Canopy Light Interception and Yield Potential in Almond

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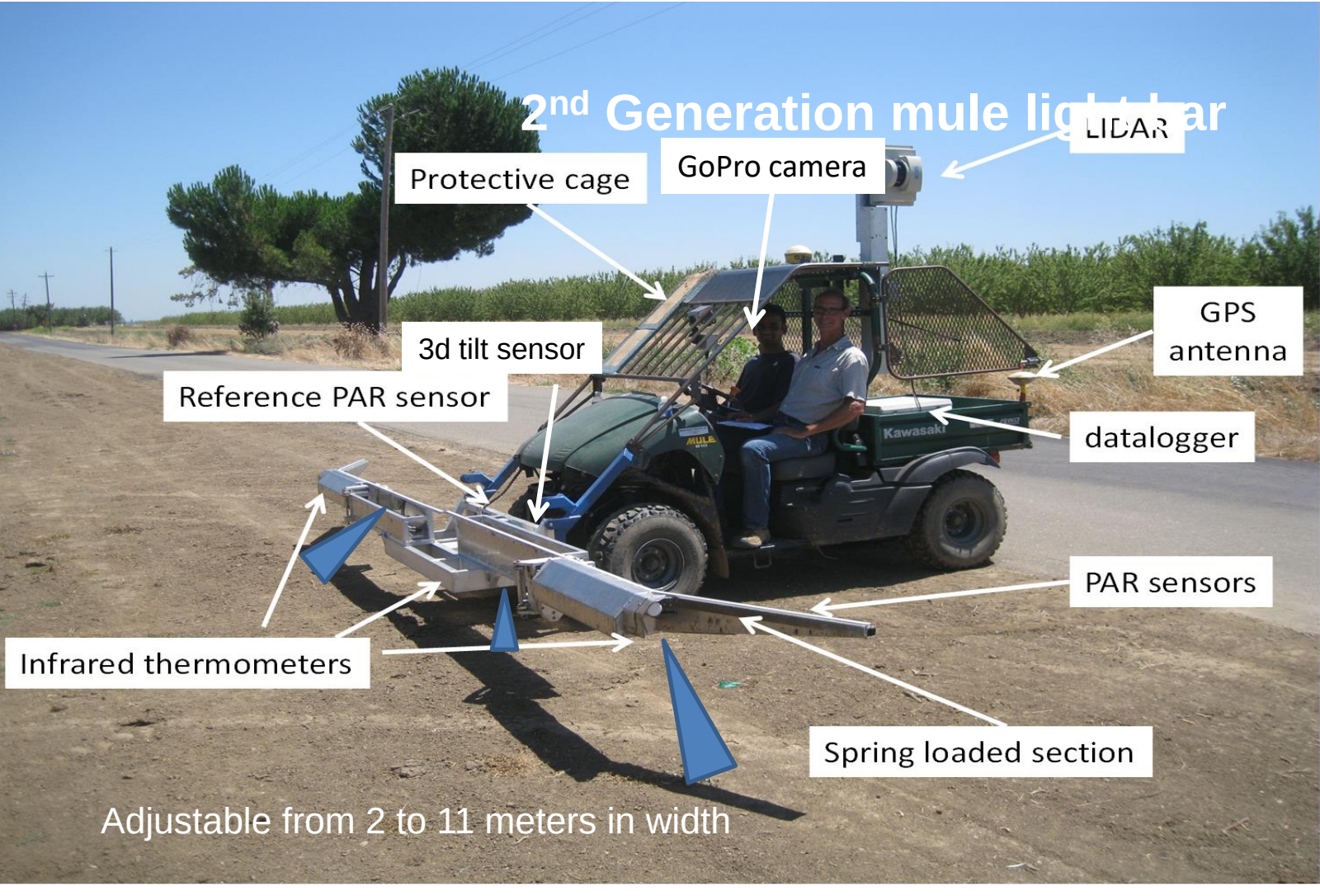
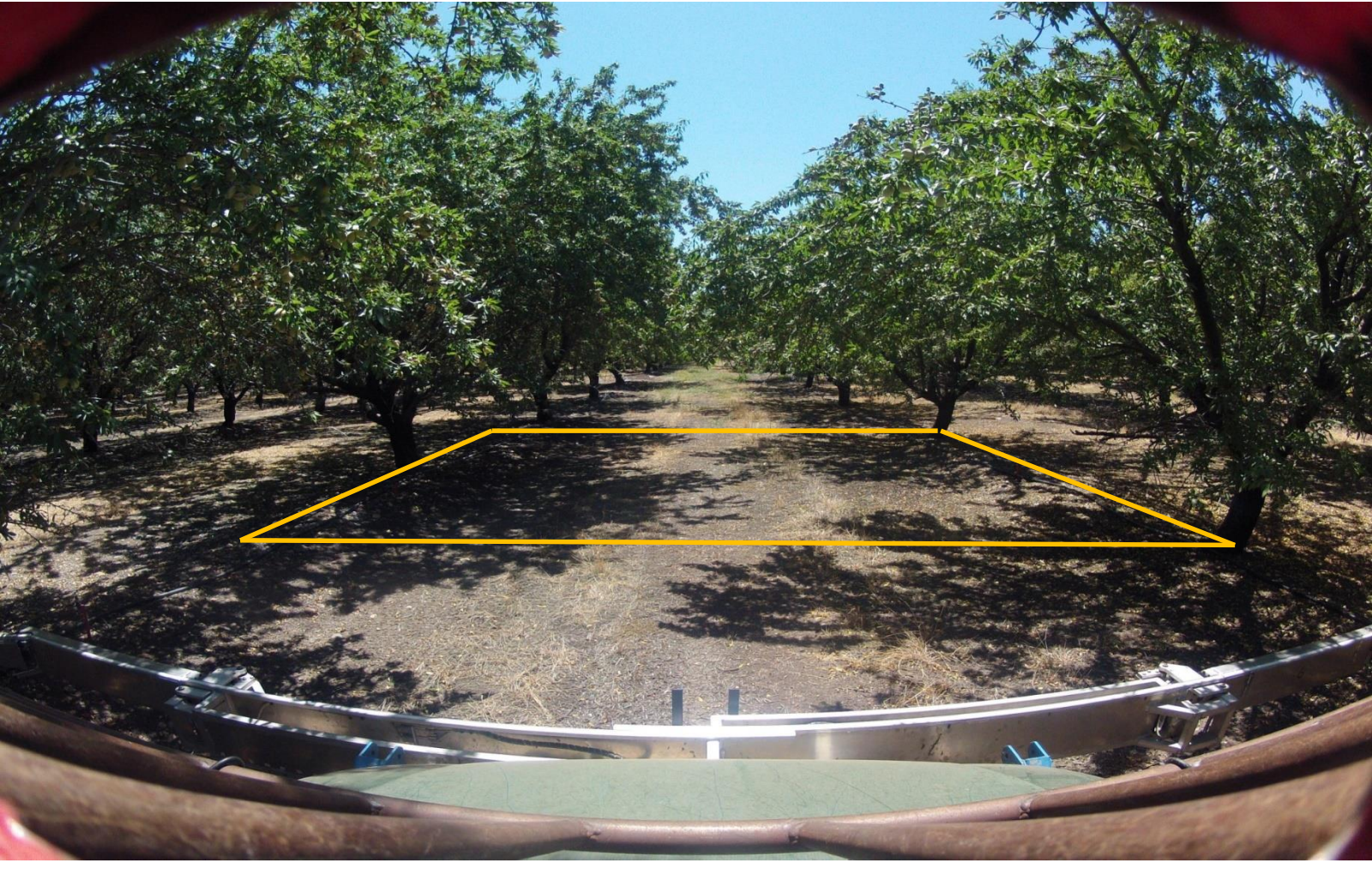
Best orchards- 4000+ kernel pounds per acre

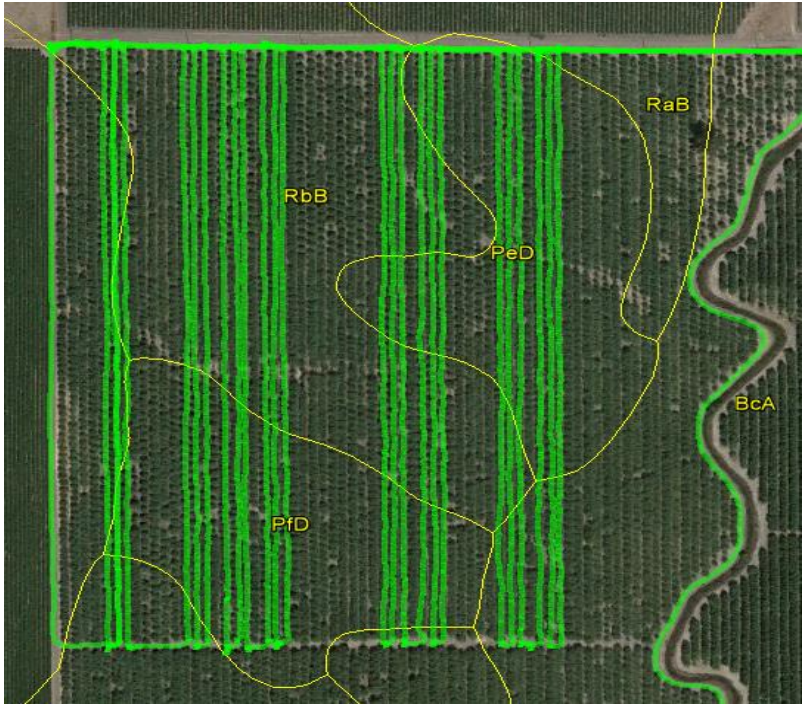

491

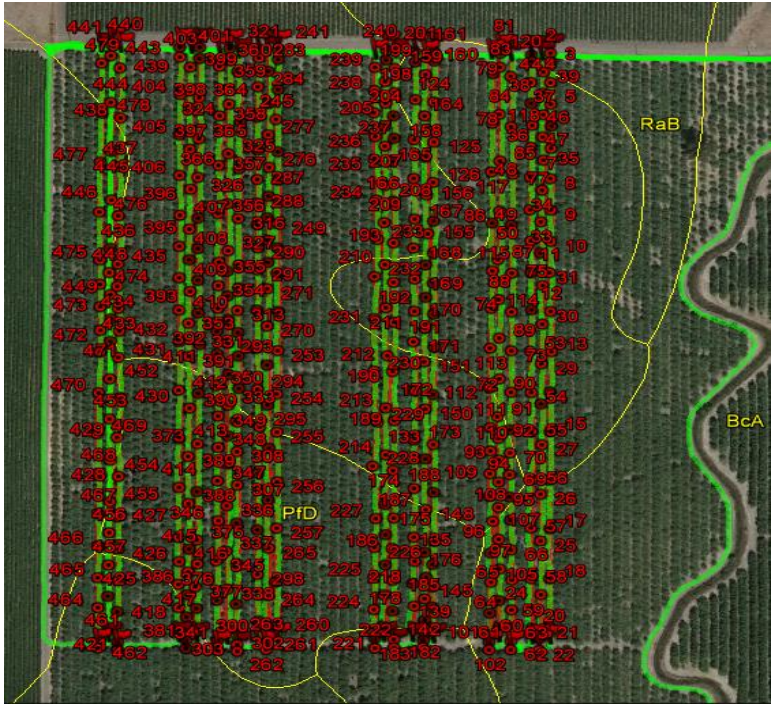

2nd Generation mule light lidar
LIDAR
Protective cage
GoPro camera
GPS antenna
3d tilt sensor
Reference PAR sensor
datalogger
PAR sensors
Infrared thermometers
Spring loaded section
Adjustable from 2 to 11 meters in width



We set up a portable weather station with temp, RH, windspeed and PAR sensors outside orchard

Normal speed of travel is about 7 mph so we can map about 14 miles within 1 hour of the time the sun is directly overhead


RaB
RbB
PeD
BcA
PfD

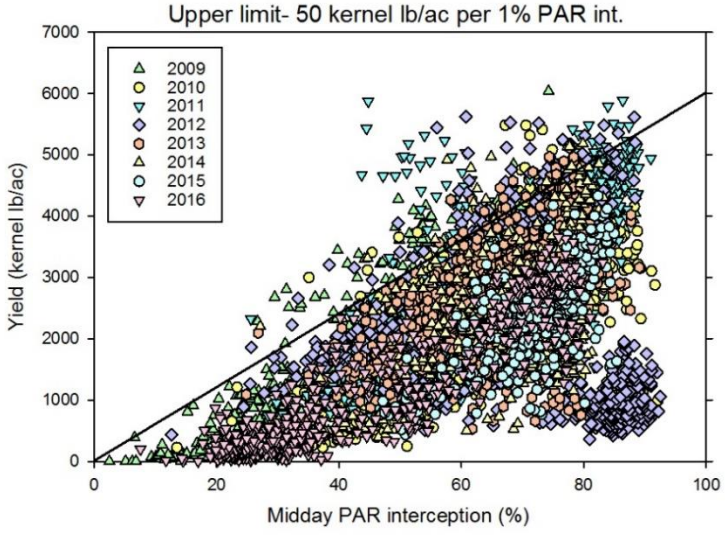

RaB
BcA
PfD

Self contained hydraulic system for operating augers, autosampler and elevator

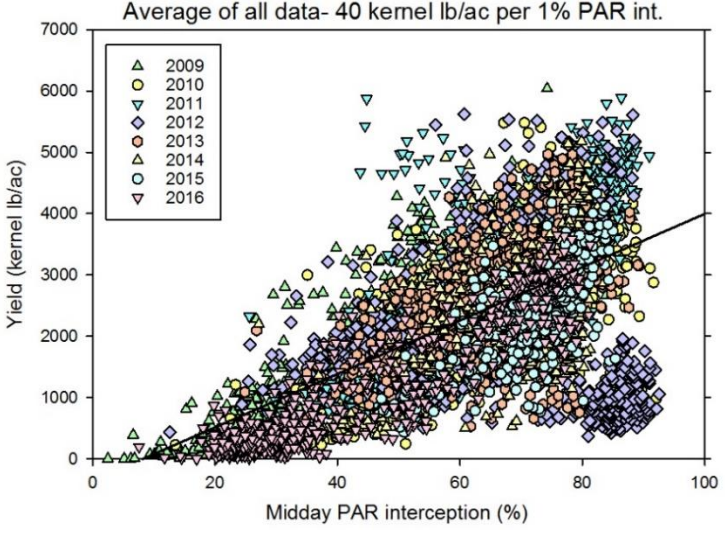
Trimble GPS acts as datalogger to collect continuous yield data

Front skirt to prevent nuts from overflowing as cart fills

Wireless controller for hydraulically operated auto sampler

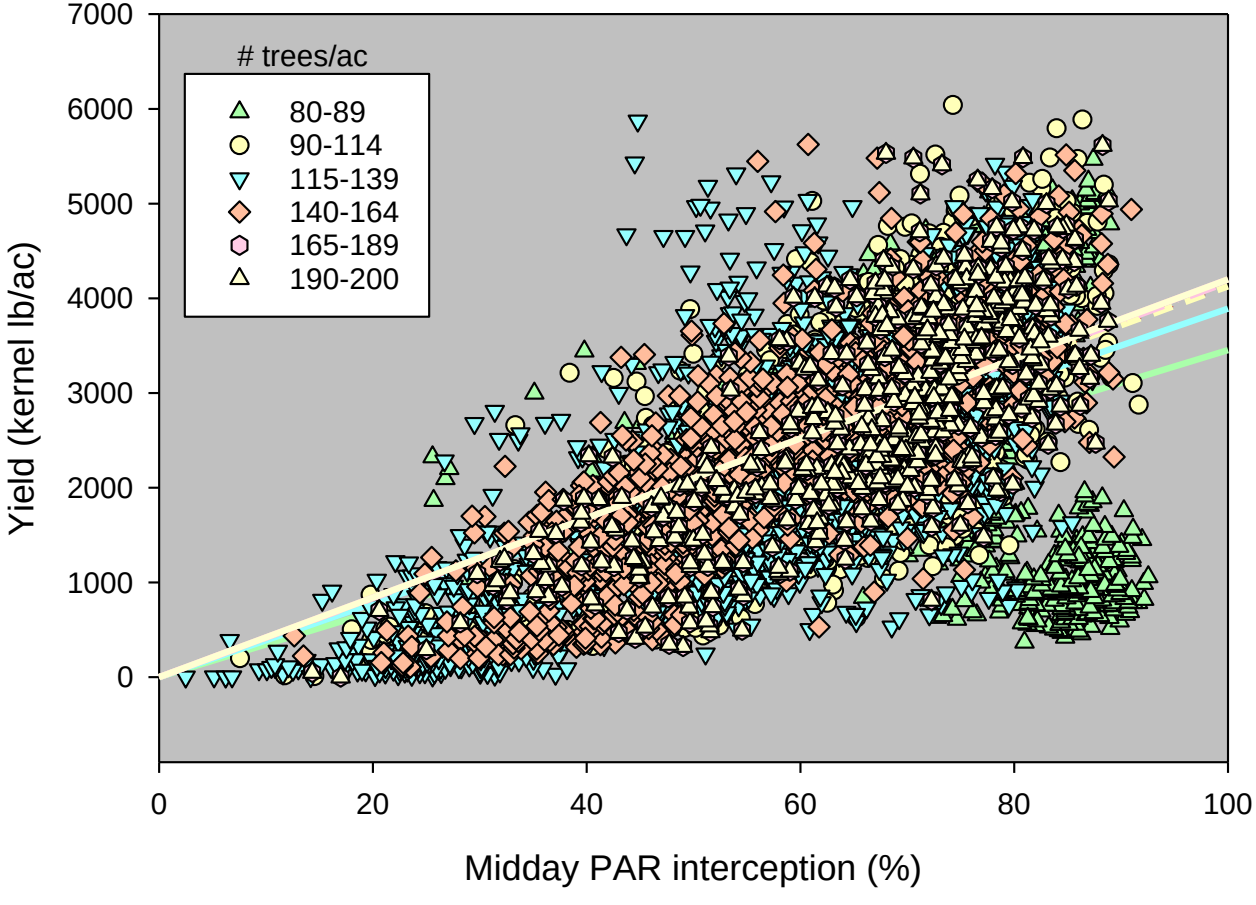


We have found the best managed orchards (but very few) can alternate around this line (50 kernel lbs/1% intercepted) after about 5 years of age

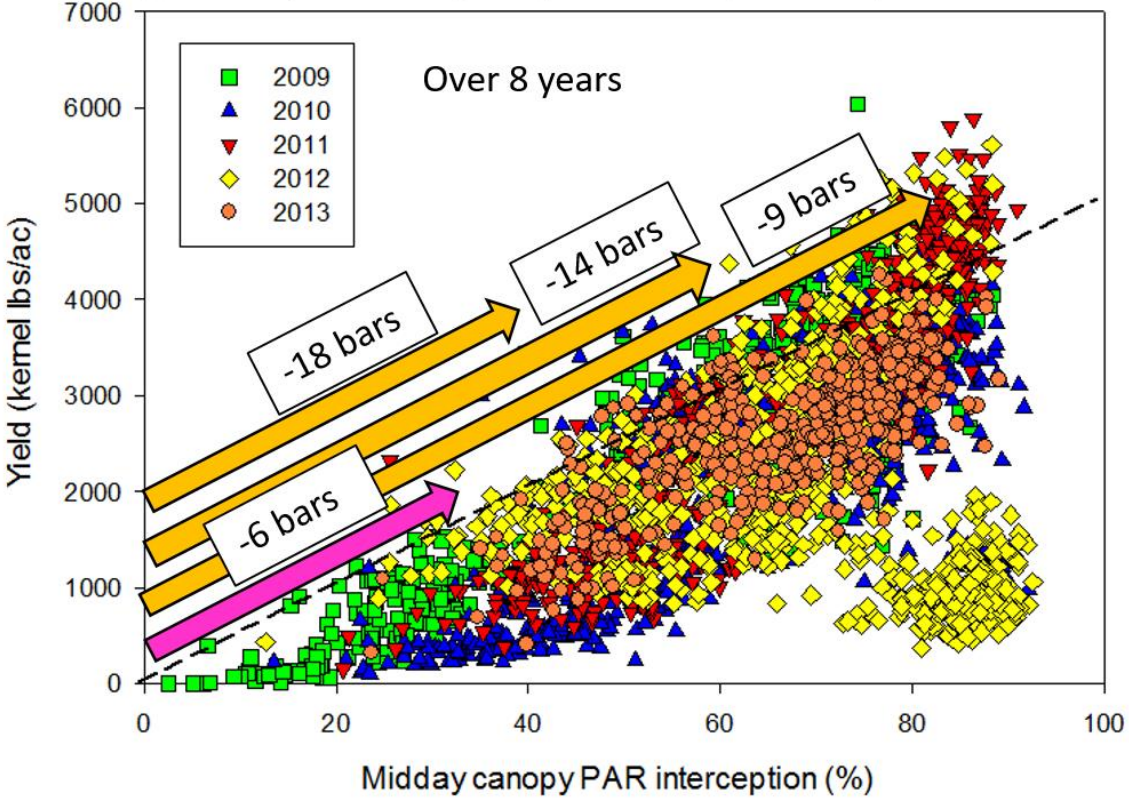


Regression through all data (40 kernel lbs/1% intercepted)

Broken up by number of trees per acre

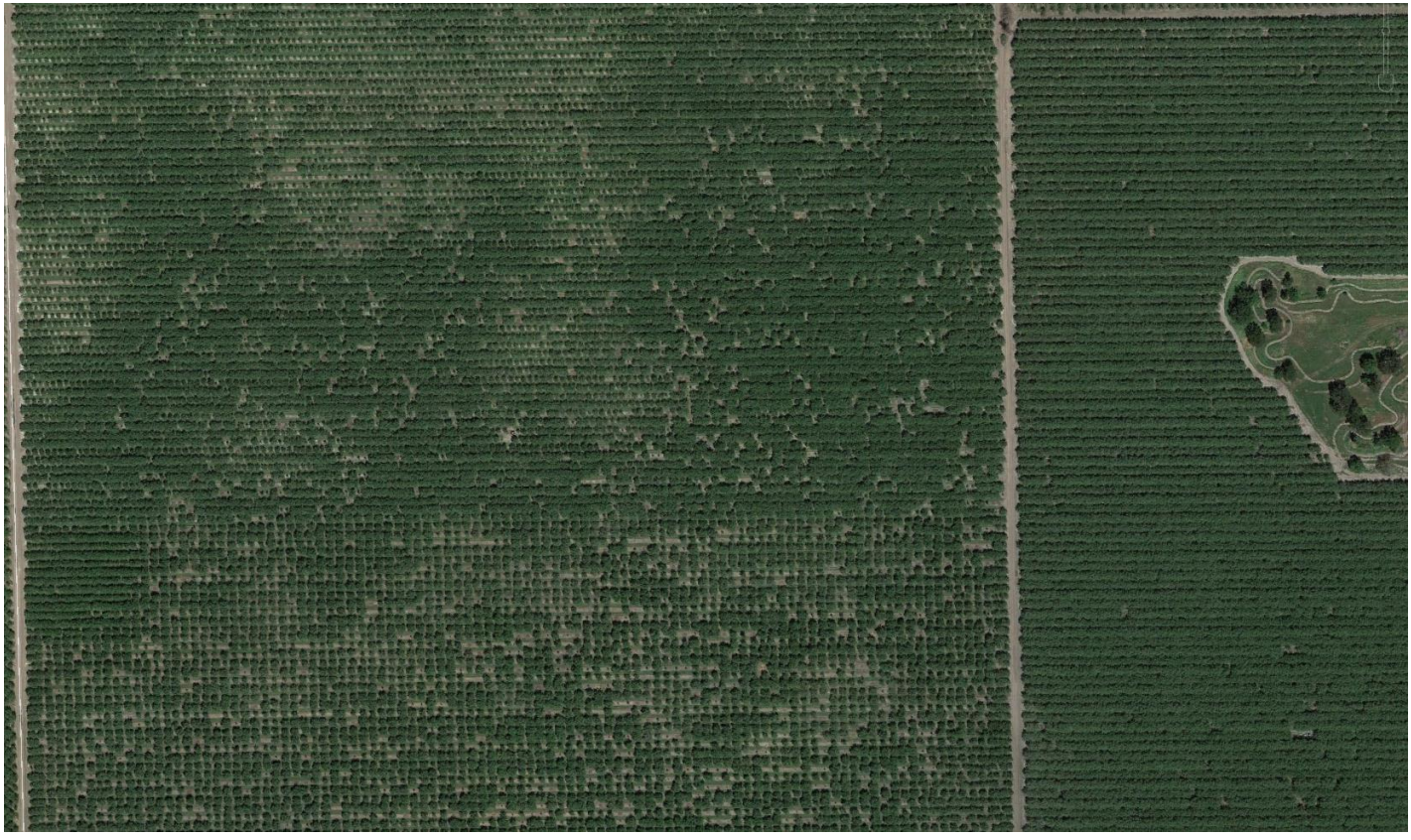


Tree growth, yield and quality can be impacted by wet as well as dry conditions



Only trees in -9 bar example would have much extension growth later in summer

Leaf expansion is dependent on previous year conditions as well as early season water status

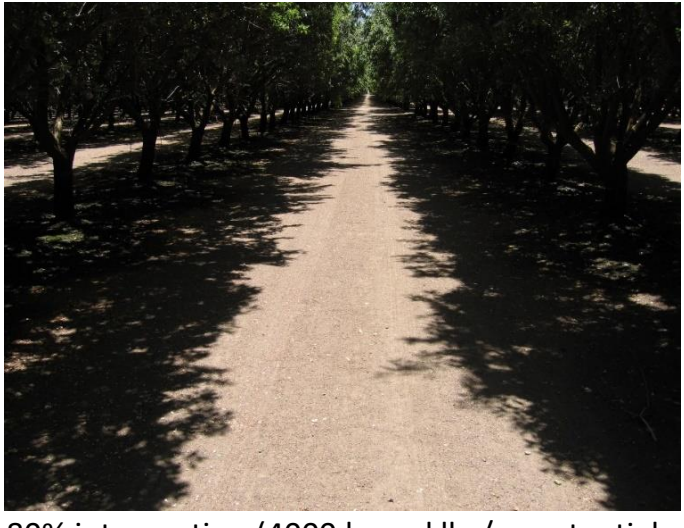


More variation in tree size when over-irrigating

- If you are meeting demand of largest trees, small ones suffer
- If you under irrigate slightly, larger trees grow more slowly and orchard becomes more uniform

39% interception (2000 kernel lbs/ac potential

50% interception (2500 kernel lbs/ac potential



80% interception (4000 kernel lbs/ac potential

90% interception (4500 kernel lbs/ac potential

39% interception (2000 kernel lbs/ac potential

50% interception (2500 kernel lbs/ac potential

80% interception (4000 kernel lbs/ac potential

90% interception (4500 kernel lbs/ac potential

What about super high density plantings on dwarfing rootstocks- can they be more productive?

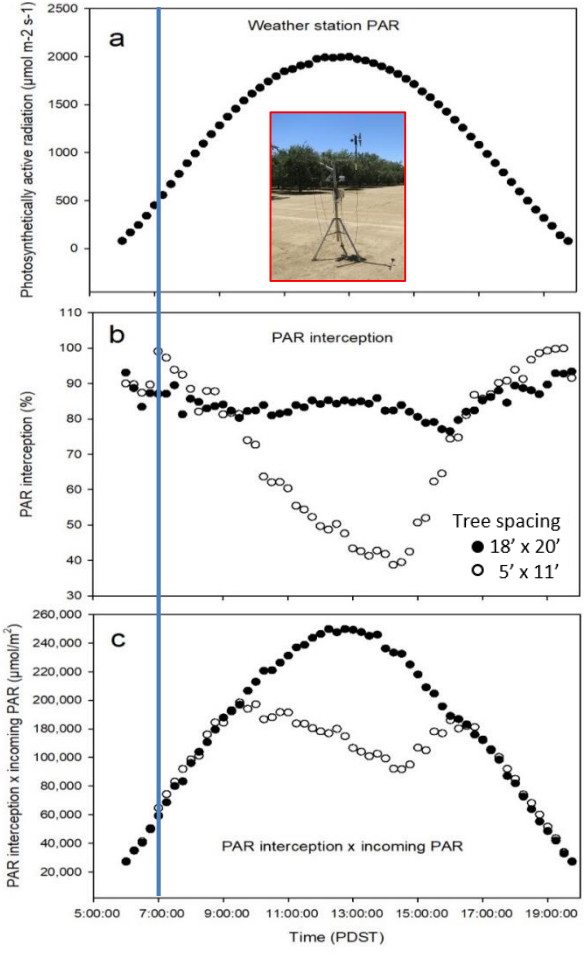
CROPS > TREE NUTS

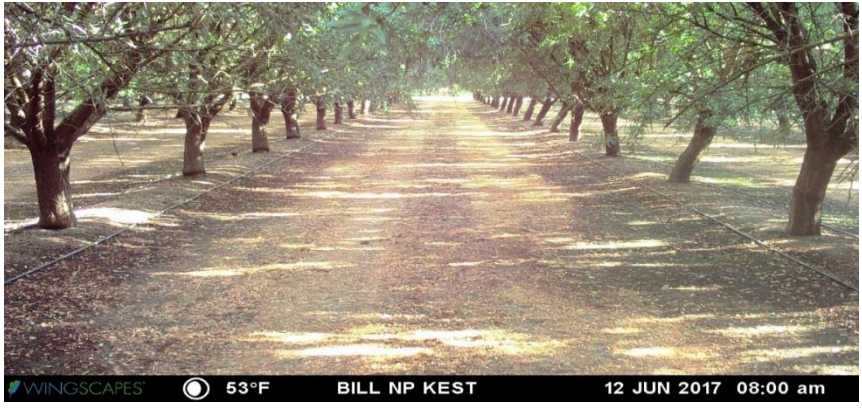
Grower trial: Super high density almond planting on dwarf rootstock holds promise

Almond trees blooming in orchard against blue, Spring sky.

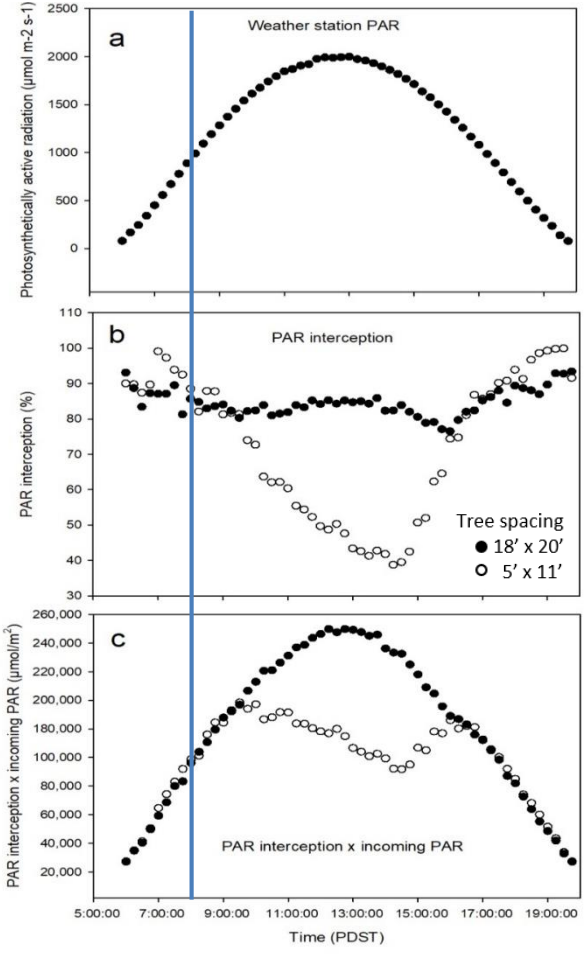
4’ x 12’
5’ x 11’

PAR = photosynthetically active radiation ($mmol^{-2}$ sec^{-1})




WINGSCAPES
53°F
BILL NP KEST
12 JUN 2017 08:00 am


WINGSCAPES
57°F
HIGHDENS ALM
12 JUN 2017 08:00 am


a
Weather station PAR
Photosynthetically active radiation (µmol m-2 s-1)
2500
2000
1500
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0
b
PAR interception
PAR interception (%)
110
100
90
80
70
60
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40
30
Tree spacing
18' x 20'
5' x 11'
c
PAR interception x incoming PAR
PAR interception x incoming PAR (µmol/m2)
260,000
240,000
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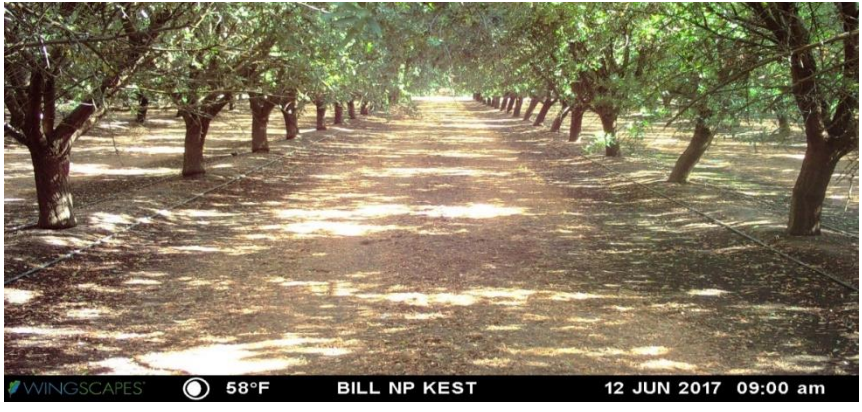
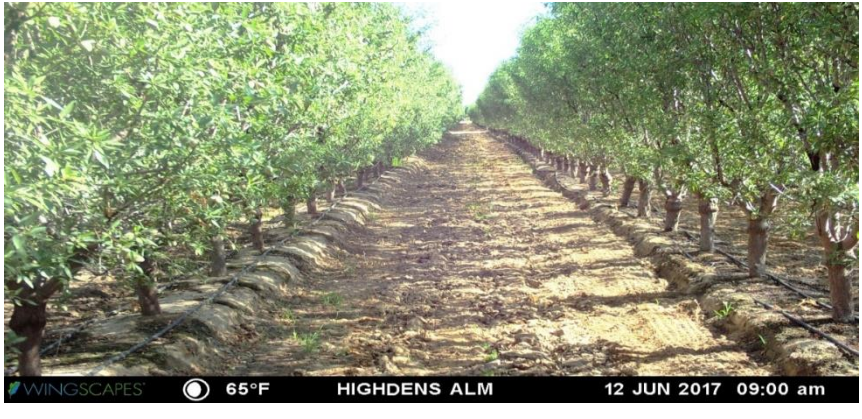
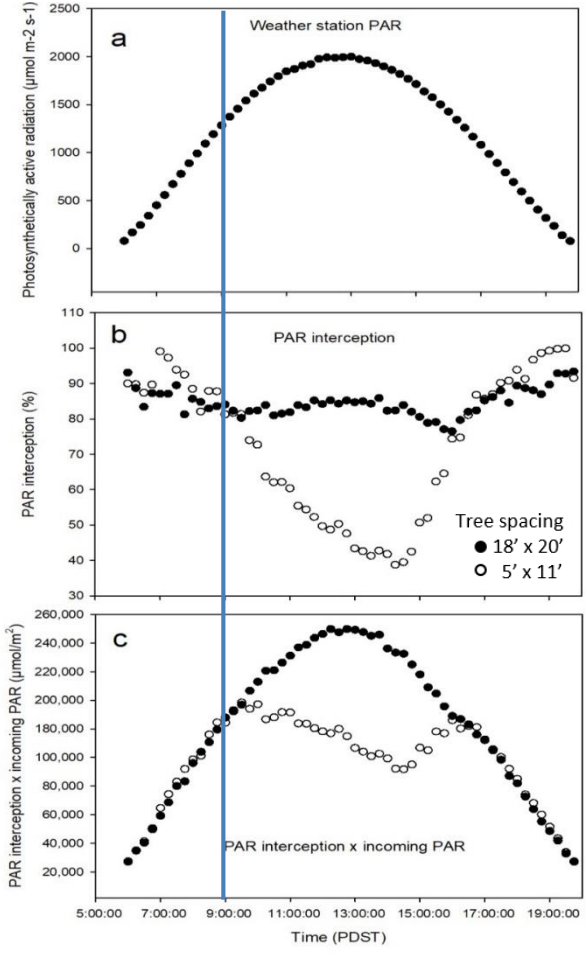
Time (PDST)


WINGSCAPES
58°F
BILL NP KEST
12 JUN 2017 09:00 am


WINGSCAPES
65°F
HIGHDENS ALM
12 JUN 2017 09:00 am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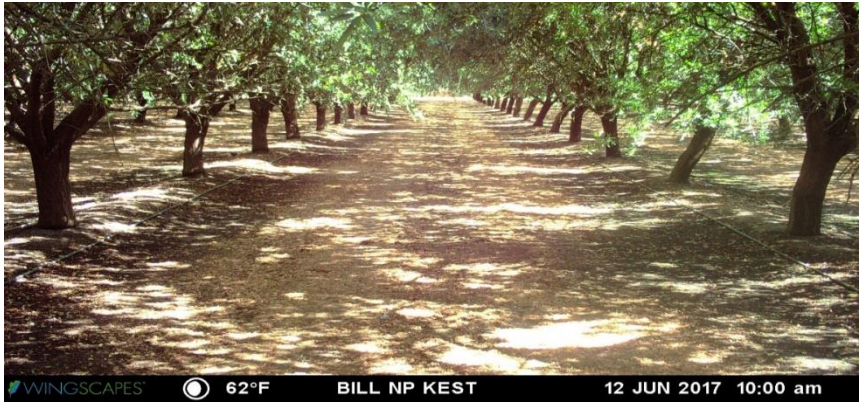
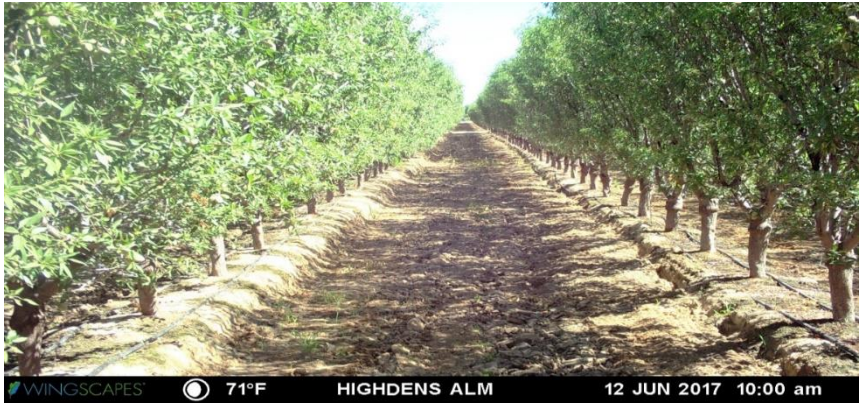

WINGSCAPES
62°F
BILL NP KEST
12 JUN 2017 10:00 am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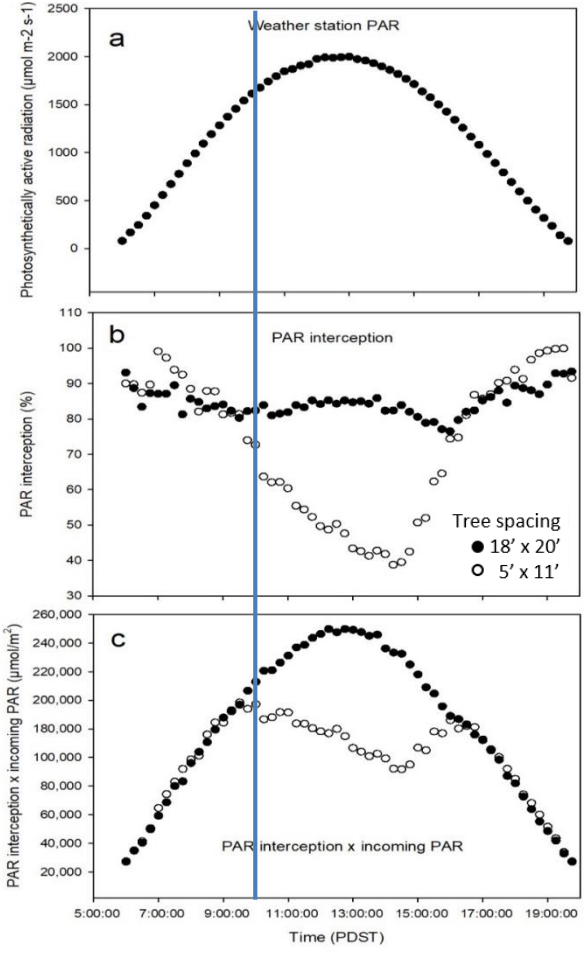
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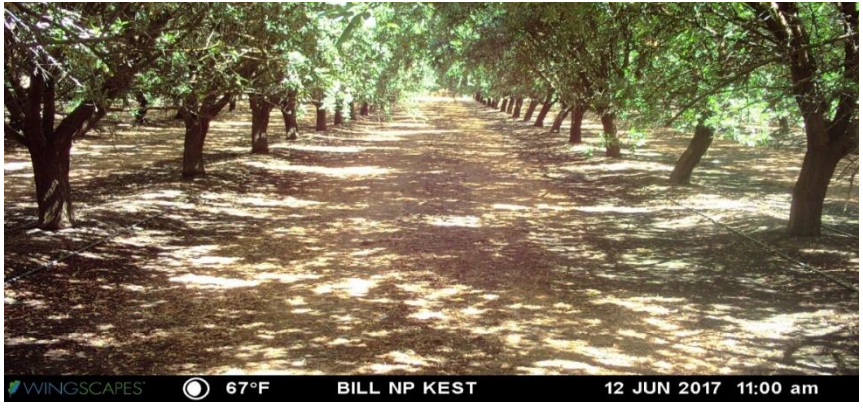
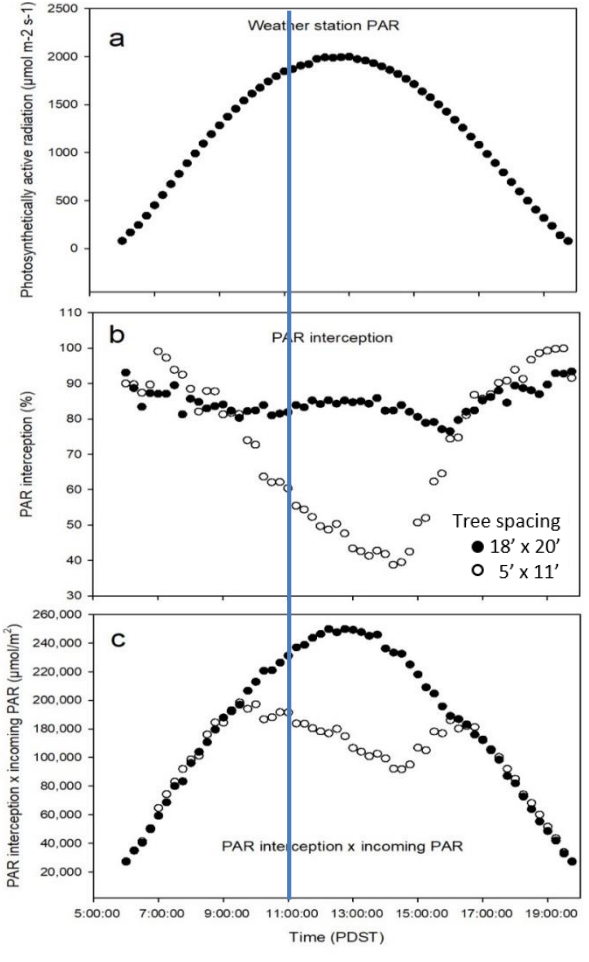

WINGSCAPES
67°F
BILL NP KEST
12 JUN 2017 11:00 am


WINGSCAPES
80°F
HIGHDENS ALM
12 JUN 2017 11:00 am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Time (PDST)


WINGSCAPES
69°F
BILL NP KEST
12 JUN 2017 12:00 pm


WINGSCAPES
89°F
HIGHDENS ALM
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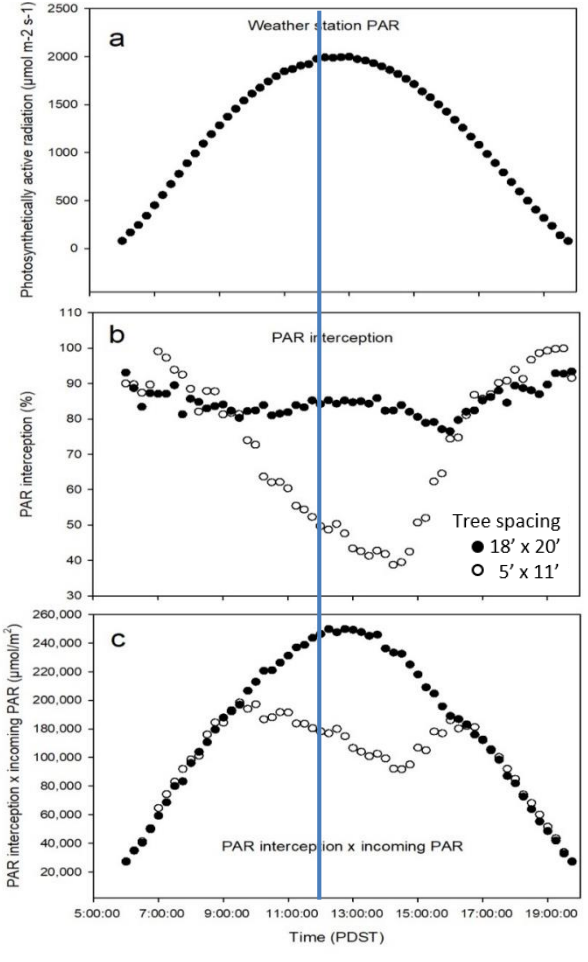
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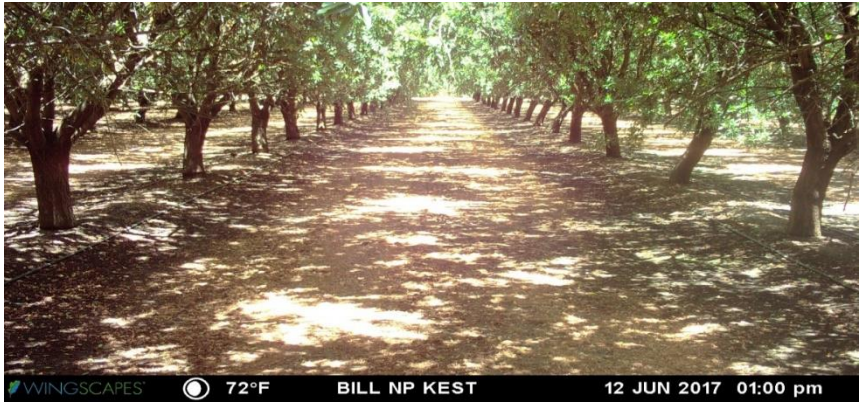
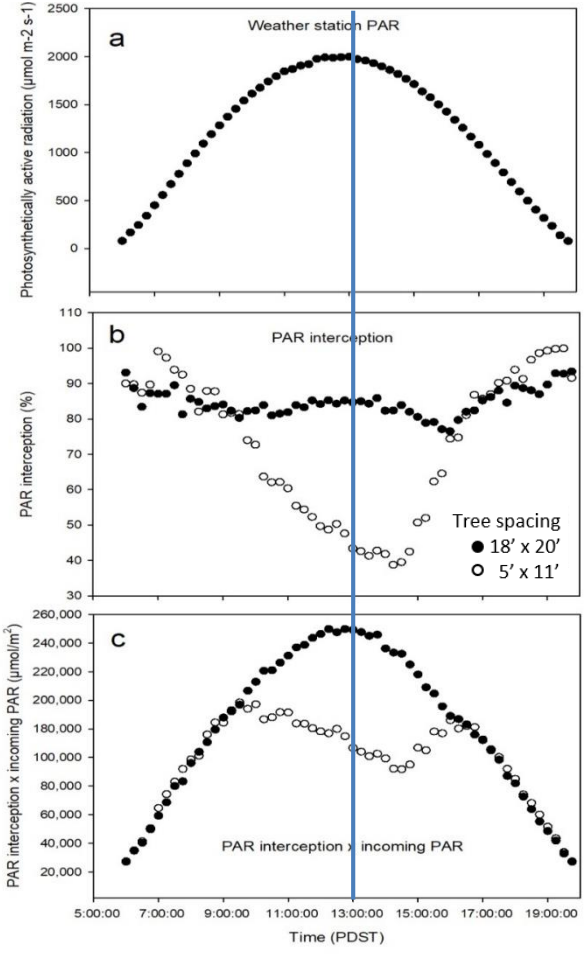

WINGSCAPES
72°F
BILL NP KEST
12 JUN 2017 01:00 pm


WINGSCAPES
93°F
HIGHDENS ALM
12 JUN 2017 01:00 pm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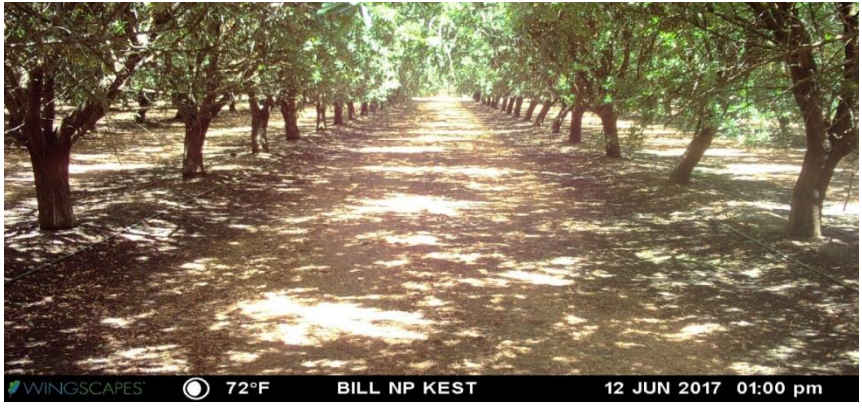
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12 JUN 2017 01:00 pm


WINGSCAPES
93°F
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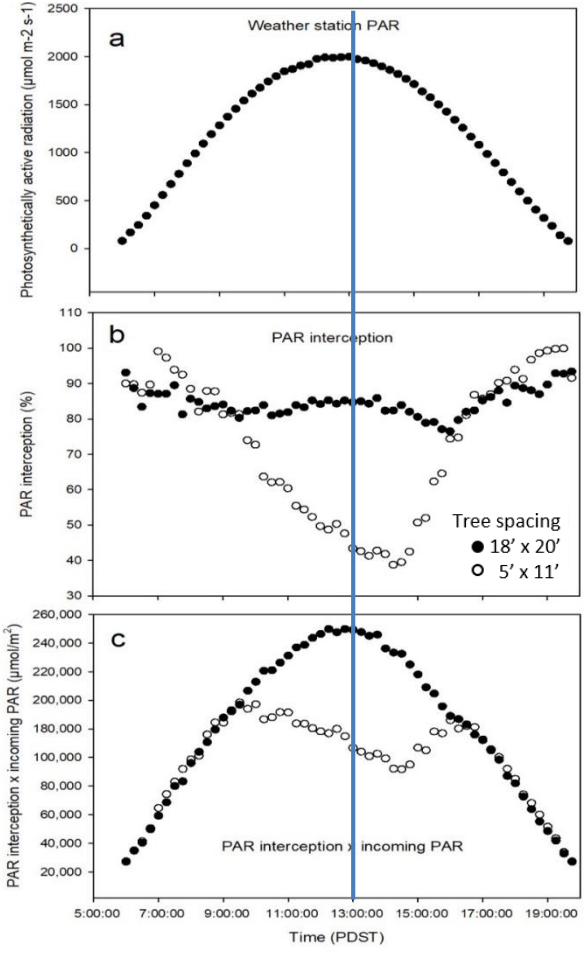
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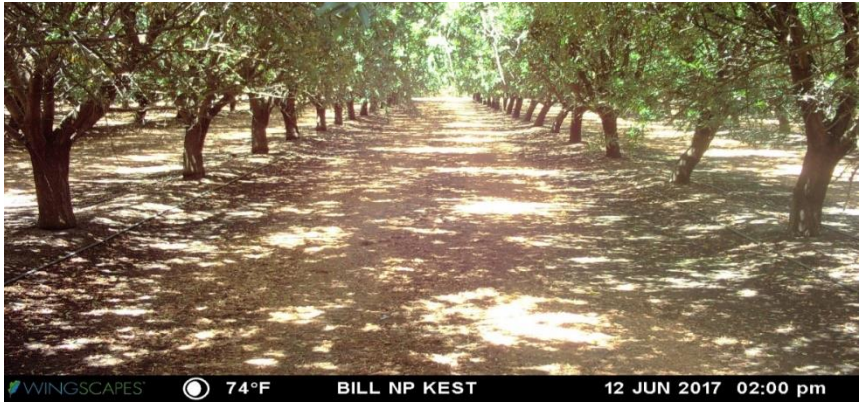
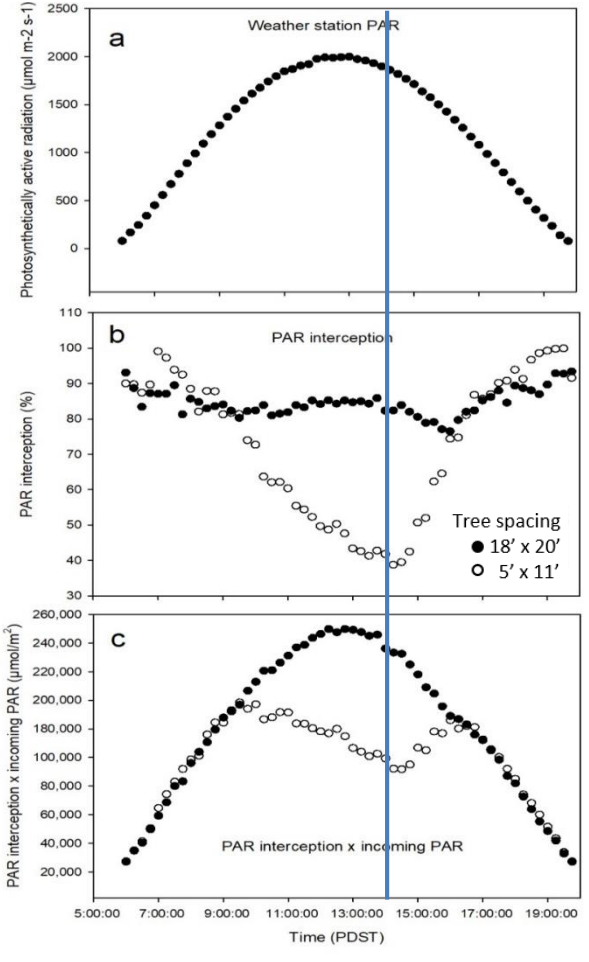

WINGSCAPES
74°F
BILL NP KEST
12 JUN 2017 02:00 pm


WINGSCAPES
96°F
HIGHDENS ALM
12 JUN 2017 02:00 pm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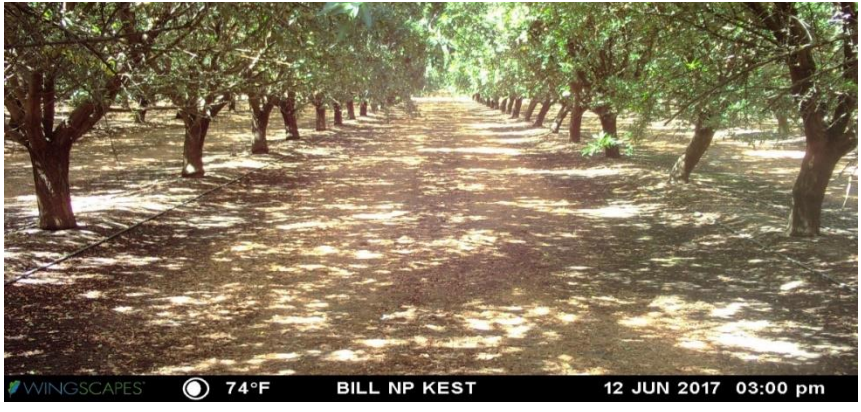
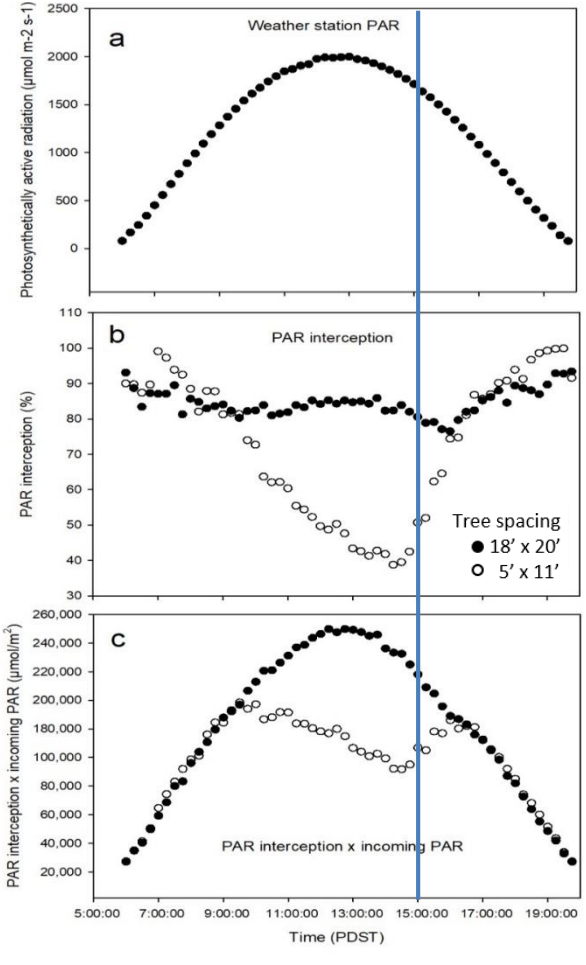

WINGSCAPES
74°F
BILL NP KEST
12 JUN 2017 03:00 pm


WINGSCAPES
95°F
HIGHDENS ALM
12 JUN 2017 03:00 pm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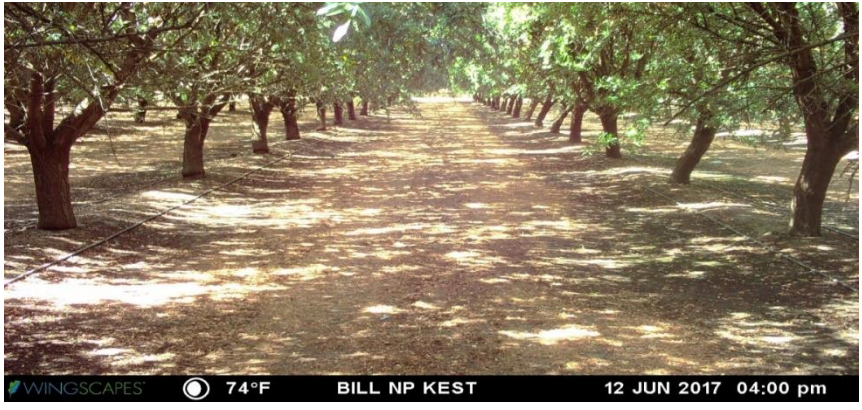
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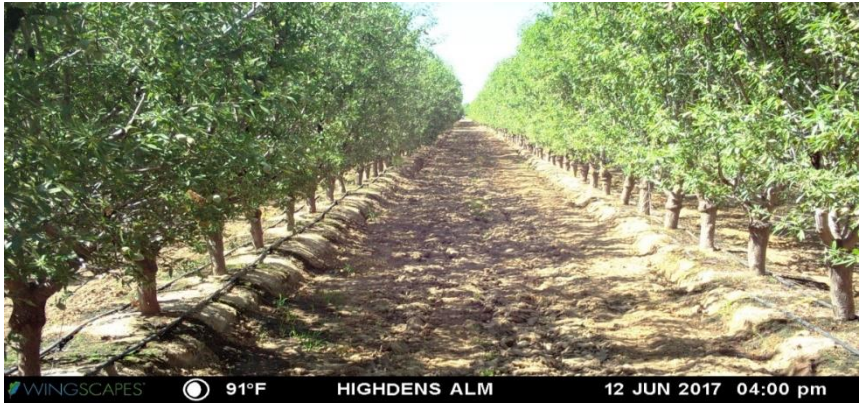
WINGSCAPES
91°F
HIGHDENS ALM
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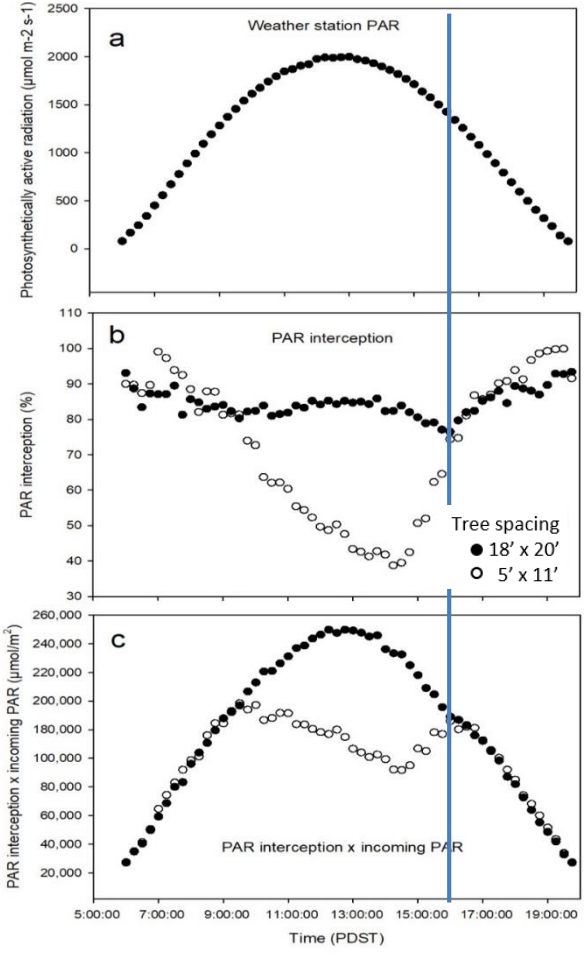
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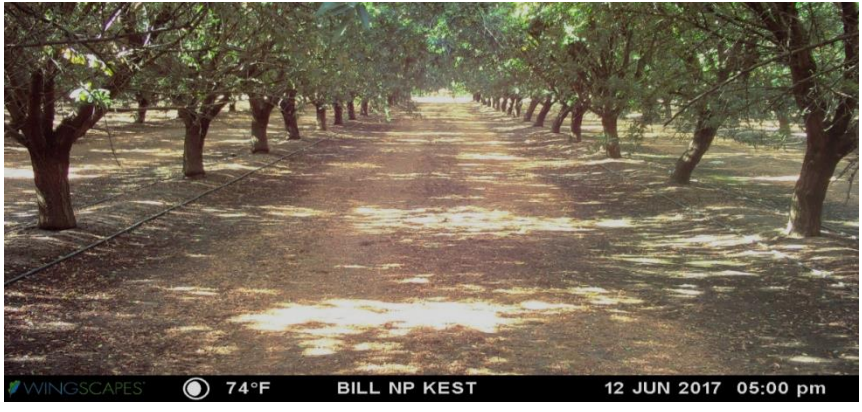
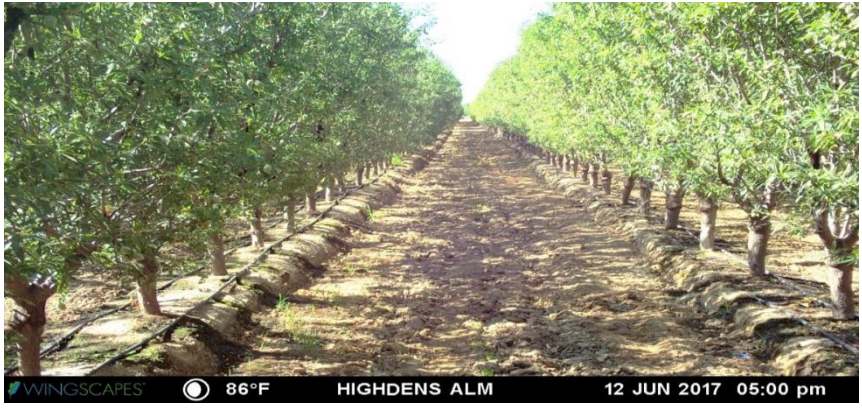
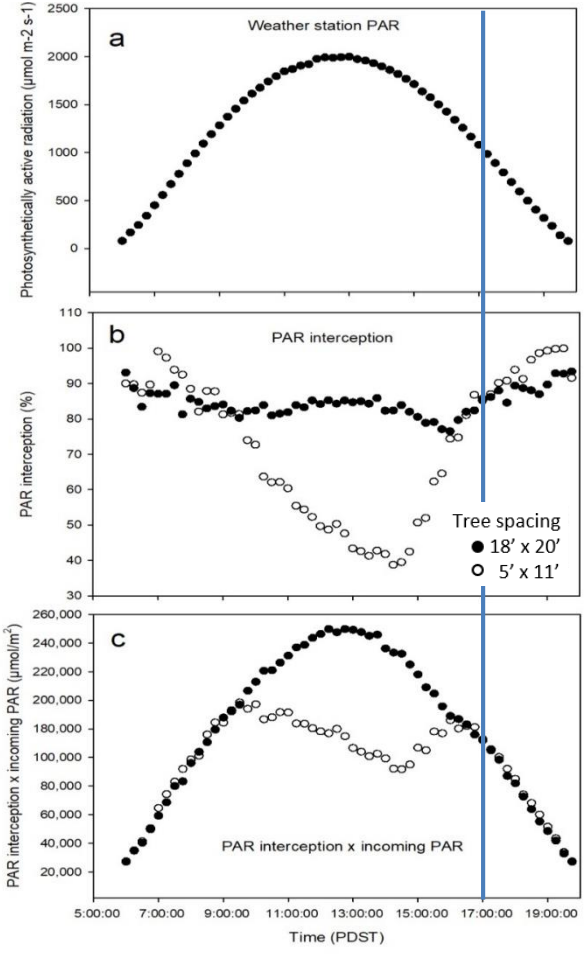
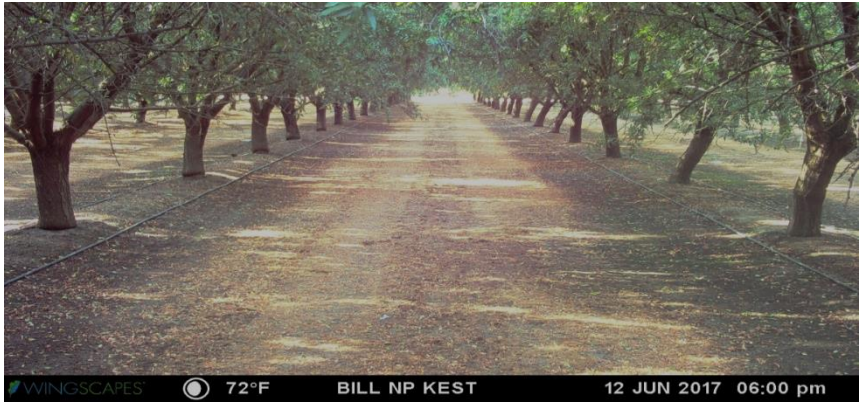
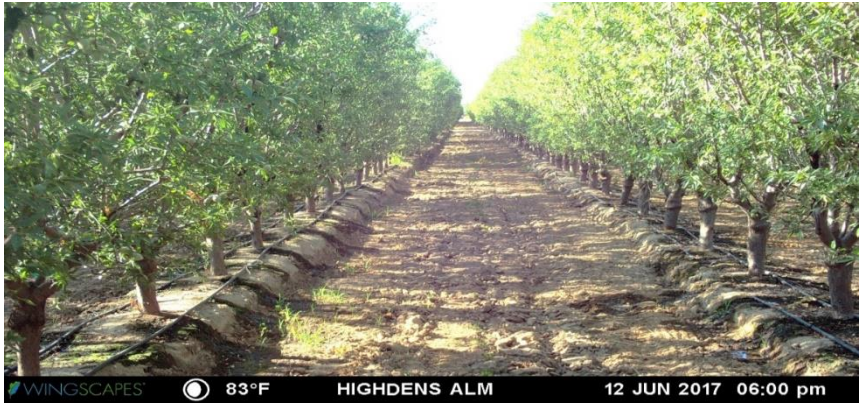
19:00:00
Time (PDST)

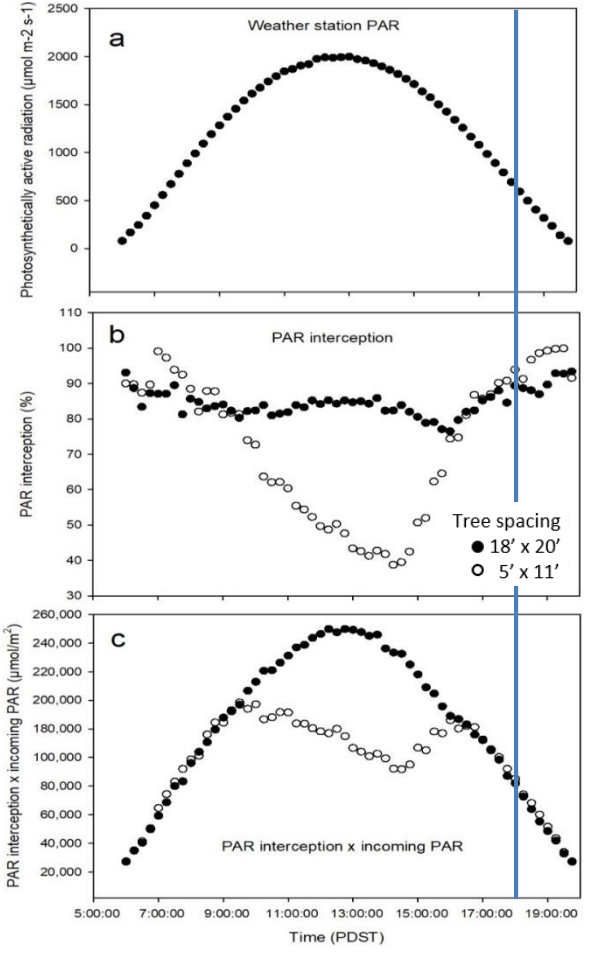

WINGSCAPES
74°F
BILL NP KEST
12 JUN 2017 05:00 pm

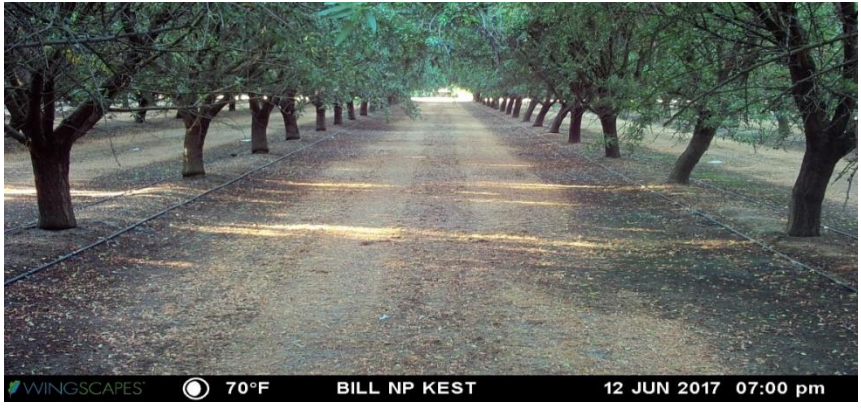

WINGSCAPES
86°F
HIGHDENS ALM
12 JUN 2017 05:00 pm


a
Weather station PAR
Photosynthetically active radiation (µmol m-2 s-1)
2500
2000
1500
1000
500
0
b
PAR interception
PAR interception (%)
110
100
90
80
70
60
50
40
30
Tree spacing
18' x 20'
5' x 11'
c
PAR interception x incoming PAR
PAR interception x incoming PAR (µmol/m2)
260,000
240,000
220,000
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
5:00:00
7:00:00
9:00:00
11:00:00
13:00:00
15:00:00
17:00:00
19:00:00
Time (PDST)

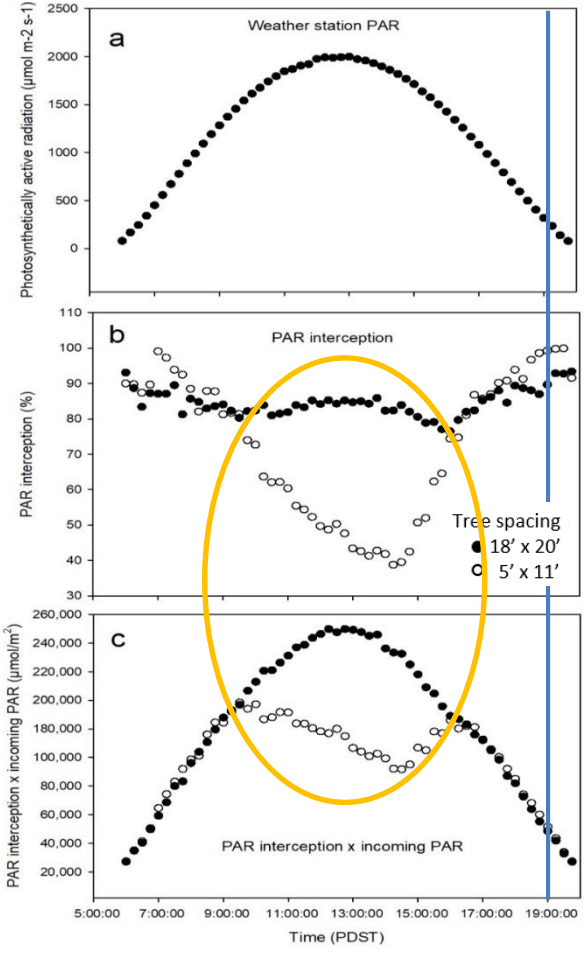

WINGSCAPES
72°F
BILL NP KEST
12 JUN 2017 06:00 pm


WINGSCAPES
83°F
HIGHDENS ALM
12 JUN 2017 06:00 pm


a
Weather station PAR
Photosynthetically active radiation (µmol m-2 s-1)
2500
2000
1500
1000
500
0
b
PAR interception
PAR interception (%)
110
100
90
80
70
60
50
40
30
Tree spacing
18' x 20'
5' x 11'
c
PAR interception x incoming PAR
PAR interception x incoming PAR (µmol/m2)
260,000
240,000
220,000
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
5:00:00
7:00:00
9:00:00
11:00:00
13:00:00
15:00:00
17:00:00
19:00:00
Time (PDST)


WINGSCAPES
70°F
BILL NP KEST
12 JUN 2017 07:00 pm


WINGSCAPES
77°F
HIGHDENS ALM
12 JUN 2017 07:00 pm


a
Weather station PAR
Photosynthetically active radiation (µmol m-2 s-1)
2500
2000
1500
1000
500
0
b
PAR interception
PAR interception (%)
110
100
90
80
70
60
50
40
30
Tree spacing
18' x 20'
5' x 11'
c
PAR interception x incoming PAR
PAR interception x incoming PAR (µmol/m2)
260,000
240,000
220,000
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
5:00:00
7:00:00
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15:00:00
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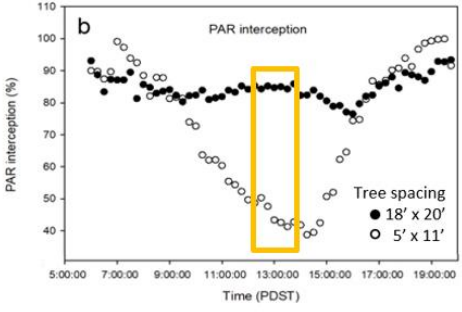
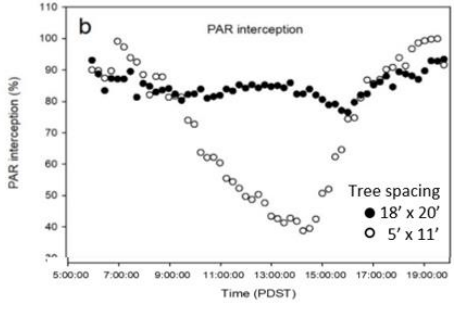
19:00:00
Time (PDST)

Midday



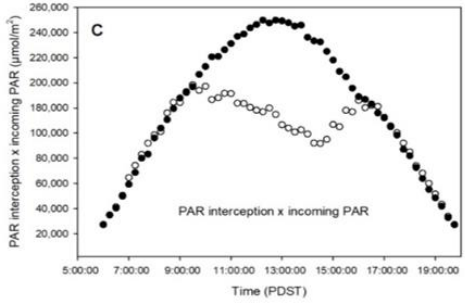
45%

Diurnal PAR



86%

Diurnal summed



76%

Yield potential based on midday PAR interception

Planting	Midday PAR int. (%)	Yield potential (kernel lb/ac)	Actual yield (kernel lb/acre)
5' x 11'	44	2200	1324
18' x 21'	83	4150	~3600

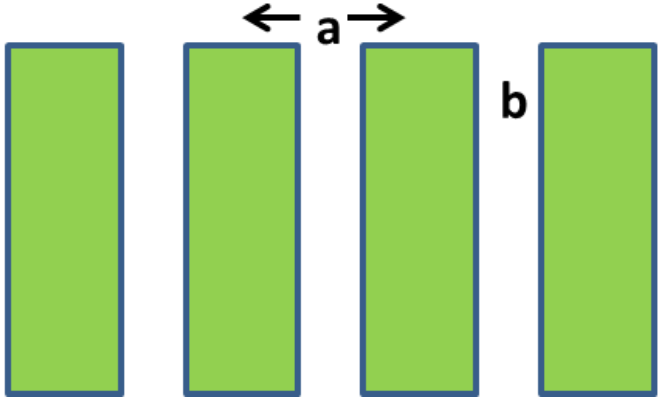
Actual yield- number is parenthesis is percent PAR (or estimate)

Orchard	3rd leaf (kernel lb/ac)	4th leaf (kernel lb/ac)	5th leaf (kernel lb/ac)
5’ x 11’	519 (24%?)	1324 (34%?)	? (44%)
18’ x 20’	1232 (39%)	2279 (48%)	4056 (83%)

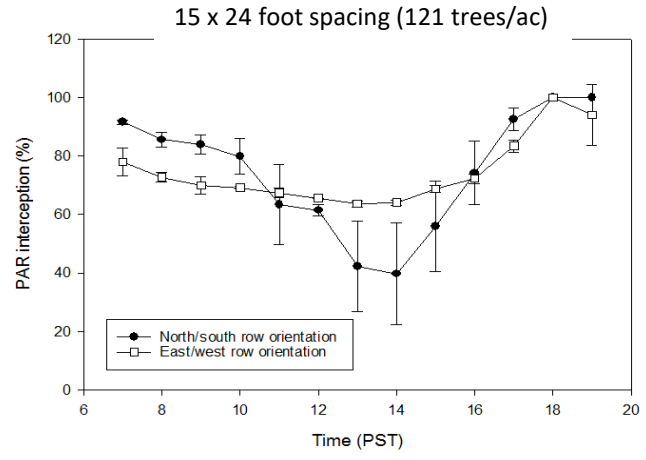
5’ x 11’

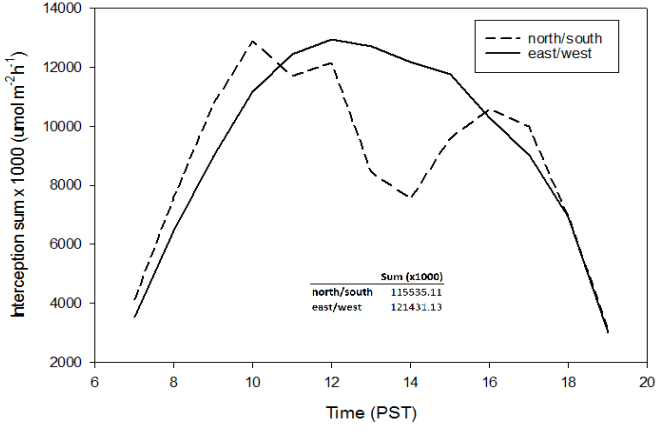
18’ x 20’

Row width (a)	Drive middle (b)	Potential PAR interception (%)	Yield potential (kernel lb/ac)	Increase
9 feet	6	33	1650	
15 feet	6	60	3000	
21 feet	6	71	3550	
9 feet	2	78	3900	+2250
15 feet	2	87	4350	+1350
21 feet	2	90	4500	+950



105% diurnal sum for east/west versus north/south





McFarland replicated variety trial planted in 2004

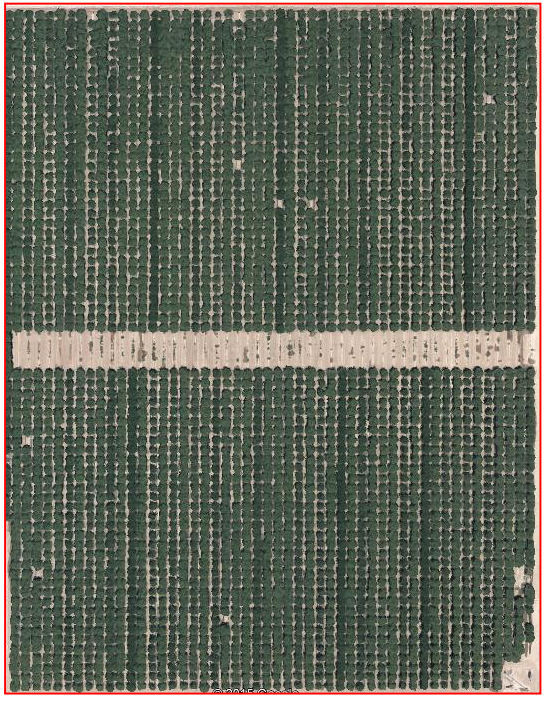
- Grower site near McFarland in Kern County
- Class 1 McFarland loam/Wasco Sandy loam
- 18’ x 20’ spacing (121 trees/acre)
- Irrigated with double line drip
- Replicated six times (approximately 35 trees/rep)

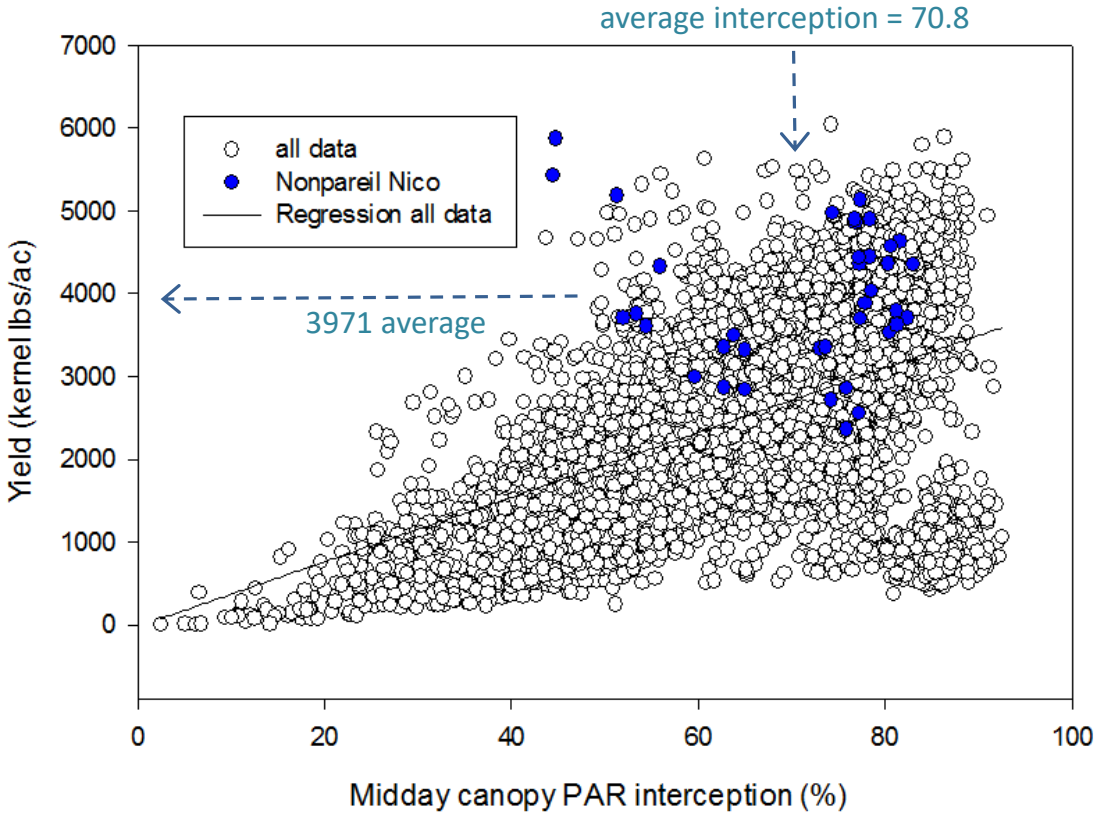
7 pollenizers

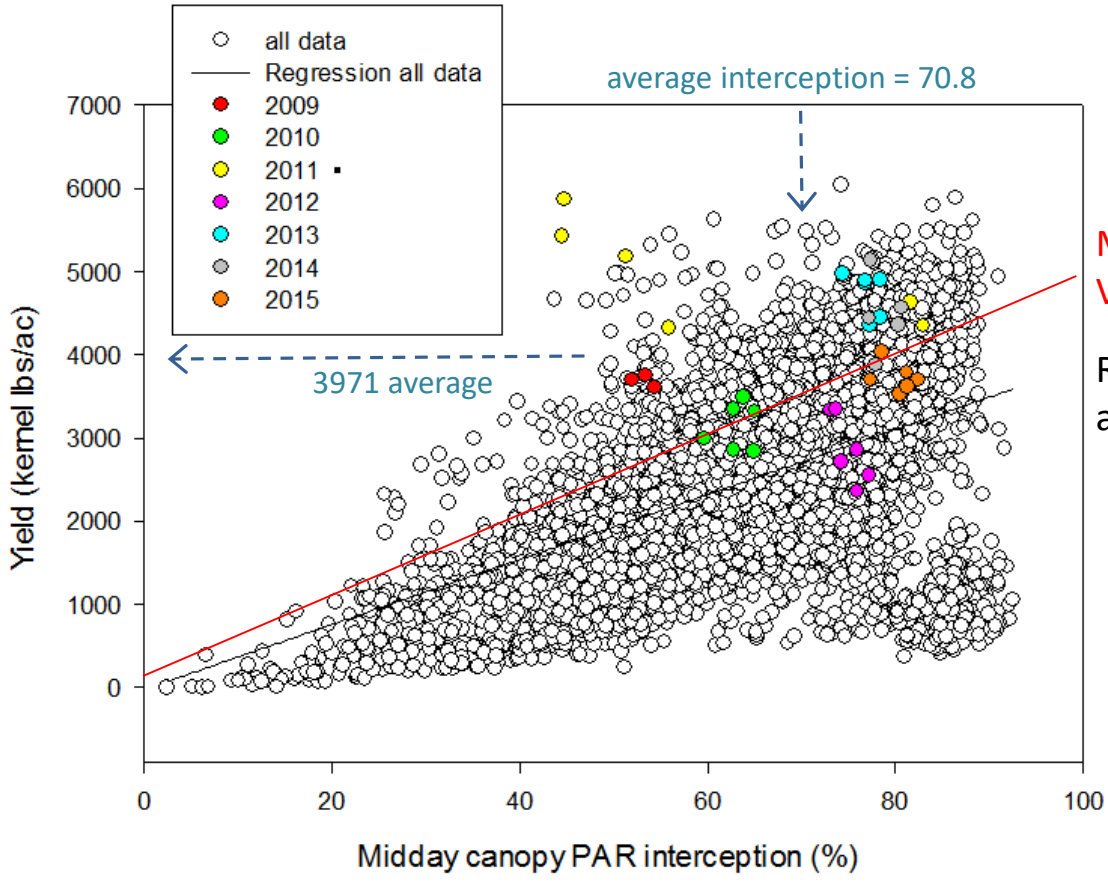
Chips
Kahl
Kester (2-19e)
Kochi
Marcona
Sweetheart
Winters

8 Nonpareil Clones

Nonpareil- 38270
Nonpareil- 5
Nonpareil- 6
Nonpareil- 7
Nonpareil- Driver
Nonpareil- Jones
Nonpareil-Newell
Nonpareil- Nico

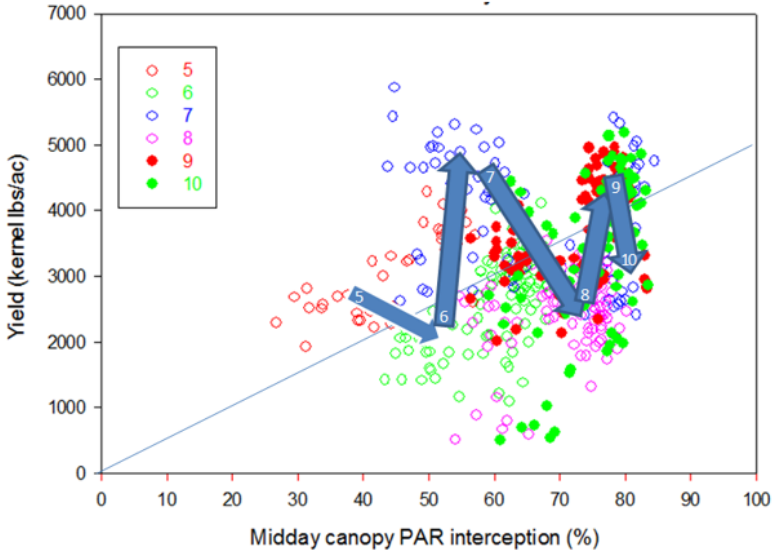



average interception = 70.8
all data
Nonpareil Nico
Regression all data
3971 average
Yield (kernel lbs/ac)
7000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
Midday canopy PAR interception (%)



McFarland Variety trial

Regresion for all sites



Blue line indicates values around which best orchards can alternate

Fig. 2. Midday canopy photosynthetically active radiation interception (PAR) versus yield by year at the McFarland Variety Trial. Arrows indicate direction of average yield from year to year and numbers on arrows indicate orchard age.

McFarland replicated variety trial- ranked by cumulative yield to 12 years

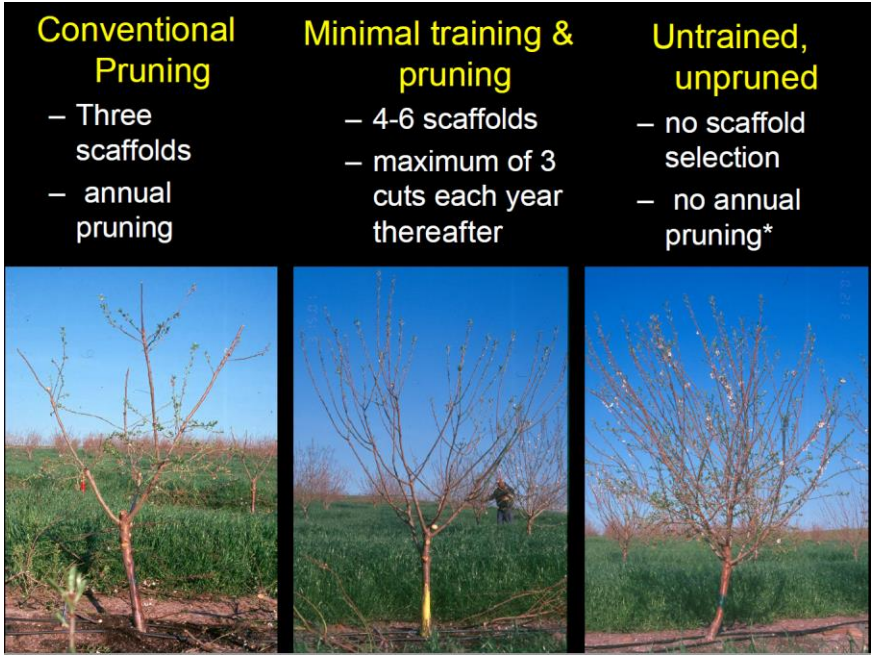
2015 Variety	No. of nuts/tree	Average kernel wt (g)	Shelling percentage	Kernel pounds per unit PAR int.	Kernel pounds per Tree	Kernel pounds per Acre	Cumulative kernel yield (lbs/acre)
Nonpareil-Nico	12982 abc	1.07 bc	68.6 ab	46.5 ab	30.8 ab	3728 ab	35046 a
Nonpareil-3-8-2-70	11502 de	1.10 b	71.3 a	41.8 bcd	27.9 bc	3383 bc	33870 ab
Nonpareil-Newell	12638 bcd	1.10 b	72.8 a	44.2 abcd	30.5 ab	3702 ab	33784 ab
Nonpareil-Driver	12664 bcd	1.07 bc	72.8 a	45.1 abc	29.9 ab	3623 ab	33447 bc
Nonpareil-7	14058 a	1.01 cd	73.9 a	46.1 ab	31.3 a	3797 a	33222 bcd
Nonpareil-5	11025 e	1.11 b	72.6 a	40.7 cde	26.9 c	3263 c	32560 bcd
Nonpareil-Jones	13579 ab	1.00 d	69.5 ab	45.1 abc	30.2 ab	3659 ab	32286 cd
Nonpareil-6	11439 de	1.06 bcd	71.0 a	40.0 cde	26.8 c	3246 c	32077 d
2-19e	7827 g	0.94 e	52.5 e	25.0 g	16.2 e	1965 e	29086 e
Winters	5464	1.06 bcd	62.1 cd	22.6 g	12.7 f	1542 f	26075 f
Chips	11843 cde	0.89 ef	57.4 d	37.2 ef	23.1 d	2806 d	25159 f
Kahl	13661 ab	0.84 f	58.4 d	47.9 a	25.4 cd	3081 cd	25127 f
Sweetheart	6953 g	0.86 f	64.9 bc	20.0	13.2 f	1607 f	23402 g
Kochi	9506 f	1.08 b	65.3 bc	35.8 f	22.7 d	2758 d	20404 h
Marcona	2798	1.27 a	26.2	13.2	7.7 g	943	17548 i

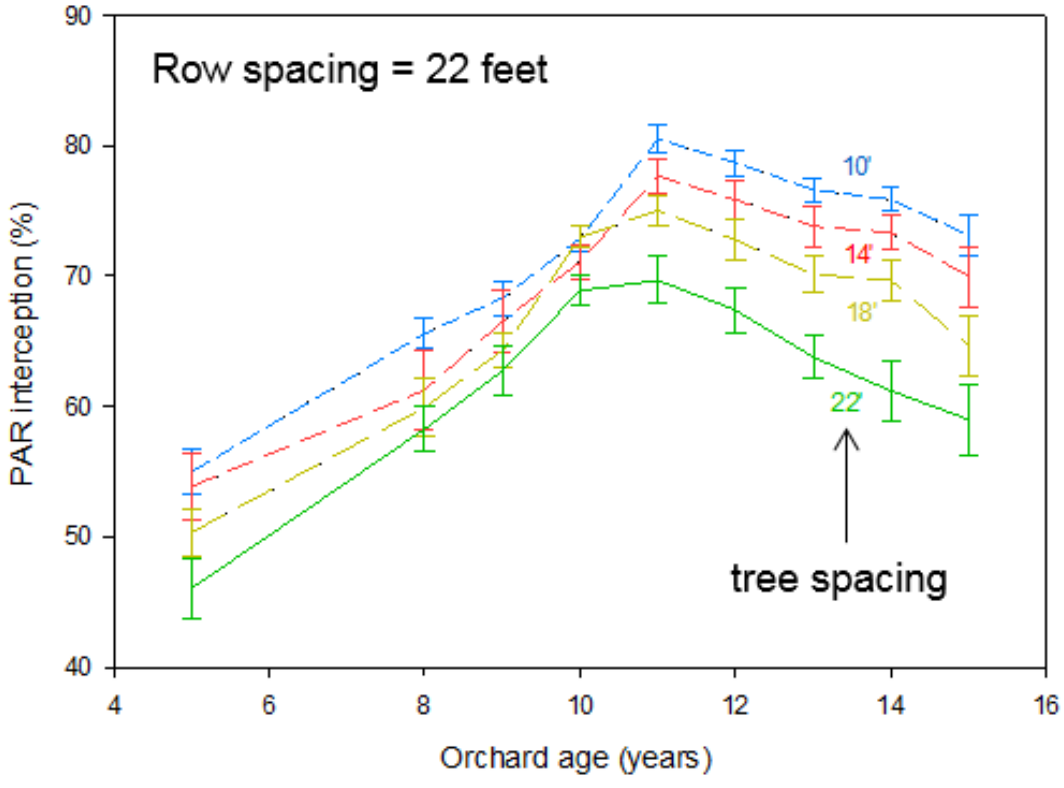
- Some separation among Nonpareil clones in terms of cumulative yield
- 2-19e (Kester) and Winters top yielding among pollenizers

How does pruning and spacing influence yield potential?

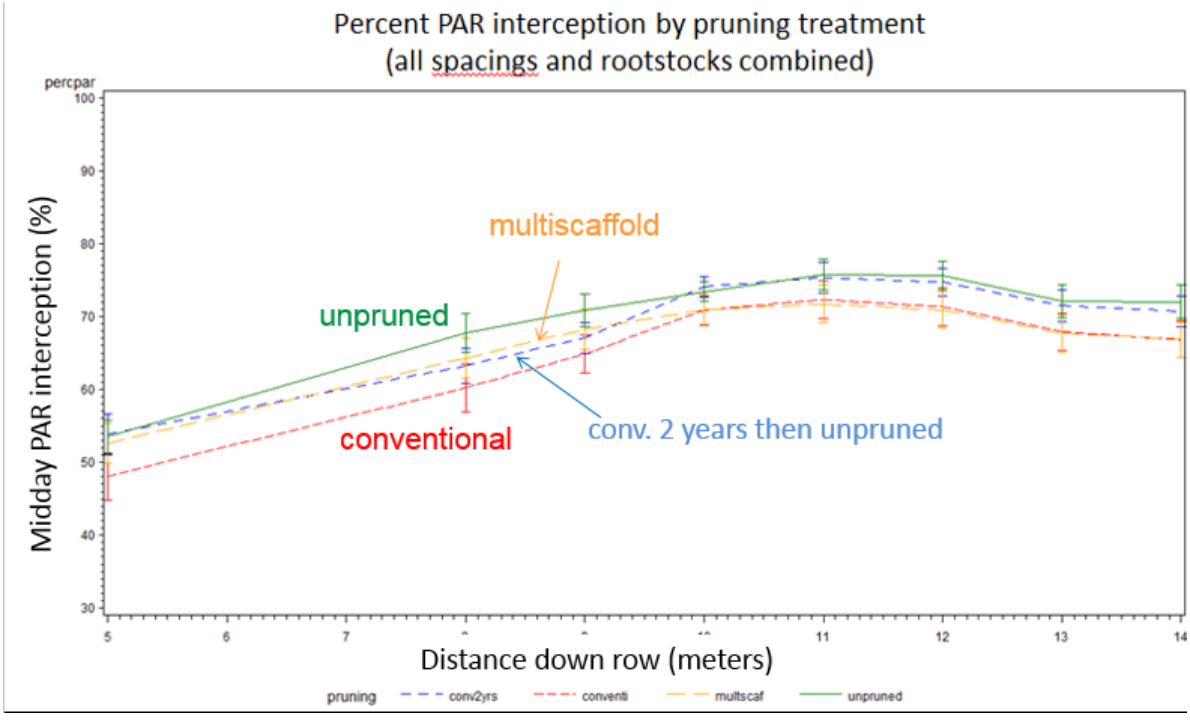
Stanislaus County Spacing/Pruning Trial (Duncan)

Planted fall, 1999
Four spacings (10’ x 22’, 14’ x 22’, 18’ x 22’, 22’ x 22’)
Four pruning strategies





The closer the in-row tree spacing, the higher the light interception
Light interception tended to peak at 11 years of age at all in row tree spacings



The unpruned treatment had the highest PAR interception

The Effects of Pruning on 2013 (14th Leaf) & Cumulative Yield

	Nonpareil		Carmel	
	2013 Yield (lb / a)	Cumulative	2013 Yield (lb / a)	Cumulative
Training & Pruning				
Trained to 3 scaffolds; Annual, moderate pruning	3199 a	32,537	2195 a	27,815
Trained to 3 scaffolds; unpruned after 2nd year	3092 a	33,762	2232 a	29,767
Trained to multiple scaffolds; Three annual pruning cuts	3093 a	31,862	2340 a	29,420
No scaffold selection; no annual pruning	3236 a	33,625	2291 a	31,127

Conclusions Stanislaus pruning/spacing trial

- Pruning has not increased yield
- Conventional annual pruning has reduced annual yield most years and also reduced cumulative yield
- Unpruned Carmel trees have grossed $4,150 more per acre than conventionally trained and pruned trees
  - Increased yield
  - Decreased pruning costs

Conclusions Stanislaus pruning/spacing trial

- Trees trained to more than 3 scaffolds are prone to scaffold breakage and needed to be tied
- Scaffold selection is less important in closely planted trees
  - Trees stay smaller so there is less weight on each scaffold
  - May not need to limb shake later in life
- Slightly more hull rot in unpruned trees but no difference in other diseases
- No difference in stick tights

Common wisdom on why almonds need to be pruned

- Manage light distribution through canopy

  Pruning exacerbates these problems
  leading to early and increased interior shading

- Rejuvenate canopy to maintain productivity

  No evidence this is the case- no benefit over 21 years

- Decrease disease susceptibility

  Uncertain- if this is the case it has not been enough to improve productivity

- Manage alternate bearing

  No data to support this

- Maintain tree size

  Can do this but comes at the expense of productivity

Why should you prune?

- Allow equipment access
- Minimize hazards to tractor drivers
- Reduce disease incidence ? (Alternaria, hull rot, rust, etc.)
- Allow sunlight to reach orchard floor to improve drying
- Remove dead or diseased limbs

Bottom line- There are reasons to prune but increasing yield is not likely one of them

Original Nickels pruning trial (Edstrom)

Variety	# of years of cumulative yield data	Conventional annual pruning	Unpruned trees
Nonpareil	21	34,176	35,082

Second generation Nickels pruning trial (Edstrom)

Nonpareil	13	31,985	33,852
Monterey	13	33,830	38,511
Carmel	13	33,575	29,935
Aldrich	13	34,167	31,454
Sum	**13**	**133,557**	**133,752**

Kern County Pruning Trial (Viveros)

Nonpareil	8	19,245	21,536
Carmel	8	21,698	23,577
Monterey	8	20,841	21,843
Sum	**8**	**61,784**	**66,956**

Stanislaus County Pruning Rootstock Spacing (Duncan)

Nonpareil	13	33,119	35,166
Carmel	13	33,771	35,767
Sum	**13**	**66,890**	**70,933**

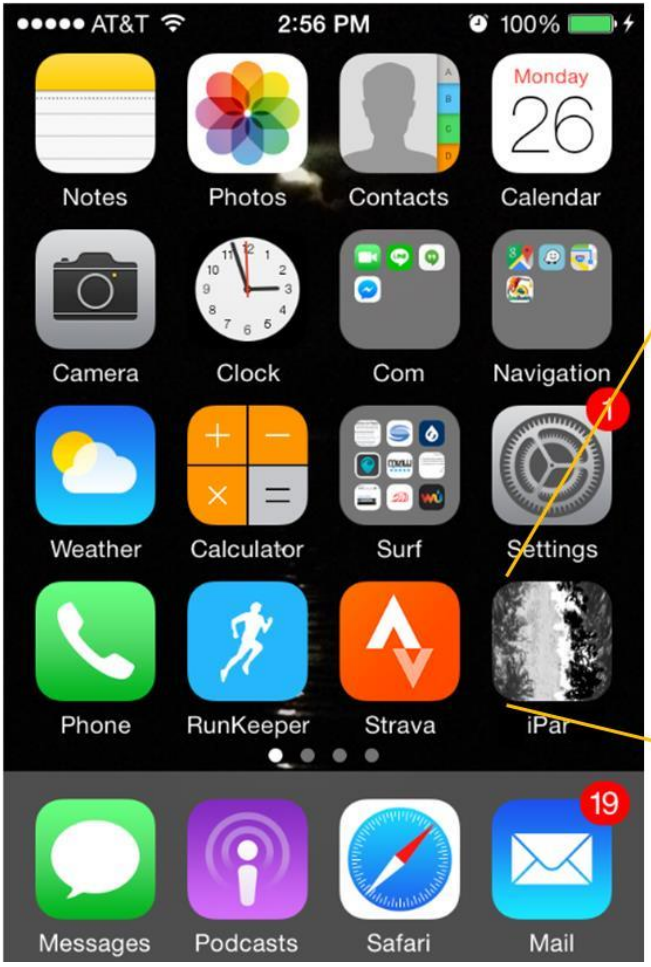
Conclusions

- Most productive almond orchards in our studies
  - 50 kernel lb/ac for each 1 percent of incoming light intercepted
  - Average of all orchards in the study is about 40
- Across the range of planting densities in our studies (80-202 trees per acre) at maturity there do not appear to be any clear density related differences in production potential for a given level of light interception
- There is some indication that higher density plantings than those in our study may potentially be able to intercept more PAR over the course of the day for a given level of midday PAR interception
- However, keeping productivity up at this density will require breeding and training work to create smaller tree structures that do not require continual hedging or training to keep trees within size range of over the row harvesters as well as new machinery for harvest and field operations

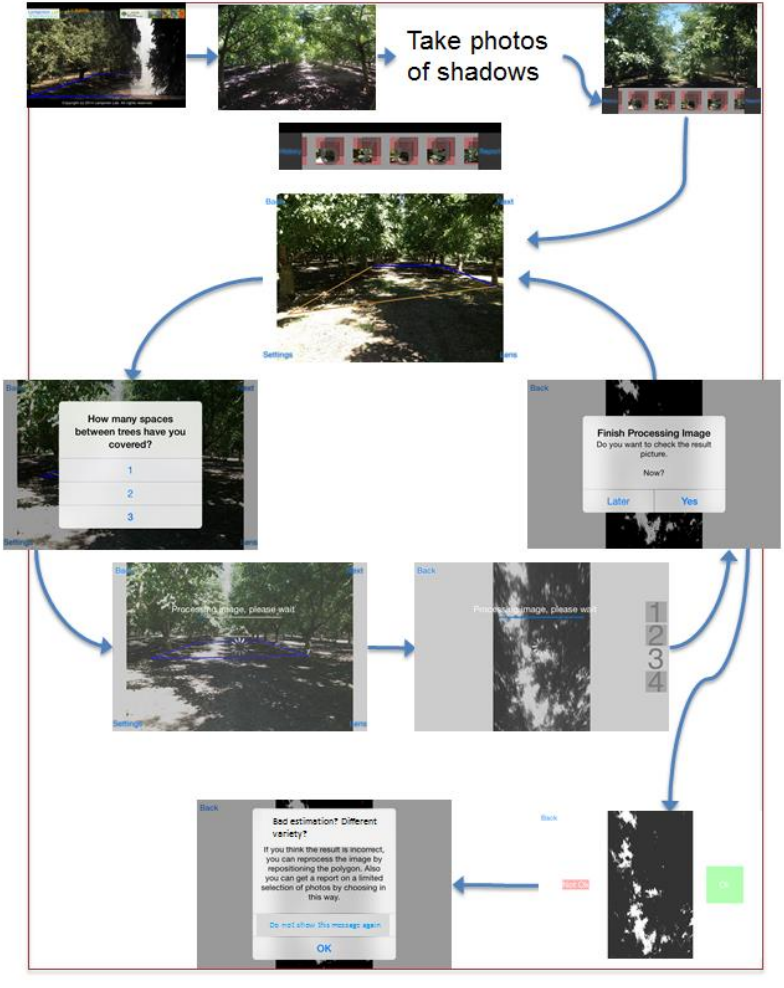
Conclusions (continued)

- There is no data to suggest that there is a need to prune mature almond trees on an annual basis
- Pruning does not sustain productivity in the short or long term (as long as 21 years)
- You should only prune to:
  - ✓Improve safety for workers
  - ✓Improve visibility of trunks to decrease chance of damaging trees with shaker
  - ✓Remove dead or diseased wood
  - ✓Improve ability to dry nuts in densely shaded orchards (mechanical hedging)

In conclusion, every pruning cut you make decreases yield (unless it is a dead branch you cut off)



Available in the Apple Store


Take photos
of shadows
How many spaces between trees have you covered?
1
2
3
Finish Processing Image
Do you want to check the result picture.
Now?
Later
Yes
Processing image, please wait
1
2
3
4
Bad estimation? Different variety?
If you think the result is incorrect, you can reprocess the image by repositioning the polygon. Also you can get a report on a limited selection of photos by choosing in this way.
Do not show this message again
OK

Done

Report

Lampinen Lab
UC Davis Plant Sciences

UCDAVIS
DEPARTMENT OF PLANT SCIENCES
College of Agricultural and Environmental Sciences

Field name: **Yolo County Almond Rootstock Trial**

Date: **July 24, 2017**

Crop: **Almond**

Start Time : **11:49 AM**

Number of Measurements: **12**

Average PAR: 70%

Yield potential: 2450-3500 lbs/ac

Estimated nitrogen needs: 166-237 lbs N/ac


Questions?
Thanks to the Almond Board of California for supporting this work