TheHelper, A User-Friendly Irrigation Scheduling Tool In Florida and Hawaii

A. Fares[1], M. Zekri[2] and L.R. Parsons[2]
[1]University of Hawaii-Manoa; [2]University of Florida.

Abstract

Efforts are being made to optimize Florida citrus production and minimize non-point source pollution of water resources through best water management practices. A user-friendly irrigation scheduling program, TheHelper, was developed to help different users understand citrus water requirements under different micro-irrigation systems based on historical evapotranspiration data and soil water holding capacities of the major Ridge and Flatwood soils. The user chooses from a menu driven the major input data: soil type, irrigation system specification, irrigation depth and available water depletion level. The program produces several outputs that can be printed including: i) a long-term, annual, irrigation scheduling program with the option of printing it; ii) develop short-term monthly, irrigation scheduling program based on different soil types, depletion levels and irrigation system specifications; and iii) develop a monthly file of the different irrigation events for the different irrigation management units.

Introduction

Water is critical for optimal growth and production of all plant crops. Optimum amounts of water at the right time allow plants to grow and produce at their best. With the exception of arid and semi-arid conditions, rainfall is the main source of water supply for most field crops. However, supplemental irrigation has been proven to increase crop yield even in areas having relatively high annual rainfall. Optimum crop production requires good irrigation scheduling programs. Efficient irrigation scheduling optimizes crop water update and minimizes water losses.

Soils in the rootzone are the reservoir from which crops can obtain their water needs. Soils have different water holding capacities depending on their texture and structure. Usually, fine textured soils have higher water holding capacities than coarser textured soils. Similarly, soils with high organic matter contents have higher water holding capacity than soils with low organic matter.

The depth of the crop roots defines the soil depth that supplies water for the crop. Deep rooted crops usually explore more water than shallow rooted crops under the same conditions. Annual crops explore different rootzone depths as a result of the growth of their root system throughout the growing season. Although during the first few weeks of growth, annual crops use water from the top few inches of soil, at maturity, their roots extend deeper into the profile and their water uptake could reach up to 5 to 6 ft below the soil surface.

Usually, less than 1% of the crop water uptake is assimilated by the plant. The rest of the water is used to cool the crop through the processes of evaporation and transpiration. Combined together, these two processes are called evapotranspiration (ET). Evaporation is the change of water from its liquid form to vapor which requires energy. Under humid conditions, if the leaves of well-watered plants or wet soils are moist, the amount of water evaporating and moving into the air is mainly determined by the energy available from solar radiation known as atmospheric demand. Although it is influenced to a certain extend by air temperature, humidity, and wind speed, ET rate is maily affected by solar radiation. Consequently, ET levels are higher during the summer

when daily solar radiation levels and temperatures are high compared with the winter when these two variables are low.

Optimization of crop growth and production requires efficient irrigation scheduling which is the decision-making process used to determine the frequency and amount of irrigation water to meet the needs of the crop. Thus, the goal of irrigation scheduling is to answer two questions: 1) when to irrigate and 2) for how long?

There are several irrigation scheduling methods that have been used for different crops under different edaphic and climatic conditions including visual symptoms, check book, plant water content, plant water stress, soil water content, and computer models using historical ET, soil water holding capacity and crop growth stage. Instrumentation based irrigation scheduling methods are more accurate than the other methods; however, they are usually expensive, require special training and may not be affordable by small growers.

The objectives of this irrigation scheduling method are: i) to collect historical evapotranspiration data and available soil water for different soil types in Florida and Hawaii in addition to calculate a monthly irrigation frequency and irrigation length based on irrigation delivery rates and irrigation depth; ii) use these data to develop a user-friendly visual basic program that can be easily used by growers.

Materials and Methods

The answer to the two main questions in any irrigation scheduling program is when to irrigate and for how long. In order to answer these two questions we have to quantify: i) how much water is available per unit length for a given soil; ii) how much is the daily ET rate? iii) how much of the available water should be depleted before starting the next irrigation? iv) how deep we want to irrigate?

How Much Water is Available for Crop uptake Per Unit Soil Length?
Available water is defined as the amount of water between field capacity and permanent wilting point (PWP). Field capacity is defined as the amount of water that a given soil can hold against gravity one (for a sandy soil) to three (a clay soil) days after its saturation. The permanent wilting point is the water content at which a crop can no longer extract water from the soil and wilt as a result of that; it is usually taken as the water content corresponding to 15-bar suction.

Table 1 shows the depth of the rootzone and the average available water for some of the major soils in Hawaii, Florida flatwood, and Florida ridge locations. These data presented in Tables 1 are used in TheHelper program.

Table 1. Rootzone depth and the average available water for some of the major soils in Hawaii, Florida flatwood, and Florida ridge locations.

	Florida Flatwood Soils						
	Immokalee	Myakka	Bradenton	Pomona	Smyrna	EauGallie	Floridana
Depth (in)	18	18	18	18	18	18	18
AWC (in/in)	0.060	0.060	0.180	0.110	0.200	0.140	0.135
	Florida Ridge Soils						
	Astatula	Archbold	Candler	Tavares	Apopka	Basinger	Zolfo
Depth (in)	36	36	36	36	36	36	36
AWC (in/in)	0.060	0.060	0.060	0.046	0.108	0.124	0.07

	Hawaii Soils						
	Oahu			Big Island	Maui	Kauai	
	Leilehua	Waialua	Hanalei	Waimea	Kula	Puhi	Lihue
Depth (in)	75	60	36	42	54	60	60
AWC (in/in)	0.11	0.12	0.17	0.12	0.15	0.11	0.14

How much is the daily ET rate?

Evapotranspiration is the main process by which available water is depleted from the rootzone of any crop. Evapotranspiration data for different citrus grown under Florida conditions have been calculated and reported in earlier studies (Koo and Sites, 1969; Rogers et al., 1983; Fares and Alva, 1999, 2000). Two daily ET averages throughout the year were computed for citrus grown under Flatwood and Ridge soil conditions (Table 2). Pan evaporation data collected from the leeward and windward locations throughout the main four Hawaiian Islands were used and multiplied by a pan factor of 0.7 to calculate the corresponding daily potential ET are also presented in Table 2.

Table 2. Evapotranspiration data (ETo) for the leeward and windward locations in different islands of Hawaii, and in the ridge and flatwood area of Florida.

Month	Oahu		Kaua'i		Hawai'i		Maui		Florida Citrus	
	WW	LW	WW	LW	WW	LW	WW	LW	Flat-wood	Ridge
	ETo (in)									
Jan	2.44	3.37	3.61	3.35	4.18	3.56	4.17	3.36	2.20	1.97
Feb	2.37	3.58	3.65	3.68	4.34	3.75	3.93	3.54	2.20	1.85
Mar	3.02	4.26	4.61	4.66	4.93	4.70	5.47	4.27	3.19	2.68
Apr	3.02	4.84	4.83	4.93	5.03	4.68	5.71	4.68	3.54	3.31
May	3.25	5.99	5.60	5.22	6.02	5.85	6.61	5.73	4.53	3.07
Jun	3.23	6.64	5.67	5.38	6.23	6.22	6.59	6.28	5.08	4.88
Jul	3.43	6.52	6.10	5.61	6.39	6.14	7.07	6.65	5.00	4.76
Aug	3.47	6.57	5.88	5.58	6.70	5.88	7.03	6.71	4.65	4.45
Sep	3.02	5.33	5.26	5.04	6.10	5.73	6.09	6.38	4.13	4.09
Oct	2.73	4.45	4.64	4.40	5.39	4.73	5.68	5.33	3.66	4.06
Nov	2.48	3.68	3.74	3.61	4.24	4.28	4.56	4.09	2.48	2.32
Dec	2.32	3.23	3.39	3.07	4.34	3.61	3.30	3.43	2.20	1.97

How much of the available water should be depleted before starting irrigation?
Water stress occurs well before the depletion of all available water. Thus, a good irrigation management should prevent yield reducing crop water stress by not depleting all available water but by maintaining the soil water content above the PWP. Optimum citrus production requires maintaining soil water content above the 33% depletion of the available water during the period from February to May to avoid potential adverse effects of water stress on flowering and fruit set (Koo, 1969). However, during the remaining part of the growing season, available water can be allowed to deplete by 67% before replenishment of the soil water back to field capacity. These two depletion levels were implemented in TheHelper; however, we allowed the user of the Hawaii version to choose a depletion level ranging between 10 and 100% of the available water.

How deep we want to irrigate?
The irrigation depth will be used to determine the amount of water available for crop water uptake. The deeper the irrigation depth the longer it takes the crop to deplete the available water and to refill the soil profile up to field capacity during irrigation. Thus, for the same ET rate it will take the crop twice as much to deplete the available water in a two-foot rootzone as compared to a one-foot rootzone. Similarly, the same irrigation system will take twice as long to refill a two-foot rootzone as it does for a one-foot rootzone. The user has the choice to use irrigation depths in quarter foot increments.

Model Description

This computer program was developed Using Microsoft Visual Basic 5.0. It is intended to help the user:
1. Understand citrus water requirements based on historical ET data and soil water holding capacities of the main Ridge and Flatwood soils.
2. Develop a long-term, annual irrigation scheduling program with the option of printing it.
3. Develop short-term, monthly irrigation scheduling program based on different depletion levels and irrigation system specifications.
4. Develop a monthly record-keeping of irrigation events for different irrigation systems and depth of irrigation with the option of saving the data into a file that can be printed or kept in record.

The program consists of six screens including the main screen (Fig. 1). Starting from the main screen, the user has five options:
1. Irrigation Records
2. Annual Schedule
3. Short-Term Scheduling
4. Print
5. Cancel

Each of these options can be activated by clicking on its corresponding TAB. Below is a brief description of each of these options.

Figure 1. This is the starting page of the TheHelper software.

1. Irrigation Records:

This option intends to help growers keep record of their irrigation events. It involves four main steps:

- First step is for the user to choose the characteristics of her/his irrigation system :
    - Wetting pattern: full circle (360°), three quarters of a circle (270°), half a circle (180°) or quarter of a circle (90°).
    - Delivery volume: the number of gallons delivered per emitter per hour GPH.
    - Wetting diameter: the user has to choose for a range between $10 - 20$ ft?.
    - Tree spacing: the user enters the in row and between row tree spacing in feet. The user clicks on the Irrigation Rate (in/h) Tab to get the equivalent irrigation depth applied by his irrigation system on the wet part of his grove. It is assumed that this irrigation system has 85% irrigation efficiency.
- Second step is where the user chooses the month of the year for which she/he is developing the irrigation record keeping.
- Third step: the user has a daily numbered table, i.e., Day 1. The user enters the number of hours of irrigation for every irrigation day for that particular month.
- Step four, the user has several options:
    - Accept Data. By pressing this Tab the user is sending the data that she/he entered to a Microsoft-Word file type called "Report.Doc".
    - Next month option clears the screen and allows the user to start fresh pages. The data of the irrigation system are not altered.
    - Exit option will terminate the program.
    - Back to MainPage returns the program to the main page.

Figure 2. This is the page were the users can enter their irrigation events that will be printed into a monthly report generated by the program.

2. Annual Schedule

This part of the program is intended to calculate an annual irrigation schedule that will result in a printable table where the user will have answer to two questions: How often to irrigate and for how long? As soon as you press the TAB of "Annual Schedule" a new screen opens that involves two main steps and a series of option TABs.

- Step 1. During this step the user chooses:
  - o Soil type from two main categories:
    - ▪ Ridge and
    - ▪ Flatwood
  - o Irrigation depth: the range to choose from starts with 0.5 to 4.0 feet with a half-foot increment.
- Step 2.   The user chooses the characteristics of her/his irrigation system mainly:
  - o Wetting pattern: full circle (360°), three quarters of a circle (270°), half a circle (180°) or quarter of a circle (90°).
  - o Delivery volume: the number of gallons delivered per emitter per hour GPH.
  - o Wetting diameter: the user has to choose for a range between 10 – 20 ft?.
- Step 3. The user has several options:
  - o Annual irrigation schedule TAB. By pressing this TAB the user is instructing the program to calculate an annual irrigation schedule. This will display a form that has two main parts
    - ▪ Part 1 has the input parameters that were used to generate the annual irrigation schedule:
      - • Irrigation system characteristics:
        - o Wetting areas (360 – 90)
        - o Delivery volume (GPH) and
        - o Wetting diameter.

- Soil type from the Ridge and Flatwood data base.
  - Part 2 includes the output of the program. It is mainly a three column table:
    - First column includes the months of the year
    - Second column is irrigation duration in hours
    - Third column is irrigation frequency in days.
      - You have three options:
        - Print the form by pressing "Print Form" TAB.
        - Return to previous screen "Back to the Annual Input Form"
        - Return to the main page "Back to MainPage".

Figure 3. This is the input page for the long-term irrigation scheduling option of the program.
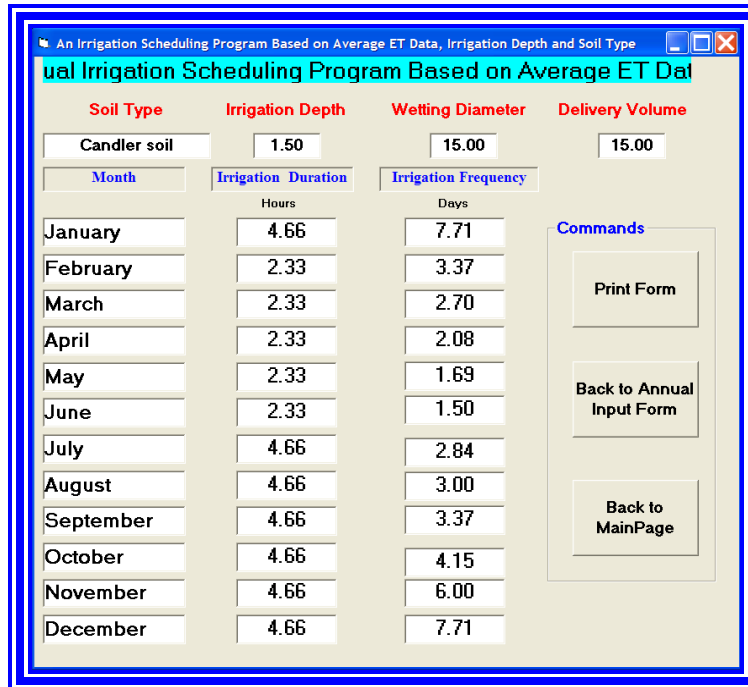
Figure 4. This is output page of the long-term irrigation scheduling option of the program.

3. Short-Term Scheduling

This option involves two screens.

a) By pressing the Short-Term Scheduling TAB, the program loads screen 1. This screen involves three steps:

- Step1. The user chooses:
  - Soil type from two categories:
    - Ridge
    - Flatwood
  - Evapotranspiration (ET) from levels:
    - Ridge
    - Flatwood
- Step 2. The user should enter two parameters:
  - The first parameter is the number of days since last 1" rainfall or long irrigation events to get an estimate on the initial water content available in the irrigation depth.
  - The Second parameter is the depth of irrigation. Usually this corresponds to the depth at which most of the roots are.
- Step 3.
  - The user goes to the commands section and chooses the "Deficit Calculation". After pressing this TAB the program calculates and displays the percentage of depletion level.
  - To go to the next step in this process, the user should press the "Next" TAB that will load the second screen of this section.
  - The user has the options:
    - to return to the main page
    - to print this page
    - to cancel the program

Figure 5. The input part of the short-term irrigation scheduling portion of the program.

b) Screen 2. After pressing the "Next" TAB in screen 1, screen 2 appears. This screen involves the following steps:

- Step 1. The user has the option of:
  - Either use the deficit level that was calculated in Screen 1
  - Or type in the deficit level as a function of depth in the crop parameters section of the form.
- Step 2. This step is used only when you choose NO in Step1. You need to have deficit level (%) as a function of depth (ft).
- Step 3. In this step, you choose the parameters of the irrigation system:
  - Delivery volume in GPH
  - Wetting diameter in feet
  - Irrigation efficiency in %
- Step 4, the command section.
  - Once you are satisfied with the input parameters just press the "Calculate" TAB to get the result of your input parameters in the "Output Results" section of the screen.
  - You can clear the input parameters and start a new calculation.
  - You can print this screen before or after the calculation.
  - You can go back to the first page or to the main page.
  - You can exit the program by pressing the "Exit" TAB.

Figure 6. The output part of the short-term irrigation scheduling portion of the program

4. **Print**
   o You can print this form by pressing the "Print" TAB.
5. **Cancel**
   o You can cancel this program by pressing the "Cancel" TAB.

Summary

Improved irrigation scheduling enables growers first to minimize the effects of water stress on crop growth and production, second to avoid excess use of water which could increase production cost and result in increased leaching losses of nutrients and soil applied agrichemicals below the rootzone. There are different irrigation scheduling methods with different degrees of accuracy and cost. Computer programs based on historical weather data, soil physical properties and crop rootzone depths have been used as irrigation scheduling methods that have advantages and disadvantages. They can be used as teaching tools for growers about the benefits of irrigation scheduling; they are a preferred method for low value crops where sophisticated and high cost irrigation scheduling methods are not economically viable. TheHelper offers citrus growers in Florida a tool that can be used to understand citrus water requirements on flatwood and ridge soils. The short- and long-term irrigation schedules could be used as general guidelines for citrus irrigation. Evaluation of this tool by growers, production managers and extension specialists could result in some adjustments.

References

Fares, A. and A.K. Alva. 1999. Field determination of citrus evapotranspiration using the mass balance method based on a continuous monitoring of the soil moisture content. Soil Sci. 164:302-310.

Fares, A and A.K. Alva. 2000. Soil water Balance components based on real-time multisensor capacitance probes in a sandy. Soil Sci. Soc. Am. J. 64:311-318.

Koo R.C.J. 1969. Irrigation requirements of citrus grown on Lakewood fine sand. Proc. Soil Crop Sci. Soc. Fla. 15:180-190.

Rogers J.S., Allen L.H., Jr., Calvert D.V. 1983. Evapotranspiration from a humid-region developing citrus grove with grass cover. Trans. ASAE. 26:1778-1792.