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

**Project No.:** **15-HORT5-Duncan**

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**Objective:**

To evaluate the interactive effects of planting density, rootstock and training / pruning techniques on tree size, structural integrity, short and long-term yield, and orchard longevity.

**Interpretive Summary:**

After 16 seasons, the data have consistently shown that annual pruning has not maintained yield better than unpruned (minimally pruned) trees. In general, the more that trees have been pruned, the lower the cumulative yields have been, although differences are often insignificant in a given year. In general, the more closely that trees have been planted down the tree row, the higher the yields, especially for the smaller Carmel variety. More closely planted trees are smaller, shake more easily, have less cumulative shaker injury on their trunks, have fewer mummies per acre, and have lost far fewer trees than widely spaced trees. So far, there has been no noticeable downside to planting trees ten feet apart down the row, other than increased planting costs, even on the very vigorous Hansen rootstock.

**Problem and its Significance:**

It is generally desirable for almond trees to fill the space in an orchard as quickly as possible during the first few years after establishment. This can be accomplished by higher density planting, minimal pruning, and ample inputs of water and fertilizer. This enables growers to bring an orchard into full production sooner and thus maximize early profits. However, after full canopy has been achieved, trees continue to grow which may eventually result in crowding, shading of lower wood, and premature yield decline. A widely held assumption is that higher density orchards may achieve higher yields earlier than more widely spaced orchards, but shading and yield decline will occur much earlier, possibly resulting in smaller long-term gains. It has also been a long-held assumption that pruning to increase light penetration throughout the canopy may increase or at least maintain yields for more years than orchards that are not pruned. Pruning was assumed to be especially important in higher density orchards.

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. Past field trials have shown that almond trees may not require much pruning to maintain high yields. In experiments conducted by Edstrom, et. al. and Viveros, et. al, minimally pruned almond trees have had yields equal to or greater than annually pruned trees for

many years – maybe the entire life of the orchard. However, trials conducted in the Sacramento Valley and Kern County are under different growing conditions than in the North San Joaquin Valley. It is important to test minimal pruning under various growing conditions.

Minimal pruning of almond trees has become the norm in California. We have established in this trial that unpruned almond trees will produce as well or better than almond trees that are annually pruned in a "conventional manner". However, it is important to continue with this trial to document the longer term effects of minimum pruning of almond trees.

**Materials and Methods:**

In the fall of 1999, a commercial almond orchard with cultivars 'Nonpareil', 'Carmel', and 'Sonora' was planted on virgin soil on the east side of Stanislaus County. The 37–acre field experiment was arranged in a multi-factorial design with four replications of each treatment for a total of 384 plots. Trees on Nemaguard, Lovell or Hansen 536 rootstocks were planted at four different in-row spacings: 22 feet, 18 feet, 14 feet or 10 feet down the row. A between-row spacing of 22' was maintained constant throughout the trial. Beginning at the first dormant period, four training and pruning strategies have been employed in this trial. They are:

1. "Standard" training; "standard" annual pruning. Three permanent scaffold limbs were selected during the first dormant pruning. These trees have been "moderately" pruned annually to keep centers open and eliminate crossing branches.
2. Minimal training & pruning. Trees were topped twice during the first growing season to stimulate secondary branching. At the first dormant pruning, five to six permanent scaffolds were selected to maintain a full canopy with a minimally open center. These trees are pruned annually by removing a maximum of three limbs on each tree.
3. "Standard" training and pruning for the first two years, then no pruning. These trees were pruned the same as in Treatment 1 above for the first two years. Other than occasionally removing branches interfering with farming practices, these trees have not been pruned in fifteen years
4. Untrained, Unpruned. No scaffold selection was made during the initial training of these trees except to remove limbs originating too low on the trunk for equipment access. These trees are not pruned except to remove limbs that become problematic for cultural operations.

Professional pruning crews are hired to prune this trial. Yields are calculated by harvesting nuts into nut buggies with built-in scales. Subsamples are collected from each plot and analyzed for kernel size and quality. Trees are inspected periodically throughout the growing season for other treatment effects such as disease incidence, mummies, etc.

**Results and Conclusions:**

**Effects of Pruning**

1. Nonpareil and Carmel yields were statistically similar among all pruning treatments in 2015, the 16$^{th}$ leaf of this orchard (**Table 1**).
2. Cumulative yield in Nonpareil trees that were trained to three scaffolds and have received moderate, annual pruning is 1131 kernel pounds per acre lower than trees that were initially trained to three scaffolds and have been largely unpruned for fifteen years.

3. Cumulative yield in conventionally trained and annually pruned Carmel trees is 3,733 kernel pounds per acre lower than untrained and unpruned Carmel trees.
4. Annual pruning has not improved light interception within the canopy as measured by a PAR meter (see 2015 final report). Annually pruned and unpruned trees both reached their maximum light interception during years 10–12 and are now beginning to decline. Annually pruned trees appear to be declining a little faster than unpruned trees.
5. At an average of $3.00 per pound, annual pruning would have reduced gross revenue by almost $13,000 per acre, including yield reduction and the cumulative cost of pruning and brush disposal.

**Effect of Tree Spacing**

1. In 2015, yield was not significantly different among the different tree spacings (**Table 1**).
2. Cumulative yields are similar for Nonpareil trees spaced 10, 14 or 18 feet apart down the row.
3. In-row spacing has affected cumulative yields much more in the smaller Carmel variety. In general, the closer the Carmel trees were planted within the row, the greater the cumulative yield.
4. Carmel trees planted 10 feet apart have cumulatively yielded about 3600 pounds per acre more than trees planted 22 feet apart.
5. Canopy light interception appears to be declining earlier and faster in the more widely spaced trees (see 2015 final report). The reason for this is unclear but may be related to more shaker injury, more scaffold failure and more trees falling over in the larger, widely spaced trees.
6. In the first 15 years of the 37-acre trial, we had to replant 39 trees in the 10’ x 22’ areas compared to 147 trees in the 22’ x 22’ spaced areas (Fig. 1).
7. This represents a loss of 7700 $ft^2$ of canopy in the closely spaced trees vs. 73,568 $ft^2$ in the most widely spaced trees (Table 2).
8. Closely planted trees are smaller than widely spaced trees (previously reported). As a result, more closely planted trees are easier to harvest, resulting in less shaker injury and fewer mummies per acre than widely spaced trees.
9. This may mean that higher density orchards will be productive longer than low density orchards, a hypothesis counter to current assumptions.
10. Currently we have not measured any disadvantage to closely planted trees.

| **Table 1.** The Effect of Pruning and Tree Spacing on Current Season (2015) and Cumulative Yield (Through 16th leaf). (Kernel lb. per acre) | | | | |
|---|---|---|---|---|
| | Nonpareil Yield | | Carmel Yield | |
| | 2015 | Cumulative | 2015 | Cumulative |
| **Training & Pruning** | | | | |
| Trained to 3 scaffolds; annual conventional pruning | 1691 a | 34,228 | 1548 a | 32,030 |
| Trained to 3 scaffolds; unpruned since 2nd leaf | 1597 a | 35,359 | 1646 a | 34,373 |
| Trained to multiple scaffolds; Three pruning cuts each year | 1538 a | 33,400 | 1536 a | 33,771 |
| No scaffold selection; No annual pruning | 1542 a | 35,167 | 1685 a | 35,763 |
| **Tree Spacing** | | | | |
| 10’ x 22’ | 1513 a | 34,306 | 1689 a | 35,409 |
| 14’ x 22’ | 1668 a | 35,060 | 1636 a | 35,232 |
| 18’ x 22’ | 1676 a | 34,680 | 1570 a | 33,496 |
| 22’ x 22’ | 1510 a | 33,252 | 1520 a | 31,800 |

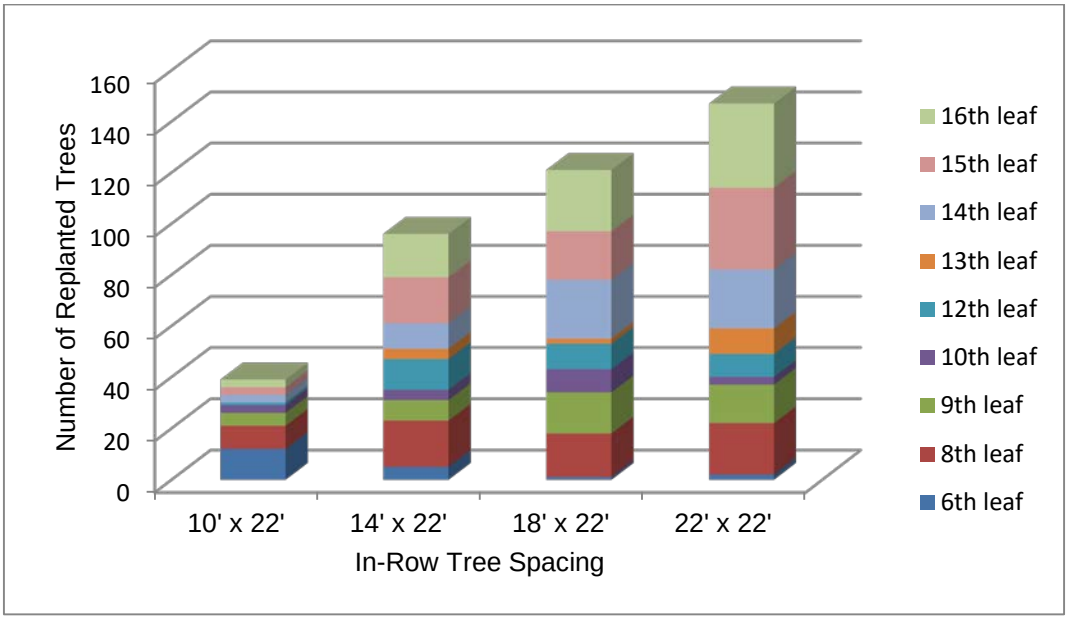


**Figure 1.** Cumulative Number of Trees That Have Needed to be Replaced Within 37 Acre Trial Area in Relation to In-Row Tree Spacing

| **Table 2. The Influence of Tree Spacing on Orchard Canopy Loss (Through the 15th Leaf)** | | |
|---|---|---|
| | Cumulative Number of Replants (on 37 acres) | Area of Missing Canopy (Square feet) |
| 10’ x 22’ | 35 | 7,700 |
| 14’ x 22’ | 81 | 24,948 |
| 18’ x 22’ | 118 | 46,728 |
| 22’ x 22’ | 152 | 73,568 |