EVAPOTRANSPIRATION BASED CITRUS IRRIGATION SCHEDULING

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Introduction

Irrigation scheduling is the process of determining (1) when to irrigate, and (2) how much water to apply. Irrigation scheduling is difficult because schedules depend on the type of crop grown, the climate, soil conditions, type of irrigation system, and management practices. Also, irrigation timing and the amount of water to apply are not independent of each other. The decisions of when and how much water to apply depend on how much water was last applied, when it was applied, and the rate of its use since it was applied. Irrigation schedules are also affected by rainfall, especially in humid areas such as Florida.

IFAS Extension Bulletin 208, "Trickle Irrigation Scheduling for Florida Citrus", presented a very detailed discussion of irrigation scheduling data needs to use the water budget method to schedule microirrigation of citrus in Florida. The reader is referred to that publication for an in-depth discussion of the water budget method.

This publication presents a generalized water budget procedure for Florida citrus irrigation scheduling. Assumptions are made which limit the ranges of data inputs to those believed to be typical of the Florida citrus industry. Florida climate and crop data are used to estimate citrus water use for this publication.

The Water Budget

Maintaining a water budget requires accounting for all additions to, extractions from, and changes in storage in the effective root zone of the crop. Water additions occur by rainfall and irrigation. Extractions occur by drainage, runoff, lateral (subsurface) flow, and evapotranspiration (ET). The depth of water that can be stored in the soil can be determined from the soil water storage capacity and the crop effective root depth. Irrigations are scheduled before the soil water storage drops to a level that causes yield reduction due to water stress. This level depends on both the crop sensitivity to water stress and economic factors, such as current market prices.

Citrus Water Use

Table 1 presents estimated long-term monthly citrus ET data. These data were obtained from the IFAS Water Resources Council Fact Sheet WRC-4, "Water Requirements for Citrus" for ridge citrus and data from the IFAS and USDA SWAP research project, Ft. Pierce, for flatwoods citrus. The average of both of these data sets were used in this publication because there were only small differences in the monthly data.

Table 1 presents monthly citrus ET data in units of both inches/day (ipd) and gallons/day/acre (gpd/acre). The conversion constant is 1.0 inch/day (over a 1-acre area) = 27,154 gallons. Because these data are based on long-term averages, irrigation schedules derived from them will only be accurate for long-term average conditions. During extreme drought conditions, ET data may be expected to be greater than these values.

Soil Characteristics

The irrigation schedules calculated in this publication are given for depths of water application per irrigation of 1.0 to 1.5 inches. This range is believed to be typical of Florida citrus soils. Irrigation schedules for other ranges of soils data may be determined by linear extrapolation from these values.

Irrigation System Types

Three types of irrigation systems are considered: (1) sprinkler (overhead), (2) micro spray (microsprinkler), and (3) drip. Computed schedules are based on coverage of 100% of the soil surface with sprinkler irrigation, 50% of the surface with micro spray systems, and 15% of the surface with drip systems. For spray systems, the 50% value is approximately the surface area covered by one 360-degree spray emitter per tree. For drip systems, the 15% value is based on drip emitters spaced at 3-ft intervals along a single lateral per tree row. The drip coverage is relatively small because of the limited lateral movement of water in typical Florida sandy soils.

If your microirrigation system area of coverage is actually different than these values, then the irrigation schedules given in this publication must be changed proportionally. Specifically, for greater areas of coverage, more water may be applied at each irrigation, but irrigations would be scheduled less often. Likewise, for smaller areas of coverage, less water could be applied at each irrigation, but irrigations would be required more often.

When irrigation is applied, some water is lost during application due to evaporation, wind drift, non-uniform application, or other such causes. Thus, extra water beyond that required for crop growth must be applied because water cannot be placed into the crop root zone with 100% efficiency. In this publication, water application efficiencies were assumed to be 75% for sprinkler, 80% for spray, and 85% for drip irrigation. These are believed to be typical values for well-designed, well-managed citrus irrigation systems in Florida.

Tabulated irrigation schedules were based on water application rates of 0.1 and 0.2 inches/hour (iph) for sprinkler, 25 and 40 gallons per minute per acre (gpm/acre) for spray, and 10, 20, and 30 gpm/acre for drip emitters. Schedules for other application rates can be determined by extrapolation from these rates.

Days Between Irrigations

The number of days between irrigations for citrus sprinkler, spray, and drip irrigation systems are shown in Table 1 for each month. A range of values is given for each entry. This is the range of days that would be appropriate for the range in irrigation applications (depths in inches) listed at the top of each column.

For example, for January and sprinkler irrigation systems, the range is 14 - 21 days for a range of irrigation applications of 1.0 - 1.5 inches of water. If your soil characteristics permit 1.0 inch of water to be stored in the soil and available for crop use between irrigations, then an irrigation should be scheduled every 14 days in January. The 14 days will be required for the trees to use the 1.0 inch of water.

If your soil characteristics allow 1.5 inches of water to be stored, then irrigations can be scheduled only every 21 days. For other depths of water storage, interpolate between or extrapolate from these data.

For spray irrigation systems, irrigations must be scheduled more often because only 50% of the soil surface is assumed to be irrigated with these systems. In that case, the available soil water in the irrigated root zone is only 1/2 of that in the entire root zone, and the days between irrigations are about 1/2 of those when the entire soil surface is irrigated. For example, in May, spray irrigation should be scheduled every 3 - 4 days depending on the soil water-holding characteristics.

For drip irrigation systems, only 15% of the soil surface is assumed to be irrigated. In this case, the available soil water in the irrigated root zone is only about 1/6 of that in the entire root zone, and the days between irrigations are about 1/6 of those when the entire soil surface is irrigated. This requires very frequent irrigations because only small amounts can be applied at each irrigation. For example, in May, drip irrigations should be scheduled every 1 - 2 days depending on the soil water-holding characteristics.

Irrigation Durations

Irrigation durations depend on the depth of water to be applied, the application rate, and the irrigation efficiency. Table 2 presents irrigation durations for typical Florida conditions. Irrigation depths again range from 1.0 - 1.5 inches for sprinkler systems, 0.5 - 0.75 inches (which is equivalent to 1.0 - 1.5 inches in the irrigated zone at 50% coverage) for spray systems, and 0.15 - 0.23 inches for drip systems.

For sprinkler systems, application rates typically range from 0.1 to 0.2 inches/hour. These rates and the assumed 75% application efficiency require durations of 13.3 - 20.0 hours at the 0.1 iph application rate and 6.7 - 10.0 hours at 0.2 iph.

For spray systems, application rates typically range from 25 - 40 gpm/acre depending on the type of spray emitter used and emitter spacings. These rates, the range of water applications, and the assumed 80% application efficiency require durations of 7.1 to 11.4 hours. For drip systems, typical application rates are lower than for spray systems. Calculated durations ranged from 2.7 to 8.0 hours for the range of water applications and the assumed 85% application efficiency.

For both spray and (especially) drip irrigation systems, care should be taken to ensure that the depth of water movement is not below the crop root zone since the entire soil surface is not being irrigated. As examples, it is very likely that water would have moved well below the crop root zone if a drip irrigation system was operated for more than 8 hours, or if a spray system was operated for more than 12 hours. In those cases, irrigations should be scheduled for shorter durations, but more frequently.

In extreme cases it may be necessary to irrigate more often than once per day, allowing time for water extraction to occur between irrigations. For drip systems which irrigate only a small fraction of the tree root zone, it may not be possible to store all of the tree's daily ET requirements in this limited root zone. A system of this type would not be capable of providing water for all of the tree's ET requirements. In general, a minimum of 25% of the root zone should be irrigated to meet all of a tree's water requirements. Research conducted at the Lake Alfred CREC showed significant yield increases when the same amount of irrigation was applied with 1 spray jet per tree as compared to 2 and 4 drip emitters per tree.

Irrigation Delays for Rainfall

Tables 1 and 2 allow irrigations to be regularly scheduled when rainfall does not occur. When rainfall occurs, the number of days to delay irrigations for rain can be determined from Table 3. The number of days to delay irrigation for rainfall can be calculated by dividing the rainfall amount in inches by the average monthly ET rate in inches/day.

For example, if 0.42 inches of rain occurs in April, the next scheduled irrigation event should be delayed by 3 days (0.42 inches / 0.14 inches/day). Note, however, that if an extremely large rainfall occurred, much of it would be lost to drainage or runoff, thus, the next scheduled irrigation would be limited by the soil water-holding characteristics and soil water depletions allowed between irrigations. Also, rainfall that occurred immediately following an irrigation could be largely ineffective because the soil would already be wet, and the next scheduled irrigation event may not change.

Summary

A water budget method was presented to schedule sprinkler, spray, and drip irrigations based on long-term average citrus evapotranspiration rates. Adjustments to schedules would need to be made when climate conditions deviate significantly from these long-term averages. Tables were presented to allow both the days between irrigations and the durations of irrigations to be determined. A method was also presented to adjust the irrigation schedule for rainfall.

Table 1. Days between irrigations.

Month	ET (ipd)	ET (gal/acre/day)	Sprinkler (1.0"-1.5")	Spray (.50"-.75")	Drip (.15"-.23")
JAN	0.07	1901	14 - 21	7 - 11	2 - 4
FEB	0.09	2444	11 - 17	6 - 8	2 - 3
MAR	0.11	2987	9 - 12	5 - 7	1 - 2
APR	0.14	3802	7 - 11	4 - 5	1 - 2
MAY	0.18	4888	6 - 8	3 - 4	1 - 2
JUN	0.17	4616	6 - 9	3 - 4	1 - 2
JUL	0.17	4616	6 - 9	3 - 4	1 - 2
AUG	0.16	4345	6 - 9	3 - 5	1 - 2
SEP	0.14	3802	7 - 11	4 - 5	1 - 2
OCT	0.12	3258	8 - 13	4 - 6	1 - 2
NOV	0.09	2444	11 - 17	6 - 11	2 - 3
DEC	0.07	1901	14 - 21	7 - 14	2 - 4

[2] Days between irrigations = depth applied (inches)/ET(inches/day

Table 2. Irrigation Durations.

System	Appl. Rate	Appl. Depth (inches)	Duration [3] (hours)
Sprinkler	0.1 iph	1.0 - 1.5	13.3 - 20.0
(Eff.=0.75)	0.2 iph	1.0 - 1.5	6.7 - 10.0
Spray	25 gpm/acre	.50 - .75	11.4 - *
(Eff.=0.80)	40 gpm/acre	.50 - .75	7.1 - 10.6
Drip	10 gpm/acre	.15 - .23	8.0 - *
(Eff.=0.85)	20 gpm/acre	.15 - .23	4.0 - 6.1
	30 gpm/acre	.15 - .23	2.7 - 4.1

[3] Duration = Appl.Depth(inches) / [Appl. Rate(iph) x Eff.(decimal)] where 10 gpm/acre = 0.022 iph, 20 gpm/acre = 0.044 iph, etc.

* Spray irrigation durations longer than 12 hours and drip irrigation durations longer than 8 hours would likely result in water movement below the tree root zone and should not be used. Instead, increase the irrigation frequency and reduce the duration proportionally.

Table 3. Days to Delay Irrigation Following Rainfall.[4]

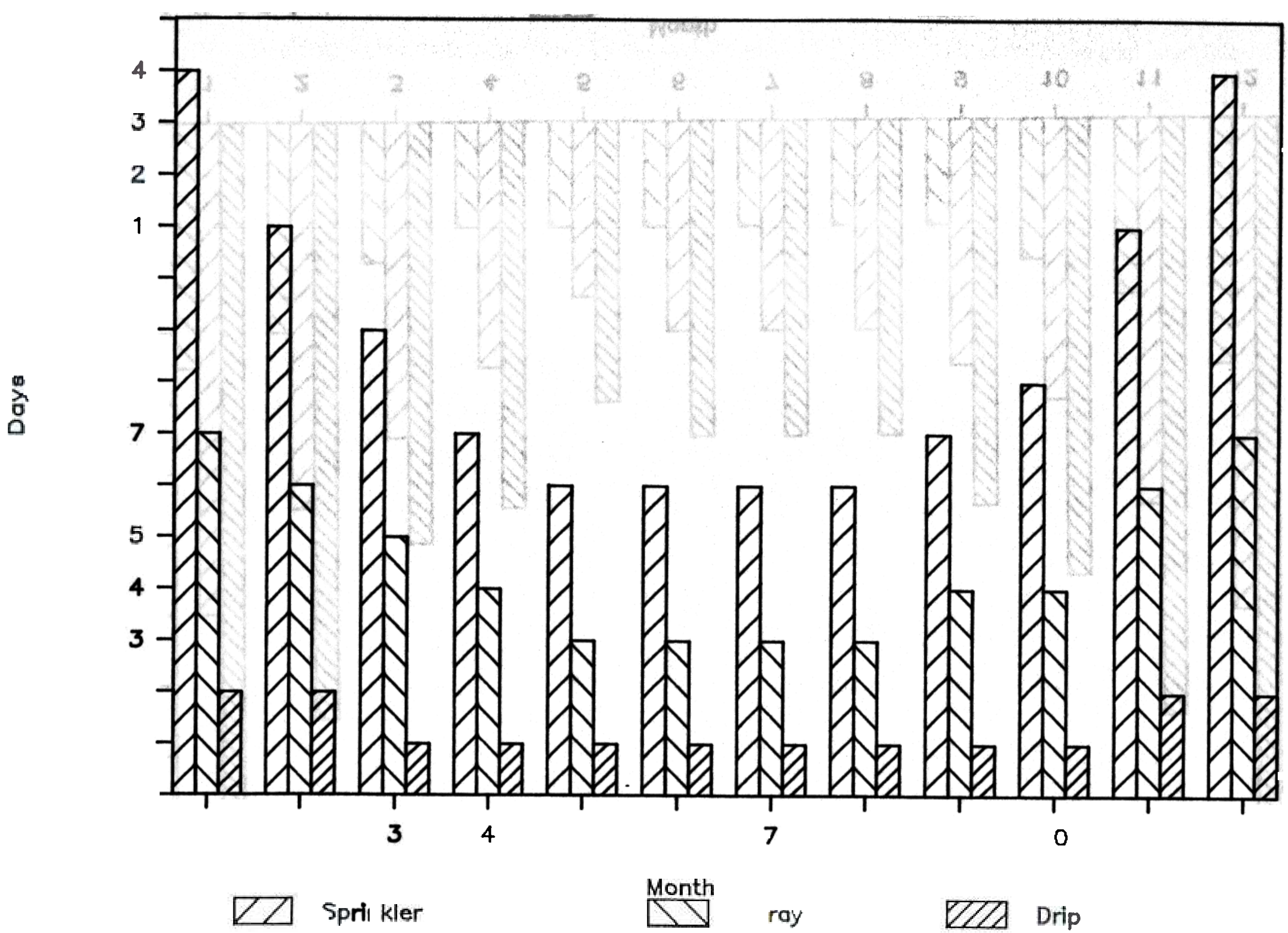
Month	Effective Rainfall Depth (inches) 0.5	1.0	1.5	2.0 **
JAN	7	14	21	28
FEB	6	11	17	22
MAR	4	9	12	18
APR	3	7	11	14
MAY	3	5	8	11
JUN	3	6	9	12
JUL	3	6	9	12
AUG	3	6	9	12
SEP	3	7	11	14
OCT	4	8	13	17
NOV	6	11	17	22
DEC	7	14	21	28

[4] Days to delay = effective rain depth (inches) / ET (inches)

** Note that effective rain cannot exceed the soil water-holding capacity. Excess rain will be lost to drainage.

LIST OF FIGURES

DAYS BETWEEN RR GAT ONS



DELAYS FOR RA.NFALL