Integration of Tree Spacing, Pruning and Rootstock Selection for Efficient Almond Production

Project No.: **09-HORT5-Duncan**

Project Leader: Roger Duncan
UCCE - Stanislaus County
3800 Cornucopia Way, #A
Modesto, CA 95358
(209) 525-6800
raduncan@ucdavis.edu

Project Cooperators and Personnel:
Bruce Lampinen, UCCE Pomology Specialist, UC Davis
Robert Longstreth, Grower

Objective:

In this trial, we examine the interaction between planting density, rootstock vigor/survival and pruning and their effects on short-term and long-term orchard profitability. The trial was established in the fall of 1999 and the orchard has now completed its tenth growing season.

Varieties
'Nonpareil', 'Carmel' and 'Sonora'. All Carmel trees were replaced early in the 2nd growing season due to widespread noninfectious bud failure (crazy top) and are therefore about one growing season behind the Nonpareil trees. Harvest data is not collected for the Sonora variety.

Rootstocks
Nemaguard, Lovell and Hansen 536. Most data is collected only for the Nemaguard and Hansen rootstocks.

Spacing
The distance between rows is constant at 22 feet throughout the trial. Down the rows, tree spacing is varied in groups of 24 trees. The four tree spacings are:
10' x 22', 14' x 22', 18' x 22' and 22' x 22'.

Four training and pruning strategies are being imposed across all varieties, rootstocks and spacing treatments. They are:

1. Standard training and pruning.
   Three permanent scaffold limbs were selected during the first dormant pruning. Trees continue to receive "moderate," annual dormant pruning to keep centers open and remove crossing limbs.
2. Standard training for 2 years, then unpruned.
   Three permanent scaffolds were selected as in the "standard" treatment. Trees were pruned normally the second dormant season. These trees have been unpruned since the second dormant season except to occasionally remove limbs that interfere with cultural operations.
3. Minimal training and pruning.
   Shoots on Nonpareil trees were tipped twice during the first growing season to stimulate secondary branching and establish a bushy tree. At the first dormant pruning, only very vigorous shoots growing in the center of the trees were removed. Four to six scaffolds were retained to maintain a full canopy. Only a maximum of three cuts per tree is now made each dormant pruning to maintain a minimally open canopy.
4. Untrained and unpruned.
   No scaffold selection was made except to remove limbs originating too low on the trunk for shaker access. There has been no annual pruning other than to occasionally remove limbs that interfere with cultural operations.

Interpretive Summary:

Tree density vs. tree size and yield.
Trees planted densely have significantly smaller trunks, have canopies that are less broad and tend to be slightly shorter than trees with wider spacing (**Table 1**). Because trees planted more closely are smaller, they have had the fewest problems with scaffold breakage and blow over. They have not had more disease problems to date.

High-density Nonpareil trees on Nemaguard rootstock had higher per acre yields during the first few years, but by the 7th growing season, yields were similar at all tree spacings. There was never a clear yield advantage to high density planting of Nonpareil on the highly vigorous Hansen rootstock. Carmel yields benefited more from closer spacing during the development years than Nonpareil, especially on the less vigorous Nemaguard rootstock. In 2009 (9th leaf), Carmel yield was similar at all tree spacings (**Table 2**). Carmel trees planted at 10' x 22' have accumulated 1169 pounds per acre more than the "standard" spacing of 18' x 22' through the 9th leaf (**Table 3**). Carmel trees planted at 14' x 22' have a cumulative yield increase of 951 pounds per acre while trees planted 22' x 22' have produced 648 pounds less than the 18' x 22' spacing.

Table 1. The Effect of Planting Density on Trunk Girth and Tree Height

Spacing (tree x row)	Trunk Circumference (cm)	Tree Height (meters)
10' x 22'	599 d	2.0 a
14' x 22'	693 c	2.1 a
18' x 22'	748 b	2.1 a
22' x 22'	797 a	2.2 a

Pruning vs. Yield

Trees that were not trained and are not pruned continue to maintain excellent yields and tend to have slightly higher yields than conventionally trained and pruned trees, although differences are not statistically significant every year (**Table 2**). This has been especially true for the Carmel variety. Through the first ten years of this experiment, untrained and unpruned Nonpareil trees have accumulated 1134 pounds per acre more than trees that are conventionally pruned annually (**Table 3**). Untrained and unpruned trees have accumulated almost 2000 pounds per acre more in the Carmel variety. There is no difference in kernel size on pruned vs. unpruned trees.

Yield vs. Rootstock

During the development years, yields were highest for both varieties on the vigorous Hansen rootstock. In the seventh-leaf (2006), yields were similar for Hansen and Nemaguard. In 2007 (eighth-leaf), yields were significantly lower for trees on Hansen compared to trees on Nemaguard. It is unclear if the lower yields of the Hansen rootstock were a result of the very wet spring in 2006 (trees on Hansen were affected more than trees on Nemaguard) or whether it was due to some other factor. In 2008, Nonpareil yields were generally higher on the Hansen rootstock again. Now in 2009, Carmel yields on Hansen were notably lower than Carmel on Nemaguard while yield was similar on both rootstocks for the Nonpareil variety. It is unclear why the yield has been so variable on the Hansen rootstock the past few years.

Table 2. The Effect of Pruning, Tree Spacing and Rootstock on Nonpareil (10th leaf) and Carmel (9th leaf) Yield and Kernel Size. 2009.

	Yield (pounds per acre)		Average Number of Kernels per Ounce	
Training / Pruning	**Nonpareil**	**Carmel**	**Nonpareil**	**Carmel**
"Standard" training & annual pruning	3667	2879 b	24.3	23.4
Trained 2 years, then unpruned	3829	3003 ab	24.4	24.1
"Minimal" training & annual pruning	3590	2961 ab	24.0	23.1
Untrained & unpruned	3853	3112 a	24.4	23.6
Spacing				
10' x 22'	3648	3117 a	24.7	24.0
14' x 22'	3904	2985 a	24.1	23.6
18' x 22'	3722	2962 a	24.2	23.5
22' x 22'	3666	2892 a	24.0	23.2
Rootstock				
Hansen	3801	2758 b	24.4	23.6
Nemaguard	3668	3220 a	24.0	23.4
$P \leq 0.05$	n.s.		n.s.	n.s.

Conclusion:

Untrained trees and trees trained to multiple scaffolds were more susceptible to blow over and scaffold failure during the development years. This was especially true for trees planted at wider spacing (larger trees). Untrained trees also have presented more safety hazards to equipment operators, requiring more safety pruning in later years. A good compromise may be to train the trees during the first two years (to reduce scaffold splitting and safety pruning in later years) and then abandon pruning in later years. Trees that were initially trained to three scaffolds but have not been pruned after the second dormant season look very acceptable, have not had scaffold breakage problems, have not created problems for equipment operators, are not overly dense and rarely need safety pruning.

To date, there has been no yield benefit to pruning. In fact, annual, conventional pruning would have reduced the grower's cumulative profits by about $3,500 and $4,400 per acre for the Nonpareil and Carmel varieties, respectively, when pruning costs (@ $150 per acre per year) and reduction in yield (using ten year average prices of $1.75 per pound for Nonpareil and $1.52 per pound for Carmel) are considered over the first ten years of this orchard. Time will tell how lack of pruning will affect longer-term production and profits.

Table 3. Cumulative Yields for Nonpareil and Carmel Almonds as Influenced by Pruning and Tree Spacing**.**

Nonpareil								
	2003 (4th leaf)	2004 (5th leaf)	2005 (6th leaf)	2006 (7th leaf)	2007 (8th leaf)	2008 (9th leaf)	2009 (10th leaf)	**Cumulative Yield (lb/acre)**
Standard training and pruning	2112	2321	No data	3108	4020	3957	3667	**19,185**
Standard training, then unpruned	2336	2460		3547	4172	3847	3829	**20,191**
Minimal training and pruning annually	2475	2348		2947	4047	3770	3590	**19,177**
Untrained and unpruned	2420	2413		3371	4151	4111	3853	**20,319**
10 x 22	2358	2487	No data	3061	3963	3903	3648	**19,420**
14 x 22	2624	2489		2900	4137	4003	3904	**20,057**
18 x 22	2100	2352		3047	4162	3943	3722	**19,326**
22 x 22	2243	2213		2911	4128	3836	3666	**18,997**

Carmel							
	2004 (4thleaf)	2005 (5thleaf)	2006 (6thleaf)	2007 (7thleaf)	2008 (8th leaf)	2009 (9th leaf)	**Cumulative (lb/acre)**
Standard training and pruning	2046	2818	1524	3533	3576	2882	**16,379**
Standard training, then unpruned	1991	3088	1854	3859	3780	3003	**17,575**
Minimal training and pruning annually	2322	3088	1820	3713	3591	3026	**17,560**
Untrained and unpruned	2384	3358	1962	3888	3673	3112	**18,377**
10 x 22	2518	3130	1819	3665	3697	3117	**17,946**
14 x 22	2363	2998	1731	3862	3789	2985	**17,728**
18 x 22	2049	2690	1617	3767	3625	3029	**16,777**
22 x 22	1815	2700	1512	3700	3510	2892	**16,129**