Irrigation Scheduling for Tropical Fruit Groves in South Florida [1]

K. W. Migliaccio and Y. C. Li[2]

Introduction

Irrigation is used primarily to satisfy plant water needs that are not met by rainfall. Although south Florida receives around 55 inches of rainfall a year, the rain is not equally distributed throughout the year (Figure 1). In fact, south Florida is often described as having a "wet season" and "dry season" environment, with two-thirds of the total rainfall occurring between May and October.

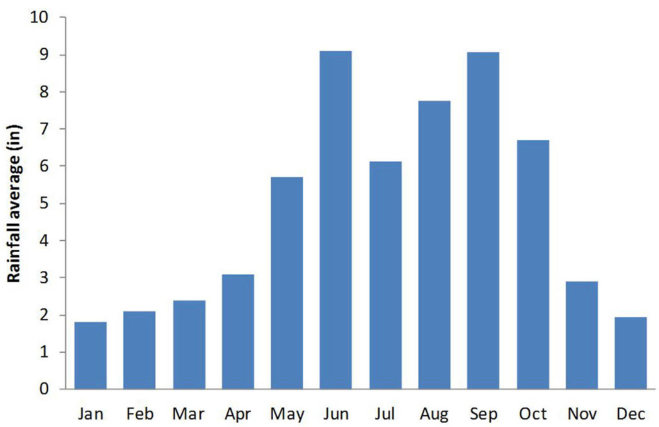

Figure 1. Average monthly precipitation measured at Miami International Airport 1949 to 2011 (National Climatic Data Center 2012).

Credits: Kati Migliaccio, UF/IFAS

Irrigation is also necessary for soil that cannot store large volumes of water. Most tropical fruit trees in south Florida are grown on gravelly or sandy soils that have very low water-holding capacities. Soil water-holding capacity is defined as the amount of water that soil can hold against the force of gravity (for practical purposes, field capacity is essentially the same as soil water-holding capacity). In other words, it is the amount of water the soil can hold without any percolation losses. Thus, soils with a high water-holding capacity store more water for plant use than soils with a low water-holding capacity. Table 1 shows common soil water-holding capacities for soils of south Florida.

Table 1. Soil water-holding capacities (inches of water per foot of soil depth) for various soil types.

Soil	Range (in/ft)	Average (in/ft)
Gravelly loam	1.0–1.4	1.2
Marl	1.2–2.4	1.8
Peats and mucks	2.0–3.0	2.5
Sand or fine sand	0.4–1.0	0.75

The precipitation characteristics and soil properties of south Florida are unique and, therefore, should be included when determining an optimal irrigation schedule. The Web Soil Survey (WSS) provides soil data and information produced

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2. K.W. Migliaccio, associate professor, Agricultural and Biological Engineering Department, and Y.C. Li, professor, Soil and Water Science Department, Tropical Research and Education Center, Homestead, FL; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. Information regarding soil types can be found on the NRCS website at http://websoilsurvey.nrcs.usda.gov/app.

In this publication, an optimal irrigation schedule is defined as the irrigation schedule that ensures tropical fruit trees experience minimal water stress and that results in minimal water waste due to percolation or runoff losses.

Depending on the tree species, trees may or may not show visible symptoms of water stress. However, by the time symptoms of water stress are visible to the eye, it is often too late to achieve complete recovery. On the other hand, some fruit trees (e.g., 'Tahiti' limes, carambola, papaya, and banana) may show a midday wilting because they cannot absorb water fast enough during the hottest part of some days. This is usually a temporary wilt, and the tree recovers over night.

Multiple tools are available for determining an optimum irrigation schedule that accounts for the unique conditions in south Florida groves.

Irrigation Scheduling Tools

Tensiometer

This device directly measures soil water potential or tension in the root zone (Figure 2). Tensiometers must be properly installed and maintained to be used effectively for scheduling irrigation (Figure 3). Tensiometers measure soil water tension in pressure units such as cbars (1 cbar = 0.01 bar; 1 bar = 14.5 psi).

Figure 2. Tensiometer before being installed in the field.

Credits: Harry Trafford

Figure 3. Tensiometer installed in very gravelly loam soil.

Credits: Kati Migliaccio, UF/IFAS

In general, the following guidelines can be used to interpret tensiometer readings for irrigation scheduling in gravelly or sandy soils:

1) Tensiometer readings of 0–5 cbars: The soils are saturated or nearly saturated as a result of recent rain or irrigation. Irrigation should be discontinued to prevent water waste and nutrient leaching through percolation or runoff.

2) Tensiometer readings of 10–20 cbars: The crops should be irrigated to water-holding capacity or to 0–5 cbars. Irrigation should be initiated at 10–15 cbars during flowering, fruit set, and development, but at other times it should be initiated at 15–20 cbars.

3) Tensiometer readings of 30 cbars and greater: The plants are likely experiencing water stress and should be irrigated immediately.

Tensiometers can be purchased as either stand-alone sensors or outfitted with magnetic switches that allow the device to trigger irrigation only when the soil tension exceeds the set point (Figure 3).

For additional information on tensiometers, see *Tensiometers for Soil Moisture Measurement and Irrigation Scheduling* (http://edis.ifas.ufl.edu/ae146) and *Tensiometer Service, Testing and Calibration* (http://edis.ifas.ufl.edu/ae086).

Capacitance Probe

Many different companies sell capacitance-based probes that are designed to be used to measure soil water volumetric content (i.e., the volume of water in the soil). The suitability of these devices can vary, and you should be cautious if selecting one of these devices for irrigation. Specifically, the device should be appropriate for the soil type and should be rigorously tested. Extension specialists can help with the selection of an appropriate capacitance probe. These instruments take advantage of the fact that the dielectric constant of water is 100, the dielectric constant of air is 1, and the dielectric constant of dry soil is in the range of 4–6. The dielectric constant describes the ability of a substance to hold an electrical charge. Therefore, soils that contain greater volumetric water contents will have a greater dielectric constant, which can be measured electronically. The probe measures the electrical capacitance of the surrounding soil-air-water mixture and converts this reading into the percentage of water in soil. Capacitance probes may consist of one sensor or multiple sensors. An example of a multi-sensor capacitance probe is depicted in Figure 4 and Figure 5.

The probes provide real-time assessment of soil water content. Thus, the data from a probe will only give information and characteristics about the area where it is installed. Data from one orchard should not necessarily be used to manage other orchards because soil and water characteristics may be substantially different among sites.

Figure 4. Multi-sensor capacitance probe being inserted into field.

Credits: Luis Barquin

Figure 5. Multi-sensor capacitance probe installed in a south Florida grove.

Credits: Luis Barquin

Evapotranspiration

Evapotranspiration refers to the evaporation and transpiration losses from the orchard. Water requirements of trees can be calculated by determining these losses using reference evapotranspiration (ET_R) data (Table 2). Reference ET is a value calculated from multiple weather parameters such as temperature, wind, and solar radiation.

Table 2. Estimated average daily reference evapotranspiration (ET_R) for south Florida.

Month	Inches/day
January	0.10
February	0.13
March	0.16
April	0.19
May	0.19
June	0.18
July	0.18
August	0.17
September	0.15
October	0.14
November	0.12
December	0.10

Actual evapotranspiration (ET_A) is determined by multiplying the cropping coefficient (K_C) by the reference ET (ET_R) (Equation 1):

$ET_A = K_C * ET_R$ (Equation 1)

The irrigation rate is then described by Equation 2:

$I = ET_A - R$ (Equation 2)

where I is irrigation and R is rainfall. Daily ET_R values are provided by the Florida Automated Weather Network (FAWN) for locations throughout Florida. This information is located on the FAWN website (http://fawn.ifas.ufl.edu/) in the "FAWN Tools" drop-down menu, under "Irrigation" and then "Evapotranspiration (ET)." The K_C values differ among crops and should be diligently calculated and changed throughout the year. Current K_C values for tropical fruit crops under south Florida conditions have not been sufficiently researched. Extension specialists or agents within your geographical area can offer suggestions for K_C values.

Irrigation rates can easily be calculated using the ET method. This approach is described in Table 3. It is important to note that this is just an example, and each location should be evaluated according to its specific characteristics.

In addition to this hand-calculation method, more sophisticated ET irrigation technology is available, including real-time ET controllers and stand-alone ET controllers. With this technology, the controller automatically receives this information and real-time weather data is used to determine the irrigation schedule. These technologies have been used successfully in Homestead, Florida, for carambola (Kisekka et al. 2010) and avocado production. Several EDIS publications outline these technologies and procedures, including *Evapotranspiration-Based Irrigation for Agriculture: Sources of Evapotranspiration Data for Irrigation Scheduling in Florida* (http://edis.ifas.ufl.edu/ae455), *Evapotranspiration-Based Irrigation for Agriculture: Crop Coefficients of Some Commercial Crops in Florida* (http://edis.ifas.ufl.edu/ae456), *Evapotranspiration-Based Irrigation Scheduling for Agriculture* (http://edis.ifas.ufl.edu/ae457), and *Evapotranspiration-Based Irrigation for Agriculture: Implementing Evapotranspiration-Based Irrigation Scheduling for Agriculture* (http://edis.ifas.ufl.edu/ae458).

Soil Water-Holding Capacity

Soil water-holding capacity is generally very low in the sandy or gravelly soils (Table 1) commonly found in south Florida. With any irrigation schedule, irrigation water should bring the soil moisture only up to the available water capacity because volumes above this amount will be lost to percolation, runoff, or evaporation. In general, the amount of water available to the trees depends on the soil water-holding capacity, the area of water application, and the volume of the root zone.

Root zone depth can typically be determined by knowing the depth of the trench in the orchard. For an established orchard, roots will be found throughout the trenched area. Trenches are typically 24 inches deep and 16 inches wide. Additional roots form a "pancake-like" layer in the plowed soil, and most active roots are found in this area. The plowed soil is typically 5–6 inches deep. If irrigation is managed to consider the trenched depth, over-irrigation will occur on locations without trenching and will result in a portion of irrigation water not being used by the fruit

Table 3. Calculation of irrigation using the ET method to analyze a one-week period of sprinkler irrigation during the month of May.

Steps	Answers
Step 1. Select the appropriate K_C value.	$K_C = 1.1$
Step 2. Calculate ET_A using Equation 1.	$ET_A = 1.1 * 0.19 = 0.21$ in/day
Step 3. Determine the soil water-holding capacity.	Soil depth = 9 inches Soil water-holding capacity = 1 in/ftAmount of water the soil can hold =9 in * 1 in/ft * ft/ 12 in =0.75 in
Step 4. Calculate Irrigation (or I) using Equation 2, considering no rainfall.	I = (0.21 in/day) * 7 days - 0 in = 1.47 in
Step 5. Determine the irrigation system delivery rate.	0.25 in/hr
Step 6. Determine the number of times per week to irrigate to minimize leaching water loss. (step 4 / step 3)	= 1.47 in / 0.75 in = 2 times
Step 7. Determine time needed to irrigate for two events. (step 4 / step 5) / step 6	= (1.47 in / 0.25 in/hr) / 2 times = 3 hrs per event
Step 8. If rainfall occurs over soil water-holding capacity, delay irrigation until next scheduled event.	

tree. In addition, fertilizer in this area may be leached beyond the root zone, which wastes fertilizer and money.

Some irrigation systems do not cover the entire field but rather focus on areas where roots are located. The area receiving spray from this type of irrigation system is termed "wetted perimeter." The wetted perimeter can be measured by turning on the irrigation and using a measuring device to determine the diameter of the wetted area. It is important to remember that the height of the micro-sprinkler or other sprinkler device influences the wetted perimeter. To determine the area from the diameter measured, see Equation 3:

$A= 3.14 (D/2)^2$ (Equation 3)

where A is the area and D is the diameter. If the diameter is in units of feet, then the area (A) calculated is in units of square feet. This value can be used to convert irrigation delivery rates that are in volumes (such as gph) into rates that are in lengths per time (such as in/hr). Irrigation rates can easily be measured in the field using a volumetrically marked container and a stopwatch. The irrigation would be initiated, and once the system was pressurized, a volume of water would be collected from an emitter and timed. This provides you with an estimate of the water delivered. Another method would be to use a catch-can type of approach. For more information on this approach see Smajstrla et al. (2005) (available at http://edis.ifas.ufl.edu/ae384). An example for sandy soils is provided in Table 4, and an example for gravelly soils is provided in Table 5. (Note: These are just examples, and each irrigation system should be evaluated in terms of its unique characteristics.)

To use the soil water-holding capacity/depletion method it is critical to know the level of depletion before irrigating. This can be complicated because of the varying factors that influence soil-water content, including precipitation, evapotranspiration, capillary rise, runoff, and percolation. This method can lead to over-irrigation if these factors are not considered in the depletion calculation. One option is to use soil water-holding capacity in conjunction with other technology such as tensiometers.

Summary

Irrigation scheduling can be accomplished using different tools. Each tool has its benefits and weaknesses (Table 6). It is critical to use each tool as it is intended to ensure tropical fruit trees have the irrigation water they need.

Table 4. Sample calculation of irrigation considering soil water-holding capacity in a sandy soil using micro-sprinkler irrigation.

Steps	Source of information	Example answers
Step 1. Determine the soil water-holding capacity.	Knowledge of soil, soil survey maps, Table 1	0.75 in water / ft soil
Step 2. Determine root zone depth.	Knowledge of field	2 ft
Step 3. Determine wetted perimeter diameter.	Measured in the field as described in text	10 ft
Step 4. Calculate area of wetted perimeter.	Area = 3.14 * (diameter/2) ^ 2	78.5 ft^2
Step 5. Determine irrigation delivery rate.	Measured in the field as described in text	21 gph
Step 6. Convert units of step 5 to cubic feet.	7.48 gallons = 1 ft^3	2.81 ft^3/hr
Step 7. Determine irrigation rate in inches per hour.	Divide step 6 by step 4 and multiply by 12	0.43 in/hr
Step 8. Calculate the time to reach soil water-holding capacity if irrigation begins when water is 50% depleted in soil.	(50%) * step 1 * step 2/ step 7	1.75 hrs

Table 5. Sample calculation of irrigation considering soil water-holding capacity in a gravelly soil using sprinkler irrigation.

Steps	Source of information	Example answers
Step 1. Determine the soil water-holding capacity.	Knowledge of soil, soil survey maps, Table 1	1.2 in water / ft soil
Step 2. Determine active root zone depth.	Knowledge of field	0.5 ft
Step 3. Determine irrigation delivery rate.	Measured in the field as described in text	0.25 in/hr
Step 4. Calculate the time to reach soil water-holding capacity if irrigation begins when water is 50% depleted in soil.	(50%) * step 1 * step 2/ step 3	1.2 hr

Table 6. List of irrigation tools with advantages and disadvantages for tropical fruit.

Tool	Advantages and disadvantages
Tensiometer	Advantages: Real-time information on soil moisture, affordable Disadvantages: Requires weekly maintenance and calibration
Capacitance probes	Advantages: Real-time information on soil moisture Disadvantages: Initial investment in equipment, wiring required, maintenance of probes requires constant calibration
Evapotranspiration (using FAWN data)	Advantages: Daily data free from FAWN Disadvantages: Must know crop coefficients, need for site-specific data (radiation, wind speed, etc.)
Evapotranspiration (using real-time controller)	Advantages: Real-time information, automated Disadvantages: Must have some knowledge to program controller, initial investment in equipment
Soil water-holding capacity	Advantages: Minimum costs Disadvantages: Use requires knowledge of all factors influencing soil moisture

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