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**Glenn C. Wright**  
Associate Specialist

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has been reviewed by  
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## Introduction

Water is essential for citrus trees (or for any plant) because it is an integral component of the biochemical reactions that occur within the plant. Water is also important because it is the carrier that moves plant nutrients and other substances throughout the tree. Water also helps maintain plant temperature through transpiration. Finally, water helps maintain leaf and fruit turgidity.

## Citrus and Water Stress

The first sign of water stress is a reduction of fruit size. However this is not very noticeable unless one is watching closely. The first noticeable sign of water stress occurs when the leaves turn a dull green and begin to curl from the edges inward (Figure 1). Continued stress will cause the leaves to begin to dry out and become crisp, starting at the leaf tip, and progressing until the entire leaf is dead. Finally, the leaves will fall off. Flowers and then fruits will also fall. The entire tree will die if water is withheld for an extended period of time.



Figure 1. Drought-stressed citrus leaves showing typical curling.

Surprisingly, citrus will often bloom about one month after being drought-stressed, if allowed to recover. Therefore, if your tree blooms abnormally in September or October, it is safe to assume that the tree has been water stressed during the summer months.

## Estimating Tree Water Use

This is the \$64,000.00 question, and the answer depends on tree age, tree size, citrus species, climate and soil type. Research from the University of Arizona has found that mature citrus trees use about 60 inches of water per year. Depending on the size of the tree, this can correspond to as much as 17 gallons of water per day in the winter and 135 gallons of water per day in the summer.

Of course the amount of water applied depends on the time of year. Nevertheless, it is fairly easy to calculate the daily water use if you know canopy diameter of your tree. Daily water use for an orange tree may be found in Table 1.

Water use for grapefruit and lemon is about 20 percent higher than that of oranges, while water use for mandarins is about 10% less. Trees planted in grass should receive about 20% more water than trees with no turf or ground cover.

Using the table gives a good estimate of the water use for a citrus tree. For a more exact calculation, see the "For the Computer Whiz" box on the last page.

## Timing Water Applications

Despite the fact that values reported in Table 1 are daily water use rates, citrus should not be irrigated daily. Frequent, shallow irrigations will likely mean that not all the roots are actually getting water, and

### *At a Glance*

- The first noticeable sign of water stress in a citrus tree is leaf curling.
- Soil should be wetted from the trunk of the tree to just beyond the drip line, to a depth of at least two feet.
- Citrus should be irrigated every 7 to 28 days depending on season and soil type.
- There are several recommended application methods.

**Table 1. Orange Water Requirements in Gallons per Day.**

Tree canopy Diameter (ft.)	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.4	0.3	0.1	0.1
4	0.3	0.4	0.9	1.3	1.6	2.1	2.4	2.2	1.8	1.0	0.4	0.3
6	0.7	1.0	2.1	3.0	3.6	4.7	5.4	5.1	3.9	2.3	1.0	0.7
8	1.2	1.8	3.7	5.3	6.5	8.4	9.6	9.0	7.0	4.1	1.8	1.2
10	1.9	2.7	5.7	8.2	10.1	13.1	15.1	14.0	11.0	6.4	2.7	1.9
12	2.7	3.9	8.3	11.8	14.6	18.9	21.7	20.2	15.8	9.2	3.9	2.7
14	3.7	5.4	11.3	16.1	19.9	25.7	29.5	27.5	21.5	12.5	5.4	3.7
16	4.8	7.0	14.7	21.0	25.9	33.5	38.6	35.9	28.0	16.4	7.0	4.8
18	6.1	8.9	18.6	26.6	32.8	42.4	48.8	45.5	35.5	20.7	8.9	6.1
20	7.5	11.0	23.0	32.9	40.5	52.4	60.2	56.1	43.8	25.6	11.0	7.5
22	9.1	13.3	27.8	39.8	49.0	63.4	72.9	67.9	53.0	31.0	13.3	9.1
24	10.8	15.8	33.1	47.3	58.4	75.4	86.7	80.8	63.1	36.9	15.8	10.8
26	12.7	18.5	38.9	55.5	68.5	88.5	101.8	94.9	47.0	43.3	18.5	12.7
28	14.8	21.5	45.1	64.4	79.4	102.6	118.1	110.0	85.9	50.2	21.5	14.8
30	16.9	24.6	51.7	73.9	91.2	117.8	135.5	126.3	98.6	57.6	24.6	16.9
Avg. Pan Evaporation (in./day)	0.11	0.16	0.21	0.30	0.37	0.45	0.44	0.41	0.32	0.22	0.16	0.1

**How to use the table:**

Measure the canopy diameter (drip-line to drip-line) of the tree in feet. Using the left-hand column of the table, find the row that corresponds to the appropriate diameter. Using the upper row of the table, find the column for the month for which you want to calculate tree water use. The daily water use will be the value where the row and column intersect. See the example below:

**Example:**

A navel orange has a 14-foot canopy diameter. For July, the tree would require 29.5 gallons of water per day.

may also increase any salt stress on the tree if salty water is a problem. Appropriate intervals for watering citrus are found in Table 2.

These intervals are meant to be guidelines, and should be modified due to local soil conditions, weather conditions or irrigation application methods. Choose the more frequent interval if you have sandy or gravelly soils, choose the less frequent interval for heavier silt or clay soils. Irrigate more frequently during periods of excessively high temperatures and less frequently when temperatures are cooler than normal, or if rainfall has been plentiful.

Since drip or microsprinkler emitters provide water to the trees in low volumes, irrigation intervals using these methods must be more frequent. For trees at least three years old, irrigation intervals should be the same as a four-month to one-year-old tree under basin or flood irrigation.

In all cases, enough water must be applied so that the tree receives sufficient water to the roots before the water evaporates out of the soil. This can be achieved if the wetted soil is shaded, the trees are mulched, or if the trees are deep watered. **Soils should always be allowed to dry out to a depth of about 6 inches before the next irrigation. This will limit the problem of soil-borne disease.**

**Table 2. Application Intervals for Irrigated Citrus Trees<sup>1</sup>.**

Time after planting	Month				
	Dec. - Feb.	Mar. - Apr.	May - Jun.	Jul. - Sep.	Oct. - Nov.
0 - 1 month	← 2 to 3 days →				
2 - 3 months	← 3 to 5 days →				
4 months to 1 year <sup>2</sup>	14 days	7 to 10 days	5 to 7 days	2 to 5 days	5 to 10 days
1 to 2 years	14 to 21 days	10 to 14 days	7 to 10 days	7 to 10 days	10 to 14 days
3 years or older	21 to 30 days	14 to 21 days	14 days	10 to 14 days	14 to 21 days

<sup>1</sup> Modified from Chott, G. and L. Bradley. 1997. Irrigation needs of citrus. Maricopa County (Ariz.) Publication No. MC17.

<sup>2</sup> Mature trees under drip or microsprinkler irrigation should be irrigated at these intervals.

## Salty Water

Salty water presents some special problems when irrigating citrus. Citrus is moderately tolerant of salty water, but salts can accumulate in the soil or on the foliage and can cause root dieback or leaf loss. Salinity will always be more of a problem on poorly drained clay or silt soils than on permeable sandy or gravelly soils.

When salty water is a problem, trees should be basin or flood irrigated. This is because leaching will be required (See below). Trees may also be drip or microsprinkler irrigated, however care should be taken so that water will not contact the leaves, since salt may burn citrus foliage (Figure 2). Salts may also plug emitter orifices. Frequent or shallow irrigations will lead to salt accumulation on the soil surface (in the form of a white crust), and accumulation in the root zone.



Figure 2. Salt damage on citrus leaves

Salt may be moved from the root zone through the process of leaching. To leach salty soil, apply large amounts of water to the soil once or twice a year. Drip or microsprinkler systems can also be used to leach salts if they are allowed to run for an extended period of time, usually 12 to 24 hours.

## Calculating How Much Water is Applied

There are two easy methods. First, water application can be measured by looking at a water meter. These meters sometimes measure in cubic feet. One cubic foot of water equals 7.5 gallons. Other meters measure in gallons. Call your municipal water company if you need help reading the meter.

To read the meter at home, first make sure that all other water-using appliances are turned off, including dishwashers and washing machines. Fill two five-gallon containers with water while watching your meter operate. If your meter reads in gallons, then ten gallons use will be indicated on the dial or screen. If your meter reads in cubic feet, then 1.33 cubic feet use will be indicated.

Another method is to turn the garden hose to a given flow and see how many gallons of water go through in one minute. If five gallons go through in one minute, then 150 gallons will be applied if the hose is left on for 30 minutes.

Drip emitters and microsprayers often are rated as to the gallonage they will emit per hour (gph). This rating will be stamped on the sprinkler or emitter body. Gallonage may

also be estimated using the water meter. Most or all of the water emitted from a microsprinkler should be applied to the soil under the tree canopy if this method is to be accurate. Gallonage may also be estimated by placing the microsprinkler or drip emitter in a 5-gallon bucket, then estimating the flow rate.

## Application Methods

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There are several acceptable application methods. Basin irrigation is often the easiest for the homeowner. Construct a 4 to 8-inch high dike around the tree that is at least as large as the tree canopy (Figure 3). Since the roots actually extend beyond the canopy, a basin that extends about one foot past the canopy is preferred. Then fill the basin as the tree needs water. Do not bank soil around the trunk. Water can touch the tree trunk safely if the trunk is not damaged, and if the tree is not planted too deeply.



Figure 3. Basin irrigated citrus tree

In older Arizona neighborhoods, trees are flood irrigated. This is very effective, but if you have grass around the tree you may need to apply additional water to wet the entire root zone. Citrus trees may also be deep irrigated, if grass is around the tree, in order to get the water to the root zone.

Bubblers, drip emitters or soaker hoses are commonly used. Be sure to buy enough bubblers or emitters to supply the tree with enough water, and distribute it around the entire base of the tree, during the period of greatest need (see Table 1). Be sure to design the system so that it can be expanded to provide more water further from the trunk as the tree grows. For drip emitters, two to six emitters per tree are sufficient. Two may be installed at first, but add more as the tree gets older. For bubblers, one or two per tree are sufficient. Insure that most or all of the water applied saturates the soil where there are roots. Do not surround citrus with concrete since this will limit the roots ability to grow.

## Mulches

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Mulches are one of the best ways to conserve irrigation water by maintaining soil moisture within the root zone. Apply two to four inches of mulch under the plant canopy. Mulch can consist of pine needles, leaves, bark, wood chips, straw, compost, or any other organic materials. Mulch should be kept from direct contact with the trunk and should be extended as the plant grows. A good cover of mulch will help to control weeds under the tree canopy, as well as reduce water evaporation. Trees that are mulched can be irrigated less frequently than those that are not mulched. Mulches also lower soil temperature, allowing for better root growth, and will eventually decompose and add valuable organic matter to the soil.

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## For the computer whiz



How can I calculate the exact amount of water my tree needs daily?  
This involves using the following two formulae:

1.  $G = \text{Area} \times E \times F$

Where:

- $G$  = the daily water requirement in gallons.
- Area = the area of land covered by the plant canopy in square feet.  
 $\text{Area} = [(\text{Diameter of tree}) \div 2]^2 \times 3.14$
- $E$  = the class A pan evaporation in inches per day. See formula 2.
- $F = 0.436$  (a conversion factor).  
 $0.436 = (7.48 \text{ gallons per cubic foot} / 12 \text{ linear inches per cubic foot} \times 0.7 \text{ (The pan evaporation factor)})$ .

2.  $E = ET_o \times K_c$

Where:

- $ET_o$  = the pan evaporation in inches per day. This can be found on the web site for AZMET, the Arizona Meteorological Network. The web page address is: <http://ag.arizona.edu/azmet/>.
- From the first page, choose Yesterday's Weather Summary, and then select the  $ET$  value for the AZMET station closest to you.
- $K_c$  = the crop coefficient for citrus. This varies by month as shown in the following table:

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
0.50	0.50	0.80	0.80	0.80	0.85	1.00	1.00	1.00	0.85	0.50	0.50

Example: For mature orange tree with a 16-foot diameter canopy, the daily water requirement in August, with an  $ET_o$  of 0.4 inches per day, and a  $K_c$  of 1.00 would be:

- $\text{Area} = [(16 \text{ ft.}) \div 2]^2 \times 3.14 = 201 \text{ ft}^2$
- $E = 0.4 \text{ inches per day} \times 1.00 = 0.40$
- $G = 201 \text{ ft}^2 \times 0.40 \times 0.436 = \mathbf{35 \text{ gallons of water per day}}$

For the same tree in January, with an  $ET_o$  of 0.1 inches per day, and a  $K_c$  of 0.50, the water requirement would be:

- $G = 201 \text{ ft}^2 \times 0.05 \times 0.436 = \mathbf{4.3 \text{ gallons of water per day}}$