WATER REQUIREMENTS OF CITRUS AND RESPONSE TO SUPPLEMENTAL IRRIGATION

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Citrus in the United States is grown in the arid climates of southern California and Arizona and the humid subtropical region of Florida. Irrigation is practiced as one of the production tools to varying degrees in all citrus-producing areas of the United States.

WATER REQUIREMENTS OF CITRUS

Water requirements of citrus estimated from evapotranspiration (ET) may range from 76 to 124 cm (30 to 49 inches) annually (2, 3, 6, 12). Water needs of trees from a climatic viewpoint can be estimated from computations of water transpired by a crop in relation to various methods of computing the potential of a given climate to evaporate water. This climatic potential is referred to as potential evaporation (PE). Methods commonly accepted for estimating this climatic potential include: 1) free water evaporation measurement, represented by class "A" pan evaporation rates, 2) the heat-budget method of Penman and modified by Van Bavel *et al.* (14) and 3) temperature methods of Thornthwaite (13) and by Blaney and Criddle (1).

Newman (12) compared the estimated annual ET with the PE calculated from these methods for 6 major citrus-producing areas of the United States (Table 1). Estimated annual ET values were 10 to 40% lower than the estimated PE, depending on the method used in calculation. The range in the coefficients of ET/PE for any one method did not exceed 10% for all 6 regions. These methods are useful in estimating the water needs of a crop or in developing a water budget of an area. Their values are limited when we try to employ these methods as aids to irrigation practices, because the soil and the plant factors are usually not included in calculations. A plant factor is included in some of the formulas; however, it is of little value in scheduling irrigation for a given crop.

Monthly estimated ET and PE from class "A" pans were plotted for Tempe, Arizona and Lake Alfred, Florida (Fig. 1) to compare the water requirements of citrus grown in arid and humid regions. Estimated ET and PE from the class "A" pan at Lake Alfred were 101 and 175 cm (40 and 69 inches) and at Tempe were 106 and 187 cm (42 and 73 inches), respectively. The coefficients of ET/PE were 0.57 for both places. The correlation coefficients between ET and PE were higher for Tempe than for Lake Alfred, although both sets of data were significant. Both PE and ET peaked in June and July in the arid regions. PE peaked in May, but the ET of trees did not peak until July and August in Florida. These variations made the PE values from the class "A" pan more applicable to arid regions of the southwestern United States than the humid region of the southeastern United States for estimating ET values.

Not all the water added to the citrus grove is used by the tree. Kalma and Stanhill (4) in Israel and Koo and Sites (10) in Florida estimated the quantitative losses of water from citrus groves by making intensive measurements of soil-moisture content and the amount of rainfall and irrigation (Table 2). Evaporation from the soil surface was higher in the arid climate of Israel than in the humid climate of Florida. Percolation losses of water beyond the root zone were considerably higher in Florida. Rainfall distribution and the very low water-retaining capacity of soil in Florida may account for the high percolation loss. The difference between water added to the soil and losses through surface evaporation and deep percolation was considered as transpiration in both studies. It was higher in Florida than in Israel. Greater leaf surface area due to the larger canopy of grapefruit trees probably can account for higher transpirational loss in Florida.

IRRIGATION BASED ON WATER REQUIREMENTS OF TREES

Field measurements in Florida have shown that citrus will use 96 to 112 cm (38 to 44 inches) of water a year depending on tree size (6,10). This does not include water lost through deep percolation. Supplemental irrigation is necessary in most years because of uneven rainfall distribution and the very low water-holding capacity of

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Table 1. Comparison of estimated annual evapotranspiration (ET) and potential evaporation (PE) of 6 major citrus-producing areas of the United States.

Location	Est. ET		Penman PE		ET/PE	Thornthwaite PE		ET/PE	Blaney & Criddle PE		ET/PE	Class "A" pan PE		ET/PE
	in.	(cm)	in.	(cm)	Coef.	in.	(cm)	Coef.	in.	(cm)	Coef.	in.	(cm)	Coef.
Santa Paula, Ca.	30	(76)	45	(114)	.67	34	(86)	.88	39	(99)	.77	--		--
Riverside, Ca.	38	(96)	56	(142)	.68	42	(107)	.90	48	(122)	.79	64	(163)	.60
Indio, Ca.	47	(119)	76	(193)	.62	58	(147)	.81	66	(168)	.71	81	(206)	.58
Tempe, Ariz.	42	(107)	66	(168)	.64	52	(132)	.81	58	(147)	.72	73	185)	.58
Weslaco, Tex.	49	(124)	70	(178)	.70	54	(137)	.91	60	(152)	.82			
Orlando, Fla.	44	(112)	61	(155)	.72	48	(122)	.92	56	(142)	.78			

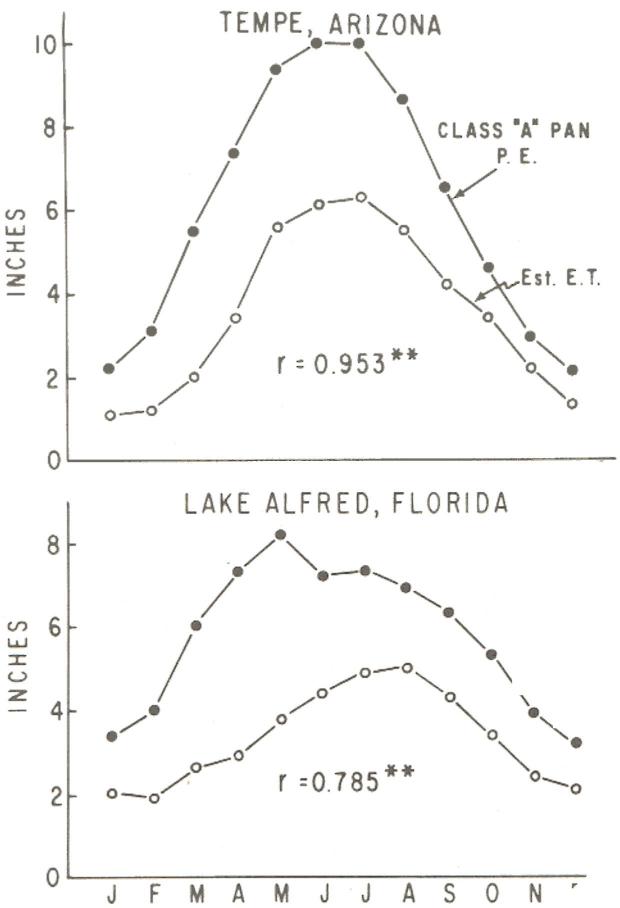

Fig. 1. A comparison of estimated evapotranspiration (ET) and potential evaporation (PE) from class "A" pan for Tempe, Arizona and Lake Alfred, Florida.

sandy soils. Irrigation practices should be closely supervised because excessive irrigation will adversely affect fruit quality while inadequate irrigation will save the trees in drought but will not contribute to maximum fruit production.

Table 2. Water balance of citrus.

	Israel (orange)			Florida (grapefruit)		
	in.	(cm)	%	in.	(cm)	%
Water added						
Precipitation	22.4	(57)	54	53.1	(135)	93
Irrigation	19.0	(48)	46	4.0	(10)	7
Total	41.4	(105)	100	57.1	(145)	100
Water consumed						
Soil evaporation	8.5	(22)	20	7.6	(19)	13
Transpiration	24.8	(63)	60	31.7	(80)	56
Percolation	8.1	(20)	20	17.8	(45)	31
Total	41.4	(105)	100	57.1	(145)	100

The frequency of irrigation and amount per application will be dependent on soil type, volume of soil in the root zone, tree size, tree density and scion-rootstock combinations. Most of these factors are fixed variables and should be considered in irrigation timing and rates of application.

Spring Irrigation

Maintenance of adequate soil moisture between fruit set and the rainy season for high fruit production cannot be over-emphasized. The rapidly changing seasonal temperature in spring and the unpredictable rainfall distribution, together with a very low water-retaining capacity of sandy soils, all present a challenge to those in citrus irrigation management. Supplemental irrigation during this period may vary from 10 to 25 cm (4 to 10 inches), depending on rainfall distribution (5, 6). Growers are advised to follow rainfall distribution and soil moisture closely during the critical spring months.

Fall Irrigation

Maintenance of adequate soil moisture in the fall is not as critical from the standpoint of fruit production as in the spring. Frequent irrigation in the fall should be avoided because it may delay the trees from going into dormancy and lower total soluble solids in the juice through dilution. Some irrigation may be necessary in the fall because rainfall in September, October and November is frequently insufficient to sustain the trees. Temporary leaf wilt in early afternoon can be used as a practical guide for fall irrigation. Five to 15 cm (2 to 6 inches) of supplemental irrigation in the fall months are sufficient in general for most years (5). Exceptions to the general recommendations include varieties of early oranges and mandarins produced primarily for the fresh fruit market. Water can be used more liberally for these varieties to hasten maturity and obtain the desired size (9).

RESPONSE OF CITRUS TO SUPPLEMENTAL IRRIGATION

Tree Growth

Supplemental irrigation will produce larger size trees as is reflected in larger tree trunks and canopies (6).

Leaf Analysis

Increasing rates of irrigation will lower the nitrogen and magnesium contents of leaves but increase the calcium content. A consistent trend was not found for the phosphorous and potassium contents of leaves.

Fruit Production

Supplemental irrigation increases fruit production, but not all species and varieties respond in the same degree. Seedless varieties respond more to supplemental irrigation than seeded varieties in general, and grapefruit show a greater response than oranges. Early orange varieties respond more to irrigation than late varieties (6, 7, 8, 9).

Fruit Quality

Fruit size. Irrigation will increase fruit size but frequently the size effects are offset by increase in fruit set. This occurs frequently in oranges and grapefruit, but less frequently in mandarins. Supplemental irrigation results in larger fruit size of lemons and limes but seldom increases the fruit set (7, 8, 11).

Fruit color. Irrigation will produce fruit with more green color in the skin, exceptions being lemons and limes (7, 8, 11).

Grade. A consistent trend has not been found.

Juice Quality

Juice content. Irrigation will increase juice content (9).

Total soluble solids and acid contents. Irrigation will lower both total soluble solids and acid content through dilution. The effects of irrigation on acid content of the juice is most noticeable in mandarins, less in oranges and least in grapefruit. It has little effect in lemons and limes (6, 7, 8, 9).

Total soluble solids/acid ratio. The effects of irrigation on total soluble solids/acid ratio follow the same trend as with acids, with mandarins showing the most response and lemons and limes showing the least.

Maturity. Irrigation will advance maturity due to increases in juice content, fruit size and total soluble solids/acid ratio. These effects are most striking with limes, lemons and mandarins, less pronounced for oranges and least for grapefruit.

LITERATURE CITED

1. Blaney, H. F. and W. D. Criddle. 1950. Determining water requirements on irrigated areas from climatological and irrigation data. *USDA Soil Cons. Serv.* SDS–TP–96.
2. Gerber, J. F., A. H. Krezdorn, J. F. Bartholic, J. R. Conner, H. H. Reitz, R. C. Koo, D. S. Harrison, E. T. Smerdon, J. G. Georg, L. D. Harris and J. T. Bradley. 1973. Water needs of Florida citrus. *Proc. Fla. State Hort. Soc.* 86:61-64.
3. Hilgeman, R. H. and F. O. Sharp. 1970. Response of 'Valencia' orange trees to 4 soil water schedules during 20 years. *Jour. Amer. Soc. Hort. Sci.* 95(6): 739-745.
4. Kalma, J. D. and G. Stanhill. 1969. Transpiration, evaporation and deep drainage losses from an orange plantation. *Israel Jour. Agric. Res.* 19(1):11-24.
5. Koo, R. C. J. 1971. A practical approach to citrus irrigation. *Citrus World* 7(11):14-16.
6. ____________. 1969. Evapotranspiration and soil moisture determination as guides to citrus irrigation. *Proc. 1st Intl. Citrus Symp.* 3:1725-1730.
7. ____________, T. W. Young, R. L. Reese and J. W. Kesterson. 1973. Responses of 'Bearss' lemon to nitrogen, potassium and irrigation applications. *Proc. Fla. State Hort. Soc.* 86:9-12.
8. ____________ ____________. ____________
9.
10.

11 Krome, W. H., R. C. J. Koo and J. W. Young. 1970. Irrigation experiments with 'Tahiti' lime in Dade County. *Proc. Fla. Stat. Hort. Soc.* 83:380-381.
12. Newman, J. E. 1968. Estimating water needs of citrus orchards. *Citrus Ind.* 49(1):19-24.
13. Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. *Geographical Rev.* 38:55-94.
14. Van Bavel, C. H. M., J. E. Newman and R. H. Hilgeman. 1967. Climate and estimated water use by an orange orchard. *Agri. Meteorol.* 4:27-37.

QUESTIONS

Q: What is the effect of rootstock on irrigation requirements?

Koo: I don't have too much experimental data on rootstocks—mostly field observations. From field observations, definitely sweet orange, seedling rootstocks and 'Cleo' require more water than rough lemon or sour orange. Also, grapefruit rootstock requires more water. Perhaps I shouldn't say require more water, but require more frequent irrigation.

Q: What about the need to irrigate for cold protection, in relation to soil moisture levels and the irrigation schedule?

Koo: In our studies, we maintain or try to maintain adequate soil moisture levels, so whether or not cold weather comes at the time to irrigate, we go ahead and irrigate. In both the 1957 freeze and the 1962 freeze, where we maintained adequate soil moisture, the trees came through in much better shape. Also, we had less fruit drop due to the freeze.

Q: Dr. Marsh, did you have a comment to make?

Marsh (California): I talked about problem solving as one of the features of tensiometer use. Problem solving, at least in our experience—I think it would probably occur more in the flatwoods than on the Ridge here—has to do with detecting situations where you have excessive soil water conditions. This often means that you have inadequate soil aeration.

Root binding suggests that the installation of the tensiometer created an environment in the immediate vicinity which is somewhat different and, therefore, somewhat more favorable than in the rest of the tree root zone. I don't know what there was in this particular case that was more favorable, but I have run into 1 or 2 instances of root binding. Frankly, you have to install the instruments in such a way that you alter the natural environment as little as possible, in order not to create a condition that would cause these roots to proliferate at a rate far greater than they would naturally in the normal, undisturbed soil.

Koo: Perhaps my thinking is faulty, but since water moves in and out of the porous cup rather freely with soil moisture, possibly more water moves out of the cup than in. Since roots grow best where water is, root binding occurs.

Reuther (California): The answer is conductivity, in my opinion—moisture conductivity. The roots in Florida soils, very sandy soils, respond to even a little bit more water more readily than they do in soils having better water conductivity.

Q: I was quite intrigued by your data indicating 50 to 60% efficiency of transpirational use by citrus trees in Florida. That is higher than most figures I have seen. Did you ignore weed transpiration and did you ignore runoff? I'm thinking particularly of flatwood soils.

Koo: In Israel, they have attained figures of 60%. In our case, runoff was discounted because it is practically zero. With respect to weed transpiration, yes and no. The middle of the rows was kept under clean cultivation because we had to make surface evaporation determinations at the same time. So under normal grove conditions where weeds are permitted in the summer, I am sure there would be a difference. However, in that particular study, we had to maintain clean cultivation.

Q: Do you have any field observations of some of these newer rootstocks as to their irrigation demands relative to sweet orange and sour orange, etc?

Koo: No, I don't have that information.

Wutscher (Texas): At the risk of incurring the ire of Dr. Marsh, the concensus in South Texas is that tensiometers don't work with us. Personally, I have done very little work with them, so I am taking everybody else's word for it. The real reason for this may be that we have cheap water. There may be other reasons, such as high rate of soil shrinkage or it may be a question of competence. Even so, we have had very little luck with them.