

Accelerated Production of Citrus Nursery Trees Using Automated Ebbandflow Subirrigation

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ABSTRACT

Ebb-and-flow subirrigation is a closed system that applies water to the bottom of the containers, reducing water and nutrient losses due to recirculation of fertilizer solution (FS). The technology can accelerate plant growth and eliminate the improper disposal of salts into the environment. Sensor-based ebb-and-flow benches can be used by the citrus nursery industry to automate subirrigation operation and apply water on demand instead of on a rigid schedule. There is a need for establishing irrigation guidelines to produce different citrus rootstocks. The objectives of this study were: 1) automate ebb-and-flow subirrigation operation using soil moisture sensors, 2) evaluate the system performance on plant growth and water use, and 3) evaluate if subirrigation shorten crop cycle and accelerate citrus liners propagation time compared to overhead irrigation. The treatments tested were five irrigation methods [three ebb-and-flow subirrigation benches with different volumetric water content (VWC) to trigger subirrigation [Θ 0.24, 0.36 and 0.48 m³/m³], capillary mat and overhead irrigation] and six citrus rootstocks (Kuharske, UFR-2, UFR-16, US-802, US-812, and X-639), arranged in a 5 × 6 factorial split-plot design (irrigation method as main

plot), with four replications. The system was automated by 20 capacitance sensors connected to a data logger, multiplexer and relay drivers, which controlled independent submersible pumps and solenoid valves. Subirrigation was turned on when VWC dropped below the set thresholds, while capillary mat and overhead ran on a rigid schedule. Sensors effectively monitored substrate VWC and controlled subirrigation. Treatments with highest VWC had higher substrate moisture and number of irrigations over time. Subirrigation at Θ 0.48 m³/m³ increased shoot height, and subirrigated treatments increased stem diameter and dry weight. Subirrigation induced higher plant growth, shortening the crop cycle and potentially anticipating the liners transplanting for grafting. The volume of water applied was higher on capillary mat and overhead irrigation. VWC Θ 0.48 m³/m³ is indicated for liner production in cone-shaped containers. US-802, US-812, and X-639 rootstocks resulted in the tallest seedlings, while Kuharske showed the widest stem diameter. This is an undergoing trial, ending in three weeks. A sequential study will determine the effects of subirrigation on grafted trees cultivated in citruspots.

OBJECTIVES

Our objectives were: 1) automate ebb-and-flow subirrigation operation using soil moisture sensors, 2) evaluate the system performance on plant growth and water use, and 3) evaluate if subirrigation shorten crop cycle and accelerate citrus liners propagation time compared to overhead irrigation.

INTRODUCTION

High-quality seedlings are necessary for the establishment of healthy citrus groves and resetting. The average annual tree loss across Florida’s citrus industry is around 6%. Replacement of unproductive trees maximize long-term returns since declining trees reduce fruit yield. There are 54 certified, active Florida citrus nurseries. In 2014-2015, 4,438,128 propagations were made for new establishment and resetting. In 2015, Florida presented 66,867,100 bearing trees in production on 501,396 acres. Nurserymen uses mainly overhead irrigation systems to water and fertilizer citrus liners and trees.

Overhead irrigation systems are characterized by minimal control of FS delivery, often leading to excessive or deficient irrigation, low quality plants, reduced irrigation efficiency and increased production costs. Part of the leachate reaches the soil with potential for environmental contamination due to the high amount of salts dissolved into the solution. The umbrella effect (i.e., water redirection by leaves) also reduces the water and nutrient uptake causing significant impact on plant growth, resulting in lack of uniformity, excessive labor for plant sorting and extended production cycles. A more efficient irrigation system is needed to decrease the environmental impacts of citrus nursery tree production, enhance plant growth and produce higher quality trees for planting in the field.

Ebb-and-flow subirrigation is a closed system that applies water to the bottom of the containers, reducing water and nutrient losses due to recirculation of FS. After watering, the pump is turned off and the unused FS returns to the reservoir by gravity for recirculation. More details regarding subirrigation is available at Ferrarezi et al. (2015) and Ferrarezi and Testezlaf (2017a,b).

The technology can improve plant growth and shorten crop cycle, anticipating liners transplant for grafting and allowing another cultivation cycle in the nursery during the year. Faster plant propagation is important due to the constant need to reset huanglongbing-affected trees and the currently lack of tree availability. Subirrigation also eliminates improper disposal of salts into the environment. One potential drawback of subirrigation is the transmission of root-infesting pathogens between containers or benches through recirculated irrigation water; however, several studies shown that subirrigation do not increase disease spread because of FS recirculation (Ferrarezi and Testezlaf, 2017a).

Subirrigation is widely used in the ornamental industry, and ebb-and-flow benches can be used by the citrus nursery industry (Ferrarezi and Testezlaf, 2017b). Sensor-based automation based on real-time VWC readings is an alternative to irrigation based on a rigid schedule. Solis et al. (2016) tested the technology in Florida; however, the system was not automated using soil moisture sensors and had the objective to determine the system economics. There is a need to establish water and fertilizer guidelines to produce citrus liners and budded trees.

METHODS

The study was conducted in a greenhouse located at the UF/IFAS Indian River Research and Education Center, Fort Pierce, FL. (Fig. 1) We tested five irrigation methods [three ebb-and-flow subirrigation benches with different VWC to trigger subirrigation [Θ 0.24, 0.36 and 0.48 m³/m³], capillary mat and overhead irrigation] and six citrus rootstocks (Kuharske, UFR-2, UFR-16, US-802, US-812, and X-639). Plots were arranged in a 5 × 6 factorial split-plot design (irrigation method as main plot), with four replications. Each irrigation treatment had six black plastic trays (RL98) with 98 yellow plastic cone-shaped containers (SC10U) (total of 120 trays and 11,760 containers) (Stuewe & Sons, Tangent/OR).

The system was automated by individual capacitance sensors (10HS; Decagon Devices, Pullman/WA, USA) connected to a data logger (CR1000X), multiplexer (AM16/32B) and relay drivers (SDM-CD16AC) (all from Campbell Scientific, Logan/UT), controlling independent submersible pumps (NK-2; Little Giant, Bluffton/IN). Substrate moisture readings were taken every 30 minutes and averaged hourly. Subirrigation was turned on when VWC drops below the set thresholds.

Overhead irrigation and capillary mat were turned based on Θ 0.36 m³/m³ in the first seven weeks, and then twice daily to reduce water use. A substrate-specific calibration was determined following the sensor manufacturer to transform the sensor readings from voltage to moisture. Substrate VWC and the number of irrigation events were monitored and recorded throughout the experimental period by the automated irrigation system. Shoot height, stem diameter, and total fresh weight were measured monthly (at 0, 30, 60, and 90 days) in 10 random plants per treatment.

Substrate was also sampled weekly to determine pH and electrical conductivity (EC) using the “Pour Thru” method. Briefly, the procedures were: a) random selection of five cone-shaped containers with plants per treatment, b) container placement on a rack for leachate collection, c) substrate saturation, d) application of distilled water (50 mL) to the substrate surface to leach out 50 mL solution into a leachate collecting tray, e) container rested for 30 minutes, and f) solution sampled to measure pH and EC using a portable meter (HI5522; Hanna, Ann Arbor/MI).

The 32-gal FS tanks (Rubbermaid, Atlanta/GA) installed underneath the benches were replenished weekly, and the total volume of FS used recorded by ¾” water flow meters connected to the data logger. This parameter reflected the water loss by plant evapotranspiration and substrate evaporation.

This study still under evaluation (week 15) and is expected to be conducted for another three weeks before termination on week 18. Data will be analyzed using normality (*Proc univariate*), analysis of variance (ANOVA) (*Proc GLM*), and Tukey’s multiple comparisons test (*lsmeans*) using SAS (version 9.4; SAS Institute, Cary/NC). Probability values ≤ 0.05 will be considered statistically significant.



Fig. 1. Overview of greenhouse experiment.

RESULTS & CONCLUSION

Sensors effectively monitored VWC and controlled subirrigation. Peaks indicate irrigation events (Fig. 2).

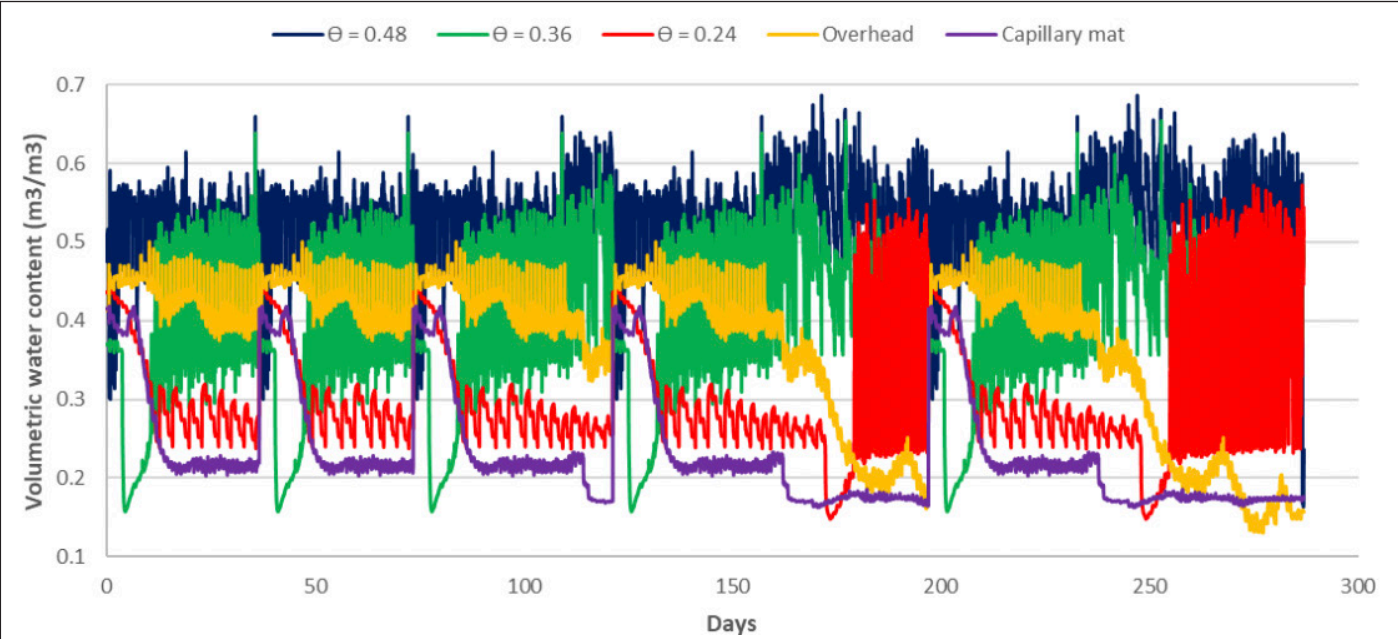


Fig. 2. Volumetric water content over time for treatments ebb-and-flow treatments Θ 0.24, 0.36, and 0.48 m³/m³, overhead irrigation and capillary mat. Each line represents one replication.

Treatments with highest VWC had higher substrate moisture and number of irrigations over time. Subirrigation at Θ 0.48 m³/m³ increased shoot height, and subirrigation increased stem diameter and dry weight (Fig. 3). Subirrigation induced higher plant growth, shortening the crop cycle and anticipating the liners transplanting for grafting, potentially allowing an extra cultivation cycle in the nursery per year. The volume of water applied was higher on capillary mat and overhead irrigation (Table 1).



Fig. 3. Height (A), stem diameter (B) and fresh weight (C) of citrus rootstock liners (Kuharske, UFR-2, UFR-16, US-802, US-812, and X-639) cultivated in different irrigation methods [three ebb-and-flow subirrigation benches with different volumetric water content to trigger subirrigation [Θ 0.24, 0.36 and 0.48 m³/m³], capillary mat and overhead irrigation at days 0, 30, 60 and 90.

Table 1. Total volume of fertilizer solution used per week by citrus rootstock liners.

	Total volume of fertilizer solution used per week (gal)															Total
	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Θ 0.24 m³/m³	-	-	-	-	-	-	16	-	10	8	11	12	8	7	7	79
Θ 0.36 m³/m³	-	-	-	-	-	-	17	-	10	6	9	7	6	7	7	71
Θ 0.48 m³/m³	-	-	-	-	-	-	14	-	14	8	13	12	9	7	7	84
Capillary mat	147	497	624	513	500	467	348	53	42	32	36	38	52	51		3400
Overhead	14	752	548	343	299	248	605	54	11	12	14	14	14	16		2942

Substrate pH was near 5.8 in all treatments except capillary mat (Fig. 4). Substrate EC sampled weekly was stable over time, which is usually not common in subirrigation (Fig. 4). Ferrarezi and Testezlaf (2017a,b) indicated subirrigation tends to accumulate salts in the growing media. This was probably the result of a low proportion of fertilizer injected into the irrigation lines.



Fig.4. Substrate pH and electrical conductivity sampled weekly using the “Pour Thru” method.

Based in our results, VWC of Θ 0.48 m³/m³ is indicated for citrus liner production in cone-shaped containers. US-802, US-812, and X-639 rootstocks resulted in the tallest seedlings, while Kuharske showed the widest stem diameter. A sequential study will determine the effects of subirrigation on grafted trees cultivated in citruspots.

CONCLUSIONS

The automated ebb-and-flow subirrigation system was successfully triggered using soil moisture sensors. VWC of Θ 0.48 m³/m³ increased plant growth in 29% and reduced water use in 98% compared to capillary mat and overhead irrigation. Subirrigation shortened crop cycle and accelerated citrus liners propagation time compared to overhead irrigation.

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LITERATURE CITED

Ferrarezi, R.S., Weaver, G.M., van Iersel, M.W., and Testezlaf, R. 2015. Subirrigation: Historical overview, challenges, and future prospects. *HortTechnology* 25(3), 262-276.

Ferrarezi, R.S. and Testezlaf, R. 2017a. Automated ebb-and-flow subirrigation for citrus liners production. II. Pests, diseases and nutrient concentration. *Agricultural Water Management* 192: 21-32.

Ferrarezi, R.S. and Testezlaf, R. 2017b. Automated ebb-and-flow subirrigation for citrus liners production. I. Plant growth. *Agricultural Water Management* 192: 45-57.

Solis, C., Khachatryan, H., and Beeson, R. 2016. Profitability of citrus tree greenhouse production systems in Florida. *EDIS* publication #FE999.