

Citrus Nursery Research Project Progress Report
Project: **Optimization of citrus nursery production in screened houses**
J. H Lieth,
Professor, Plant Sciences Department, UC Davis
December 10, 2015

The project was started approximately 1.5 years ago with the objective of developing soilless production methods for citrus nursery growers with the specific aim to benefit growers who are shifting from outdoor container production to production in screenhouses and greenhouses.

The core facet to this was to identify whether some methods commonly used in hydroponics could be used by this industry. It is already known that nursery production can be done well without field soil, using irrigation practices where fertilizer nutrients are in dissolved in the irrigation water and application to the plants is through drip systems using some level of automation (at least timers, perhaps also sensors). Throughout this project all irrigation and fertilization was done with drip systems controlled by irrigation timers.

Hydroponic production methods can involve systems where the root zone of plants consists of substrate. There are also hydroponic systems where only liquid is present and those are useful for various purposes but we are not considering liquid culture as the production method for citrus nursery. (That may come later, if at all).

Hydroponic production using substrates can be further separated into two areas: use of inorganic substrates (perlite, rockwool,...) versus substrate mixes where a significant portion is organic matter (peat, coir, sawdust, bark, etc). The various commonly-used mixes were developed in the 1950s by plant pathologists at UC Berkeley. The term Ucmix evolved at that time to represent a mix consisting of peat, redwood sawdust, and sand and the best-management practice was to pasteurize the components or the final mix. It is relevant to note that Ucmix evolved in an era where fertilization was done by applying granular fertilizers, and irrigating so done so that at least 20% of the applied water would leach out and be discarded. In other words, NOT hydroponics. Hydroponic production methods are ones where the roots of plants are exposed to water many times per day, sometimes the same water again and again. It is this approach that we are particularly interested in testing in substrate-based production of citrus nursery stock.

At urging of the CCNB the project was developed to focus on coconut coir in addition to Ucmix. As such each of our trials has had 4 treatments: the control is Ucmix (1:1:1 by volume peat, redwood sawdust, sand) irrigated daily with a significant leaching fraction and all nutrients dissolved in this water to approximate half-strength Hoagland's solution. This level of nutrition is generally adequate for slow-growing woody plants; for herbaceous plants or fast-growing plants we typically need to add some additional fertilizer. Half-strength Hoagland's solution typically does not result in nutrient deficiency symptoms, but may well result in smaller plants. This type of production is very common in container nursery settings, although most growers would push the plants harder with more nutrient and water.

In addition to the above control treatment, we also used Ucmix as the substrate for plants where we captured and recirculated the irrigation water. I had found in other research that Ucmix actually can work quite well for this, but the key constraint is that water must flow past the roots several times per day so as to avoid depletion of dissolved oxygen in the liquid around the roots.

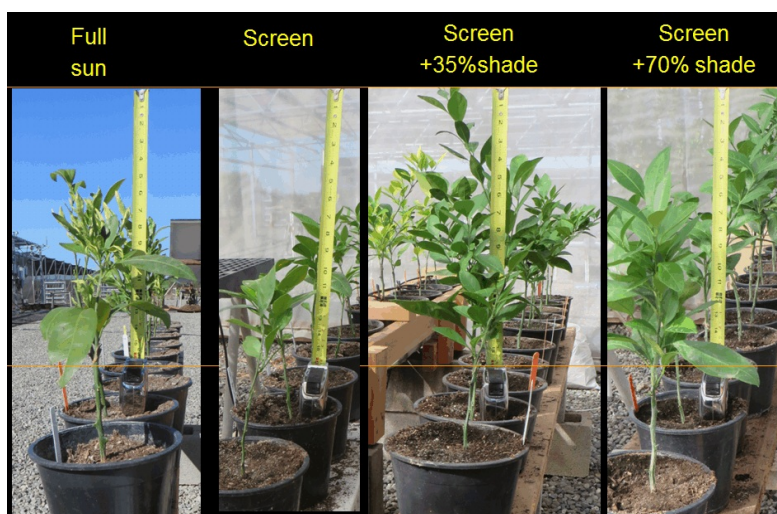
In addition to using UCMix, we had two additional treatments where coconut coir was used instead of the UCMix. As such the two Coir treatments are pure coir (with a lot of fiber content) with no additional amendments.

It was decided, with input from the CCNB, that the plant material used in this study should not be lemons or larger oranges (as I had initially considered), but rather mandarins. The industry is moving towards Carrizo as the rootstock; so that was also suggested. In first trial we used Owari Satsuma Mandarin Orange but there was a shortage of plants on Carrizo at the time so that trial was not on Carrizo. By the start of the second trial (2015) we were able to get plants on Carrizo. In preparation of needing a more stable supply of plants we also began growing Carrizo plants from seed so that we could eventually make plants as needed. It was also suggested that I work with the variety Tango, but we have not found that available to us. We do expect the next trial to be with Tango on Carrizo.

First year trial

The first trial was conducted in screen compartments in a shadehouse at UCDavis. One treatment has no shade other than the screen itself (thrips-exclusion screen). Another treatment had 35% shade over the screen house; while yet another treatment had 70% shading. We also grew a set of plants nearby in full sun. It should be noted that this was in Davis, CA where we have hot, dry summer conditions. The trial was conducted until well into the winter months and the experiment was terminated as conditions threatened to get so cold that we needed to anticipate frost damage.

To our surprise it made little difference which of the substrate or irrigation treatments were used in the outdoor, full-sun treatments. Those plants showed significant stress despite the most optimal irrigation possible. As such these plants were the smallest of all our plants after several months. All the plants in the screenhouses were larger.



The plants in the screenhouse that had no additional shading performed reasonably well and grew better than the plants growing outdoors despite the fact that conditions were significantly hotter in the screenhouse than outdoors. The largest plants were found in the screenhouse with 70% shade. We had expected to see some stretching and weak plants perhaps with lesser amount of leaf area and total biomass, but this was not the case.

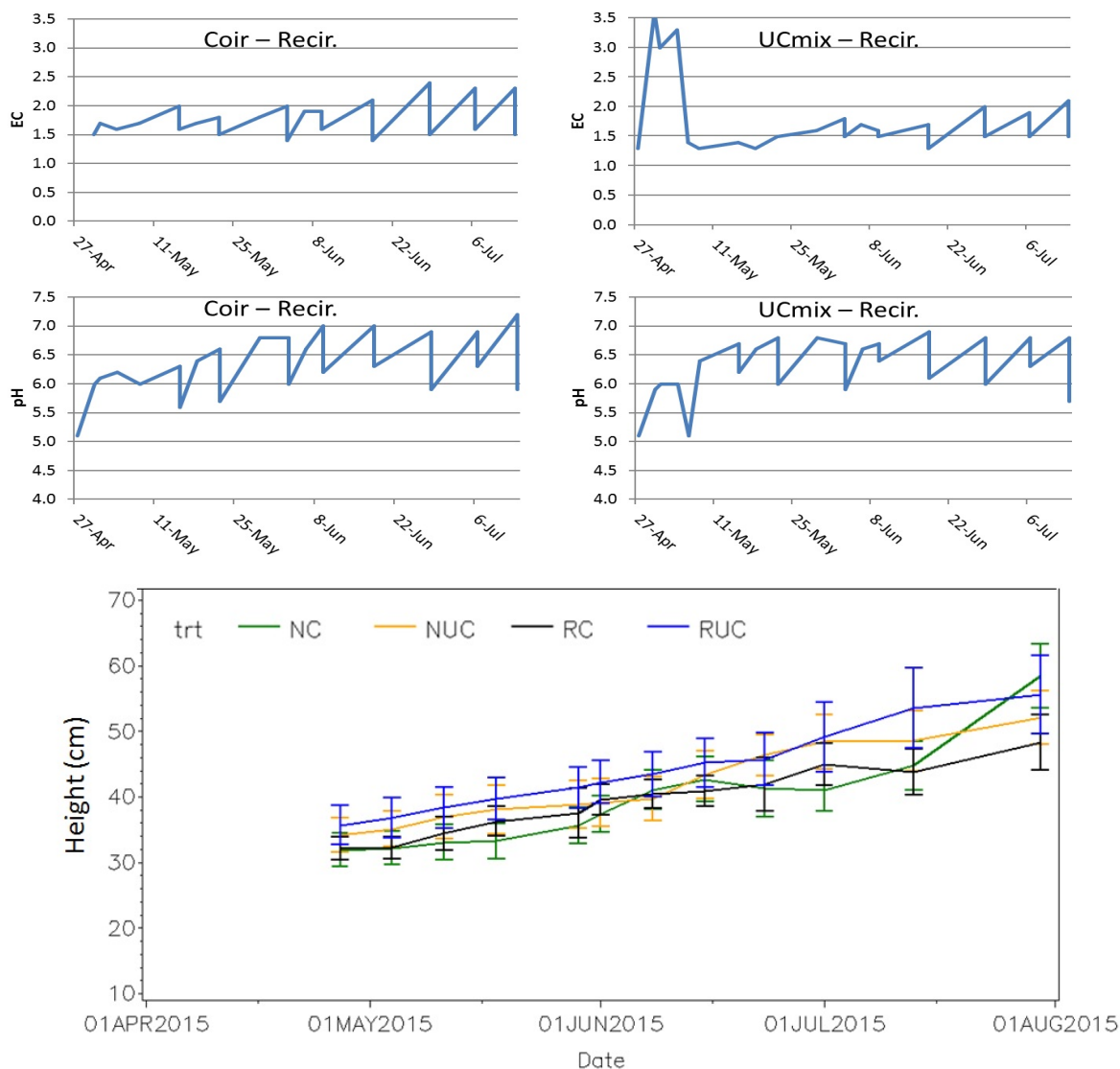
In this trial we did see some nutrient deficiency issues for plants where the water was recirculated. It was not clear why this was happening and we hoped to do more manipulation of the nutrients in the second year. There were no plant production differences between Coir versus UCMix.

Second Trial:

During spring of 2015 we purchased new plants from Four Winds Growers; this time we were able to get Clementine on Carrizo. We set this trial up to have the same design but to use taller containers. We had learned from growers that the industry primarily works with tall containers.

I saw the PropTech systems and was impressed with the combination of conical shaped container along with stands for these. We obtained this system and used UCmix and coir as before. The recirculation system was completely redesigned and rebuilt to fit the PropTech system. The key design change in the second trial was to use plastic rain gutters instead of plastic film to conduct water into reservoirs. We separated the drainage into 4 separate systems (one for each of the treatments); as such it is no longer possible to create a completely randomized design. The system was initially constructed in a greenhouse during the spring.

After the rooted plants were transplanted and set up into the 4 treatment groups (UCmix/Coir vs irrigation with and without recirculation), we started to see again that the plants in the recirculation were showing lighter colored foliage reminiscent of nitrogen deficiency. We had begun to track the EC and pH more closely than before; while there were some interesting dynamics, on the whole nothing suggested that the nutrients were not balanced. At the same time there were no significant differences in plant growth (as measured by height) in the 4 treatments:



During the summer the system was transferred into two screenhouses:



Year 2 setup; Above: screenhouse; 70% shade level
Below plants in the darkest treatment as of Dec 9 2015



Prior to the summer the technician who was doing the work left my research team for a job with a prominent berry growers. I handed the project off to another of my MS students who had recently finished his thesis. As the new person came on board, I made the decision to alter the course of the trial to see what it might take to get those plants greened up, and to do it in a way that would be consistent across all treatments. So as we moved the plants from the greenhouse into the new set-up in the screen compartments I redistributed the plants so that half of the plants with nutrient deficiency symptoms would be in the non-recirculated treatments (so as to see if this would restore the foliage color to deep green). Indeed this initially seemed to work. Thus this confirms that in the recirculated irrigation we need to manage the fertility differently from the non-recirculated treatment. This will be a focus in future work.

Just as this was beginning to move forward, the second technician also left to take a job in the industry; for two months I had no employee on this project to assist with data collection and management. In October I brought a new graduate students into my group to work on this project; that person is currently bringing the project back up to the desired level of productivity. But as can be seen in the photo above, we are not there yet. We still have not resolved the nutrient issues.

The plants are currently still in place, and growing reasonably well (although many show nutrient deficiencies). We can draw the following conclusions from these plants despite the nutrient issues:

In relation to the choice of substrates, the plants are doing well with both coir or UCmix; the Proptech systems is remarkably good. There is no circling of roots and the air pruning is creating a nearly perfect root system in both. When I pull plants out to inspect the root system, I do find that the coir is holding together slightly better than the UCmix. This is probably due to the fact that the sand results in more weight so that holding the plants by the stem causes the lower part of the rootzone to pull away slightly; but root growth was excellent in both so that the root zones are holding together well.



UCmix – Recir.

Coir – Recir.

UCmix – non-Recir.

Coir – non-Recir.

Inspection of the photos of the root zone suggests that in both cases, there is a zone at the top of the container where there are fewer roots. In the coir this seems to be a slightly smaller zone (top 1 - 2 cm) which with UCmix it is typically 4 to 5 cm. This can be explained by considering the moisture release curve for these two substrates.

Generally UCmix and Coir have very similar curves for depths to about 20 to 25 cm, but in deeper containers, the water column will be such that the top of the substrate will be fairly dry and in UCmix it is slightly drier. It was thought that this would not be an issue in the recirculated system but even there we see this same effect. I conclude from this that the depth of the containers should not be increased further as it would simply result in more substrate at the top where the roots are not growing well. The Proptech containers are slightly more ideal for coir, but the sand in the UCmix make that medium slightly more compatible with field soils at time of planting into an orchard.

The air pruning of the Proptech pots is indeed working as designed. I have no reservation about recommending this system, although I have not done any trials to see how such plants fare when planted into an orchard.

Growing citrus nursery stock with recirculation is definitely possible but any advantages that I envisioned requires that the nutrition be handled differently. We do not yet know what that

needs to be. Thus our need for a third year of research.

I had also, during the second year, started to get things ready to work with growers at their operation to test some of the approaches on a small scale. But with the departure of the technicians, the start of this work has been delayed.

Work with Carrizo.

One of the portions of this project was to grow the rootstock (Carrizo) as mother block into the same type of system (UCmix/Coir; with and without recirculation) and to explore generating cuttings in a way that is similar to what is done with roses where this is known to work well. In that system cuttings are harvested from mother blocks and the grafting is done at the same time as the rooting. In the industry this is done but does seem to take much longer than is typical with many woody ornamental plants. So I believe there is room for improvement here. I had also hoped that I would have a stream of rooted cuttings to use in various additional side-trials to explore the various issues with nutrition.



Young Carrizo plants growing in greenhouse.

In terms of rooting, we have done some work to try to root cuttings under various colors of LED light and to try to use water culture to accomplish the rooting (which did not work). In another project I developed a method that generates rooted cuttings very quickly; unfortunately, to date this work has not resulted in any success with Carrizo. But we only have had one flush of cuttings and the mother plants have not yet reached full size. These plants will soon be planted in to the relevant production systems.

For the third year I am proposing to do work where we attempt to push the nutrition in the recirculated treatments to resolve the nutrient deficiency symptoms. We will do this with both the rootstock as mother plants and grafted plants nursery product.

A new graduate student is now on board and has been working with the citrus plants of the second trial to learn the basics. We anticipate that the proposed work will make a good MS thesis project.