Better Growing

By Tim Spann, PhD
Research Program Director

High Density Groves: Fact or Fiction?

"High density groves have a greater yield potential than standard density groves." Many people believe this statement to be true. And you can find many growers who will tell you that their high density blocks yield more than their standard density blocks. So, it was met with great dismay when I said at a recent California Avocado Society seminar that it doesn't matter how many trees you have per acre, because trees per acre is not what determines yield potential. What? How can that be? Let's do a little investigation.

> *"... it doesn't matter how many trees you have per acre, because trees per acre is not what determines yield potential."*

Light Interception

In the Spring 2019 issue of *From the Grove* I wrote an article titled, "Optimize Productivity by Pruning for Maximum Light." The takeaway from that article was that fruiting branches will only grow where there is light. We've all seen this in the form of old trees, 25 or 30 feet tall, with the first branch starting at 15 feet. There's no production in the tree's interior because there's no light.

A tree's leaves are energy factories. They take in carbon dioxide from the air and combine it with water taken up by roots to produce carbohydrates and oxygen using the power of sunlight. This is called photosynthesis and looks like the accompanying graphic.

Light Energy

$$6CO_2 + 6H_2O = C_6H_{12}O_6 \text{ (sugar)} + 6O_2$$

Thus, in any orchard of any fruit crop, the name of the game is maximizing sunlight interception.

Generally, you should always be able to see spots of dappled sunlight hitting the orchard floor, even in the densest of canopies. But why would you want to see light hitting the orchard floor? Shouldn't it all be captured by the leaves? Light hitting the orchard floor is wasted, right? Not exactly.

Consider the leaves in a tree's canopy as layers. Each layer captures sunlight. If the first layer captures all of the light, there's nothing left for the second layer. By ensuring that a small amount of sunlight is reaching the orchard floor, you are ensuring there is light penetrating all the way through the canopy and each layer of leaves has light to capture. In turn, those leaves can support fruit production throughout the tree's canopy and not just on the outside.

More Trees = More Sunlight Captured

The common belief is that by planting trees at higher densities more sunlight will be captured, thus more efficiently utilizing the sunlight falling on a given acre. But does this pencil out? Let's see.

First, a couple of assumptions:

1. The height of trees, no matter their density, does not exceed 80 percent of row spacing. This ensures that the shadow cast by one row does not prevent light from reaching the lowest leaves of the trees in the next row.

2. Within the tree row, the trees are allowed to grow together. That is, if the trees are 20 feet apart, adjacent trees grow to fill that 20-foot gap.

3. We will assume a six-feet-wide open space between rows for picking access. Although we will look at what affect narrowing that gap has in some instances.

4. For simplicity of calculations, we will assume all tree canopies are cubes. That is, the volume of the canopy can be calculated as: (tree height) x (tree width in the row) x (tree width across the row).

Traditional Spacing: 20 x 20 feet = 109 trees per acre (tpa)

- Each tree is allocated 400 square feet in the grove
- Trees are kept to 16 feet tall (assumption 1)
- Trees are 20 feet wide within the row (assumption 2)
- Trees are 14 feet wide across the row (assumption 3)
- Thus, each tree actually occupies 280 square feet (20 x 14)
  - 280 square feet x 109 tpa = 30,520 square feet or 70 percent of an acre
- Each tree's volume is 4,480 cubic feet (16 x 20 x 14)
  - 4,480 cubic feet x 109 tpa = 488,320 cubic feet of canopy per acre

Modern Spacing: 15 x 15 feet = 194 tpa

- Each tree is allocated 225 square feet in the grove
- Trees are kept to 12 feet tall
- Trees are 15 feet wide within the row
- Trees are 9 feet wide across the row
- Thus, each tree actually occupies 135 square feet
  - 135 square feet x 194 tpa = 26,190 square feet or 60 percent of an acre
- Each tree's volume is 1,620 cubic feet
  - 1,620 cubic feet x 194 tpa = 314,280 cubic feet of canopy per acre

High Density #1: 12 x 14 feet = 260 tpa

- Each tree is allocated 168 square feet in the grove
- Trees are kept to 11 feet tall
- Trees are 12 feet wide within the row
- Trees are 8 feet wide across the row
- Thus, each tree actually occupies 96 square feet
  - 96 square feet x 260 tpa = 24,960 square feet or 57 percent of an acre
- Each tree's volume is 1,320 cubic feet
  - 1,056 cubic feet x 260 tpa = 274,560 cubic feet of canopy per acre

High Density #2: 10 x 10 feet = 436 tpa

- Each tree is allocated 100 square feet in the grove
- Trees are kept to 8 feet tall
- Trees are 10 feet wide within the row
- Trees are 4 feet wide across the row

- Thus, each tree actually occupies 40 square feet
  - 40 square feet x 436 tpa = 17,440 square feet or 40 percent of an acre
- Each tree's volume is 640 cubic feet
  - 320 cubic feet x 436 tpa = 139,520 cubic feet of canopy per acre

Ok, I know what you are saying to yourself. You wouldn't leave six feet between every row in a high density planting. You'll allow the rows to grow more to fill in the space between rows and keep maybe every fifth row wide as a drive row to place bins and accommodate harvesting. So for simplicity, let's say that there's only four feet of open space on average between rows in a high density planting. Let's see what that does to the numbers.

High Density #1: 12 x 14 feet = 260 tpa with 4 feet open between rows

- Each tree is allocated 168 square feet in the grove
- Trees are kept to 11 feet tall
- Trees are 12 feet wide within the row
- Trees are 10 feet wide across the row
- Thus, each tree actually occupies 120 square feet
  - 120 square feet x 260 tpa = 31,200 square feet or 72 percent of an acre
- Each tree's volume is 1,320 cubic feet
  - 1,320 cubic feet x 260 tpa = 343,200 cubic feet of canopy per acre

High Density #2: 10 x 10 feet = 436 tpa with 4 feet open between rows

- Each tree is allocated 100 square feet in the grove
- Trees are kept to 8 feet tall
- Trees are 10 feet wide within the row
- Trees are 6 feet wide across the row
- Thus, each tree actually occupies 60 square feet
  - 60 square feet x 436 tpa = 26,160 square feet or 60 percent of an acre
- Each tree's volume is 640 cubic feet
  - 480 cubic feet x 436 tpa = 209,280 cubic feet of canopy per acre

In this scenario, a 12 x 14 planting, with four feet open between rows, just barely edges out a traditional spacing of 20 x 20 concerning the ground area covered by tree canopy, but the traditional spacing still has a larger total canopy volume per acre. And thus, a greater yield potential!

Why Then Do People See Higher Yields on High Density Plantings?

The answer to this question lies in an assumption that I didn't state. In all this number crunching, I assumed that all things were equal in terms of grove management. The same fertilizer regime, the same pruning regime, etc. However, this is rarely the case.

The first major change that often occurs when moving to high density plantings is the variety. Most growers would agree that 'Hass' trees at a 10 x 10 spacing is not manageable. It's a pruning nightmare. Instead they'll plant 'Lamb Hass', 'Gem', 'Reed' or another variety with a more narrow, upright growth habit that lends itself to planting at higher densities.

Second, high density plantings force you into a routine pruning regime. This is because a high density planting that isn't pruned will quickly become too dense (maybe even as soon as the fourth year), the interior canopy will be lost and the yield will plummet. Recovery from this scenario requires drastic pruning that will take the trees one to two years to recover from. Just the opposite is true for a standard density planting. Many growers do not follow a routine pruning regime, the trees become tall, the canopy becomes a big umbrella, the interior and lower branches are lost and all the production moves to the top of the canopy. These trees will probably cost you more to harvest, but as anyone who has seen an old grove with 25 trees per acre knows, these trees can still produce, albeit not at optimal levels.

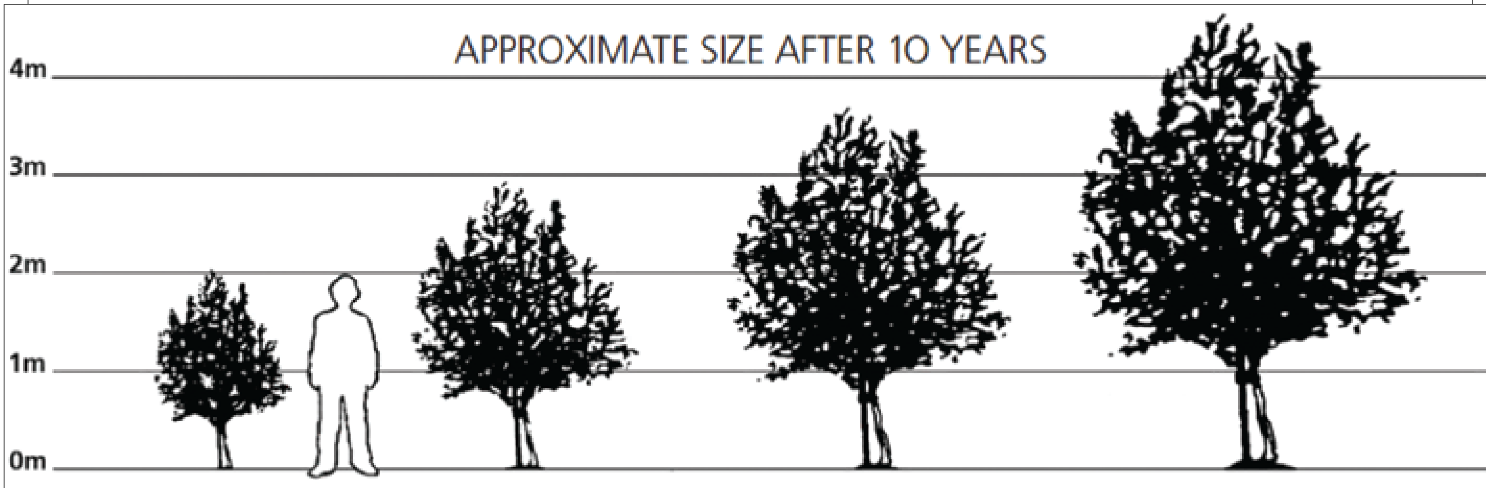
Lastly, many growers make other improvements to their overall management program along with increasing planting density. Some growers will implement a program of girdling limbs to stimulate production. Others will move to a more intensive fertility program to support the higher yields they see being produced. After all, it costs a lot of money to plant 260 or 436 trees per acre, and that is a huge psychological motivator to manage that investment properly.

What About Other Tree Fruits?

Given how the numbers appear to work, why do we hear about other fruit crops, like apples and cherries, with ridiculous planting densities on the order of 1,200 trees per acre? The crops that can plant at those densities have one key advantage that we don't have in avocados — size controlling rootstocks.

Apples for example have a range of rootstocks that control tree height to very specific degrees. If you want an apple tree 15 feet tall you plant a tree on one rootstock. If you want an apple tree that is only 5 feet tall you choose another rootstock. Thus, the pruning that needs to be done on apples is primarily to generate fruit wood and not to control height.

These systems also plant the trees on trellises so that the canopy of the tree may only be one foot wide. Trees one



DWARF		SEMI DWARF		MODERATE		VIGOROUS	
FRUIT	ROOTSTOCK	FRUIT	ROOTSTOCK	FRUIT	ROOTSTOCK	FRUIT	ROOTSTOCK
APPLE	M9	APPLE	M26	APPLE	MM106	APPLE	M25
PEAR	QUINCE 'C'	PLUM	PIXY	PEAR	QUINCE 'A'	PLUM	BROMPTON
CHERRY	GISELA 5	PEAR	QUINCE 'C'	PLUM	ST JULIEN 'A'	CHERRY	CHERRY F.12.1
		CHERRY	GISELA 5	DAMSON	ST JULIEN 'A'	PEAR	WILD PEAR
				CRAB APPLE	MM106		
				QUINCE	QUINCE 'A'		

A cartoon showing the relative size of various fruit trees grown on different size controlling rootstocks. Image from Walcot Organic Nursery https://walcotnursery.co.uk/.

foot wide and only six feet tall can be planted in rows less than five feet apart and still achieve maximum productivity, while allowing all work to be done easily from the ground.

Why Plant High Density?

At this point you may be asking yourself, "Why bother planting avocado trees at high density?" First, it's the only planting system that makes sense for certain varieties. The Gem variety for example, will never grow large enough to fill its allocated space in a grove if planted at 20 x 20 feet; there will simply be too much open ground when the trees mature to be viable.

Another benefit of high density plantings is higher production early in the life of the grove. My prior calculations have been based on mature trees. However, in the early years of a grove, before trees fill their allocated space, having more trees is beneficial. For example, a grove planted at 109 tpa may see its first commercial harvest in year 3 and you might expect to pick 4-5 pounds of fruit per tree (436-545 pounds per acre). Now imagine that the tree density is 260 tpa. Those trees will probably still not have filled their space in year 3, but your yield has increased to 1,040-1,300 pounds per acre. Thus, although a high density grove costs more to plant, it generates more yield and income sooner than a wider spaced grove and can result in positive cash flow years before a traditionally spaced grove.

High density plantings definitely have their advantages, especially with certain varieties and to generate early income from a new grove. When managed properly — the right variety, a good pruning program started early in the life of the grove — high density plantings can achieve almost unbelievable yields. However, those yields are not, strictly speaking, the result of simply having "more stems per acre." They are the result of a grove management system that is well planned and well executed.

A poorly managed grove — one without a good pruning program and well-managed irrigation and fertilization program — will be a poorly producing grove regardless of how many trees are planted per acre.