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Research paper

Irrigation scheduling and soil moisture dynamics influence water uptake by Huanglongbing affected trees

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ABSTRACT

Improved understanding of citrus water use and soil moisture distribution in Huanglongbing (HLB) (*Candidatus* Liberibacter asiaticus) affected groves is critical for devising appropriate recommendations for optimizing water use and sustaining citrus yields. Thus, a study was conducted to investigate soil moisture movement and water use patterns in central, south-central and southwest Florida. Treatments included: 1) daily irrigation (Daily), 2) University of Florida Institute of Food and Agricultural Sciences recommended scheduling characterized by irrigating every two days to replace water used by crop evapotranspiration (IFAS), and 3) irrigation scheduled half the number of days between irrigation recommended by IFAS and Daily (Intermediate). The total irrigation was designed to meet estimated crop water use (ET_c) for mature citrus equaling 1127 mm, 1138 mm, and 1211 mm, and 1211 mm per year at Avon Park, Arcadia and Ave Maria, respectively. Field capacities (FC) and available water capacity (AWC) varied between 0.062 $cm^3\ cm^{-3}$ to 0.11 $cm^3\ cm^{-3}$, with AWC estimated to be 86% to 91% of FC. Irrigation set points for irrigation scheduling were estimated at 33 and 50% of allowable soil water depletion (ASWD) and varied between 0.020 and 0.033 $cm^3\ cm^{-3}$ while 50% ASWD varied between 0.031 and 0.050 $cm^3\ cm^{-3}$. Daily water use largely varied between 0.02 and 0.18 $g/d/cm^2$ in Summer 2013, 0.01–0.15 $g/d/cm^2$ in Fall 2013 and 0.01 and 0.24 $g/d/cm^2$ in Spring 2014. Water use pattern was largely of the order Daily > IFAS > Intermediate. Moisture contents were similar among irrigation schedules varying between 5–20%, 1–14% and 5–25% at 15-, 30-, and 45-cm soil depths, respectively, increasing with depth possibly as a result of uptake in the top 30 cm. These findings should help in refining limits for available water contents and estimating irrigation water demand to sustain citrus productivity of HLB infected trees.

1. Introduction

Citrus greening (HLB) is the major disease affecting citrus production in Florida and has eliminated > 30% trees and reduced yields in citrus groves in the state (Gottwald et al., 2007; Irey et al., 2006, 2008; Manjunath et al., 2008; USDA, 2016). The problem is exacerbated by the fact that HLB-affected trees show excessive fruit drop, resulting in fruit losses estimated to be around $150 million annually (Gottwald et al., 2007; Albrigo and Syvertsen, 2015). The fruit is not suitable for the fresh market or juice processing due to significant increase in acidity and bitter taste resulting in economic losses (Bassanezi et al., 2009; Dagulo et al., 2010). In addition, HLB-infected trees exhibit decreased root length density that potentially limits water and nutrient accumulation (Graham et al., 2013; Kadyampakeni, 2012; Kadyampakeni et al., 2014a,b). 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 affected by HLB. More importantly, investigating the response of HLB affected trees to varied irrigation schedules would improve our understanding about the disease dynamics with regard to plant-soil-water-relationships and help commercial citrus growers manage water more efficiently. Information generated from such field studies is critical for developing appropriate guidelines for growers to maintain orange tree yields to optimum production levels while conserving water resources. The objectives of the study were to 1) determine water retention characteristics and irrigation set points for the soils at the three sites, 2) determine soil moisture distribution patterns in the citrus irrigated zones, and 3) compare water use of mature citrus using three different irrigation schedules but similar irrigation rates.

Abbreviations: IFAS, Institute of Food and Agricultural Sciences; AWC, available water capacity; AWSD, allowable soil water depletion; ET_c, crop evapotranspiration; HLB, Huanglongbing

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Table 1
Average tree characteristics based on stem and leaf areas.

Site	Irrigation schedule[a]	Summer 2013	Fall 2013	Spring 2014
			Leaf area (cm^2)	
Avon Park	IFAS	16517 ± 4271[b]	8089 ± 2451	11218 ± 6572
Avon Park	Intermediate	20737 ± 7318	16023 ± 11913	9747 ± 3655
Avon Park	Daily	14459 ± 11500	10021 ± 8238	5865 ± 2708
Ave Maria	IFAS	17220 ± 9445	22614 ± 12178	16220 ± 5620
Ave Maria	Intermediate	7403 ± 4627	8559 ± 3312	6731 ± 3377
Ave Maria	Daily	8919 ± 2087	11269 ± 6003	6307 ± 2288
Arcadia	IFAS	16185 ± 5168	12825 ± 10833	9294 ± 8526
Arcadia	Intermediate	8803 ± 7270	8206 ± 7306	4466 ± 1362
Arcadia	Daily	20736 ± 7318	10854 ± 6611	8299 ± 2800
			Stem area cm^2)	
Avon Park	IFAS	2.63 ± 1.09	1.95 ± 0.24	1.79 ± 0.45
Avon Park	Intermediate	2.17 ± 0.74	2.32 ± 1.10	2.56 ± 1.04
Avon Park	Daily	1.86 ± 0.75	2.55 ± 1.39	2.53 ± 1.51
Ave Maria	IFAS	3.81 ± 0.82	4.48 ± 1.81	4.63 ± 1.36
Ave Maria	Intermediate	2.74 ± 1.50	2.47 ± 1.17	2.59 ± 1.23
Ave Maria	Daily	4.73 ± 2.39	2.56 ± 0.95	2.56 ± 0.95
Arcadia	IFAS	2.72 ± 0.91	2.25 ± 1.06	2.86 ± 1.91
Arcadia	Intermediate	5.53 ± 1.46	5.30 ± 1.20	3.53 ± 1.43
Arcadia	Daily	3.80 ± 2.86	4.00 ± 2.25	5.06 ± 2.41

[a] Irrigation schedule: IFAS = University of Florida Institute of Food and Agricultural Sciences recommended scheduling characterized by irrigating every two days to replace water used by crop evapotranspiration; Daily - daily irrigation; Intermediate - irrigation scheduled half the number of days between irrigation recommended by IFAS and Daily. All the irrigation schedules targeted replacing full crop evapotranspiration each day.
[b] Mean ± standard deviation of 4–6 replications.

Table 2
Soil physical properties that affect water use and soil moisture dynamics.

Site	Depth	θ_{sat}[a]	θ_r[b]	FC[c]	AWC[d]	33% ASWD[e]	50% ASWD	Bulk density	K_{sat}[f]
	cm	$cm^3\ cm^{-3}$						$g\ cm^{-3}$	$cm\ h^{-1}$
Ave Maria	0–15	0.370	0.010	0.097	0.087	0.029	0.044	1.518	15.82
Ave Maria	15–30	0.352	0.010	0.072	0.062	0.020	0.031	1.526	13.97
Ave Maria	30–45	0.390	0.010	0.093	0.083	0.027	0.042	1.613	13.22
Avon Park	0–15	0.321	0.009	0.109	0.100	0.033	0.050	1.611	20.74
Avon Park	15–30	0.387	0.009	0.083	0.074	0.025	0.037	1.606	19.22
Avon Park	30–45	0.396	0.009	0.093	0.084	0.028	0.042	1.635	18.33
Arcadia	0–15	0.443	0.010	0.109	0.099	0.033	0.050	1.491	16.42
Arcadia	15–30	0.453	0.010	0.105	0.095	0.032	0.048	1.329	12.51
Arcadia	30–45	0.450	0.010	0.110	0.100	0.033	0.050	1.467	10.51

[a] θ_{sat} = moisture content at saturation.
[b] θ_r = moisture content at permanent wilting point.
[c] FC = field capacity moisture content.
[d] AWC = available water capacity.
[e] ASWD = allowable soil water depletion.
[f] K_{sat} = saturated hydraulic conductivity.

2. Materials and methods

2.1. Site description

The experiments were conducted at Ave Maria (lat. 26°16′N, long. 81°25′W) in the southwest Florida flatwoods (Collier county), Arcadia (lat. 27°13′N, long. 81°39′W) in the south-central flatwoods (Desoto County), and 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).

2.2. Experimental design

The experiment was arranged in a randomized complete block design with 4 replications for sap flow measurements. The irrigation scheduling treatments for conventional irrigation were as follows: 1) daily irrigation (Daily), 2) University of Florida Institute of Food and Agricultural Sciences recommended scheduling characterized by irrigating every two days to replace water used by crop evapotranspiration (IFAS), and 3) irrigation scheduled half the number of days between irrigation recommended by IFAS and Daily (Intermediate). The total irrigation was designed to meet estimated crop water use (ET_c) for mature citrus equaling 1127 mm per year in Avon Park (Florida Automated Weather Network average from 1 January 2004 to 31 December 2013 at Sebring, FL, 16 km from the study site), 1138 mm per year in Arcadia (Florida Automated Weather Network average from 1 January 2006 to 31 December 2012, at Arcadia, 3 km from the study site) and 1211 mm per year at Ave Maria (Florida Automated Weather Network average from 1 January 2002 to 31 December 2012, at Immokalee, 9 km from the study site). Similar amounts of citrus water use were reported earlier (Morgan et al., 2006; Jia et al., 2007; Romero et al., 2009). The trees at all sites were spaced at 4.6 m x 7.6 m.