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

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Project No.:

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Objective:

- To evaluate the interactive effects of rootstock, tree spacing and pruning strategies on tree growth and yield of Nonpareil and Carmel almonds.

Problem and its Significance:

It is generally desirable for almond trees to fill the available space in an orchard as quickly as possible. This should enable a grower to bring an orchard into full production sooner and thus maximize early profits. Planting trees densely on a vigorous rootstock and pruning lightly theoretically should fill space in an orchard more quickly. However, after full canopy has been achieved, trees continue to grow, potentially resulting in crowding, shade-out of lower fruiting wood and prematurely declining yields. It is also possible that more densely planted orchards may be more prone to foliar diseases such as rust, Alternaria leaf spot or hull rot.

As canopies from adjacent trees begin to grow into one another, growers may feel it is necessary to prune more heavily to allow sunlight to penetrate the canopy and preserve lower fruiting wood. It is therefore possible that more densely planted orchards may require more severe pruning. On the other hand, densely planted trees should remain smaller and may actually require less pruning. In experiments conducted by Edstrom, et. al. at the Nickels Estate in the Sacramento Valley, minimally pruned almond trees had yields equal to or greater than annually pruned trees for more than twenty years. However, this was a fairly low vigor site and it is unknown whether a more vigorous orchard would yield the same results.

Several research trials have been conducted in California that have independently examined rootstock selection or pruning strategies for almond. There are no reports on the influence of planting density on the short and long-term production sustainability of almond. One could expect a significant interaction between tree spacing, pruning and rootstock. It is therefore important to examine these three farming practices in one, integrated trial.

Methods:
A 37-acre, multi-factorial research trial was planted in eastern Stanislaus County to evaluate the interactive effects of variety, rootstock, planting density and pruning. The experimental orchard was planted into virgin soil that had been slip plowed to mix underlying soil layers. Potted trees were planted in fall 1999, drip irrigated and allowed to grow into dormancy. During the dormant period, all side shoots were trimmed and trees were headed as is common practice when planting dormant trees. Details of the trial are listed below.

Varieties. 'Nonpareil', 'Carmel' and 'Sonora'. All Carmel trees were replaced in the spring of 2000 due to widespread noninfectious bud failure and are therefore one season behind the Nonpareil trees.

Rootstocks. Nemaguard, Lovell and Hansen 536.

Spacing. The distance between rows remains 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' & 22' x 22'

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

1. **"Standard" training & 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, then unpruned.** Three permanent scaffolds were selected as in the "standard" treatment. Trees were pruned normally the second dormant season due to the large number of water sprouts that were triggered by the first dormant pruning. These trees have been unpruned since the second dormant season except to remove occasional root suckers or low limbs that interfere with cultural operations.

3. **"Minimal" training & 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, four to six scaffolds were selected to maintain a full canopy. Few, vigorous shoots growing in the center of the trees were removed. Only a maximum of three cuts per tree is now made each dormant pruning to maintain a minimally open canopy.

4. **Untrained & 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 remove occasional root suckers and low limbs that interfere with cultural operations.

Results.
Influence on tree vigor. Trees in this plot have grown very vigorously. Training and subsequent pruning has had a profound effect on canopy size and shape. Trees that received standard training and pruning the first dormant period had many more root suckers than minimally trained or untrained trees (Table 1). Although Hansen tended to sucker less than Nemaguard or Lovell, differences were not significant between rootstocks.

Table 1. The Influence of Tree Training on the Severity of Root Suckering.

Number of root suckers per tree. (Evaluated at second dormant pruning.)				
	Standard Trained (3 scaffolds)	Minimally Trained (4-6 scaffolds)	Untrained (no scaffold selection)	Average
Nemaguard	4.2	1.3	0.1	**1.9**
Lovell	3.5	1.4	0.1	**1.7**
Hansen	3.2	0.6	0.0	**1.3**
Average	**3.6**	**1.1**	**0.07**	

During the second dormant period (after the first-leaf), the orchard was exposed to a winter storm with strong winds. A total of 14 trees blew over and 10 other trees had significant scaffold failure. All affected trees were Nonpareil. Of the 14 trees that blew over, 13 were untrained and unpruned (Table 2). The other tree was minimally pruned. Eight of the trees were on Lovell rootstock, four were on nemaguard and two were on Hansen. Of the ten trees with significant scaffold failure, six were untrained and unpruned, three were minimally pruned and one was standard trained and pruned. These data illustrate that trees with larger, denser canopies are more prone to blowover. These data also confirm other reports that Hansen rootstock has better anchorage and is less prone to blowover.

Table 2. Effect of Tree Training on Blow Over and Scaffold Breakage of First-leaf Trees

	Standard Trained	Minimally Trained	Untrained
Blowovers	0	1	13
Broken Scaffolds	1	3	6

Effect of Rootstock on Tree Blow Over and Scaffold Breakage of First-leaf Trees

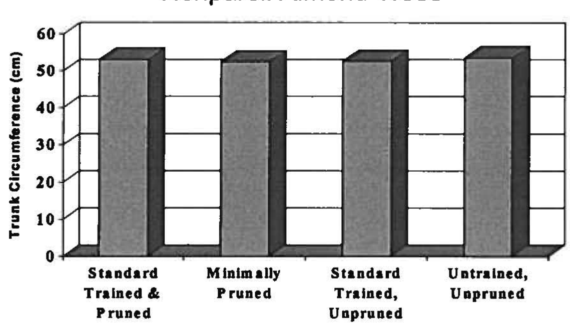
	Hansen	Nemaguard	Lovell
Blowovers	2	4	8
Broken Scaffolds	5	2	3

Although pruning treatments have not significantly affected trunk circumference (Figure 1), pruning has affected the size and shape of the canopy.

Trees on Hansen rootstock have the largest trunk circumferences (Figure 2).

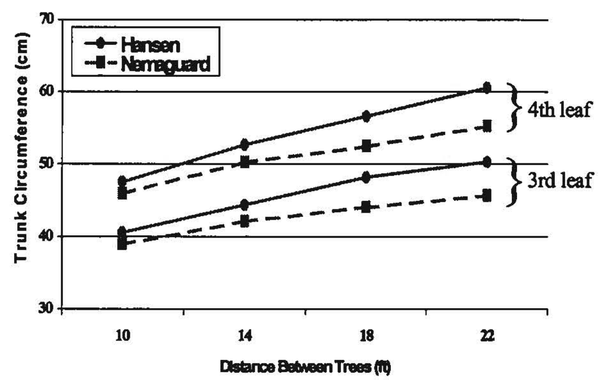
Tree spacing has had a significant effect on tree size (Figure 2). Due to intra-tree competition, trees planted ten feet apart were already smaller than more widely planted trees after just the second growing season as measured by truck circumference. By the third-leaf, even trees 18 feet apart were smaller than those spaced 22 feet apart. This shows that intra-tree competition can be utilized to manage tree size.

Fig. 1. Trunk Circumference as Influenced by Training & Pruning Style of 4th-Leaf Nonpareil Almond Trees



*Pruning style did not influence trunk circumference

Fig. 2. The Influence of Tree Spacing and Rootstock on Trunk Size of Nonpareil Almond Trees



<u>Influence on Yield</u>. Yield data for this report are for Nonpareil on nemaguard and Hansen rootstocks. Yield data for Carmel were not yet available by the date of this report.

Trees on Hansen rootstock had higher yields than those on nemaguard (Table 4). This probably reflects the significant difference in tree size between the two rootstocks.

Tree spacing has had a smaller than anticipated effect on yield per acre, especially on the vigorous Hansen rootstock. As discussed above, spacing and rootstock have had significant effects on tree size. In turn, spacing and rootstock have had significant effects on yield per tree. Trees on Hansen rootstock planted 22 feet apart had slightly more than twice the yield <u>per tree</u> as those planted only 10 feet apart (Table 4). However, because there are less than half as many trees per acre in a 22' x 22' spacing as compared to a 10' x 22' spacing, <u>tree spacing had no effect on **per acre** yield</u> for Nonpareil trees on Hansen rootstock. Because trees on nemaguard are less vigorous and fill available space more slowly, tree spacing had more of an impact on yield. Trees on Nemaguard planted more closely had higher yields per acre than those spaced farther apart.

Table 4. Yield per Tree and per Acre for Nonpareil Almond on Two Rootstocks at Four In-row Spacings

	Nemaguard		Hansen	
Tree Spacing Down the Row	Lb. per Tree	Lb. per Acre	Lb. per Tree	Lb. per Acre
10’	12.6	2495	12.5	2479
14’	17.0	2376	18.4	2601
18’	19.9	2184	22.9	2520
22’	22.9	2054	27.8	2500

Although pruning and training treatments have had no significant effect on trunk circumference, canopy volume appears much larger in minimally trained and untrained trees (visual observation). Despite this apparent difference in canopy size, training and pruning has had no significant effect on Nonpareil yield (Table 5). Similar results were obtained the previous year (4^{th} leaf).

Table 5. Yield per Acre (lb.) of 5^{th} Leaf Nonpareil Almond as Influenced by Tree Spacing and Pruning[1]

	10’	14’	18’	22’	Average
Standard trained Standard pruned	2362	2435	2478	2008	2321
Standard trained Unpruned	2527	2710	2230	2371	2460
Minimum trained Minimum pruned	2432	2465	2292	2204	2348
Untrained Unpruned	2627	2345	2409	2270	2413
Average	2487	2489	2352	2213	

[1]Yields are a combination of trees on nemaguard and Hansen rootstocks.

Discussion.

So far, there has been no yield advantage or disadvantage to pruning. Trees that had no scaffold selection would look unacceptable to most growers due to limb congestion in the crotch of the trees and the presence of many crossing limbs. So far these trees have not been more difficult to harvest or had excessive scaffold splitting, but this may become an issue in the future. Trees that were initially trained to three scaffolds but are not annually pruned look very acceptable and are not overly dense.

Trees have only just completed their fifth growing season and very little lower fruiting wood has been lost to shade out. This trial needs to be monitored for several more years to determine the long term effects of pruning and spacing. Even though untrained and unpruned trees appear to have much larger canopies, yields are similar to trees that were trained to three scaffolds and receive a moderate amount of pruning each year. The reason is unclear and will be examined more closely in the future.

It seems logical to expect that trees spaced ten or fourteen feet apart would have significantly higher yields per acre than trees spaced 22 feet apart during the first few years of production. However, competition between trees begins well before the canopies of adjacent trees begin to commingle. In this orchard, tree size was affected by tree spacing possibly during the first growing season, even for trees planted 18 or more feet apart. Trees planted 22 feet apart are the largest and extend farther out into the drive row. It is possible that trees planted 10 or 14 feet apart will never adequately fill the space between the 22 foot rows and thus may ultimately have lower per acre yields. If this occurs, it would indicate that orchards with trees planted closely down the rows should also have less space between rows. It may turn out that the advantage to high density plantings in a vigorous site is not higher yields, but smaller trees which are easier to harvest, easier to spray and may require less pruning with comparable yields. High density plantings may improve yields where orchards are planted on weak ground or low vigor rootstocks.

One might expect that the reason densely planted trees are smaller than widely planted trees is due to increased competition for water and nutrients. However, leaf tissue analyses of these fifth-leaf trees showed no nutrient differences between differently spaced trees (data not shown). In addition, pressure bomb readings taken in June did not indicate a clear relationship between tree spacing and midday stem water potential. Differences in stem water potential will be evaluated more closely in the future.