Spacing budded citrus in greenhouse benches to increase trunk caliper

By Richard C. Beeson Jr., Stephen Toomoth and Kevin Hancock

A few years ago, citrus rootstocks were germinated in Speedling trays, planted outside in rows and then budded in the field. Exposed to wind and rain, with space to bud between rows, bud shoots grew thick stems that could stand up to the elements. With unrestricted root systems, irrigation was supplemental, not essential.

Now, all trees for outplanting are produced in phyto-sanitary greenhouses in small root-constricting pots, in soilless substrates, where both water and nutrients need to be applied precisely for optimum growth. With little mechanical stress (wind and rain) and crowded conditions, bud shoots grow tall and spindly, competing for sunlight and leaning against their neighbors for mutual support. To be marketable, the rule of thumb is that bud shoots must be at least “two eighths” (one-quarter inch) in diameter an inch above the bud union. Outdoors, this was easily achieved, but not in greenhouses.

For any plant or animal to develop a sturdy frame caliper (stem or trunk diameter for plants), it has to be exposed to mechanical stress. For plants, the response to mechanical stress is termed “thigomorphogensis,” simply defined as the response of plants to movement. This response to movement can be seen everywhere, from vegetable seedlings in greenhouses to forests. Plants on the edge of plantings are subjected to more movement due to wind or brushing, and thus are shorter with larger stems than those in the middle. The trick for rapid

x		x	x	x		x	x	x		x	x
x	x		x	x	x		x	x	x		x
x	x	x		x	x	x		x	x	x	
	x	x	x		x	x	x		x	x	x
x		x	x	x		x	x	x		x	x
x	x		x	x	x		x	x	x		x
x	x	x		x	x	x		x	x	x	
	x	x	x		x	x	x		x	x	x
x		x	x	x		x	x	x		x	x
x	x		x	x	x		x	x	x		x
x	x	x		x	x	x		x	x	x	

Figure 1. *Apopka spacing. This configuration has 25 percent open space within a bench and allows at least the equivalent of one open hole adjacent to each tree. It is set up as lines of three trees with an open hole between groups of three. This is staggered each succeeding row by one plant and repeated.*

and uniform stem or trunk growth for growers of all plants is to expose most, if not all, plants to sufficient movement and sunlight. Yet due to the high cost of phyto-sanitary greenhouse space, the tendency is to pack as many trees as possible into production areas, such that overhead cost per tree is lowered.

This reasoning is sound only if all trees obtain marketable size in a reasonable amount of time. However, due to the crowding of the trees and the lack of resulting thigomorphogenic response, many trees on the interior grow tall and spindly, requiring additional time to develop marketable trunk caliper. Many growers have recognized this phenomenon without knowing what it was, and have combated it by physically moving interior trees to the outside and vice versa. This is very labor intensive, and thus costly, especially if trees are micro-irrigated.

Other growers have sacrificed the number of trees they produce by spacing trees out. This is often a “2-1” spacing, where two rows of trees are set pot-to-pot, with an empty row between them. Another spacing pattern is placing trees like they were on the black squares of a checker

Figure 2. *Ebb-and-flow tables during the testing stage. Plants in the middle were used to test and refine the automated weighing of five plants in the middle of a table to determine daily tree water use.*

Figure 3. *Example of one of the two ebb-and-flow tables used to evaluate the effect of spacing on budded tree growth. This is the pot-tight spacing seen from the middle of the greenhouse.*

board. Both of these sacrifice a lot of production space. The "2-1" occupies only 67 percent of production space, while checker-boarding utilizes only 50 percent. The effectiveness of these spacings on trunk caliper growth has never been quantified.

In August 2012, we set out to evaluate the influence of spacing on shoot caliper growth. Based on previous research with woody shrubs, it was known that plant transpiration was the same at 67 percent coverage of a bed area as when plants were completely isolated. But at 100 percent coverage, transpiration — and likely photosynthesis — declined by 40 percent. So a spacing pattern with 75 percent plant coverage was targeted (Figure 1, page 14). This "Apopka spacing" is simply a staggered spacing of three pots, then skipping one pot. This allows each plant to have at least one side with an empty space next to it.

During the third week of August 2012, a demonstration trial was set up at the Mid-Florida Research and Education Center in Apopka in a clear double polyethylene roof greenhouse with 30 percent shade cloth along the sides. Budded trees in 5-inch diameter pots, 10 inches tall, were donated by a commercial citrus nursery operation. The potting media was 100 percent fine coconut coir (fiber from the outer husk of a coconut). Trees had been budded with Hamlin on Swingle rootstock in the middle of May. Bud shoots were generally around 6 inches tall when the trial started. Pots were placed in two identical ebb-and-flow benches, oriented north-south (Figure 2). The benches were 3.5 feet wide and 6.5 feet long. Trees in the east bench were set pot tight (Figure 3) and consisted of 84 trees. Trees on the west bench were spaced at the Apopka spacing and numbered 67 trees. Each bench was irrigated nightly over the 7-month period, raising the water level up to 3.5 inches above the bottom of the pots, then draining it out over a 15-minute period.

Beginning in November, trees were fertigated at 100 ppm (parts per million) nitrogen (N) (20-10-20) once every other week. In January, this was increased to 200 ppm N one week, then 100 ppm the following week until mid-March. Water loss from a group of five trees near the middle in each bench was determined daily using a computer-controlled weighing system. Trees were drenched twice to control leafminers, and given a one-quarter teaspoon of cheated iron (Sequestrene 138) in November. Buds were pinched when they reached the top of the stake, approximately 24 inches, then as needed thereafter.

Beginning in mid-December 2012, shoot caliper was measured on each tree 1 inch above the bud union. The percentage of trees obtaining one-quarter inch in caliper or larger was calculated for each table each month. Shoot measurements were stopped in mid-March when the first table achieved 80 percent marketable size trees.

RESULTS

From the first measurement, the percentage of spaced trees with one-quarter inch or greater calipers was more than trees set pot tight (Figure 4, page 17). Over the next three months, as winter gave way to spring and longer days, the differences in the percentage of marketable-size trees continued to increase. By 10 months after budding, 81 percent of the spaced trees had achieved marketable size, compared to 29 percent for pot-tight trees. By mid-March 2013, there were 54 trees in the spaced bench compared to 28 trees in the pot-tight bench that had reached marketable size.

Water use per tree was always higher in the spaced bench than the pot-tight bench after the 47 percent shade cloth was removed in late September, even though both were measured near the middle of the bench (Figure 5, page 17). Water use declined for both sets of trees through the end of December with decreasing day lengths, then increased rapidly after February with increasing day lengths and tree growth. Photosynthesis is generally tightly linked to

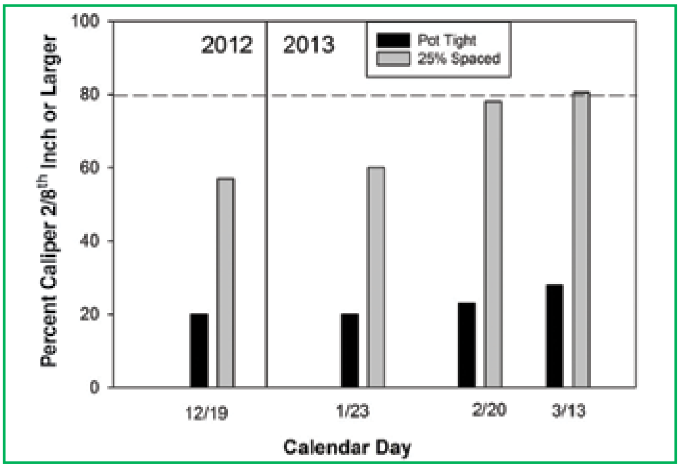

Figure 4. *Effects of pot spacing of 10-inch-tall pots on tree trunk caliper measured 1 inch above the bud union. Percentages were based on 84 trees in the pot-tight table and 67 trees in the 25 percent spaced table.*

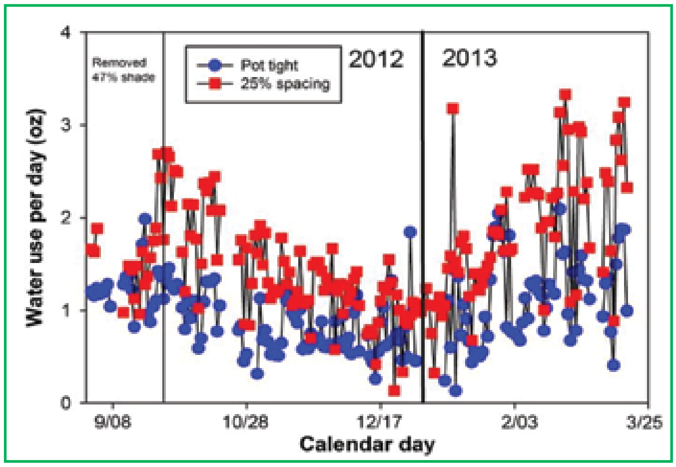

Figure 5. *Individual tree water use of citrus budded in mid-May 2012 in 10-inch-tall pots, from the first of September 2012 until March 13, 2013. Each point is the average of five trees in the middle of a flood table.*

transpiration, thus higher daily water use of spaced trees confers the likelihood of higher photosynthesis. This corresponds well with the greater shoot caliper growth we observed.

There were a few issues that negatively impacted the outcome of this demonstration project equally across both tables. Foremost was the fact that 100 percent fine coconut coir was too fine a material for daily ebb-and-flow irrigation. It held too much water and too little air. This was likely the cause of many trees exhibiting signs of root rot, especially in the lower 4 inches of the pots, even though they were drenched several times with Subdue. With higher transpiration rates, the spaced trees' roots seemed visually less impacted than pot-tight trees.

In summary, differences in trunk caliper between spaced and pot-tight citrus trees were significant, especially considering these were round 5-inch diameter pots, which have at least a 25 percent greater spacing between trees than the more common traditional 4-inch wide citrus pots. We hope to replicate this experiment in the near future using traditional citrus pots under commercial production greenhouse conditions.

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