IRRIGATING CITRUS AND PISTACHIO

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CITRUS IRRIGATION

Seasonal water-use by citrus is moderate compared to that of other perennial fruit and tree crops in the San Joaquin Valley. A reasonable estimate for crop evapotranspiration for citrus (ET_c) for the current year may be obtained by multiplying a crop coefficient (K_c) of approximately 0.65 (for citrus) by reference evapotranspiration (ET_o).

Table 1. Normal year weekly evapotranspiration and water requirement for mature citrus in the southern San Joaquin Valley *(Adapted from "Crop Water Use - A Guide to Scheduling Irrigations in the Southern San Joaquin Valley, 1977-1991" Department of Water Resources, Published March 1993.)*

Week Ending		Weekly ET_c [1] (inches/week)	Daily ET_c (gallons/acre/day) [2]	Water requirement for system with 85% distribution uniformity (gallons/acre/day)
Jan	7	0.14	540	635
	14	0.16	620	730
	21	0.18	700	825
	28	0.22	855	1005
Feb	4	0.25	970	1140
	11	0.28	1085	1275
	18	0.33	1280	1505
	25	0.37	1435	1690
Mar	4	0.42	1630	1920
	11	0.47	1825	2145
	18	0.51	1980	2330
	25	0.57	2210	2600
Apr	1	0.63	2445	2875
	8	0.68	2640	3105
	15	0.74	2870	3375
	22	0.81	3140	3695
	29	0.87	3375	3970
May	6	0.94	3880	4565
	20	1.06	4110	4835
	27	1.10	4265	5020
June	3	1.13	4385	5160
	10	1.16	4500	5294
	17	1.17	4540	5341
	24	1.20	4655	5475
July	1	1.21	4695	5525
	8	1.21	4695	5525
	15	1.20	4655	5475
	22	1.17	4540	5340
	29	1.14	4420	5200
Aug	5	1.10	4265	5020
	12	1.05	4075	4795
	19	1.00	3880	4565
	26	0.95	3685	4335
Sept	2	0.90	3490	4105
	9	0.85	3300	3880
	16	0.80	3100	3640
	23	0.73	2830	3330
Oct	7	0.64	2480	2920
	14	0.59	2290	2695
	21	0.52	2015	2370
	28	0.46	1785	2100
Nov	4	0.40	1550	1825
	11	0.34	1320	1555
	18	0.28	1085	1275
	25	0.23	890	1045
Dec	2	0.18	700	825
	16	0.12	465	545
	23	0.11	425	500
	31	0.13	505	595
TOTAL		**34.5 inches/year**	**2.9 acre feet/year**	**3.4 acre feet/year**

[1] Crop coefficient K_c times ET_o for grass reference crop, $ET_c = (K_c)(Et_o)$.
[2] 1 acre inch = 27,150 gallons or 3630 cubic feet.

Normal year weekly ET_c for mature citrus in the southern San Joaquin Valley is presented in Table 1. Generally, within the typical range of planting densities and tree height used in citriculture, mature citrus ET_c on a per acre basis is relatively constant and values in Table 1 will apply to a wide range of citrus plantings. Closely spaced trees will mutually shade each other reducing water use on a per tree basis, but since there are more trees per acre, water use per acre will be similar to that for more widely spaced trees. Mutual shading does not begin to become an important factor until trees are five years old or older and then only for close spacing. Estimates of ET_c requirements for young trees as a percentage of that used by mature citrus are presented in Table 2 for a wide versus a close spacing. Since the evaporation component accounts for a much larger percentage of ET_c in young orchards, differences in wetted surface area and frequency of irrigation have relatively large effects on ET_c. The soil-water status of young trees should be checked frequently because over-irrigation is one of the major causes of reduced growth and disease in new and immature citrus plantings.

In addition to distribution uniformity and tree age, the actual water that must be applied to citrus is a function of many variables, such as weather, tree canopy health, tree height, rooting depth, salinity, heat advection from neighboring property, and other factors. The values presented in these tables are meant to be estimates only. Some method of measuring soil-water availability, such as tensiometers or other devices or methods, should be in-place in the field to check that water application estimates have a firm basis in reality. Water-use much greater or less than that estimated in these tables may suggest a problem with the scheduling method or irrigation system currently in use. Under- or over-irrigation may result in loss of yield and reduced tree health. Over-irrigation has also been shown to leach nitrogen and other fertilizers and pesticides into ground water.

Table 2. Evapotranspiration of immature citrus trees expressed as a percentage of mature citrus trees ET_c , (see Table 1), for wide and close planting density in the Southern San Joaquin Valley.

Tree age (years)	Per acre ET_c requirement of immature citrus as a percentage of mature citrus[1] wide spacing (22' x 22')	narrow spacing (11' x 22')
0-1	5	10
2	13	25
3	18	36
4	26	52
5	40	65
6	50	70
7-8	60	80
9-10	70	95
11-12	90	100
13	100	100

[1] These values are meant to be used as an estimate only. Irrigation and soil-moisture status should always be physically checked in the field.

REGULATED DEFICIT IRRIGATION IN NAVEL ORANGES

Research has generally shown that a straight reduction in ET_c across the season, spread uniformly across the stages of citrus fruit development, can result in loss of yield and decrease in fruit size. An experiment in Riverside demonstrated that a 14, 28, or 43% decrease in applied water resulted in a 9, 18 or 36% decline in yield, respectively.

The goal of regulated deficit irrigation for citrus is to find periods during the development of the fruit when irrigating at a level less than the full ET_c requirement of the crop will not reduce fruit quality or yield.

Some evidence suggests that maturing navel orange fruit subjected to rapid fluctuations of temperature in May and June, may be more susceptible to 'puff and crease' which is a malady of the rind and which can severely reduce fruit quality. If so, oranges maturing in the San Joaquin Valley of California this season should demonstrate more puff and crease at harvest in response to the large and rapid temperature fluctuations experienced by the crop early this season. Some varieties of navel orange, such as Frost Nucellar, are more susceptible to puff and crease than other varieties. Dr. Goldhamer found over a three-year period (from 1998-2000) that irrigating Frost Nucellar navel orange trees at 50% of full citrus evapotranspiration (ET) during the period from May 15 to July 15 decreased the number of fruit with puff and crease from 30% in the fully irrigated trees to 10% in the RDI trees. This difference increased the percentage of fancy fruit from 22% to 35% of the pack out. Yield, fruit number and fruit size were not affected by RDI and approximately eight inches of water was saved on average every year over the three years of the trial. For RDI to be conducted effectively, growers must have the ability and tools to estimate citrus ET, water application rates, soil-water holding capacity, irrigation application rates and crop water stress accurately. For those familiar with an instrument called the 'pressure bomb', Dr. Goldhamer suggests irrigating at 50% ET beginning in mid-May until a mid-day shaded leaf-water potential of -20 bars is attained in the trees, at which point the trees can be returned to full irrigation.

Late-maturing navel orange quality has also been improved by RDI. In an experiment conducted by Dr. Goldhamer from 2004-2006, in an orchard of Lane Late navels, the targeted RDI for the water stressed trees was 50% of full citrus ET and the stress was applied evenly throughout the season. During the season from June through October, mid-day shaded leaf-water potentials of lower than -30 bars were recorded regularly with the pressure bomb. At harvest, RDI oranges peaked on the desirable sizes 56 and 72 compared to the overly large sizes 24 to 40 in the oranges irrigated at full citrus ET. The RDI treatment did not result in a reduction in yield. The RDI trees grossed an average of $6220 versus $3610 an acre as a result of reduced fruit granulation and the improved size distribution. Substantial water savings also accrued. On average for the three-year experiment, the RDI trees were irrigated annually with an average of 17 inches of water compared to the normal 37 inches.

Uncontrolled stress may increase fruit drop or reduce fruit size, so attempts to apply this research at the field-scale should be approached carefully. Dr. Goldhamer said stressed trees showed cupped leaves and yellowing of leaves, but that the trees and fruit recovered once irrigations resumed.

PISTACHIO IRRIGATION

Pistachio has the ability to survive extreme drought but requires substantial irrigation to produce a large crop of split nuts (see Table 3). Irrigating at full ET_c in August has been shown to be necessary to insure adequate nut split. Estimates of mature pistachio ET_c appear in Table 3, and for immature pistachio trees in Table 4. Table 3 was developed by Dr. David Goldhamer. Use of cover crops will increase the irrigation requirement of the orchard substantially if they are irrigated through late spring, summer and early fall.

Note in Table 3 that regulated deficit irrigation in the shell hardening stage, which normally occurs in the period from mid-May through the end of June, appears possible without harming crop quality or yield. Reducing ET_c by 50% during this time period will save approximately 10 inches of water (0.83 acre-ft/acre). As for citrus, over-irrigating young trees is one of the primary causes for poor tree growth.

Table 3. San Joaquin Valley pistachio water use (ET_c) for normal and proposed regulated deficit irrigation (RDI) regimes. Irrigation schedule early in the season must take into account stored winter rainfall.

Growth Stage	Approximate phenology	ET_o Period	Reference water use K_c (inches)	Crop Coeff. period	Normal ET_c level (inches)	Proposed RDI ET_c (%)	Proposed RDI (inches)
	Bloom	Apr 1-15	2.36	0.07	0.17	100	0.17
Stage 1	Leafout	Apr 16-30	2.36	0.43	1.01	100	1.01
	Shell Expansion	May 1-15	3.19	0.68	2.17	100	2.17
	Shell Hardening	May 16-31	3.40	0.93	3.16	50	1.58
Stage 2	Shell Hardening	June 1-15	3.84	1.09	4.19	50	2.09
	Shell Hardening	June 16-30	3.84	1.17	4.49	50	2.25
	Nut Filling	July 1-15	4.13	1.19	4.92	100	4.92
	Nut Filling	July 16-31	4.41	1.19	5.25	100	5.25
Stage 3	Nut Fill./Shell Split	Aug 1-15	3.54	1.19	4.21	100	4.21
	Shell Splitting	Aug 16-31	3.78	1.12	4.23	100	4.23
	Hull Slip	Sept 1-15	2.66	0.99	2.63	100	2.63
Harvest	Harvest	Sept 16-30	2.66	0.87	2.31	25	0.58
	Postharvest	Oct 1-15	1.71	0.67	1.15	25	0.29
Postharvest	Postharvest	Oct 16-31	1.83	0.50	0.91	25	0.23
	Postharvest	Nov 1-15	0.80	0.35	0.28	25	0.07
	TOTALS				**41.10**		**31.70**

Table 4. Approximate irrigation requirement for immature pistachio[1] in the southern San Joaquin Valley.

Tree age (years)	Irrigation Requirement (acre-feet/year)	Approximate fraction immature tree ET_c of mature ET_c
0-1	0.2	.05
2	0.9	.24
3	1.6	.43
4	1.6	.43
5	2.3	.62
6	2.3	.62
7 +	3 - 3.8	1.0

[1] For trees spaced 18 ft in the row and 20 ft between rows. Since the evaporation component accounts for a much larger percentage of ET_c in young orchards, differences in wetted surface area and frequency will have relatively large effects on ET_c. Actual soil-water storage should be physically monitored in the field before scheduling irrigation.