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

Project No.: 06-HORT3-Duncan

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Interpretive Summary:

In this trial, Nonpareil and Carmel trees on nemaguard or Hansen rootstocks have been planted at four spacings; the closest spacing is 10' x 22' (198 trees per acre) and the widest is 22' x 22' (90 trees per acre). Within the various planting arrangements, we are also experimenting with four different pruning strategies, including "minimal" pruning and some trees that had no scaffold selection and have never been pruned except for equipment access. The trees have now finished their seventh growing season. During the first few years, trees planted more densely had higher yields on the less vigorous nemaguard rootstock but not on the highly vigorous Hansen rootstock. However, trees on nemaguard have now filled the space between trees, even at the 22' x 22' spacing, and there is no longer a yield advantage to closer spacing regardless of rootstock. However, trees planted more closely are smaller, have had the fewest problems with scaffold breakage and have not had more disease problems to date. Trees that have been trained and pruned "conventionally" have had the lowest yields every year while trees that had no scaffold selection and are not pruned have the highest yields but more hull rot. Untrained or minimally trained trees were more susceptible to blowover and scaffold failure during the first dormant period. Through the first seven years of this trial, there has been no yield benefit to pruning. This trial must be monitored for many years to determine the effects on long-term profitability.

Objective:

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

Problem:

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.

Materials and 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 and ripped six feet deep to mix underlying soil layers. Potted trees were planted in the fall of 1999 and are irrigated with double-line drip. Leaf analyses indicate more than adequate levels of most nutrients, including 2.7-3.0% nitrogen. This is a vigorous orchard.

Varieties. 'Nonpareil', 'Carmel' and 'Sonora'. All Carmel trees were replaced in the spring of 2001 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 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 & 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 low limbs that interfere with cultural operations.

Results and Discussion:

Effect of rootstock, planting density and pruning on tree size.

In February 2006, trunk circumference was measured for trees on Hansen and nemaguard rootstocks (Table 1).

Table 1. The Effect of Rootstock, Tree Spacing and Pruning on Trunk Circumference of 7th-leaf Nonpareil and 6th-leaf Carmel Almond Trees. February, 2006				
	Trunk Circumference (cm)			
	Nonpareil		Carmel	
	Nemaguard	Hansen	Nemaguard	Hansen
In-row Spacing				
10'	52.5	52.1	46.7	43.0
14'	59.0	62.3	51.3	52.0
18'	62.0	68.2	52.7	53.3
22'	66.4	74.0	58.5	56.2
Pruning treatment				
1	60.8	64.7	51.9	50.6
2	59.3	64.4	51.7	51.0
3	60.0	63.9	53.4	51.3
4	59.8	63.6	52.1	51.6

Trunks of Nonpareil trees on Hansen rootstock are significantly larger than trees on nemaguard, except for trees planted only ten feet apart. Carmel trees on Hansen are not significantly larger, although they usually have been in other rootstock trials. Tree spacing has had a significant effect on tree size. Trees planted only ten feet apart have the smallest trunk circumference while trees planted 22 feet apart have the largest trunks. Pruning treatments have had no effect on trunk circumference. 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 four years (pruning treatment #2) also have an upright growth shape but the canopy appears slightly denser. Most growers would not object strongly to the appearance of these trees. Lower limbs on trees that were not trained and have never been pruned (pruning treatment #4) have a more horizontal growth habit. The lowest of these limbs interfered with trunk shaking initially and have now been removed. Lower limbs in this pruning treatment tend to stick out into the drive row. Although these limbs are most likely adding to the yield in this treatment, they make equipment operation treacherous and necessitate removal or enclosed cab equipment.

Pruning and spacing vs. scaffold breakage. The "weepy" growth habit of the untrained & unpruned Carmel trees, as well as the minimally pruned trees has been troublesome. In fact, the trunks of some Carmel trees in these pruning treatments split, resulting in complete tree failure (Fig. 1). Tree spacing has had a much more significant effect on tree failure than pruning (Fig. 2). While 15 trees in the 22' x 22' spacing treatment had significant scaffold failure, only 2 trees spaced at 14' x 22' and no trees

spaced 10' x 22' had significant scaffold breakage. These data suggest that scaffold selection and pruning are much more important in widely spaced trees than in high density orchards.

Fig. 1. The Effect of Pruning on Scaffold Splitting 2005

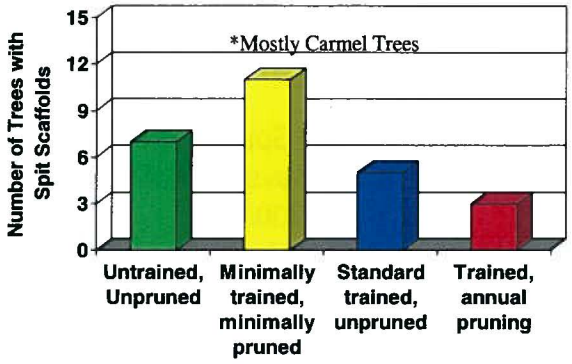
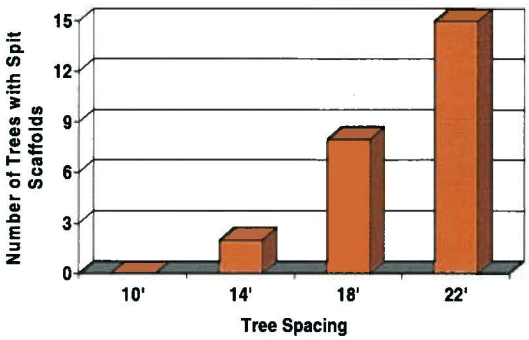


Fig. 2. The Effect of Tree Spacing on Scaffold Splitting of Almond Trees. 2005



Rootstock survival in wet soil. The spring of 2006 was very cool and wet. The soil in this test orchard has a high clay content and gets very "mucky" when wet. A low area cuts through the test plot, perpendicular to the rows. Therefore, all three rootstocks were subjected to a prolonged period of saturated soil conditions well after leafing out this year. In May, 2006, rootstocks were evaluated for tolerance to saturated soils and were rated as either "mildly" affected, "severely" affected or dead (Table 2). Although none of the three rootstocks performed well in saturated soil, almost twice as many trees on Hansen were at least "mildly" affected. While three trees on nemaguard and six trees on lovell were rated as "severely" affected, 16 trees on Hansen were rated as severely affected. There was no difference between nemaguard or lovell.

Table 2. Tolerance of Nemaguard, Lovell and Hansen Rootstocks to Saturated Soil Conditions. Spring, 2006

	Dead	Severely Affected	Mildly Affected	Total Affected
Nemaguard	6	3	14	23
Lovell	8	6	13	27
Hansen 536	5	16	21	42

Influence of tree spacing on yield.

Yields for the Carmel variety could not be processed in time for inclusion in this report but will be discussed at the Almond Conference. Yields were slightly higher for Nonpareil trees on Hansen rootstock than on nemaguard, presumably because Hansen trees are larger. Per tree yields were directly related to tree spacing: trees spaced the farthest apart are the largest and have the highest per tree yields (Fig. 3). However, now that trees planted the farthest apart (22' x 22') have almost filled all of their

available space, per acre yields are essentially the same for all spacings (Fig. 4). During the first years of harvest, trees planted more densely had higher per acre yields on nemaguard rootstock but not on the highly vigorous Hansen rootstock. Nonpareil trees on nemaguard have now filled the space between trees, even at the 22' x 22' spacing, and there is no longer a yield advantage to closer spacing regardless of rootstock. Although Carmel yields have not yet been processed, yields will probably be lower for trees planted at the wider spacing due to the smaller tree size of the Carmel variety. This would indicate that Carmel trees should probably be planted more closely than Nonpareil trees.

Fig. 3. Effect of Tree Spacing & Rootstock on per Tree Yield of Seventh-leaf Nonpareil. 2006

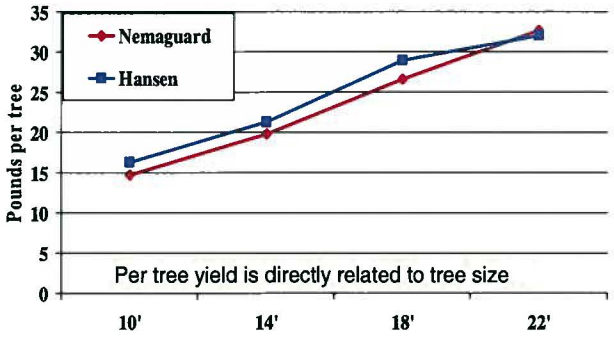
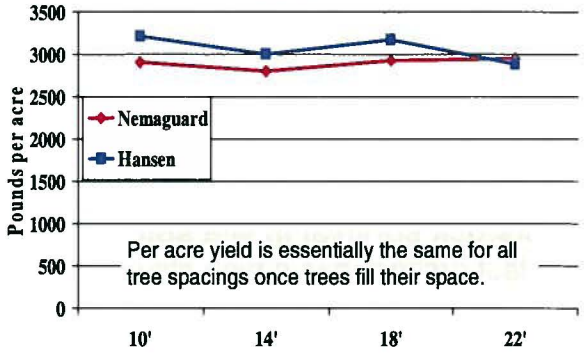
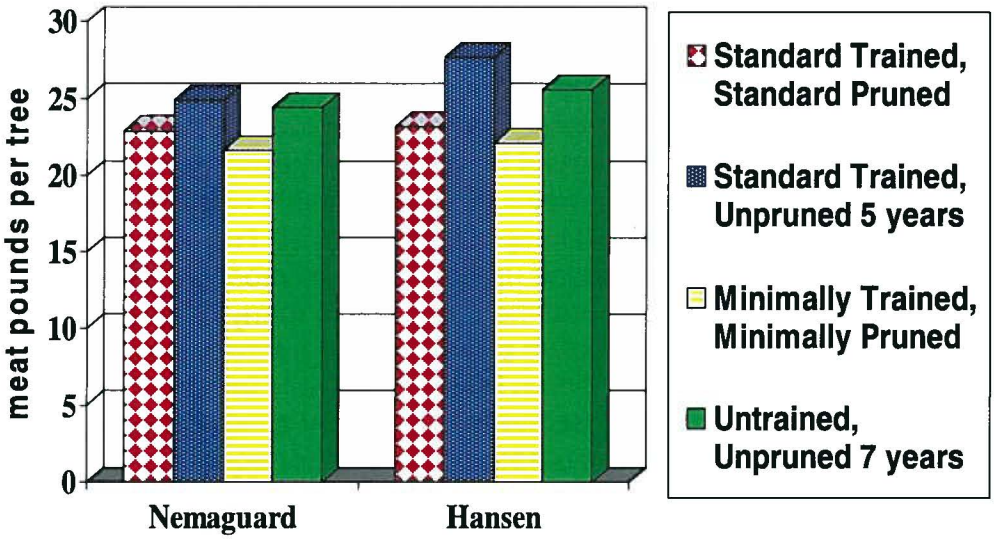


Fig. 4. Effect of Tree Spacing & Rootstock on per Acre Yield of Seventh-leaf Nonpareil. 2006



Influence of tree training and pruning on yield. As in past years, unpruned trees tended to have higher yields than conventionally pruned trees. During the first few years, yields from the minimally trained, minimally pruned trees have been similar to the unpruned trees. However, because pruners are allowed only three cuts per tree in the "minimally pruned" treatment, they tend to choose large limbs to remove and make saw cuts rather than several small cuts with pruning shears. It is possible that these large pruning cuts removed a substantial amount of fruiting wood, resulting in lower yields.

Fig. 5. The Influence of Training & Pruning on Yield of 7th-leaf Nonpareil Almond Trees. 2006



Yield per Acre of 6th leaf Carmel on Hansen Rootstock 2006					
	10'	**14'**	**18'**	**22'**	**Mean**
Red	1804	1637	1389	1161	**1498**
Blue	1648	1805	1587	1576	**1654**
Yellow	2080	1816	1561	1385	**1711**
Green	2129	1666	1730	1771	**1824**
Mean	**1915**	**1731**	**1567**	**1473**	

Yield per Acre of 6th leaf Carmel on Nemaguard Rootstock 2006					
	10'	**14'**	**18'**	**22'**	**Mean**
Red	1614	1427	1279	1259	**1395**
Blue	1799	1799	1746	1702	**1762**
Yellow	1818	1690	1619	1697	**1706**
Green	1659	2002	2019	1545	**1806**
Mean	**1723**	**1730**	**1666**	**1551**	

Discussion:

Through the seventh-leaf, there has been no yield advantage to training and pruning of Nonpareil almond trees. Annual pruning of Carmel trees has significantly reduced yields (by 367 and 411 pounds per acre compared to the blue and green pruning treatments, respectively). While unpruned Carmel trees have higher yields, these trees have had an excessive amount of scaffold breakage. If Carmel trees (probably most varieties) are allowed to grow without training, they probably need to be tied unless they are planted closely together which will keep the trees small. Trees in this trial that had no scaffold selection would probably look unacceptable to most growers due to limb congestion in the crotch of the trees and the presence of many crossing limbs. Many of the untrained trees may require corrective pruning in the future to prevent hazardous conditions for equipment operators. Trees that were initially trained to three scaffolds but have not been pruned since the second-leaf look very acceptable, have not had scaffold breakage problems, have not created problems for equipment operators and are not overly dense. Time will tell how lack of pruning will affect long-term production.