HS1333

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Citrus Nursery Production Guide, Chapter 8: Stock Plant and Tree Production: b) Irrigation and Fertilization[1]

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Introduction

Citrus tree production in nurseries can be divided into three stages: production of rootstock liners, transplant of rootstocks into larger containers, and bud grafting. The rootstock liners are produced in cone-shaped containers or ellepots, while the transplanted rootstock and grafted trees are grown in four-inch square citrus pots. The containers are filled with commercial soilless potting mix of diverse composition to guarantee optimal water-holding capacity and adequate drainage for increased tree performance.

Because the containers have a small volume, frequent irrigation and fertilization are required to meet crop water and nutrient requirements and accelerate tree growth. Well-designed and properly managed irrigation systems provide uniform water and nutrient delivery and efficient water and nutrient distribution (Salvador et al. 2016).

The irrigation management methods commonly used in greenhouse commercial nursery production are soil- or weather-based methods. Soil-based methods are related to estimating the moisture by manually sensing the substrate (an empirical and inaccurate method), by monitoring the weight of the container, or more precisely, by using soil moisture sensors (Spann and Ferguson 2014). Commercially available sensors use one of many technologies such as time-domain and frequency-domain reflectometry to measure soil moisture. The sensor chosen depends on experience, application, cost, knowledge, operation, and maintenance. Information about soil moisture sensors for citrus irrigation (benefits, sensor choices, and sensor installation steps) is available in Schumann et al. (2018).

Weather-based irrigation scheduling methods involve monitoring environmental parameters and calculating evapotranspiration (ET), allowing greater precision in the irrigation management (Allen et al. 1998). ET is a term used to define the water consumed by plants over a period of time, representing the water loss occurring from evaporation and transpiration. Evaporation occurs when water changes to vapor on either soil or plant surfaces. Transpiration refers to the water lost by the leaves.

Available plant-based methods rely on using sophisticated and more expensive equipment such as a Scholander chamber, portable gas analyzer, sap flow, stem diameter variation and leaf turgor pressure sensors and others. Interpretation of these plant-based measurements often create practical difficulties of implementation that currently limit commercial application (Jones 2004; Fernández 2017).

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Although these irrigation management methods are commercially available, most nurseries use a rigid schedule based on timers to control irrigation. This strategy is empirical, and does not take water demand into consideration for water application. Improvements such as use of soil moisture, weather parameters, and plant-based measurements are necessary to optimize tree performance and save water resources.

The determination of adequate nutritional guidelines for citrus nursery trees is also needed for maximum tree performance (Girardi et al. 2005). The most important aspect of nutrition is to allow for vigorous tree growth without causing root bounding and allowing immediate tree set in the field after planting. To accomplish such results, nurseries use granular, controlled-release and water-soluble fertilizers separately or in combination to apply macro- and micronutrients to the potted trees. In order to maximize tree growth, several growers apply nutrients and biostimulants foliarly in an attempt to boost nutrition and produce high-quality trees able to sustain biotic (pests and diseases) and abiotic (soil and environmental conditions, drainage) stresses after transplanting into the field.

The objective of this chapter is to provide general information on irrigation and fertilization for production of citrus nursery trees in seedbeds, nurseries, and budwood increase blocks.

Irrigation of Rootstock Liners in Seedbeds

Citrus rootstock liners are traditionally watered using hose nozzles, rain wands, and perforated polyvinyl chloride (PVC) pipes (Figure 1A and 1B) (Salvador et al. 2016) as well as overhead microsprinklers (Figure 1C) and spray bars (Figure 1D) (Testezlaf and Ferrarezi 2017). Those methods soak the plant canopy in order to guarantee that water reaches the substrate, because leaves block the substrate surface due to the umbrella effect. Overhead irrigation favors leaf diseases; presents low application efficiency; results in excessive fertilizer solution loss with potential for contamination of soil, groundwater, and the water table; and requires intensive labor use.

The spray bars are designed to apply water automatically through nebulizer sprays mounted on metal structures that move on rails along the greenhouse. The water amount applied is controlled by adjusting the speed of the sprayer (faster runs reduce the amount of water applied). To eliminate the potential damage caused by the droplets, nebulizer sprays should produce small droplets, but with sufficient flow to cross the leaf canopy and reach the substrate (Testezlaf and Ferrarezi 2017).

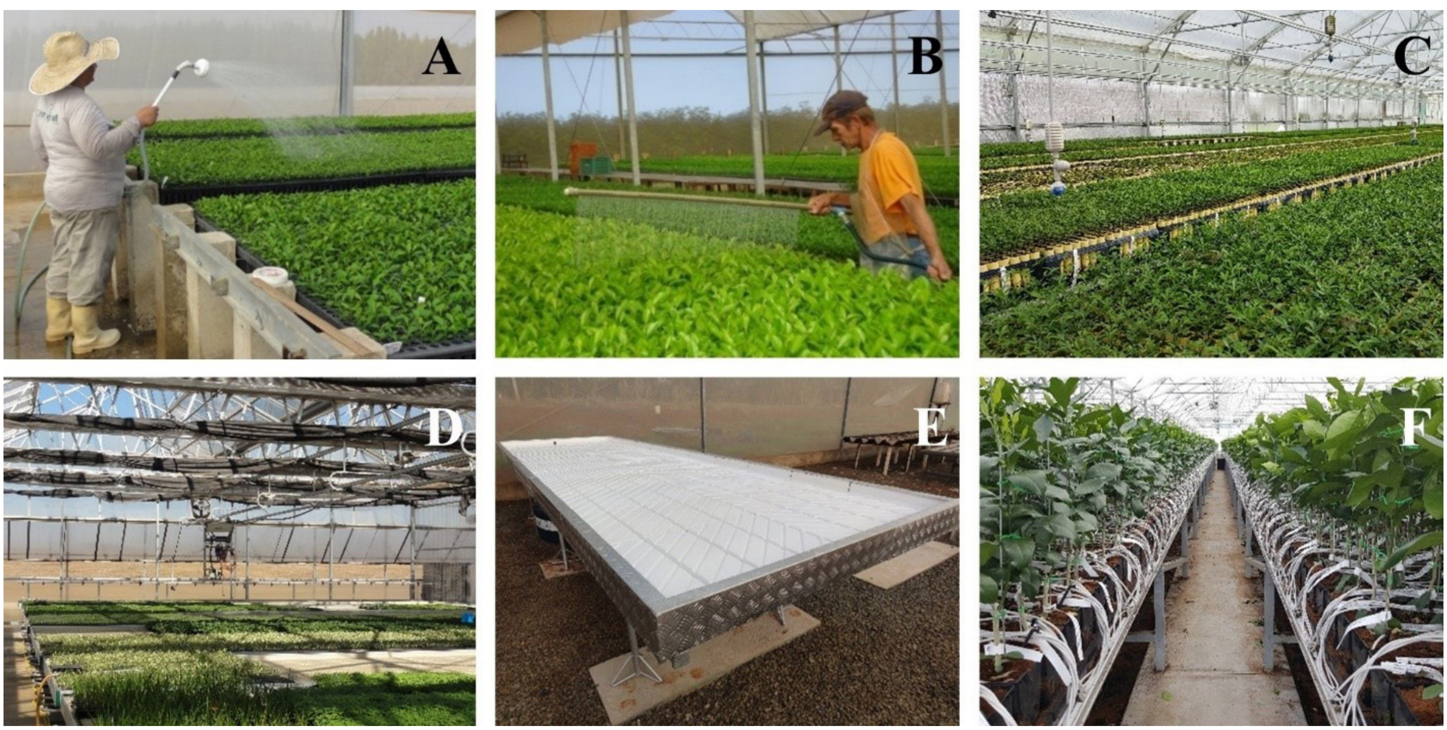

Figure 1. Demonstration of irrigation and manual application of fertilizer solution for the production of rootstock liners, trees, and budwood increase block: A) hose nozzles and rain wands; B) perforated polyvinyl chloride (PVC) pipes; C) rotating minisprinklers; D) spray bar; E) ebb-and-flow subirrigation benches; and F) drip irrigation.
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New, innovative irrigation methods are needed to increase irrigation efficiency and eliminate the drawbacks of overhead irrigation (Carvalho et al. 2019). Subirrigation is an irrigation method that applies water to the bottom of containers and allows fertilizer solution recirculation. The system induces the water vertical movement by using the substrate capillary rise principle. Advantages and disadvantages of the technology are described in Ferrarezi et al. (2015). Several examples of subirrigation equipment are available (Ferrarezi et al. 2015). The most widely used equipment is the ebb-and-flow bench (Figure 1E). The benches are usually filled with water up to ⅓ of the container height.

For comparative purposes, data available in the literature indicate that the sprinkler irrigation has irrigation efficiency of 9%, drip irrigation and capillary mats of 53%, and the subirrigation benches of 77% in the cultivation of potted plants (Neal and Henley 1992). A high value of efficiency indicates that little water is lost by percolation, reducing the leaching of nutrients to the soil and reducing the potential of environmental contamination by salinization.

Subirrigation is widely used by the ornamental plant production industry (Ferrarezi et al. 2015). Studies on the application of subirrigation for citrus production began in 2007 in São Paulo, Brazil. Several technical details have been published to assist potential users. Among those studies are the determination of the relationship between the water level height and the water retention time in the substrate moisture in subirrigation (Ferrarezi et al. 2016), and the validation of operational parameters for the use of subirrigation benches (Ribeiro et al. 2017). Studies about the effects of subirrigation on the production of citrus rootstock liners are available in Ferrarezi and Testezlaf (2017a, 2017b). Results demonstrated that ebb-and-flow subirrigation was successfully used to produce 'Rangpur' lime (*Citrus* × *limonia*) liners, shortening the crop cycle in 30 days by anticipating the transplant for grafting and allowing production of *Phytophthora*-free trees compared to trees irrigated manually by overhead irrigation using breaker nozzles. The system monitoring and operation was successfully automated using soil moisture sensors, a promising technology to optimize citrus nursery tree production.

In Florida, Solis et al. (2016) compared subirrigation benches with sprinkler irrigation, drip irrigation, and capillary mats and observed that production results were similar and that subirrigation saved water because of higher irrigation efficiency. However, the investment cost of drip irrigation is more advantageous than subirrigation and manual irrigation with hose nozzles and rain wands. This is related to the lack of commercial systems available for subirrigation application in citrus production and the high cost of infrastructure and manual labor.

Recently, Ferrarezi et al. (2019) tested five irrigation methods (three ebb-and-flow subirrigation benches with different volumetric water content [VWC] to trigger subirrigation [0.24, 0.36, and 0.48 m^3/m^3], capillary mat, and overhead irrigation) and six citrus rootstocks (Kuharske, UFR-2, UFR-16, US-802, US-812, and X-639) in a study at the UF/IFAS Indian River Research and Education Center in Fort Pierce, Florida. The automated ebb-and-flow subirrigation system was successfully triggered using soil moisture sensors. VWC of 0.48 m^3/m^3 increased plant growth by 29% and reduced water use by 98% compared to capillary mat and overhead irrigation. Subirrigation shortened the crop cycle and accelerated citrus liners propagation time compared to overhead irrigation.

Irrigation of Transplanted Rootstock and Grafted Trees in Citrus Pots

In addition to manual overhead irrigation, the most used system for the production of nursery trees in citrus pots is drip irrigation using drippers with multiple outlets connected to microtubes, which are characterized by simplicity of operation and maintenance (Fig. 1E) (Carvalho et al. 2019). The system can have one emitter with one- or multi-outlet small tubes to route the water from the emitter to the trees. These small tubes are called distribution or spaghetti tubes, are usually ¼- or ⅛-inch-diameter, and are made of polyethylene or soft vinyl (Testezlaf and Ferrarezi, 2017).

Most trees are watered daily to maintain substrate at field capacity and to minimize leaching. However, Girardi et al. (2018) showed distinct biometric (tree growth), physiological (CO_2 assimilation rates and water-use efficiency), and biochemical (leaf nutrient concentrations and starch concentration) responses to regulated deficit irrigation, which may contribute to significant water savings and decrease the risks of certain diseases. There were negative effects on tree quality that need to be further investigated.

Irrigation in Budwood Increase Blocks

The most common irrigation method used for budwood increase blocks is drip followed by overhead manual irrigation (using hose nozzles, rain wands, and overhead microsprinklers) (Carvalho et al. 2019). Trees are cultivated either in the soil or in large pots for prolonged periods. Nurseries usually use a rigid schedule based on timers to control irrigation. Nonetheless, the use of automatic timers can be problematic because they do not take into consideration water demand, water availability, environmental conditions, and plant growth stage.

Fertilization in Seedbeds and Nurseries

With the introduction of the use of containers, soilless substrates, and protected environments in the production of citrus rootstocks and trees, several studies were performed to determine adjustments in fertilization and mineral nutrition demands to obtain better results (Bernardi et al. 2000; Carvalho et al. 2000; Serrano et al. 2004; Girardi et al. 2005; Prado et al. 2008).

Bataglia et al. (2008) indicated the nutritional guidelines for citrus nurseries using a system called “Diagnosis and Recommendation Integrated System” (DRIS) to monitor factors that affect the nutritional status of plants. Chemical analyses of foliar macronutrient contents were determined in a reference population, DRIS indices were calculated, and optimum nutrition level determined for transplanted rootstocks and grafted trees (Table 1).

The reference standards of Bataglia et al. (2008) indicate that ‘Swingle’ citrumelo (*Citrus paradisi* cv. Duncan × *Poncirus trifoliata*) requires higher concentrations of N, Mg, and S when compared to other rootstocks (Table 1). Grafted nursery trees at the *end of the first growth flush* and *before the final pruning* also have higher N and K concentrations, showing the shoot’s ability to define nutrient demand. A similar study with ‘Rangpur’ lime and ‘Swingle’ citrumelo rootstocks ready for grafting in a commercial citrus nursery showed that DRIS is efficient in establishing regional criteria for nutrient sufficiency range (Rezende et al. 2017).

Fertilization in nurseries typically uses granular, controlled-release, and/or water-soluble fertilizers (fertigation using separate tanks). In general, a fertilizer solution containing the concentration (in mg L^{-1}) N (200), P (18), K (152), Ca (140), Mg (29), and S (21) is considered balanced for the cultivation of citrus plants in substrate using fertigation (Bataglia et al. 2008). However, the knowledge of the chemical composition of the irrigation water and substrate is important to make adjustments in this nutrient solution and to determine the concentrations of micronutrients that should be incorporated into the final fertilizer solution.

Fertilization in Budwood Increase Blocks

With regard to the nutrition of the budwood increase blocks, an adequate balance of nutrients is necessary to avoid deficiencies (Carvalho et al. 2019). The same granular, slow-release, and water-soluble fertilizers for fertigation (supplied using separate tanks of pre-prepared blends or complete solutions) can be used but in larger rates. It is recommended to maintain adequate concentrations of N, P, Mg, and micronutrients to stimulate the growth of sprouts that will produce the buds for grafting. Bataglia et al. (2008) recommend a balanced formulation for grafted trees that should be adjusted for the budwood increase blocks based on the soilless substrate and scion/rootstock combination.

Arbuscular Mycorrhizae Fungi

Positive effects of mineral nutrition on growth of different transplanted rootstocks and grafted trees have been obtained with the use of arbuscular mycorrhizae fungi (Wu and Xia 2006; Wu et al. 2010) and other beneficial microorganisms (Bogas et al. 2016; Back et al. 2016). However, despite the fungi’s great potential, especially for the current model of citrus tree production system using soilless substrates and greater environmental control, there are no references to a larger scale evaluation, and their use is restricted to a few commercial nurseries.

Conclusions

The advances in citrus tree production since 2007 have improved the tree quality and resulted in higher performance in the field. Adequate irrigation and fertilization on nursery trees in seedbeds, nurseries, and budwood increase blocks is key to accelerate tree production and guarantee growers will receive a tree that will result in profitable crop yield. Further research is needed to recommend water requirements, irrigation methods and frequency, fertilizer types, sources and rates, and updated guidelines for different varieties and rootstocks.

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Table 1. Foliar nutritional guidelines for transplanted rootstocks ['Rangpur' lime (*Citrus × limonia*), 'Cleopatra' (*Citrus reshni*), 'Sunki' (*Citrus sunki*) mandarins], and 'Swingle' citrumelo (*Citrus paradisi* cv. Duncan × *Poncirus trifoliata*), and 'Pera' sweet orange (*Citrus sinensis*) grafted on 'Sunki' mandarin and 'Valencia' sweet orange grafted on 'Swingle' citrumelo at the end of the first growth flush and before the final pruning. Adapted from Bataglia et al. (2008).

	Transplanted rootstock		**Grafted trees 'Pera' on 'Sunki' and 'Valencia' on 'Swingle'**	
Nutrient	**'Rangpur', 'Cleopatra' and 'Sunki'**	**'Swingle'**	**End of the first growth flush**	**Before the final pruning**
	------------------------- % -------------------------			
N	2.5–3.5	3.0–4.0	3.5–4.0	3.0–4.0
P	0.20–0.25	0.22–0.28	0.22–0.28	0.20–0.24
K	1.5–2.0	1.6–2.2	2.2–2.6	2.1–2.8
Ca	2.0–3.0	2.5–3.5	1.6–2.3	2.0–2.7
Mg	0.27–0.38	0.35–0.45	0.28–0.41	0.23–0.35
S	0.25–0.35	0.30–0.45	0.25–0.35	0.29–0.37
	------------------------- mg/kg -------------------------			
B	50–120	90–150	55–110	90–170
Cu	5–30	5–30	5–30	10–30
Fe	100–200	100–200	100–200	120–250
Mn	50–200	100–250	40–200	70–180
Zn	20–70	25–70	25–55	40–90