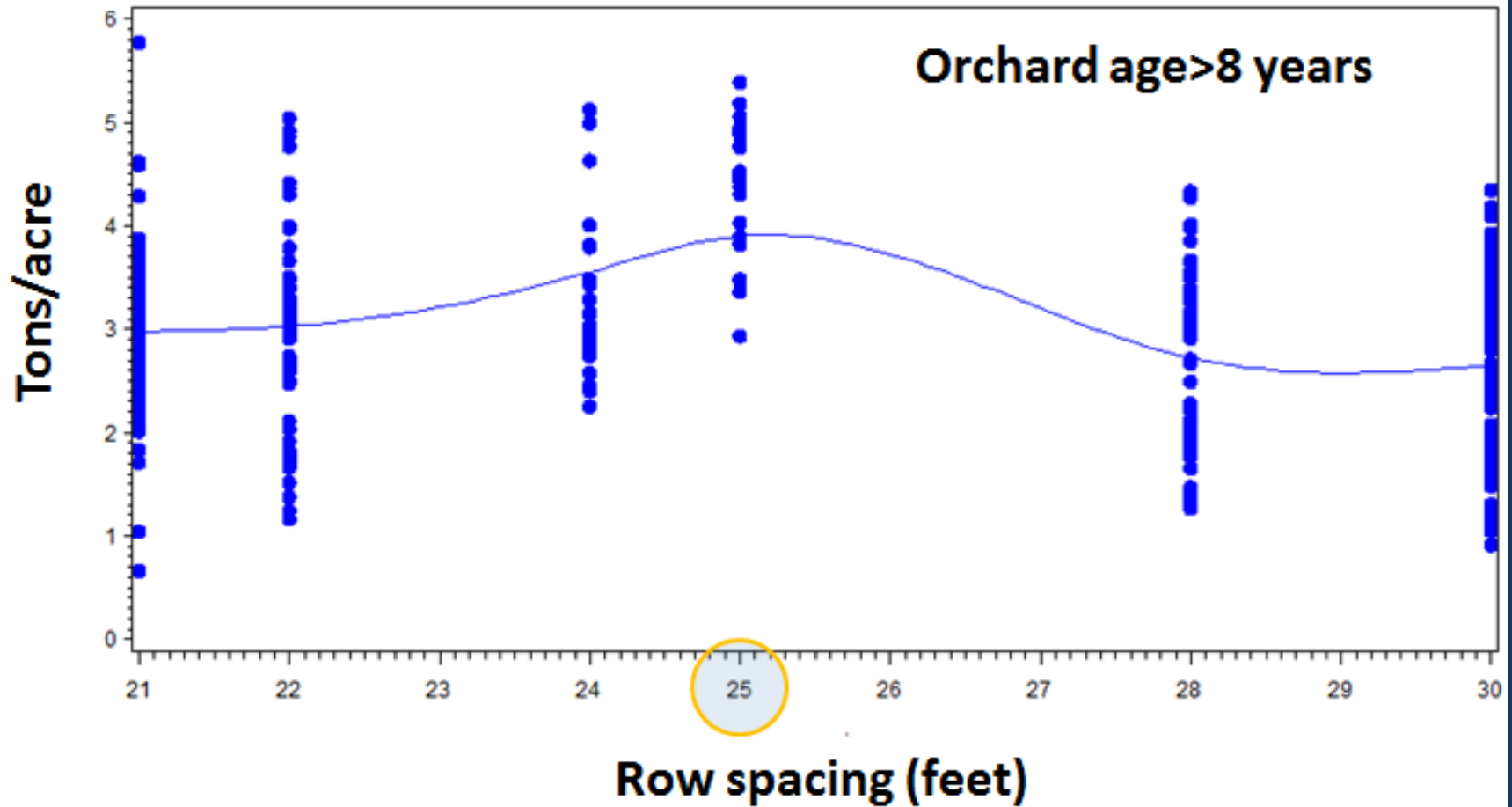


Trees per acre



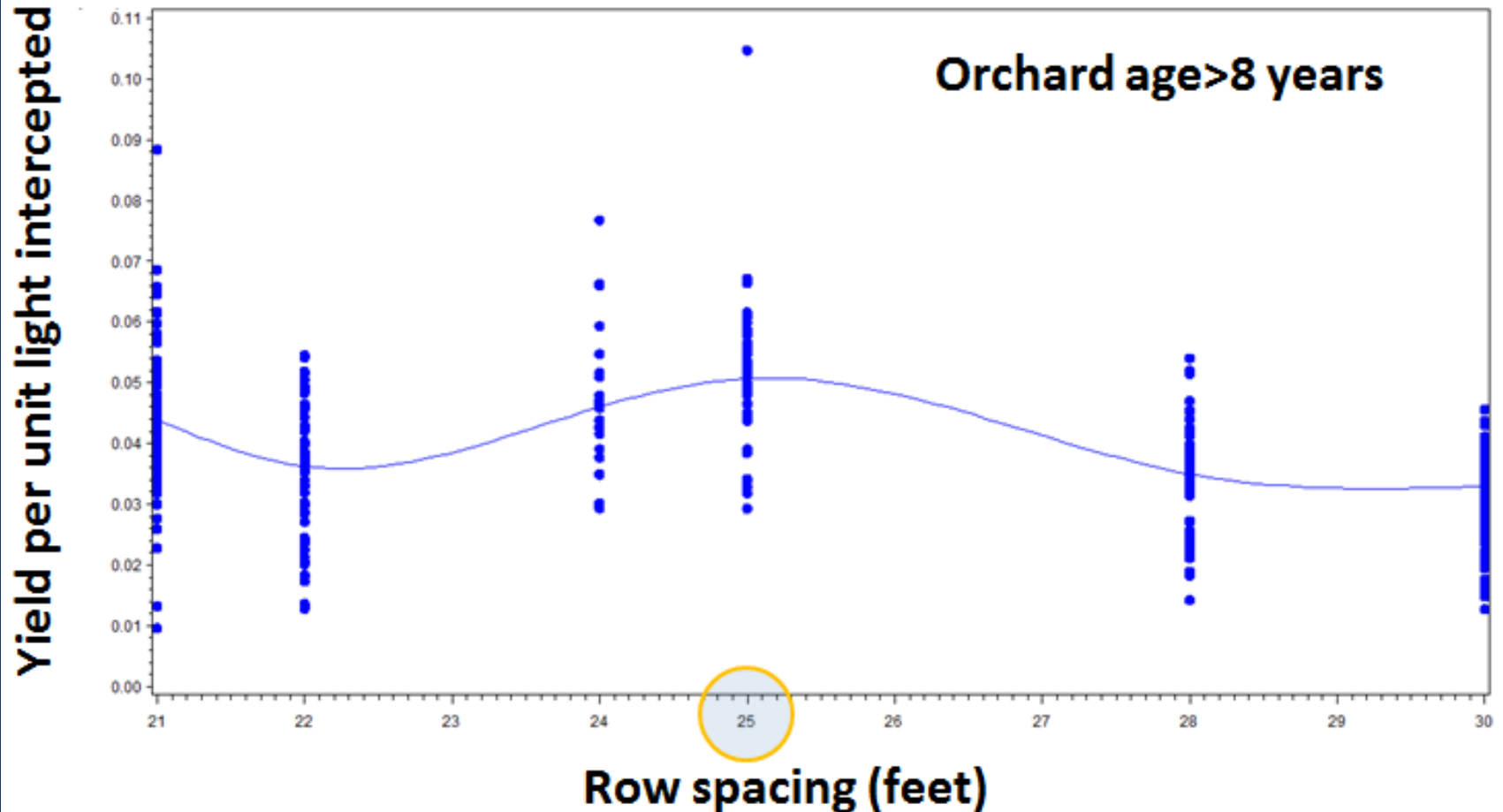
Tons per acre versus row spacing

Highest yield occurred at a row spacing of ~25 feet



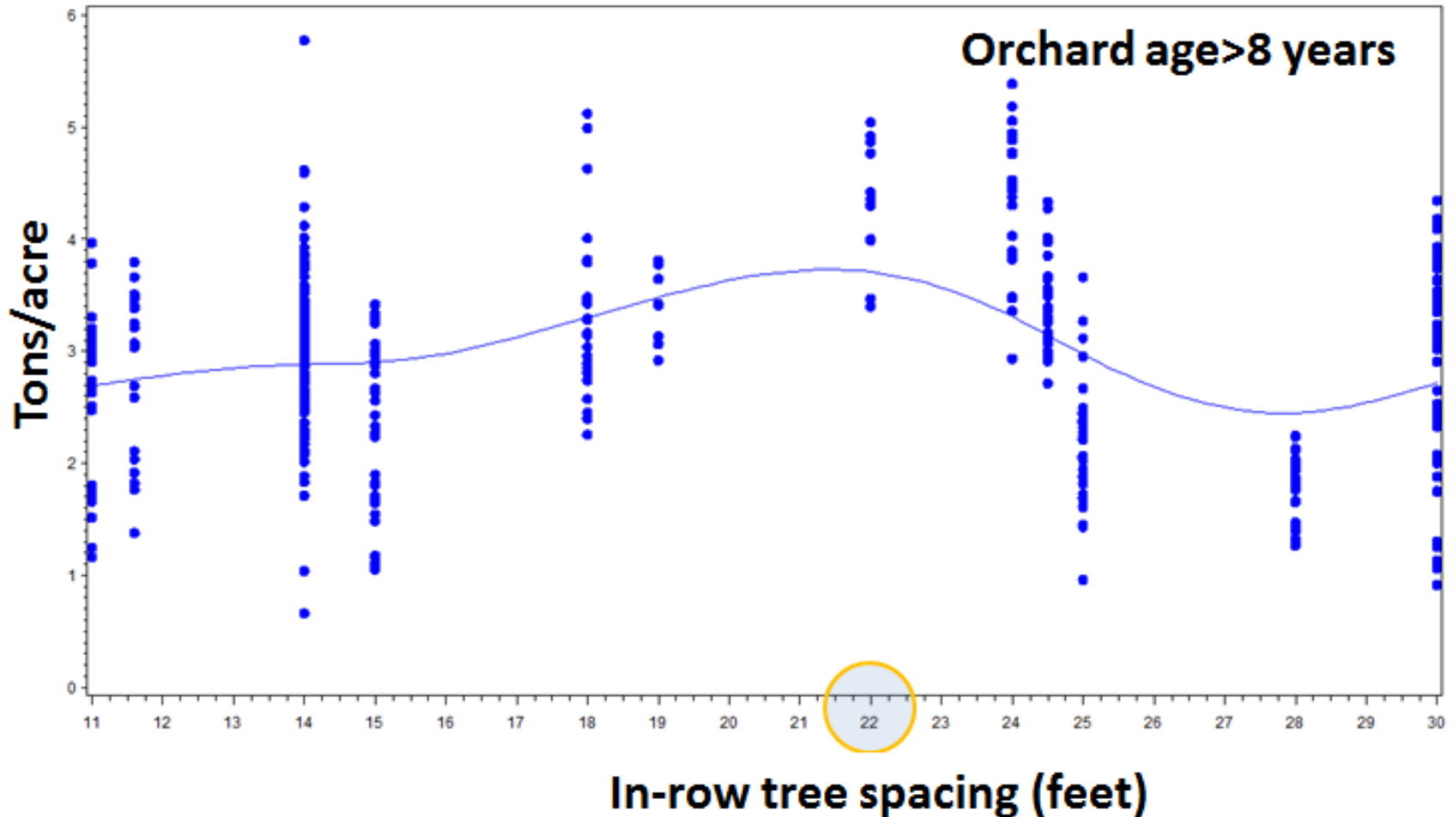
Yield per unit light intercepted versus row spacing

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.

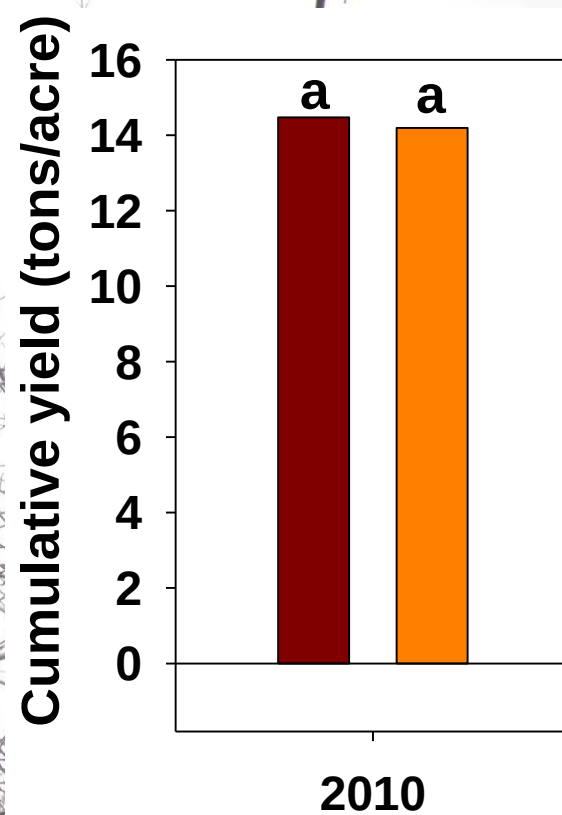
How pruning/non-pruning influences canopy development and yield



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)



Unpruned

March 2008

lateral
branching
(preformed
growth
only)



Unpruned

Feb 2009

elongation
(neoformed
growth)



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



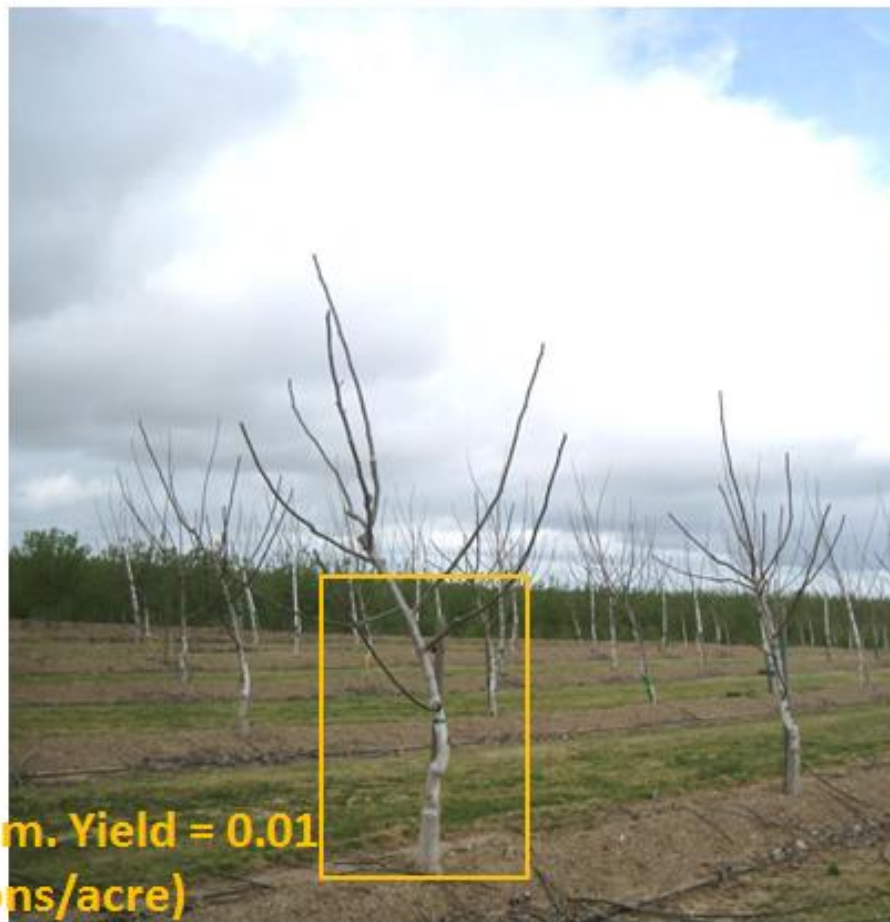
Unpruned



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

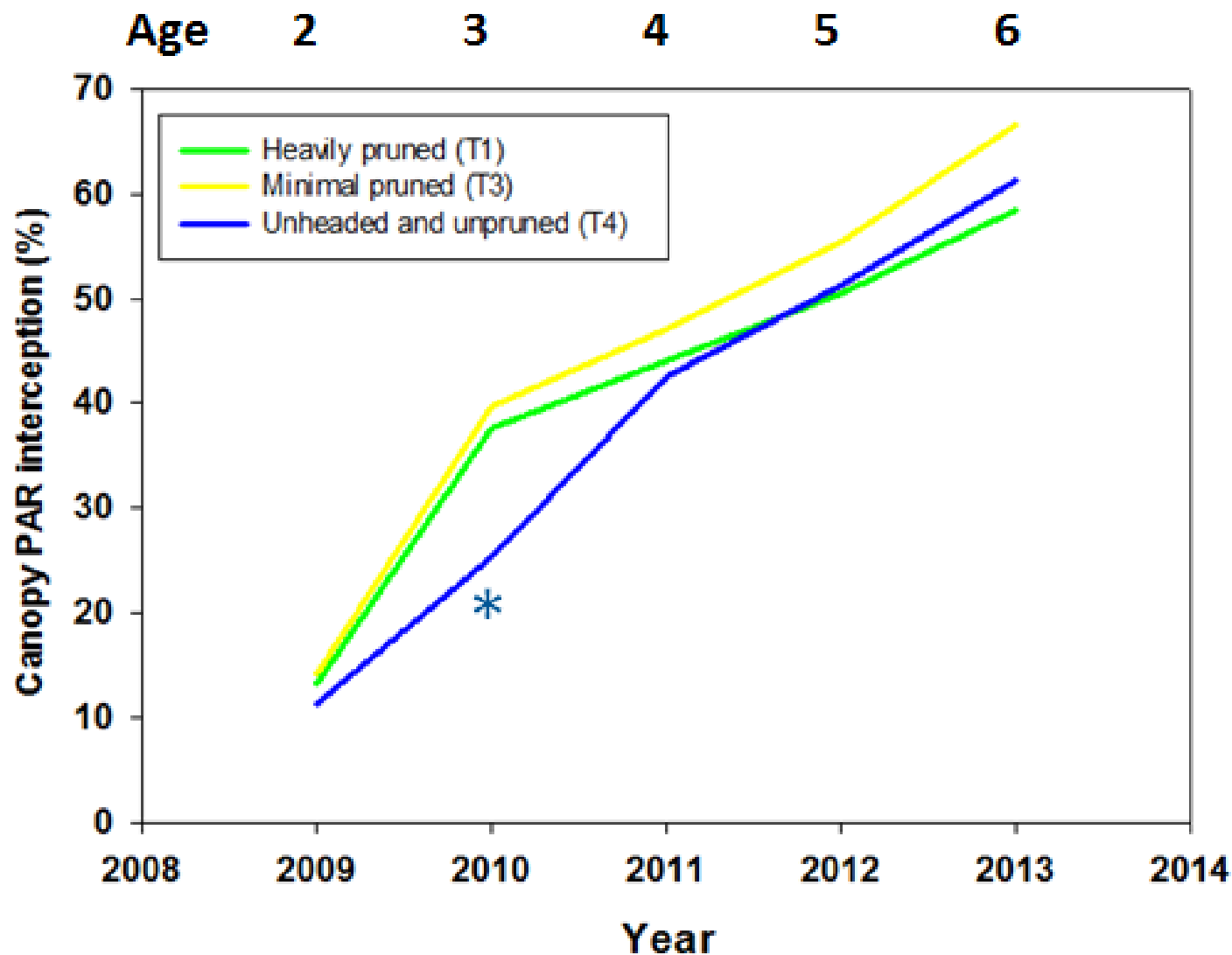
4.84

01/01/13

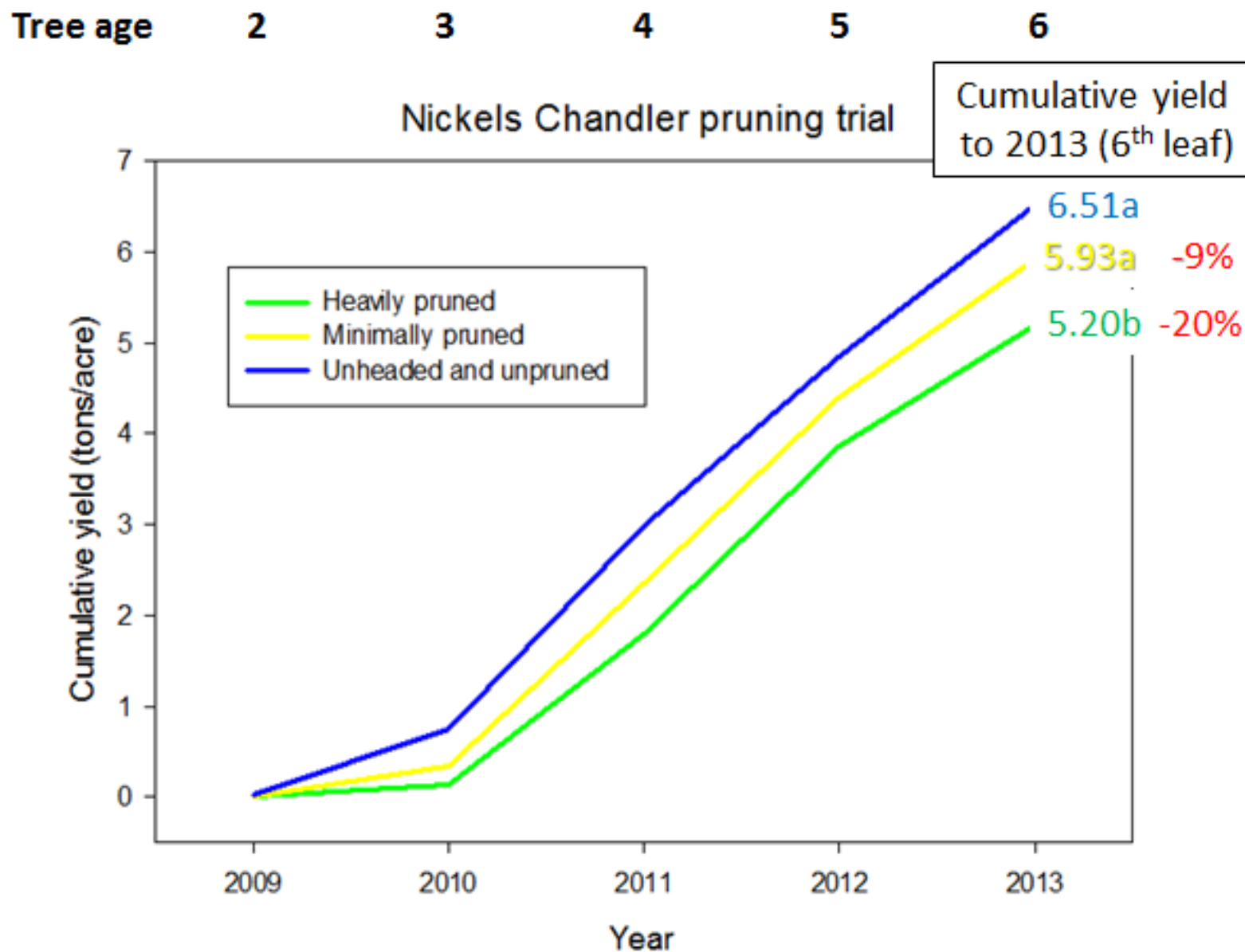


2/24/14

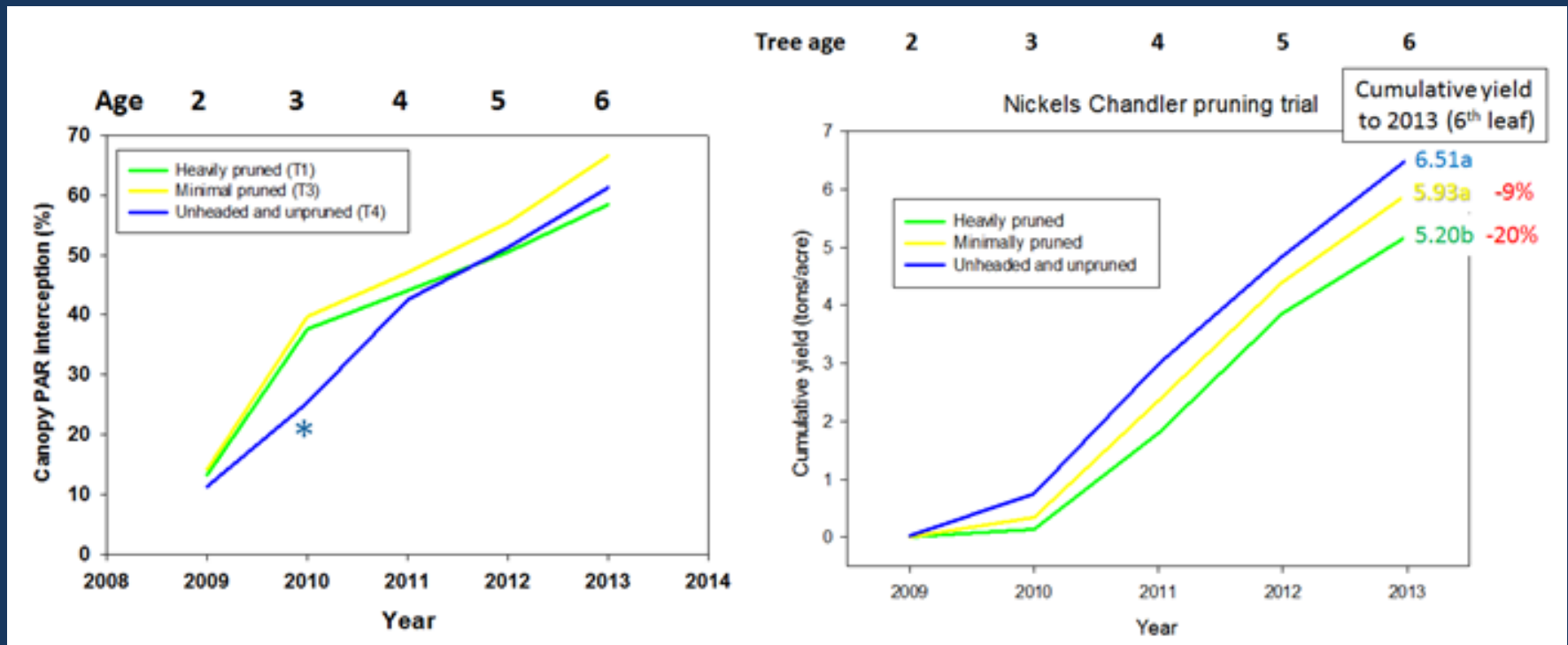
Midday canopy light interception by treatment and year for Chandler



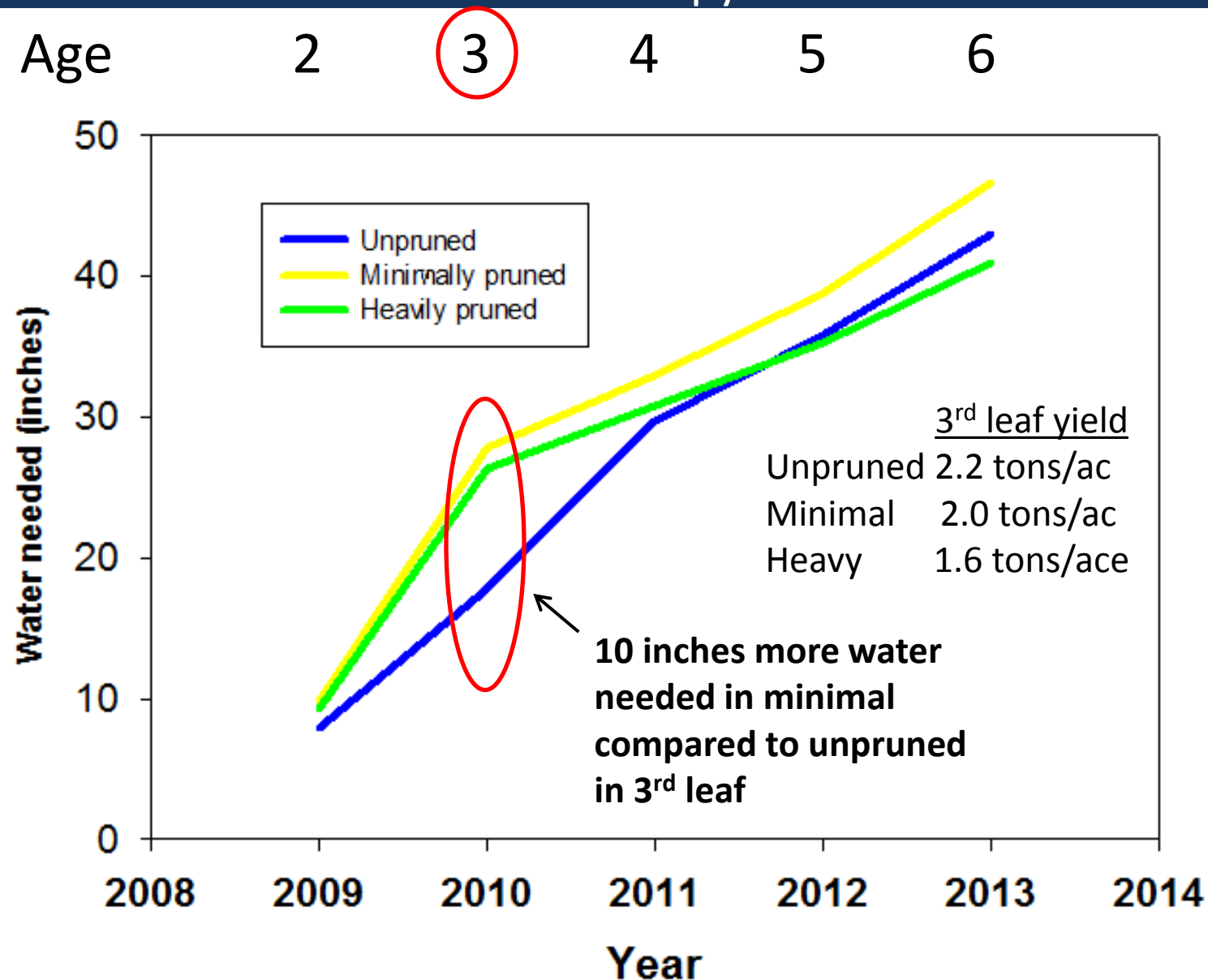
Cumulative yield by treatment and year for Chandler



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



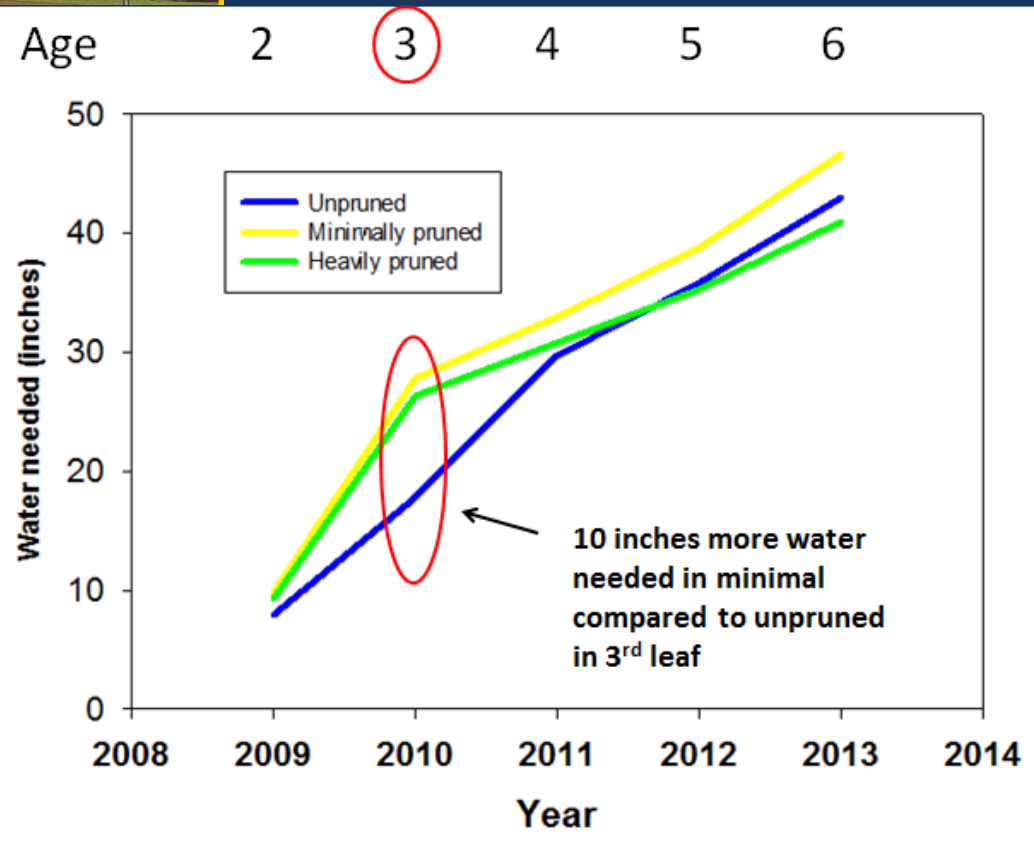
Water needed to support canopy based on proportion of 42 inches needed at 60% canopy cover





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 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	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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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

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

3rd Leaf Forde in Yolo County



3nd Leaf Howard in Butte County



3nd Leaf Chandler in Tulare County



3nd Leaf Chandler in Lake County

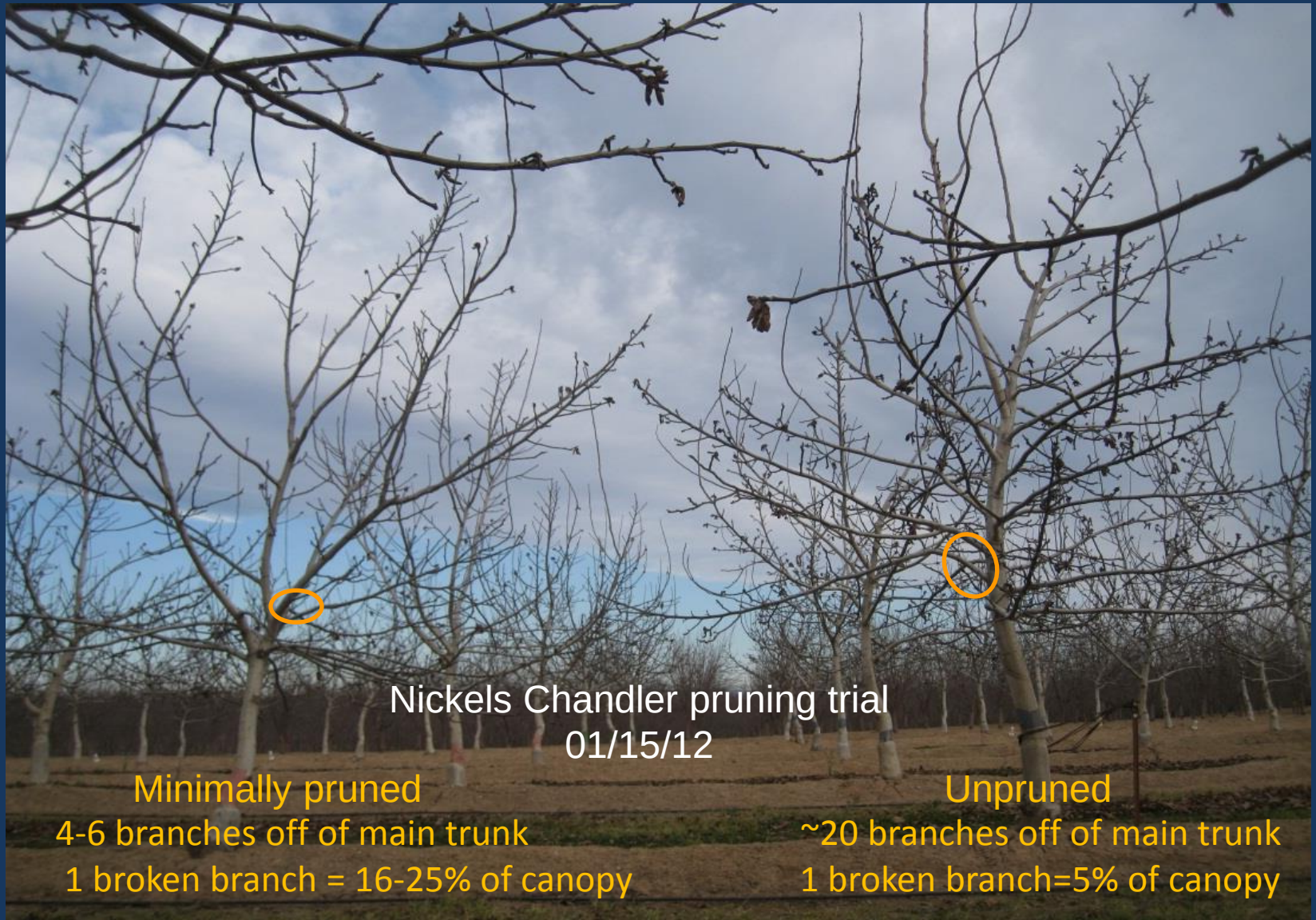


3nd Leaf Chandler in Merced County



4nd 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

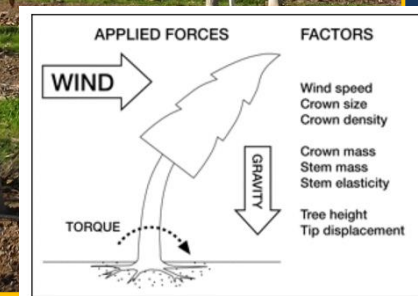
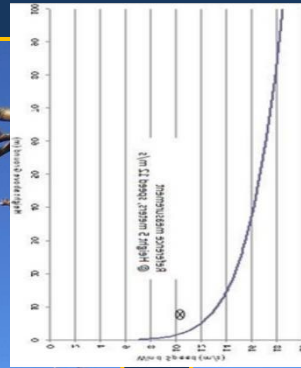
Flatter branch angles

Shading related
dieback will occur
earlier

December 2021

Heavily pruned

Unheaded/unpruned



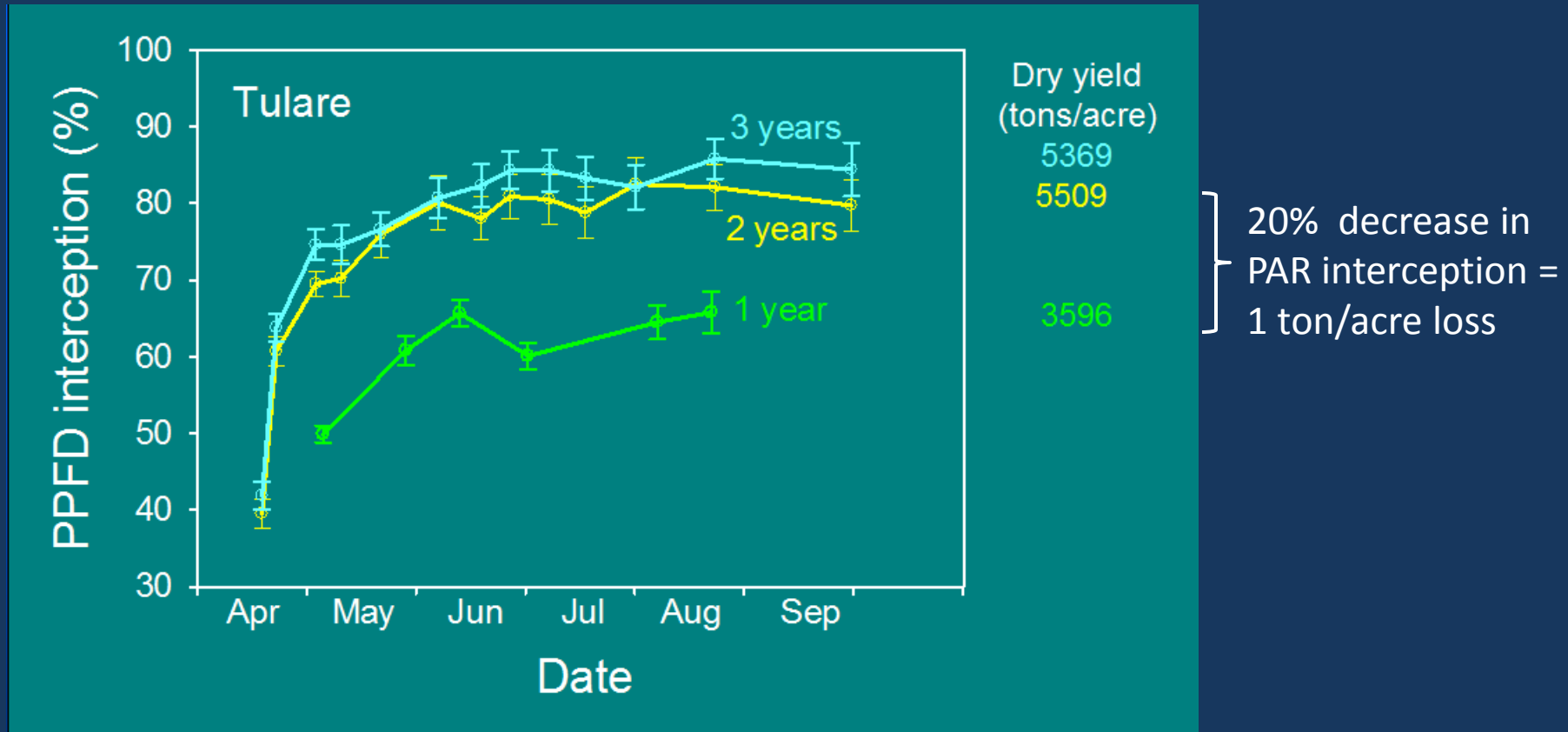
Minimally pruned

Unheaded/unpruned

How hedging influences canopy development and yield



Tulare growth and yield responses to mechanical hedging Solano County 2003



#nuts

2

10

20

26

primary
shoot



~3 to 6+ feet

cut

branching
point



0

1

2

3

4

1

2

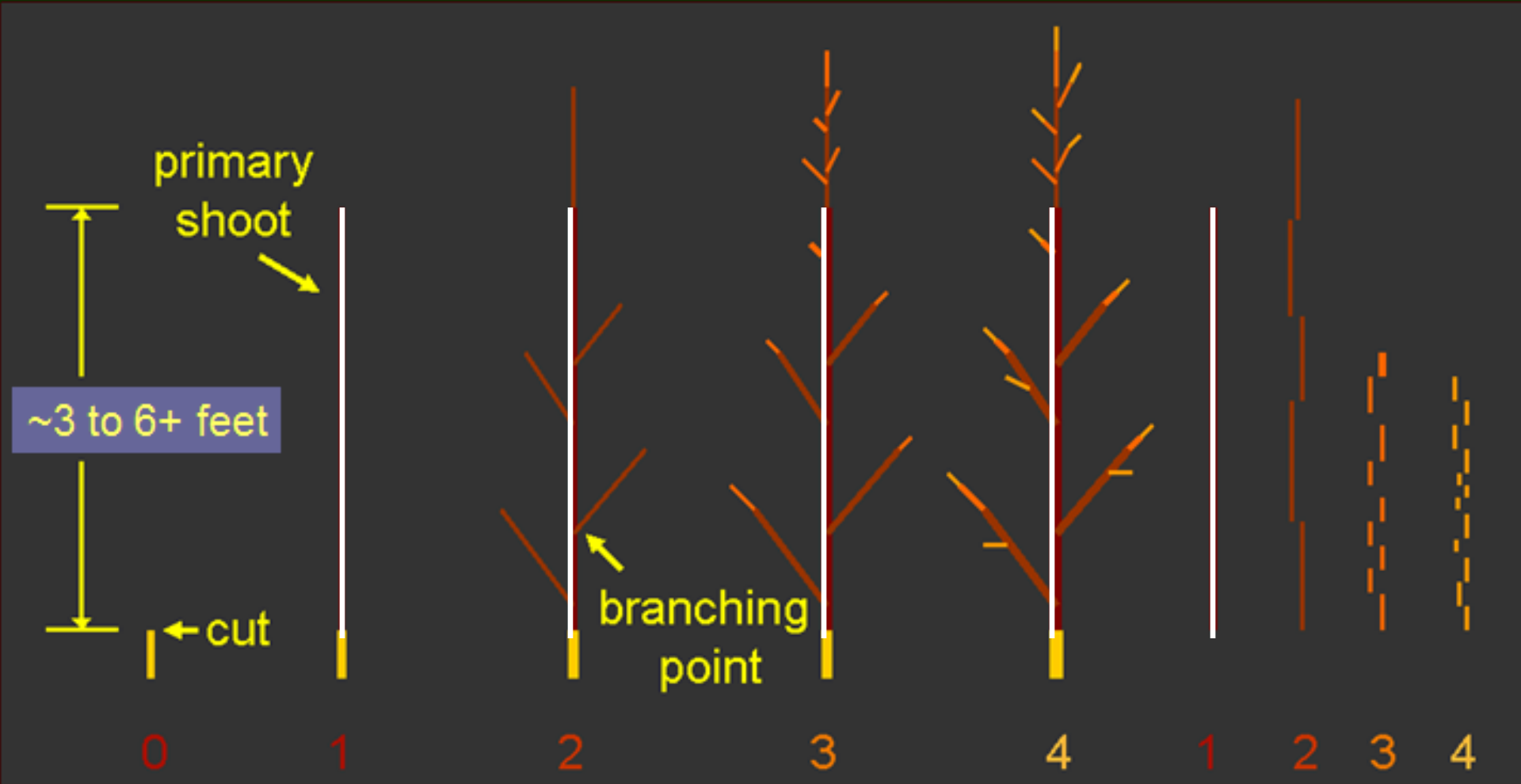
3

4

Years after hedging →

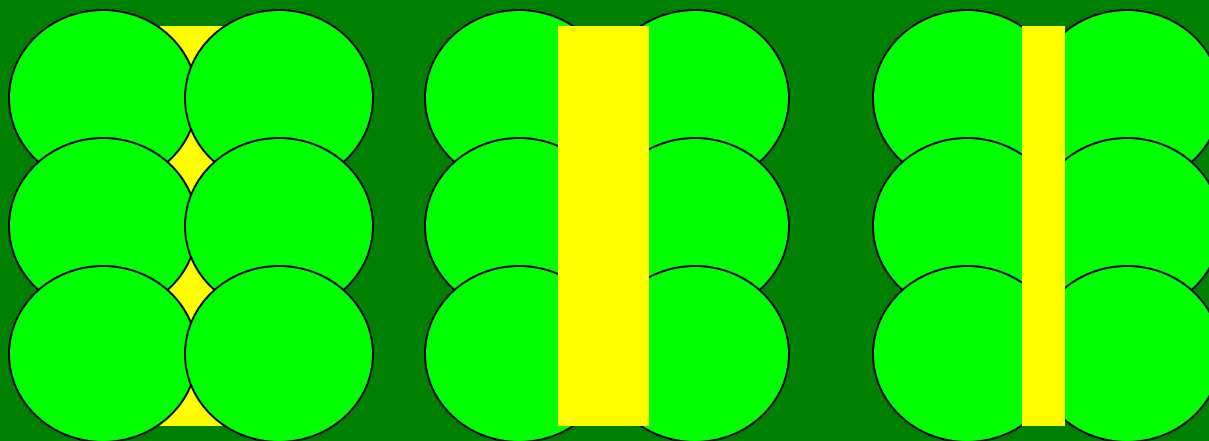
↑ Total by year

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

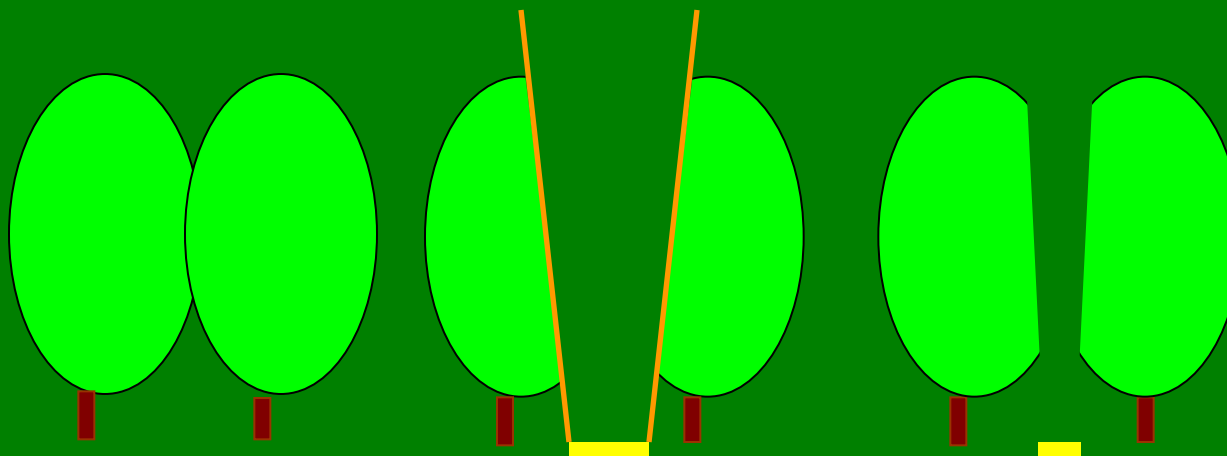


High density

top
view



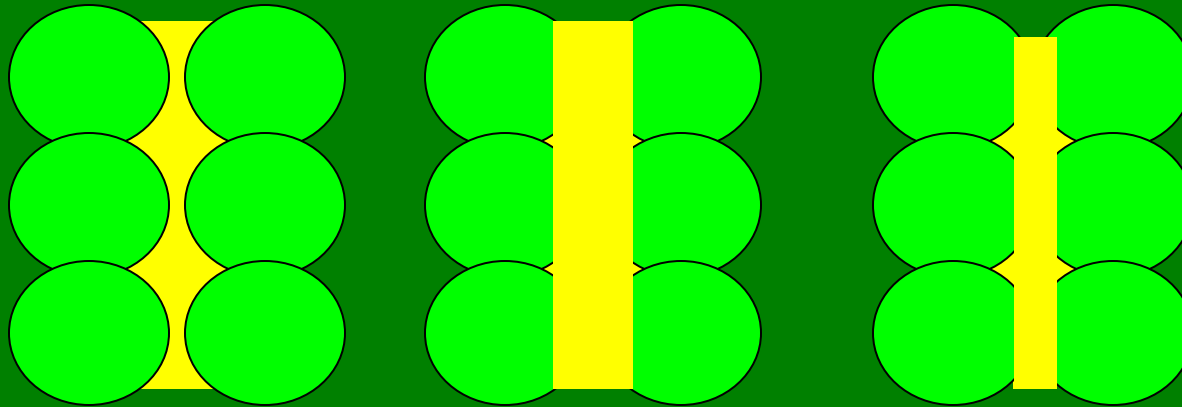
side
view



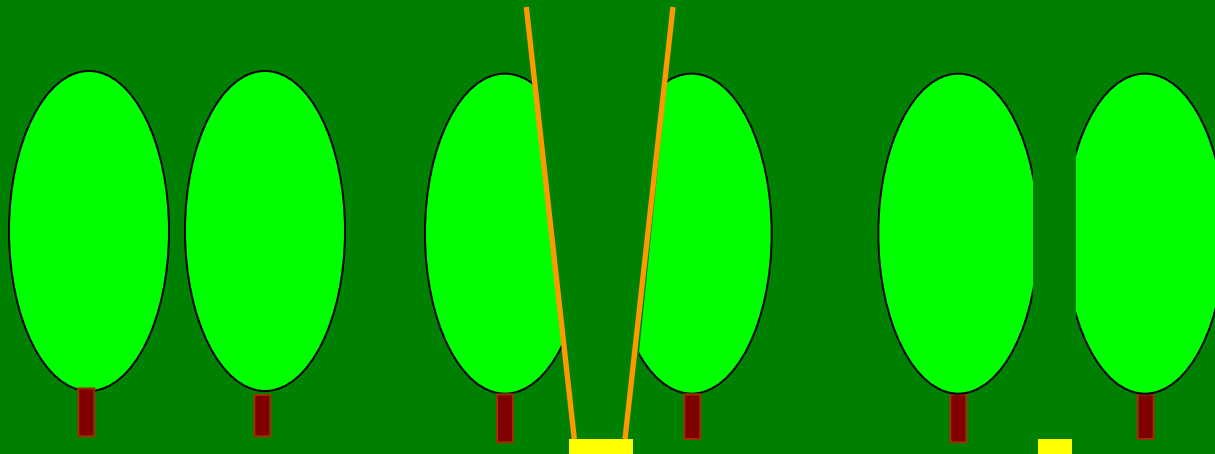
	before hedging	after hedging	one year later	3 yr ave.
PAR int.	85%	70%	80%	83%
Yield potential	4.2 tons 3.6 tons/ac	3.2 tons/ac 2.4 tons/ac	4.0 tons/ac 2.9 tons/ac	3.8 3.0

Moderately high density

top
view



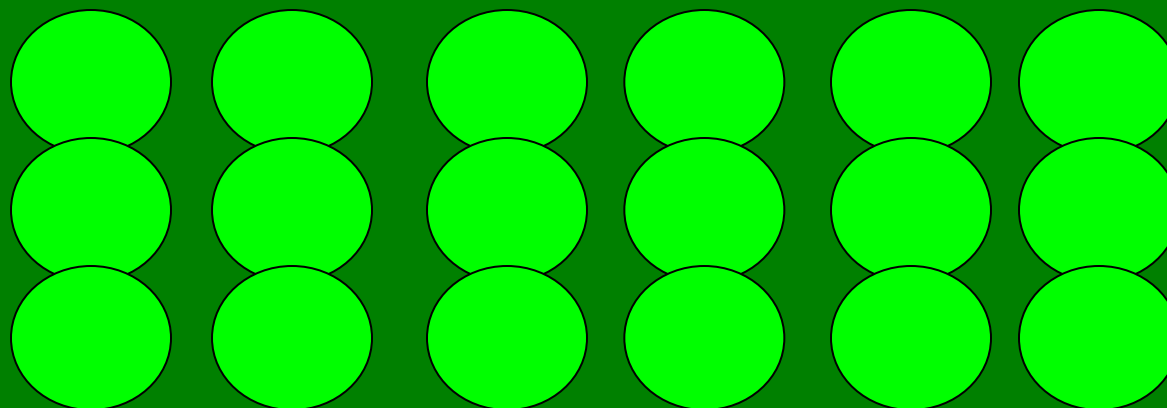
side
view



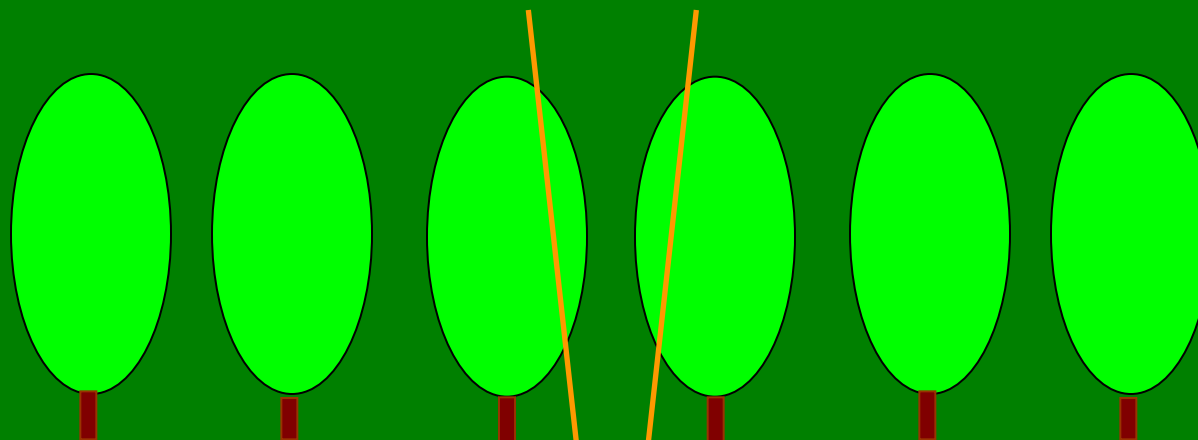
	before hedging	after hedging	one year later	3 yr ave.
PAR int.	80%	65%	75%	73%
Yield potential	4.0 tons/ac 3.4 tons/ac	2.7 tons/ac 2.5 tons/ac	3.7 tons/ac 2.8 tons/ac	3.5 tons/ac 2.9 tons/ac

Lower density with no hedging

top
view

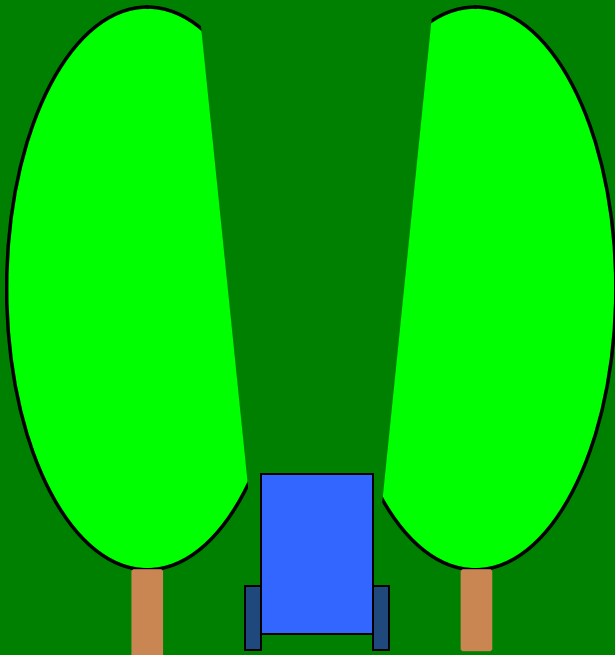


side
view

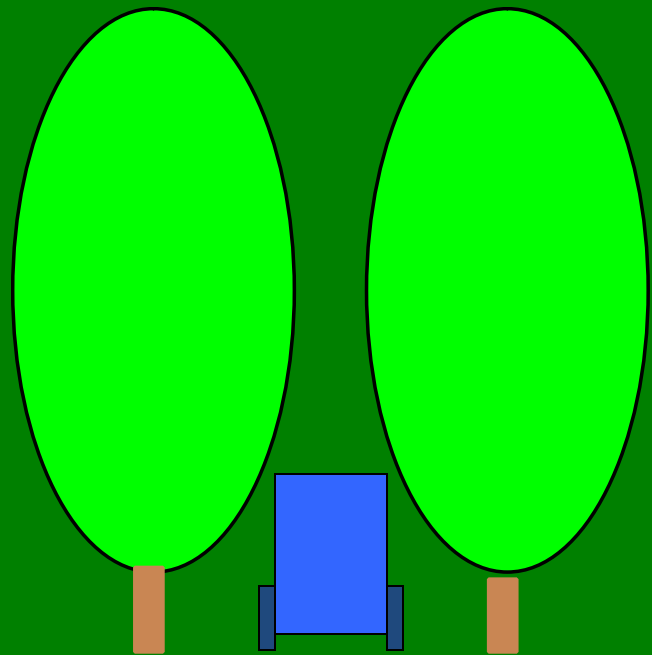


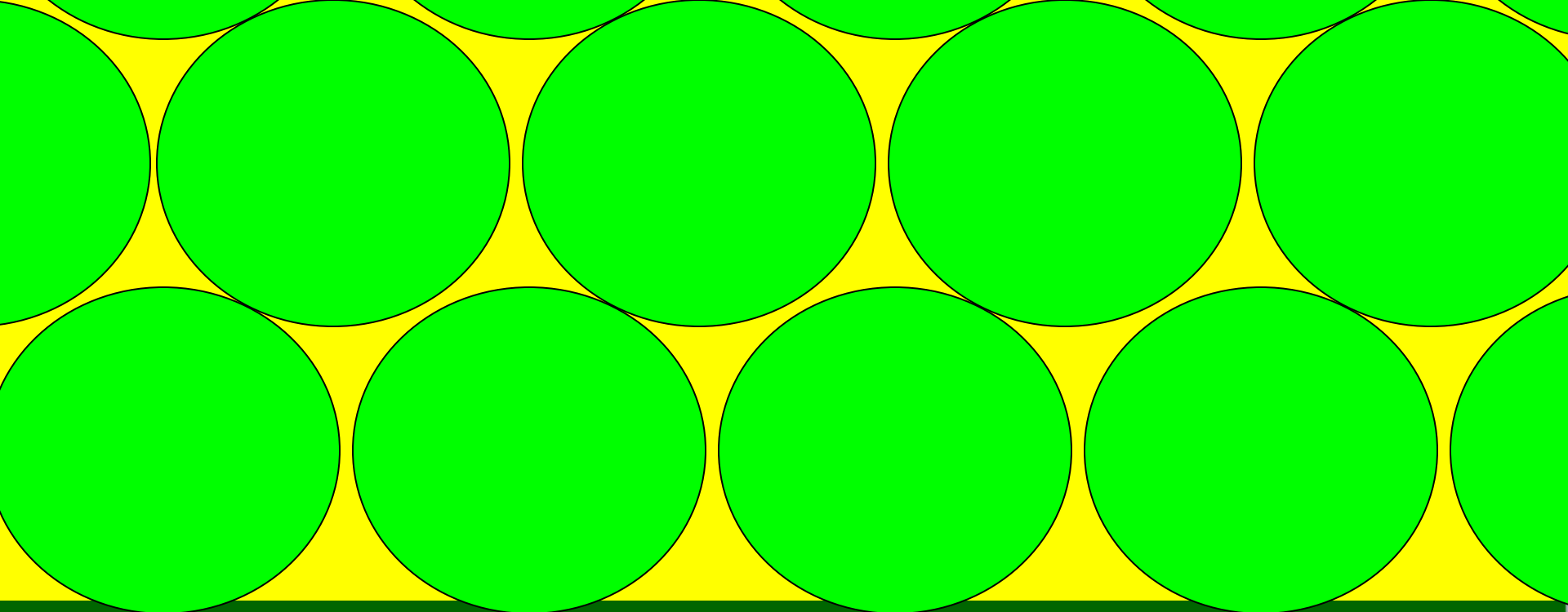
	unpruned	unpruned	unpruned	3 yr ave.
PAR int.	75%	76%	77%	76%
Yield potential	3.75 tons/ac	3.8 tons/ac	3.85 tons/ac	3.8 tons/ac

High density with
hedging

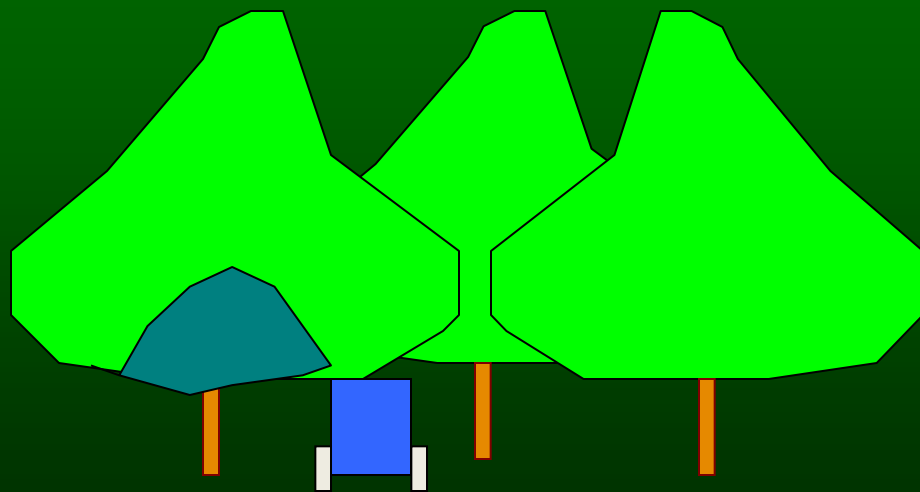
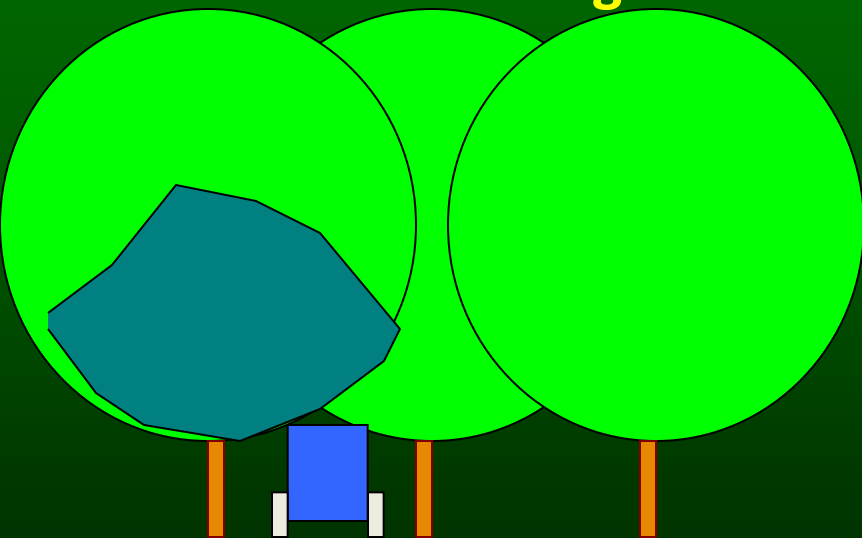


Lower density with
no hedging





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

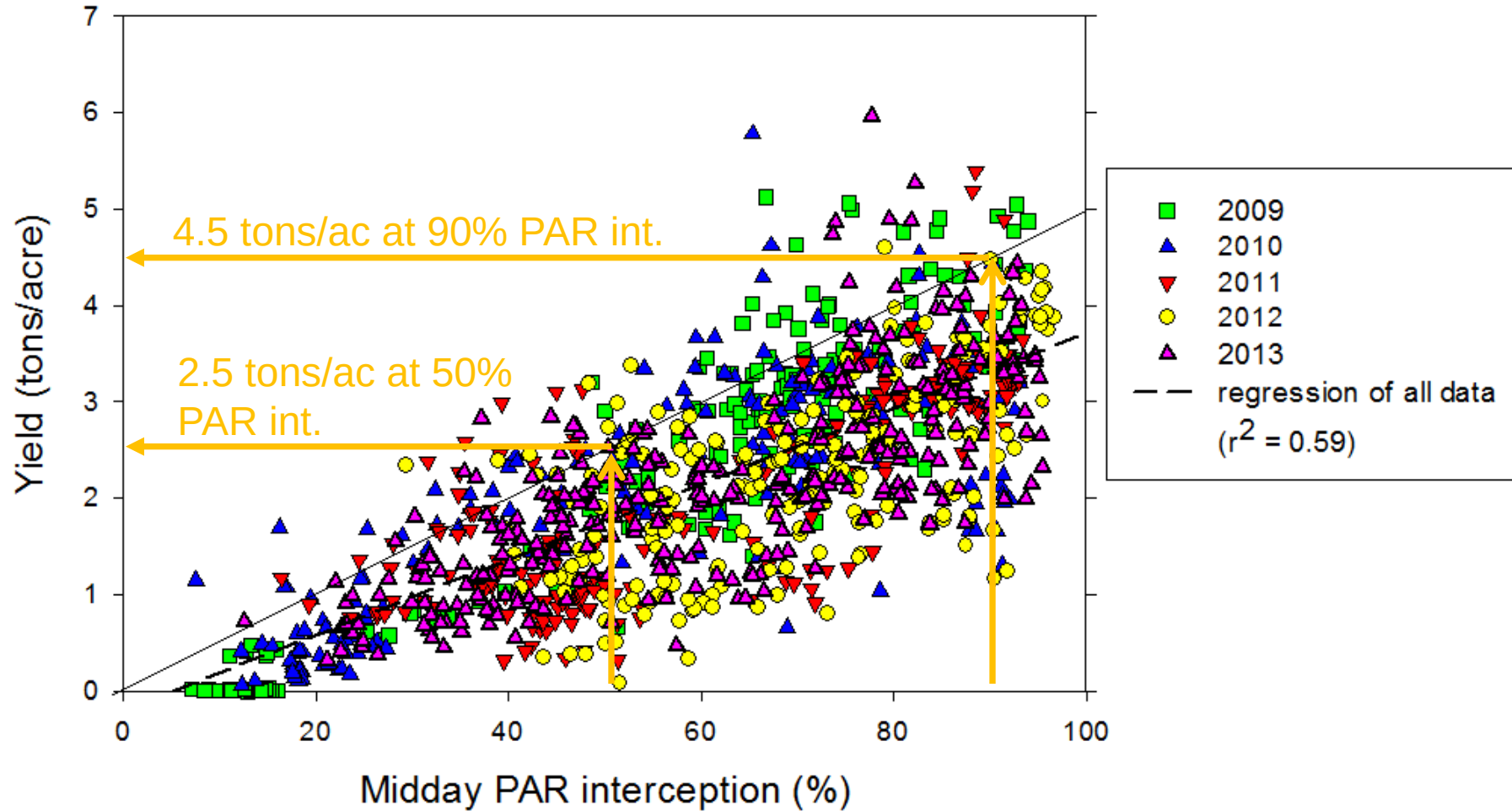


Conventional spacing

Summary of 3 scenarios

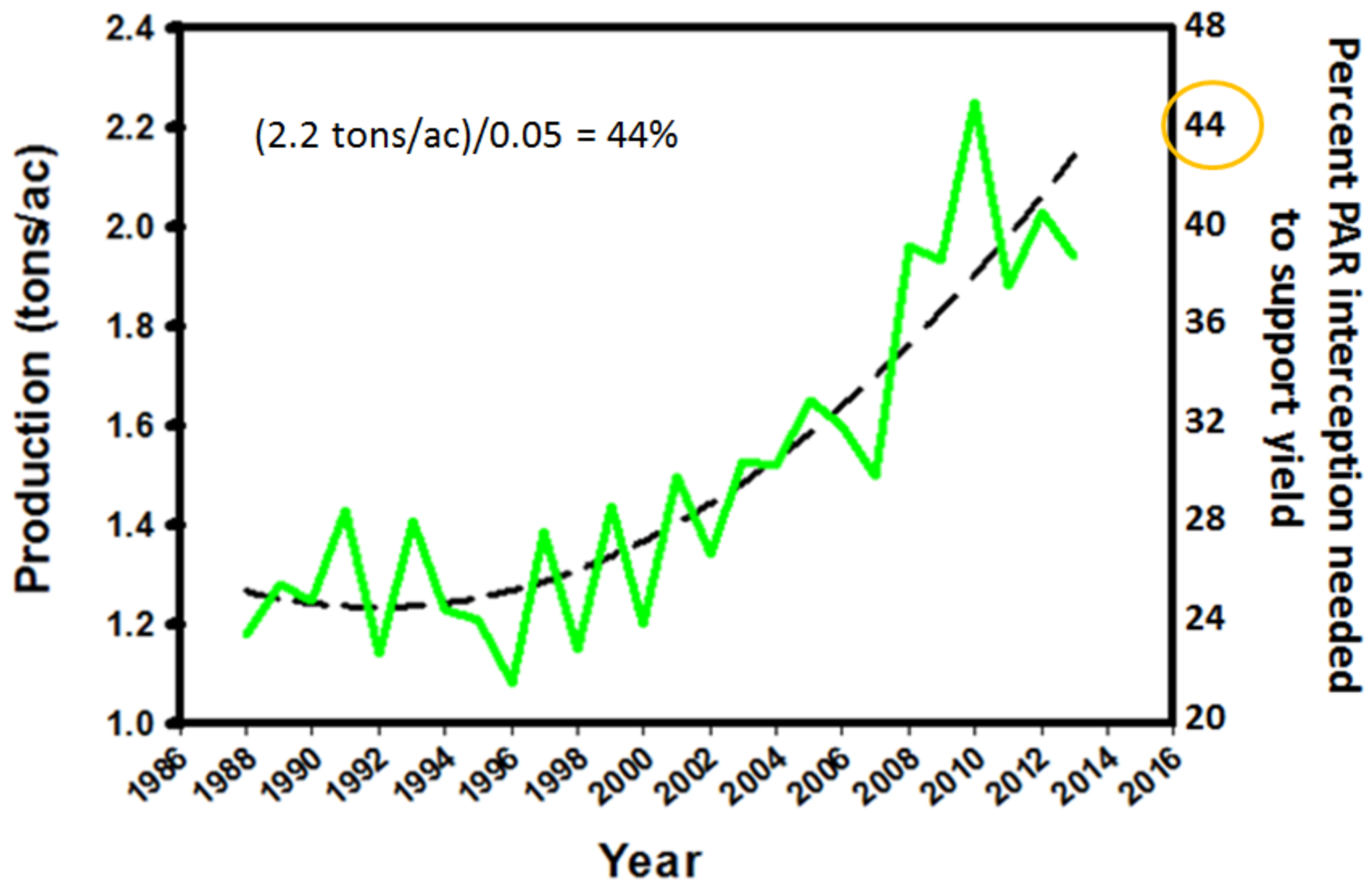
Scenario	Year 1	Year 2	Year 3	Average
High density	70% 3.5 2.4	80% 4.0 2.9	85% 4.2 3.6	83%(int.) 3.8 3.0 (actual)
Unpruned, slightly wider spacing	75% 3.75	76% 3.80	77% 3.85	76% 3.8
Conventional spacing	91% 4.55	92% 4.60	93% 4.65	91% 4.60

All walnut data 2009-2013

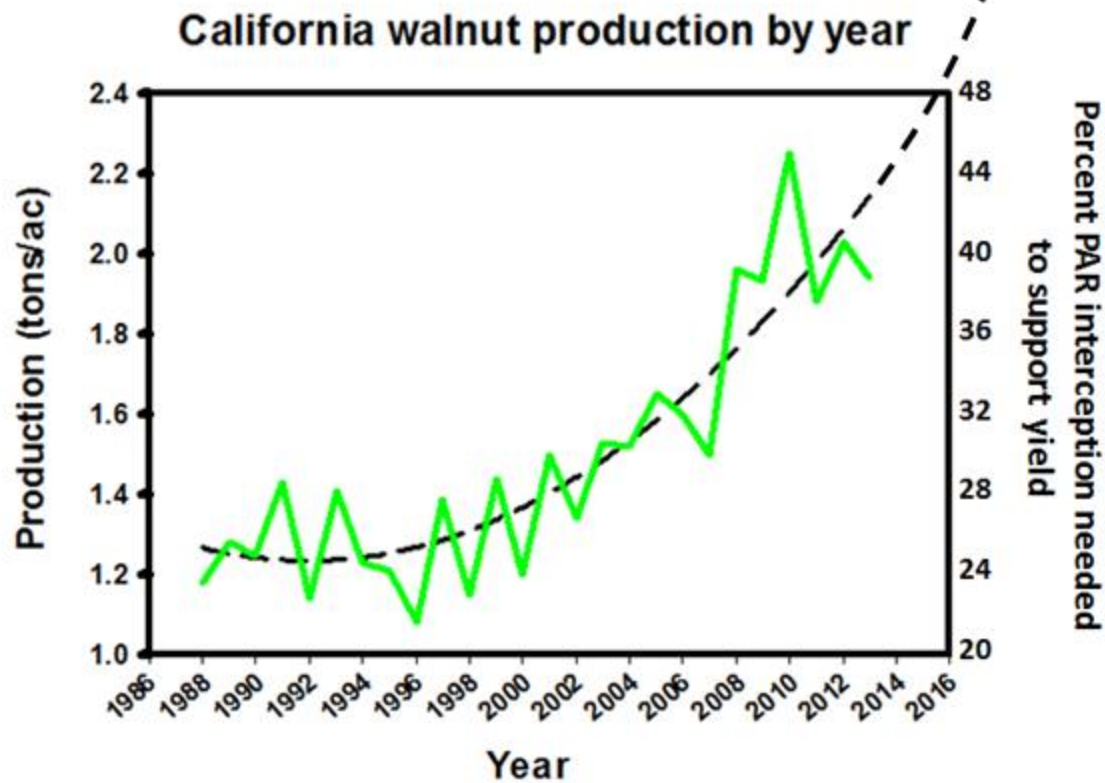


Best orchards can produce 0.05 tons/acre for each 1% of the PAR they intercept (solid black line in figure)

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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, forming a canopy overhead. The ground is covered in shadows and patches of grass. In the foreground, a metal structure, possibly part of a vehicle or machinery, is visible, with a curved metal bar and some mechanical components. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in yellow on the left side of the image.

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

A perspective view looking down a long, straight row of young trees in a hedgerow. The trees are planted in neat rows on both sides of a central path, creating a tunnel-like effect. The ground is covered in dirt and sparse grass, with shadows from the trees cast across it. In the foreground, a metal frame, likely part of a vehicle or machinery, is visible, suggesting the photo was taken from inside a vehicle. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in yellow on the left side of the image.

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



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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, forming a canopy over a dirt path. The path is dappled with sunlight and shadows. In the foreground, a metal structure, possibly part of a vehicle or a fence, is visible, with a rusty metal bar running across the bottom of the frame.

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

A perspective view looking down a long, straight row of young trees in a hedgerow. The trees are planted in neat rows, creating a sense of depth. The ground is covered in dark mulch and dappled with sunlight and shadows from the trees. In the foreground, a metal frame, likely part of a vehicle or machinery, is visible, suggesting the photo was taken from inside a vehicle. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in yellow on the left side of the image.

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

A perspective view looking down a long, straight row of young trees in a nursery. The trees are planted in neat rows, and their shadows are cast onto the ground. In the foreground, a metal frame, likely part of a transport vehicle, is visible. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in the lower-left corner.

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



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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with sunlight filtering through the leaves, creating a dappled light effect on the ground. The ground is covered in dark mulch or soil. In the foreground, a metal structure, possibly part of a machine or a fence, is visible, with two large, curved metal pipes or tubes extending from the bottom corners towards the center. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in yellow on the left side of the image.

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



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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with sunlight filtering through the leaves, creating dappled shadows on the ground. The ground is a mix of dirt and grass. In the foreground, a metal structure, possibly part of a vehicle or a fence, is visible, partially obscuring the view. The text "13 year old hedgerow Howard planting (14' x 21')" is overlaid in yellow on the left side of the image.

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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with sunlight filtering through the leaves, creating a pattern of light and shadow on the ground. In the foreground, a metal frame, likely part of a vehicle or machinery, is visible, suggesting the photo was taken from inside a vehicle. The ground is a mix of dirt and sparse grass.

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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with sunlight filtering through the leaves, creating dappled shadows on the ground. The ground is a mix of dirt and sparse grass. In the foreground, a curved metal structure, possibly part of a vehicle or machinery, is visible, framing the bottom of the image. The sky is visible at the far end of the row, appearing bright blue.

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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with sunlight filtering through the leaves, creating a pattern of light and shadow on the ground. A metal railing or fence runs across the bottom of the frame, suggesting the viewer is looking from a vehicle or a walkway. The ground is a mix of dirt and sparse grass, with shadows from the trees. The sky is visible at the far end of the row, appearing clear and blue.

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

A perspective view looking down a long, straight row of mature trees in a hedgerow. The trees are dense and green, with their shadows cast onto the ground. The ground is a mix of dirt and sparse grass. In the foreground, a metal structure, possibly part of a vehicle or a fence, is visible, with some blue components. The sky is visible at the end of the row, showing a clear blue color.

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



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

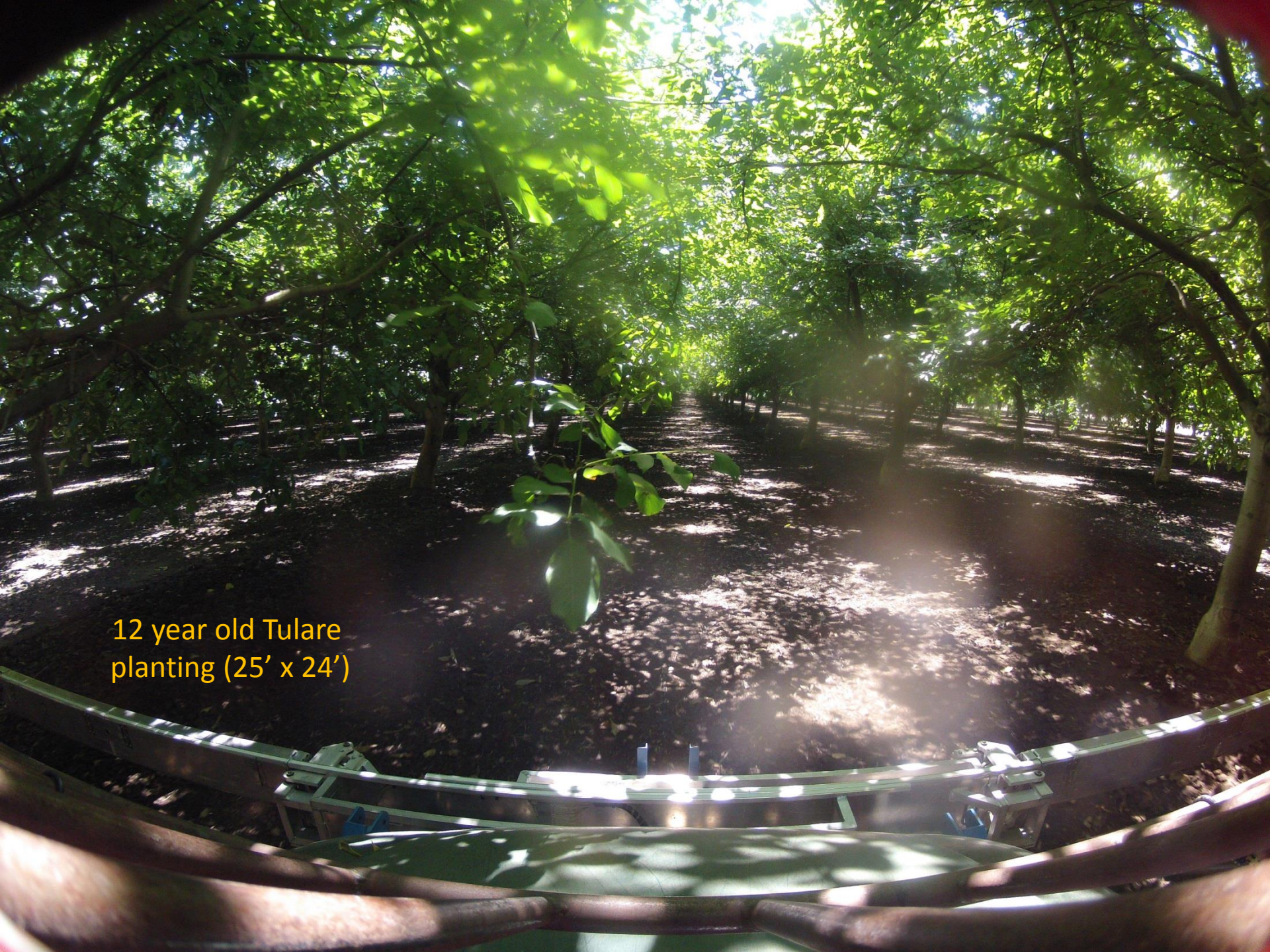
Conventional spacing



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



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



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



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 wide-angle, fisheye photograph of a mature orchard. The scene is filled with rows of trees, their green leaves creating a dense canopy. Sunlight filters through the branches, casting a pattern of light and shadow on the ground. In the foreground, a curved metal structure, possibly part of a machine or a support system, is visible. The overall atmosphere is peaceful and well-maintained.

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



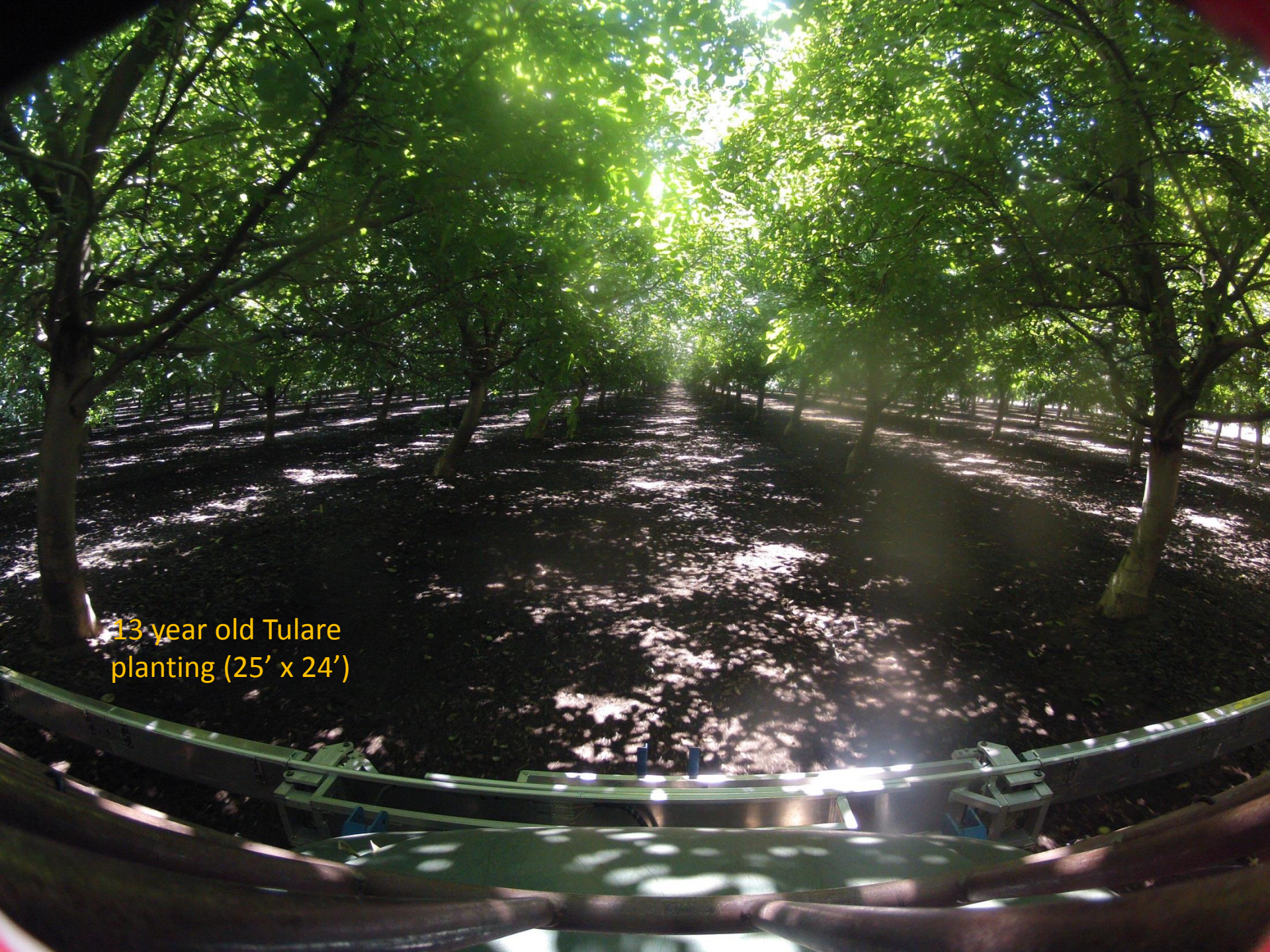
13 year old Tulare
planting (25' x 24')



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



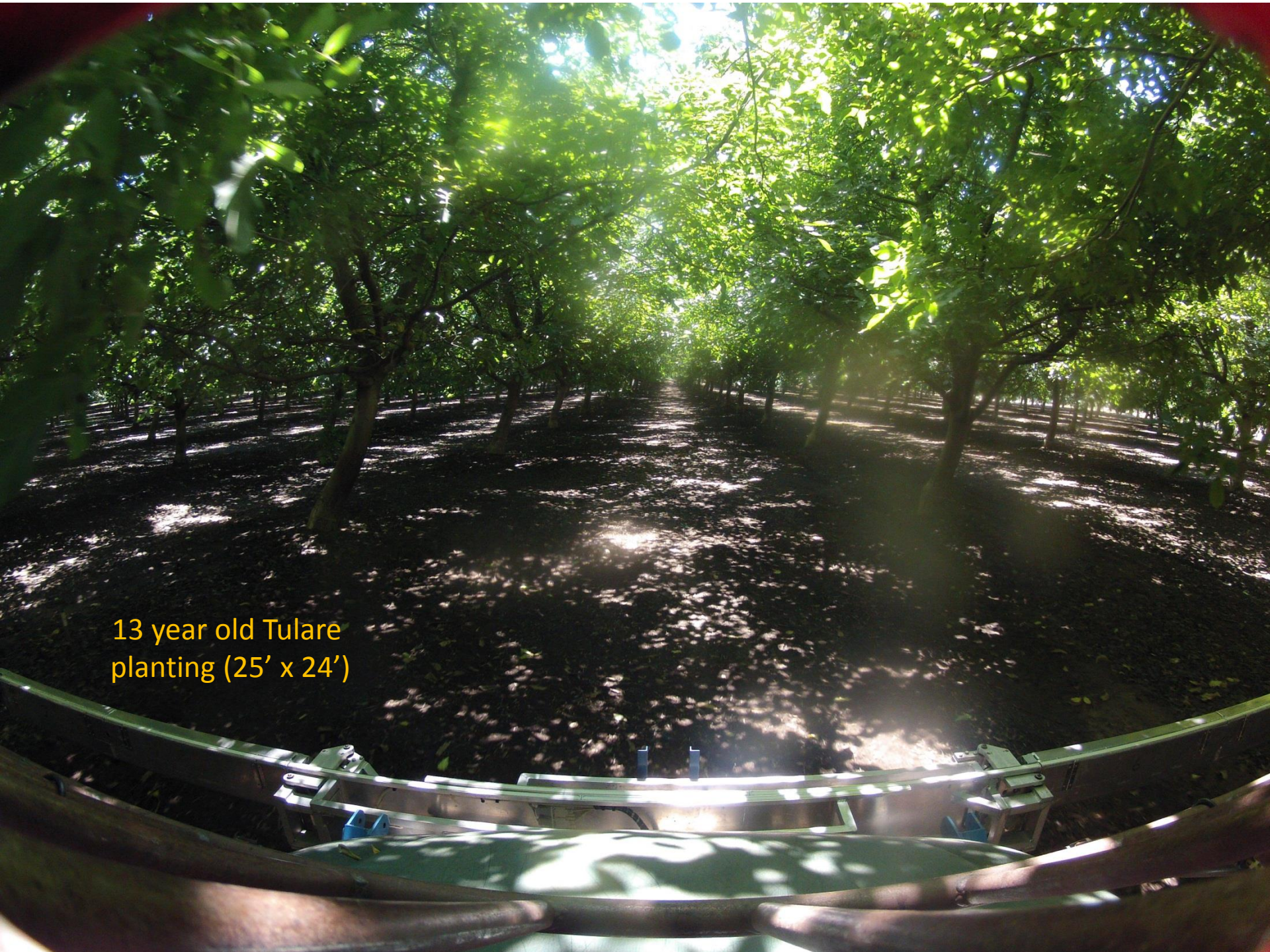
13 year old Tulare
planting (25' x 24')



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



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



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



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



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**

A photograph of a walnut grove with sunlight streaming through the trees, creating a hazy, ethereal atmosphere. The sunbeams are visible as bright rays cutting through the air, illuminating the ground and the lower branches of the trees. The trees have dense green foliage, and the ground is covered with dry leaves and twigs.

Questions?

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