
Integration of Tree Density & Minimal Pruning for Efficient Almond Production

Project No.: HORT5

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A. Summary (*In laymen's terms – emphasize key findings and recommendations*)
2020 marked the 21st season for this very long-term pruning & spacing trial. The pruning treatment portion of this trial was terminated at the end of 2018 (19th leaf) but data collection continued for the spacing portion through 2020. Throughout the duration of this trial, 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 were often insignificant within a given year. Based on results of this trial, annual pruning would have cost the grower between \$7,500 and \$14,000 per acre in cumulative pruning costs and loss of production, depending on variety and rootstock. In general, trees on Nemaguard rootstock have the highest cumulative yields at the more closely planted spacings (10 – 14 feet apart down the row), especially for the smaller Carmel variety. For the most vigorous trees (Nonpareil on Hansen rootstock) yields have tended to be highest in the more moderate spacings (14' – 18'). 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. It appears that orchards with trees planted closely down the row may be easier to maintain and have a longer productive lifespan than more widely, conventionally spaced orchards.

B. Objectives (*300 words max.*)

To evaluate the long-term effects of three key management factors: tree spacing (planting density), rootstock, and training/pruning strategies on orchard production and longevity.

C. Annual Results and Discussion

Effects of Pruning

- Pruning has not increased or sustained yield in the short term or long term. Pruning either has had no effect or has reduced yield, especially in the Carmel variety.
- At current almond prices and labor costs, conventional training and annual pruning would have reduced net income by \$7,500 - \$14,000 per acre in this trial, including pruning, stacking & shredding costs plus lower cumulative yield.
- Although untrained & unpruned trees tend to have the highest yields, they have been more prone to scaffold failure, especially in widely spaced trees.
- Sometimes pruning is needed for safety, equipment access, removing broken or diseased limbs, etc. but the reason to prune should justify the expense and potential yield loss.

- 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. annual report). Annually pruned and unpruned trees both reached their maximum light interception during years 10–12 and are now declining. Annually pruned trees appear to be declining a little faster than unpruned trees.
- The best strategy appears to train the tree to be structurally strong during the first 1-2 years and then only if necessary, for safety or equipment access thereafter.

Effect of Tree Spacing

- In 2020, the 21st leaf of this orchard, Nonpareil yield for trees on nemaguard was highest in the most closely planted trees (10' x 22') and decreased significantly as tree spacing increased. The most closely planted Nonpareil trees on Nemaguard produced 1102 lb more per acre than trees spaced widely (22 feet). Cumulatively, the most closely spaced trees have outyielded the most widely spaced trees by 8298 pounds per acre over the span of this trial.
- Cumulatively, Carmel trees on Nemaguard planted ten feet apart have yielded 8,010 pounds per acre more than trees planted 22 feet apart. There is a direct relationship between tree spacing and yield; the closer the trees are planted, the higher the annual and cumulative yields.
- Cumulatively, Nonpareil trees on Hansen tend to have higher yields at the more moderate spacings (14 & 18 feet apart), but the pattern is less clear and the differences are relatively small.
- Closely planted trees are smaller than widely spaced trees (Figs 2-4). 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.
- In the first 20 years of the 37-acre trial, we have had to replant 42 trees in the 10' x 22' areas compared to 175 trees in the 22' x 22' spaced areas (Fig. 1). This represents a loss of 9240 ft² of canopy in the closely spaced trees vs. 84,700 ft² in the most widely spaced trees.
- Canopy light interception appears to be declining earlier and faster in the more widely spaced trees (see previous annual reports to the Almond Board). 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.
- This may mean that higher density orchards will be productive longer than low density orchards, a hypothesis counter to previous assumptions.
- Yield advantage to tight in-row spacing is highly dependent on inherent tree vigor. Lower vigor trees (small varieties, less vigorous rootstocks, poor soil) will benefit most from tight spacing. Vigorous trees may not have a substantial yield increase if planted at high density. However, the risk of yield loss due to overly close planting may have been overstated in the past.
- There are advantages to tighter spacing other than yield. Trees planted closer together are smaller. This results in less need for training & pruning, less tree structural failure, easier harvest, less trunk injury, fewer mummies and perhaps a longer lasting orchard.

Table 1. The Effects of In-row Tree Spacing & Rootstock on 2020 and Cumulative Yield (through 21st Leaf) ¹				
	Nonpareil			
	Nemaguard		Hansen	
	2020 yield (lb / a)	Cumulative	2020 yield (lb / a)	Cumulative
Tree Spacing				
10' x 22'	2695 a	46,647	2567 a	47,713
14' x 22'	2277 ab	46,384	2161 a	48,190
18' x 22'	2038 bc	40,749	2571 a	51,258
22' x 22'	1592 c	38,349	2239 a	47,015
Nonpareil x rootstock	2151 a	43,032	2385 a	48,544
	Carmel			
10' x 22'	2661 a	51,254	1971 a	40,625
14' x 22'	2141 a	47,736	1665 a	41,063
18' x 22'	2441 a	46,246	1836 a	39,888
22' x 22'	2210 a	43,239	1932 a	38,031
Carmel x rootstock	2363 a	47,119	1851 b	39,902

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

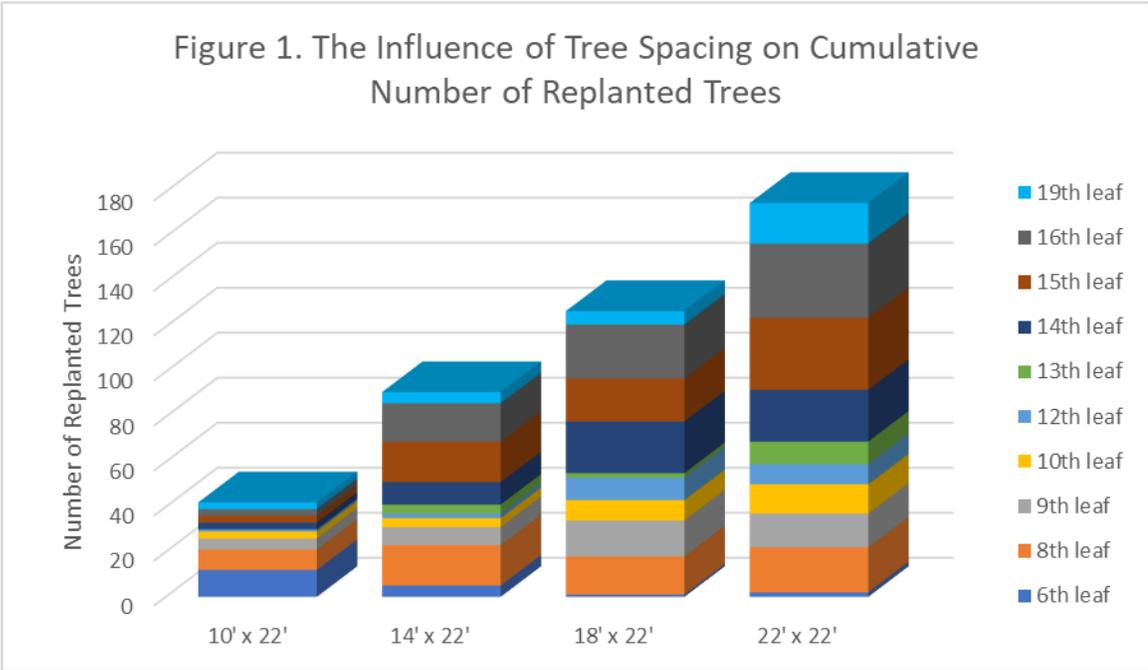


Fig. 2. The Influence of Tree Spacing on Tree Size of Third-Leaf Almond Trees

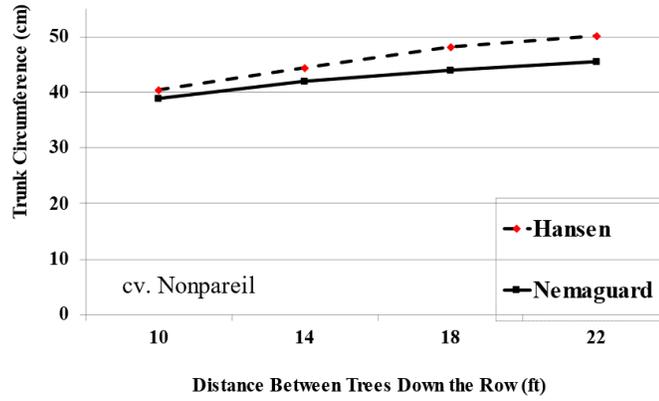


Fig. 3. The Influence of Tree Spacing on Tree Size of Sixth-Leaf Almond Trees

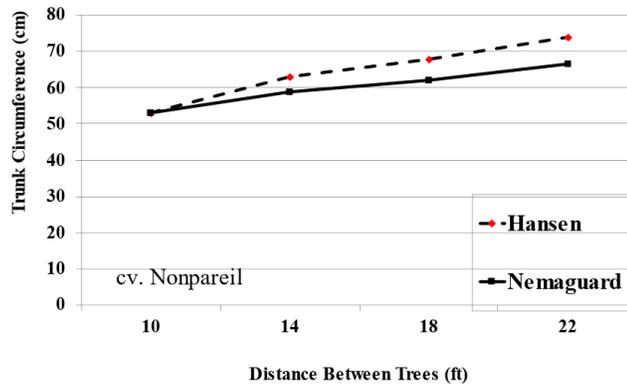
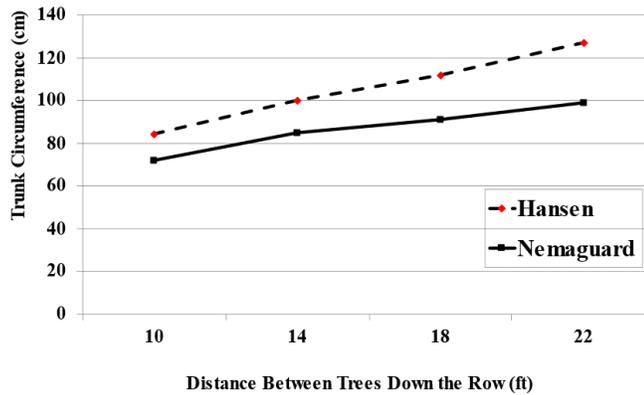


Fig. 4. The Influence of Tree Spacing on Tree Size of 20th-Leaf Almond Trees



D. Outreach Activities

Information from this trial has been disseminated at multiple events through the years, including three field days, the UC Almond Production Shortcourses, Almond Board of California webinar (11-19-19, ca 36 participants) Almond Industry Annual Conferences, North San Joaquin Valley Almond Days and other UCCE county extension events and the UCCE Stanislaus Newsletter, *The Scoop on Fruits & Nuts*.

E. Materials and Methods (500 word max.):

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. “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 and operator safety.

The same professional pruning contractor has been hired to prune this trial throughout the years. Yields are calculated by harvesting nuts with a commercial pick-up machine and elevating them into conveyer carts (Flory Industries) with load cells built-in to the axels and tongue. 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.

In 2019, the pruning portion of the field trial was terminated after 19 years. The orchard was sold to a new grower and we were unable to continue the pruning treatments. Yield in the tree spacing treatments was monitored through 2020.