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Preliminary Data on Water Uptake by Huanglongbing Infected Trees

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Improved understanding of citrus water use and soil moisture distribution in Huanglongbing (HLB) (*Candidatus* Liberibacter asiaticus) infected and affected groves is critical for devising appropriate recommendations for optimizing water use and sustaining citrus yields. Thus, a study is being conducted to investigate water use patterns and soil moisture movement in central, south-central and southwest Florida. Treatments being evaluated include: 1) daily irrigation (Daily); 2) Institute of Food and Agricultural Sciences (IFAS) recommended scheduling; and 3) irrigation scheduled half the number of days between irrigation recommended by IFAS (Intermediate). The irrigation amounts of the daily and intermediate irrigation schedule are reduced to provide similar amounts of water to the IFAS recommendation over long periods of time. Preliminary results indicate that water use per unit leaf area ranged from 0.09 to 0.10 oz/inch^2/day at all sites depending on irrigation schedule. Moisture contents were similar among irrigation schedules varying between 5% to 20%, 1% to 14%, and 5% to 25% at 6-, 12-, and 18-inch soil depths, increasing with depth possibly as a result of uptake in the top 12 inches. These preliminary findings should help in refining limits for available water contents and estimating irrigation demand estimations to sustain citrus productivity of HLB infected trees.

Citrus greening (HLB) is the major disease affecting citrus production in Florida having destroyed 30% or more of trees statewide and reduced yield significantly (Gottwald et al., 2007; Irey et al., 2006, 2008; Manjunath et al., 2008). The problem is exacerbated by the fact that HLB-infected trees are plagued by excessive fruit drop (Gottwald et al. 2007) and the fruit is not suitable for fresh market or juice processing due to a significant increase in acidity and bitter taste resulting in added economic losses (Bassanezi et al., 2009; Dagulo et al., 2010). In addition, HLB-infected trees exhibit decreased root length and density which potentially limits water and nutrient absorption (Graham et al., 2013; Kadyampakeni, 2012; Kadyampakeni et al., 2014a, 2014b). Improved water management could increase water and nutrient use efficiency and tree production in HLB-affected groves. Currently, there is no information on the water use of mature trees infected and affected by HLB. Such information is critical for developing appropriate guidelines for growers to optimize yields while conserving water resources. The present study was conducted to 1) compare water use of mature citrus using three different irrigation schedules but similar irrigation rates, and 2) determine soil moisture distribution in the citrus irrigated zones.

Materials and Methods

Site description. The experiments were conducted in four locations: 1. at Ave Maria (lat. 26°16' N, long. 81°25' W), 2. in the southwest Florida flatwoods (Collier county), 3. Arcadia (lat. 27°13' N, long. 81°39' W) in the south-central flatwoods (Desoto County), and 4. Avon Park (lat. 27°36' N, long. 81°31' W) in the central ridge (Highlands county). The soils at Ave Maria are classified as Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods) (USDA, 1998a). The soil at Arcadia is classified as a Smyrna fine sand (sandy, siliceous, hyperthermic Aeric Haplaquods) (USDA, 1998b) while the soil classification at Avon Park is Astatula sand (hyperthermic, uncoated Typic Quartzipsamments) (USDA, 1998c).

Experimental design. The experiment was arranged in a randomized complete block design with four replications for sap flow measurements. The irrigation scheduling treatments for conventional irrigation were as follows: 1) daily irrigation (Daily), 2) Institute of Food and Agricultural Sciences recommended scheduling (IFAS), and 3) irrigation scheduled half the number of days between irrigation recommended by IFAS (Intermediate). The trees at all sites were spaced at 15 x 25 ft.

Measurement of sap flow. Sap flow sensors (Dynamax Inc., Houston, TX, USA) were installed on four branches on each tree per irrigation schedule (each branch serving as a replicate). Measurements were taken of branch diameters prior to installation of the sensors. The sap flow sensors were connected to a data logger (CR 1000, Campbell Scientific Inc., Logan, UT, USA) to record data every hour. Flow data obtained from the logger were then converted to water flow per unit leaf area per unit time ($kg \cdot m^{-2} \cdot s^{-1}$). The sap flow measurements were done for 10 to 14 d.

Stem water potential measurement. Stem water potential was measured in 4 leaves per tree. Leaves were wrapped in plastic and aluminum foil the day prior to data collection to allow the water potential of the leaves to equilibrate with the water potential of the stem. Wrapped leaves were cut at the petiole with a razor

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blade and stem water potential was measured using a pressure chamber (Model 1000, PMS Instrument Co., Corvallis, OR) that was pressurized at 1 MPa/30 s using compressed nitrogen.

Soil moisture determination. Soil water sensors were used to measure volumetric soil moisture content at the three sites (EC-5 and 10HS, Decagon Devices, Pullman, WA). Soil moisture was measured hourly at 6- and 12-inch depths using the EC-5 soil moisture sensor and the HS10 sensor at 18-inch depth. Each block contained one data logger for recording soil moisture content.

Visual survey analysis and polymerase chain reaction assays. Trees were visually evaluated for any visual HLB symptoms. Trees that were asymptomatic for HLB were identified and used for the study. Thereafter, real-time polymerase chain reaction (PCR) assay to determine *C*. Liberibacter asiaticus infection was used on the selected trees every six months.

Statistical analysis. The data were analyzed using GLM Mixed Model Type III procedures using SAS (version 9.3 for Windows; SAS Institute, Cary, NC) when assumptions for analysis of variance were satisfied. We evaluated differences in sap flow and stem water potential between irrigation schedules, sites and interactions between sites.

Results and Discussion

Sap flow and stem water potential between irrigation schedules and sites. Intermediate irrigation schedule had greater sap flow ($P < 0.05$) than IFAS irrigation but showed similar trends to Daily irrigation at Arcadia (Fig. 1). However, Daily irrigation consistently showed greater sap flow at both Ave Maria and Avon Park than IFAS and Intermediate irrigation schedules ($P<0.001$) (Fig. 1). IFAS and Intermediate irrigation schedules showed similar sap flow trends at Ave Maria and Avon Park. Stem water potential was greater for Daily than Intermediate but similar to IFAS at Arcadia and Avon Park ($P < 0.05$) suggesting that Daily irrigation schedule resulted higher water use than Intermediate (Fig. 2). At Ave Maria, the trend was surprisingly different ($P < 0.01$) in the order of Daily > Intermediate > IFAS. We found significant interaction ($P < 0.0001$) between site and irrigation schedule possibly due to differences in soil characteristics. The soil at Avon Park are well drained Entisols while the soils at Arcadia and Ave Maria are poorly drained Spodosols and this might have impacted water use. The PCR assays showed that the Intermediate irrigation block at Ave Maria, and Daily and Intermediate irrigation blocks at Arcadia were HLB positive. All the trees at Avon Park were asymptomatic and HLB negative. Thus, overall, it appears the water use in HLB positive and negative trees were

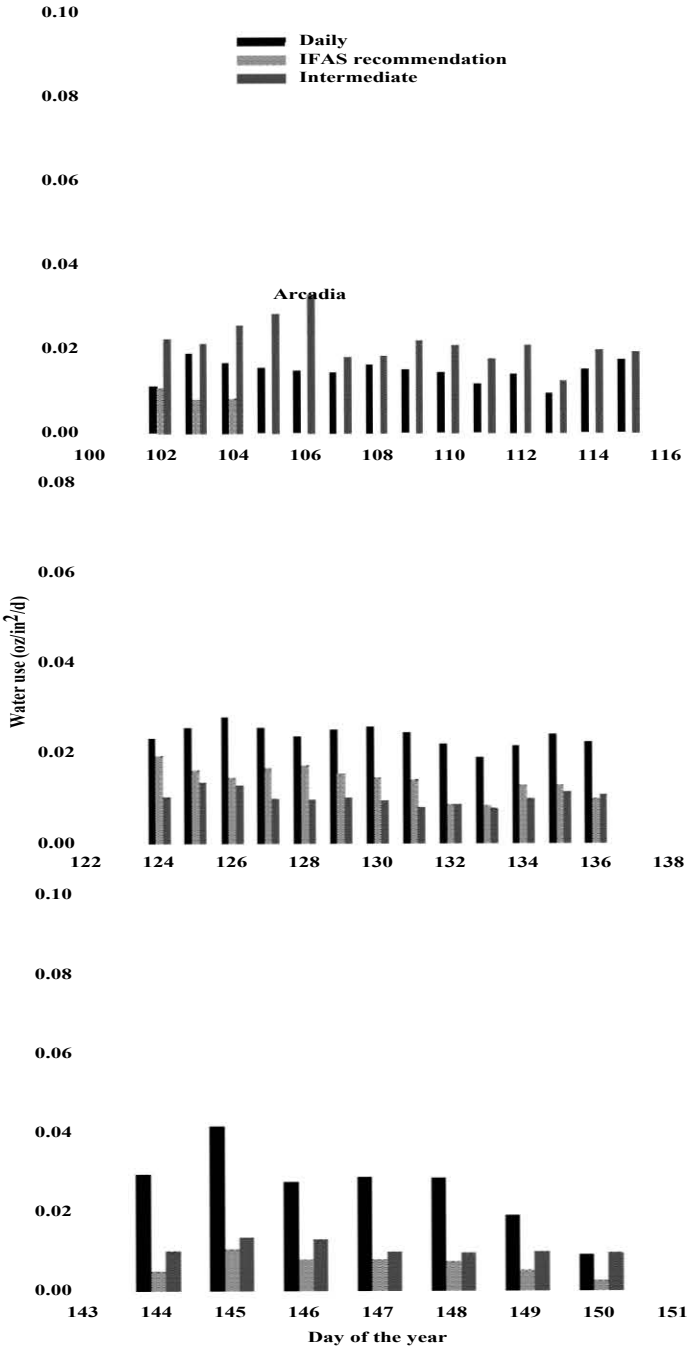

Fig. 1. Sap flow measurements for Arcadia (top), Ave Maria (middle) and Avon Park (bottom). Error bars represent 1 standard deviation of four replicates.

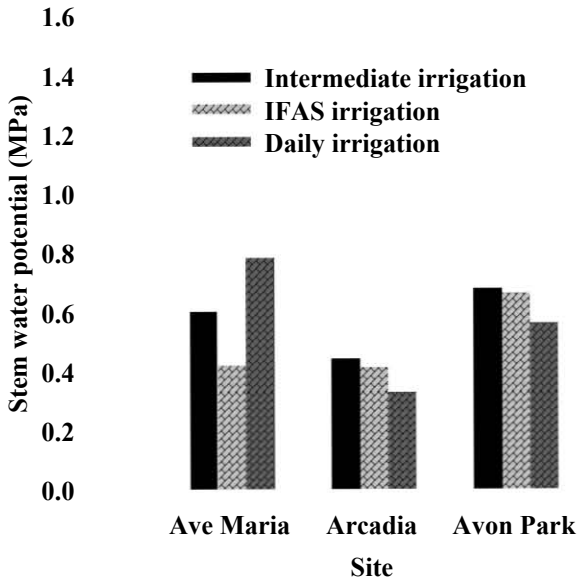

Fig. 2. Stem water potential between intermediate irrigation, IFAS irrigation and daily irrigation at Ave Maria, Arcadia and Avon Park. Error bars represent 1 standard deviation of four replicates.

similar. Further analysis will be done on the HLB positive and negative trees under the same irrigation schedule at each site to confirm these observations.

Soil moisture distribution pattern by depth, irrigation and site. Soil moisture at 6- and 18-inch depths at Arcadia varied between 0.025 and 0.25 $cm^3 \cdot cm^{-3}$ and remained below 0.10 $cm^3 \cdot cm^{-3}$ at 12-inch depth. The moisture at Ave Maria was largely between 0.03 and 0.15 $cm^3 \cdot cm^{-3}$ at all depths though IFAS irrigation schedule showed greater soil moisture contents than the other two irrigation schedules at 18-inch depth. We observed soil moisture contents below 0.07 $cm^3 \cdot cm^{-3}$ at 6- and 12-inch soil depths at Avon Park probably because this is an excessively drained Entisol with very low water holding capacity. The soil moisture contents at 18-inch depth at Avon Park varied between 0.025 and 0.18 $cm^3 \cdot cm^{-3}$.

Conclusions and Considerations for Further Research

Water use pattern was of the order Daily > IFAS > Intermediate at Ave Maria. Water use was similar between Daily and IFAS but lower than Intermediate irrigation for HLB positive trees at Arcadia. For healthy trees at Avon Park Daily irrigation was greater than both IFAS and Intermediate irrigation schedules. All soil moisture regimes were close to field capacity, but IFAS and Daily irrigation schedules appeared to be ideal for managing HLB infected trees compared to the Intermediate irrigation schedule.

An on-going weighing lysimeter greenhouse experiment at Southwest Florida Research and Education Center on two major citrus rootstocks where the prevalence of the HLB vector, the Asian psyllid (*Diaphorina citri*), is kept out will address the need for comprehensive evaluation of water use of HLB-infected and disease free trees under controlled conditions. Measurements include automated recording of changes in weight of the lysimeters and soil moisture contents and periodic stem water potential.

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