The Economics of High Density Avocado Groves

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Planting density is something of a hot topic recently. In the Fall 2019 issue of the California Avocado Commission's (CAC) *From the Grove*, I authored an article titled, "High Density Groves: Fact or Fiction." And while that article has not generated the amount of feedback I expected, it has generated strong reactions — both positive and negative. The point of that article was not to say high density planting is good or bad, but to get the reader to think about what happens when trees are planted more closely together.

Table 1. Pine Tree Ranch high density planting trial yield data for 'Hass' on 'Toro Canyon'. The trees were planted in June 2014 and the first harvest took place in spring 2017.

Spacing (tree x row)	Yield (pounds/acre)				Average yield (pounds/ acre)	Cumulative total (pounds)
	2017	2018	2019	2020		
15 x 20	4,284	1,672	1,864	6,255	3,518	14,075
10 x 20	5,600	3,257	5,826	5,705	5,097	20,388
7.5 x 20	8,329	3,471	11,180	5,644	7,156	28,624
15 x 15	4,991	2,528	6,511	5,310	4,835	19,340
10 x 15	10,475	3,127	15,899	1,924	7,856	31,425
7.5 x 15	9,665	6,250	16,905	2,934	8,938	35,754
15 x 10	9,129	1,039	12,174	8,361	7,675	30,703
10 x 10	12,157	7,632	17,744	5,502	10,758	43,035

I believe there is a general misconception that, when planted more closely together, something "magical" happens and trees become more productive. If trees are simply planted more closely together and every other aspect of management remains the same as when trees are planted farther apart, then the trees will become crowded and yields will decline. And that was the key takeaway from the earlier article — if planting at high density, every other aspect of management cannot stay the same.

In fact, data collected from a high-density trial at Pine Tree Ranch and from other growers and researchers would support the notion that high density planting likely makes good economic sense, at least in the early years of the grove. However, growers should be aware of the potential risks as well as potential rewards associated with high density plantings before choosing a spacing for their grove.

Let's explore some of the economics of high density 'Hass' plantings and see how it pencils out. I also pose some questions for you, the reader, to ponder and ask for your insights. You just may get an honorable mention in a future article.

The Experimental Site

In June 2014, a spacing trial was planted at CAC's Pine Tree Ranch demonstration grove in Santa Paula. The planting consists of 'Hass' on 'Toro Canyon' planted at eight different spacings with row spacings ranging from 20 feet to 10 feet, and between tree spacings of 15 feet to 7.5 feet. These spacings equate to tree densities from 145 trees per acre to 435 trees per acre. Table 1 shows the spacings, trees per acre and yields per acre since the first harvest in 2017. It should be noted that the planted area of each spacing is less than one-acre (ranging from 0.15 to 0.44 acres), and the per-acre yields were calculated from the actual yield and the number of trees at each spacing.

No pruning was done on any of these tree spacings from 2014 through 2018. In spring 2019, following harvest, the trees were pruned due to crowding in the tightest spacings. In the tightest spacings — 10 x 15, 7.5 x 15, 15 x 10, 10 x 10 — many of the trees had completely lost their interior and lower leaves and were essentially sticks after pruning. This is reflected in the generally large yield declines for these spacings in 2020. Despite these declines, the four tightest spacings had the highest average yield per acre as well as the highest cumu-

lative pounds of fruit from 2017 through 2020. Through the first four years of production, there has been essentially no difference in the fruit size distribution based on tree spacing, nor has there been any difference in the percentage of grade 1, grade 2 or cull fruit.

Some may argue that the yields in this trial could have been even higher than what we experienced if we had started to prune earlier, and they may be correct. Unfortunately, there is no consensus on the best pruning technique for high-density plantings, and we chose not to prune until year five when the trees became crowded and something had to be done.

Table 2. Gross annual and four-year cumulative returns for 'Hass' trees on 'Toro Canyon' rootstock planted in June 2014 at eight different spacings.

Spacing (tree x row)	Trees per acre	Gross Returns				Total Gross Returns
		2017	2018	2019	2020	
15 x 20	145	$6,863	$1,896	$3,202	$7,881	$19,843
10 x 20	218	$8,971	$3,693	$10,009	$7,188	$29,862
7.5 x 20	290	$13,343	$3,936	$19,207	$7,111	$43,598
15 x 15	194	$7,996	$2,867	$11,186	$6,691	$28,739
10 x 15	290	$16,781	$3,546	$27,314	$2,424	$50,066
7.5 x 15	387	$15,483	$7,088	$29,043	$3,697	$55,310
15 x 10	290	$14,625	$1,178	$20,915	$10,535	$47,253
10 x 10	436	$19,476	$8,655	$30,484	$6,933	$65,547

Costs and Assumptions

Annual gross income and four-year total gross income based on the calculated per acre production for each spacing is shown in Table 2. For the purposes of this article, we have used the California industry average price per pound for 2017, 2018 and 2019 (californiaavocadogrowers.com/industry/industry-statistical-data), which is an average across all varieties, sizes and growing methods, to calculate gross returns. For 2020, the year-to-date average price per pound as of March 31 has been used (californiaavocadogrowers.com/industry/pounds-and-dollars-variety).

Some of the costs incurred from planting through harvest in spring 2020 are shown in Table 3. Tree costs were calculated based on a total tree cost of $70 per tree, which includes the price of the tree, planting labor, staking, whitewash and above ground irrigation.

As mentioned previously, the trees were pruned for the first time in 2019 after harvest. All-in pruning costs — labor (all-in $28/hr), equipment, brush stacking and chopping, whitewashing as needed — were $4.88 per tree ($2,128 per acre for the 10 x 10 spacing). This is similar to Dr. Gary Bender's estimates ($2,004 per acre) from a recent high density trial he conducted in Valley Center (see "Improvement of Yield Per Acre by Close Spacing, Pruning of Close-Spacing 'Hass' and 'Lamb Hass' Trees, Final Report" at californiaavocadogrowers.com). Note that the widest spacings, 15 x 20 and 15 x 15, have not yet required any pruning.

Harvesting costs are based on actual per pound harvesting costs in each of the four seasons, summed across all four years to determine a cumulative harvesting cost for each spacing (Table 3). Over the four years, harvesting costs have ranged from $0.17 to $0.22 per pound, for an average of $0.19 over the four years.

Table 3. Gross cumulative returns, expenses, and net returns for 'Hass' trees on 'Toro Canyon' rootstock grown at eight different spacings after the fourth harvest season.

Spacing (tree x row)	Total Gross Returns	Expenses			Net returns
		Tree cost	Pruning	Harvest	
15 x 20	$19,843	$10,150	$0	$2,582	$7,111
10 x 20	$29,862	$15,260	$1,064	$3,879	$9,659
7.5 x 20	$43,598	$20,300	$1,415	$5,551	$16,332
15 x 15	$28,739	$13,580	$0	$3,717	$11,442
10 x 15	$50,066	$20,300	$1,415	$6,219	$22,132
7.5 x 15	$55,310	$27,090	$1,889	$7,078	$19,254
15 x 10	$47,253	$20,300	$1,415	$5,933	$19,605
10 x 10	$65,547	$30,520	$2,128	$8,411	$24,488

The overall net returns — this figure does not account for all expenses, so it is not a true net return — based on the gross returns less the known costs for each spacing also are shown in Table 3.

Water and fertilizer costs were not specifically tracked in this trial because the irrigation was not divided and managed separately for each of the spacings. Some general thoughts on these costs are discussed later in the article.

Which Spacing Makes the Most Sense/Cents?

Over the first four years of harvest, the 10 x 10 spacing produced the highest average yield (10,758 pounds per acre) and the highest cumulative pounds (43,035 pounds). And even though the upfront tree costs were triple for the 10 x 10 spacing, it returned the most gross and net income over the first four harvest seasons. This is comparable to the results that Gary Bender reported for his trial in Valley Center, where he achieved an average of 14,662 pounds per acre for 'Hass' trees at 10 x 10 spacing over the first three harvest seasons.

So, if the grove lifespan were six years, that would be the end of the story. But an avocado grove can remain productive for 25 years or more. Thus the question: is a 10 x 10 'Hass' planting sustainable for the life of the grove?

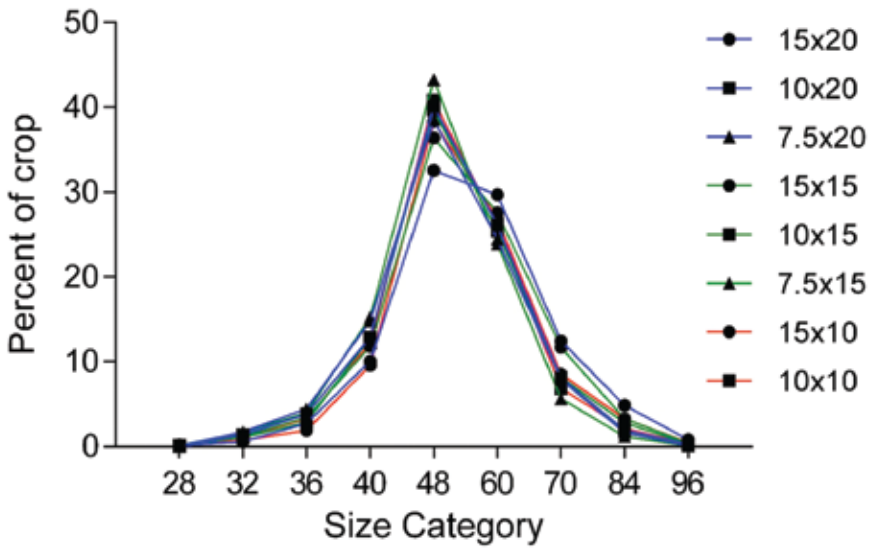
In the case of the specific planting at Pine Tree Ranch, the answer is no. Through lengthy discussions with our grove manager, we concluded that the annual pruning necessary to maintain trees at 10 x 10 spacing would result in our yields plateauing about where they were this year, 5,000 to 6,000 pounds per acre. Thus, we made the decision to remove every other tree on a diagonal, resulting in a 20 x 14 offset spacing.

In speaking with Gary Bender, he says the trial in his report has not been pruned in the past two years and it has "gone kinda crazy." The amount of pruning that is required on tightly spaced trees is often a tough pill for many growers to swallow — either nearly mature fruit, bloom, young fruit, or some combination thereof are going to be removed with pruning in California. Gary suggests the grove owner should take a vacation during pruning, which is not a bad idea — unless the grove owner is the one doing the pruning.

Our experience at Pine Tree Ranch, coupled with Gary Bender's observations indicate just how critical pruning — maybe even twice per year — is to the success of high-density plantings.

Within the next four years or so, the 15 x 20 spacing can be reasonably expected to mature to a sustained average production of about 12,000 pounds per acre. This is based on production from a two-acre mature block at approximately this same spacing also at Pine Tree Ranch. True, California's average per acre production is only 5,750 pounds per acre over the past five years, but past performance has shown that at this location, with current management practices, 12,000 pounds per acre is a reasonable yield target.

Of course, there are some economies that come with high density plantings. Trees spaced closely together and kept to 8 feet tall are easier to pick than large trees so harvesting is easier and more efficient. This could possibly result in lower harvesting costs, although I was unable to confirm this. In speaking with a major labor contractor, he said it is unreasonable to expect just the labor costs for avocado harvest to be less than $70 per bin (7.7¢ per pound, assuming 900 pounds per bin), but $85 to $100 (9.4¢ to 11.1¢ per pound) is more common. A quick phone survey of several field reps from various handlers indicated current harvest prices from 11¢ to 12¢ per pound on the low end to as high as 26¢ per pound on the high end. The lowest prices are for young trees on flat ground



Average fruit size distribution over four years for 'Hass' trees at eight different spacings.

and the highest prices are for tall old trees on slopes. There also is a split between north and south, with the north generally seeing prices 2¢ to 4¢ per pound lower than the south. Information shared by one of the state's largest growers revealed an average price of 14.3¢ per pound for harvesting over the past five years. With current labor costs, it may not be reasonable for the average grower to expect to pay much less than 15¢ per pound for harvesting unless they use in-house labor and deliver the fruit to the packinghouse.

What about water and fertilizer costs? There is little difference in water costs after the first couple of years. During the first two years after planting, when many growers use drip emitters on their trees, water use and cost will be directly related to the number of drip emitters per acre. Thus, water costs will be higher in the early years of a high-density planting compared with a wider spacing. However, once the trees are switched to micro-sprinklers, the usage differences diminish. This is because micro-sprinklers should be sized (output and spray diameter) to the spacing of the trees. The comparison is more, lower output micro-sprinklers per acre (high density) compared to fewer, higher output micro-sprinklers per acre (wider spacing). Fertilizer costs in the long term should be based on production — higher yields remove more nutrients so a higher yielding grove needs more fertility per acre regardless of tree spacing. If a high-density grove produces more fruit than a wider spaced grove the fertility costs will be proportionally higher and vice versa.

Should You Plant Trees at High Density

I believe that there is much more to consider than just tree density when deciding how to plant your grove. It has been said that there are four things necessary to be able to successfully grow avocados at high density:

- Pruning techniques
- Varieties adapted to high density
- Dwarfing rootstocks
- Plant growth regulators

What is the right way to prune 'Hass' trees planted close together? Ask 10 growers who have tried it and you are likely to get 10 different answers. There is no consensus on how to prune widely spaced trees much less those planted close together. True, some growers have figured out how to manage trees at a given spacing in their grove, but their method is not necessarily going to translate to your grove with your soil, your water, your fertilizer program, your... You get the idea.

Among all the tree fruits, avocados are the most variable from tree to tree and grove to grove. They are still very similar to their wild ancestors growing in the jungles of Mexico and Central America because we haven't been selecting them for hundreds (or even thousands) of years like we have apples, peaches, and many other tree fruit. In other words, they display high phenotypic plasticity — the ability of a single genotype ('Hass') to appear different when grown in different environments. This makes managing avocados at any spacing more difficult than other tree fruit.

There have been some advancements in varieties adapted to high density plantings. 'Gem', 'Lamb Hass' and 'Reed' are all more upright, narrow trees compared to 'Hass' and better suited to high density planting. Although they may lend themselves to high density planting, varieties other than 'Hass' may have other issues such as market acceptability or premature fruit drop.

Avocado breeding is extremely difficult and slow, so advancement in rootstock development has not been rapid. And with issues such as phytophthora root rot and salinity taking center stage, there has been no focus on developing a dwarfing rootstock. That's not to say it can't be done. There are Persea species known to be of small size but introducing that trait into existing rootstocks will be a very slow process.

Plant growth regulators (PGRs) are frequently asked about. It is unlikely that the current chemicals (triazoles such as uniconazole and paclobutrazol) on the market that are used on avocados in other countries will ever be registered for use in the United States. These products have very long residual times in the environment and some data suggests they also may have some adverse human health effects. The fact is these chemicals are not registered for use on any food crop in the U.S. — except for very restrictive uses on a few select vegetable seedlings younger than four-weeks-old in containers in

'Hass' trees spaced 10 x 10 feet one year after being heavily pruned.

'Hass' trees spaced 10 x 10 feet after being thinned on the diagonal to create a spacing of 20 x 14 feet.

greenhouses. It is possible that new PGRs could be developed in the future, but this area of research has greatly diminished with chemical manufacturers in recent years.

Maybe the best option is a hybrid approach — plant trees close enough together to take advantage of high early production when there is no competition for light between trees, then thin the trees at six-years-old or so, and then remove the whole grove at 12-years old and start again. This potentially maximizes yields by only maintaining the trees for their most productive youthful years. And, it affords the opportunity to change variety and rootstock as new ones become available.

Conclusion

There is no doubt that more closely spaced trees produce higher yields and higher returns in the early years of an avocado grove. The question remains, are those high production levels and returns sustainable with the 'Hass' cultivar? Surprisingly, evidence from long term trials in California is lacking — perhaps that is an answer? However, Greg Partida, former professor of plant science at Cal Poly Pomona, said it best, "The economics are pretty straightforward. As an industry, we can no longer keep doing what has been in the past. Tree canopy management takes a commitment. Doing nothing should not be an alternative" (in "Avocado Canopy Management for Greater Yields and Orchard Efficiency", California Avocado Society Yearbook 1996).

Smaller trees have many advantages, including increased worker safety, harvesting ease and efficiency, and better spray coverage. But there are limits to how small a tree can be realistically maintained given its natural growth tendencies and currently available rootstocks. A cultivar like 'Gem', which is naturally a narrow, upright tree, can be planted at high density (as high as 600 trees per acre), without the need to take the extraordinary measures necessary to maintain closely spaced 'Hass' trees. At modest yields of 25 pounds per tree, 'Gem' can easily produce more than 12,000 pounds per acre sustainably.

Perhaps Greg Partida was right, we can no longer keep doing what was done in the past — trying to grow a large spreading tree at high density — when good alternatives exist.

What has been your experience with high-density 'Hass' plantings? What do you think the avocado grove of the future will look like? Reach out and let me know.

The author thanks John Cornell for his thought-provoking criticisms of the Fall 2019 article, and contributions to and critique of this article.