National Foliage Foundation Final Research Project Report

Final Report Deadline: Final report is due within 30 days after completion date indicated on original grant proposal application. (If additional time is needed, please contact FNGLA office for an extension.)

Purpose of Final Report: It will provide a comprehensive evaluation of the research project and how funding this project has benefited the foliage industry. In addition, the final report will help board members evaluate future research projects.

Report Content:
1) Copy of this cover sheet completed 2) Review the industry needs addressed and summarize completely the research conducted, 3) Identify how the results will benefit the industry including the potential economic impact that it will have. 4) Indicate any future research that is identified as a result of current project. 5) If any portion of the research has been published, provide location of any professional or published information

Required Report Format and Documentation:
- MS Word Document version must also be submitted either via email to lreindl@fngla.org or compact disc.
- One (1) copies of any published articles or reports on funded research written as of November.

Project Title: Comparison of Growth and Water Use of Irrigation systems during Production of Budded Citrus in Phyto-Sanitary Greenhouses.

Institutions Where Research was conducted University of Florida Mid-Florida Research and Education Center

Total Endowment Funds Given $ 43,390 Grant Period 5/15/2013 to 2/15/15
Project Completion Date 1/14/15

Researcher/Institution Information:
List the names of all individual(s) or affiliated organization involved in the research. Please list the principal researcher for the project first.

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2. Review of Industry needs addressed.

At their December 2012 meeting, the Citrus Nursery Executive Committee identified their top research priority to be a comparison of budded tree growth and irrigation requirements among the 4 irrigation systems available. These were overhead, micro-irrigation (drip), ebb and flow (flood), and a self-contained capillary mat (Aquamat). Among their concerns was the occasional outbreak of citrus canker within a greenhouse and its rapid spread by overhead irrigation. Overhead irrigation was the most prominent form of irrigation used in citrus greenhouse production, and also the least expensive. In addition to limiting disease outbreaks, they were also concerned about the potential of Water Management Districts developing irrigation quotas without research to support those limits. Further concerns were how difference irrigation systems impacted trunk caliper growth. Caliper size is the most critical measurement of when a tree is of marketable size. The research reported here was developed to answer these questions posed by the Committee.

The four systems have their pros and cons. Overhead irrigation is likely the easiest and least expensive to install and maintain. However it creates excessive moisture in the canopies that can spread foliar disease, such as citrus canker. As trees achieve marketable heights, much of the applied water is retained in the foliage, often falling between pots instead of in the pot, requiring higher volumes applied. Drip irrigation is likely the most expensive irrigation system in terms of labor and material cost. Drip irrigation requires one or more supply lines down a bed and manifolds that thread tubing to each individual pot. Should an emitter clog or be pulled out or the tubing be cut, there is no redundancy for supplying water to that pot. Sub-irrigation eliminates wetting the foliage and provides redundancy by having water available everywhere on a bed. Yet it could spread *Phytopthora* if diseased trees are in the bed. To be effective, the substrate has to have good capillary action to pull the water up into the pot, but still provide enough air to inhibit disease. Commonly used 60% peatmoss: 40% perlite substrates works very well for sub-irrigation. Ideally the benches should be nearly level. The depth of the water should be shallow, but the duration needs to be worked out for each substrate. Aquamat is a special type of subirrigation. It is a 4 layer system that allows water movement to the driest areas and it greatly reduces evaporation. However it's cost is closest to that of drip irrigation, but with the same ease of moving pots as overhead or sub-irrigation.

The objectives of this research were to:

1. To quantify the volume of water required by these 4 available irrigation systems to produce 80% market size trees.
2. To compare tree trunk caliper growth among available irrigation systems. Trunk caliper was used to determine when 80% of the trees per irrigation system had obtained marketable size. This was considered to be point where trees in that group were available for marketing.

Accomplishments:

Rootstocks were received from BriteLeaf Nursery the first week of January 2014. By the second week of January, 2160 rootstocks had been transplanted into 4 x 14 inch citrus pots. Trees were randomly distributed across 12 – 4 x 7 ft tables using the Apopka spacing. This resulted in 180 trees per table. Tables were evenly distributed among 4 irrigation regimes: overhead, flood, Aquamat and drip stakes in a randomized design. Fertilizer, 18 g of 15-9-12 Osmocote Plus (Everret Inc.) was applied to each tree at potting. For trees designated to be overhead irrigated, fertilizer was top dressed. For all other irrigation regimes, the fertilizer was mixed in the substrate about half way down the pot. All trees received 1/8th teaspoon of Kocide and ½ teaspoon of Sprint iron on 1/24/14. Trees were hand irrigated as needed the first few weeks. Thereafter irrigation was based on water loss from 6 weighed containers per table. Initially irrigation was set to occur at 3 oz. of water loss per tree. Irrigation volumes were gradually scaled up to around 30% (6 oz.) of the estimated amount of plant available water (18 oz.) per pot.

Trees were grown until the first of May when 10½ tables were professionally budded using Valencia 14-19 for half the trees and Valencia F-55-1 for the other half. Two budwood sources were used because there were not enough viable buds available to bud all the trees the same. Two weeks later, the remaining 2 ½ tables were budded similarly. Two weeks after budding, wraps were removed and trees were pinned to force bud break of the inserted bud.

By the 17th of June, bud shoots were large enough such that rootstock shoots were removed and bud shoots were staked using 1/8" in diameter galvanized rods. As shoots reached the top of a stake, the terminal bud was pinched to the stake height (30"). Buds elongating below the top 6" were removed. Shoots initiating at or above the 6" line were allowed to grow, but were also pinched back at the top of the stake. Most trees had obtained the 30" height by early August.

While height was generally sufficient for marketable trees, trunk caliper was not. Minimum calipers for marketing are 3/8" in diameter. Random visual observations delayed the beginning of these measurements until August 8th. Because there were up to 180 trees per table, tables were subsampled by measuring branch caliper of each tree across 4 rows along the short width of a table. When the subsamples obtained >85% marketable size, the remaining trees of that half the table were measured. If half a table achieved >80% marketable trees, remaining trees on a table were measured. Data collection was stopped when >80% of all trees on a table achieved marketable size on 14 January 2015.

Trunk caliper was measured 8 times from the first of August 2014 until the middle of January 2015 (Table 1). Measurements were terminated when a replication achieved greater than 80% marketable size. The final percentage per irrigation system was calculated when all 3 replications had achieved higher than 80%. When an irrigation system was complete, average volume of water applied was calculated.

Trees overhead irrigated obtained >80% marketable size across all 3 tables when measured 3 Nov (Table 1). Trees irrigated by flood (ebb and flow) achieved the 80% marketable trees on all 3 tables by 26 Nov. For both drip and Aquamat treatments, one table of each had achieved >80% marketable size by 26 Nov. However to achieve >80% for the 2 remaining tables, drip-irrigated trees finish a month later at the end of December, with Aquamat trees finishing 3 weeks after that in the middle of January.

Table 1. Mean percentage of measured trees within each irrigation system that had obtained marketable size (3/8”) in shoot caliper after each 3 week period.

Irrigation system	Flood	Aquamat	Drip	Overhead
Aug 08	2.2	1.4	0	13.6
Aug 27	5.9	9.5	0	55.9
Sept 16	25.0	28.0	2.7	69.0
Oct 9	25.0	28.0	2.7	70
Nov 3	74.2	50.2	40.0	83.7 finished
Nov 26	86.3 finished	75.9	75.0	
Dec 23		80.0	89.3 finished	
Jan 14		85.4 finished		

The slow rate of trees obtaining marketable size when irrigated by drip the first 2 months was due to insufficient irrigation. Until early September, irrigation of drip irrigated tables was based on the number of trees per table and replacement irrigation. Due to poor bud take, all 3 replications retained only 50 to 60% of the original number of trees that were budded. Thus they received about half the irrigation applied at budding since all emitter were still functioning. Concurrently it was observed that even after irrigation, containers were light. This was determined due “tunneling” of water through the substrate because it was emitted from a single narrow source. This limited the amount of water that was absorbed horizontally in the substrate. This was corrected by extending the irrigation duration beyond replacement values.

Total irrigation volumes to achieve the objectives varied over 8-fold (Table 2). The most water conserving system was the Aquamat. On average, 293 gal were applied, averaging 10.5 gal per ft^2 over the 12 month production time. Drip irrigation was the next most water conserving system, applying 445 gal per table. Drip irrigation was the second to last system achieve at least 80% marketable size, achieving this in 11 months. Average irrigation volumes were 16 gal per ft^2. Trees irrigated by flood irrigation were over 80% marketable size the end of November, 10 months after potting. To achieve this, an average of 717 gal was applied at rate of 25.6 gal per ft^2. This could be substantially lower with smaller drain holes or a zero pressure drain valve. The irrigation system that produced trees to marketable size the fastest was overhead irrigation. The penalty for this was a greater than 3-fold application of water compared to the flood; with an acceleration of growth of only 3 weeks. On average, 2,444 gal of irrigation was applied by overhead irrigation per table. This averaged to 87 gal per ft^2. Even at this rate, trees around the edges of the tables had to be hand watered beginning 3 months after budding.

Table 2. Mean irrigation volumes and the months of production time required to achieve a minimum of 80% of marketable caliper size trees (3/8th). Each mean is the average of 3 table replicates. Each table was 4 x 7 ft and originally held 180 trees prior to budding.

Measure	Overhead	Flood	Drip	Aquamat
Month to size	9	10	11	12
Irrigation (gal)	2,444 ± 276	717 ± 21	445 ± 11.2	293 ± 8.7

While overhead irrigated trees finished the fastest, irrigation rates for these tables were gradually increased to account for the "umbrella" effect of tall, full canopies. Previously, canopy density effects on water penetration to container substrates were quantified for 3 shrub species (Beeson, 1994). As canopy density increased by placing containers closer together, the percentage of water reaching a pot's substrate surface declined. In a nut shell, increasing density resulted in more water being channeled to the gaps between containers than into the containers themselves. Additionally, dense canopies hold abundant water and must be saturated before much overhead water trickles to surface of the substrate in a container. Use of high pressure nozzles directed downward over a bench of trees would increase the percentage of water absorbed by the substrate.

Flood irrigation, as practiced here, could also be improved to lower overall irrigation volumes. Generally two – ¾ inch holes were drilled at the lowest spots in a table. Water in-flow had to be high enough to overcome the instant drainage and allow sufficient time for water uptake by containers. These large holes were installed limit water standing in a table due to concerns of root rot. These concerns have since been shown to be unfounded using the common Canadian peat moss:perlite blends. Despite a slightly (3 weeks) longer production period, it is likely more economical to use flood irrigation than the 3-fold higher volume overhead irrigation.

Drip irrigation volumes reported here could also be reduced by a slight change in irrigation cultural practices. Tree growth improved when the irrigation time was increased, but it also resulted in a significant waste of water as the wetting front remained relatively narrow initially, to slowly spread laterally within the substrate. Applying the irrigation in 2 to 4 pulses of 2 to 3 minutes, separated by some length of time, would allow water to move laterally in the substrate between pulses. This could not be done in this experiment, but would have reduced the irrigation volumes applied.

Trees grown on Aquamat required the least volumes of water, but were also the slowest irrigation system in terms of production marketable size trees. This also can be improved. Aquamats hold a finite volume of water. When this is exceeded, excess water weeps through the small holes in the top layer. When this occurs, excess water is wasted by evaporation. If this happens consistently, algae will grow on the upper surface. Since trees on Aquamats could not be weighed to determine when irrigation should occur, their irrigation frequency was based on the first flood table. This likely reduced their growth since trees on the flood table absorbed more water than could be absorbed from the Aquamat. If irrigation was more frequent to counteract the lower volumes of water, growth of trees on Aquamats could be as rapid as overhead irrigated trees with many fold less volumes of water.

3. Identify how the results will benefit the Citrus Nursery Industry.

Results of this study can be used in two different ways. For individual producers, volumes of water reported for each irrigation system can be used to determine, based on their water quantity and quality, which irrigation system will be most appropriate for their greenhouse operation. For example, if using municipal water, overhead irrigation would be the most costly. Secondly, these results can be used when applying for water permits for current or future expansions and to garner cost-sharing funding from FDACS for conversion of overhead irrigation to other, more water conserving systems.

4. Identify future research resulting from this project.

As described at the end of Section 2, this project reported multi-fold reductions in irrigation volumes applied for all alternative systems to overhead irrigation. It also offered directions, based on data and observation, that could further reduce irrigation volumes for these alternative systems. In addition these non-overhead systems would maintain, and likely accelerate tree growth and therefore production. A potential follow-up would be to implement the suggested changes at the end of Section 2, and enlist an economist to determine which system(s) are the most cost-efficient.

5. Notification of data publication.

Results will be formatted and submitted for publication in a referred journal in March 2015, with a trade journal brief submitted for publication when the refereed publication is released.

Literature cited

Beeson, Jr. R. C., and T. H. Yeager. 2003. Plant canopy affects sprinkler application efficiency of container-grown ornamentals. HortScience. 38: 1373-1377.