Almond Spur Dynamics- Maintaining Orchard Productivity

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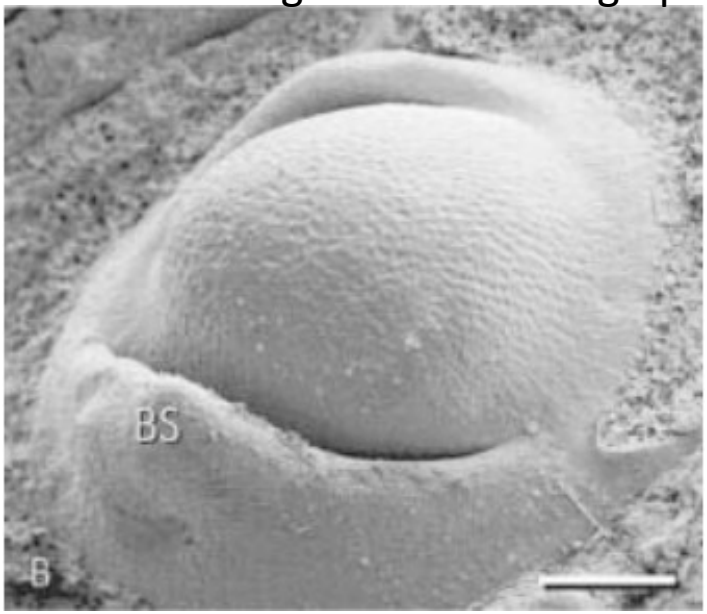
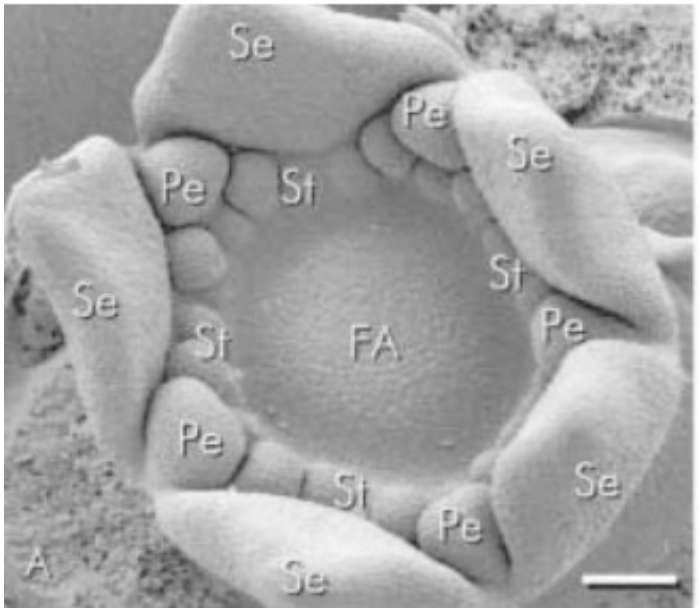
What is a spur?

A short proleptic shoot that can have both leaves and flowers.

The buds for a proleptic shoot were formed during the <u>previous summer</u> as were the flower primordia

Scanning electron micrographs of an almond flower bud





Br = bract
Bs = bud scale
FA = floral apex
Pe = petal
Se = sepal
St = stamen

Stage 1

Stage 6

Stage 1 occurs just after initiation of hull split and stage 6 is complete by the completion of hullsplit

J. Amer. Soc. Hort. Sci. 126(6):689–696. 2001.

Almond Flower Development: Floral Initiation and Organogenesis

Bridget M. Lamp,[1] Joseph H. Connell,[2] Roger A. Duncan,[2] Mario Viveros,[2] and Vito S. Polito[3]
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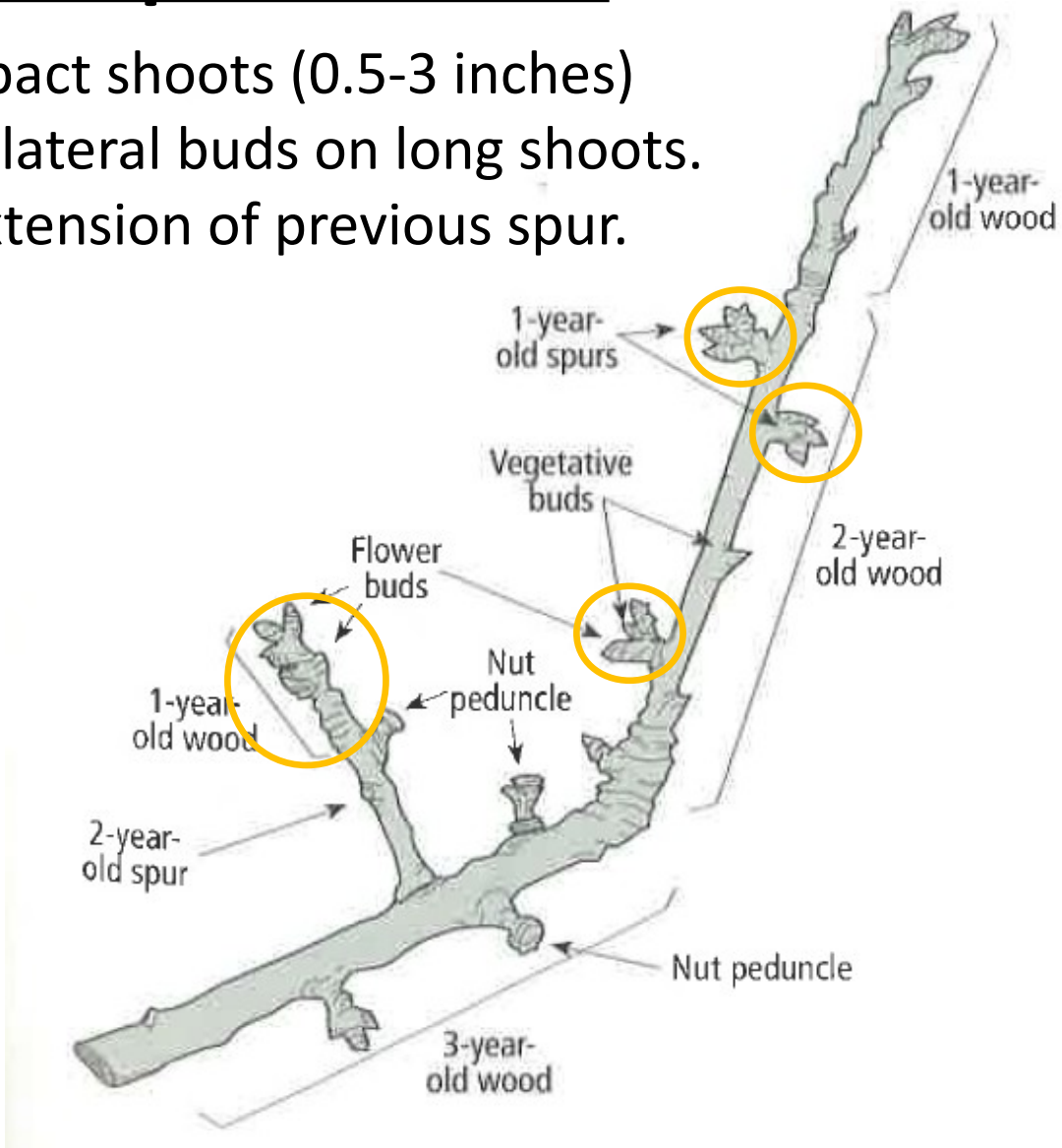
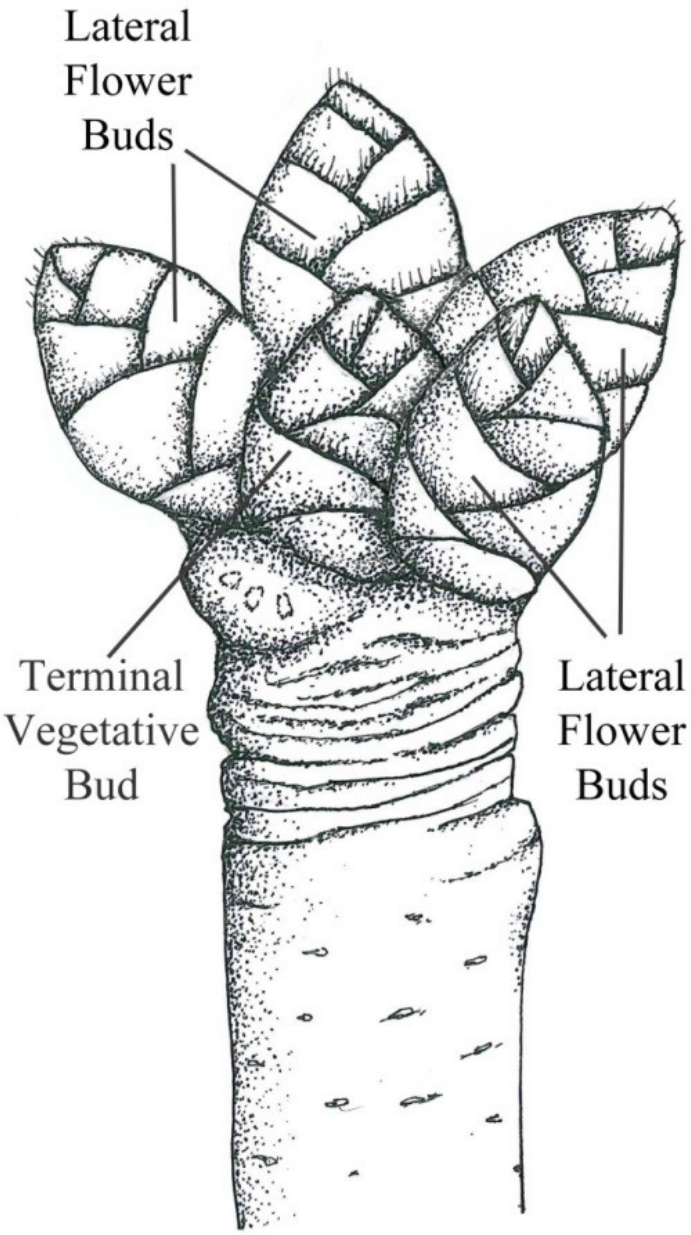
Where are spurs borne?

- Short/compact shoots (0.5-3 inches)
- Grow from lateral buds on long shoots.
- Terminal extension of previous spur.

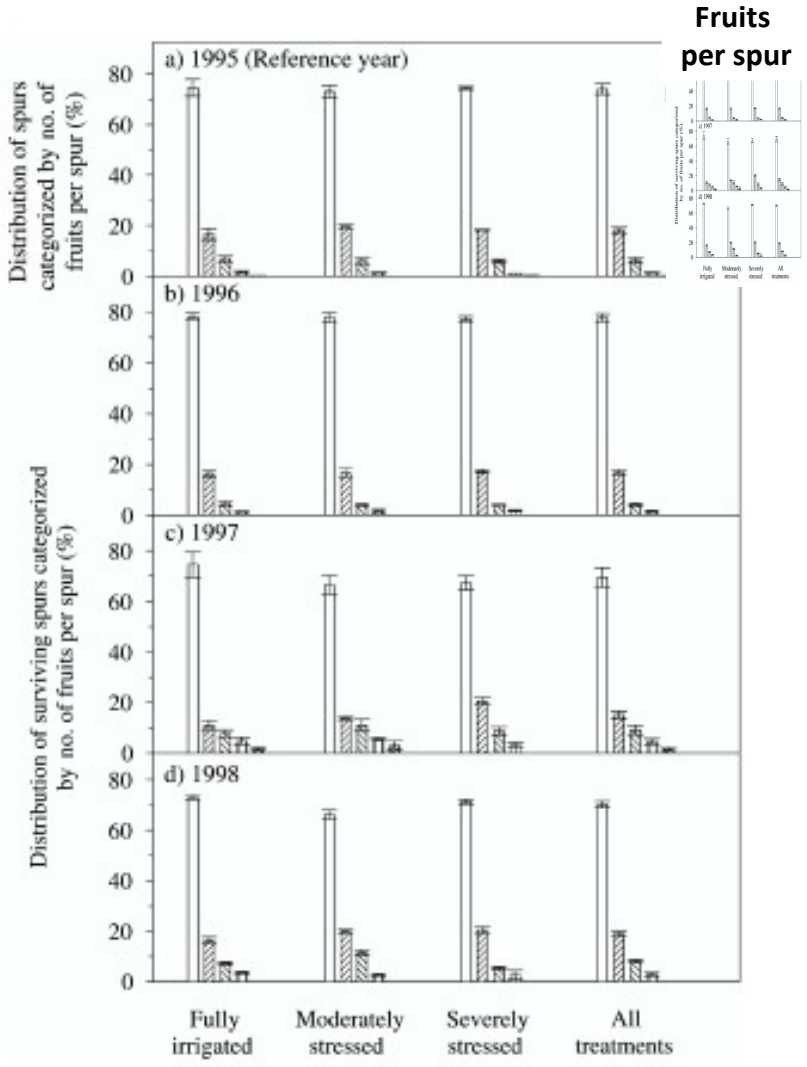




Thanks to Heather Hartzog, USDA Aphis and Elizabeth Fitchner (UCCE Tulare County) for this image

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

G. ESPARZA,[1] T. M. DEJONG,[2,4] S. A. WEINBAUM[2] and I. KLEIN[3]

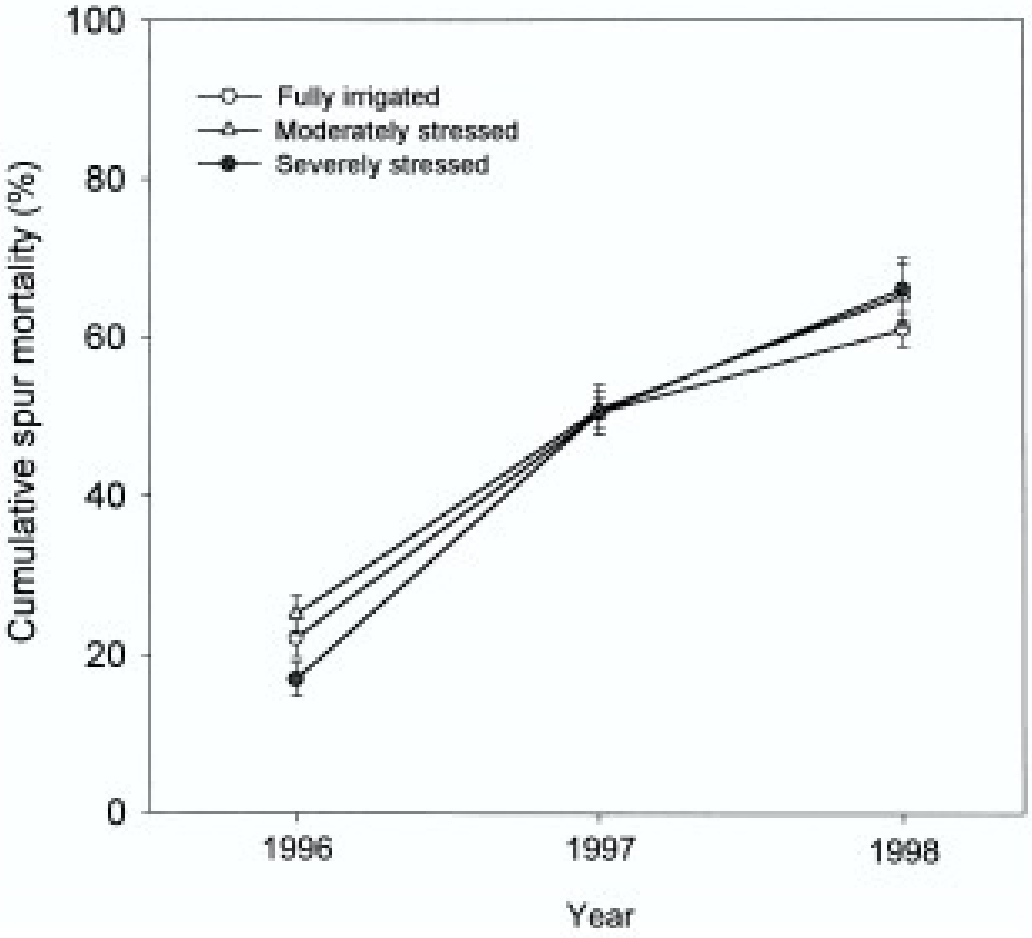


Fruits per spur

Three irrigation treatments

- Fully irrigated
- Moderately stressed
- Severely stressed

Spur mortality over the three years of the Esparza et al. study.



Little effect of irrigation on spur mortality but 66% of spurs had died after 3 years

Main impact of stress was on vegetative growth

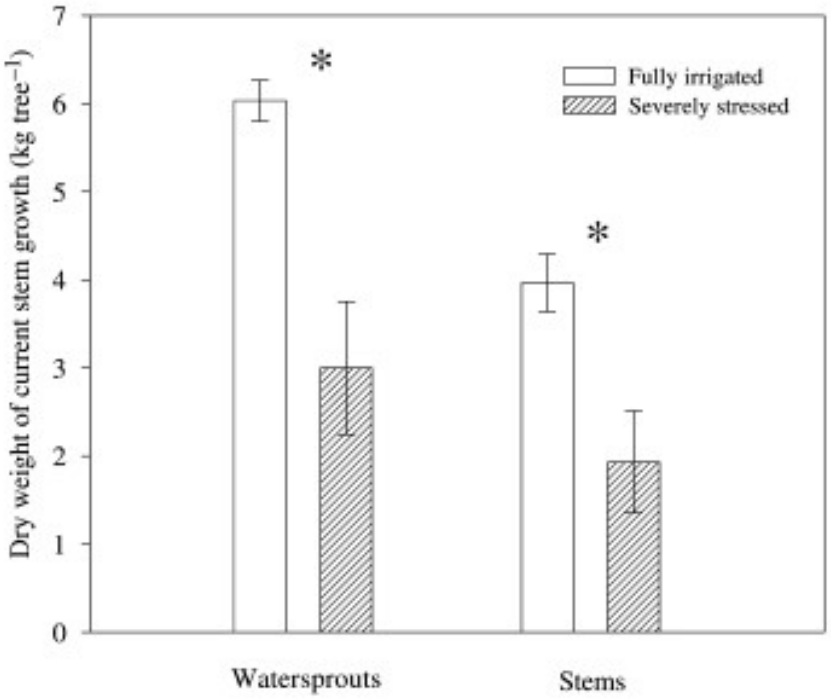
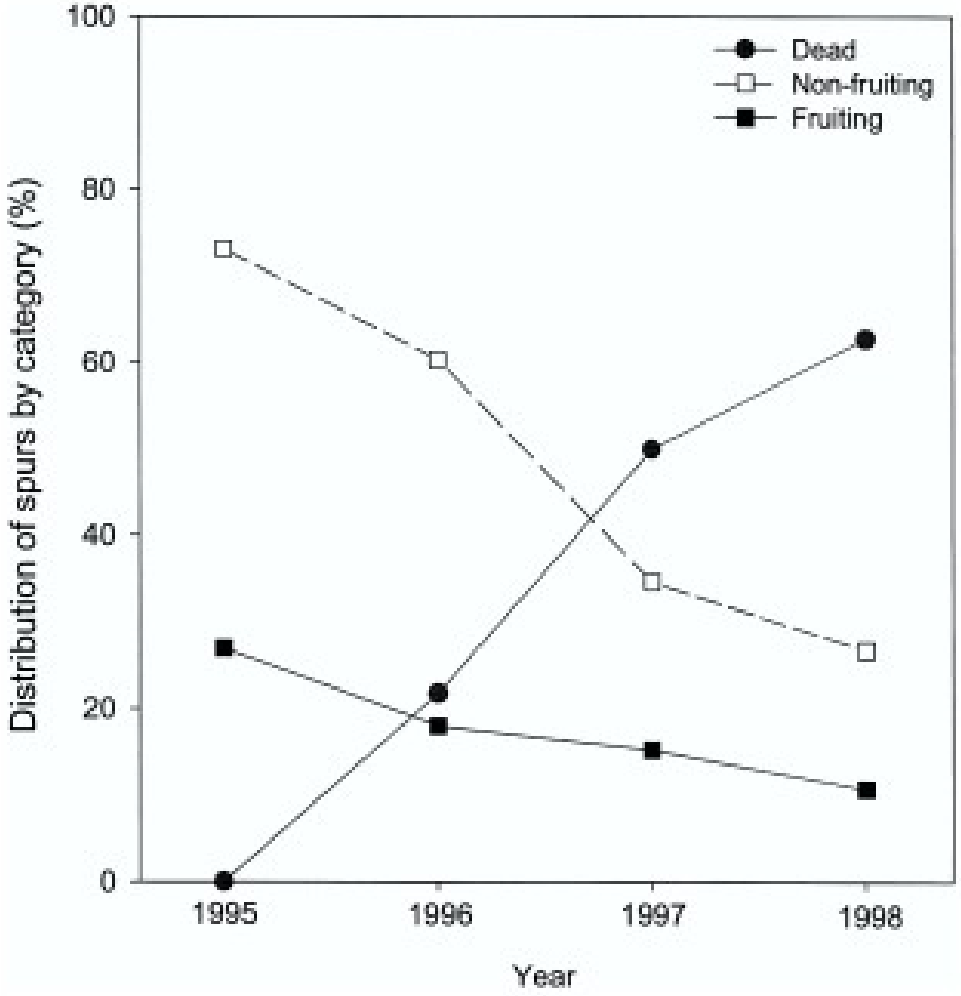


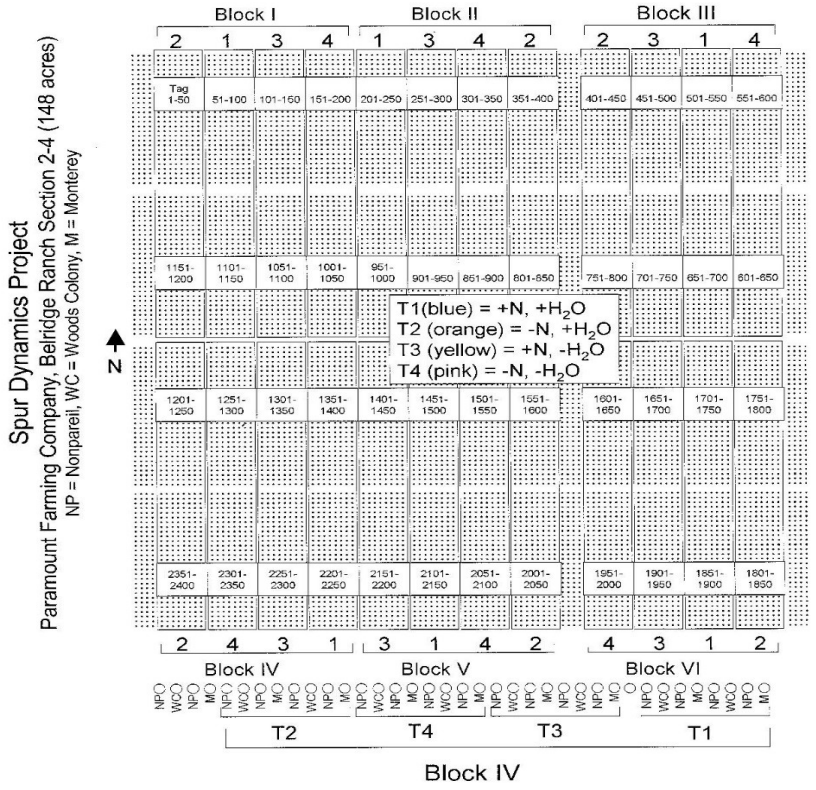
Figure 8. Effects of water stress on tree stem and sprout growth (kg_{dw} $tree^{-1}$) of cv. Nonpareil almond trees. Irrigation treatments began during the summer of 1995 and were repeated during the 1996 and 1997 summers. Bars represent the standard errors of the mean of three entire trees. Asterisks represent statistical differences according to the *t*-test ($P < 0.05$).

The results of the Esparza study provided the motivation for the Spur Dynamics Study that we initiated in 2001.



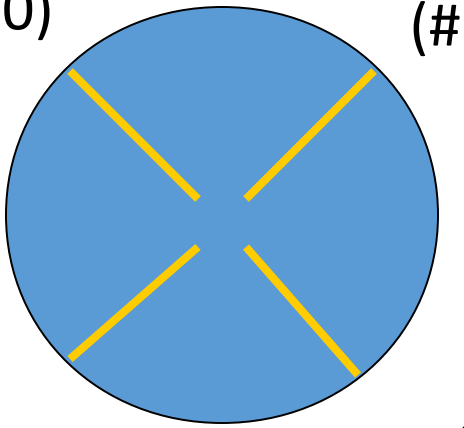
Spur Dynamics Study 2001-2009

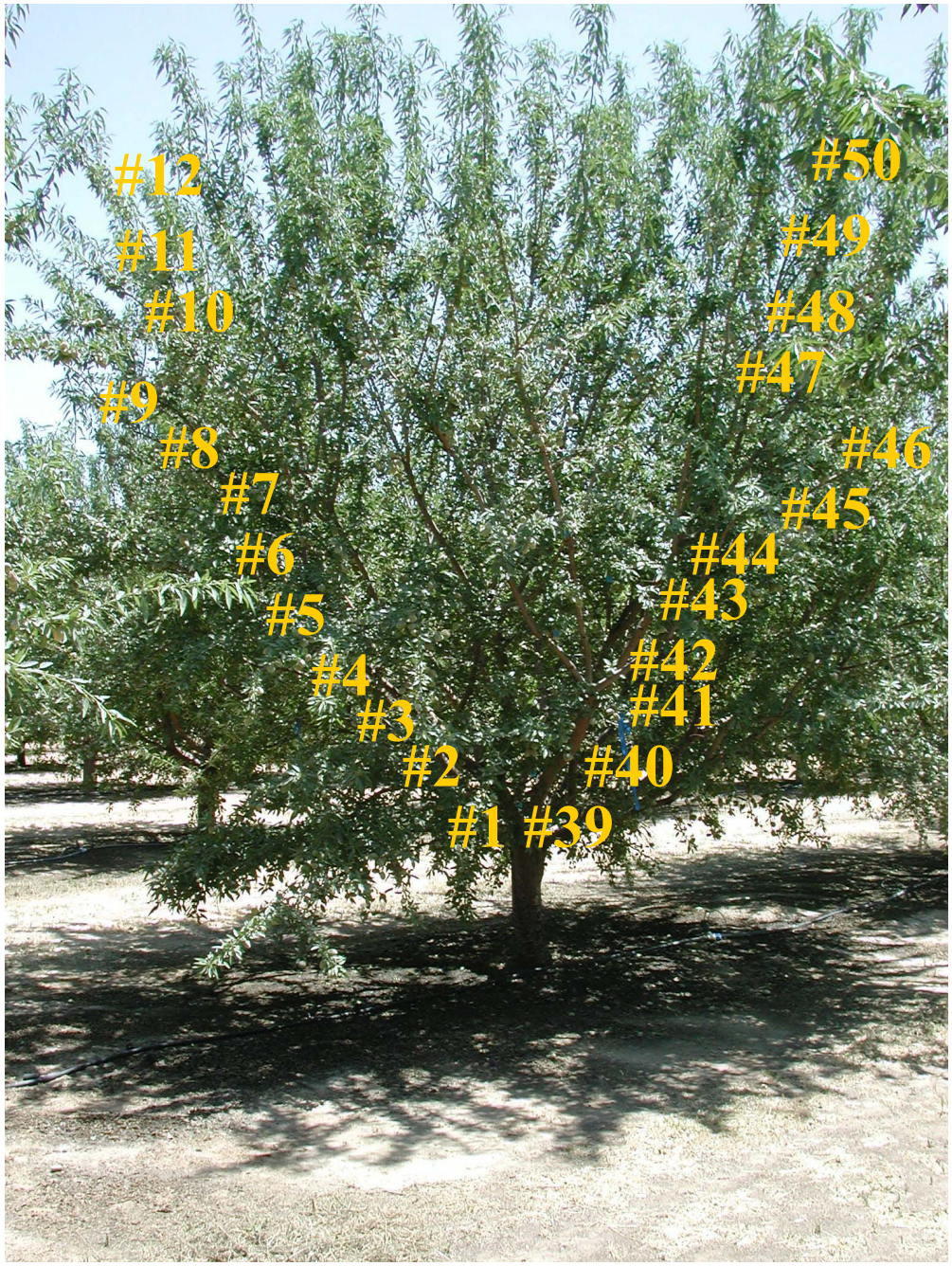
- Western Kern County
- 5 year old orchard
  - 146 acres
  - 37 acres per treatment
- Nonpareil, Monterey and Wood Colony
- Spacing
  - 24’ between rows
  - 21’ within row



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

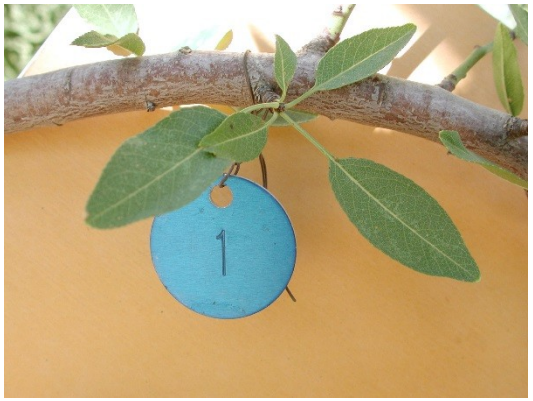
Top View





·Tagged spurs were followed over 7 years to determine treatment effects on spur longevity and productivity

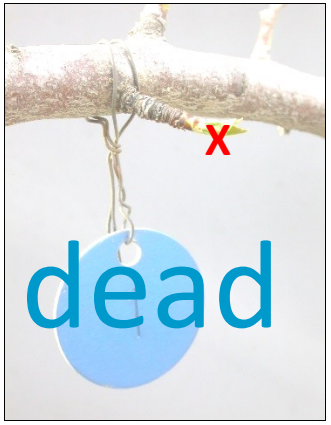
May 1, 2001



Oct. 3, 2001

Jun 24, 2002

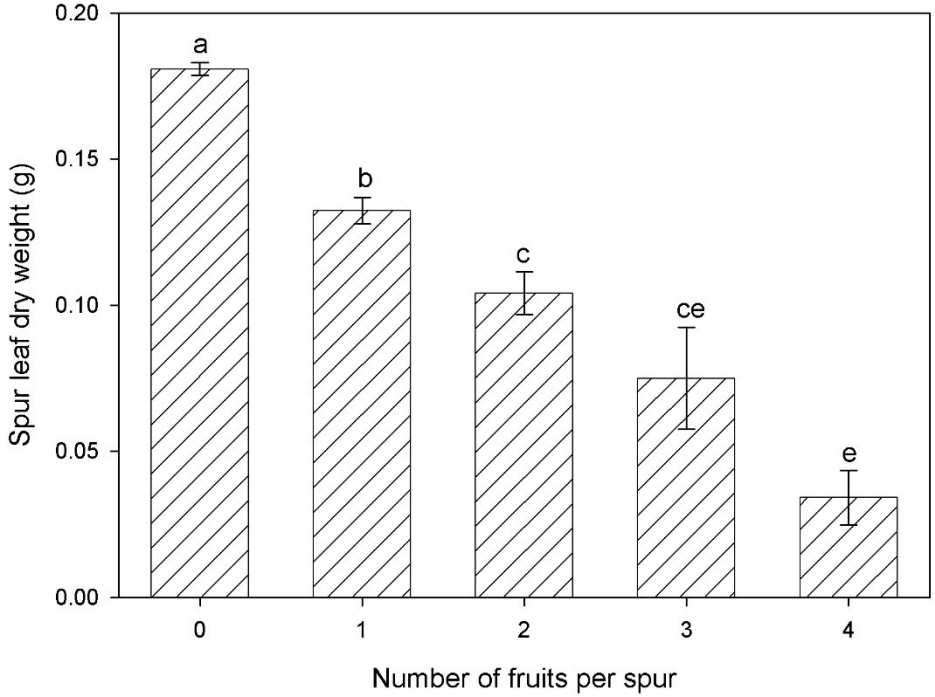
Feb 15, 2005



Feb 2006

Managing an almond orchard can be seen as managing a collection of spurs

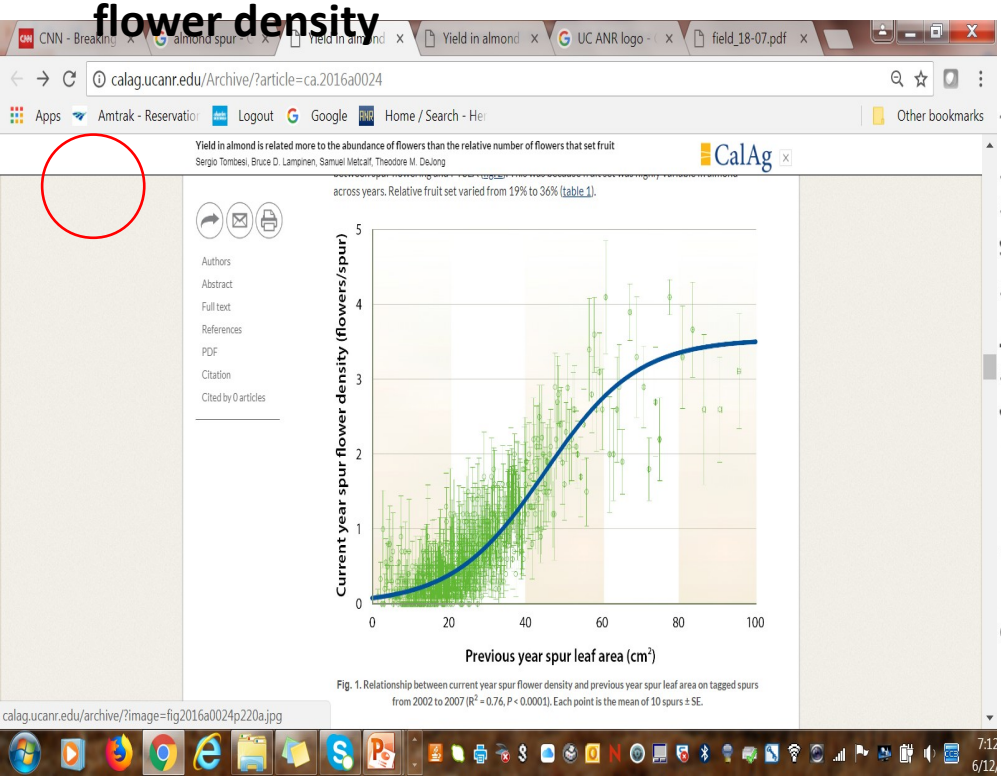
- A spur that flowers one year has a very low probability of flowering the next year since increased spur set decreases current year leaf dry weight



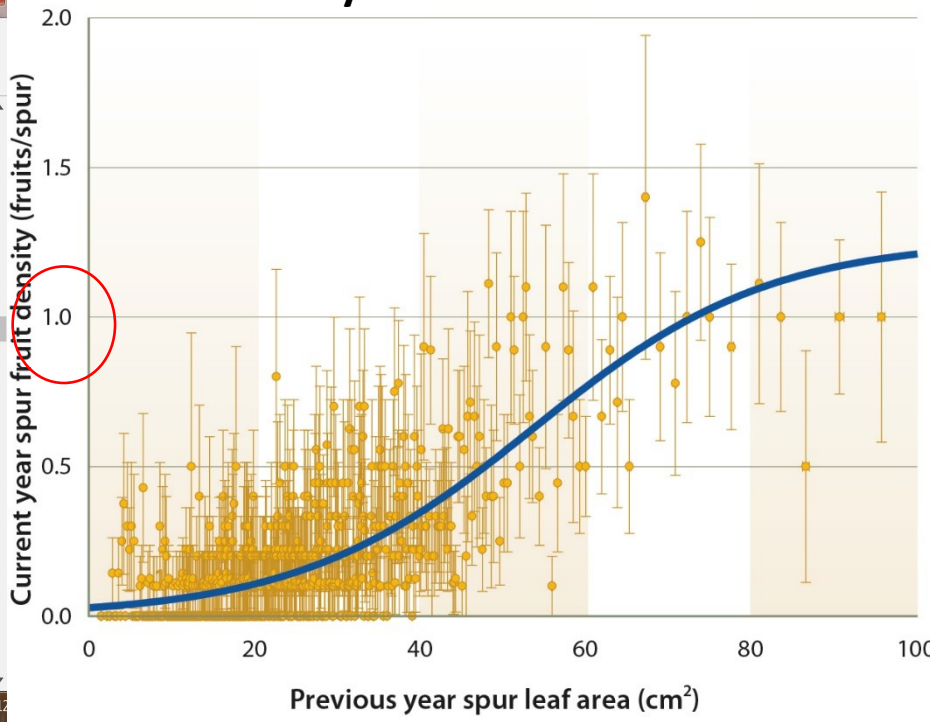
Mature almond trees produce >80% of total yield on spurs

Floral Density and Fruit Density on Spurs is positively related to prior year spur leaf area

Current year spur flower density



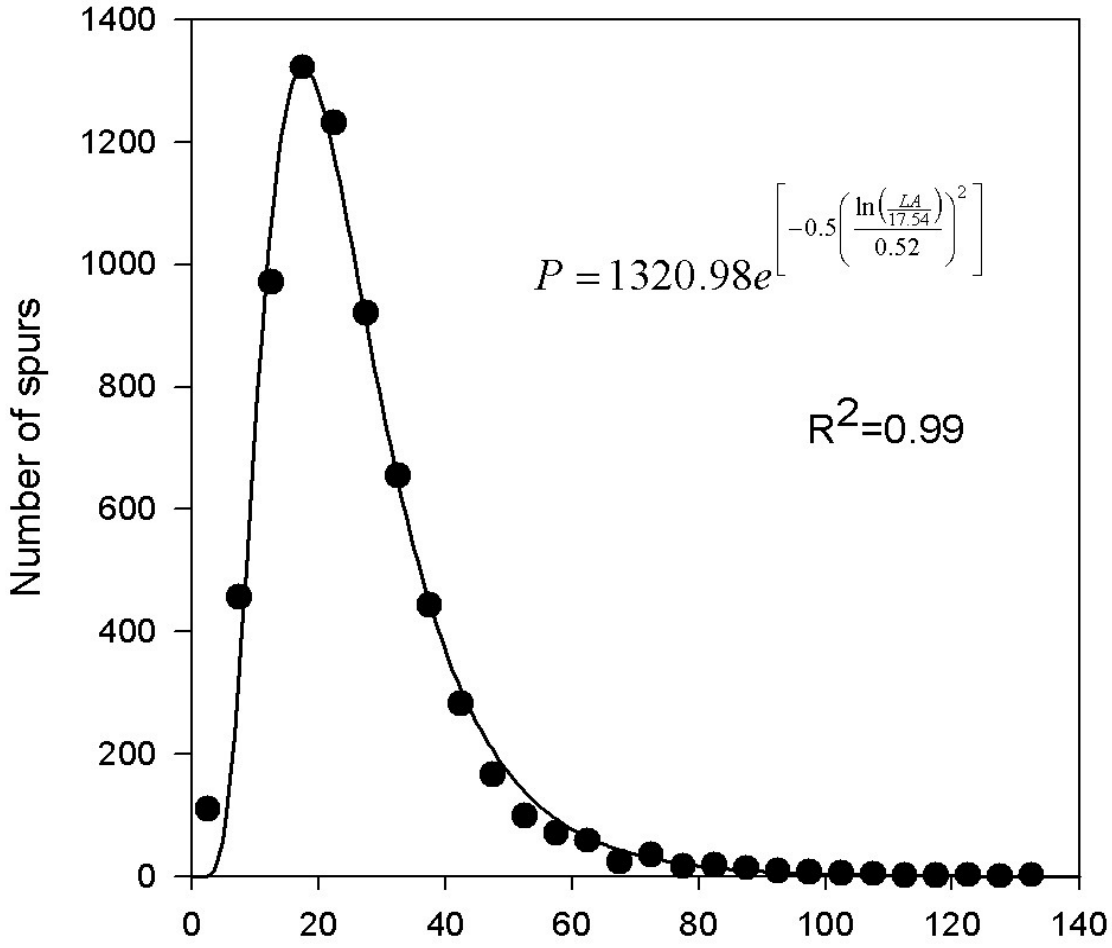
Current year spur fruit density



Previous year spur leaf area

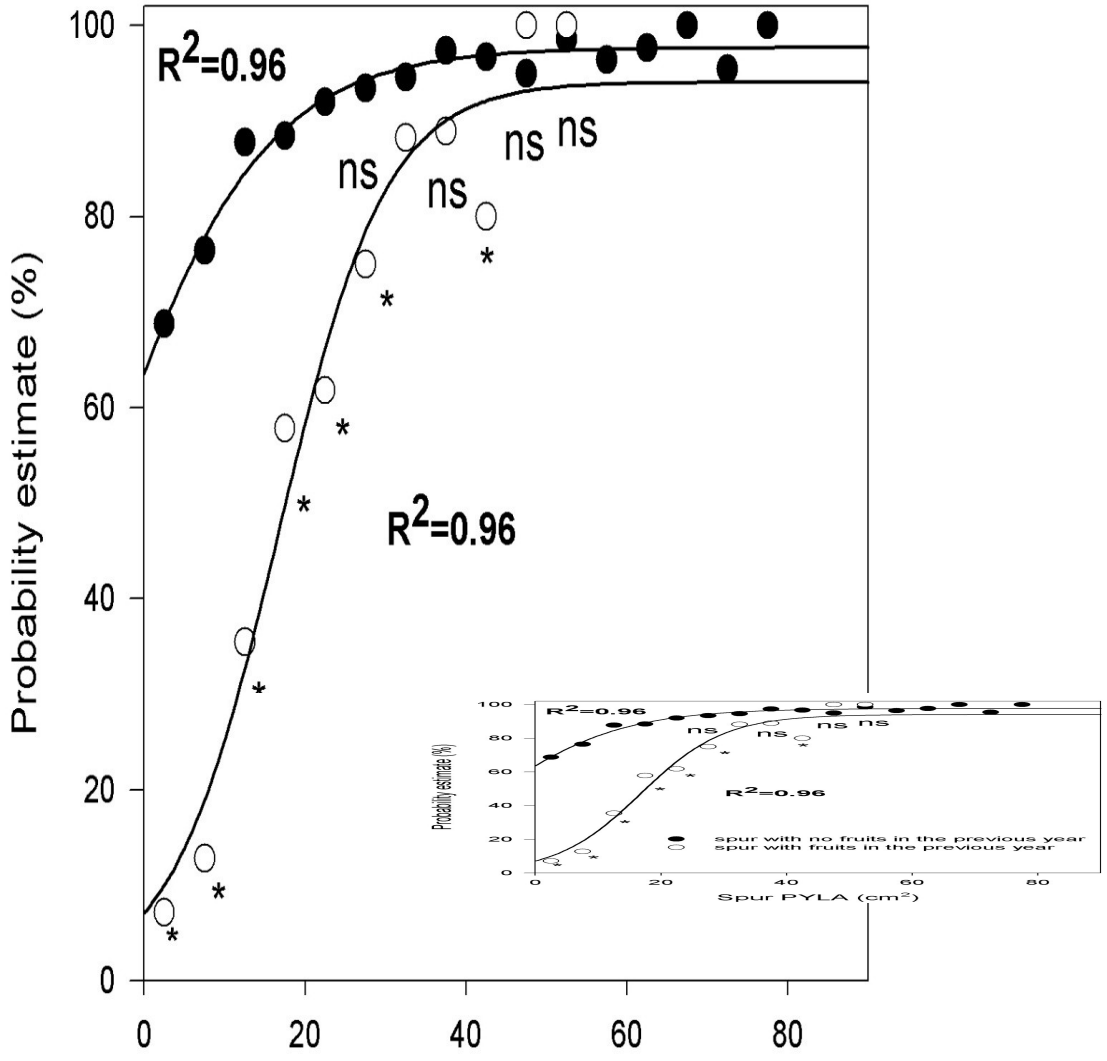
Tombesi, et al. 2016

Spur distributions with respect to their previous year leaf area

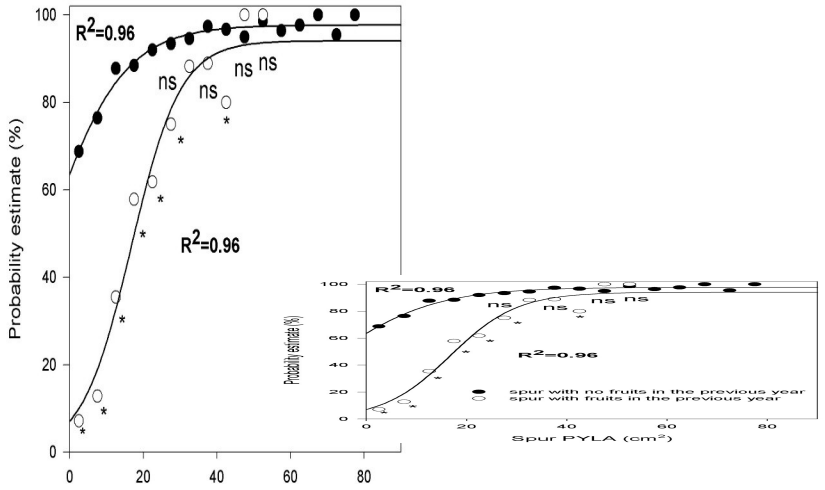


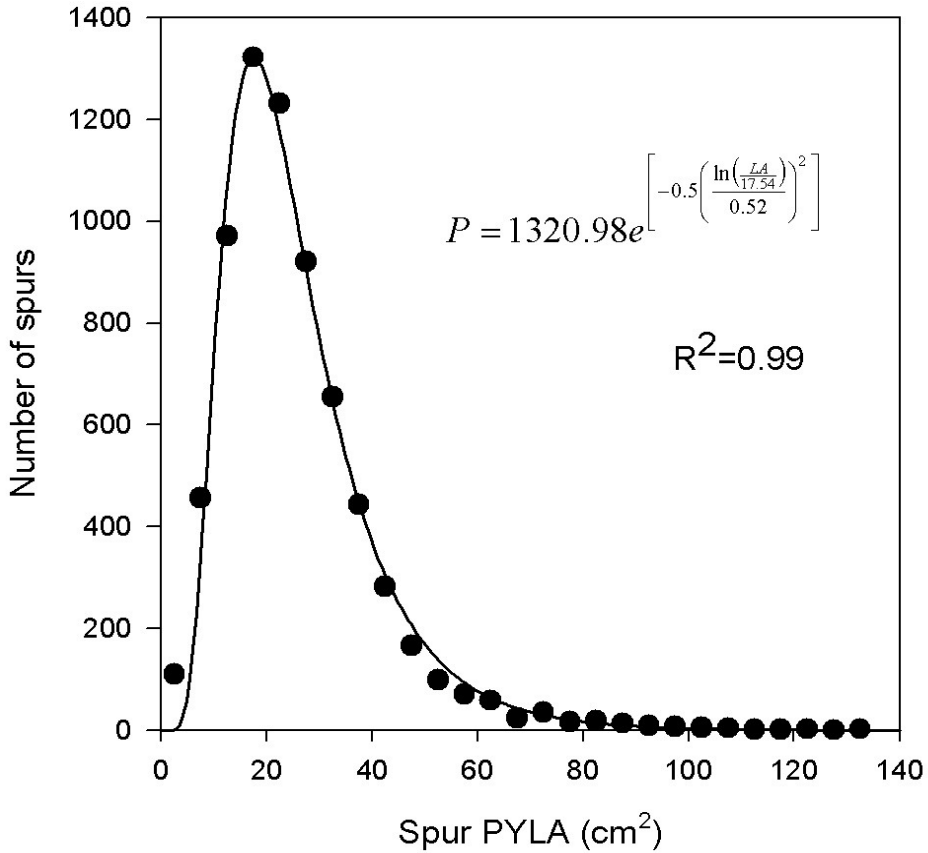
Spur previous year leaf area (cm2)

(20 cm2 is equal to about 3 square inches)

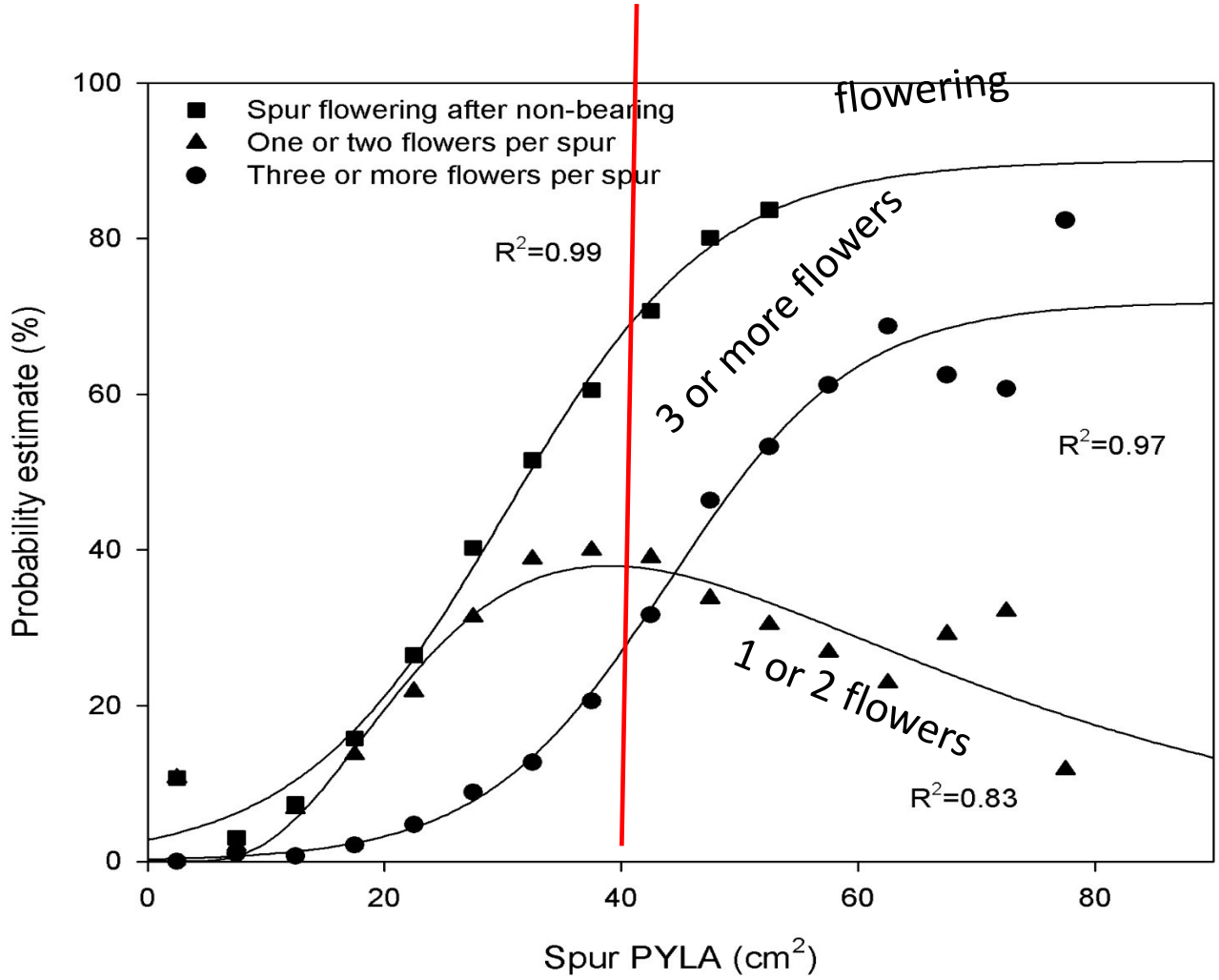


Spur previous year leaf area (cm2)


Probability estimate (%)
R^2=0.96
ns
ns
ns ns
R^2=0.96
Spur with no fruits in the previous year
Spur with fruits in the previous year
Spur PYLA (cm²)


Number of spurs
$P = 1320.98e^{\left[-0.5\left(\frac{\ln\left(\frac{LA}{17.54}\right)}{0.52}\right)^2\right]}$
R^2=0.99
Spur PYLA (cm²)

Spurs with greater than 40 cm2 (6 square inches) of leaf area in the prior year have over 80% probability of flowering in the current year.

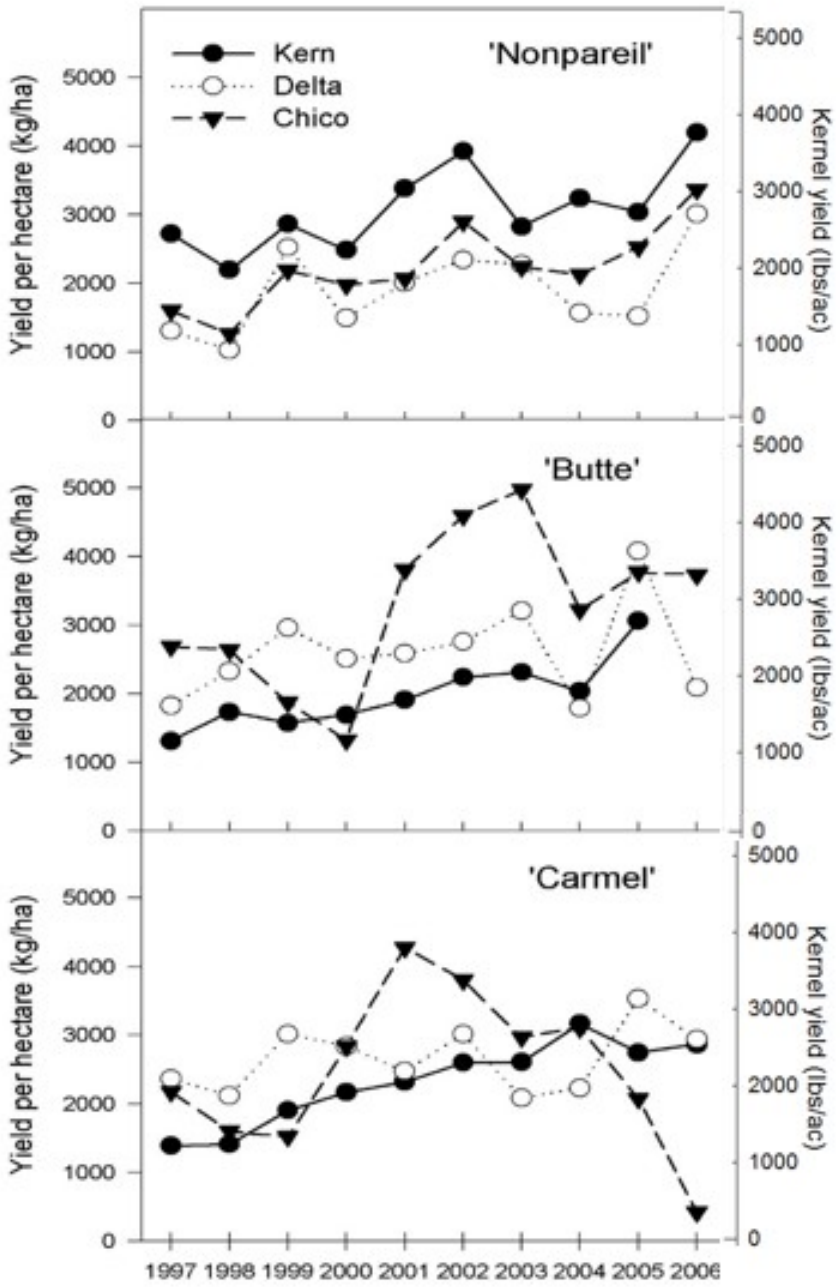


Are almonds alternate bearing?

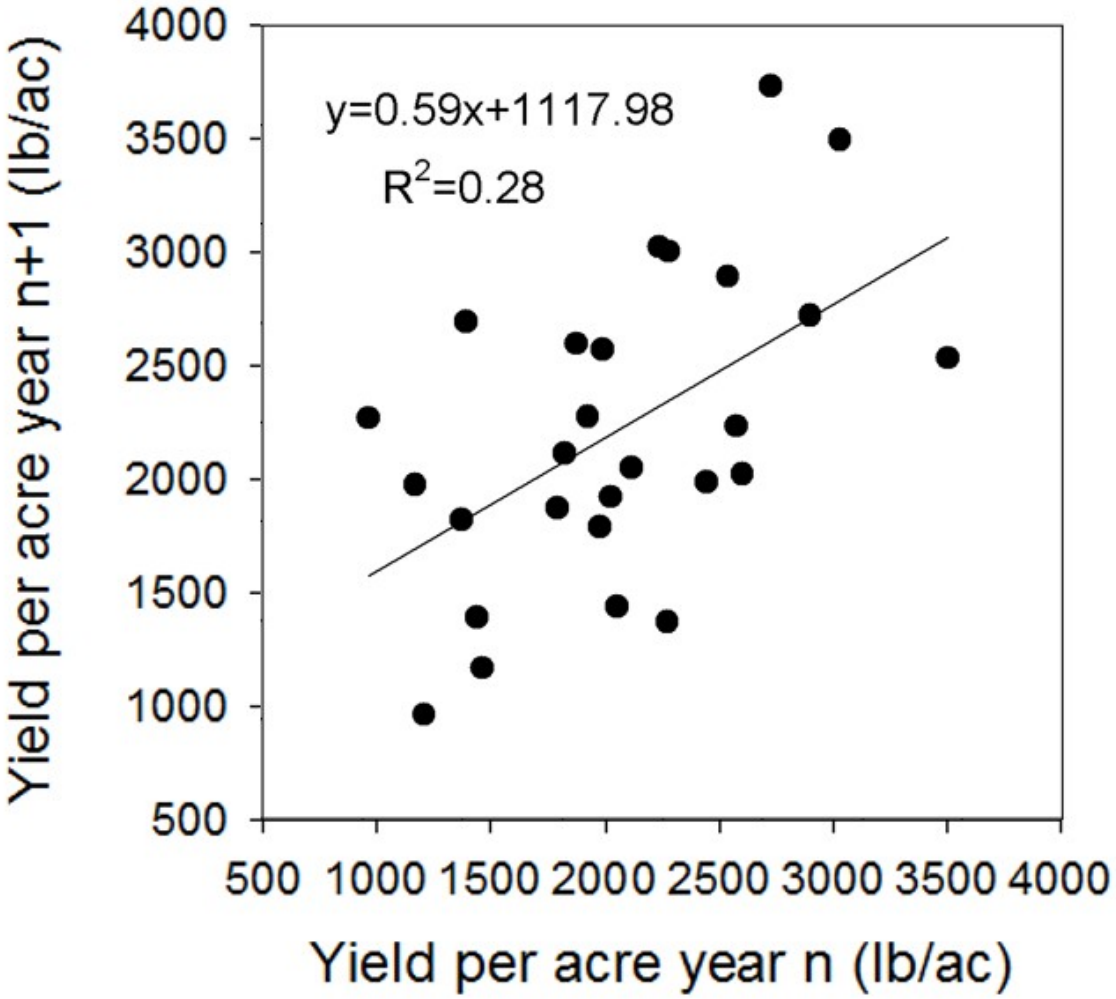
Regional Variety Trial Data

Yield trends from 1997 to 2006 in Chico, Delta and Kern orchards for ‘Nonpareil’, ‘Butte’ and ‘Carmel’.

Some trends toward alternate bearing in some cultivars and locations but the patterns are not very clear.

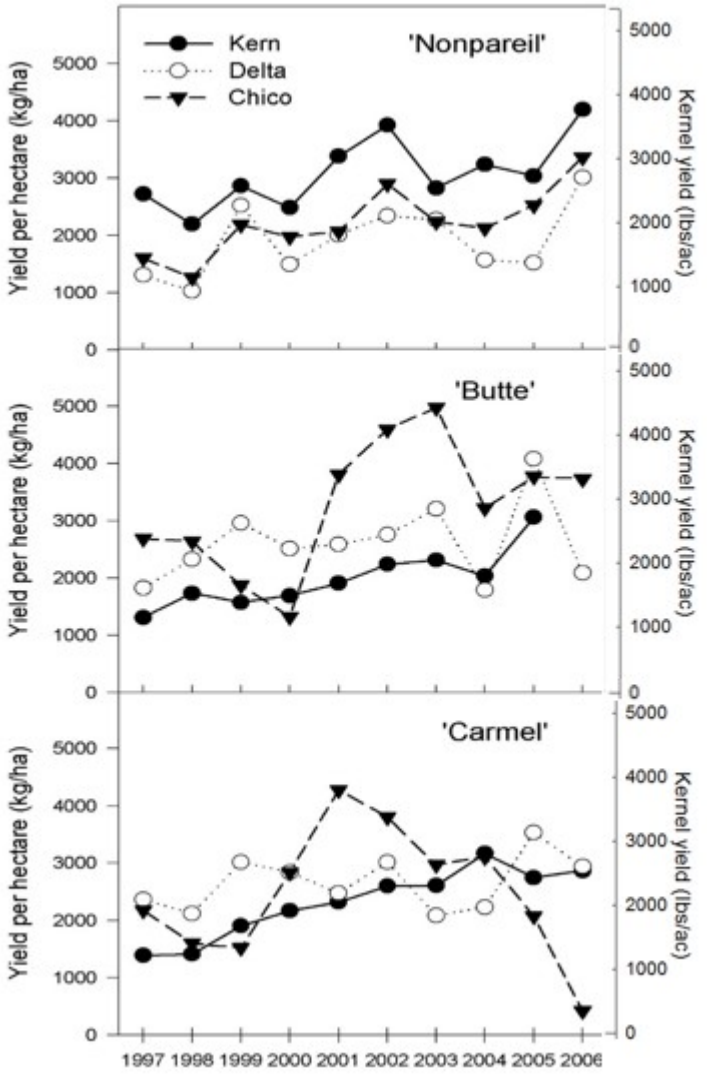


Correlation between yield per acre in year n and yield per acre in year n=1 of 'Nonpareil' in the three orchards considered in Figure 1. **No clear evidence of alternate bearing.**

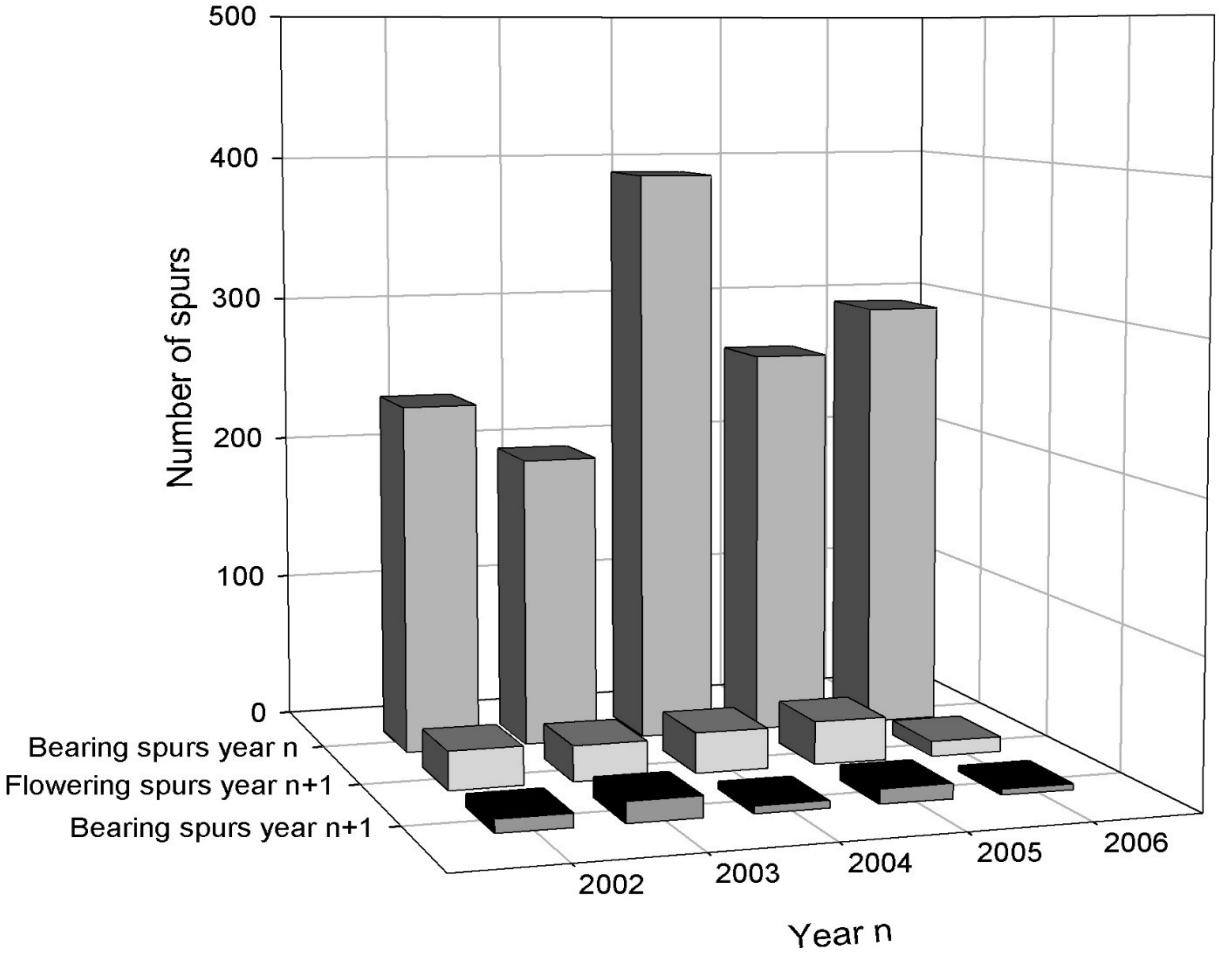


Bienniality index for ‘Nonpareil’, ‘Carmel’, ‘Butte’ in the three Regional Variety Trial locations (Kern, Delta and Chico).

	Bienniality index			
	Kern	Delta	Chico	Ave.
‘Nonpareil’	77%	66.7%	44.4%	62.7%
‘Carmel’	55.6%	66.7%	22.2%	48.2%
‘Butte’	44.4%	55.6%	44.4%	48.1%



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.**



If only a few spurs can bear fruit in two subsequent years, why aren’t almonds strongly alternate bearing?

Total number of spurs, and percentage of flowering and bearing spurs per each year. **Only about 15% of the spurs bore in a single year.**

Year	Total number of spurs	Flowering spurs	Bearing spurs	Spur % set
2002	1887	27.13%	12.56%	46.3
2003	2086	24.83%	9.44%	38.0
2004	2106	37.27%	18.57%	49.8
2005	1746	39.46%	15.12%	38.3
2006	1895	47.81%	15.57%	32.6
Mean		35.30%	14.25%	41.0%

Percentage of spurs that died by year

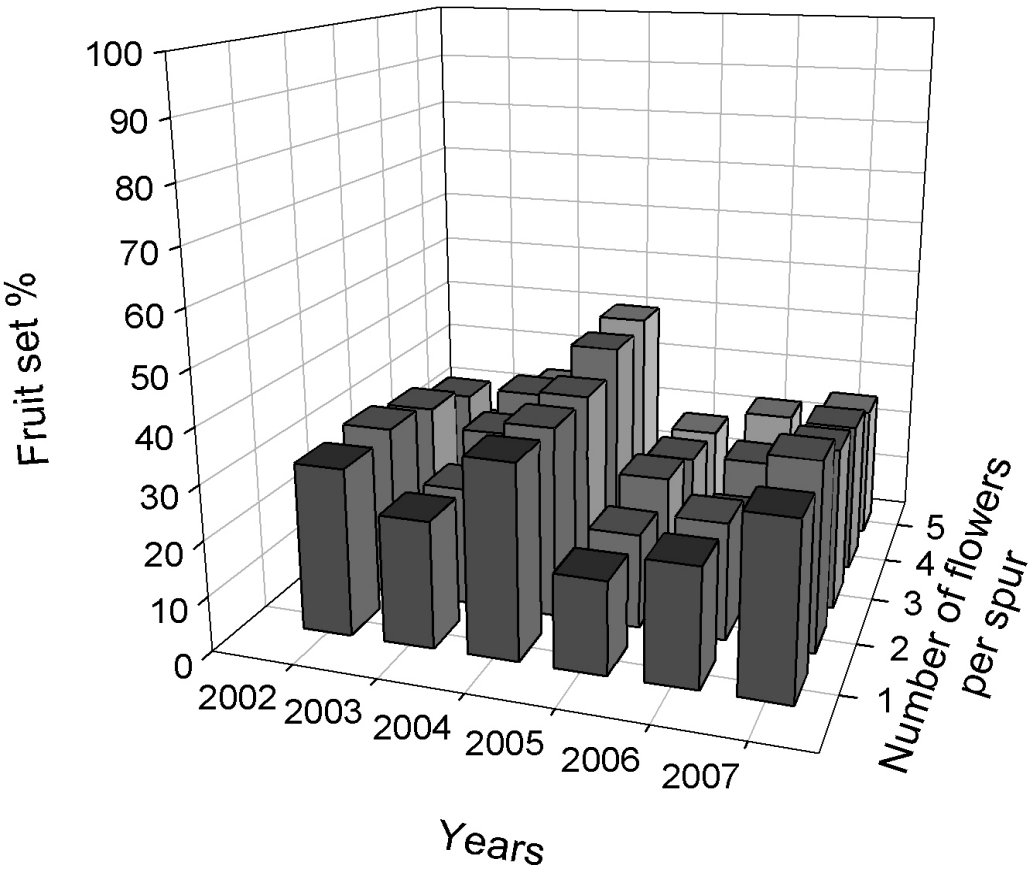
	2002 Percent dead	2003 Percent dead	2004 Percent dead	2005 Percent dead
T1(+N, +H2O)	6.0 a	13.5 a	10.3 a	29.7 a
T2(-N, +H2O)	7.3 a	5.5 c	4.5 b	29.2 a
T3(+N, -H2O)	6.3 a	10.7 ab	8.7 a	23.2 b
T4(-N, -H2O)	8.3 a	7.8 bc	7.3 a	21.3 b

The orchard where we did the spur dynamics trial was removed in 2016. We found tags on spurs that were still alive in the spring of 2016- this would be 15 years that they lived.

Spurs remaining viable after 15 years were mainly on the moderate water, moderate nitrogen treatment and least on high water high nitrogen treatment

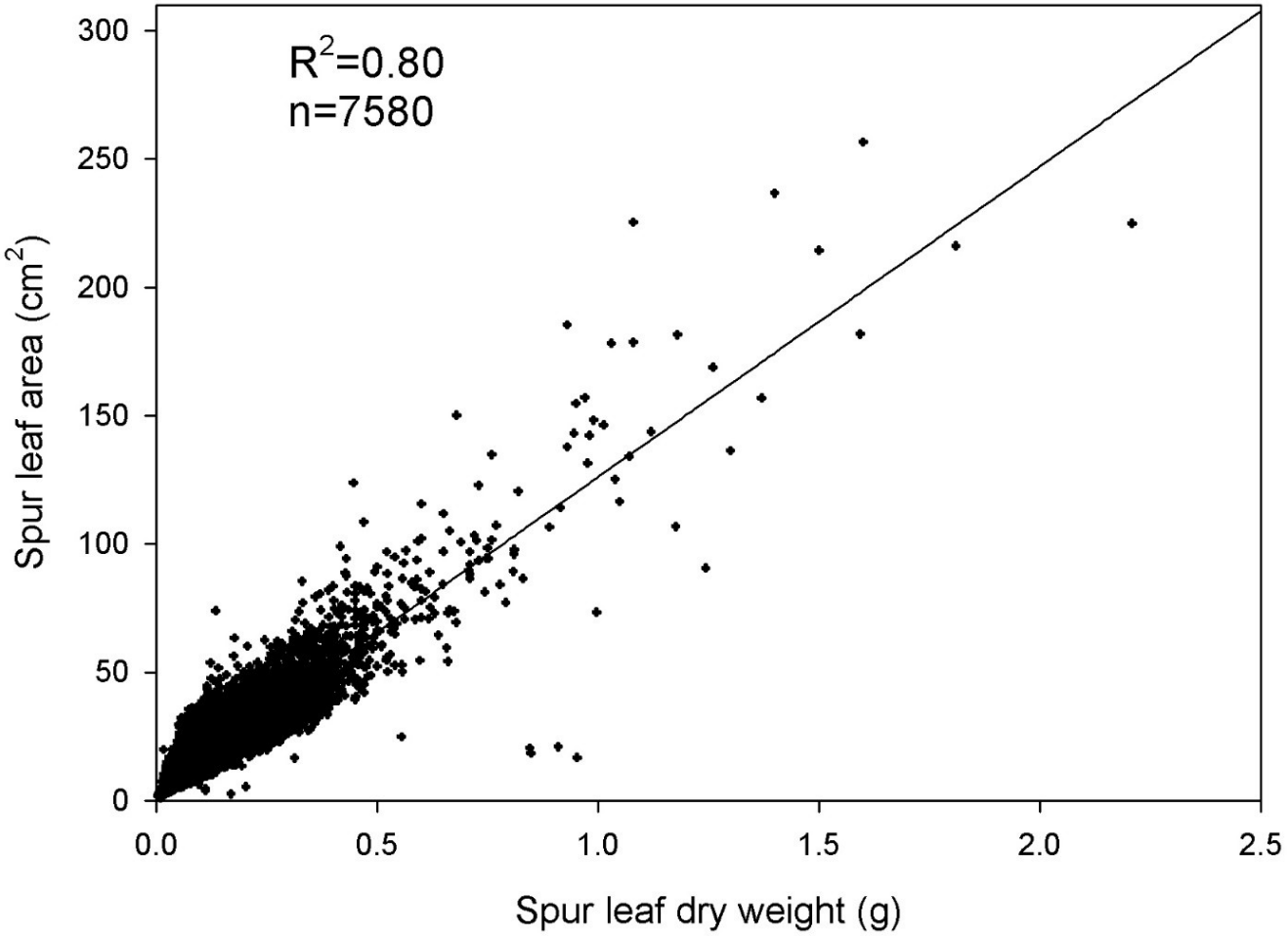
Using the spur dynamics data to analyze Fruit Set

Fruit set in spurs bearing 1,2,3,4 and 5 flowers over 6 years.

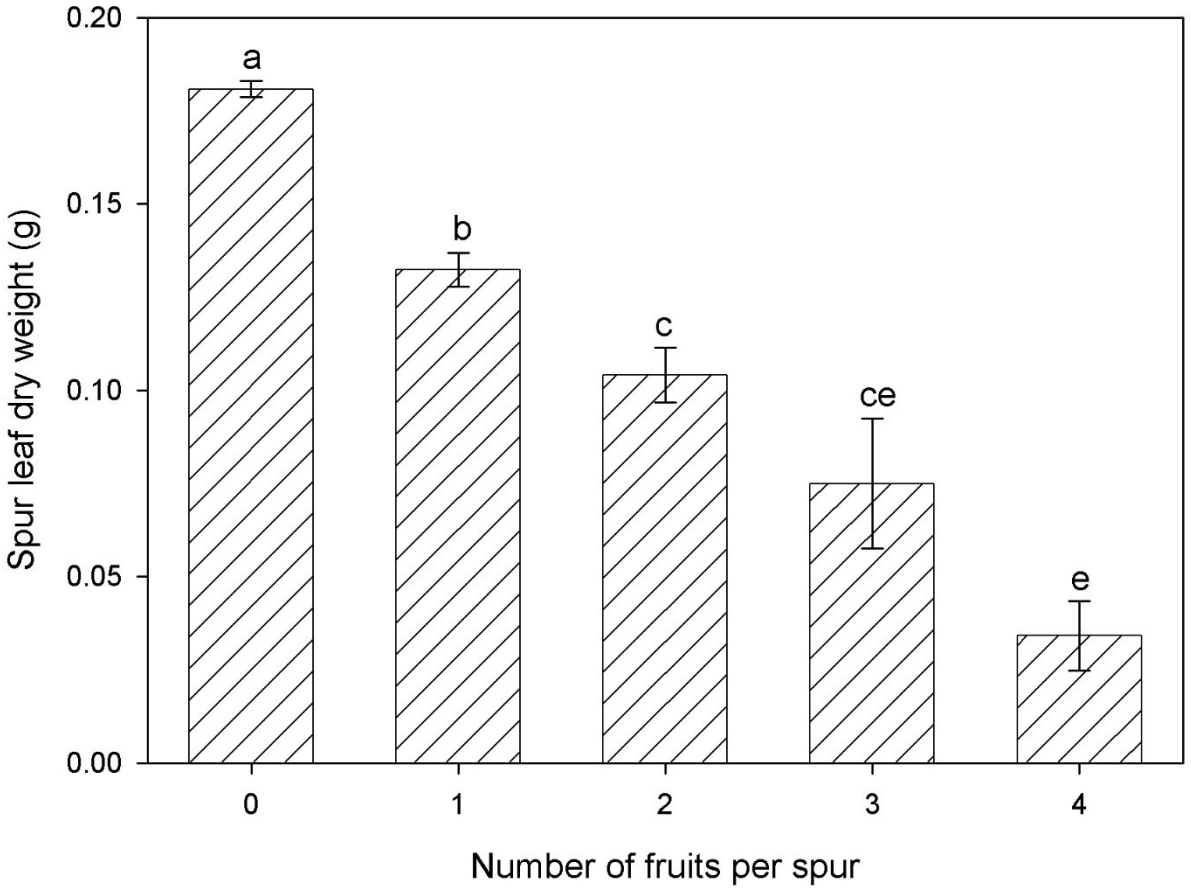


Fruit set was fairly constant for spurs with 1-5 flowers per spur.

Relationship between spur leaf dry weight (g) and spur leaf area (cm2).



Mean spur leaf dry weight (g) in spurs with 1, 2, 3, 4 and no fruits. Error bars represent standard error (0 fruit n=4,424; 1 fruit n=580; 2 fruits n=158; 3 fruits n=25; 4 fruits n=8). **Increased fruit set/spur decreases current year spur leaf dry weight (area).**

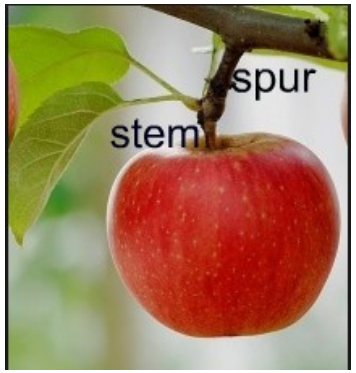


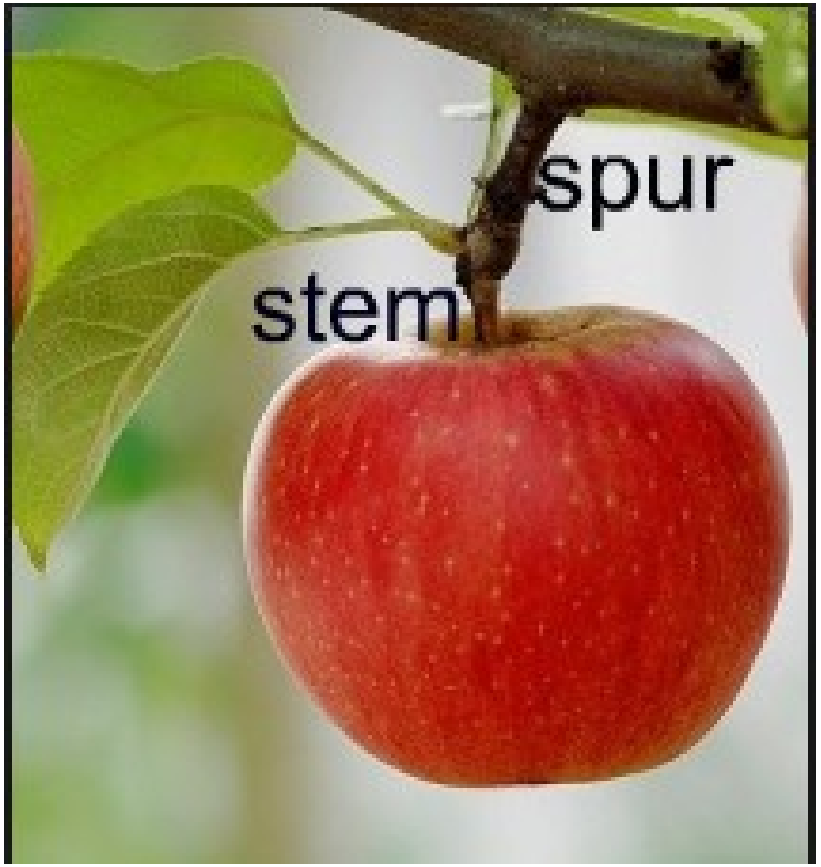
Bottom Line

Unlike apples and some other spur-bearing species, current year fruit set is negatively related to current year spur leaf weight (and leaf area). This is likely due to the different bearing habit of the two species.

- Almonds bear laterally on last years wood and new spur leaves are distal to the fruit
- Apples are borne terminally and new spur leaves are proximal to the fruit

This may also partially explain why almond spurs rarely bear fruit in two consecutive years since next years flowering is dependent on this years spur leaf area.





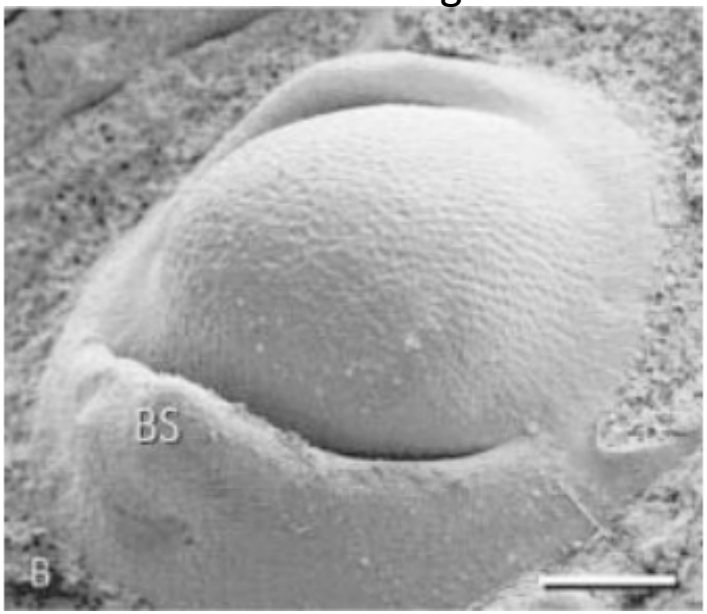
Leaves proximal to fruit

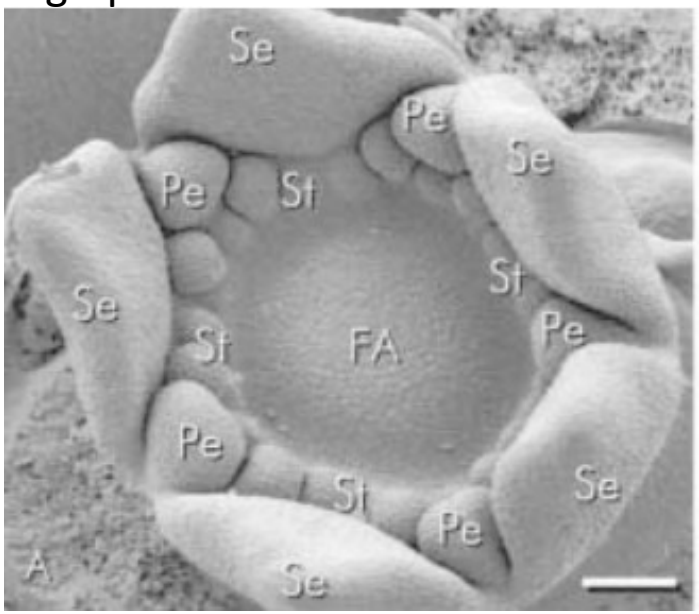
Leaves distal to fruit

Remember that the critical flower differentiation stage for next years flower buds is occurring during the current year hull split period

If you practice hull split deficit irrigation, be sure to do so with the use of a pressure chamber to assure stress is not too extreme

Scanning electron micrographs of almond buds





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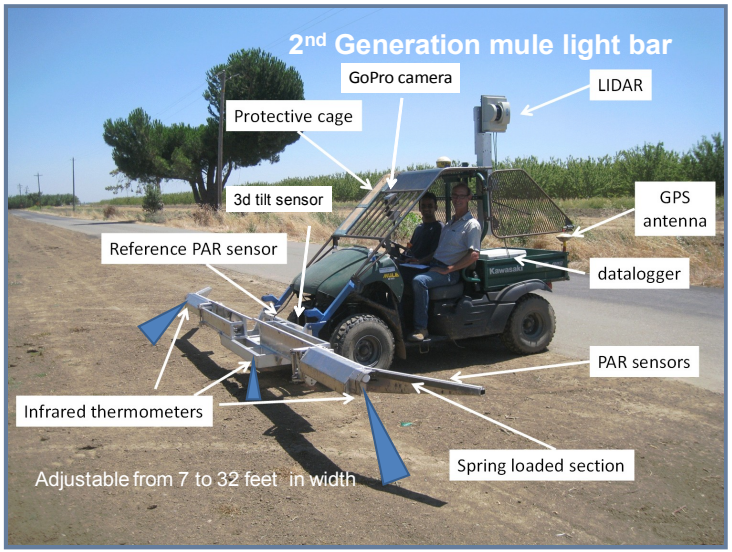
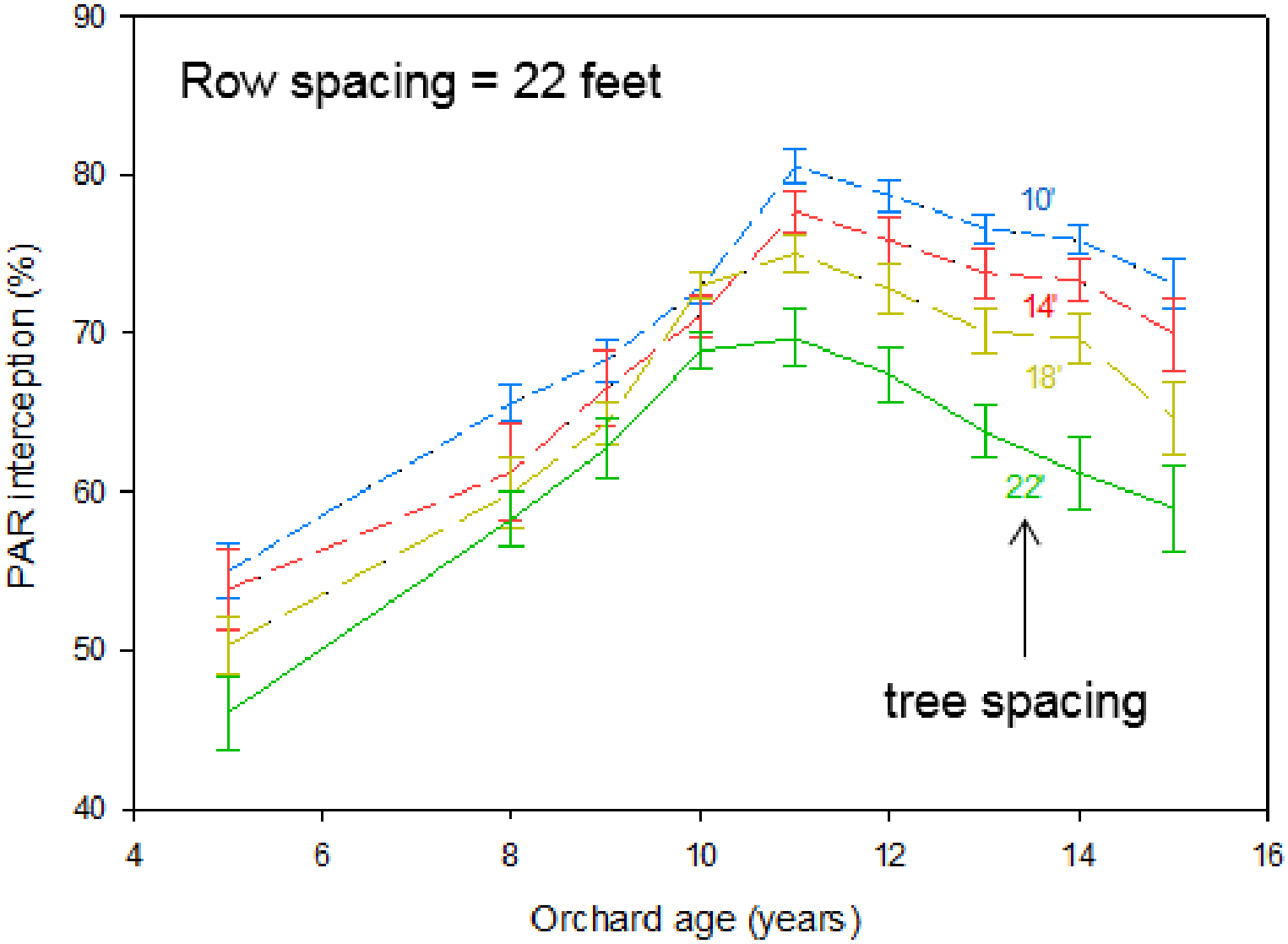
Stage 1

Stage 6

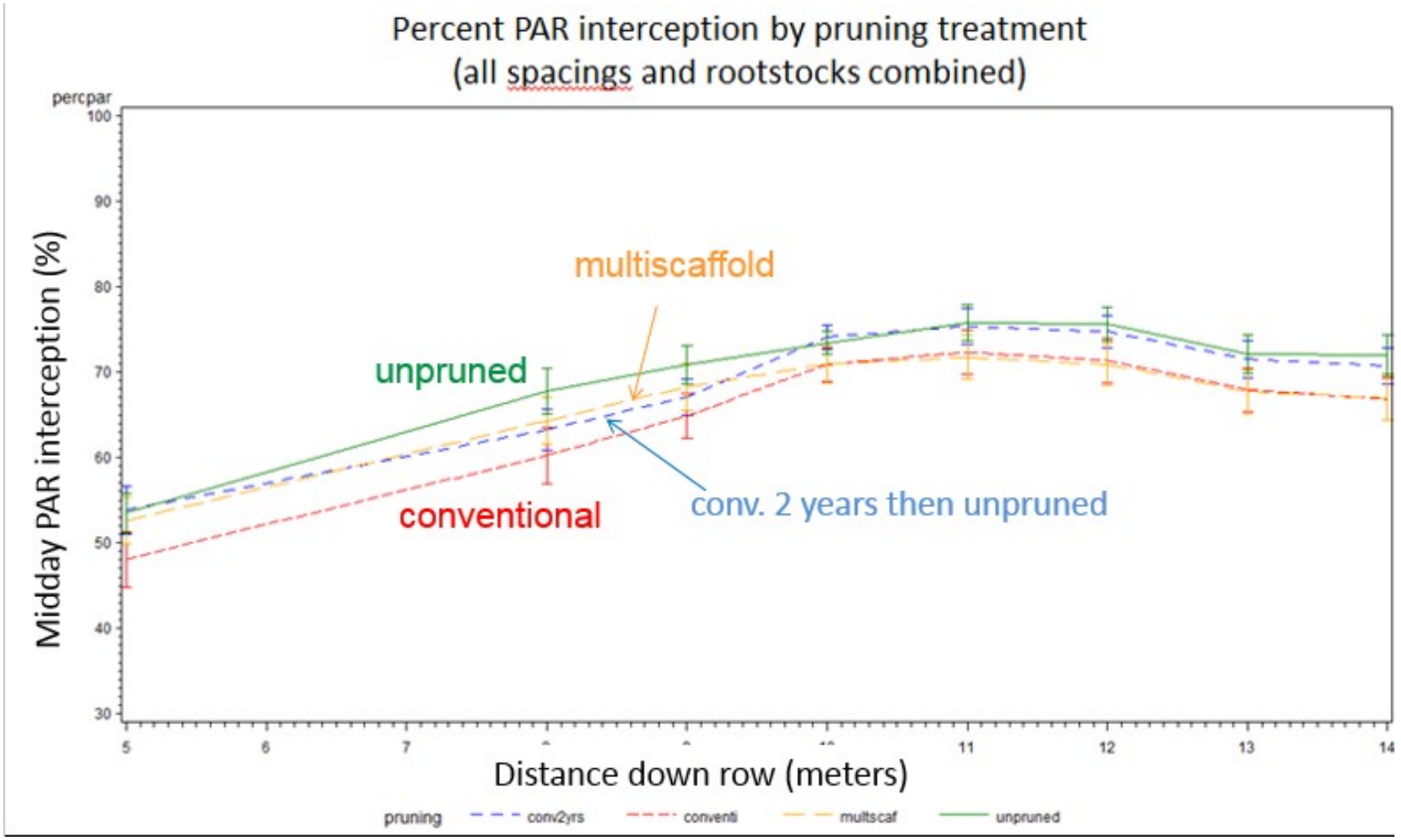
Stage 1 occurs just after initiation of hull split (up to 3 weeks later in Nonpareil) and stage 6 is complete by the completion of hullsplit

How does this relate to midday canopy light interception and pruning?





Light interception tended to peak at about 11 years of age at all in row tree spacings


Percent PAR interception by pruning treatment
(all spacings and rootstocks combined)
percpar
Midday PAR interception (%)
100
90
80
70
60
50
40
30
5
6
7
11
12
13
14
Distance down row (meters)
multiscaffold
unpruned
conventional
conv. 2 years then unpruned
pruning
conv2yrs
conventi
multscaf
unpruned

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**

Common wisdom on why almonds need to be pruned

- Manage light distribution through canopy
  Pruning exacerbates these problems leading to 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
  Perhaps, but no data to support this
- Maintain tree size
  Perhaps, but will likely come at the expense of productivity

Summary

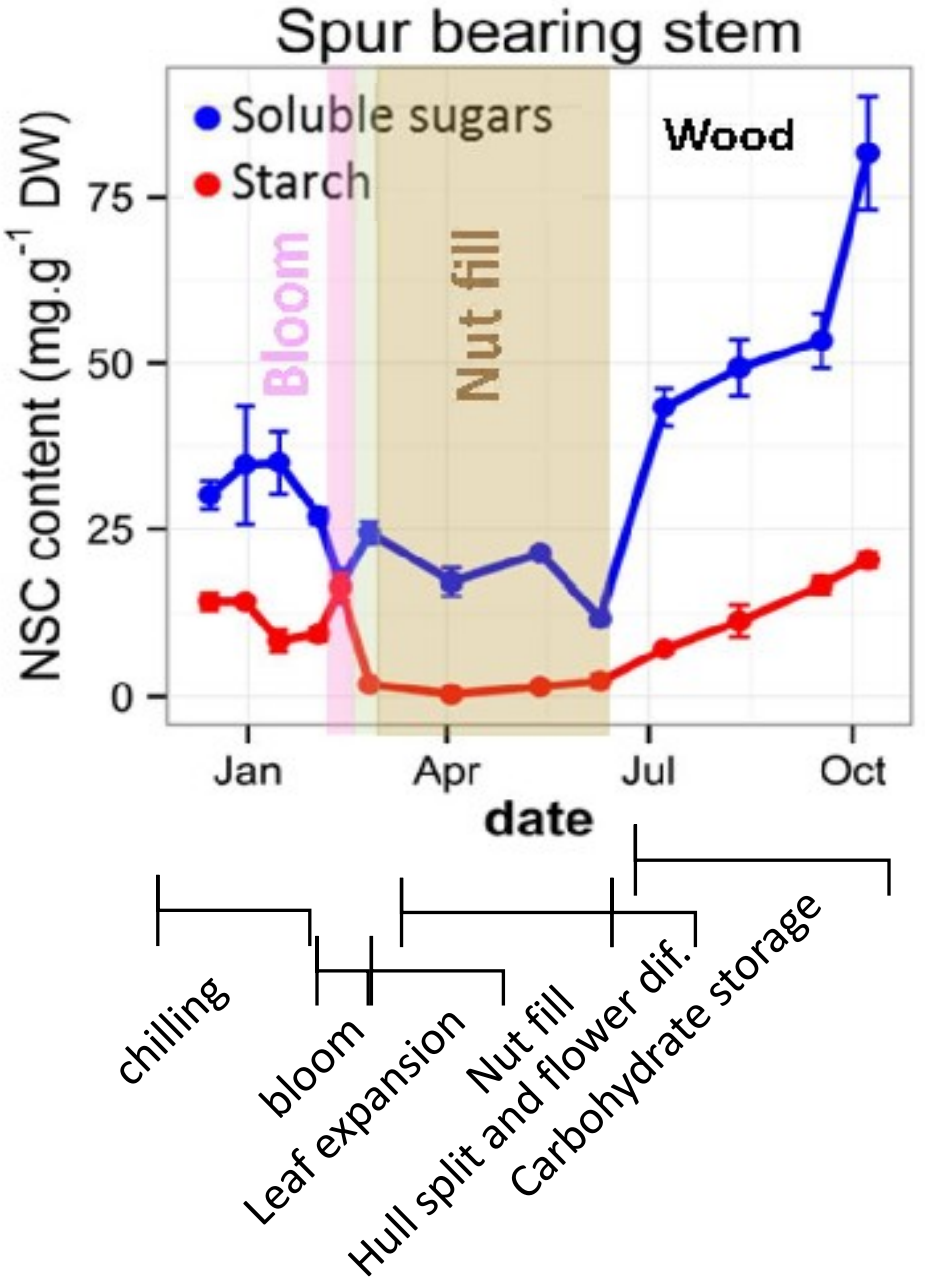
- There is no data to suggest that there is a need to prune mature almond trees on an annual basis
- Pruning does not sustain productivity in the short or long term (as long as 21 years)
- You should only prune to:
  - ✓ Improve safety for workers
  - ✓ Improve visibility of trunks to decrease chance 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)

How do you best manage the spur population?

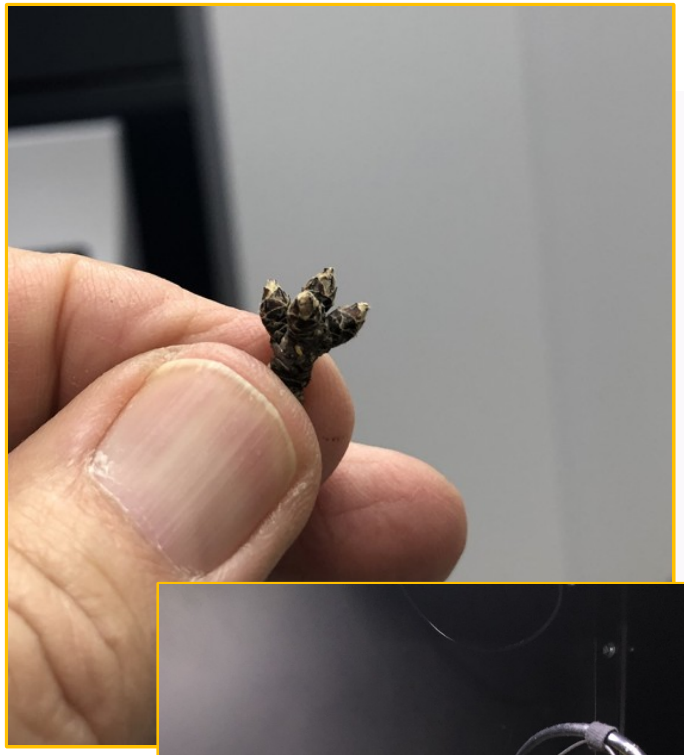
- Spurs need a certain amount of leaf area in the previous year to have a high probability of flowering and setting nuts in the current year
- Make sure management decisions are optimal since all of the factors below can affect leaf area and hence next years bloom
  - Good irrigation management
  - Good nutrition management
  - Good pest/disease management
- All 3 of the management practices above can help improve leaf size which should lead to increased likelihood of a higher percentage of spurs flowering and fruiting the following year
- The spur dynamics study suggests that spurs can live much longer than was previously thought
  - Spur death was mostly due to shading rather than age related death

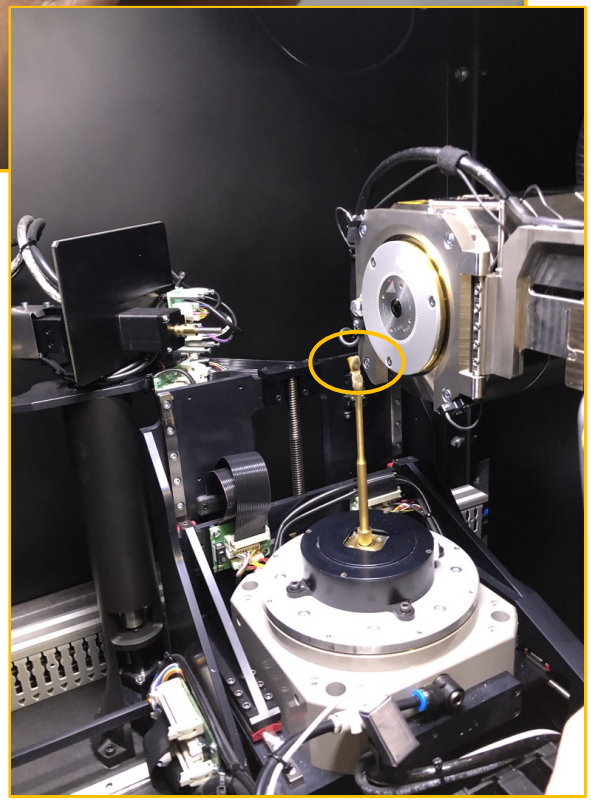
Discussion

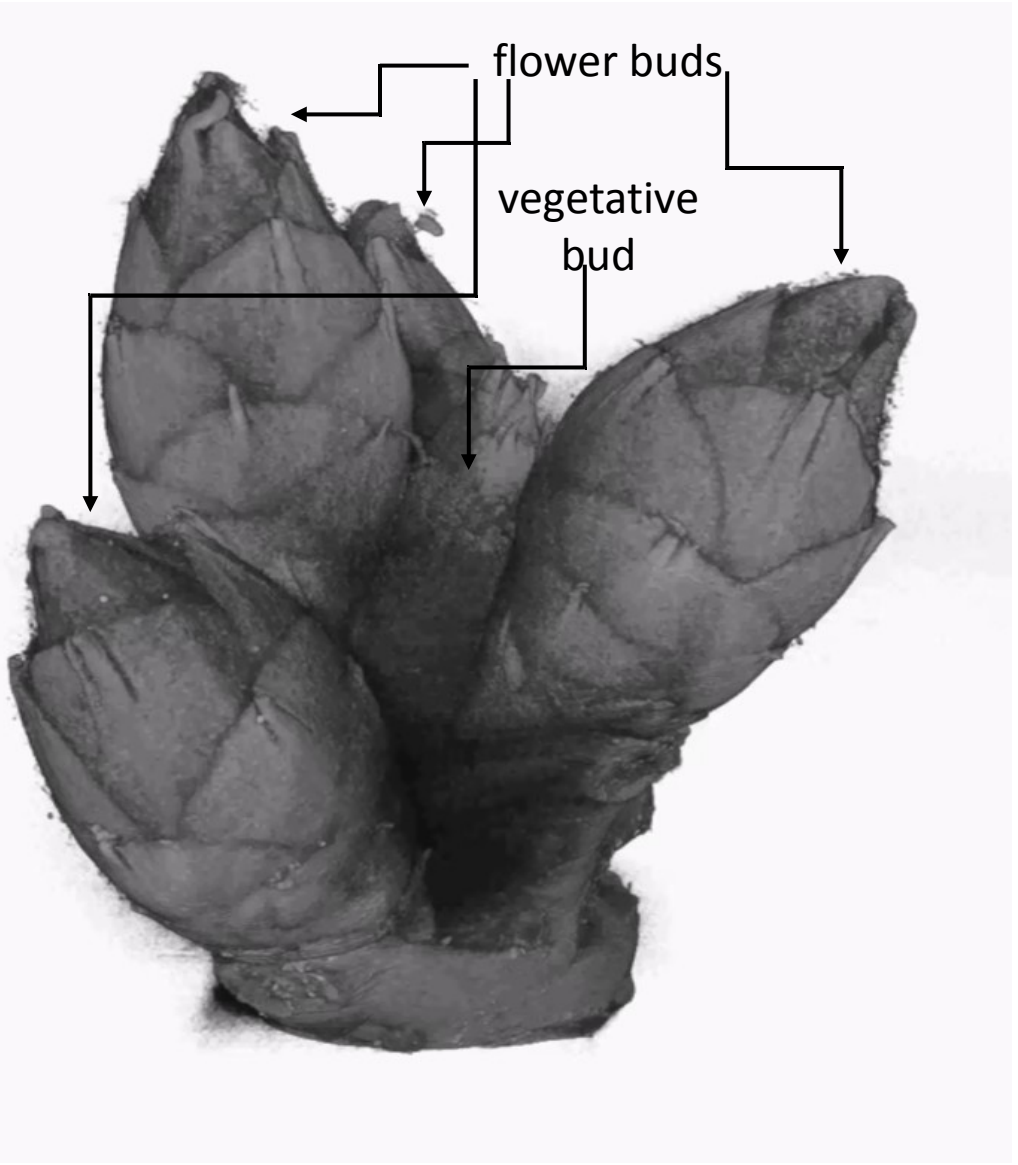
There is no time to slack off on management!

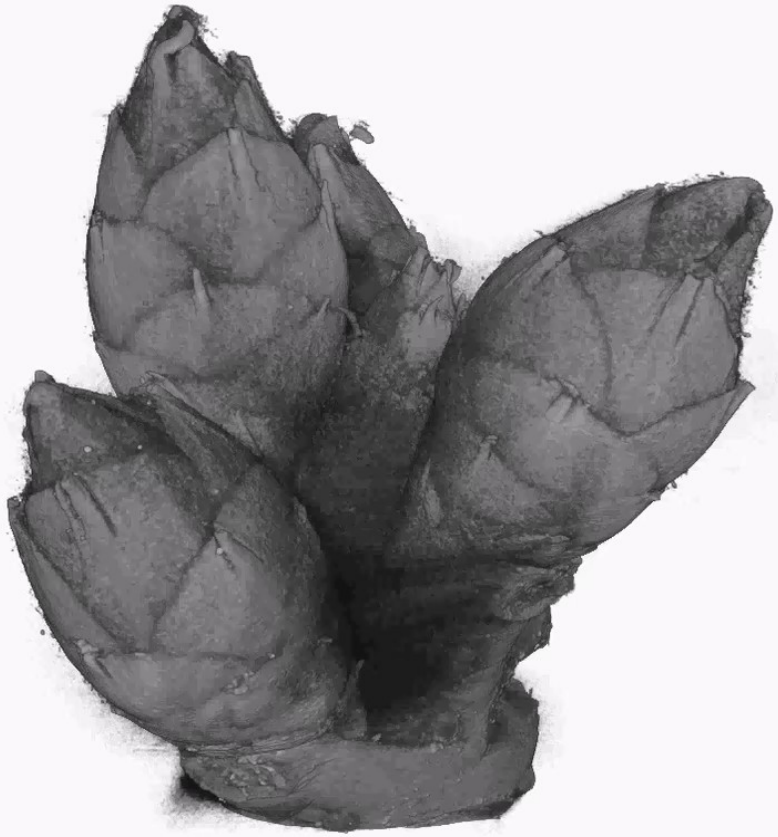


High resolution computed tomography (HRCT)





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When you see an almond orchard that is extremely lush green in mid-summer, it generally means there is very little crop.

West Coast Nut July 2018 (Fitchner and Lampinen)

Understanding Seasonal Vegetative Growth on Almond

By: Elizabeth J. Fichtner | UCCE Farm Advisor, Tulare and Kings Counties
Bruce Lampinen | CE Specialist, UC Davis

Evaluation of flowering and fruit set on almond allows for within-season assessment of orchard productivity; however, understanding the vegetative growth dynamics of almond allows growers to consider parameters affecting productivity years into the future. Vegetative growth of almond has two main components: vegetative shoot growth and spur production. Vegetative shoot growth provides the overall architecture of the canopy, and spur production generates the tissues that give rise to the majority of fruit in subsequent seasons. Both vegetative shoot growth and spur production are key components to the development of an economically sustainable and productive orchard.

Timing of Vegetative Growth

All buds (vegetative and flower) are formed during the prior season. Because almond has one of the lowest chill requirements of permanent crops grown in California, the chill requirement is generally fulfilled by January. 1. As temperatures increase, growth initiation is induced, and bud break ensues, with flower buds breaking in advance of vegetative buds. Vegetative shoot growth proceeds at a somewhat uniform rate throughout the season on young trees, but the duration of spur elongation is short and generally complete by April or early May.

Vegetative Buds

On almond, vegetative buds can be distinguished from flower buds by shape.

Figure 1. The apical bud on a spur is always vegetative (A). Spurs can give rise to long vegetative shoots (B), remain vegetative (c), or support nut development (D). All photos courtesy of Elizabeth Fichtner.

Figure 2. Spurs are always borne on the prior year's wood. (Illustration: Tombesi, et al. 2016).

Flower buds are thick and oval; vegetative buds are pointy and triangular. On shoots, flower buds are generally formed on either side of a vegetative bud. On spurs, the apical bud is always vegetative (**Figure 1A**, *page 30*), and this bud can give rise to either further spur growth (**Figure 2**, *above*) or a vegetative shoot (**Figure 1B**, *page 30*). Spurs in positions with high light interception are more likely to give rise to vegetative shoots than new spur growth.

Vegetative Shoot Growth

Vegetative buds may give rise to long vegetative shoots that support future spur production. During the early years of orchard establishment, long shoot growth is the main component of vegetative development on almond. On mature trees, vegetative shoot growth occurs under conditions of low crop, high vigor, and in regions of the canopy where there is excessive light interception. Canopy regions with excess light include external/exposed areas and empty spaces resulting from broken limbs.

Spurs

Spurs are short, compact vegetative shoots, approximately 0.5-2 inches long (**Figure 2**, *above*). Spurs arise on vegetative shoots or on spurs produced in the prior season (**Figure 2**, *above*). Within a season, the duration of spur growth is generally short, with spur extension completed by April or early May. Spurs are always formed on the prior year's wood, and remain vegetative for one to two years prior to flowering. As a consequence, the process from vegetative shoot growth to spur production and flowering may take four seasons.

Spurs support approximately 80 percent of the total almond yield in a given year, yet only about 20 percent of the total spur population on a tree supports nut production each year. The fact that only one in five spurs bear fruit in a season is explained by the dynamic status of spurs between years. A portion of spurs remain only vegetative in a given year (**Figure 1C**, *page 30*), whereas others may support one to five flowers that may develop into single fruit-bearing spurs or multiple fruit-bearing spurs (**Figure 1D**, *page 30*). Due to the reliance on a localized carbon economy, individual spurs tend to alternate bear, meaning that spurs that bear fruit one year tend not to flower or bear fruit the following year.

Comprehensive View On Vegetative Growth

In new almond plantings (**Figure 3A**, *above*), growers should expect the mainstay of vegetative growth to be production of long vegetative shoots (**Figure 3B and C**, *above*). Although the majority of the future crop is produced on spurs, it will take time for bearing spurs to be represented in the canopy. Consider that spurs are produced on the prior year's wood and will remain vegetative for one to two years before entering productivity. Patience is needed as these vegetative spurs store carbohydrates to support future nut development.

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Figure 3. In young trees (A), the majority of growth is comprised of vegetative shoots (B and C).

The Dynamic State of Spurs in Almond

By: Elizabeth J. Fichtner, UCCE Farm Advisor, Tulare and Kings Counties, and Bruce Lampinen, CE Specialist, UC Davis

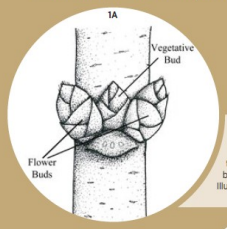
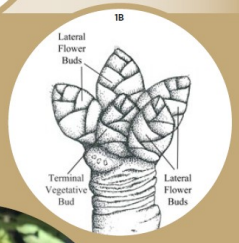


Figure 1. Buds form in leaf scars on vegetative shoots; a vegetative bud is generally positioned between two flower buds **(A)**. On spurs, the terminal bud is always vegetative; the lateral buds may be either vegetative or floral buds **(B)**. Illustrations courtesy of H. Hartzog.



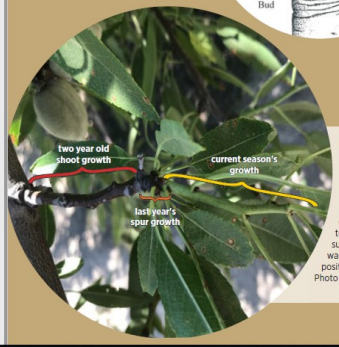


Figure 2. The probable life history of this shoot started two years ago, with a short shoot giving rise to a spur last year. In the current year, the apical bud on the spur gave rise to a vegetative shoot, suggesting that the spur was in a light-exposed position in the canopy. Photo courtesy of E. Fichtner.

Over 80 percent of the almond crop is borne on short, compact vegetative shoots called spurs. Each season, however, only a portion of the spur population on a given tree supports fruit production. Because of their role in supporting productivity and yield, maintenance of a healthy spur population contributes to the economic sustainability of an orchard. Understanding the dynamic states of spurs between seasons and the conditions promoting spur productivity and survival may enhance orchard management practices to maintain or increase yields in future years.

What are Spurs?

Spurs are short, compact vegetative shoots (approximately 0.5-2 inches long) that are borne on the prior season's wood. Spurs are either formed from lateral buds on vegetative shoots (*Figure 1A, top left*) or from vegetative buds on spurs (*Figure 1B, middle left*). When spurs give rise to further spur growth over sequential years, it may be difficult to visually evaluate the age of a spur due to the compact nature of growth (*Figure 2, bottom left*). The apical bud on a spur is always vegetative (*Figure 1B, middle left*); however, spurs can also support up to six flower buds in a season (*Figure 3B, page 63*). The duration of spur growth on almond is short and generally complete in April or early May.

Spurs Exhibit a Localized Carbon Economy

Spurs are considered semi-autonomous with respect to carbon supply, meaning that spurs serve as both the main source and sink of carbohydrates utilized in vegetative and reproductive growth. As a result, spurs remain vegetative (*Figure 3A, page 63*) for one to two years prior to flowering. Although not immediately productive, vegetative spurs with adequate leaf area produce and store carbohydrates for support of future flowering and nut development. In fact, the leaf area of spurs is a better predictor of potential for flower bud development than the number of leaves per spur. Spurs with less than 10 cm2 leaf area are unlikely to support viable buds (floral or vegetative); spurs with 10-12.3 cm2 leaf area are likely to support only vegetative buds; and spurs with >12.3 cm2 have a higher probability of supporting flower buds. Due to the carbohydrate demand of setting fruit, few spurs flower the year after bearing.

Spur Leaf Area Influences Flower Bud Development

Flower buds can be differentiated from vegetative buds by both shape and position. Flower buds are generally positioned on either side of a vegetative bud on shoots (*Figure 1A, page 62*), or in lateral positions on spurs (*Figure 1B, page 62*). Vegetative buds are triangular and pointy, whereas flower buds are thicker and more oval than vegetative counterparts. In early summer, buds manifest in leaf axils, but it is impossible to differentiate between floral and vegetative buds until late August or early September. Even in late summer,

Continued on Page 64

Figure 3. Approximately 80 percent of spurs remain vegetative **(A)** in a given year. Floral spurs **(B)** may support up to 6 flower buds in a year, but not all flower buds give rise to fruit.
Photos courtesy of B. Lampinen.

West Coast Nut September 2018 (Fitchner and Lampinen)

Thank you!

This year → Next year

Thanks to the Almond Board of California for funding various aspects of this work