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

Project No.: **14-HORT5-Duncan**

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Objectives:

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

Interpretive Summary:

- This trial has completed its 15th season and the data have remained consistent. Annual pruning has not increased or maintained yield better than unpruned (minimally pruned) trees. In general, the more those trees have been pruned, the lower the cumulative yields have been, although differences are often insignificant in a given year.
- Cumulative yield in Nonpareil trees that were trained to three scaffolds and have received moderate, annual pruning is 1088 kernel pounds per acre lower than trees that had no scaffold selection and have been largely unpruned for fifteen years.
- Cumulative yield in conventionally trained and annually pruned Carmel trees is 3,604 kernel pounds per acre lower than untrained and unpruned trees.
- Annual pruning has not improved light interception within the canopy as measured by a PAR meter. 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.
- At current market prices (greater than $4 per pound), annual pruning would have reduced gross revenue by at least $10,000 per acre due to yield reduction, not including a cumulative cost of about $3,000 per acre in pruning and brush disposal.
- In general, the closer the trees were planted within the row, the greater the cumulative yield, especially in the Carmel variety.
- Nonpareil trees planted 10 or 14 feet apart down the row have cumulatively yielded about 3200 pounds per acre more than trees planted 22 feet apart.
- Carmel trees planted 10 feet apart have cumulatively yielded about 5200 pounds per acre more than trees planted 22 feet apart.
- 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.

- Canopy light interception per acre appears to be declining earliest and fastest in the most widely spaced trees.
- So far there has been no noticeable downside, other than increased planting cost, to planting trees ten feet apart, even on the very vigorous Hansen rootstock.
- Orchards with trees planted closely down the row may have a longer productive lifespan than orchards with trees planted 18 or more feet apart.

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 is gaining in popularity. 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”, at least for the first fifteen years. 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. There are six trees per plot. 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:

- In general, annual light interception data indicate that maximum light interception in this orchard occurred from the tenth through the twelfth leaf and is now beginning to decline (**Figures 1 & 2**). These data are very similar to other data obtained in almond orchards throughout California.

Pruning

- Annual pruning has not improved the light interception dynamics in this trial (**Figure 1**). Trees that have been pruned annually never achieved levels of canopy light interception that unpruned trees have and appear to dropping off faster.
- Peak light interception of annually pruned trees was about 3.5% less than unpruned trees, representing a reduction in yield potential of about 150 kernel pounds per acre.
- In the most current year (2014), Carmel yield was lowest in the annually, conventionally pruned trees. Nonpareil yield was similar in all pruning treatments (**Table 1**).
- In most years Nonpareil yields are statistically similar in conventionally pruned, minimally pruned and unpruned trees. Cumulatively, unpruned Nonpareil trees have yielded just 1088 pounds more than conventionally trained & pruned trees (**Table 1**).
- In most years, Carmel yields are highest in the untrained and unpruned trees. Cumulatively, untrained & unpruned Carmel trees have yielded 3604 pounds more than conventionally pruned trees through the 15th leaf (**Table 1**).
- Conservatively, the cost of pruning, stacking brush and shredding every year, plus the value of lost yield would have cost the grower over $7000 per acre to date. At current market value (~$4.50 / pound), opportunity cost would have been over $13,000 per acre.
- Trees trained to multiple scaffolds are more prone to scaffold failure and tree blow over (young trees), especially in widely spaced trees (previously reported).
- Pruning has not affected kernel size (previously reported).

- It appears that pruning may not be necessary to improve or maintain almond yield, at least through the first two thirds of an orchard's life.

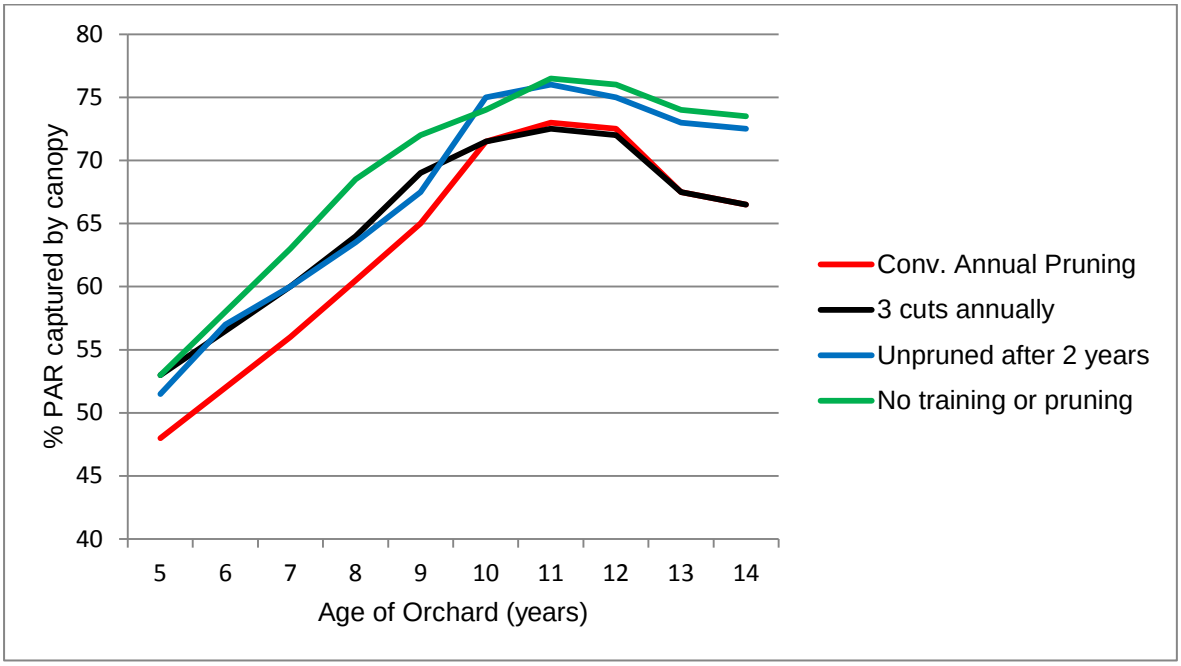

Figure1. Sunlight interception by the canopies of different pruning systems. Each percent of Photosynthetically Active Radiation (PAR) is equivalent to an increase in yield potential of about 50 kernel pounds per acre.

Table 1. The Effect of Pruning and Tree Spacing on the Most Current Season and Cumulative Yield (Through 14th leaf). (Kernel lb. per acre)

	Nonpareil Yield		Carmel Yield	
	2013	Cumulative	2014	Cumulative
Training & Pruning				
Trained to 3 scaffolds; annual conventional pruning	3199 a	32,537	2867 b	30,682
Trained to 3 scaffolds; unpruned since 2nd leaf	3092 a	33,762	3163 a	32,930
Trained to multiple scaffolds; Three pruning cuts each year	3093 a	31,862	3028 ab	32,448
No scaffold selection; No annual pruning	3236 a	33,625	3159 a	34,286
Tree Spacing				
10' x 22'	2922 a	37,382	3267 a	36,942
14' x 22'	2992 a	37,331	3209 a	35,615
18' x 22'	2876 a	35,424	3002 ab	33,602
22' x 22'	2683 b	34,181	2738 b	31,745

Spacing

- The most widely spaced trees never achieved canopy light interception comparable to more closely spaced trees (**Figure 2**).
- Canopy light interception appears to be declining earlier and faster in the more widely spaced trees (**Figure 2**). 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 15 years of the trial, we have had to replant 39 trees within the 37 acre trial in the 10' x 22' spaced trees compared to 147 trees in the 22' x 22' spaced trees (**Figure 3**). 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**).
- In in the most recent year, Nonpareil and Carmel yields were lowest in the widest tree spacing (22 x 22). Yields were similar in the 10' x 22' and 14' x 22' tree spacing (**Table 1**).
- Cumulative yield for the Nonpareil variety is 3201 pounds per acre higher in the most closely spaced trees compared to the most widely spaced trees (**Table 1**).
- Cumulative yield for the smaller Carmel variety is 5197 kernel pounds per acre higher than the widest tree spacing (**Table 1**).
- The yield gap between closely planted and widely planted trees appears to continue to widen, especially for the smaller Carmel variety. (**Figures 4, 5, 6 & 7**).
- 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.
- Currently we have not measured any disadvantage at all to closely planted trees, even Nonpareil on vigorous Hansen rootstock planted ten feet apart.

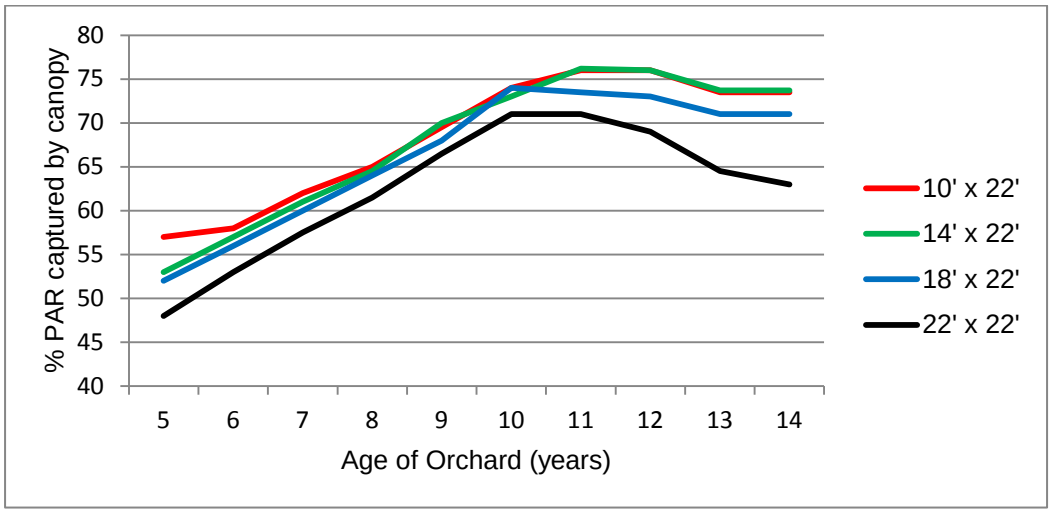

Figure 2. The effect of in-row tree spacing on total canopy sunlight Interception. Widely spaced trees took longer to achieve maximum sunlight capture and have declined sooner than more closely spaced trees.

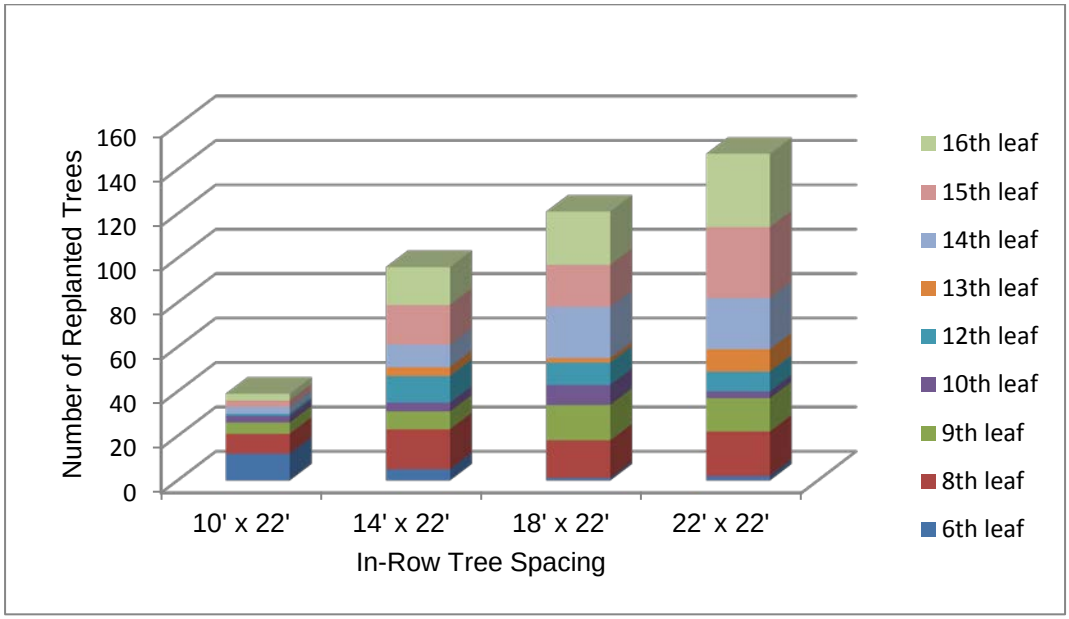

Figure 3. Cumulative number of trees that have needed to be replaced within 37 acre trial area in relation to in-row tree spacing.

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

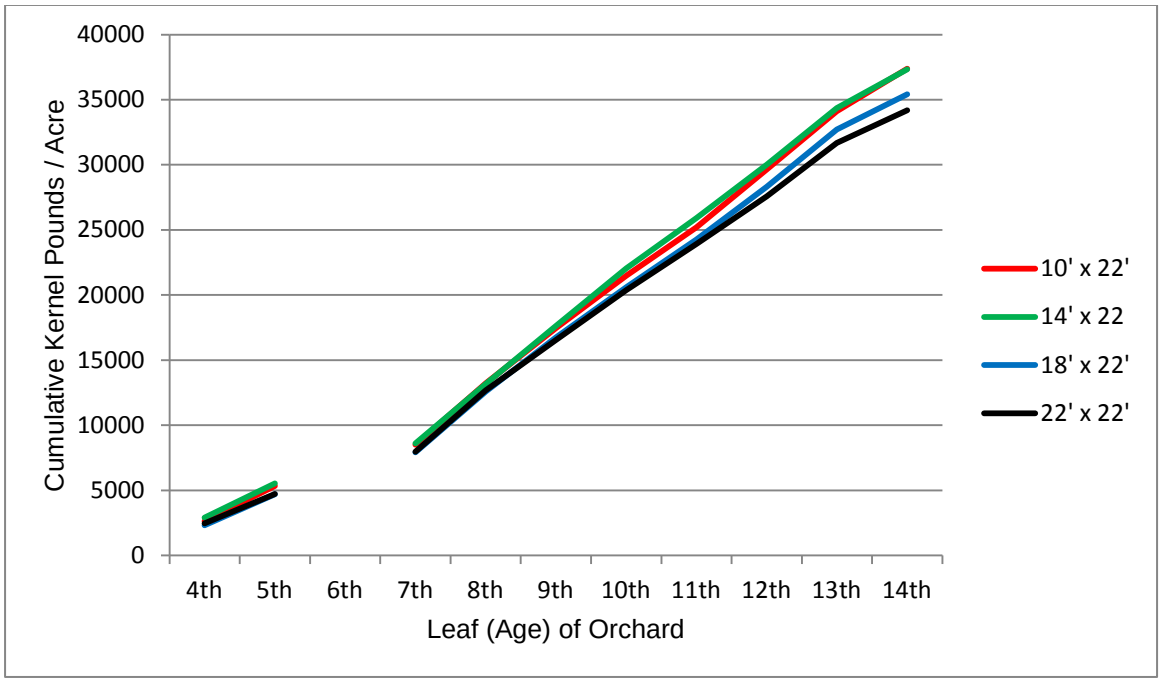

Figure 4. Cumulative yield of Nonpareil in relation to in-row tree spacing 4th - 14th leaf

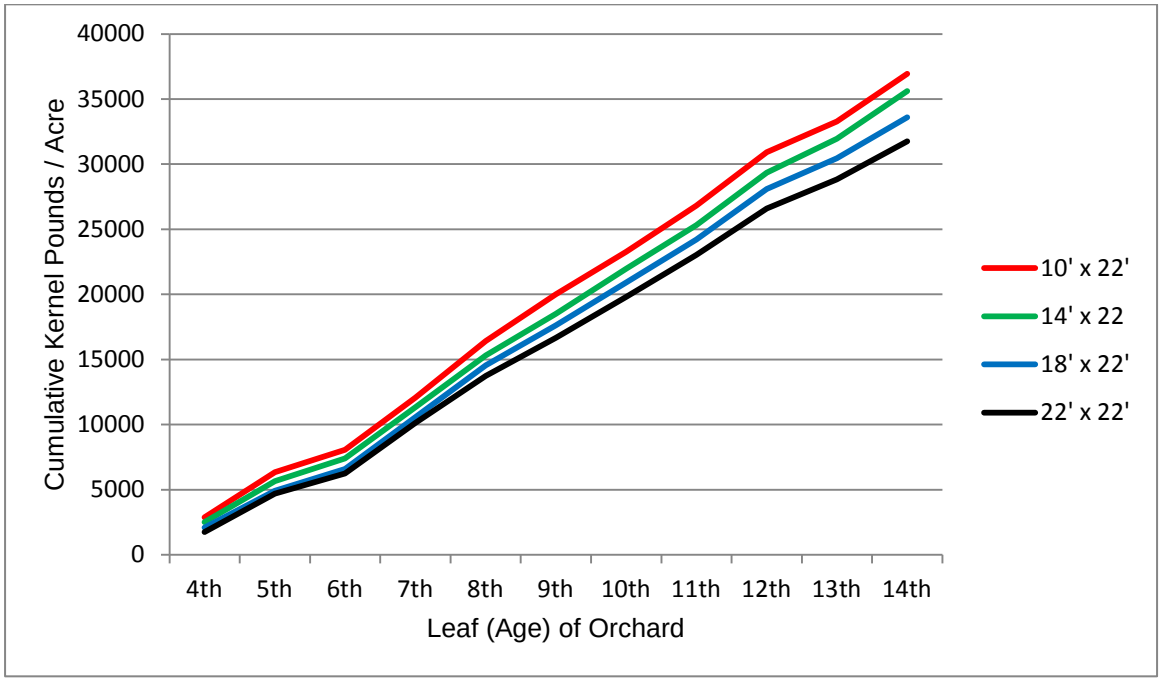

Figure 5. Cumulative yield of Carmel in relation to in-row tree spacing.

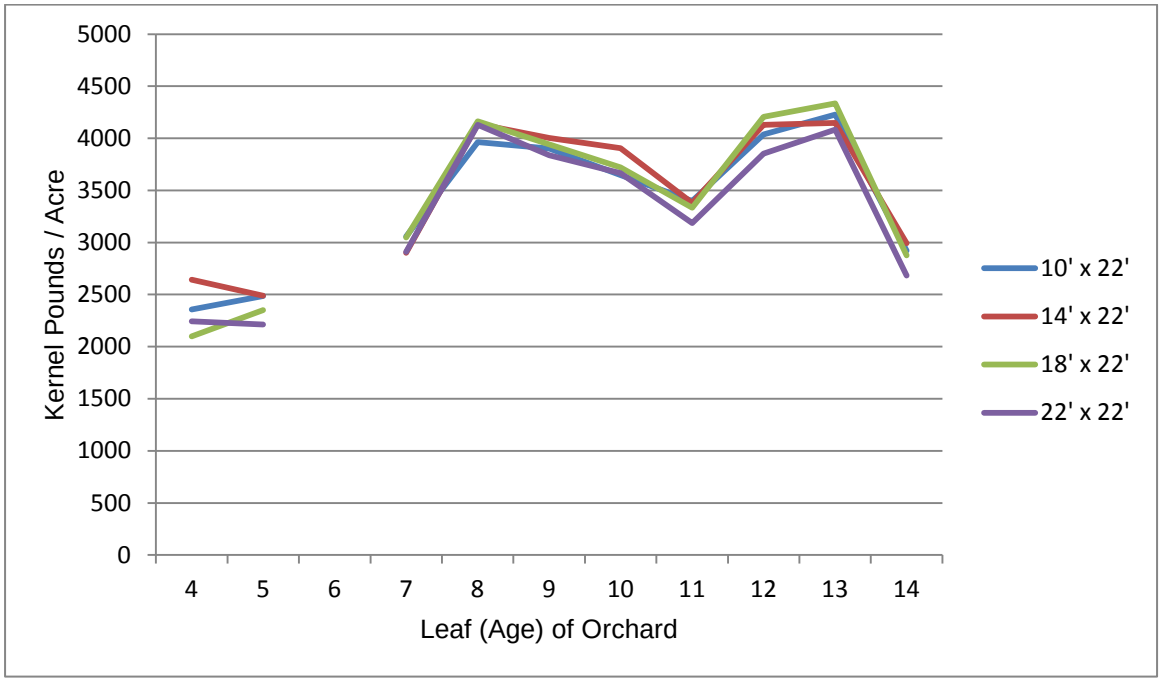

Figure 6. Yield dynamics of Nonpareil almond in relation to in-row tree spacing (4th - 14th leaf)

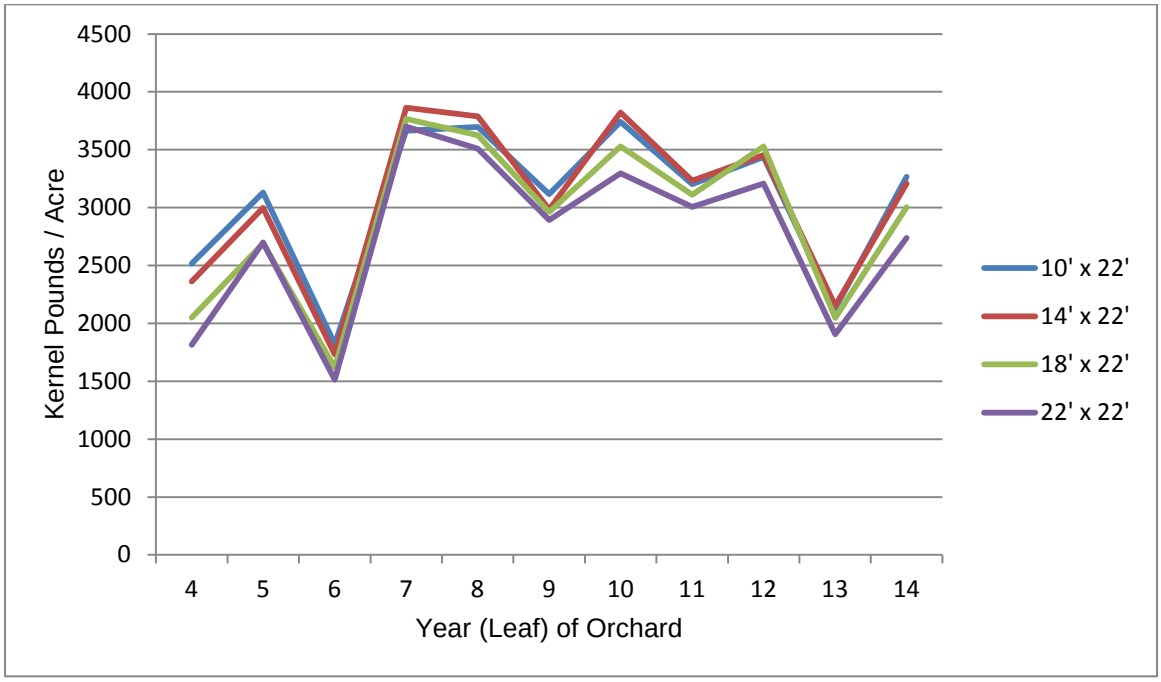

Figure 7. Yield dynamics of Carmel almond in relation to in-row tree spacing (4th - 14th leaf)

Rootstock. During the development years, yields were highest for both varieties on the vigorous Hansen rootstock (previously reported). In 2007 (eighth-leaf), yields were significantly lower for trees on Hansen compared to trees on Nemaguard. It is assumed that the lower yields of the Hansen rootstock in 2007 were a result of the very wet spring in 2006 (trees on Hansen were affected more than trees on Nemaguard). Carmel trees on Hansen continue to produce substantially less than Carmel on Nemaguard in this trial. This is very different than results seen in other rootstock trials and it may demonstrate that Hansen is not the appropriate rootstock for the relatively heavy soils of the Sierra foothills that often remain saturated throughout much of the spring.