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

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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.

Trial description:
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 and ripped six feet deep to mix underlying soil layers. Potted trees were planted in fall 1999 and are irrigated with double-line drip. Leaf analyses indicate more than adequate levels of most nutrients, including 2.7-2.8% nitrogen. This is a vigorous orchard.

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. Data is collected only for Nonpareil and Carmel.

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

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' and 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. 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, only very vigorous shoots growing in the center of the trees were removed. Four to six scaffolds were selected 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 & 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.

Pruning Costs. A commercial pruning crew is hired each year to prune this trial. Workers were monitored to determine the amount of time it took them to prune each treatment in November, 2004. Trees planted at 18' x 22' were used for time comparisons. The average time it took to prune these 5th – leaf trees along with associated pruning costs are shown in Table 1 below.

Table 1. Average Time Required and Associated Costs to Prune Fifth-leaf Nonpareil Almond Trees Under Various Pruning Treatments.

	Average time to prune one tree	Calculated pruning cost per acre[1]
1. Standard training and annual pruning	3 min, 50 sec	$78.14
2. Standard training, no annual pruning	0	$0
3. Minimal training, minimal annual pruning	1 min, 43 sec	$34.80
4. No training, no annual pruning[2]	30 sec[3]	$9.16

[1]Based on 110 trees per acre and a cost of $11.10 per hour for contracted labor. Dollar amount shown does not include the cost of stacking brush and brush removal.
[2]Low limbs that interfere with cultural operations had to be removed from some trees.
[3]Estimated.

Pruners were instructed to make a maximum of three cuts per tree in pruning treatment #3. These cuts tended to be large saw cuts which were more time consuming than pruning shear cuts. Due to horizontal growth of lower limbs in pruning treat #4, low limbs that interfered with cultural practices had to be removed from approximately 1/3 of the trees in 2005. Costs shown in Table 1 do not include labor or equipment costs for stacking and removing brush from the orchard. Stacking and burning brush is estimated to cost an additional $24.00 per acre for an annually pruned orchard. Total estimated cost of pruning treatment #1 is about $102.00 per acre.

Effect of Rootstock, Planting Density and Pruning on Tree Size. Trees in this plot have grown very vigorously. Trees that received standard training and pruning the first dormant period had many more root suckers than minimally trained or untrained trees in their second leaf (see 2004 Almond Conference Proceedings).

During the second dormant period, a wind storm blew over a total of 14 trees and 10 other trees had significant scaffold failure. Of the 14 trees that blew over, 13 were untrained and unpruned. 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 untrained or minimally trained trees are more susceptible to blowover and scaffold failure.

In December 2004, trunk circumference was measured for trees on Hansen and Nemaguard rootstocks (Table 2). Tree height and canopy width (perpendicular to tree rows) were measured in June 2005 for trees on Nemaguard rootstock.

Table 2. The Effects of Rootstock, Tree Spacing and Pruning on Trunk and Canopy Size of 6th – leaf Nonpareil Almond Trees				
	Trunk Circumference (cm)		Tree Height (feet)	Canopy Width (ft)
	Nemaguard	Hansen	Nemaguard	Nemaguard
In-row Spacing				
10’	48.0	50.3	17.4	18.5
14’	53.5	57.0	18.0	19.4
18’	56.1	61.0	17.5	19.9
22’	59.2	66.3	18.7	21.0
Pruning treatment				
1	54.5	58.2	18.0	19.4
2	53.9	58.9	17.5	19.4
3	53.9	58.8	18.4	19.9
4	54.4	58.8	17.4	20.2

Tree spacing has had a significant effect on tree size. Trees planted only ten feet apart had the smallest trunk circumference while trees planted 22 feet apart had the largest trunks. Tree spacing also had a significant effect on canopy width. Trees planted 22 feet apart extended 1 ½ feet further out into the drive row than trees planted only 10 feet apart. Trees planted 22 feet apart have almost completely filled the canopy across the rows while trees planted ten feet apart still have more space to fill. This suggests that when trees are planted more closely down the row, between-row spacing may also be reduced. There was no clear tree spacing effect on tree height.

Pruning treatments have had no effect on trunk circumference or canopy width. There is a noticeable difference in canopy shape between pruning treatments, although this has been difficult to characterize numerically. Trees trained to three scaffolds and pruned annually (pruning treatment #1) have a more upright and open growth characteristic. Trees trained to three scaffolds but have not been pruned for three years (pruning treatment #2) also have an upright growth shape but the canopy appears slightly more dense. Most growers would not object strongly to the appearance of these trees. Trees that were not trained and have never been pruned (pruning treatment #4) have a more horizontal and weepy growth habit and appear extremely dense. The growth habit of these trees makes it very difficult to see the trunks and makes harvest more difficult. Limbs extending horizontally into the drive rows also make cultural activities more treacherous. The weepy growth habit of the untrained & unpruned trees has been especially troublesome in the Carmel variety. In fact, the trunks of some Carmel trees in this pruning treatment have split and will need to be removed this fall. Trees that were minimally trained (4-6 scaffolds) and are minimally pruned every year (pruning treatment #3) have a more weepy growth habit than trees trained initially to three scaffolds – whether pruned annually or not. However, they are not as troublesome as the completely untrained and unpruned trees.

For all tree spacing and pruning treatments, trunks of trees on Hansen are significantly larger than trees on Nemaguard rootstock.

Mid-day stem water potential was determined for all planting densities and for pruning treatments #1 and #4 on July 12 and August 16, 2005. Tree water status was not affected by planting density or pruning style in this drip-irrigated orchard (Table 3).

Table 3. Almond Tree Water Status as Influenced by Planting Density and Pruning Style

Tree Spacing	Stem Water Potential (bars)[1]
10’	-11.4
14’	-12.7
18’	-11.0
22’	-12.2
Pruning Treatment	
#1 Standard Training and Pruning	-11.7
#4 No Training, No Annual Pruning	-12.0

[1]Stem water potential data among treatments are not statistically different at $P \leq 0.05$.

Influence on Hull Rot. Hull rot (bread mold) was fairly severe in this trial in 2005. Prior to harvest, Nonpareil trees were rated for hull rot severity on a scale from 0 - 5 (0 = no hull rot, 5 = bottom 1/3 of tree entirely affected). Results are shown in Figs. 1 and 2. Hull rot was fairly severe in all spacing and pruning treatments. Tree spacing did not significantly influence hull rot severity. However, hull rot was affected by tree training and pruning. Standard trained and annually pruned trees had the least hull rot while the untrained and unpruned trees had the most hull rot. Hull split appeared to be more advanced on standard trained & pruned trees than untrained, unpruned trees on the evaluation date (observation only). If the hull split period is prolonged in untrained, unpruned trees, this may explain why hull rot was more severe.

Figure 1. The Effect of Pruning on Hull Rot of Nonpareil Almond

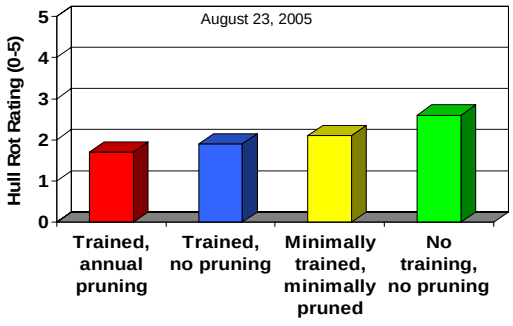
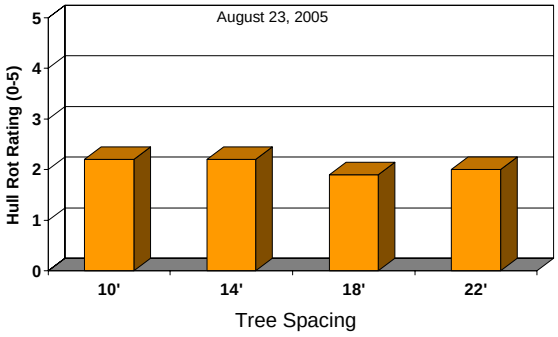
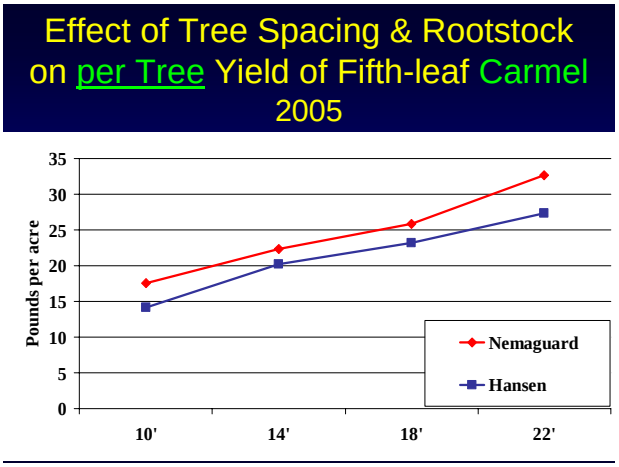


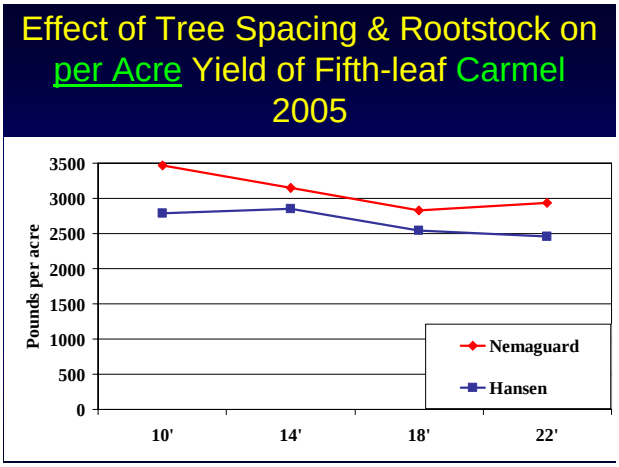
Figure 2. The Effect of Tree Spacing on Hull Rot of Nonpareil Almond



Influence on Yield. Due to mechanical problems, we were unable to collect yield data for the Nonpareil variety in 2005. In 2004 (fifth-leaf), Nonpareil trees on the more vigorous Hansen rootstock out-yielded those on Nemaguard. There was no benefit to planting trees densely on Hansen rootstock because widely spaced trees quickly grew large and filled the available space. Closely planted trees on the less vigorous Nemaguard rootstock had higher per-acre yields than widely spaced trees on Nemaguard. Yield advantages of more closely spaced trees on Nemaguard may be less apparent as the orchard matures. There was no significant yield difference between pruning treatments in 2004 (2004 Almond Board Proceedings).

In 2005, Carmel trees on Hansen yielded less than Carmel on Nemaguard. Trunk circumference measurements in previous years have shown that the Carmel trees on Hansen are smaller than those on Nemaguard. The reason for this is unclear. Other rootstock trials have shown almonds on Hansen, including the Carmel variety, are usually larger when grown on Hansen. As with the Nonpareil variety, Carmel trees planted more densely have smaller trunk circumference than Carmel trees planted farther apart. As in previous years, per tree yields are less on smaller, more densely planted trees. Because Carmel trees are smaller than Nonpareil, dense planting lead to a per acre yield advantage.

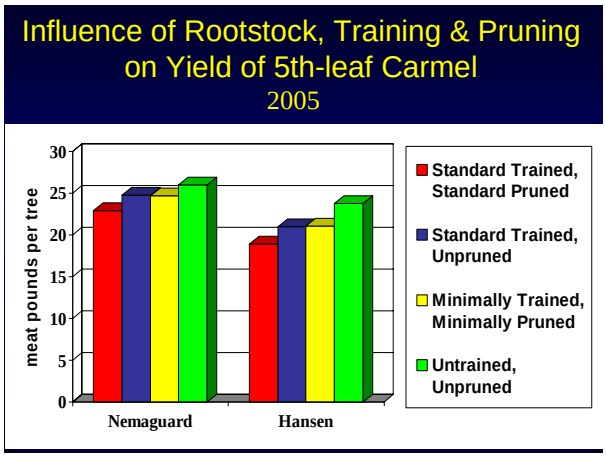




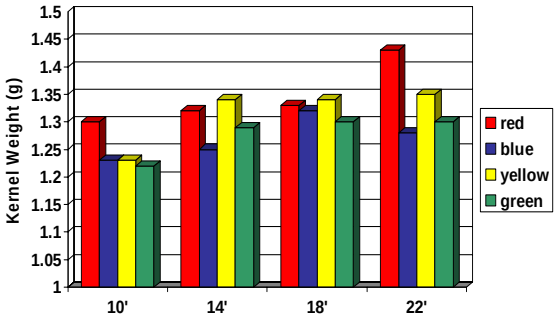
Pruning had a significant effect on yield of Carmel trees in 2005. The highest yielding trees were untrained and unpruned (26.0 pounds per tree on Nemaguard & 23.8 pounds per tree on Hansen). The lowest yielding trees were trained to three scaffolds and pruned annually (22.9 pounds per tree on Nemaguard & 18.9 pounds per tree on Hansen). This equates to an average difference of four pounds per tree or an equivalent of 495 pounds per acre in a 16' x 22' orchard. This represents a gross income loss of approximately $1500 per acre, plus pruning costs in the annually pruned trees.

Pruning and spacing treatments that had the lowest yields tended to have the largest kernels. However, although handlers are paid more for larger kernels, growers are not

paid differentially. Therefore there is no financial advantage for growers to adjust management strategies to achieve larger kernel size.



Carmel Kernel Size Related to Tree Spacing & Pruning. 2005



Discussion.

Competition between trees begins well before the canopies of adjacent trees begin to commingle. 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. Planting trees densely may only offer a yield advantage when orchards are planted on weak ground or are on 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, pressure bomb readings taken in 2004 and 2005 did not indicate a relationship between tree spacing and midday stem water potential. In addition, leaf tissue analyses of fifth-leaf trees showed no nutrient differences between differently spaced trees (Table 4).

Table 4. Comparison of Leaf Nutrient Content of Differently Spaced Nonpareil Almond Trees. July, 2004.[1]

Tree Spacing	N (%)	P (%)	K (%)	S (ppm)	B (ppm)	Ca (%)	Mg (%)	Cu (ppm)
10 ‘	2.7	.12	1.6	1538	28	3.8	0.69	10.6
14’	2.8	.13	1.7	1545	30	3.8	0.66	10.6
18’	2.8	.13	1.6	1530	29	3.7	0.68	10.6
22’	2.8	.13	1.7	1540	29	3.6	0.65	10.3

[1]Leaf nutrient values were not statistically different at P< 0.05.

Through the fifth-leaf, there was no yield advantage or disadvantage to training and pruning Nonpareil almonds. Time will tell how pruning will affect long-term production. 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.

Nonpareil trees have not had excessive scaffold splitting, but Carmel trees are suffering from the lack of attention. Many Carmel trees are beginning to “mushroom” and some have split all the way to the ground. Many of the untrained trees may require fairly severe corrective pruning in the future to prevent further scaffold breakage and to reduce hazardous conditions for equipment operators. Trees that were initially trained to three scaffolds but are not annually pruned look very acceptable and are not overly dense.