Citrus Nursery Research Report:

Optimization of citrus nursery production in screened houses

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Introduction

Citriculture is one of the most important fruit industries in the United States, contributing about $3.38 billion per year in 2014-2015 (USDA, 2015). However, the industry is affected by the diseases outbreak called Citrus Greening diseases, caused by bacteria called Huanglongbing (HLB) which is transmitted by the Asian Citrus Psyllid. The first instances of the disease in the USA were in Florida in 2005 and it quickly spread across nation and was introduced to Southern California in March 2012 (Grafton-Cardwell, 2016). Since then, the California Citrus Nursery Board requires the production of young trees, mother plants, and propagation to be moved inside a protective structure, like a screen house or greenhouse, and requires the mesh on such screening to be able to prevent movement of thrips (CDFA, 2014). Unfortunately, tight mesh restricts air movement so that screenhouse temperature in the summer in California is very high. Citrus is known to do reasonably well under some heat stress (Hatfield & Prueger, 2015), but the condition is not ideal for rapid vegetative growth needed by the nursery growers.

Intensive fertigation (fertilizer dissolved in irrigation water) without circulating system or “Open Hydroponics” is a management practice that was developed in Spain and implemented in Australia, South Africa, and the United States and was claimed to increase yield during unfavorable condition (Falivene et al., 2005). Unfortunately, the method also introduces the risk of soil acidification and salt accumulation in the root zone (Falivene et al., 2005). These potential environmental concerns are not limited to citrus, but are found in any open or flow-through hydroponic practices. Discarded solution usually results in point-source pollution that can contaminate lakes and streams as well as groundwater, especially because nutrient concentration in wastewater from hydroponic system is typically higher than traditional practice due to higher application rate (Grasselly, 2005). Therefore, there is a need to increase water and nutrient use to improve this particular system.

Growing plants under fertigation approaches requires that the root zone of the plants be constituted to have fairly high hydraulic conductivity as well as high water and fertilizer holding capacity while providing adequate oxygen for root metabolism. As such most field soils can be improved upon through incorporation of various other materials (e.g. organic matter). However, the most optimal conditions occur when substrate materials are used; generally, most field soils are not used in such an approach. Thus, this area of agriculture is called "Soilless Culture" (Raviv and Lieth, 2008). A key facet of this type of agriculture is to reclaim the excess irrigation water and to resupply this to the plants repeatedly, each time augmenting the irrigation solution with additional water and fertilizer. Such production methods are known to have many positive results, including reduction of water and fertilizer as well as improvements of the quality of the agricultural product. It is the hypothesis of this project that plant production of young citrus trees can be improved through the use of soilless culture methods.

Objectives

In this study, a recirculating method is proposed as a strategy that will allow plants to grow faster under intensive fertigation while minimizing water and carbon footprint during production. Moreover, the impact of screenhouse environment, with and without additional shade, will also be evaluated to see whether adding extra shade during summer production could alleviate heat stress in the plants.

Materials and Methods

Plant material and growth condition

Trials were conducted inside a screenhouse in UC Davis South Campus (Davis, CA) facility in Summer 2017. Prior to this time, research was conducted to identify how to build a system that would allow us to test various types of root zone materials and various approaches to water and fertilizer management. In 2017, two identical racks were installed inside two different screen houses with the same dimensions (25'x 18'x 7.5'), one screenhouse being set up with shade while the other had no shade: a series of tubular photovoltaic (PV) modules (Solyndra, Fremont, CA) provided shading (~70% less light penetration compared to no shading). The temperature, relative humidity, and solar radiation levels varied throughout the trial. No additional cooling was installed.

Young citrus plants, Tango mandarin (*Citrus reticulata Blanco*) grafted on C-35 citrange rootstock were obtained from Four Winds Growers (Watsonville, CA) on June 2nd 2017. Plants were transplanted into 10 x 20 inches deep air pruning pots (Proptek, Watsonville, CA) on the following days. The pots were filled with either coconut coir (FibreDust LLC., Cromwell, CT) or citrus mix (Berger, Watsonville, CA). These plants were hand-watered for about 3 weeks to allow for some adaptations before randomly being placed into the rack system at each screen house. Plants were arranged in checkered pattern with a density of 2.7 plants/ft^2 (29 plants/m^2).

Treatments

The experiment was conducted as 3 factors (shade, substrate, and system) and 2 levels (regular shade vs extra shade, recirculating vs flow-through, coir vs citrus mix) study for a total of 8 treatments as shown in Table 1.

Table 1. Experimental design

Shade	Substrate	System	Treatmen
Regular	Coconut	Flow through	SH1_A
Regular	Citrus Mix	Flow through	SH1_B
Regular	Coconut	Recirculating	SH1_C
Regular	Citrus Mix	Recirculating	SH1_D
Extra	Coconut	Flow through	SH3_A
Extra	Citrus Mix	Flow through	SH3_B
Extra	Coconut	Recirculating	SH3_C
Extra	Citrus Mix	Recirculating	SH3_D

Each treatment had 14 replicates or plants. The plants were fertigated daily using nutrient mix formulated similar to the one suggested by Furlani et al. (2009) for citrus nursery production in soilless culture. In the recirculating system, the leachate was collected in separate container and was sampled for volume, EC and pH and chemical composition (N, P, K, and S). Every 3 to 4 days this leachate was mixed with the main nutrient solution in the system causing gradual increase in EC. Volume of water loss in recirculating system was also recorded by adding the total top up volume and drainage volume. In the flow-through system, the leachate was not collected, and the main reservoir was topped up with fresh nutrient solution every 3 to 4 days. During the study, growth performance was measured based on these parameters: scion length and stem diameter (Gruber et al., 2013), and number of leaf and total leaf area (Mazzini et al., 2010). Scion length was measured from the grafting point to the tallest point of the plant. Stem diameter was measured about 1 inch above the grafting point.

The experiment was conducted starting June 29th 2017 for 3 months divided into 3 phases for about 4 weeks each. At the end of each phase, nutrient solution was flushed and replaced with a fresh one. During the first phase, from June 29th to July 26th (4 weeks), plants were fertigated using drip system 11 times a day for one minute every hour from 8 am to 6 pm at 1 gph. Moreover, side branches were removed in the middle of this phase to encourage main stem growth. In this phase, pH was adjusted using phosphoric acid. During the second phase, from July 26th to August 24th (4 weeks), plants were fertigated 10 times a day for one minute every hour from 9 am to 6 pm at 1 gph. In this phase, pH was adjusted using nitric acid. Lastly, during the third phase which lasted from September 7th to October 5th (4 weeks), plants in recirculating system was still fertigated for 10 times a day, while plants in flow-through system was fertigated just once at 10 a.m for 10 minutes to mimic the current industry practice.

Leaf Area Estimation

Leaf area was estimated using a regression model, where leaves area was regressed against the length (L), width (W), L^2, W^2, and LxW. Model was built using 79 randomly sampled leaves from the trial plants taken from pruned plant material (after pruning). Length was measured from the lamina tip to the base point of petiole along the midvein, width was measured along the widest section of the leaf, and area was measured using leaf scanner, LI-3100 (Licor, USA). The regression procedure was done using SAS Studio (SAS, Cary, NC). The resulted best fit line had R^2 equal to 0.994206 and is shown below:

$$y = 0.005811 + 0.22289 * \mathrm{L} - 0.1235 * L^2 - 0.53934 * \mathrm{W} - 0.14357 * W^2 + 1.020576 * L * W \quad \text{(Eq. 1)}$$

Statistical Analysis

All statistical analysis in this study was performed using SAS Studio (SAS, Cary, NC). For all growth parameters, the comparison between means obtained from each treatment was performed using Tukey's HSD (p=0.05), which was suitable for unequal sample sizes due to losses during experiment.

Result

Initial data

Experiment was initially performed using 112 plants that were divided into 8 treatment groups. Table 2 shows that all plants had relatively similar height, stem diameter, leaves count and leaves area. Data for scion length and stem diameter was taken on June 29th when the experiment first started, while data for leaves counts and area was taken from July 26th to account for pruning and training that happened on July 14th.

Table 2. Tukey's mean separation test of initial data for all treatments ($p < 0.05$).

Treatment	N	Scion Length (cm)	Stem Diameter (mm)	Leaves Count	Leaves Area (cm^2)
SH1_A	14	18.0 [a]	3.45 [a]	15 [a]	142 [a]
SH1_B	14	18.3 [a]	3.53 [a]	17 [a]	183 [a]
SH1_C	14	19.1 [a]	3.56 [a]	17 [a]	187 [a]
SH1_D	14	19.3 [a]	3.68 [a]	16 [a]	153 [a]
SH3_A	13	17.6 [a]	3.59 [a]	13 [a]	174 [a]
SH3_B	14	18.8 [a]	3.47 [a]	11 [a]	111 [a]
SH3_C	14	16.9 [a]	3.57 [a]	13 [a]	166 [a]
SH3_D	14	19.3 [a]	3.39 [a]	13 [a]	141 [a]
* Means with the same letter are not significantly different.					

Scion length

Over the duration of the experiment, scion length growth varied between treatments, although the trends were similar across the treatments. Based on Figure 1, there was not much growth observed between July 13th to July 27th. This could be explained by pruning event that took place on July 14th. During pruning, most side branches were removed to induce strong lead stem growth. Furthermore, the growth during August was relatively slower than the growth in September. This might be due to August being the hottest month of the year in Davis and the occurrence of several heat waves during this month.

Tukey's mean separation was performed on the final measurement data taken on October 5th, 2017 to determine the effects of each variables on scion length. The result (Table 3) shows that overall only the shade condition affected the scion length significantly, while system and substrate did not. Furthermore, the average incremental growth per phase was also investigated to find out when the shade condition started to affect the plant growth. The result (Table 4) shows that shade conditions significantly affected the plants growth in phase 2 and 3, but not in phase 1.

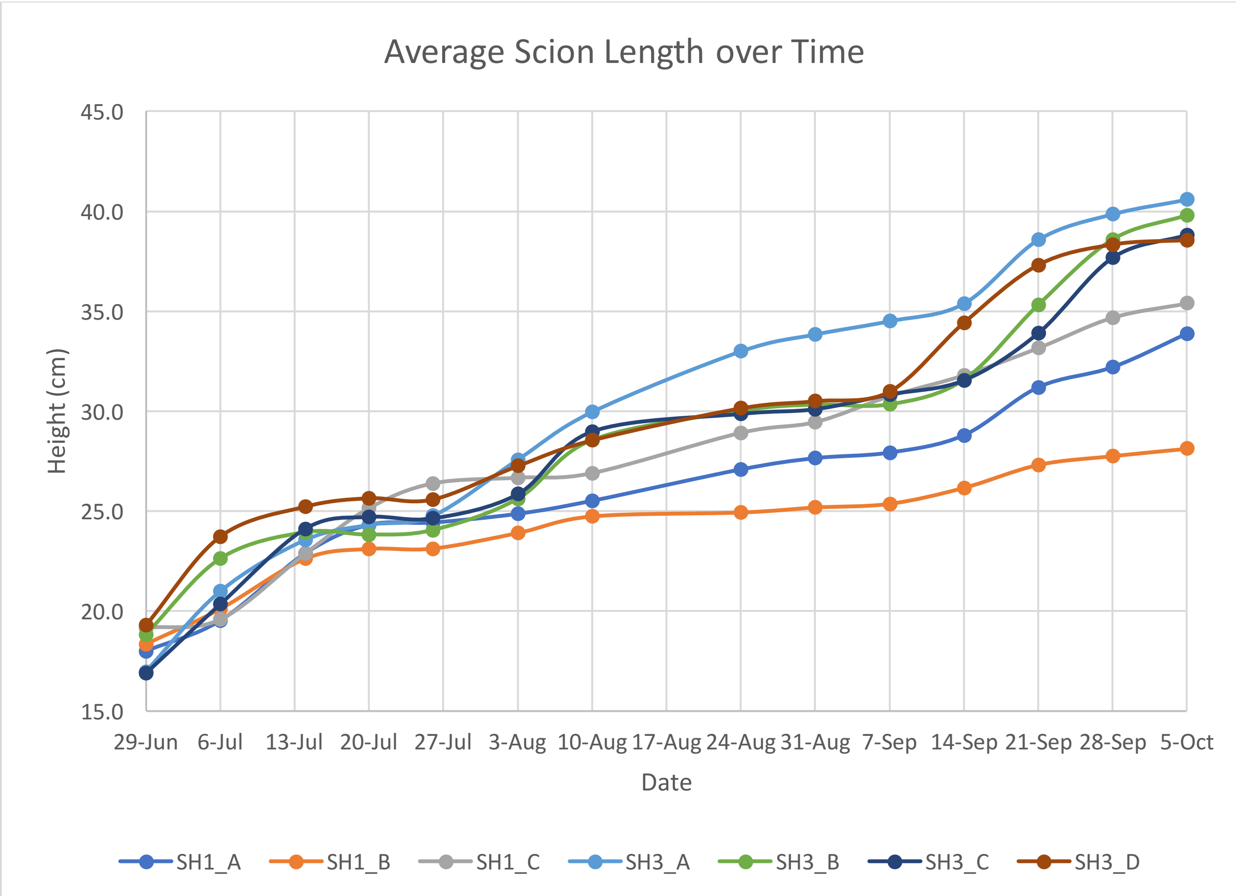

Figure 1. Average scion length for all treatments from June 29th to October 5th, 2017.

Table 3. Tukey's mean separation test for final scion length using three classes: system, substrate, and shade ($p < 0.05$).

Final Scion Length (cm)			
Means with the same letter are not significantly different.			
Tukey Grouping	N	Mean	System
A	56	37.3	Recirculating
A	54	35.9	Flow Through
Tukey Grouping	N	Mean	Substrate
A	56	37.2	Coconut Coir
A	54	36.1	Citrus Mix
Tukey Grouping	N	Mean	Shade
A	56	39.4	Extra
B	54	33.7	Regular

Table 4. Tukey's mean separation test for scion length growth in different shade conditions for each phase.

Shade	N	Scion Length Growth (cm)		
		Phase 1	Phase 2	Phase 3
Extra	55**	6.90^{a}	5.84^{a}	7.78^{a}
Regular	56**	6.85^{a}	2.81^{b}	4.44^{b}
* Means with the same letter are not significantly different.				
** N for regular shade decreased to 54 during phase 2 and 3 due to sample lost, while N for extra shade increased to 56 during phase 2 and 3 due to replacement of lost sample				

Stem diameter

Unlike the scion height, the growth in stem diameter was not affected by pruning nor seasonal change in temperature. Figure 2 shows that the growth in diameter throughout the experiment was almost linear. Tukey's mean separation was performed on the final measurement data taken on October 5th, 2017 to determine the effects of each variables on scion length. The result (Table 3) shows that overall only the substrate affected the scion length significantly, while system and shade condition did not. According to the result, coconut coir is more suitable for production of young citrus nursery than the commercial citrus mix. The difference in stem diameter were first observed during phase 2 and continued into phase 3 (Table 6).

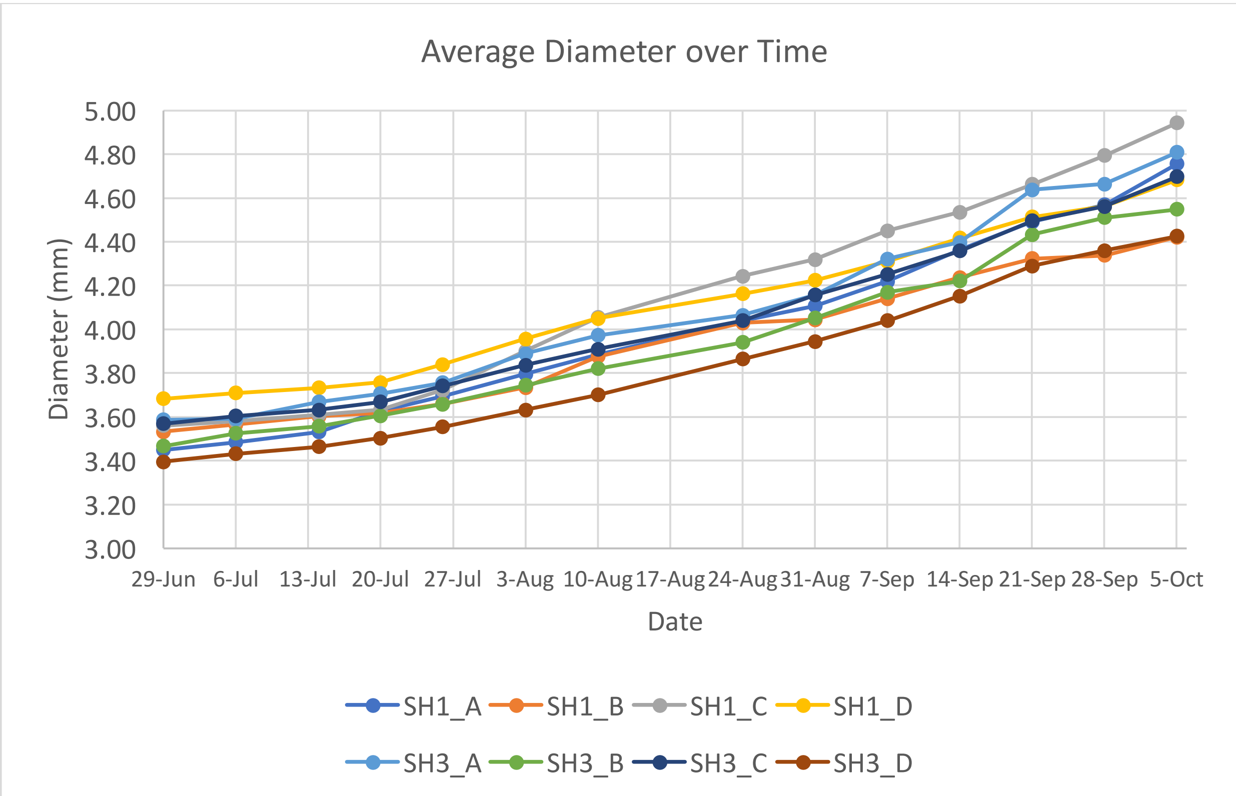

Figure 2. Average scion diameter for all treatments from June 29th to October 5th, 2017.

Table 5. Tukey's mean separation test for final scion diameter using three classes: system, substrate, and shade ($p < 0.05$).

Final Scion Diameter (mm)			
Means with the same letter are not significantly different.			
Tukey Grouping	N	Mean	System
A	56	4.69	Recirculating
A	54	4.64	Flow Through
Tukey Grouping	N	Mean	Substrate
A	56	4.80	Coconut Coir
B	54	4.52	Citrus Mix
Tukey Grouping	N	Mean	Shade
A	54	4.71	Regular
A	56	4.62	Extra

Table 6. Tukey's mean separation test for scion stem diameter growth in different substrates for each phase.

Substrate	N	Scion Stem Diameter Growth (mm)		
		Phase 1	Phase 2	Phase 3
Coconut Coir	55*	0.19[a]	0.38[a]	0.49[a]
Citrus mix	56*	0.16[a]	0.31[b]	0.36[b]
* Means with the same letter are not significantly different.				
** N for citrus mix shade decreased to 54 during phase 2 and 3 due to sample lost, while N for coconut coir increased to 56 during phase 2 and 3 due to replacement of lost sample				

Leaf count and area

Shade condition was found to influence leaf morphology, where extra shading tended to reduce the number of leaves and increase the individual leaf area. The difference in final leaf count per plant under different shading conditions was significant (Table 7), while the difference in final leaf area per plant was not statistically significant (Table 8). Although the difference in total leaf area was not statistically significant, qualitatively the difference was noticeable. Moreover, leaves from plants under extra shade condition were overall rounder than the ones under regular shade condition.

Table 7. Tukey's mean separation test for final leaf count per plant using three classes: system, substrate, and shade ($p < 0.05$).

Final Leaf Count			
Means with the same letter are not significantly different.			
Tukey Grouping	N	Mean	System
A	54	55	Flow Through
A	56	53	Recirculating
Tukey Grouping	N	Mean	Substrate
A	56	56	Coconut Coir
A	54	51	Citrus Mix
Tukey Grouping	N	Mean	Shade
A	54	60	Regular
B	56	48	Extra

Table 8. Tukey's mean separation test for final leaves area per plant using three classes: system, substrate, and shade ($p < 0.05$).

Final Leaves Area (cm^2)			
Means with the same letter are not significantly different.			
Tukey Grouping	N	Mean	System
A	56	631.77	Recirculating
A	54	622.38	Flow Through
Tukey Grouping	N	Mean	Substrate
A	56	696.08	Coconut Coir
B	54	555.69	Citrus Mix
Tukey Grouping	N	Mean	Shade
A	56	665.19	Extra
A	54	587.73	Regular

Table 9. Tukey's mean separation test for final leaf length to width ratio using three classes: system, substrate, and shade ($p < 0.05$).

Leaf Length: Width Ratio			
Means with the same letter are not significantly different.			
Tukey Grouping	N	Mean	System
A	56	1.83	Recirculating
A	54	1.82	Flow Through
Tukey Grouping	N	Mean	Substrate
A	56	1.85	Citrus Mix
B	54	1.80	Coconut Coir
Tukey Grouping	N	Mean	Shade
A	54	1.86	Regular
B	56	1.79	Extra

Water quality

In the beginning, the EC of the drainage solution coming from treatments in citrus mix substrate was found to be much higher than the EC from coconut coir. It was suspected that the citrus mix substrate had slow release fertilizer in the mix. To account for this, the recirculating nutrient solution for treatments in citrus mix substrate were refilled with water instead of fresh nutrient solution to maintain similar EC for all treatments. This was done, until the EC of the drainage solution were similar for all treatments. Nutrient solution was change at the beginning of every phase, except during phase 1. Nutrient solution was changed in the middle of the trial on July 14th during phase 1. In general, EC at the end of each phase (over 4 weeks duration) was increased about 1.5 dS/m, from around 2.0 dS/m to 3.5 dS/m.

During the entire experiment, pH was kept at 5.5 to 6.5 level. During phase 1 and the beginning of phase 2 (July until mid-August), pH was relatively stable. However, pH the following period was fluctuated more with a tendency of decreasing in pH. During this period, there was a major construction happening on experiment site, which was suspected to cause significant changes in groundwater composition and overall buffering capacity of the nutrient solution.

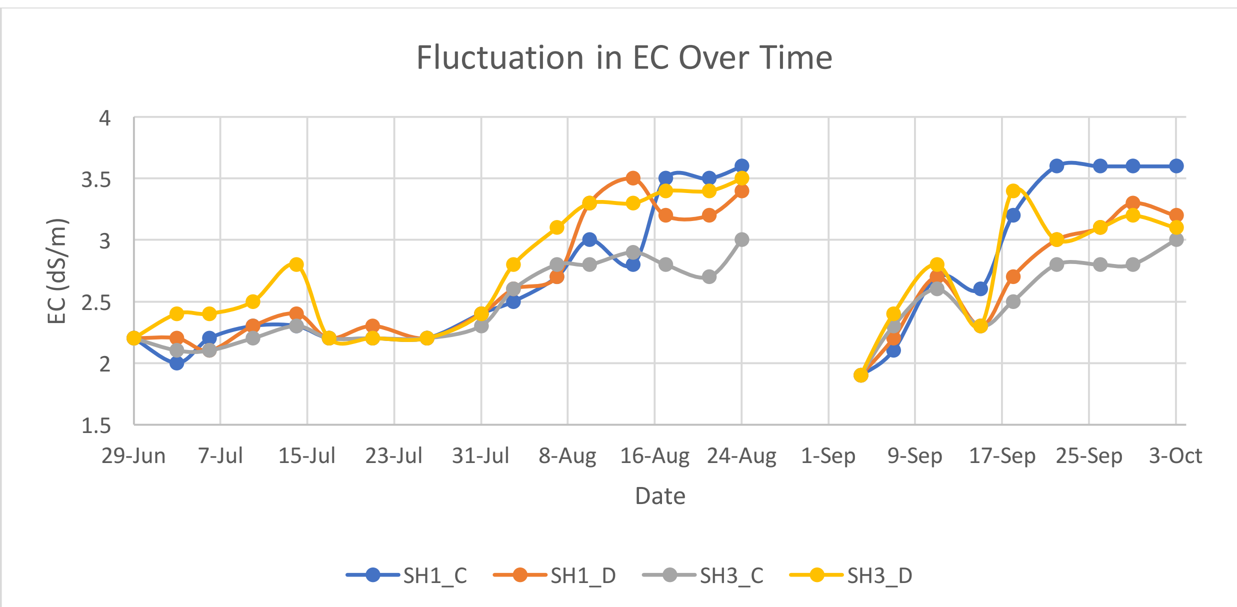

Figure 3. EC of recirculating nutrient solution from June 29th to October 3rd, 2017.

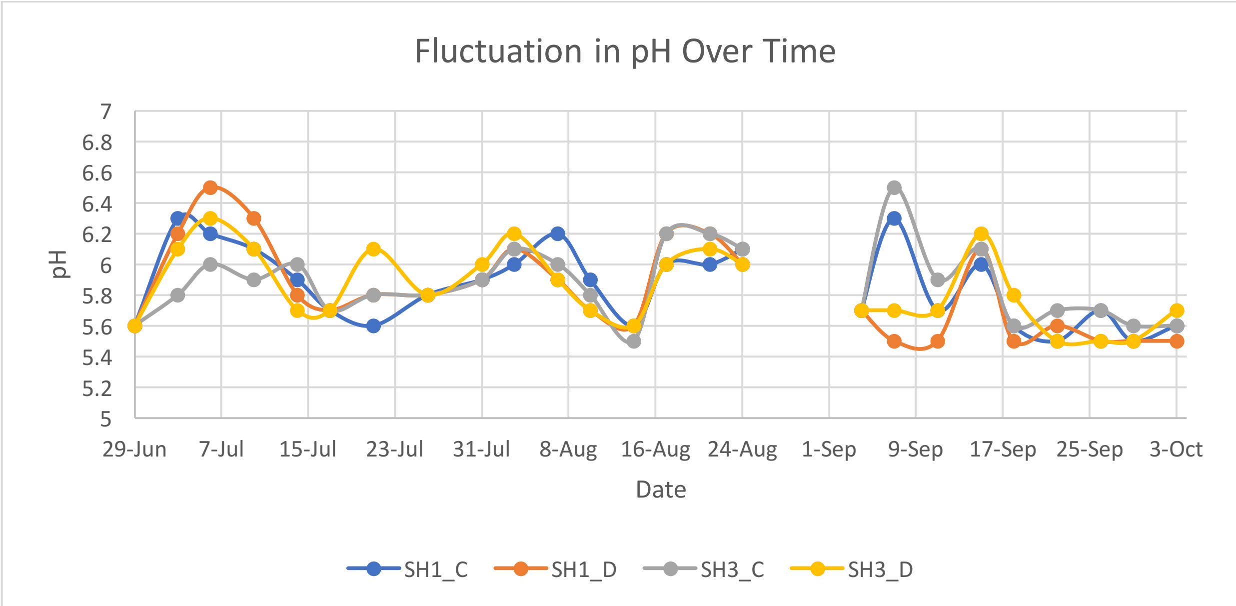

Figure 4. pH of recirculating nutrient solution from June 29th to October 3rd, 2017.

Qualitative observations

Phase 1

The experiment started on June 29th, 2017 with 112 uniform young citrus plants (Figure 5). After two weeks, some marginal burns or yellowing on leaves were observed for the plants under the regular shade (Figure 6). This might be due to heat waves occurred on July 7th to July 9th, 2017 when the maximum outside temperature reached up to 110F, while the inside temperature was even higher (personal data). By the end of phase 1, most plants regardless the treatments showed some degrees of iron and zinc deficiency symptom which are commonly linked to excessive level of phosphorus (Figure 7); during this phase phosphoric acid was applied to bring the pH of nutrient solution down. Nevertheless, plants under regular shade condition seemed to also show burned tips end edges on the leaves, which is common symptom for salt toxicity (Figure 7). The heat stress seemed to exacerbate the deficiency symptoms. Yellow patches, which are linked to zinc deficiency were observed on leaves for plants under the regular shade condition (Figure 8). On the other hand, darkening of leaf veins, which are linked to iron deficiency, were more pronounced in leaves for plants under the extra shade condition (Figure 8), although yellow blotches were also observed in some leaves. Moreover, no burns were detected on leaves for this treatment.

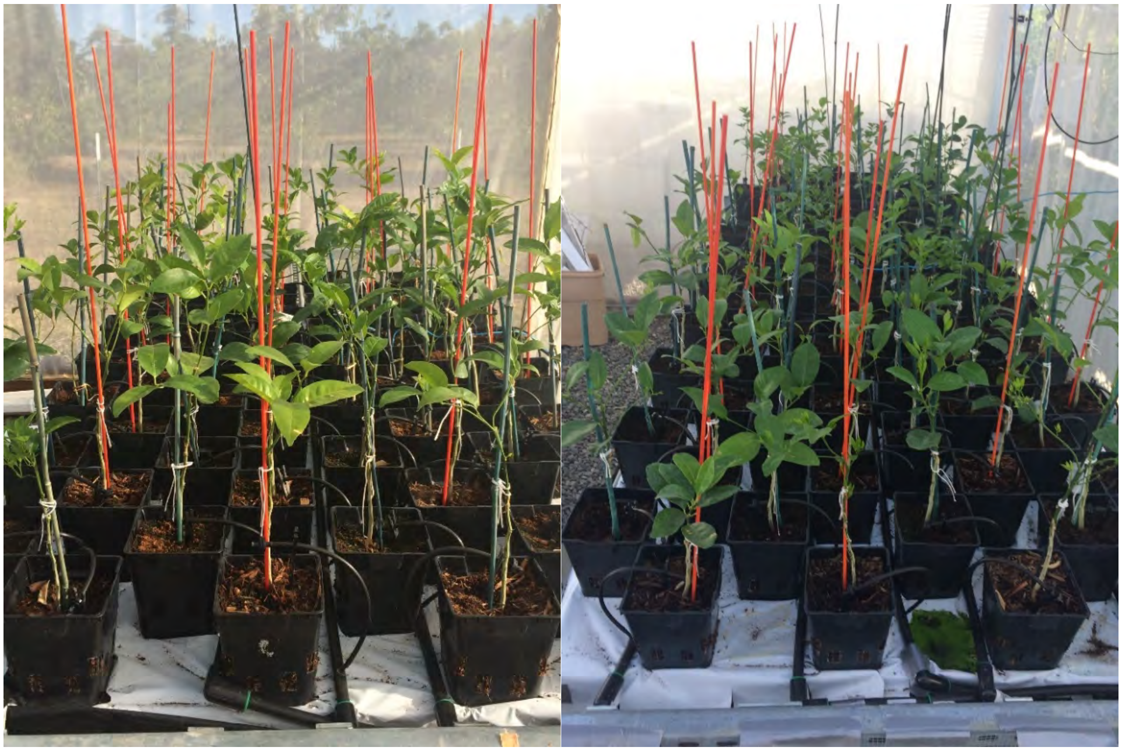

Figure 5. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the beginning of experiment on June 29th 2017.

Figure 6. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the middle of Phase 1 on July 13th 2017.

Figure 7. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the end of Phase 1 on July 26th 2017.

Figure 8. Nutrient deficiency and/or toxicity symptoms on a sampled leave from a plant inside regular shade house (left) vs extra shade house (right).

Phase 2

In phase 2, the use of phosphoric acid was replaced with nitric acid to alleviate the damage due to excessive phosphorus. Plants, regardless of their treatment, showed improvement after the change was made. Mineral deficiency symptoms were not found in the new growth and the extra nitrogen coming from nitric acid seemed to boost the number of new leaves (Figure 9 & 10). Some burns on older leaves were still observed during the beginning of phase 2 (Figure 11), but these leaves were defoliated and replaced with healthy younger leaves by the end of phase 2 (Figure 12). Unfortunately, one of the pumps failed during this phase, causing drought on plants under flow through and regular shade treatments. The incident itself affected two rows of plants with different substrates. Qualitatively, plants in coconut coir suffered less than the ones in mixed substrate, where two plants were lost, and more leaves were wilted.

Figure 9. Leaves condition of the same plant inside extra shaded house before (left) and after (right) application of phosporic acid was switched into nitric acid. Picture was taken a week apart from each other.

Figure 10. Leaves' condition of the same plant inside the regular shade house before (left) and after (right) application of phosporic acid was switched into nitric acid. Picture was taken a week apart from each other.

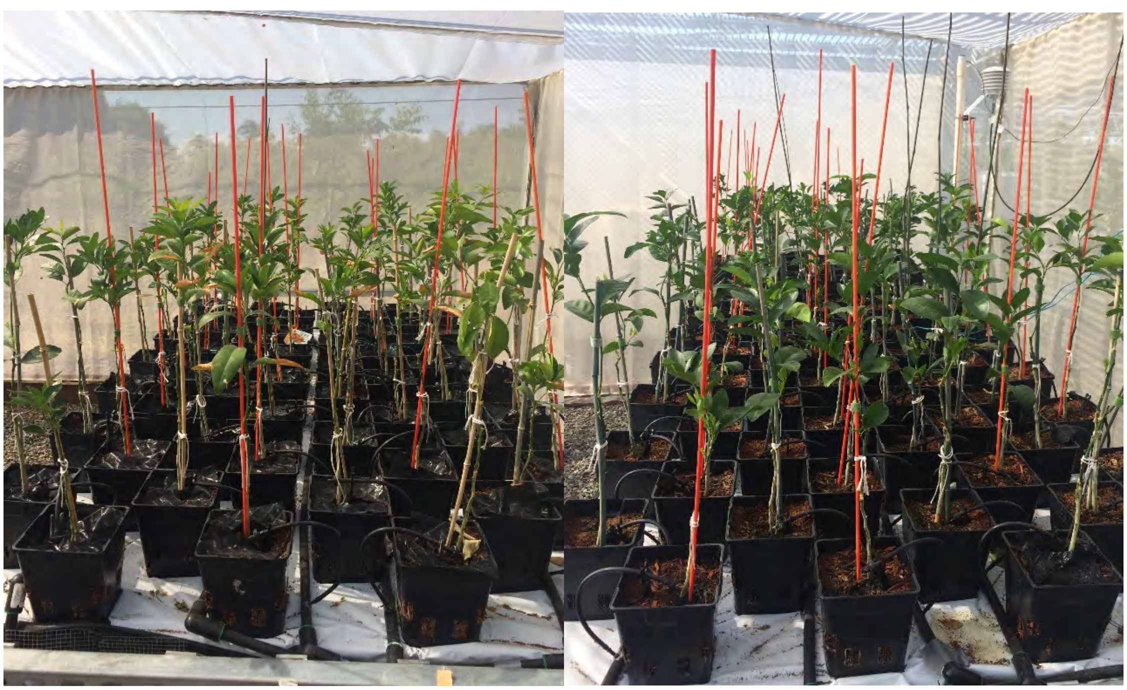

Figure 11. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the beginning of Phase 2 on August 1st, 2017.

Figure 12. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the end of Phase 2 on August 24th, 2017. The pump failure affected the 5th (coconut coir) and 6th (citrus mix) rows from the left on the left picture.

Phase 3

There was no anomaly observed during phase 3. All plants, regardless of treatments, experienced the fastest growth during this phase.

Figure 13. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the beginning of Phase 3 on September 4th, 2017.

Figure 14. Young citrus inside regular shade screen house (left) vs extra shade screen house (right) at the end of Phase 3 on October 3rd, 2017.

Discussion

Effect of shading

Incesu et al. (2016) found that in hot arid conditions, similar to summer condition in Davis, black shading 75% and alumni shading 50% increased the total leaf number and total chlorophyll content in navel orange seedling due to lesser chlorophyll degradation in leaves under shaded condition; high temperature was responsible for chlorophyll degradation. Higher chlorophyll content was possibly responsible for higher scion length in the extra shade treatment. Other studies claimed that shading increase the plant growth by reducing midday depression, hence increasing maximum carbon dioxide assimilation rate (Raveh et al. 2003, Jifon and Syvertsen 2003). In this study, the total number of leaves by the end of trial was significantly higher under regular shade treatment than extra shade treatment. The result did not agree with previous studies (Raveh et al. 2003 and Incesu et al. 2016). It was suspected that the stress on plants due to nutrient imbalance during Phase 1 was responsible for this phenomenon. Once the affected leaves had abscised, plants started putting on many new leaves. Nevertheless, the younger leaves tended to be smaller in size compared to leaves from plants under extra shade treatment. As the result, there was no significant different in term of leaves area for both treatments. Furthermore, shading also affected the leaf morphology; leaves under extra shade treatment appeared to be rounder than the ones under regular shade treatment; hence a lower length:width ratio. The result did not agree with the reported leaf shade response, where shade tended to induce leaf elongation in simple leaf (Xu et al. 2009). One possible explanation for this is that leaves under regular shade might be more prone to zinc deficiency as shown in Figure 8, which is known for causing narrow elongated leaf in citrus.

Effect of substrate

In our study, two different substrates were used, knowns as “citrus mix” and “coconut coir”. These substrates had different physical properties which affected how water was retained in the substrate. During our trial, there was a pump failure incident that caused losses in two sample plants; both plants were in citrus mix substrate (Figure 12). This implied that coconut coir retained water longer and provided a better insurance in case of pump failure. Furthermore, plants in coconut coir had significantly bigger scion diameter compared to plants in citrus mix. The difference on stem diameter was more obvious starting on phase 2 when the pump failure incident happened. During the failure, the salinity of the rootzone in citrus mix substrate might have been higher than in coconut coir, possibly explaining the smaller stem diameter on plants in citrus mix substrate since stem diameter is sensitive to salinity in water and/or rootzone as reported by Brito et al. (2014).

Effect of system

None of the growth parameters tested in this study suggested any significant difference between recirculating and flow-through system. This was a surprise because in nearly all crops (typically herbaceous plants growing in hydroponics) there are typically some improvements. Nevertheless, there was a significant decrease in water use in recirculating system. During the experiment, the drainage level was kept over 20% for all circulating treatments. The average percentage of total refill solution coming from the drainage solution during this study was 32% and 45% for the regular and extra shade treatments respectively. This means that recirculating system could save up to 45% water and nutrient overall compared with flow-through system; in the flow-through system, this drainage solution would have been discarded right away.

Conclusion and Further Study

In this study, the effect of shade, substrate, and system on young citrus growth were investigated. The result suggested that additional shade provided by PV tube installed on top of screen chamber promoted faster growth on scion length. While the result was suitable for screening and initial study, further study should isolate and investigate each variable separately to minimize interaction effect, if any, between variables. Since the novel idea proposed in this project is on recirculating system, further study could be staged in a commercial nursery to compare the standard practice versus the recirculating system. This study suggested that recirculating the nutrient solution did not have detrimental effect on plant growth; but it also did not have a substantial positive effect on plant production.

As such our results indicated that use of a recirculating system is possible and worthwhile as a best-management practice as it saves fertilizer and water without compromising production. Unfortunately, farmers might still be reluctant to adopt the system due to complicated nutrient management. Prolong use of nutrient solution in recirculating system could result in nutrent imbalance which further causing sub-optimal plant growth. Therfore, understanding nutrient uptake patern could improve management practice that normally relies solely on solution pH and electrical conductivity (EC) monitoring and control. A good predictive model could help farmer to decide when to change the solution and to know the nutrient composition of the waste solution.

Therefore, futher study should focus on building nutrient uptake model based on climate and plant development stages and be specricially investigated for soilless culture methods involving recirculation. Michaelis-Menton kinetics were successfully used to predict nutrient uptake model in other crops such as tomato and rose (Silberbush and Lieth 2004; Mattson and Lieth 2007; Massa et al. 2011; Kempen, 2015). Thus, simillar approach could be used to model the nutrient uptake in young citrus.

Another possible area to explore is the down-stream treatment for the discarded nutrient solution. The discarded solution typically still contains a significant macronutrients, though in non-optimum composition. Studies on treating hydroponic or nurseries waste water using microalgae had shown promising results based on algae removal capability and biomass or lipid accumulation (Bertoldi et al. 2009, Hultberg et al. 2013, Aravinthan et al. 2014, and Zhang et al. 2017). Incorporating aquatic plants and/or microalage to the overall system could provide additional valuable products, hence added profit; for human consumption (Becker, 2007 and Chan et al. 2017), aquaculture (Jung et al. 2017), biosorption material (Colica, et al. 2012), and fertilizer (Rossi et al. 2017). We have already done some initial work with algea using the discarded solutions from the trails reported above.

References

Becker, E. W. 2007. Micro-algae as a source of protein. *Biotechnol. Adv.* 25, 207–210

Brito, M. E. B., K. S. A. de Brito, P. D. Fernandes, H. R. Gheyi, J. F. Suassuna, W. dos Santos Soares Filho, A. S. de Melo, and D. A. Xavier. 2014. Growth of ungrafted and grafted citrus rootstocks under saline water irrigation. *African Journal of Agricultural Research* 9(50):3600-3609.

California Department of Food and Agriculture. Citrus nursery stock pest cleanliness program regulations. Retrieved July 11, 2017, from https://www.cdfa.ca.gov

Chan, E. W. C., Wong, S. K., & Chan, H. T. 2017. Ulam Herbs of *Oenanthe javanica* and *Cosmos caudatus:* an overview on their Medicinal Properties. *Journal of Natural Remedies*, 16(4), 137-147.

Colica, G., Caparrotta, S., Bertini, G., & DePhilippis,R. 2012. Gold biosorption by exopolysaccharide producing cyanobacteria and purple non-sulphurbacteria. *J.Appl.Microbiol.*113,1380–1388

Falivene, S., Goodwin, I., Williams, D., & Boland, A. 2005. Open Hydroponics - Risks and Opportunities - Stage 1. *Land & Water Australia*. ER050975.

Fulcher, A., LeBude, A. V., Owen, J. S., White, S. A., & Beeson, R. C. 2016. The Next Ten Years: Strategic Vision of Water Resources for Nursery Producers. *HortTechnology, 26*(2), 121-132.

Furlani, P.R., Zanetti, M., & Bataglia, O.C. 2009. Citrus nursery production in soilless culture. *Acta Hortic*. 843, 255-260.

Grafton-Cardwel, E.E. 2016. Asian Citrus Psyllid and Huanglongbing Disease. Oakland: *UC ANR Publication* 7411.

Grasselly, D., Merlin, G., Sédilot, C., Vanel, F., Dufour, G. & Rosso, L. 2004. Denitrification of soilless tomato crops run-off water by horizontal subsurface constructed wetlands. *In International Conference on Sustainable Greenhouse Systems* 691, 329-332.

Gruber, B., Boman, B., Hancock, K., Kumar, P., & Britt, J. 2013. Fertilizer and irrigation effects on the growth of potted citrus nursery trees. *Citrus Industry Online*.

Hatfield, J. L., & Prueger, J. H. 2015. Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes, 10*, 4-10.

İncesu, M., Yeşiloğlu, T., Çimen, B. and Yılmaz, B. 2016. Effects of nursery shading on plant growth, chlorophyll content and PSII in 'Lane Late' navel orange seedlings. *Acta Hortic*. 1130, 301-306

Jifon, J. L., and J. P. Syvertsen. 2003. Moderate shade can increase net gas exchange and reduce photoinhibition in citrus leaves†. *Tree Physiology* 23(2):119-127.

Jung, J.-Y., J. H. Damusaru, Y. Park, K. Kim, M. Seong, H.-W. Je, S. Kim, and S. C. Bai. 2017. Autotrophic biofloc technology system (ABFT) using Chlorella vulgaris and Scenedesmus obliquus positively affects performance of Nile tilapia (Oreochromis niloticus). *Algal Research* 27(Supplement C):259-264.

Kempen, E. 2015. Nutrient and water use of tomato (Solanum Lycopersicum) in soilless production systems (Doctoral dissertation). *Stellenbosch University*.

Massa D, Incrocci L, Maggini R, Bibbiani C, Carmassi G, Malorgio F, Pardossi A. 2011. Simulation of crop water and mineral relations in greenhouse soilless culture. *Environmental Modelling Software* 26, 711-722.

Mattson NS, Lieth LH. 2007. Modelling macronutrient absorption of hydroponically-grown cut flower roses. *Acta Horticulturae* 751, 129-135.

Mazzini, R. B., Ribeiro, R. V., & Pio, R. M. 2010. A simple and non-destructive model for individual leaf area estimation in citrus. *Fruits, 65*(5), 269-275.

Raviv, M. and J H Lieth. 2008. Soilless Culture – Theory and Practice. Elsevier, Amsterdam. pp 587.

Raveh, E., S. Cohen, T. Raz, D. Yakir, A. Grava, and E. E. Goldschmidt. 2003. Increased growth of young citrus trees under reduced radiation load in a semi-arid climate. *J Exp Bot* 54(381):365-373.

Rossi, F., H. Li, Y. Liu, and R. De Philippis. 2017. Cyanobacterial inoculation (cyanobacterisation): Perspectives for the development of a standardized multifunctional technology for soil fertilization and desertification reversal. *Earth-Science Reviews* 171(Supplement C):28-43.

Silberbush M, Lieth JH. 2004. Nitrate and potassium uptake by greenhouse roses (*Rosa hybrida*) along successive flower-cut cycles: a model and its calibration. *Scientia Horticulturae* 101, 127-14

U.S. Department of Agriculture, National Agricultural Statistics Service. 2015. Citrus Fruits 2015 Summary. *USDA*, Washington, DC.

Xu, F., W. Guo, W. Xu, Y. Wei, and R. Wang. 2009. Leaf morphology correlates with water and light availability: What consequences for simple and compound leaves? *Progress in Natural Science* 19(12):1789-1798.