Almond Spur Dynamics - Maintaining Orchard Productivity

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UC Davis/UC ANR
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 previous summer as were the flower primordia.
Stage 1 occurs just after initiation of hull split and stage 6 is complete by the completion of hullsplit.

Scanning electron micrographs of an almond flower bud.

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

Almond Flower Development: Floral Initiation and Organogenesis

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Department of Pomology, University of California, Davis, CA 95616
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. WEINBAUM² and I. KLEIN³

Three irrigation treatments
- Fully irrigated
- Moderately stressed
- Severely stressed

Fruits per spur

Distribution of spurs categorized by no. of fruits per spur (%)
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
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.
Tagged spurs were followed over 7 years to determine treatment effects on spur longevity and productivity.
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

Spur distributions with respect to their previous year leaf area

$$P = 1320.98 e^{-0.5 \left( \frac{\ln\left( \frac{44}{17.54} \right)}{0.52} \right)^2}$$

$$R^2 = 0.99$$

(20 cm² is equal to about 3 square inches)
Spur previous year leaf area (cm²)
$P = 1320.98e^{-0.5 \left( \frac{\text{Spur PYLA}}{0.52} \right)^2}$

$R^2 = 0.99$
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


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.**

![Graph showing correlation between yield per acre year $n$ and year $n+1$]

Equation of the line:

$$y = 0.59x + 1117.98$$

$R^2 = 0.28$
Bienniality index for ‘Nonpareil’, ‘Carmel’, ‘Butte’ in the three Regional Variety Trial locations (Kern, Delta and Chico).

<table>
<thead>
<tr>
<th>Bienniality index</th>
<th>Kern</th>
<th>Delta</th>
<th>Chico</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Nonpareil’</td>
<td>77%</td>
<td>66.7%</td>
<td>44.4%</td>
<td>62.7%</td>
</tr>
<tr>
<td>‘Carmel’</td>
<td>55.6%</td>
<td>66.7%</td>
<td>22.2%</td>
<td>48.2%</td>
</tr>
<tr>
<td>‘Butte’</td>
<td>44.4%</td>
<td>55.6%</td>
<td>44.4%</td>
<td>48.1%</td>
</tr>
</tbody>
</table>
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.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of spurs</th>
<th>Flowering spurs</th>
<th>Bearing spurs</th>
<th>Spur % set</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1887</td>
<td>27.13%</td>
<td>12.56%</td>
<td>46.3</td>
</tr>
<tr>
<td>2003</td>
<td>2086</td>
<td>24.83%</td>
<td>9.44%</td>
<td>38.0</td>
</tr>
<tr>
<td>2004</td>
<td>2106</td>
<td>37.27%</td>
<td>18.57%</td>
<td>49.8</td>
</tr>
<tr>
<td>2005</td>
<td>1746</td>
<td>39.46%</td>
<td>15.12%</td>
<td>38.3</td>
</tr>
<tr>
<td>2006</td>
<td>1895</td>
<td>47.81%</td>
<td>15.57%</td>
<td>32.6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>35.30%</td>
<td>14.25%</td>
<td>41.0%</td>
</tr>
</tbody>
</table>
### Percentage of spurs that died by year

<table>
<thead>
<tr>
<th></th>
<th>2002 Percent dead</th>
<th>2003 Percent dead</th>
<th>2004 Percent dead</th>
<th>2005 Percent dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1(+N, +H2O)</td>
<td>6.0 a</td>
<td>13.5 a</td>
<td>10.3 a</td>
<td>29.7 a</td>
</tr>
<tr>
<td>T2(-N, +H2O)</td>
<td>7.3 a</td>
<td>5.5 c</td>
<td>4.5 b</td>
<td>29.2 a</td>
</tr>
<tr>
<td>T3(+N, -H2O)</td>
<td>6.3 a</td>
<td>10.7 ab</td>
<td>8.7 a</td>
<td>23.2 b</td>
</tr>
<tr>
<td>T4(-N, -H2O)</td>
<td>8.3 a</td>
<td>7.8 bc</td>
<td>7.3 a</td>
<td>21.3 b</td>
</tr>
</tbody>
</table>
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).

\[ R^2 = 0.80 \]
\[ n = 7580 \]
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 year's 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

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 hull split
How does this relate to midday canopy light interception and pruning?
Row spacing = 22 feet

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)

Midday PAR interception (%) vs. Distance down row (meters)

- Pruning
- Conv 2 yrs then unpruned
- Multiscaffold
- Unpruned
- Conventional
<table>
<thead>
<tr>
<th>Variety</th>
<th># of years of cumulative yield data</th>
<th>Conventional annual pruning</th>
<th>Unpruned trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpareil</td>
<td>21</td>
<td>34,176</td>
<td>35,082</td>
</tr>
<tr>
<td>Monterey</td>
<td>13</td>
<td>33,830</td>
<td>38,511</td>
</tr>
<tr>
<td>Carmel</td>
<td>13</td>
<td>33,575</td>
<td>29,935</td>
</tr>
<tr>
<td>Aldrich</td>
<td>13</td>
<td>34,167</td>
<td>31,454</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>13</strong></td>
<td><strong>133,557</strong></td>
<td><strong>133,752</strong></td>
</tr>
</tbody>
</table>

Original Nickels pruning trial (Edstrom)

<table>
<thead>
<tr>
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<th>Unpruned trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpareil</td>
<td>13</td>
<td>31,985</td>
<td>33,852</td>
</tr>
<tr>
<td>Monterey</td>
<td>13</td>
<td>33,830</td>
<td>38,511</td>
</tr>
<tr>
<td>Carmel</td>
<td>13</td>
<td>33,575</td>
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Second generation Nickels pruning trial (Edstrom)

<table>
<thead>
<tr>
<th>Variety</th>
<th># of years of cumulative yield data</th>
<th>Conventional annual pruning</th>
<th>Unpruned trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpareil</td>
<td>8</td>
<td>19,245</td>
<td>21,536</td>
</tr>
<tr>
<td>Monterey</td>
<td>8</td>
<td>21,698</td>
<td>23,577</td>
</tr>
<tr>
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<td>8</td>
<td>20,841</td>
<td>21,843</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>8</strong></td>
<td><strong>61,784</strong></td>
<td><strong>66,956</strong></td>
</tr>
</tbody>
</table>

Kern County Pruning Trial (Viveros)

<table>
<thead>
<tr>
<th>Variety</th>
<th># of years of cumulative yield data</th>
<th>Conventional annual pruning</th>
<th>Unpruned trees</th>
</tr>
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<tr>
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<tr>
<td><strong>Sum</strong></td>
<td><strong>8</strong></td>
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<td><strong>66,956</strong></td>
</tr>
</tbody>
</table>

Stanislaus County Pruning Rootstock Spacing (Duncan)

<table>
<thead>
<tr>
<th>Variety</th>
<th># of years of cumulative yield data</th>
<th>Conventional annual pruning</th>
<th>Unpruned trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpareil</td>
<td>13</td>
<td>33,119</td>
<td>35,166</td>
</tr>
<tr>
<td>Carmel</td>
<td>13</td>
<td>33,771</td>
<td>35,767</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>13</strong></td>
<td><strong>66,890</strong></td>
<td><strong>70,933</strong></td>
</tr>
</tbody>
</table>
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)
When you see an almond orchard that is extremely lush green in mid-summer, it generally means there is very little crop.
Understanding Seasonal Vegetative Growth on Almond

West Coast Nut July 2018 (Fitchner and Lampinen)

Vegetative buds

Flower buds will first and new vegetative buds appear as a result of stem extensions.

Vegetative shoots

Vegetative shoots will be visible in the spring and early summer.

Timing of Vegetative Growth

All buds (vegetative and flower) will occur during the spring. Flower buds will form the year before the tree is planted, and vegetative buds will form in the spring of the first year for new plantings.

Sporadic

Sporadic growth can occur at any time during the season. Periods of sporadic growth can last for several days or weeks and may be interrupted by periods of vegetative growth.

Comprehensive View on Vegetative Growth

In new almond plantings (Figure 1), growth should be expected to be sporadic in the first growing season due to the limited vegetative growth in the spring and early summer. Although for most of the future years the growth will be consistent, it is essential to be prepared for sporadic growth by having an adequate number of mature trees available for transferring to other fields or planting in new areas.
The Dynamic State of Spurs in Almond

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

Over 90 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 4.3-12 inches long) that are borne on the primary and secondary 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 grow due 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 1B, 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 their 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 67) 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 19 cm² leaf area are unlikely to support viable buds (flower or vegetative), spurs with 10-12 cm² leaf area are likely to support only vegetative buds, and spurs with >12.5 cm² have a higher probability of supporting flower buds. Due to the carbohydrate demand of setting fruit, low spur flower the year after flowering.

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 4A, page 62), or in lateral positions on spurs (Figure 4B, page 62). Vegetative buds are triangular and purplish, whereas flower buds are thicker and more oval than vegetative counterparts. In early summer, buds mature in leaf axils, but it is impossible to differentiate between floral and vegetative buds until late August or early September.

Continued on Page 64

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