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

Project No.: **17-HORT5-Duncan**

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Objective:

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

Interpretive Summary:

After 17 seasons, the data have consistently shown that annual pruning to improve light penetration and preserve the lower canopy has not maintained yield better than trees that have been essentially unpruned except for equipment access and safety. In general, the more that trees have been pruned, the lower the cumulative yields have been, although differences are often insignificant within a given year. Based on results of this 17-year trial, annual pruning would have cost the grower over $10,000 per acre in cumulative pruning costs and loss of production. In general, trees on Nemaguard rootstock have the highest cumulative yields at the most closely planted spacings (10 – 14 feet apart down the row), especially for the smaller Carmel variety. There is no clear cumulative yield advantage to high density planting for trees on the vigorous Hansen rootstock. In the last two seasons, Nonpareil yields have tended to be highest in the more moderate spacings (14' – 18'). It is unknown if this trend will continue in the last few years of production. 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, regardless of 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, using vigorous rootstocks, 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 high density orchards may achieve higher yields sooner than more widely spaced orchards but shading and yield

decline will occur 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 pruning to maintain high yields. In experiments conducted by Edstrom, et. al. and Viveros, et. al, minimally pruned almond trees 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 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. <u>"Standard" training; "standard" annual pruning</u>. 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. <u>Minimal training & pruning</u>. 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. <u>"Standard" training and pruning for the first two years, then no pruning.</u> 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. <u>Untrained, Unpruned</u>. 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 and operator safety.

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

- In 2017, (the 18th leaf), untrained & unpruned Nonpareil on Nemaguard trees yielded more per acre (811 lb.) than trees that were originally trained to three scaffolds and have been moderately pruned each year (**Table 1**).
- 2017 Nonpareil yields were statistically similar for all pruning treatments on Hansen rootstock (**Table 1**).
- Carmel yields were low overall in 2017. There was no significant difference among pruning treatments on either rootstock.
- Cumulatively, trees that have been pruned every year have lower yields than trees that are not pruned (other than access or safety). This is consistent among both varieties and rootstocks.
- Annual pruning of the Carmel variety has reduced cumulative yield by 2091 – 6075 lb. per ace through the 18th leaf.
- Cumulative yields are highest on untrained (no scaffold selection) and unpruned trees, regardless of variety or rootstock.
- Including pruning costs ($308 / acre for pruning, stacking and shredding) and cumulative yield reduction (average price of $3.00 / pound), a grower who pruned this orchard annually would have reduced his/her cumulative net income by more than $10,000 per acre during this period.
- This 18-year-old trial confirms that pruning does not increase or even maintain almond tree yields, even in the very long term.
- Even though untrained trees tend to have the highest yields, we have had more problems with scaffold failure and equipment access in these trees, requiring more “safety pruning” than trees initially trained to three scaffolds.
- Trees that were initially trained to three scaffolds and then essentially unpruned for the next fifteen years have cumulative yields similar to untrained trees but have required very little safety pruning through the years.
- In this trial, “minimally” pruned trees often have the lowest yields. This is likely because when pruners are allowed only three cuts per tree, they tend to make larger cuts, often removing more wood than in the “conventional” pruning treatment.
- Annual pruning has not improved light interception within the canopy as measured by a PAR meter (see Lampinen, et. al. 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.

Effect of Tree Spacing

- In 2017, yield tended to be highest in the moderately spaced trees of 14 – 18 feet down the row.
- Cumulatively, Carmel trees on Nemaguard planted ten feet apart have yielded 6,620 pounds per acre more than trees planted 22 feet apart. There is a linear relationship, the closer the trees are planted, the higher the cumulative yields.
- Cumulatively, Nonpareil trees on Nemaguard and Carmel trees on Hansen tend to have higher yields at the more densely planted spacings (10 and 14 feet apart), but the pattern is less clear and the differences are relatively small.
- Canopy light interception appears to be declining earlier and faster in the more widely spaced trees (data not shown here, 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.
- 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 (**Figure 1**, data previously reported).
- 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 3**).
- 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.
- This may mean that higher density orchards will be productive longer than low density orchards, a hypothesis counter to current assumptions.

Table 1. The Effect of Pruning on 2017 (18th Leaf) and Cumulative Yield of Nonpareil and Carmel Almond Varieties on Nemaguard or Hansen Rootstocks

	Nonpareil on Nemaguard		Nonpareil on Hansen		Carmel on Nemaguard		Carmel on Hansen	
	2017	Cum.	2017	Cum.	2017	Cum.	2017	Cum.
Annual Standard Training & Pruning	2244 b*	38,487	3097 a	40,278	2016 a	41,210	1149 a	31,571
Annual Minimal Pruning	1754 b	37,488	3014 a	38,658	1744 a	40,578	1299 a	35,801
Unpruned After Two Years	2069 b	39,182	3044 a	41,372	1771 a	42,187	1395 a	35,707
Untrained & Unpruned	3055 a	40,270	3055 a	41,729	1824 a	43,301	1445 a	37,646

*Data followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2. The Effect of In-row Spacing on 2017 (18th Leaf) and Cumulative Yield of Nonpareil and Carmel Almond Varieties on Nemaguard or Hansen Rootstocks

	Nonpareil on Nemaguard		Nonpareil on Hansen		Carmel on Nemaguard		Carmel on Hansen	
	2016	Cum.	2016	Cum.	2016	Cum.	2016	Cum.
10’ x 22’	2087 a	39,591	2942 ab	39,422	2074 a	43,264	1245 a	34,718
14’ x 22’	2089 a	39,966	3008 ab	40,553	1698 ab	41,084	1236 a	35,738
18’ x 22’	2309 a	38,089	3492 a	42,419	1952 ab	38,932	1464 a	34,371
22’ x 22’	1633 b	36,769	2767 b	39,669	1631 b	36,644	1343 a	32,560

*Data followed by the same letter are not significantly different (P< 0.05).

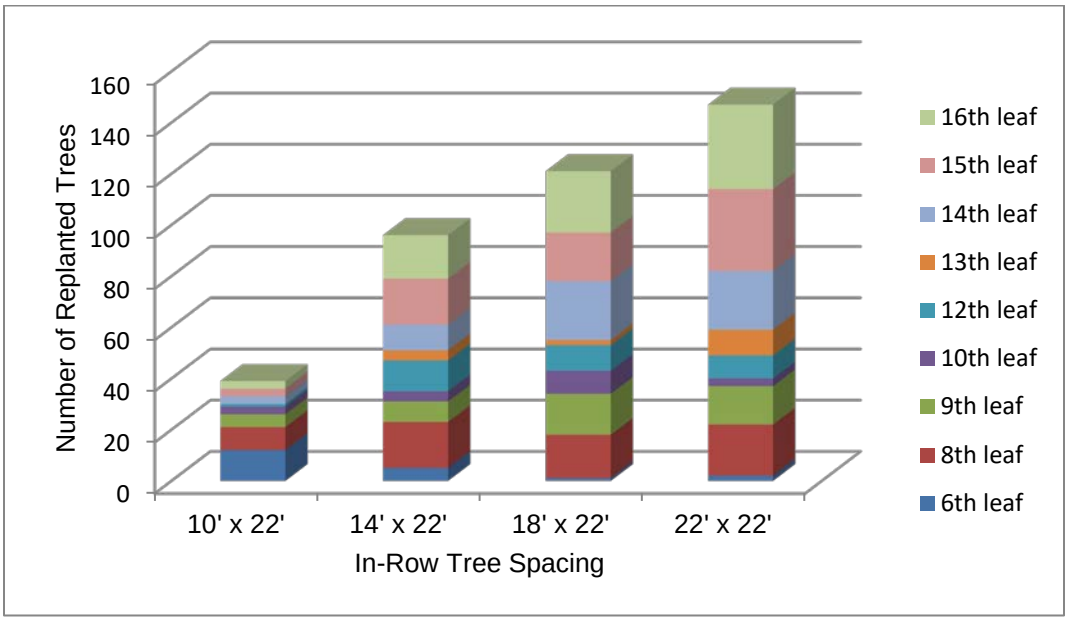

Figure 1. Cumulative Number of Trees That Have Needed to be Replaced Within 37 Acre Trial Area in Relation to In-Row Tree Spacing

Table 3. 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