ET-Based Irrigation Scheduling for Papaya (*Carica papaya*) in Florida[1]

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Introduction

Papaya (*Carica papaya*) is an important fruit crop grown in south Florida with an estimated area of 356 acres (Crane 2018). Miami-Dade County accounts for almost 81% of papaya production in Florida. The estimated papaya production value is $1.9 million based on an average yield of 29,000 pounds per acre, 85% pack-out rate, and $0.40 per pound price value. Typical cultural practices and pest and disease management guidelines for papaya can be found in Crane and Mossler (2008). Three irrigation scheduling methods (set schedule, ET-based, and tensiometer-based) were tested for papaya production in south Florida. ET-based irrigation scheduling was found to conserve water effectively. This document primarily focuses on the ET-based irrigation scheduling techniques for papaya under Florida conditions.

Importance of Papaya Irrigation in Florida

On average, Florida receives 40 to 60 inches of rainfall per year (Zhang et al. 2017). However, spatial and temporal rainfall distribution is erratic, which results in periods of drought and excessive soil moisture. This discrepancy in distribution combined with well- to excessively drained limestone-based and sandy soils with low water holding capacity makes irrigation necessary for optimal papaya growth and production. Drought-stressed papaya plants drop flowers, leaves, and young fruit and produce smaller fruits with lower sugar content. Science-based irrigation management is the key to ensure a supply of adequate water for this fast-growing plant. Traditionally, irrigation management used calendar-based scheduling. This was not efficient due to the potential for underirrigation or overirrigation, leaching of water, nutrients, and chemicals below the root zone, and subsequent unavailability for plant uptake. Significant progress has been made in the development of advanced irrigation scheduling techniques that conserve water. However, the adoption rates of these new technologies by stakeholders is rather slow partially due to lack of information on the benefits of these technologies. This document provides useful information about ET-based irrigation scheduling to different stakeholders including papaya growers, UF/IFAS Extension agents working with farmers, and/or the general public.

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Papaya Irrigation Research in Florida

Migliaccio et al. (2010) conducted two 2-year studies to compare different irrigation scheduling methods for papaya production. The treatments included:

Set schedule: Traditional set irrigation schedule based on 1–1.5 hours of drip irrigation per day, 3–7 times per week depending on the weather and crop growth stage. This method was commonly practiced by local producers in south Florida during the time the experiment was designed between 2006 and 2009.

ET-based: Evapotranspiration (ET)-based irrigation, using historical ET data from the Florida Automated Weather Network (FAWN; https://fawn.ifas.ufl.edu/) weather station near the experiment site and estimated monthly papaya crop coefficient (Kc) values. The Kc values were adjusted by plant age as follows: 1.0, 1.2, and 1.5 for 0–3 months old, 4–6 months old, and 7 months and older, respectively.

Tensiometer-based: Soil water content-based irrigation scheduling, using switching tensiometer values to initiate irrigation at three different prespecified tensions: 10 kPa (0.1 bar), 15 kPa (0.15 bar), and 25 kPa (0.25 bar). Tensiometers were placed within the root zone, about 1 foot from the base of papaya plants and at a 6.5-inch soil depth.

Results from these field trials: The daily water application rate for the ET-based irrigation scheduling was only 34–35% of that for the set schedule treatment across the two years of both studies. Similar water savings (31–36%) were also found for the three tensiometer-based irrigation treatments. However, ET-based irrigation scheduling may be more convenient and easier to implement than the tensiometer-based irrigation. Tensiometer-based irrigation scheduling requires frequent monitoring of the tensiometer to evaluate its accuracy, periodic cleaning and maintenance, and reinstallation of malfunctioning tensiometers. The readily available information utilized for ET-based irrigation is based on near-real-time or historic ET values and crop coefficient (Kc) values; with this method, no field equipment is needed.

Papaya plant growth as measured by trunk diameter and trunk height was greater with ET-based and tensiometer-based irrigation treatments than it was with set schedule irrigation treatment. This suggests the set schedule irrigation management may have overirrigated the papaya plants, kept the root zone too wet, and caused mild oxygen stress and/or leaching of nutrients from the root zone, reducing papaya plant growth.

In general, there was no significant difference in the number of fruit and amount of fruit production per acre among the irrigation scheduling treatments. However, the traditional set irrigation scheduling method used 64–69% more water than the ET- and tensiometer-based irrigation scheduling methods. Most importantly, fruit production per unit of water applied was less for the set schedule irrigation management treatment compared to the ET-based and tensiometer-based irrigation scheduling treatments. ET- and tensiometer-based irrigation scheduling resulted in more efficient use of water with the same fruit production compared to the set irrigation scheduling method.

Implementing ET-Based Irrigation Scheduling for Papaya in Florida

The aim of improving irrigation scheduling and technology for papaya is to: (1) save and use water more efficiently; (2) increase crop yields and quality; (3) potentially increase crop yield per unit of water used (i.e., more yield per gallon of water applied); (4) reduce leaching of water, nutrients, and chemicals below the root zone; and (5) offer user-friendly irrigation scheduling methods that do not increase labor or irrigation costs. In addition, implementing an ET-based irrigation scheduling method could save water and potentially energy costs without reducing crop yields.

From a management viewpoint, the advantages of ET-based irrigation scheduling include no installation and maintenance of soil moisture probes (tensiometers), the use of readily available near-real-time or historic ET information, and the use of monthly generalized papaya crop coefficient (Kc) values to calculate the amount of irrigation water needed. However, the availability of reliable Kc values at different crop stages could make ET-based irrigation scheduling challenging.

Implementing ET-based irrigation scheduling may be accomplished by gathering the information outlined below (Parameters 1–4) or installing a smart irrigation controller (Dukes et al. 2019). Review the capabilities and availability of needed data prior to purchasing an automated smart irrigation controller.

The information needed for implementation of ET-based irrigation scheduling is mostly similar for different crops except for information about the crop itself. The general steps for ET-based irrigation scheduling are outlined below based on the following EDIS publications. Some of the documents are part of a series on ET-based irrigation scheduling for agriculture. This series can be found at https://edis.ifas.ufl.edu/topic_series_ET-based_irrigation_scheduling_for_agriculture. The information is also useful for inputs for smart irrigation controllers.

- Kisekka, I., K.W. Migliaccio, M. D. Dukes, B. Schaffer, J. H. Crane, and K. Morgan. 2016. *Evapotranspiration-Based Irrigation for Agriculture: Sources of Evapotranspiration Data for Irrigation Scheduling in Florida*. AE455. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/ae455
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- Migliaccio, K. W., and Y. C. Li. 2018. *Irrigation Scheduling for Tropical Fruit Groves in South Florida*. TR001. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/tr001
- Dukes, M. D., M. L. Shedd, and S. L. Davis. 2019. *Smart Irrigation Controllers: Operation of Evapotranspiration-Based Controllers*. AE446. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/ae446

The parameters needed for ET-based papaya irrigation scheduling are outlined below.

Parameter 1

Consult sources of standard reference evapotranspiration (ET_o) data for irrigation scheduling (see https://edis.ifas.ufl.edu/ae455 for more details). ET_o is available for current or historical periods. Recent or historical ET values can be used to calculate crop water demands.

GETTING RECENT ET VALUES FROM FAWN SITE

- Go to http://fawn.ifas.ufl.edu/.
- Click **Tools** on the top menu.
- Click **Evapotranspiration** (ET) under Irrigation.
- A table with daily ET_o for the past 7 calendar days and the 7-day average ET_o for each of the FAWN weather station sites will appear. A graph with the past 14 days' ET_o for selected FAWN sites is also available. The 7-day average ET can be used along with crop coefficient (Kc) values to calculate recent crop water use for the following week's irrigation needs.

HISTORICAL REFERENCE ET VALUES (ET_o)

These data can also be obtained from FAWN by clicking on the **Data Access** menu tab and selecting **Report Generator**. For example, 10 years' worth of monthly data may be downloaded and compiled to produce a 10-year average ET per month value for Homestead, Florida (Table 1).

Parameter 2

Obtain estimated papaya crop coefficient (Kc) values.

Parameter 3

Determine the water holding capacity of soils where papaya is planted. Published data can be used. The published information is available from several sources, including the USDA National Cooperative Soil Survey (http://websoilsurvey.nrcs.usda.gov/app) and Migliaccio and Li (2018) (https://edis.ifas.ufl.edu/tr001).

Parameter 4

For ET-based irrigation scheduling, calculate actual monthly evapotranspiration rate (ET_c) by multiplying ET_o by crop coefficient (Kc) values appropriate for the plant age in the field (Table 4).

Then, calculate the irrigation amount (I) using on-site or local rainfall data and ETc values for papaya. For example, if rainfall is 0.1 in/day in July, the irrigation amount needed for papaya plants 7 months or older during the month of July is calculated as: $I = ET_c$ - R (rainfall) = 0.28 in/day – 0.1 in/day = 0.18 in/day

Parameter 5

Determine or use published irrigation delivery rates of the irrigation system in use (emitter rates). Soil beds with a 3-ft width, 6-in depth, and variable length are commonly used in papaya production in south Florida. Typically, two lines of drip tape or tube are used per row of papaya and, depending on the type purchased, have emitters every six, eight, or more inches along the lines. See the manufacturer's discharge rate per foot of tube length, or run the irrigation system and catch the water emitted from a 12-inch length of the tube over a period of time to calculate the amount of water emitted per foot per minute. Such information is needed to set up a smart irrigation controller as well.

ET-Based Irrigation Scheduling Steps

The steps that are needed to develop ET-based irrigation scheduling for papaya are summarized with examples in Table 5. A 50% water depletion (commonly used value) was used to calculate irrigation requirements in Table 5.

Summary

Commercial papaya producers in Florida have several options to improve the efficiency of their irrigation systems without sacrificing crop yields and quality. These include the implementation of manually calculated and managed ET-based irrigation scheduling or the use of a smart irrigation controller with appropriate input options to accurately manage irrigation scheduling. Effectively implementing an ET-based irrigation scheduling system would conserve water, which in turn reduces the potential for leaching nutrients and chemicals past the root zone into the aquifer.

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Table 1. Monthly average ET_o values (inches per day) based on 10 years' historical monthly observations at the UF/IFAS Tropical Research and Education Center, Homestead FAWN station.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	0.12	0.14	0.17	0.22	0.19	0.17	0.18	0.19	0.14	0.15	0.14	0.10
2010	0.10	0.11	0.12	0.17	0.20	0.21	0.20	0.18	0.17	0.17	0.13	0.12
2011	0.11	0.14	0.18	0.21	0.22	0.20	0.18	0.16	0.16	0.13	0.13	0.12
2012	0.13	0.13	0.18	0.18	0.18	0.19	0.17	0.18	0.16	0.16	0.13	0.10
2013	0.11	0.13	0.16	0.17	0.18	0.17	0.16	0.17	0.14	0.14	0.12	0.09
2014	0.09	0.14	0.17	0.20	0.22	0.17	0.17	0.19	0.15	0.15	0.12	0.10
2015	0.11	0.13	0.17	0.19	0.22	0.22	0.19	0.17	0.15	0.15	0.12	0.09
2016	0.09	0.13	0.17	0.20	0.20	0.19	0.19	0.18	0.15	0.32	0.21	0.13
2017	0.15	0.17	0.22	0.23	0.24	0.18	0.20	0.20	0.18	0.16	0.13	0.13
2018	0.14	0.16	0.21	0.23	0.18	0.20	0.21	0.20	0.18	0.19	0.14	0.14
Average	**0.12**	**0.14**	**0.18**	**0.20**	**0.20**	**0.19**	**0.19**	**0.18**	**0.16**	**0.17**	**0.14**	**0.11**

Table 2. Estimated papaya Kc values for south Florida based on Migliaccio et al. (2010).

Age of Plants in the Field	Kc Values	Comments
0–3 months old	1.0	Newly planted and young plants
4–6 months old	1.2	Plants begin to flower and set fruit; fruit development period
7 months and older	1.5	Mature plants continue to flower and develop fruit

Table 3. Soil water holding capacities (inches of water per foot of soil depth) for various soil types in south Florida based on Migliaccio and Li (2018).

Soil Type	Range (in/ft)	Average (in/ft)
Gravelly loam (rockland soils, Miami-Dade County)	1.0–1.4	1.2
Marl (clay-like calcareous soil, low-lying areas in Miami-Dade County)	1.2–2.4	1.8
Peats and mucks (south of Lake Okeechobee)	2.0–3.0	2.5
Sand or fine sand	0.4–1.0	0.70

Table 4. Monthly evapotranspiration rates (ETc) based on historical potential evapotranspiration (ET_o) data and average crop coefficient (Kc) values. (K_c values were based on personal communication, J. H. Crane 2019).

Month	Average ET_o (in/day)	Age of Plants (months) (Kc = crop coefficient value)		
		0–3 (Kc = 1.0)	4–6 (Kc = 1.2)	>7 (Kc = 1.5)
		ETc (in/day)		
Jan	0.12	0.12	0.14	0.17
Feb	0.14	0.14	0.16	0.21
Mar	0.18	0.18	0.21	0.26
Apr	0.20	0.20	0.24	0.30
May	0.20	0.20	0.24	0.30
Jun	0.19	0.19	0.23	0.28
Jul	0.19	0.19	0.22	0.28
Aug	0.18	0.18	0.22	0.27
Sep	0.16	0.16	0.19	0.24
Oct	0.17	0.17	0.21	0.26
Nov	0.14	0.14	0.17	0.21
Dec	0.11	0.11	0.14	0.17

Table 5. Summary of steps for developing ET-based irrigation management scheduling.

Step	Source of Information	Example Answers	Comments
1. Select applicable monthly ET_o.	Table 1 (July)	0.17 in/day	Monthly value for Homestead.
2. Select appropriate Kc value based on tree age.	Table 2 (plants > 7 months old)	1.5 in/day	Estimated Kc value for mature plants.
3. Determine active root zone depth.	Measured in field	6 inches (0.5 ft)	Typical depth of beds in Homestead.
4. Select applicable soil water holding capacity.	Table 3 (gravelly loam)	1.2 in/ft x 0.5 ft depth = 0.6-inch bed soil depth	From published data.
5. Determine the irrigation delivery rate.	Manufacturer rating	0.1 in/hr	For more accuracy, measure in the field.
6. Calculate time to reach soil water holding capacity if irrigation begins when water is 50% depleted in soil.	50% water depletion x 0.6-inch water holding capacity x (0.6-inch root depth/0.1 in/hr)	1.8 hr (1 hr, 48 min); assume no recent rainfall event	Assume no more than a 50% soil water depletion to trigger an irrigation event.