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Drought Tree Effects: 2014 and Beyond

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Drought Tree Effects:
2014 and Beyond

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Key Observations in 2014

- Every almond production region is relying on groundwater extensively to meet crop water demand. Groundwater levels declined in all production regions. Rates of decline are relatively lower in the northern regions and higher moving south.

- Areas of the west side and southern San Joaquin Valley are the main production regions also challenged by declining groundwater quality in addition to declining groundwater conditions.

- Water supply for irrigation is closer to equilibrium with crop demand in the northern production regions. This is related to higher rainfall and being near areas of origin of surface water that recharge groundwater. However, crop yields are often not as high as in the southern regions with intermediate or lower rainfall.

- Groundwater extraction in every almond production region is under increasing scrutiny with respect to competition for drinking water and impacts on stream and river flows.

Anticipating 2015

- Even if 2014/15 turns out to be a “wet” year, it is going to take time to recover from this drought (particularly further south). Any recovery can potentially be short lived.

- If the drought continues, cumulative effects of short water supplies are inevitable for the almond crop. Declining water quality will be additive. Some areas will experience more impact than others.

- Successful farm operations excel at adapting and optimizing their situation and a strong almond commodity helps make it possible. Prudent decisions lie ahead concerning:
  - New acreage to plant and old acreage to pull
  - Investment and payback of costly water resources
  - Integrating new technology and concepts into almond cultural practices

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Almond spur population dynamics:

Tree productivity as a function of spur flowering, fruiting, mortality and renewal

Ted DeJong, Bruce Lampinen, Sam Metcalf, Sergio Tombesi
Plant Sciences, UC Davis

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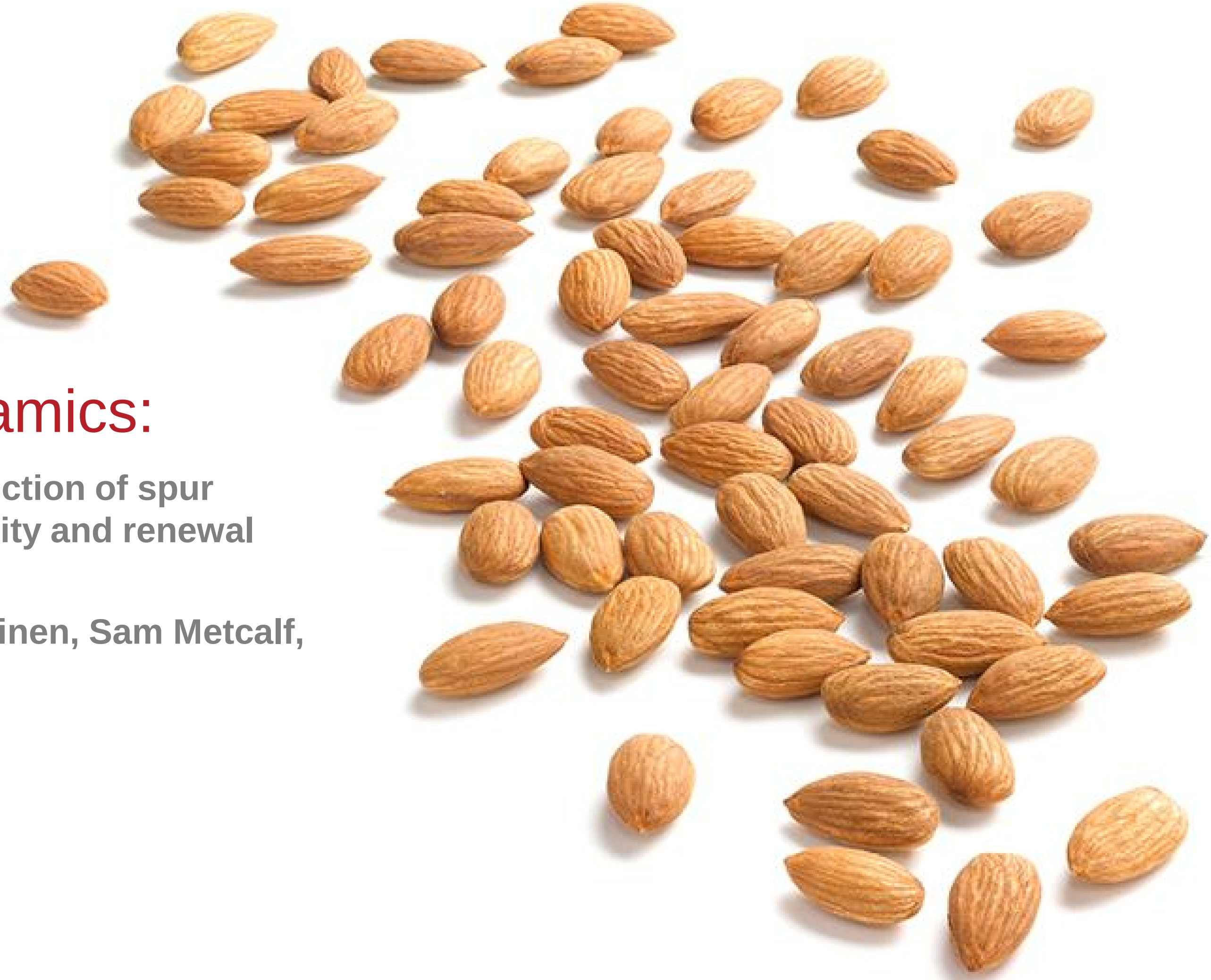


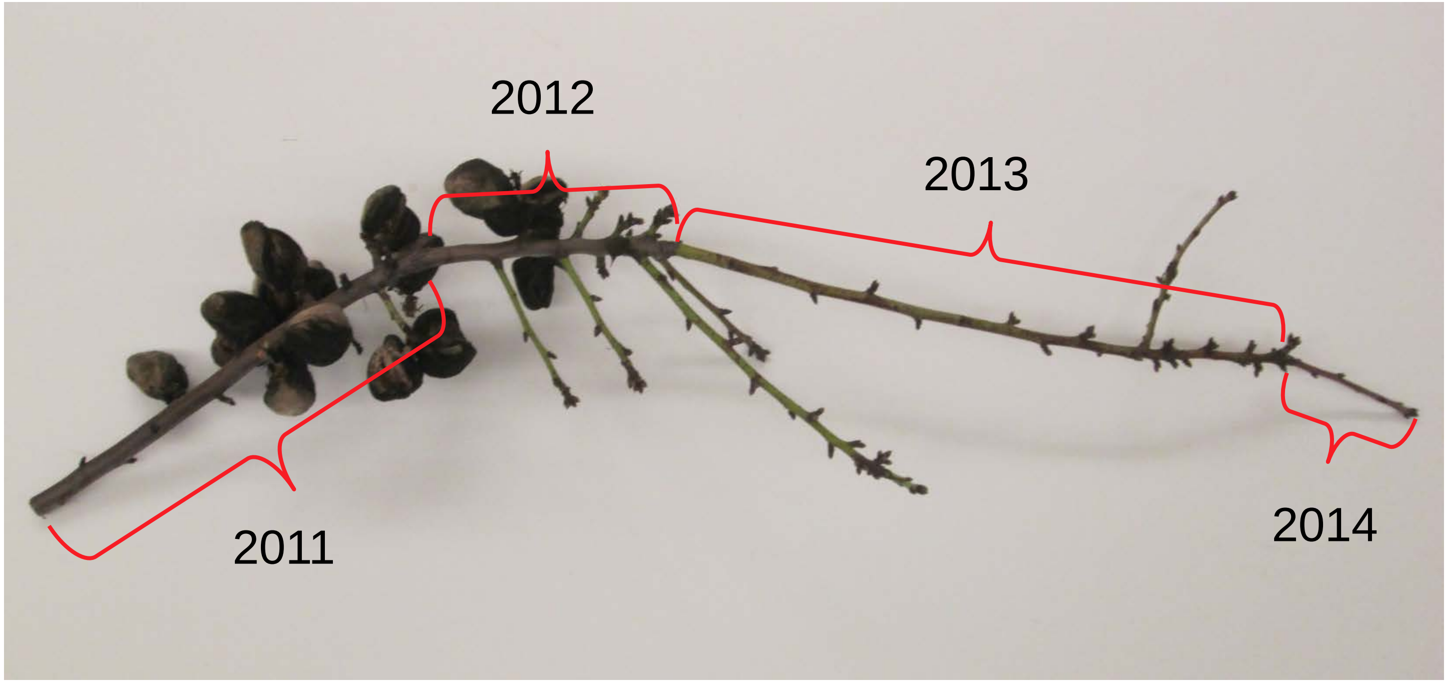
Almond spur population dynamics

- Most of you probably think about growing almonds as managing orchards or trees but I would like to emphasize that growing almonds is really about managing productive spur populations. At orchard maturity most almonds are produced on spurs. So **maintaining healthy spur populations is the key to high yields.**

Bearing habit of almond shoots.

4-year-old almond branch.

Nuts are primarily produced on spurs on older wood.



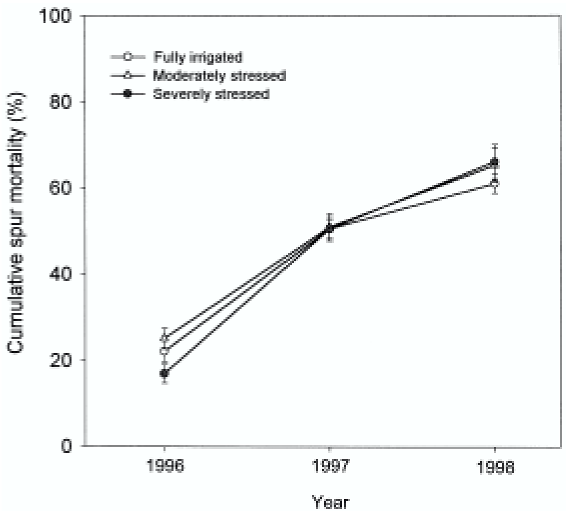
Effects of irrigation deprivation during the harvest period on yield determinants in mature almond trees.

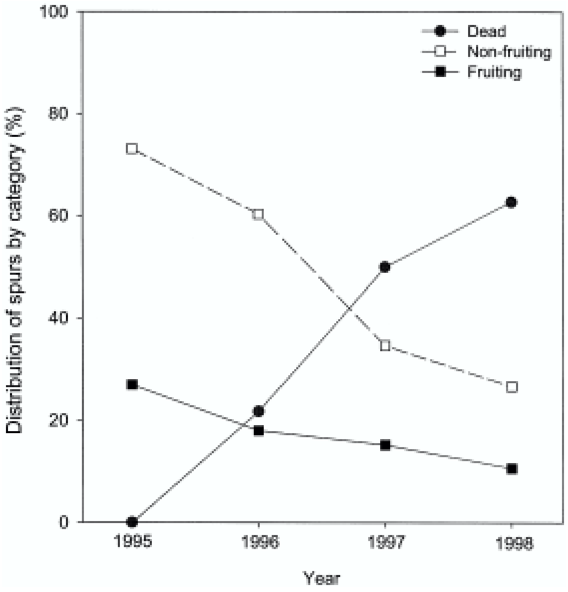
Esparza, DeJong, Weinbaum and Klein (2001)
Tree Physiology 21: 1073-1079

Tagged 2185 spurs in 1995 and followed for 3 yrs. Deficit irrigation treatments had little effect on spur mortality but an average of 15-20% of tagged spurs died each year.

Tree yields were only affected after 3 years of deficit irrigation during harvest.

Largest effect of deficit irrigation was reduced shoot growth in next year.



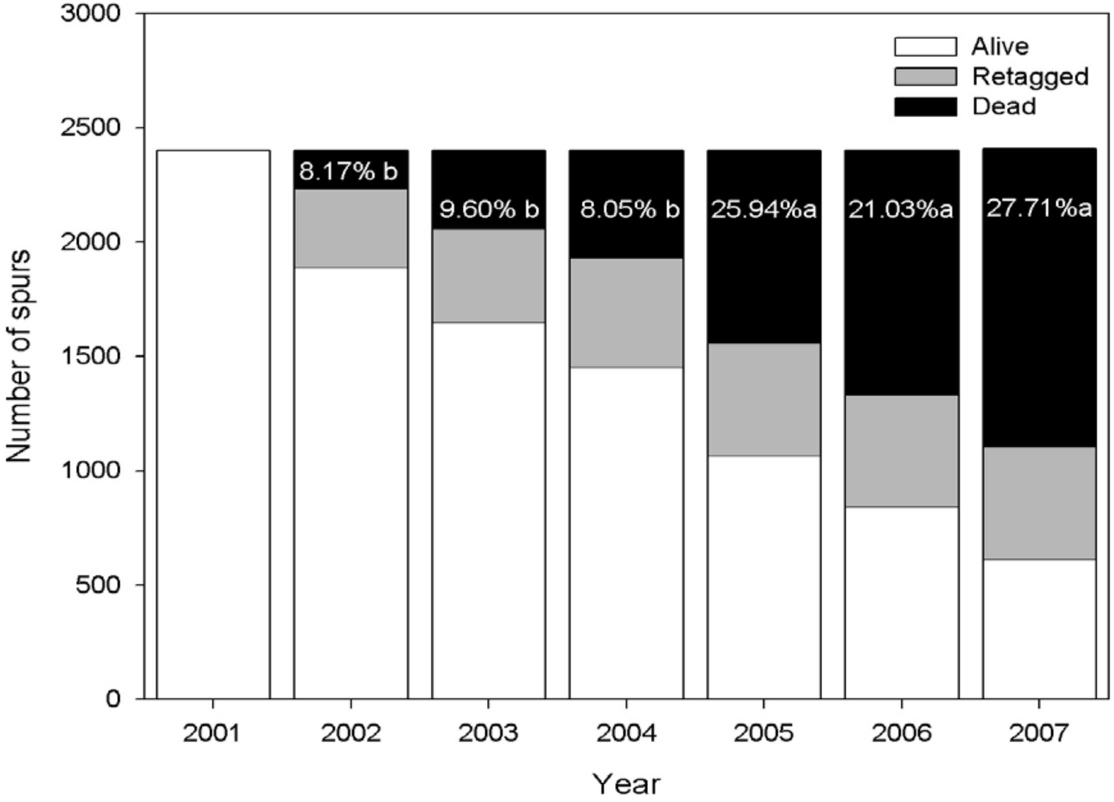


Spur dynamics study

- In 2001 Bruce Lampinen's lab initiated the Spur Dynamics study. They tagged 2400 spurs (50 spurs /tree in 48 trees) and followed the behavior of those spurs for 7 years (retagging new spurs in similar locations when spurs were lost or dead for the first 3 years).

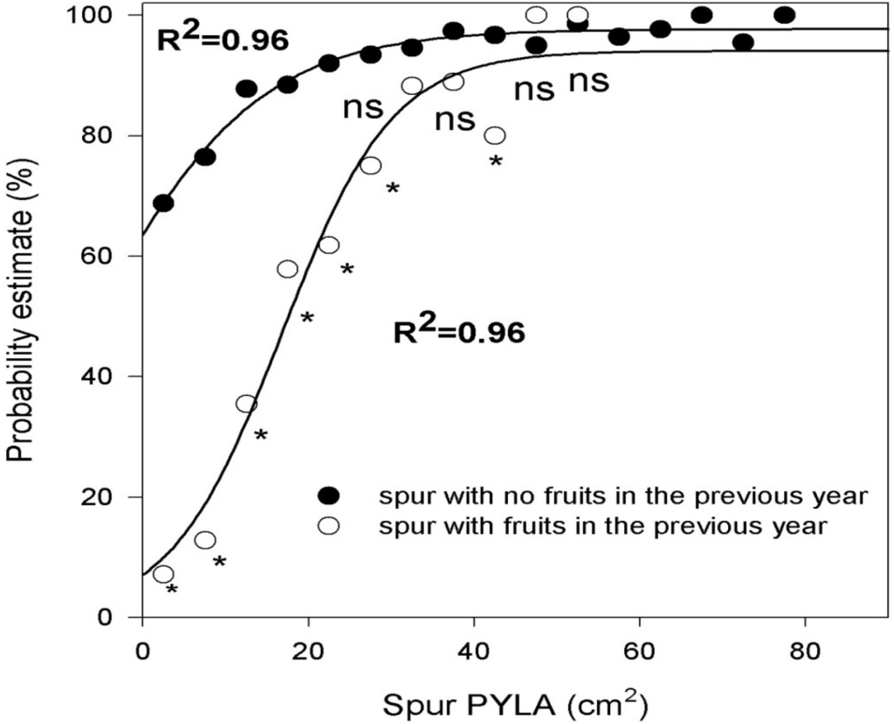
Number of living, dead and retagged almond spurs tagged in 2001 (total 2400). Percentages reflect the number of dead spurs in relation to the number of spurs alive in the previous year in each year. Black bars indicate cumulative number of dead spurs.

In the first 4 years spur mortality was ~ 8 – 10% but during the last 3 years it was > 20%.



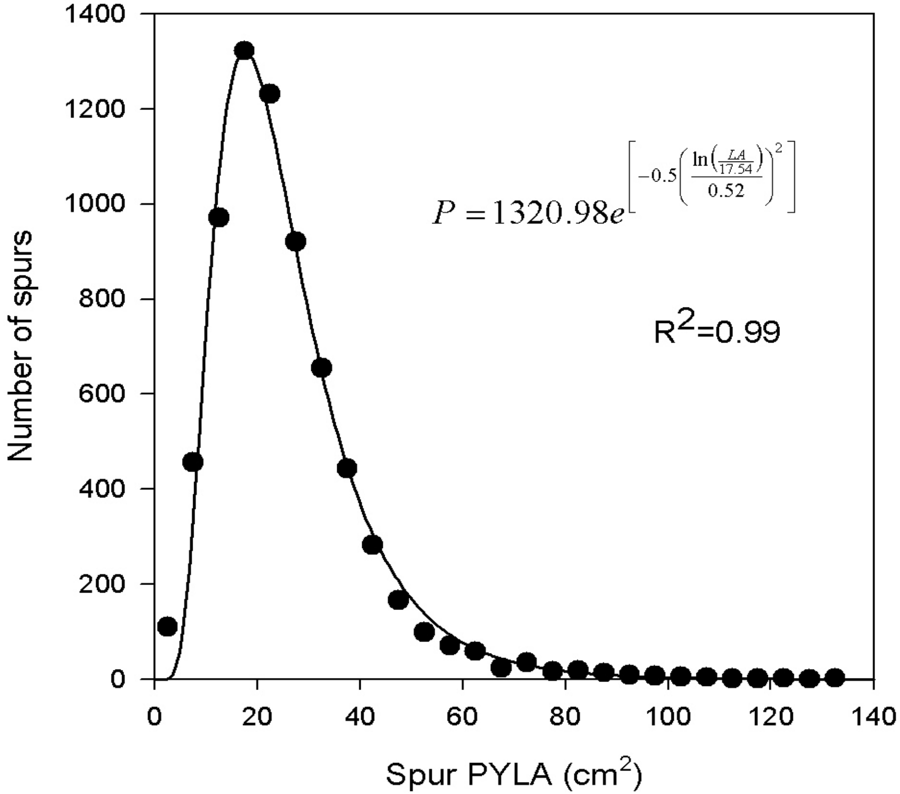
Probability estimation (%) of **spur survival** after bearing and not bearing fruit in the previous year in relation to previous year spur leaf area (PYLA, cm^2)

Bearing spurs were more likely to die in subsequent year than non-bearing spurs and spur death was strongly related to previous year spur leaf area.



Spur distributions with respect to their previous year leaf area (PYLA, cm^2)

Most spurs have previous year leaf areas of < 40cm^2.



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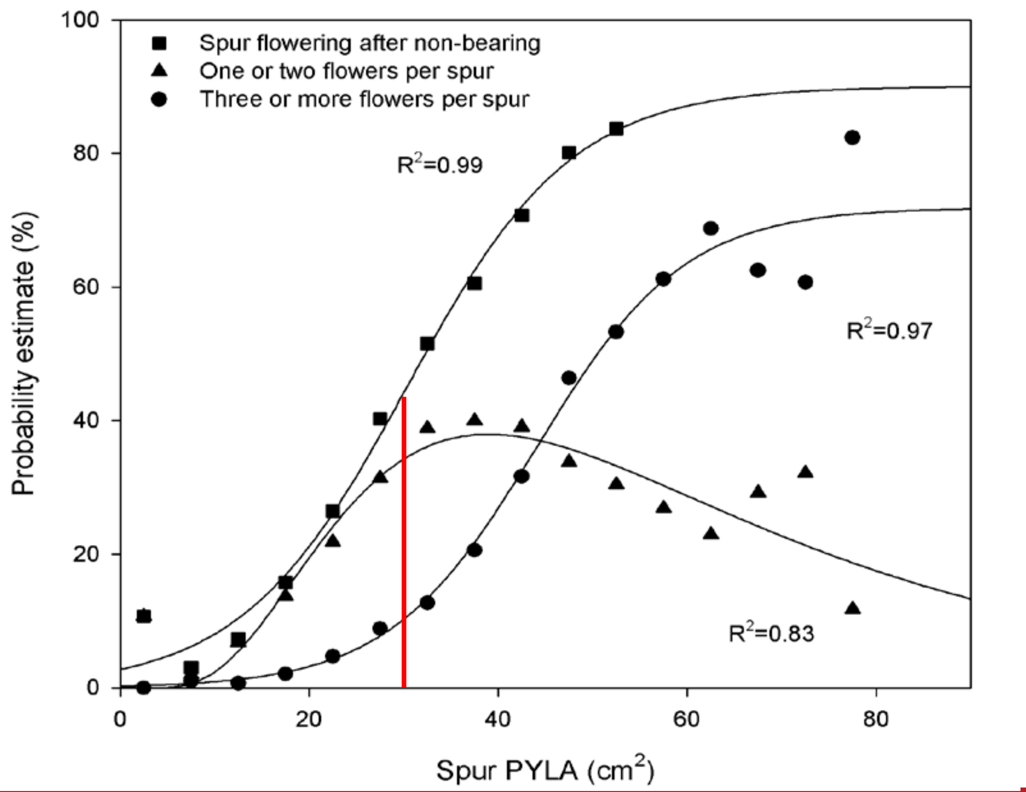
Probability estimation (%) for spur flowering and spur bearing fewer than 2 flowers or more than 2 flowers after not bearing in the previous year in relation to frequency classes of spur previous year leaf area (PYLA, cm^2)

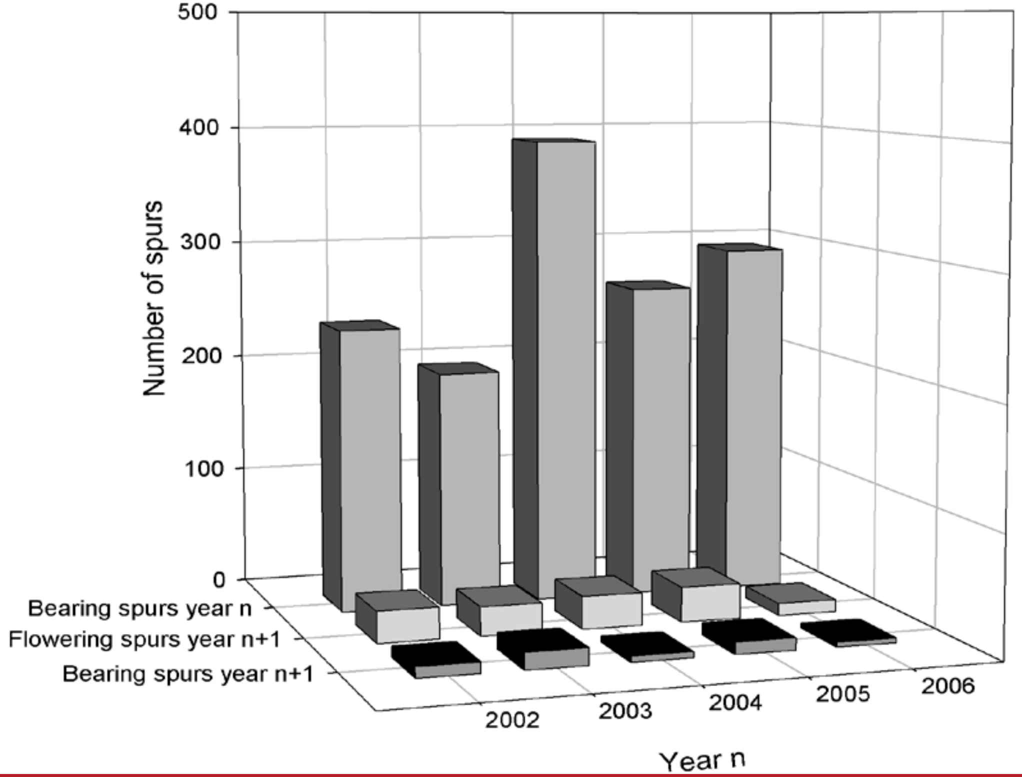
Spurs with PYLA of < 30 cm^2 have < a 50% chance of flowering.

Spur probability of flowering and bearing multiple flowers increases with PYLA.



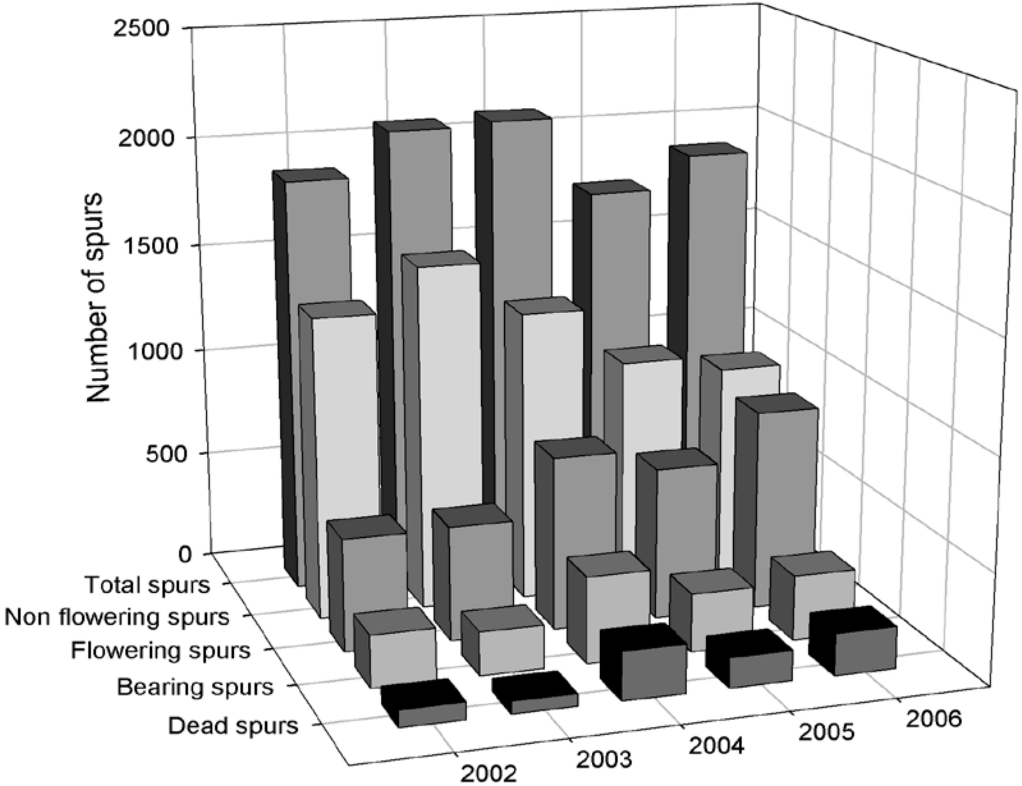
Number of bearing spurs in the year n and return bloom and fruit bearing in the subsequent year.

There was a strong tendency for a spur not to bear fruit in two sequential years.



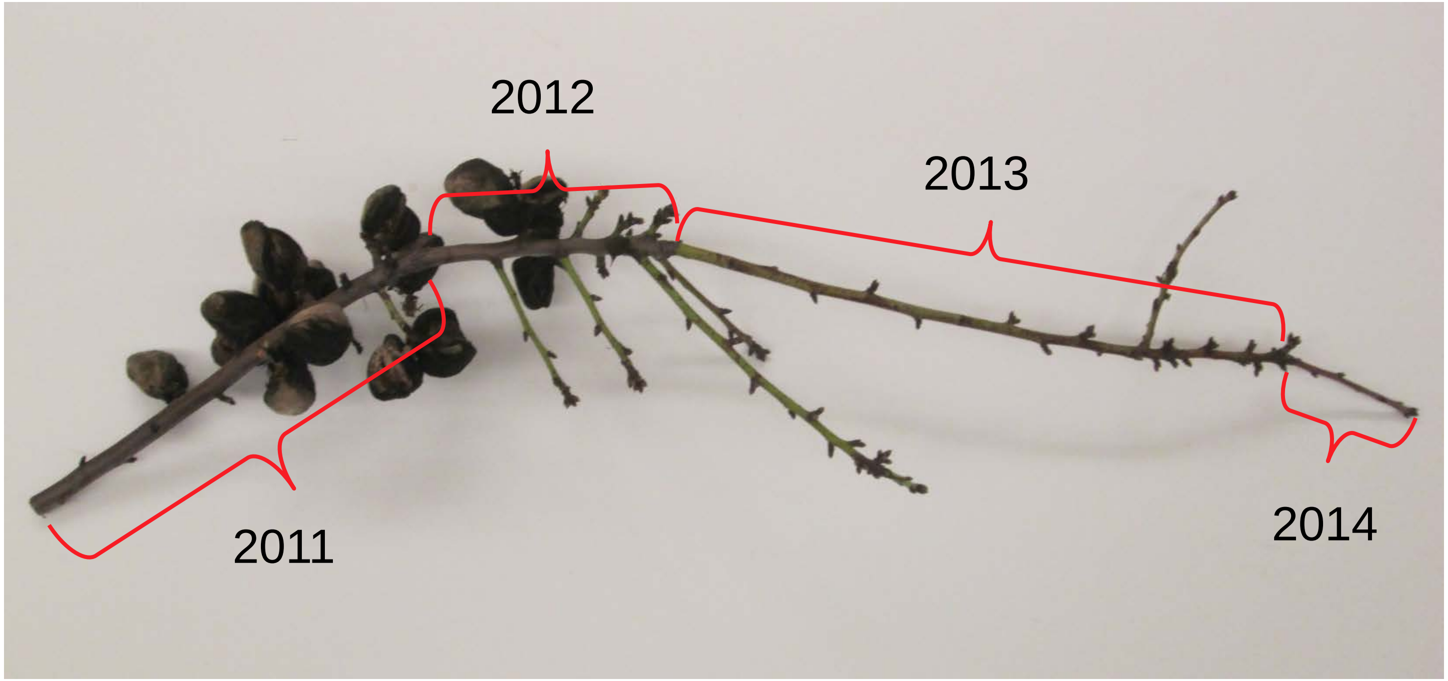
Spur population description over 5 years (including retagged spurs). Number of total spurs, non flowering spurs, flowering spurs, bearing spurs and dead spurs in the following year after bearing.

Spur population is very dynamic.



Renewing fruiting sites and developing new spurs

The new growth in 2013 and 2014 provides new fruiting sites as old spurs die.



But new shoots on the top of the trees also provide new spurs over time.

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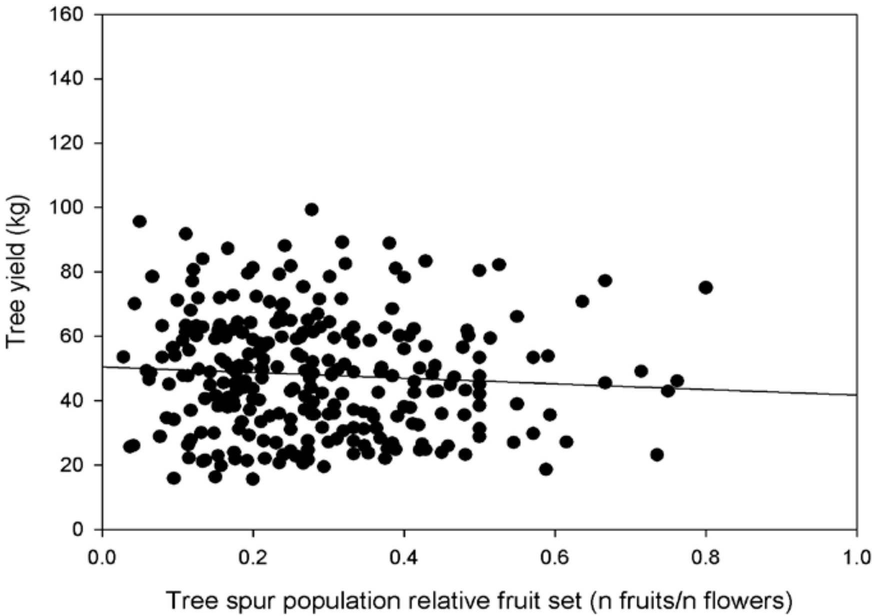
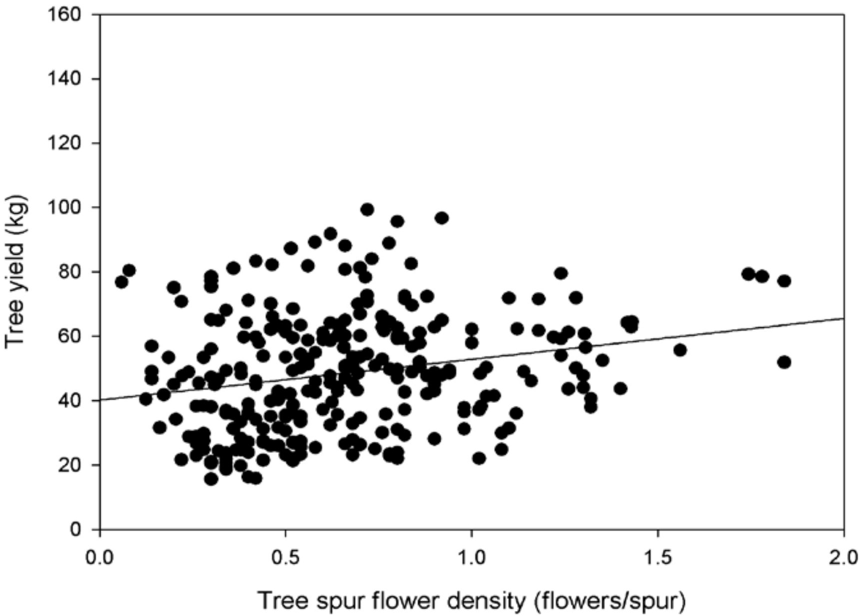
We also attempted to determine the relative importance of relative fruit set and flower density (flowers/spur) for tree yield.

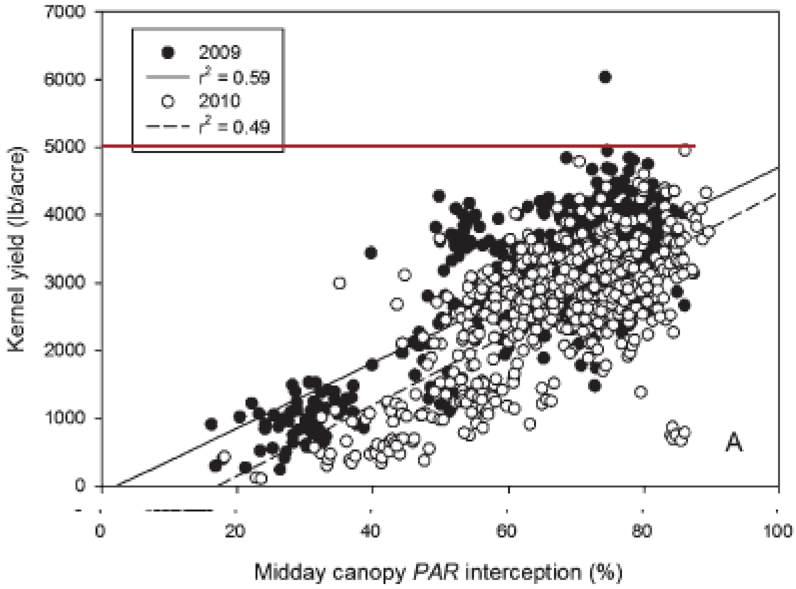
In this study flower density was more important than % set in determining tree yield.





The maximum potential yield of almond trees is ~5000 lbs per acre. What does the spur population of that orchard look like?

- 5000 lbs with 454 nuts per lb = 2,270,000 nuts per acre
- With average of 1.25 nuts per bearing spur then there were 1,816,000 bearing spurs per acre.
- If there are 121 trees/acre (18x20 ft) then there were about 15,008 bearing spurs per tree. If that represents 14.25% of the spur population then there were ~105,319 active spurs per tree.
- Of those 100,000 spurs
  - ~15% are resting (bore previous year)
  - ~15% bear fruit
  - ~20% flowered but did not bear fruit
  - ~25-40% are resting (not sure why, probably low LA)
  - ~10-25% die **(must be replaced)**



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Bottom Line

- **Almond orchard yields are dependent on maintaining a healthy population of spurs. Spur mortality and productivity is a function of previous year leaf area.**
- **Spur death is a given so annual replacement of spurs is essential for future production.**
- **Spur extension growth and spur leaf growth occurs in early spring, right after bloom; and shoot extension growth (providing new sites for renewing the spur population) occurs during the "grand period of growth" in the two months after bloom.**
- **It is essential that trees do not experience a significant amount of water stress during the first 2 months after bloom to maintain a healthy population of productive spurs for future productivity.**
- **The current year's crop is probably less sensitive to spring water stress than future year crops.**

Further reading

- Effects of irrigation deprivation during the harvest period on leaf persistence and function in mature almond trees. Klein, I., G. Esparza, S.A. Weinbaum, and T.M. DeJong. (2001) *Tree Physiology* 21:1063-1072.
- Effects of irrigation deprivation during the harvest period on yield determinants in mature almond trees. Esparza, G., T.M. DeJong, S.A. Weinbaum, and I. Klein. (2001) *Tree Physiology* 21:1073-1079.
- Effects of irrigation deprivation during the harvest period on nonstructural carbohydrate and nitrogen contents of dormant, mature almond trees. Esparza, G., T.M. DeJong, and S.A. Weinbaum. (2001) *Tree Physiology* 21:1081-1086.
- Spur behaviour in almond trees: relationships between previous year spur leaf area, fruit bearing and mortality. Bruce D. Lampinen, Sergio Tombesi, Samuel Metcalf and Theodore M. DeJong. (2011) *Tree Physiology* 31: 700-706.
- Relationships between spur- and orchard-level fruit bearing in almond (*Prunus dulcis*) Sergio Tombesi, Bruce D. Lampinen, Samuel Metcalf and Theodore M. DeJong. *Tree Physiology* (2011) 31: 1413-1421.
- Relationships between spur flowering, fruit set, fruit load and leaf area in almond trees. Sergio Tombesi, Bruce D. Lampinen, Samuel Metcalf and Theodore M. DeJong. *(submitted for publication)*

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Stress impacts on spur dynamics

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UC Davis Plant Sciences

Ted DeJong, Sergio Tombesi, Samuel Metcalf, William Stewart and Ignacio Porris-Gómez

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Spur Dynamics Irrigation and Nitrogen treatments

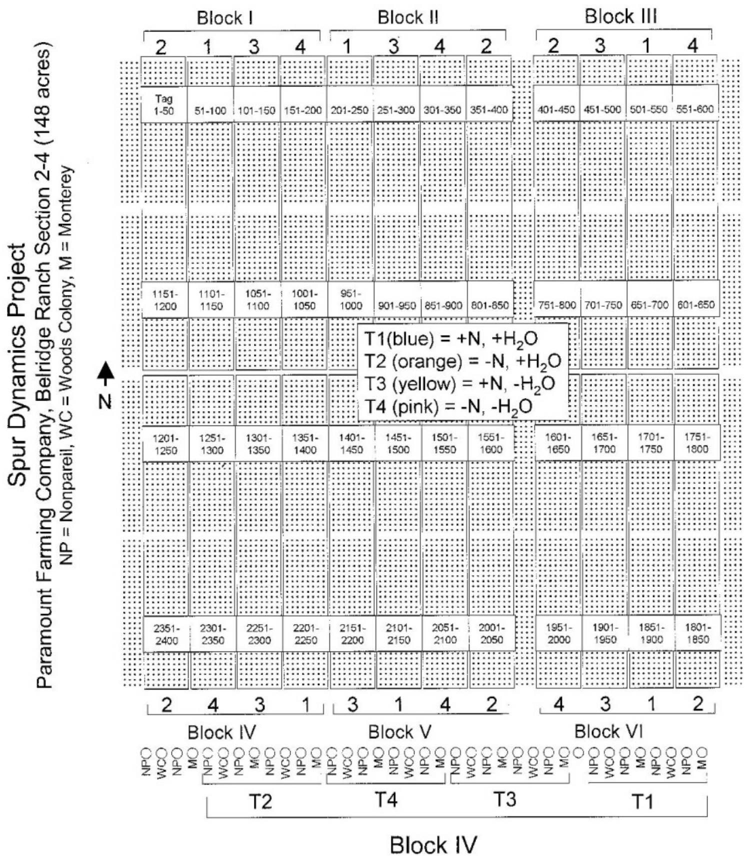
Treatments

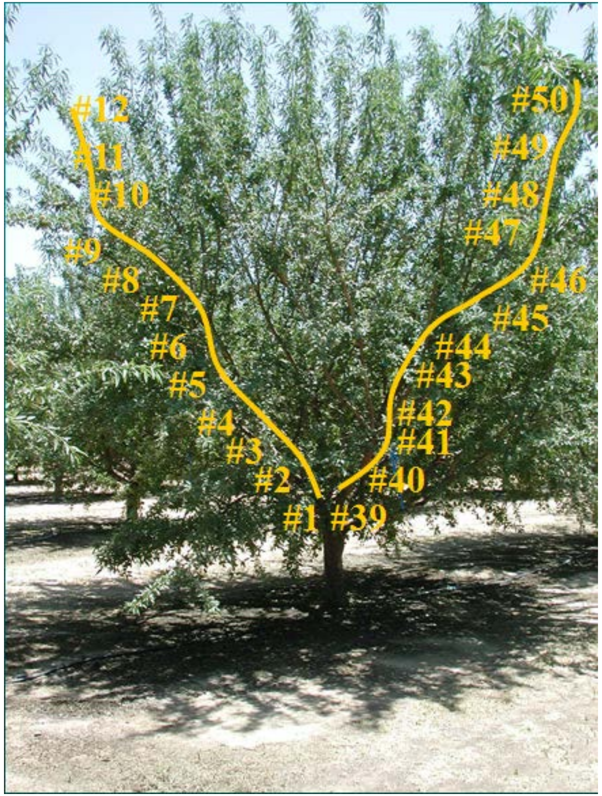
- T1 = + N, + water
- T2 = moderate N, + water
- T3 = +N, moderate water
- T4 = mod. N, mod. Water

Moderate nitrogen- fertilize when leaf N falls below 2.2%

Moderate water- irrigate when midday stem water potential reaches -12 bars (mild stress)

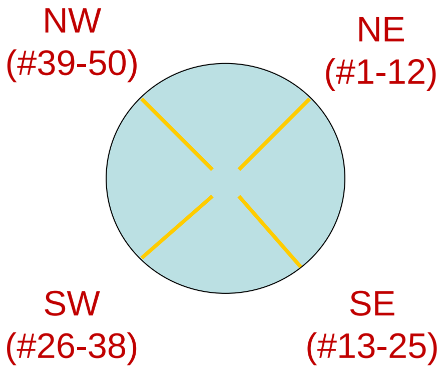
Spur dynamics plot map and tagging locations





- 2400 spurs were tagged in 2001- distributed around tree and throughout canopy

Top View



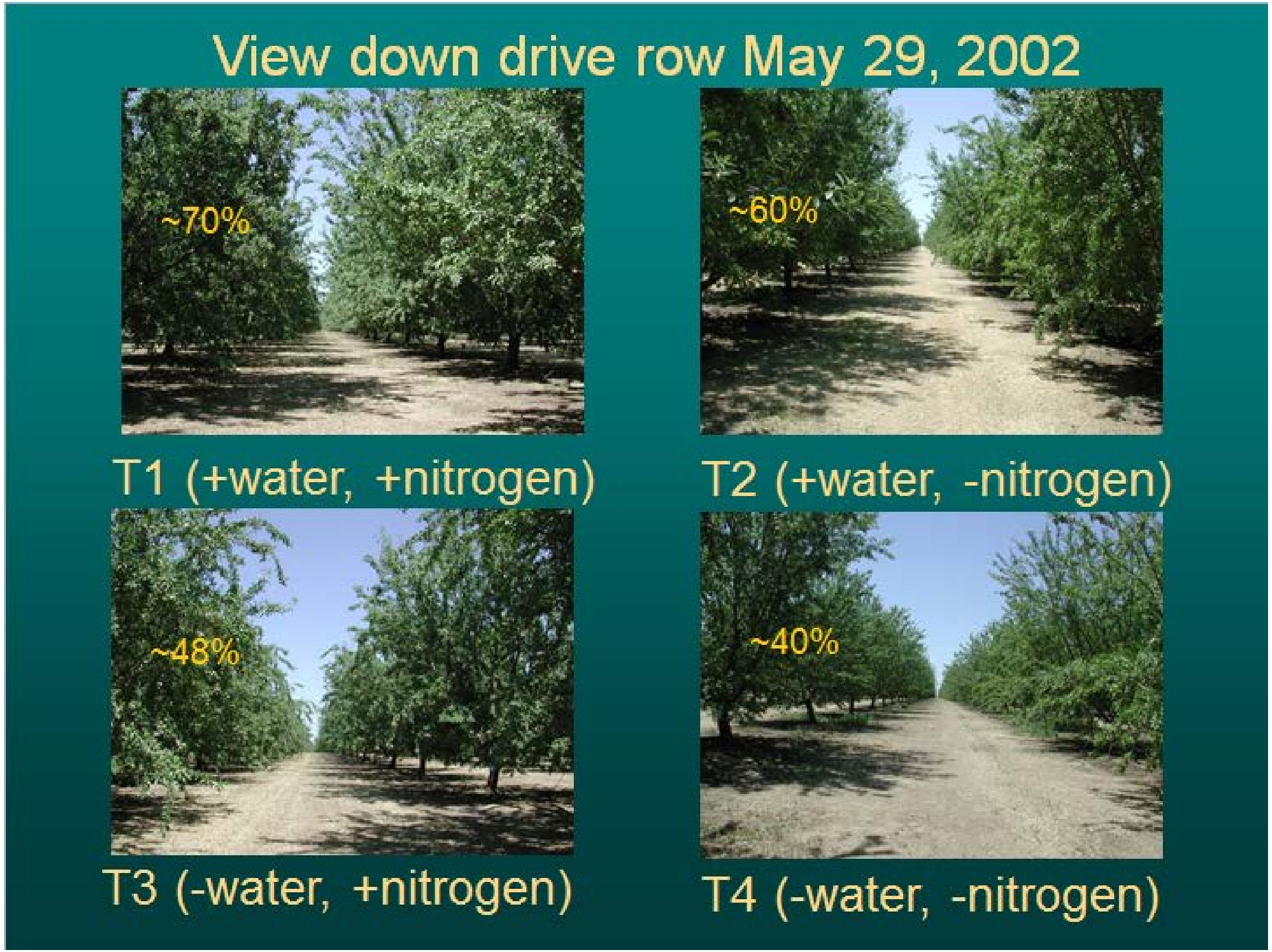
Large replicated trial covering 146 acres

Spur Dynamics Irrigation and Nitrogen treatments

- Treatments were imposed from 2001 to 2008
- In general water deficit effects were greater than nitrogen deficit effects

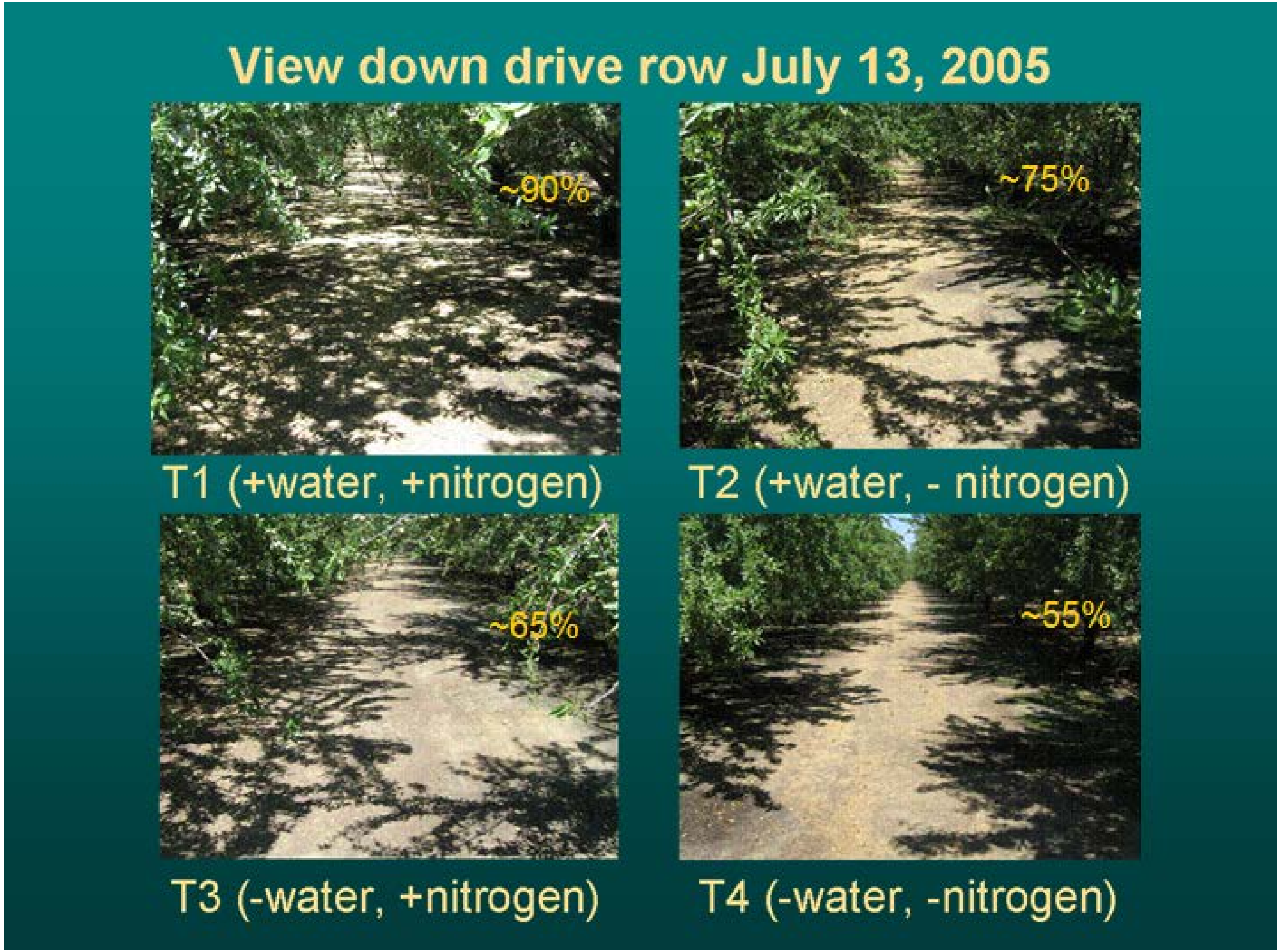
Spur Dynamics Irrigation and Nitrogen treatments

Views of each treatment in May 2002, one year after treatments were imposed



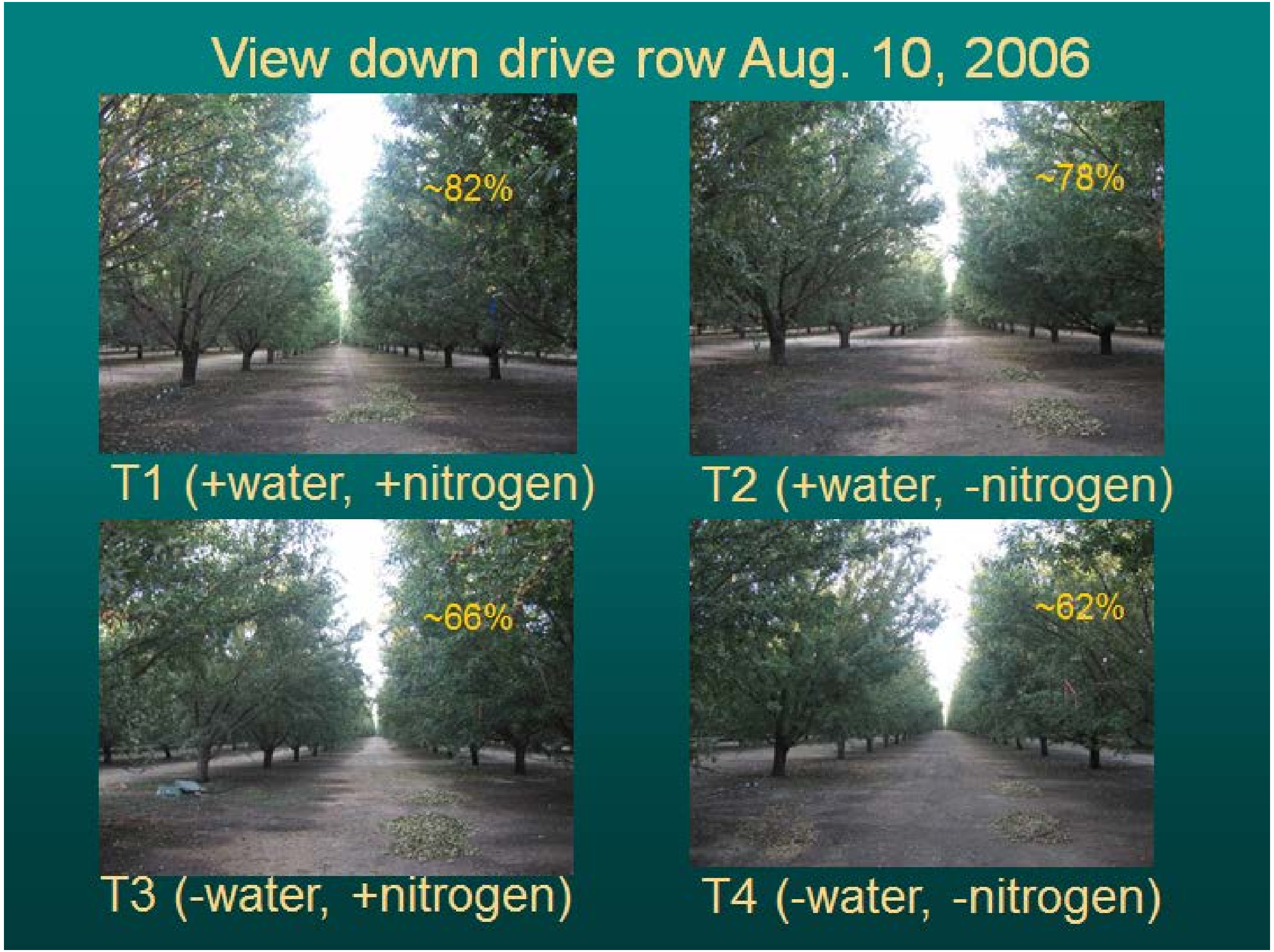
Spur Dynamics Irrigation and Nitrogen treatments

Views of each treatment in July 2005, four years after treatments were imposed



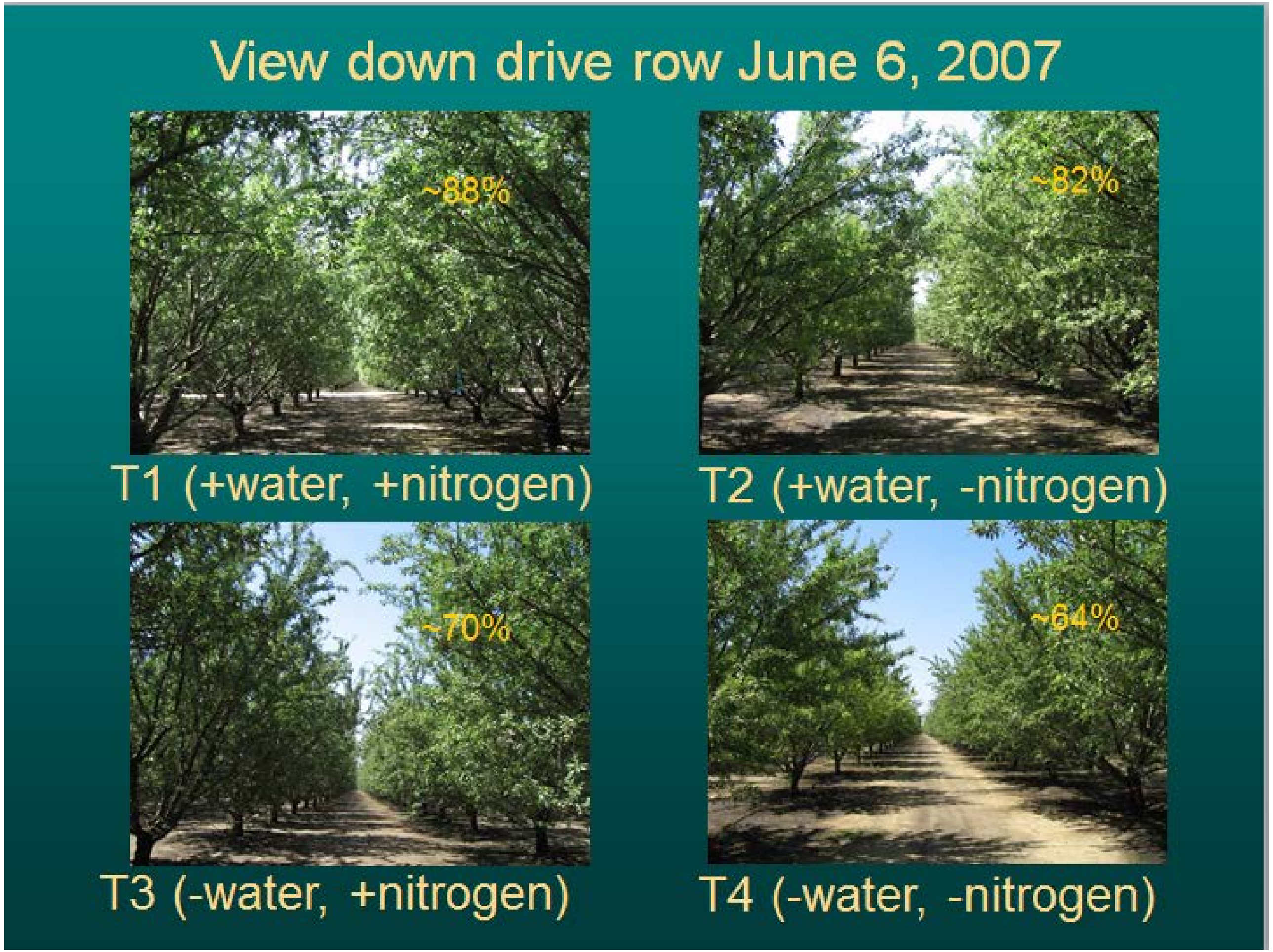
Spur Dynamics Irrigation and Nitrogen treatments

Views of each treatment in August 2006, five years after treatments were imposed (orchard was mechanically hedged the previous winter)

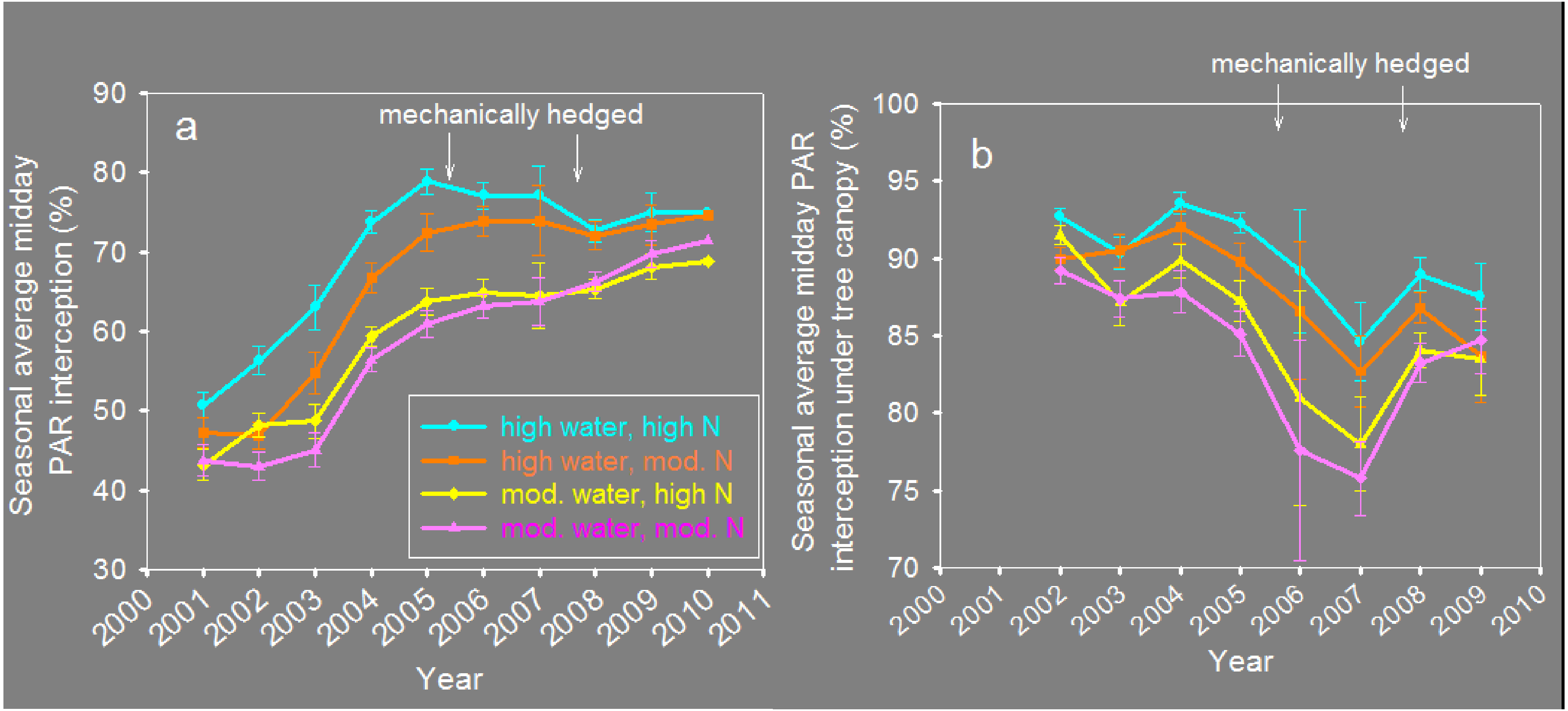


Spur Dynamics Irrigation and Nitrogen treatments

Views of each treatment in June 2007, six years after treatments were imposed

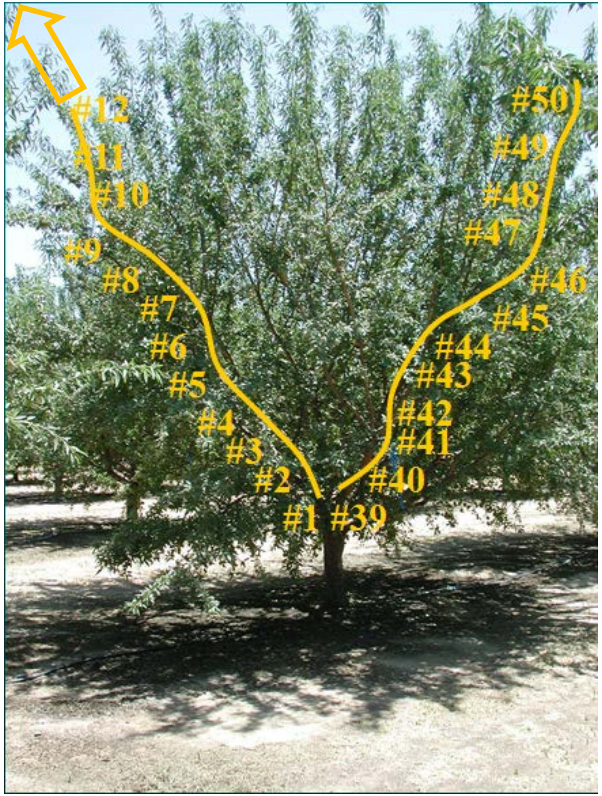


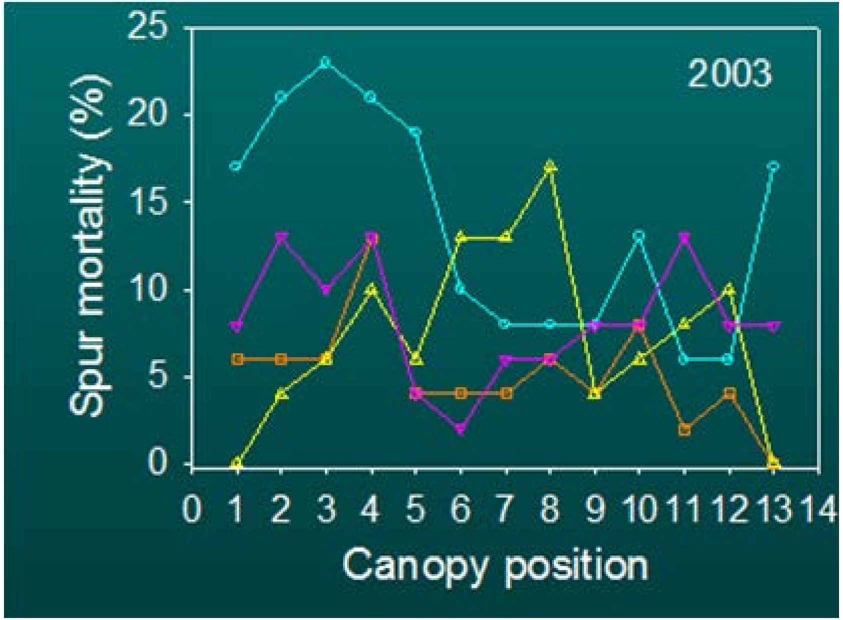
Spur Dynamics Orchard Midday Canopy Light Interception



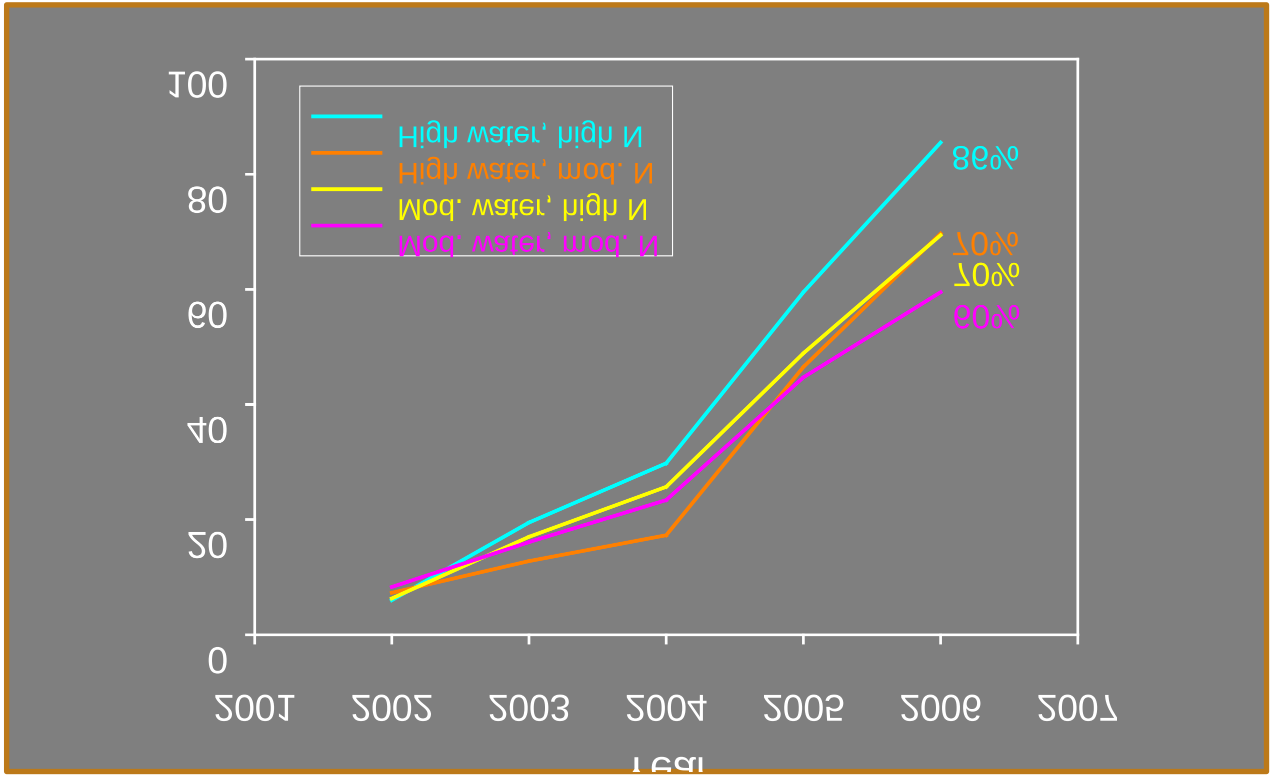
Overall　　　　Under tree

Spurs on the high water/high nitrogen treatment trees died out more rapidly, particularly in the lower positions but were replaced by new spurs on new extension growth





Spurs on the high water/high nitrogen treatment trees died out more rapidly, particularly in the lower positions but were replaced by new spurs on extension growth



Over the first six years a large number of the tagged spurs died with the most loss occurring in the high water high N treatment and the least in the moderate Water, moderate N treatment

Cumulative yield and average yield per unit light intercepted for the 2001 to 2008 seasons (8 years that treatments were imposed)

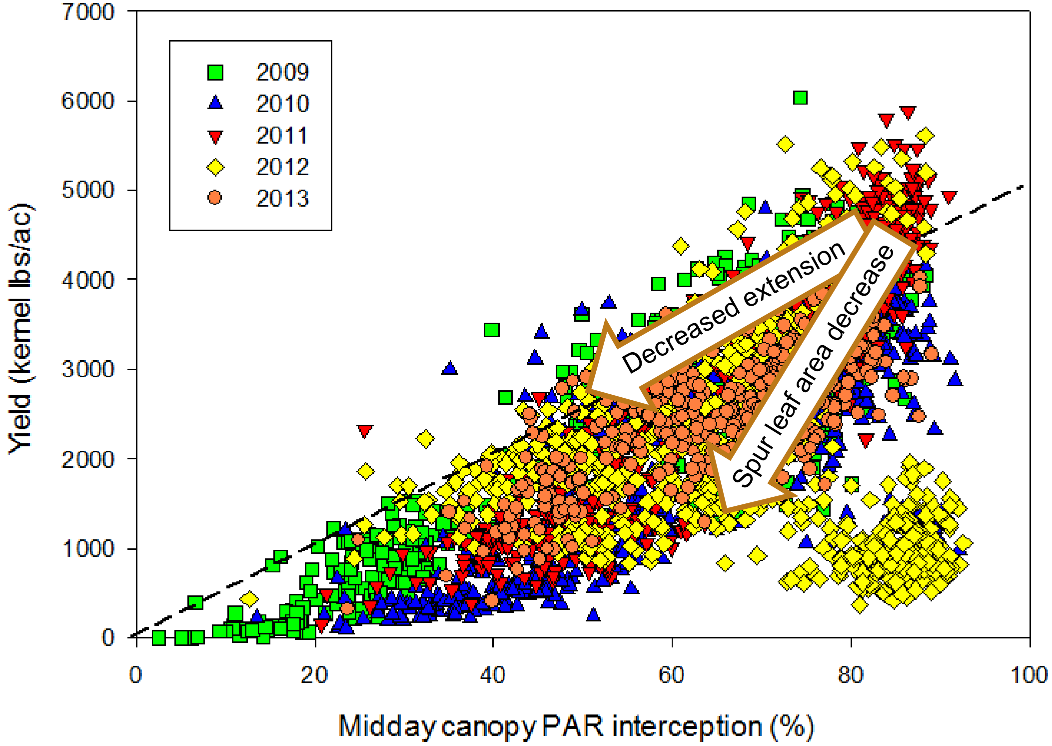
Treatment	Cumulative yield (pounds/acre)	Percent of T1 yield	2007 light intercept. (%)	Average yield per unit light intercepted	Percent of T1
T1 (high N, high water)	18,819 a		77.1 a	37.4 a	
T2 (mod. N, high water)	**15,559 b**	83	74.0 a	33.7 a	90
T3 (high N, mod. water)	**14,861 b**	79	**64.6 b**	34.9 a	93
T4 (mod. N, mod. water)	**11,177 c**	59	**63.8 b**	**30.7 b**	82

This is likely due to more vegetative spurs because of lower leaf area

Yield loss due to water or nitrogen stress has two components

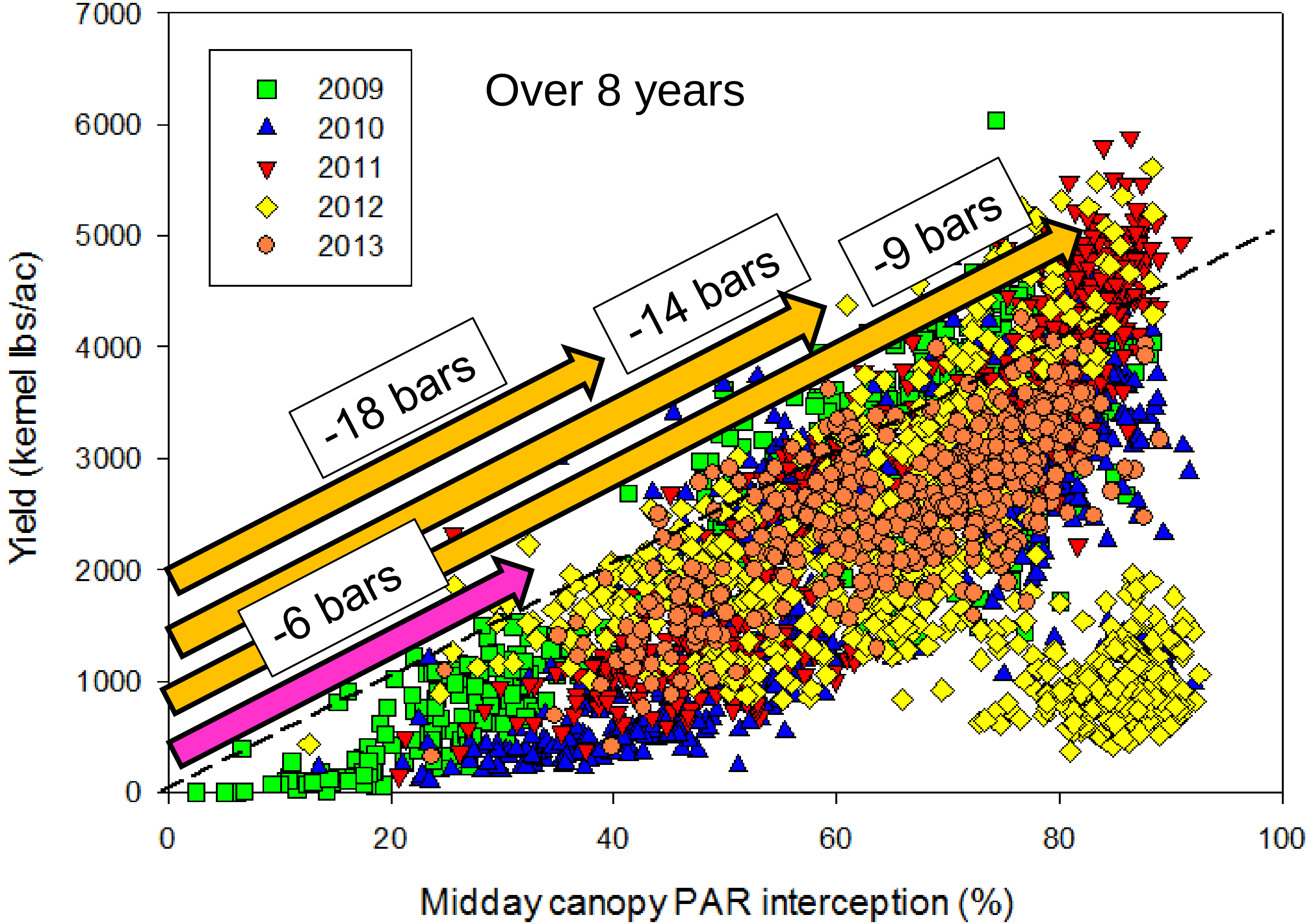
-Decreased leaf area on spurs

-Decreased extension growth leads to less light interception



Both of these impact the following year crop more than the current year (unless stress is severe enough to cause drop, current season effects are mainly smaller nut size)

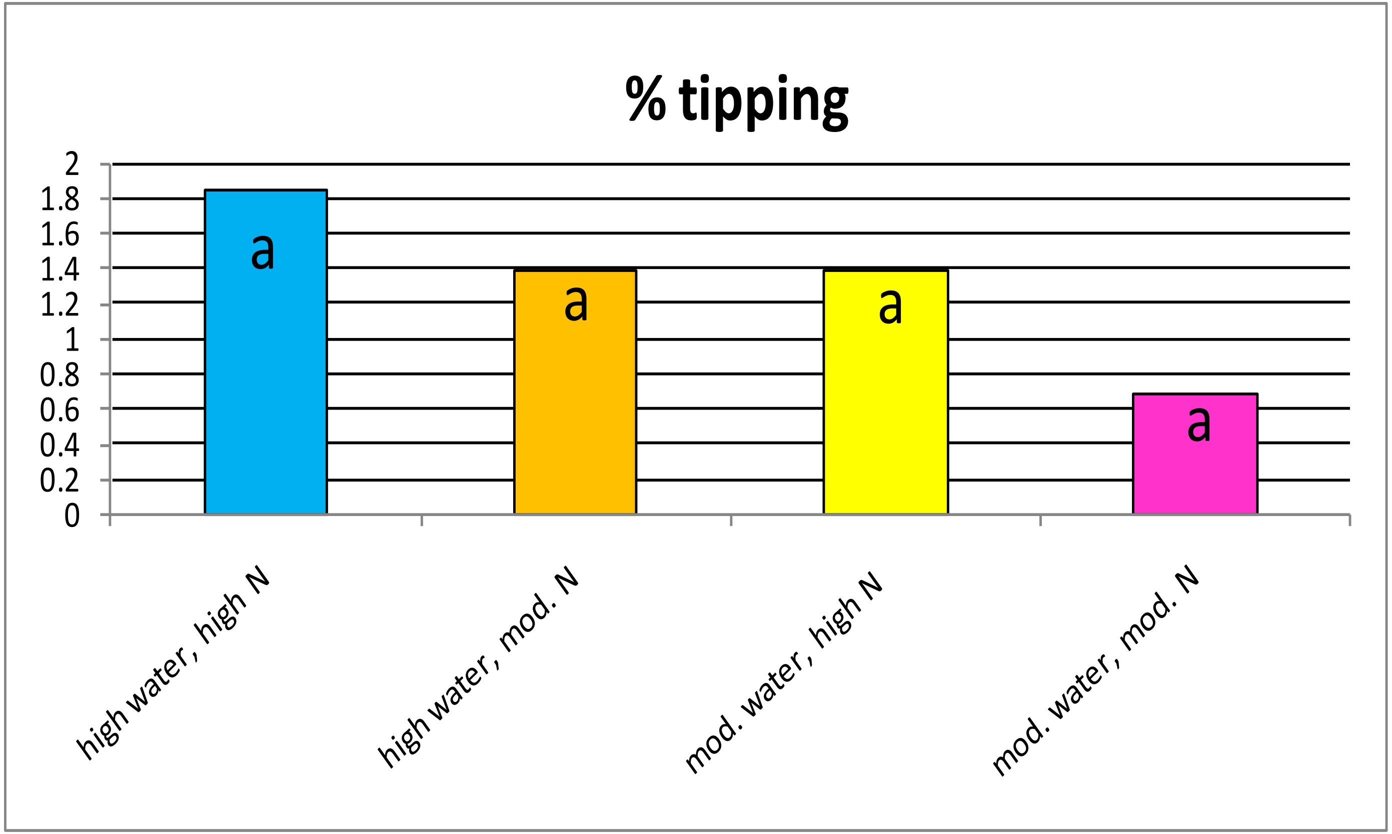
Tree growth, yield and quality can be impacted by wet as well as dry conditions



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

In 2011 we surveyed the trees in the spur dynamics trial for death, damage and disease (3 years after all were returned to grower irrigation)



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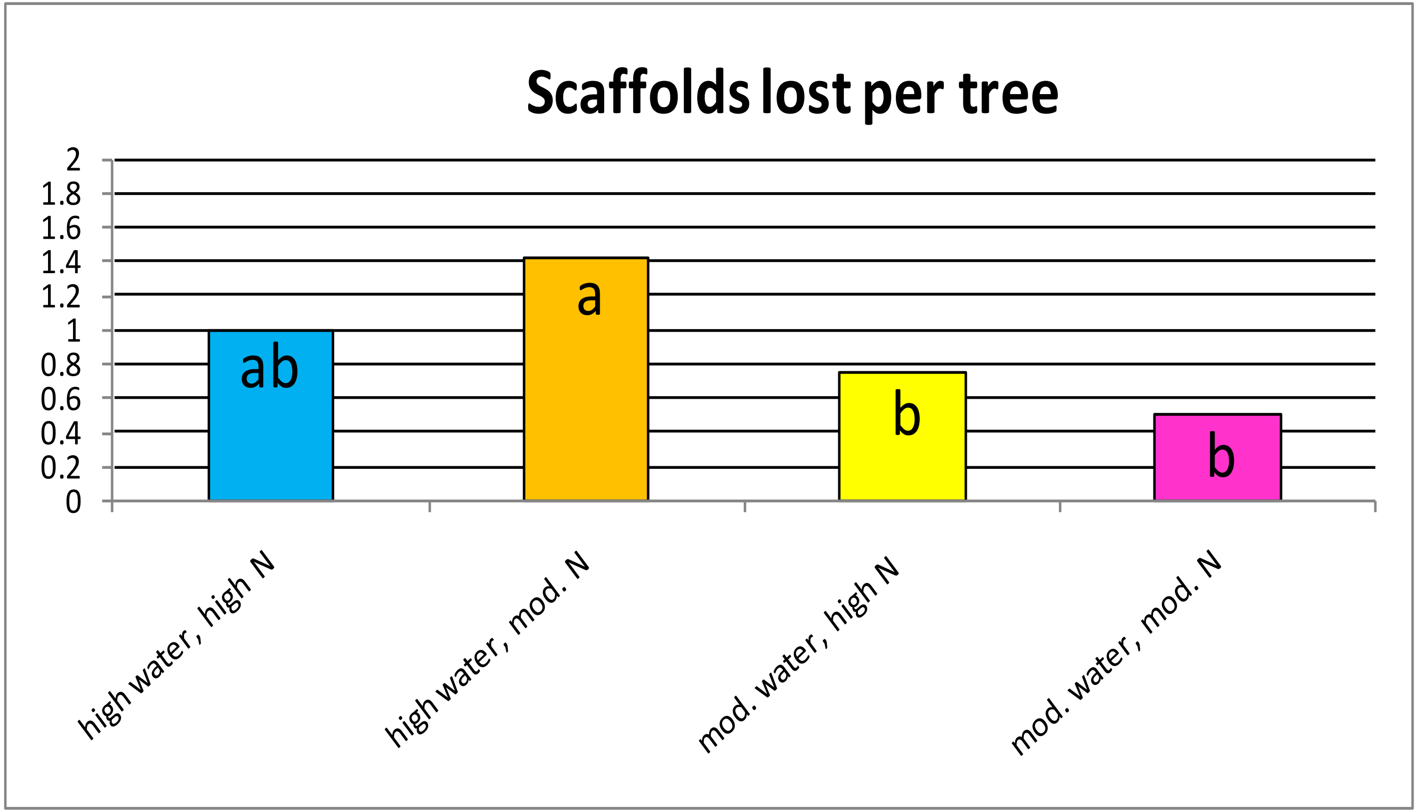

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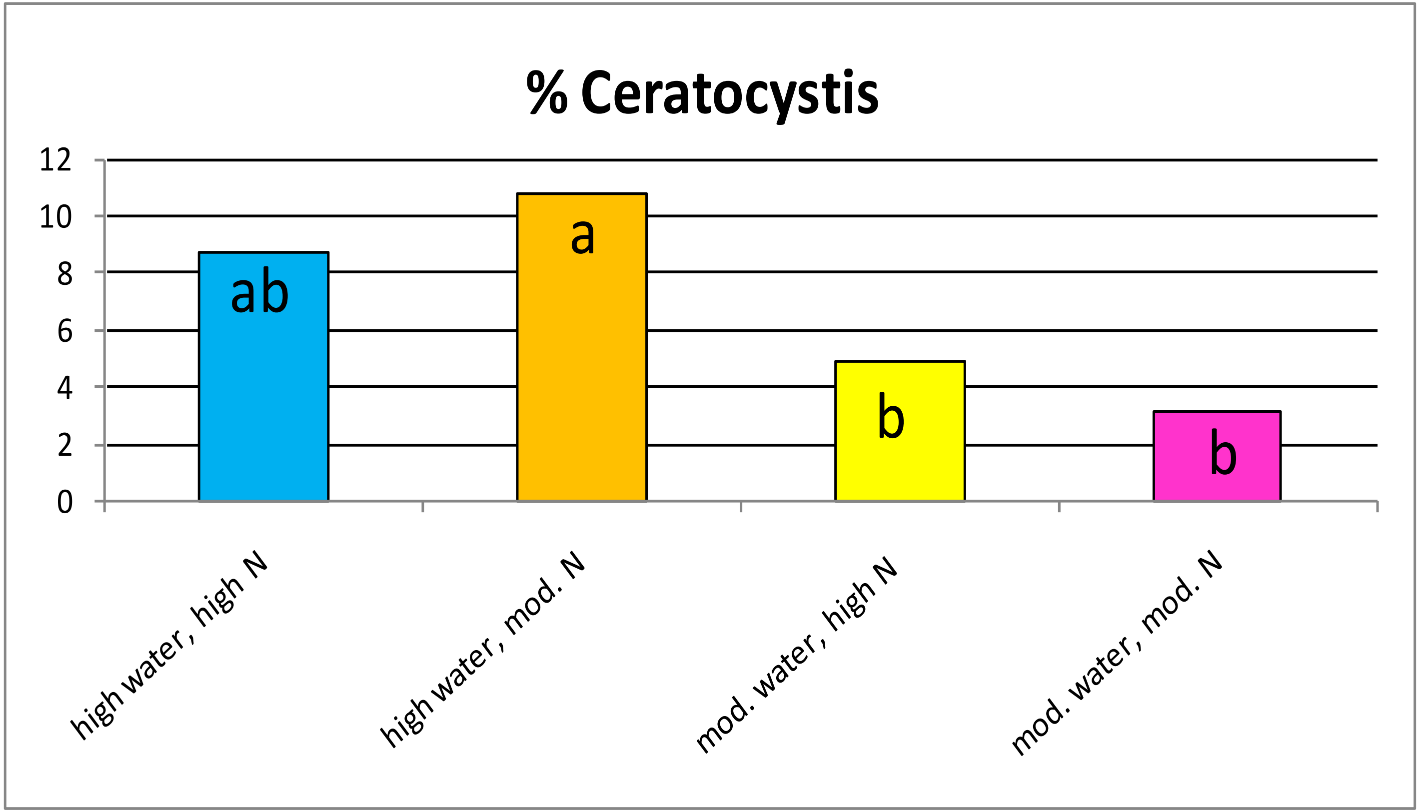

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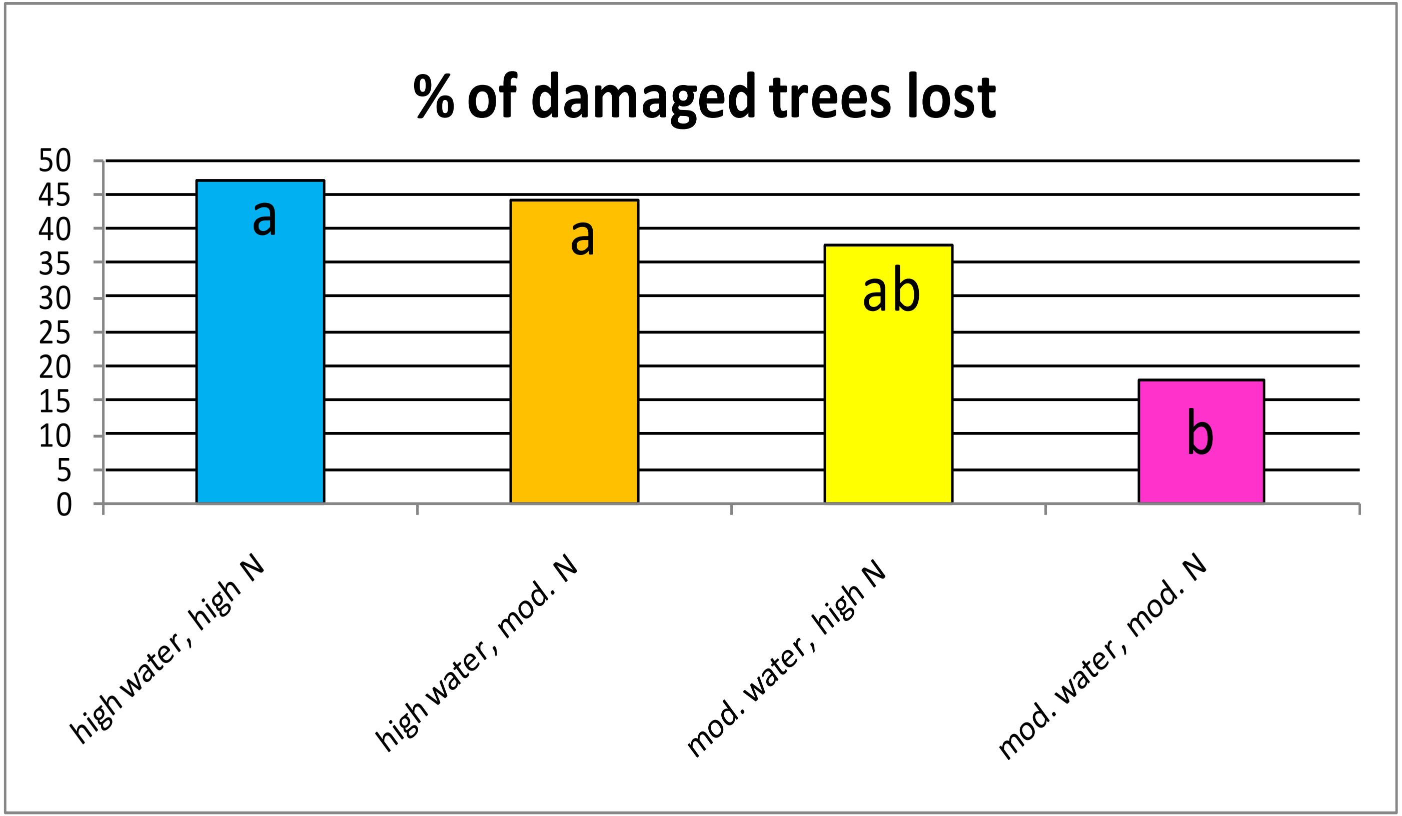

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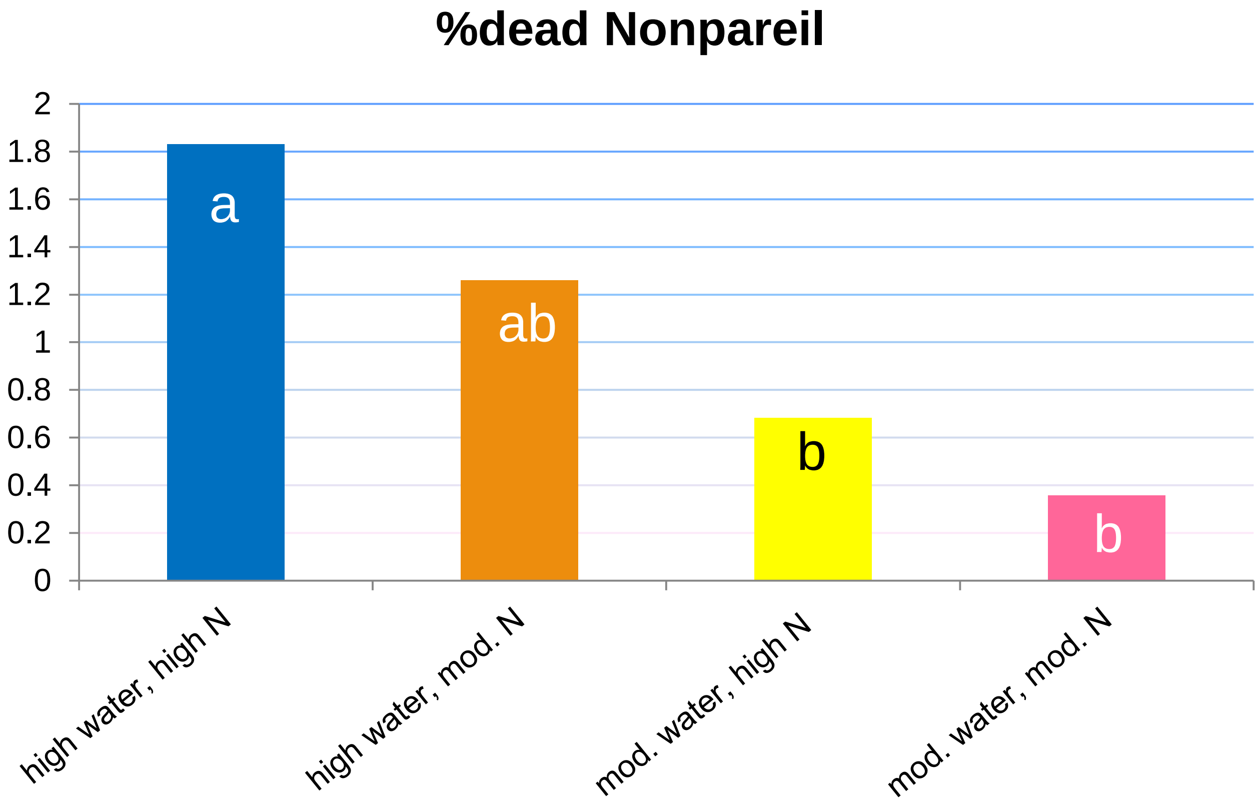
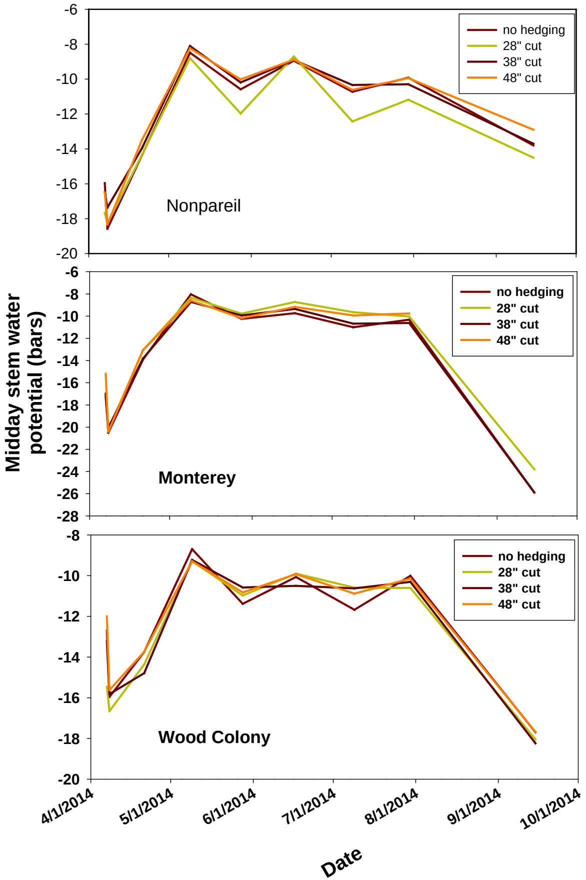
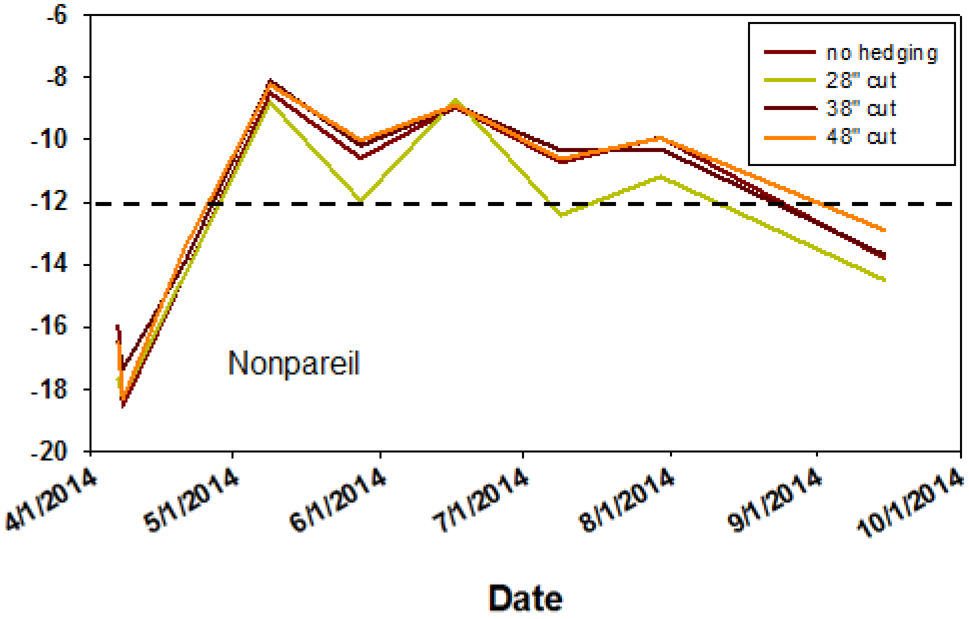


Midday stem water potential for Kern County almond hedging trial 2014

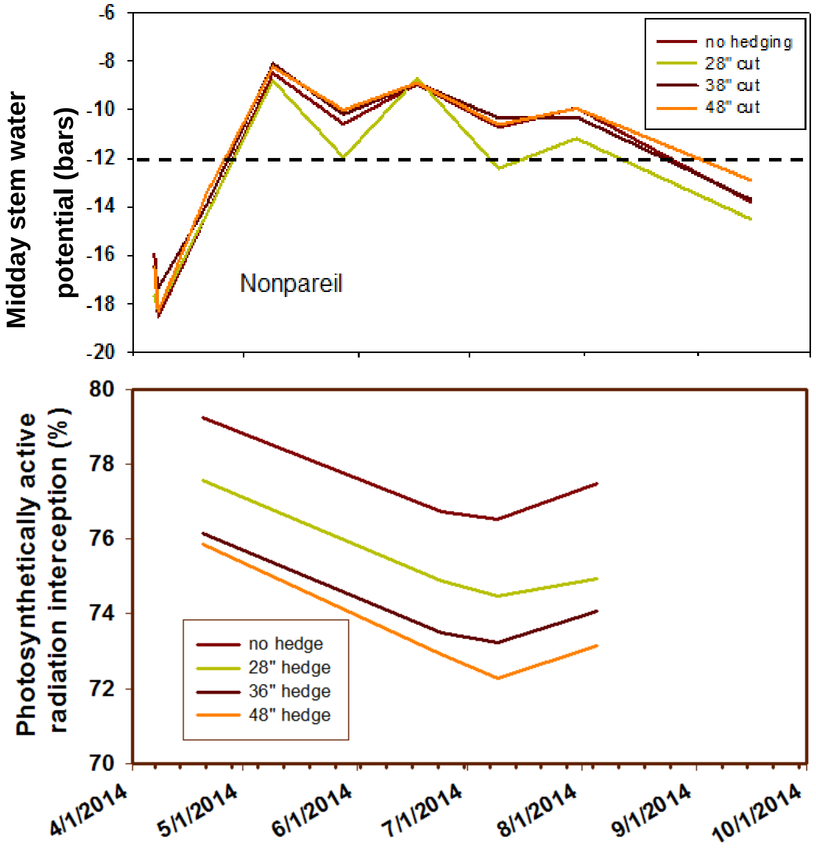




For more information on the hedging trial see poster **65** 14-HORT19-Lampinen

Mechanical Hedging

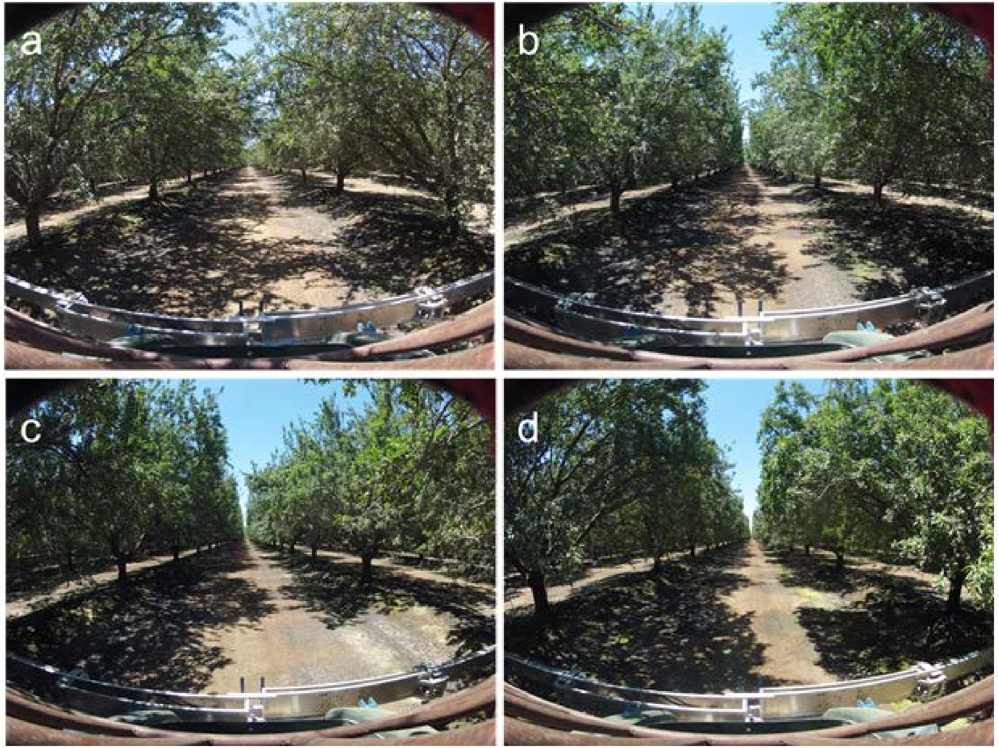
Stress early in season can impact seasonal canopy development



Looking closer you can see yellow leaves in tree and dried leaves on ground

These leaves falling off should be supporting current year nuts and subsequent year flowering/nuts

Light bar data show very little extension growth in 2014



Photos of unhedged (a), 28” hedged (b), 38” hedged (c) and 48” hedged treatments taken in July 2014

This combined with the leaf loss that occurred mid-summer suggests negative impacts of early season stress on yield may be substantial in 2015

Treatment	2013 PAR interception (%)	2013 yield (kernel lbs/ac)	2013 yield per unit PAR intercepted	2014 PAR interception (%)	2014 yield (kernel lbs/ac)	2014 yield per unit PAR intercepted
No hedge	78.8 a	3226 a	40.9 a	76.7 a	2414 a	31.6 a
28” hedge	78.9 a	3178 a	40.3 a	74.9 ab	2274 a	30.6 a
38” hedge	78.1 a	3351 a	42.9 a	73.5 b	2287 a	31.2 a
48” hedge	77.5 a	3192 a	41.2 a	72.9 b	2337 a	32.1 a

Conclusions

Yield loss due to water stress (either too much or too little) has two components

1) Early season stress

Decreased leaf expansion leading to reduced spur leaf area

- Smaller nut size and/or nut drop in current season
- Less chance that spurs will flower in the following season

2) Stress later in summer

Decreased nut size (shrivel) in current season

Decreased shoot extension growth

- Fewer new spurs
- Less canopy expansion resulting in little increase in light interception

Pushing trees in early years with lots of water and nitrogen may have implications for long term orchard health

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Drought Tree Effects:

2014 and Beyond

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Cooperators:

Dave Doll

John Edstrom

Allan Fulton

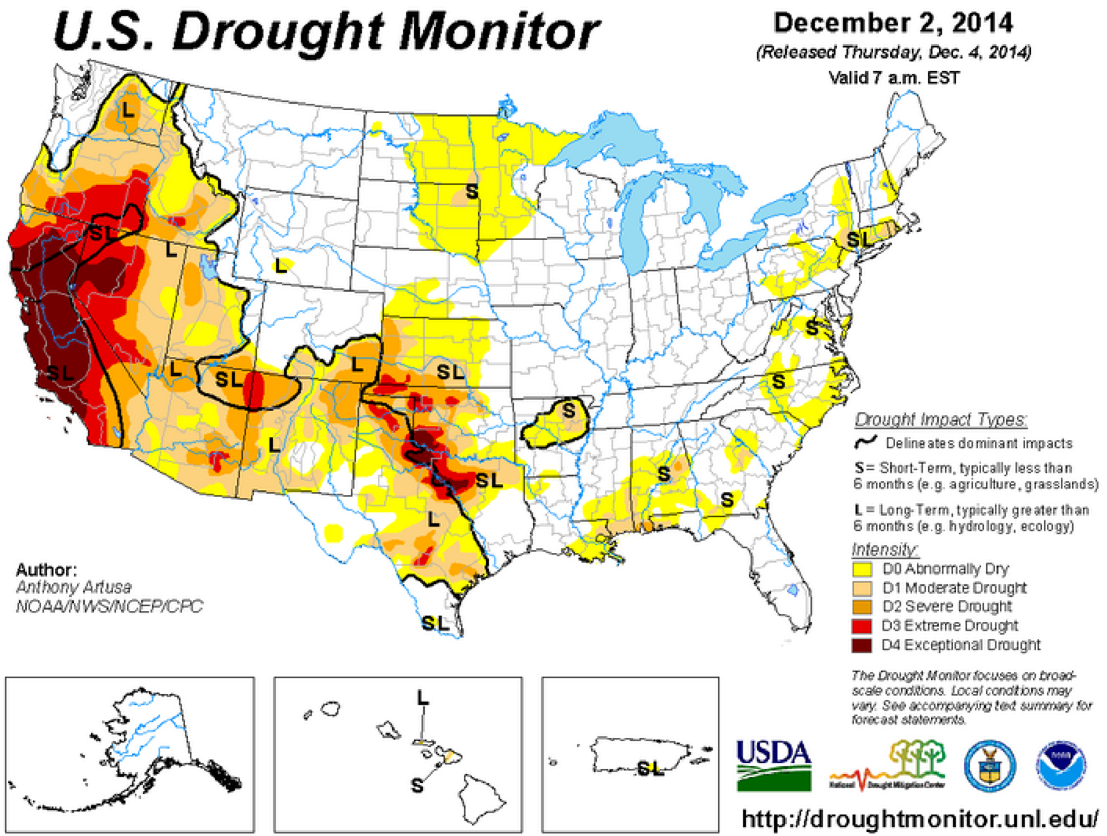
Bruce Lampinen

Blake Sanden

Larry Schwankl

Gerardo Spinelli

The current US Drought Monitor



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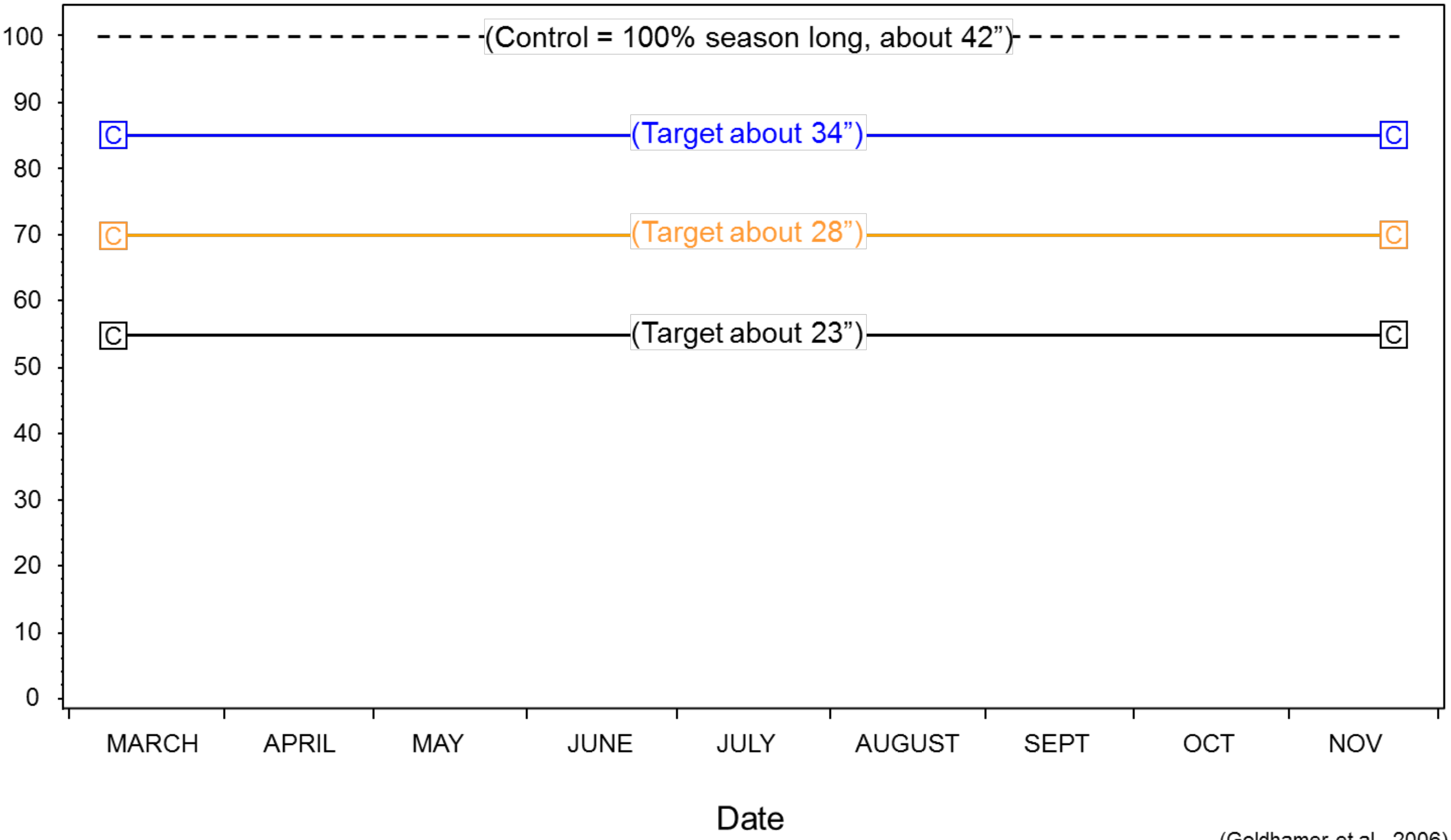
Previous drought studies in almond

- 1993 -1996 study (Goldhamer et al, 2006), Southern SJV, 18 year-old orchard
- 3’ root zone, 7.5” average rainfall during study (no pre-irrigation)
- Control (100% Etc = 42”)
- 3 levels of irrigation deficit (34”, 28”, 23”) (80%, 67%, 55%)
- 3 patterns* of deficit

*Question: are there particular stages that are more ‘drought sensitive?’

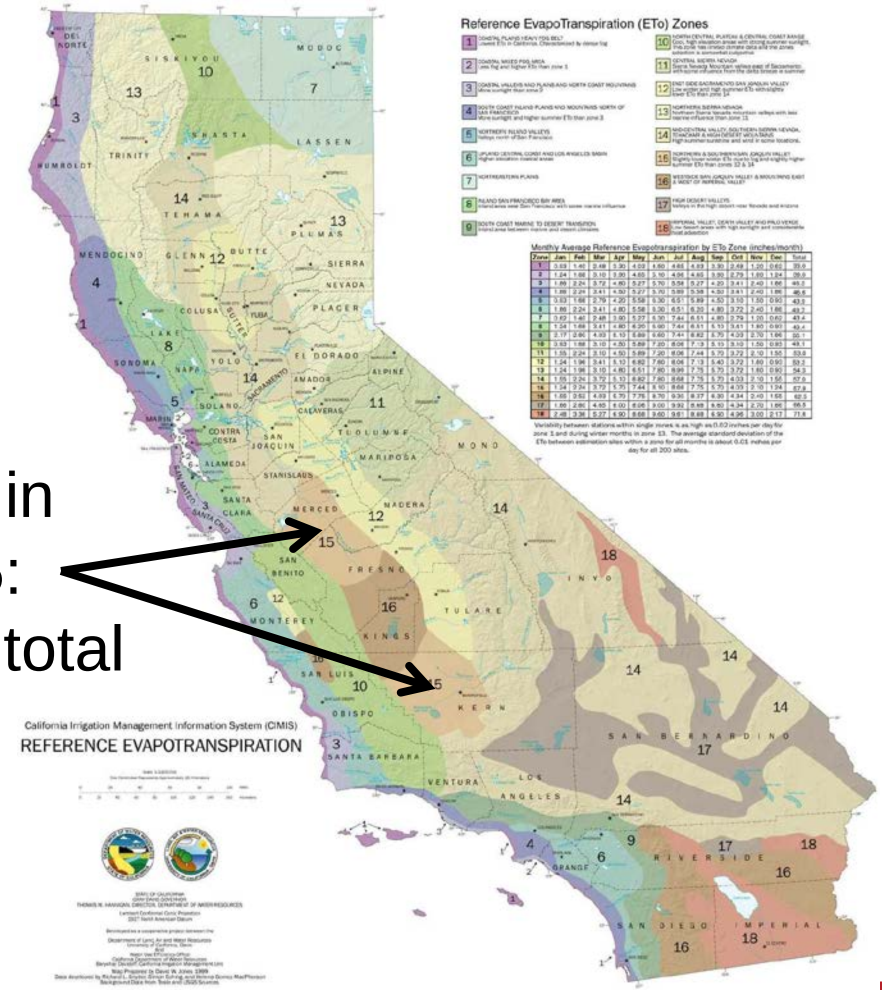
"C" pattern: Equal irrigation deficit all season



(Goldhamer et al., 2006)

Month	"/week
Feb	0.25
Mar	0.6
Apr	1.15
May	1.78
June	2.15
July	2.4
Aug	2.15
Sep	1.5
Oct	0.9
Nov	0.35
Dec	0.13

Almonds in
Zone 15:
53" season total



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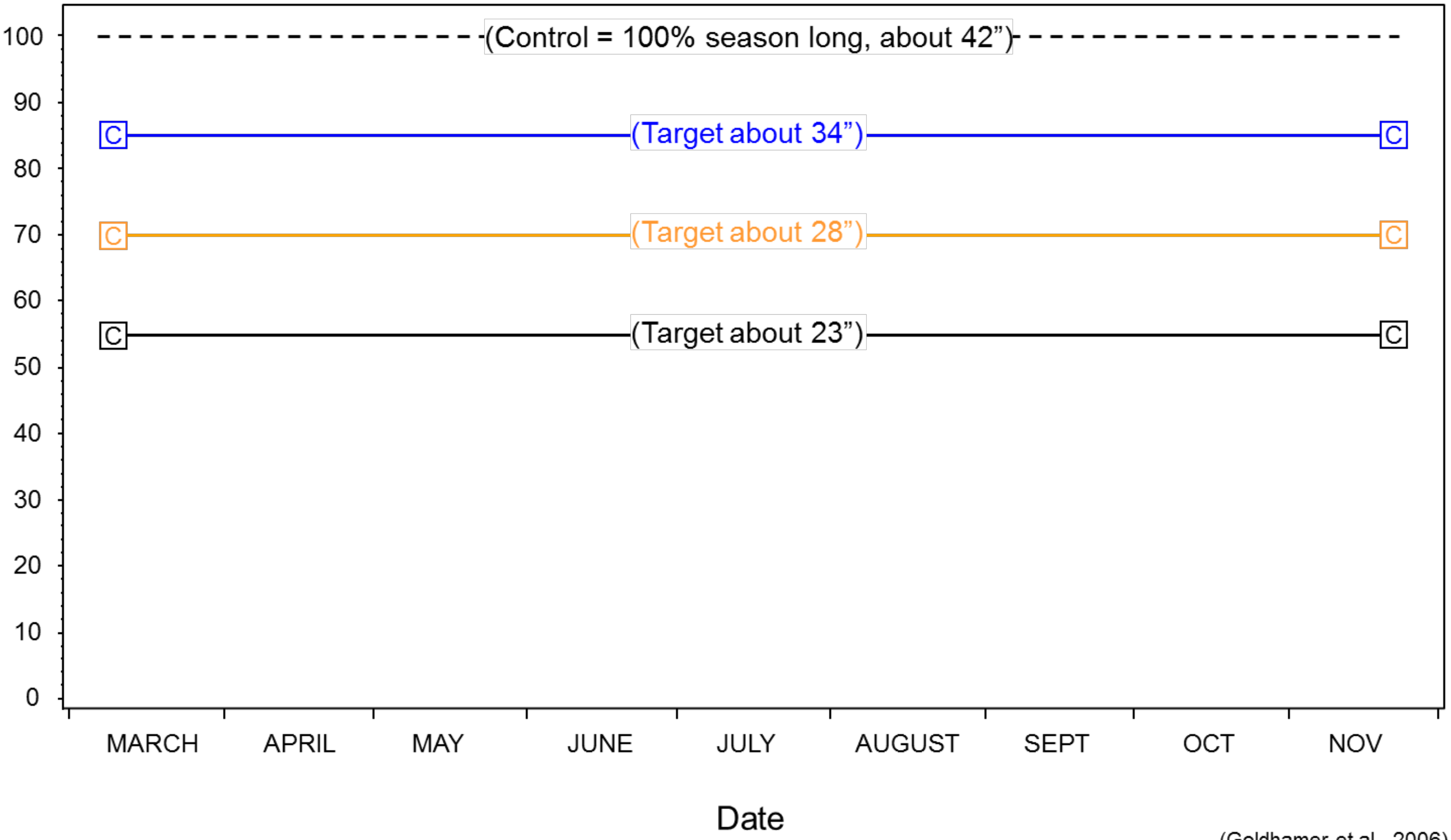
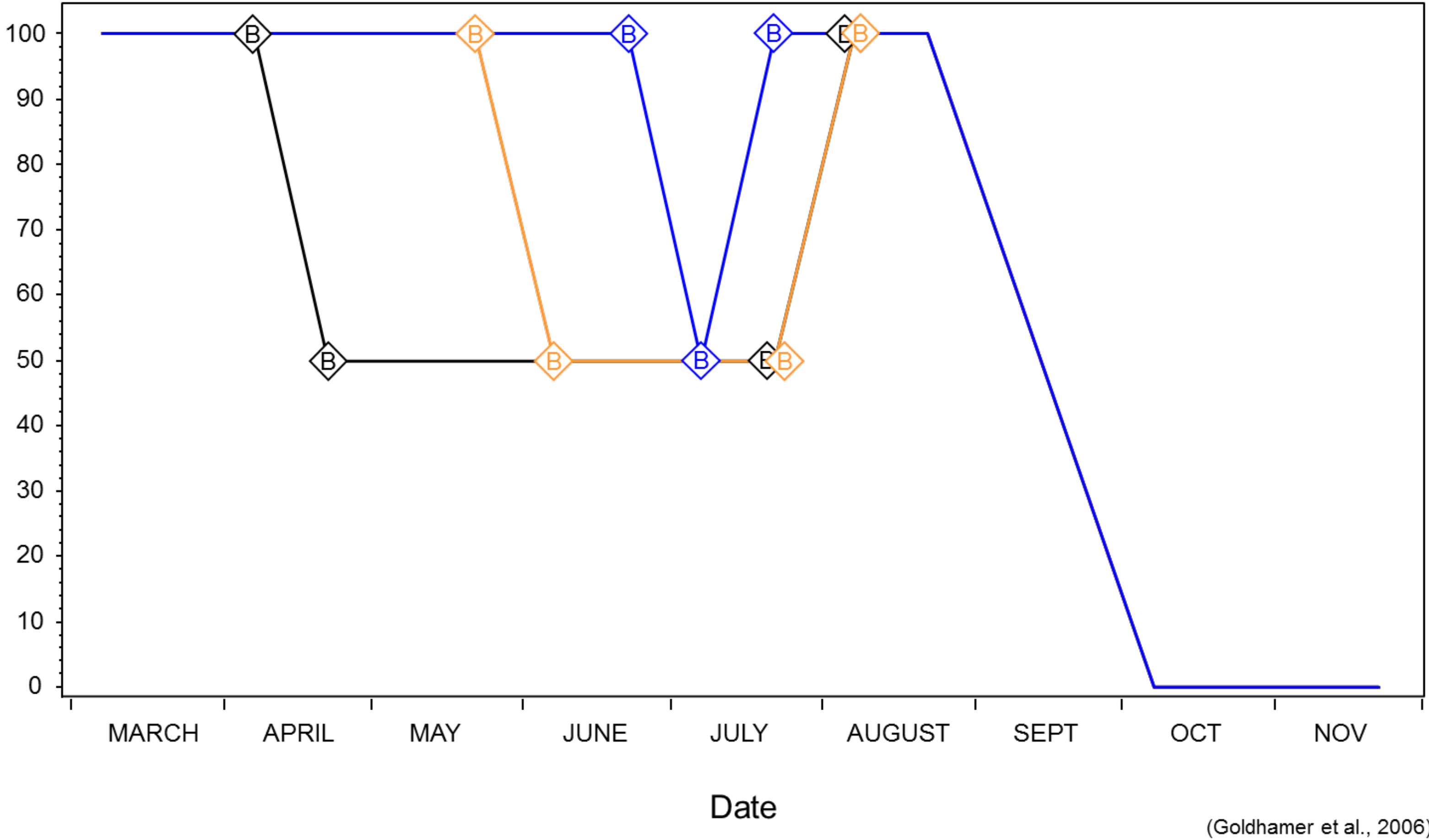
“C” pattern: Equal irrigation deficit all season



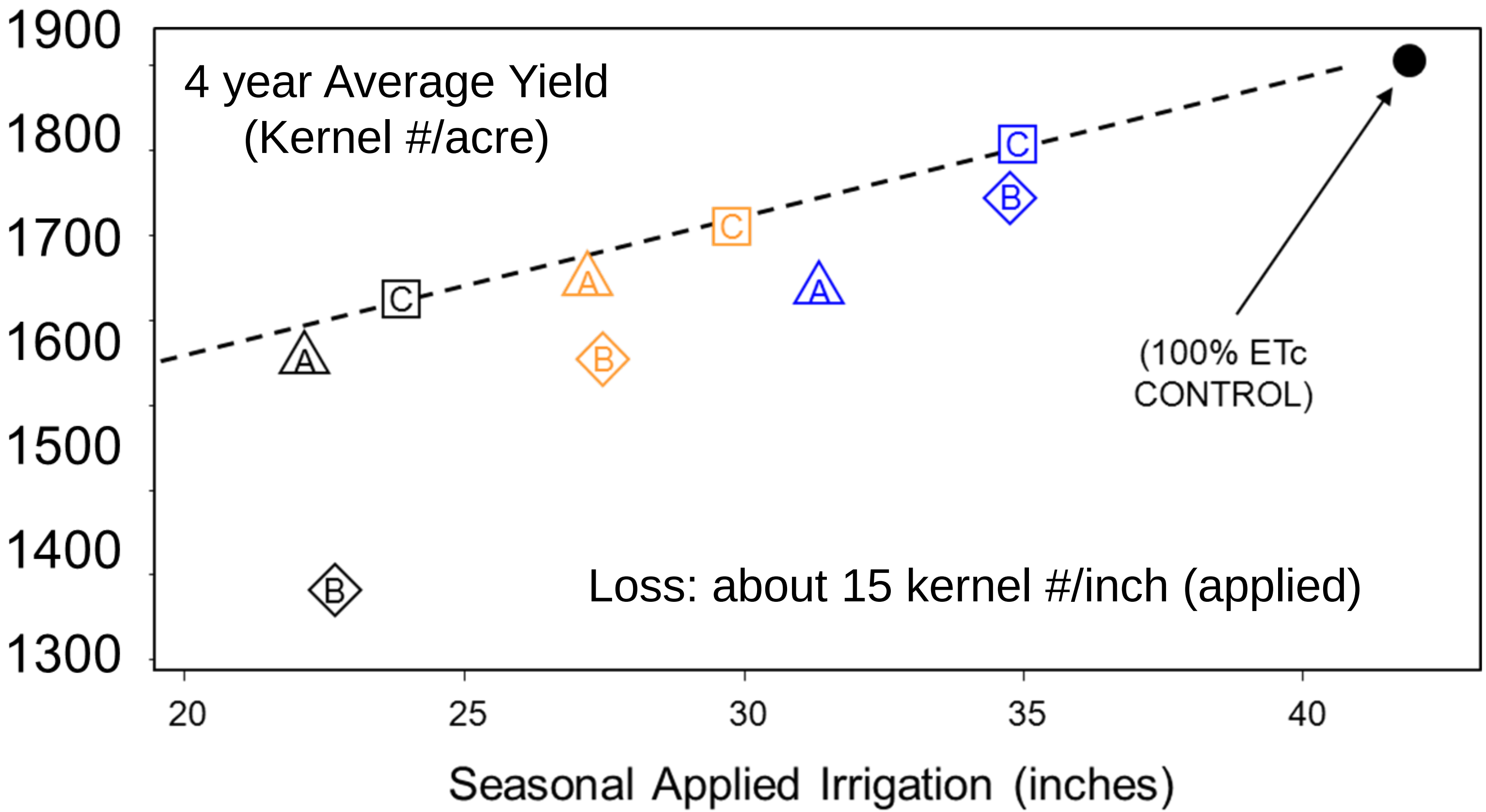
(Goldhamer et al., 2006)

“B” pattern: Some deficit early, most deficit post-harvest



(Goldhamer et al., 2006)

Result: an **even deficit** over the season always gave the best result.



(Goldhamer et al., 2006)

‘Severe Drought’ Study in almonds, 2009

- Main questions:

1) How much water does it take for an almond tree to survive?

2) Will application of small amounts of water (5”, 10”) over the season help?

3) Is there a critical level of tree water stress that will cause tree death or dieback?

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June 29, 2009

Control tree

- 9.8 bars SWP

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June 29, 2009

10” tree

- 25 bars SWP

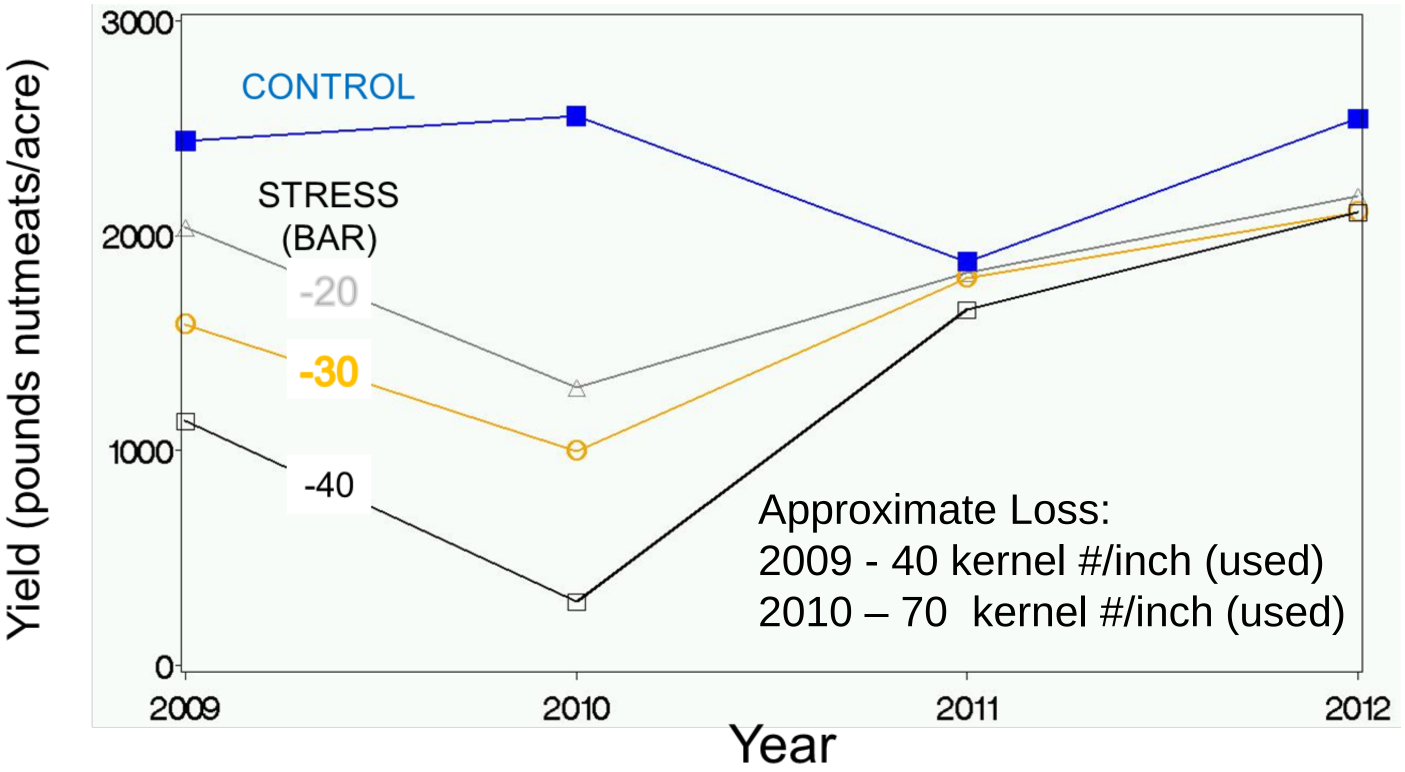
June 29, 2009

0” tree

- 40 bars SWP

This tree had reached -63 bars on July 14, 2009, and by July 28 was completely defoliated.
But notably, did not die!

Yield: The biggest reduction occurred in the year <u>following</u> the stress (i.e., carryover effect)

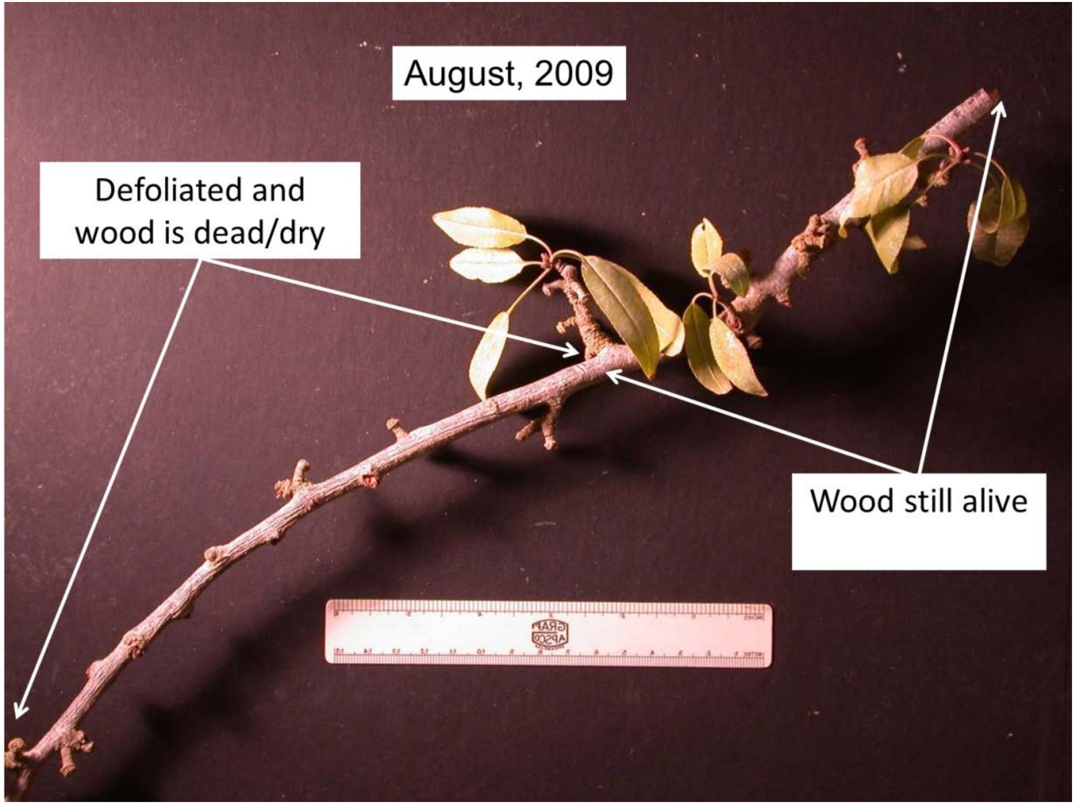


Additional treatments in the drought study: Canopy modification (pruning, spraying).

Year	Yield (pounds nutmeats/acre)	
	Non-modified	Pruned or P+S
2009	1030	730
2010	320	600
2011	1450	1170
2012	1540	1610
Average	**1080**	**1030**

Conclusion: Canopy reduction by 50% to 'help trees survive' does not help anything.

Other results relevant to severe stress: Minimal twig dieback was observed in 2009



In the worst case, dieback affected 20% of the canopy after 2 years (in 2011)

Other “interesting” symptoms of severe stress

- Re-sprouting in the fall when given some postharvest irrigation (by mistake).

- About 3 days of delay in full bloom the following spring.

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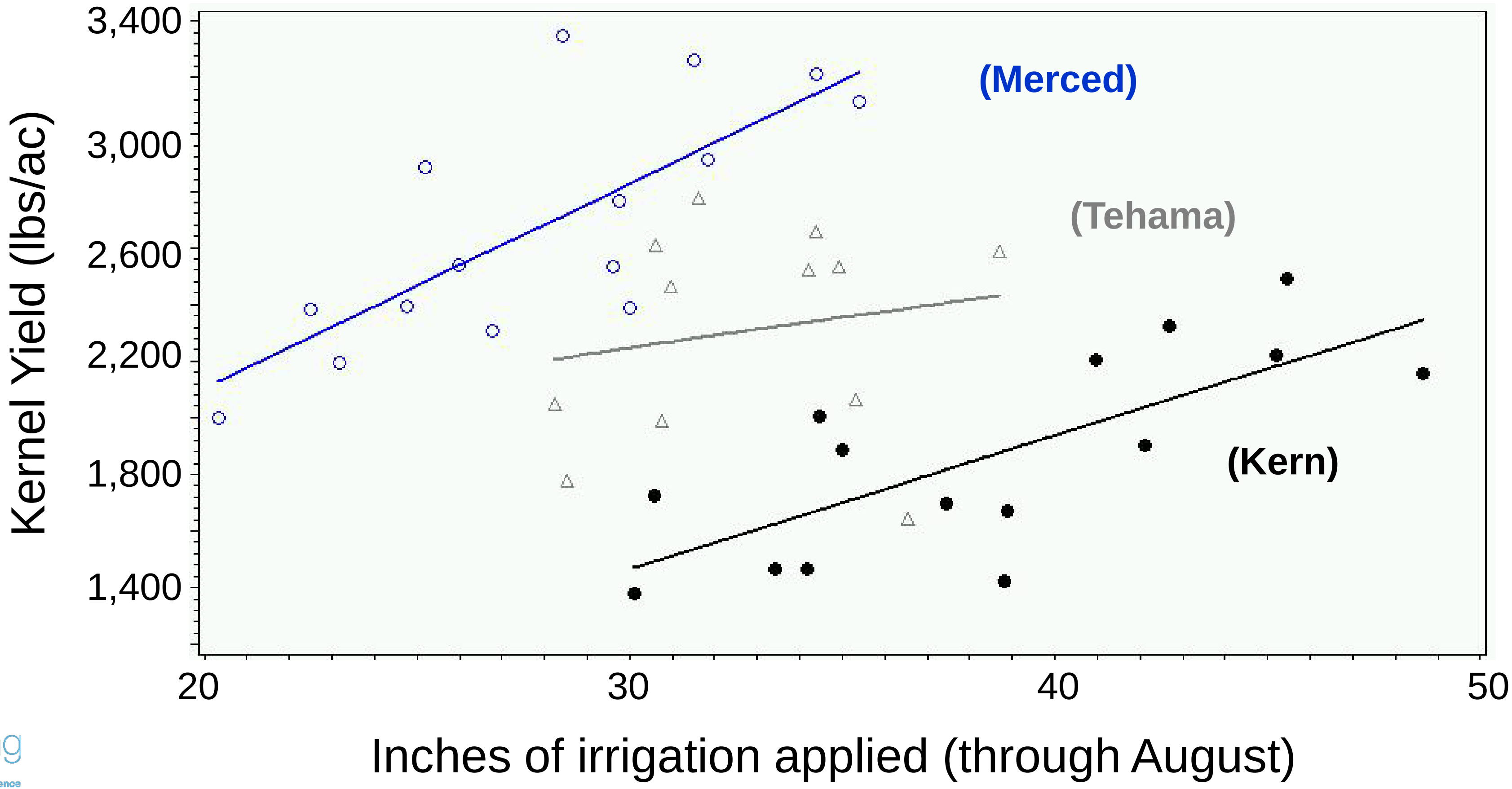
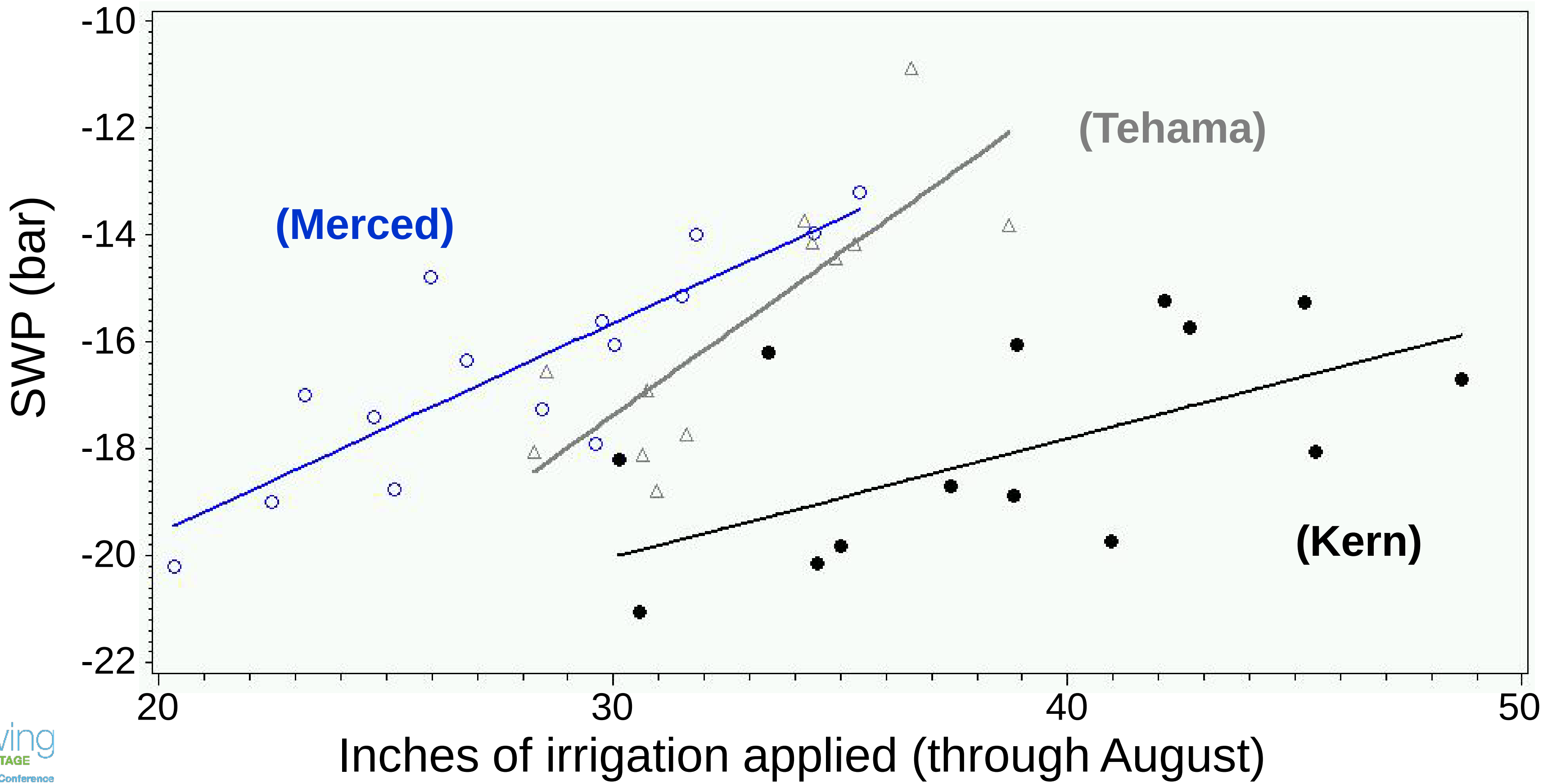
Water Production Function yields and SWP's: Year 2

From 20 to 70 kernel pounds per inch of applied water, depending on the site.



Water Production Function yields and SWP's: Year 2

Parallel differences in SWP may indicate why.



An issue we don’t have much (any?) data on:
The need for WINTER IRRIGATION

THE

Agricultural Journal

OF THE CAPE OF GOOD HOPE.

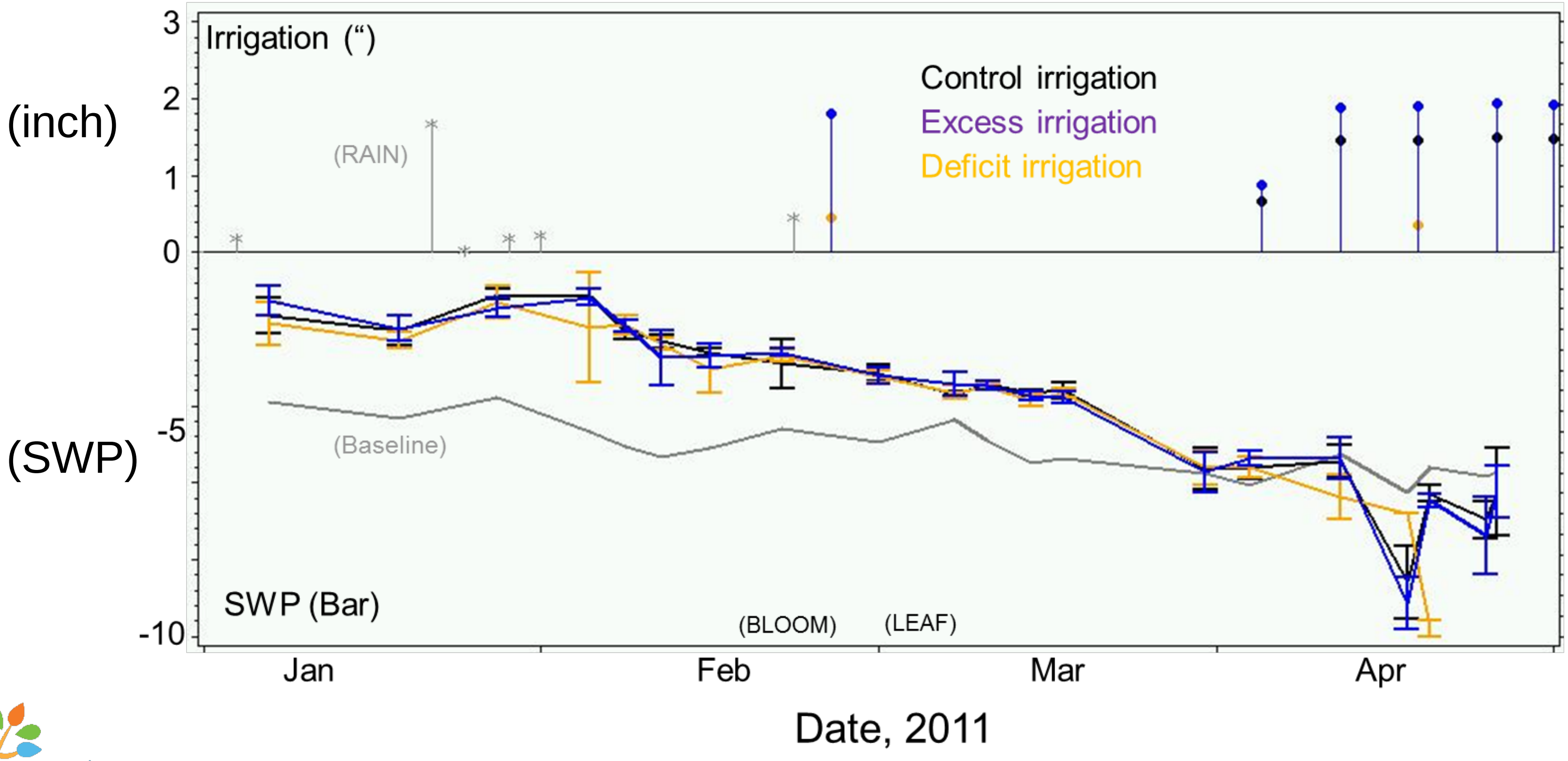
No. 6.	JUNE, 1907.	VOL. XXX.

?

“They require only so much moisture from the ground as may serve to keep their tissues in a normal healthy state, and prevent mischief or death by their younger parts transpiring more than they receive.”

(E.P., 1907).

Dormant shoot SWP in Kern Co. following a very wet 2010 December



(Sebastian Saa Silva et al, unpublished)

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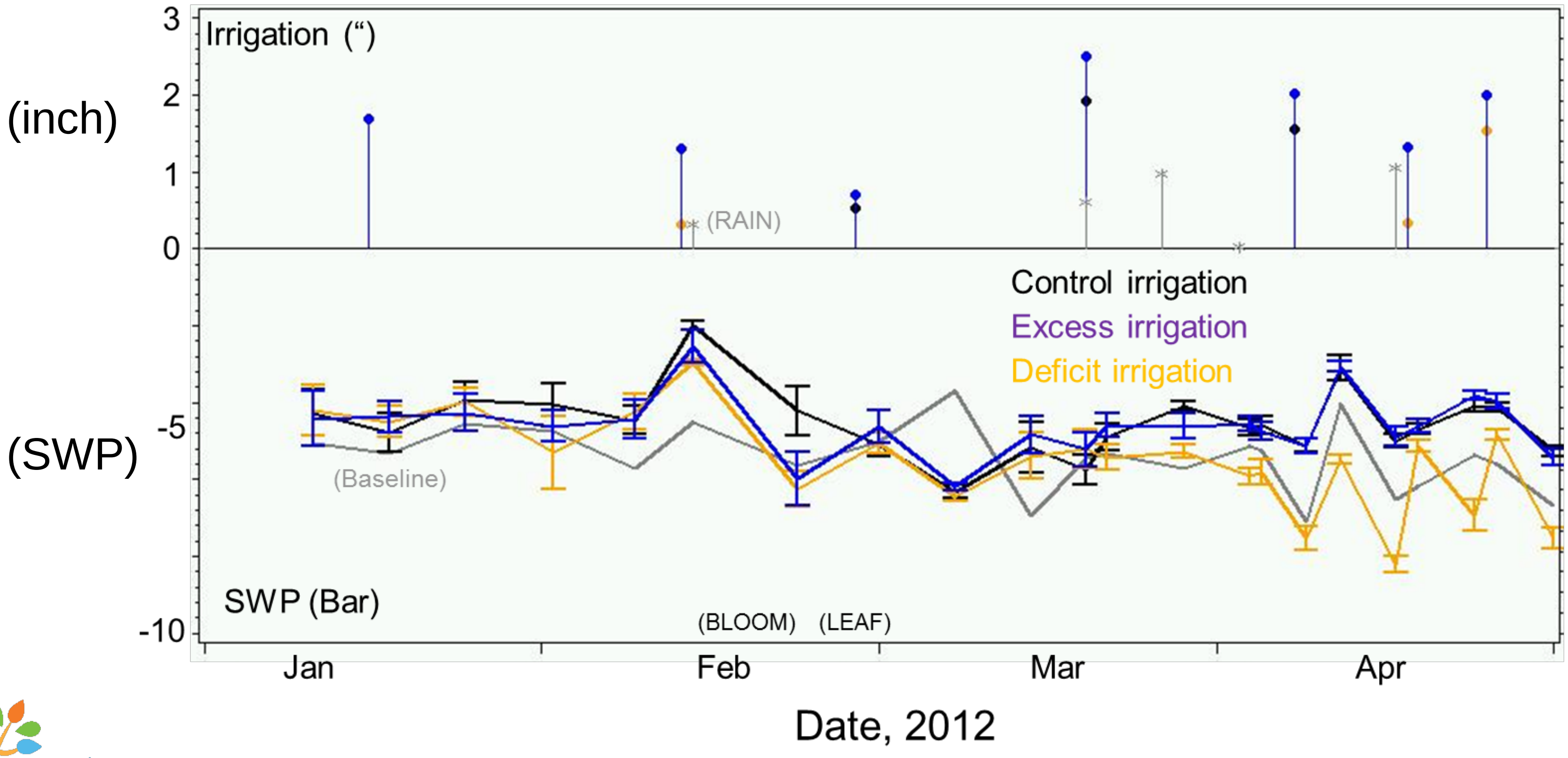
Dormant shoot SWP in Kern Co. following a very dry 2011 December



(Sebastian Saa Silva et al, unpublished)

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Take home points: dealing with a drought

1) Control weeds to save stored soil water
2) "Slow and steady" appears to win the race – irrigate with a constant fraction of ET throughout the season (whatever you can afford, even small amounts of water will help)
3) Almonds can survive severe stress with minimal dieback, but carryover effects on bloom and set will have a substantial effect on next years yield
4) Pruning/whitewash sprays appear to have no beneficial effect
5) Almonds do respond to water during dormancy, but we don't yet know how much stress is needed to impact yield. Our best guess at this point: wait until 3-4 weeks before bloom and if it hasn't rained, fill soil profile to 2ft. If rains follow, there will still be room for water.

Thanks for your attention and support

THANK YOU!