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Agriculture & Natural Resources

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Summer 2008

SPECIAL DROUGHT INFORMATION ISSUE

INSIDE THIS ISSUE

This year we are facing two critical issues affecting agricultural production. Water deliveries will be limited, and rapidly rising energy costs may complicate irrigation management.

This newsletter is a compilation of articles by Kern County Farm Advisors to address water conservation. The various sections provide specific water management information for a number of agricultural crops as well as home landscapes. These articles may refer to additional information available either at our office, 1031 South Mt. Vernon Avenue, or on our web site: http://cekern.ucdavis.edu. Further information may be found on the California Department of Water Resources website http:/www.owue.water.ca.gov/ which also lists some publications of UC Cooperative Extension. These can be downloaded from the web site.

We hope the enclosed information is useful to you. Please feel free to call our office if you need more details. Our advisors are available to answer questions and work with you.

Darlene Liesch
County Director

IRRIGATING CITRUS AND PISTACHIO

Craig Kallsen, Citrus and Pistachio Advisor

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.

GrowthApproximate Stagephenology		ET_o Period	Reference water use K_c (inches)	Crop Coeff. period	Normal ET_c level (inches)	Proposed RDI ET_c (%)	Proposed RDI (inches)
Stage 1	Bloom	Apr 1-15	2.36	0.07	0.17	100	0.17
	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
Stage 2	Shell Hardening	May 16-31	3.40	0.93	3.16	50	1.58
	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
Stage 3	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
	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	Postharvest	Oct 1-15	1.71	0.67	1.15	25	0.29
	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.

IRRIGATING COTTON WITH A LIMITED WATER SUPPLY

Blaine R. Hanson and Allan Fulton
Originally published in California Cotton Review, Volume 14
Updated by
Brian Marsh, Cotton, Small Grains, Corn & Silage Advisor

Because water allotments have been dramatically reduced this year, we will review principles of water management with limited supply. The same topic is reviewed in California Cotton Review, Vol. 9, March 1989. For additional information see "Late Season Irrigation Management Recommendations" in Vol. 60, Aug 2001 available at http://cottoninfo.ucdavis.edu

STRETCHING THE WATER SUPPLY!

Variety Selection. A more determinant type of cotton plant will require less water than an indeterminate type. A general observation is that determinate Acala varieties experienced the most sensitivity to the timing of water stress with yields severely declining when sustained water stress levels below –22 bars occurred shortly after crop cutout. Moderately indeterminate to indeterminate varieties were affected least by exposure to late season water stress imposed during the period between cutout and last mature boll. Limited information is available on how a specific newer variety responds to water stress conditions.

Irrigation Timing. During seasons with water shortages, production can be better sustained by consistent management allowing only moderate stress through boll maturity and avoiding periods of severe stress. Crop growth from emergence to peak bloom (mid July) is most sensitive to water stress. Consequently, timing of the first and for some soils, the second crop irrigations are most important. Irrigate to protect the early season fruit from water stress and dropping. This will avoid delayed crop maturity and increased late season water usage.

A valuable tool to assist is controlling water stress is the pressure chamber. The pressure chamber provides a direct measurement of plant water stress and can be used in several fields to prioritize the need for irrigations in each field. If you have access to a pressure chamber, it is recommended for SJ-2 during drought conditions that irrigation be applied when the pressure chamber reading is 18 bars. This practice should be continued through July. Measurements of 20 bars can be tolerated in August and still fully mature the fiber.

Applying Water Efficiently. A key to successfully managing a water-short season is controlling the amount and uniformity of applied water by the furrow irrigation system. Candidates for poor uniformity, and thus substantial water losses past the root zone include fields with sandy or loamy soils, one-half mile run lengths, and large advance times (time required for water to reach the end of the field). Under these conditions, much water can infiltrate below the root zone, which is undesirable, particularly when the water supply is limited.

The uniformity of furrow systems can be improved by getting the water to the end of the field faster. Particular emphasis should be placed on preirrigations and first crop irrigations, where soil intake rates are the highest. Measures to improve the uniformity of a furrow irrigated field, and thus stretch a limited water supply by reducing deep percolation losses, include the following:

- Reduce the run length and the set time by one-half. Under adequate irrigation conditions, this measure can reduce the deep percolation by at least 50 percent. Do not reduce furrow flowrates to less than that normally used.
- Convert to surge irrigation. This has the potential of reducing deep percolation by 30 to 40 percent.
- Improve slope uniformity. Flat spots in the field can greatly increase the time required for water to reach the end of the field. An evaluation of a furrow irrigated field with flat areas revealed that about three hours were required for the water to flow about 150 feet in the flat areas compared to about 45 minutes in the sloped areas.
- Reuse the tailwater. The above measures can increase the amount of tailwater. Thus, stretching a limited water supply will require recovery of the tailwater for use elsewhere.

A measure commonly recommended for improving uniformity of furrow systems is to increase the furrow inflow rate. Studies, however, have shown that this is not very effective for furrow irrigation. Increasing the inflow rate does advance the water faster across the field, but at the same time, higher infiltration rates occur because more surface area of the furrow is wetted. These higher infiltration rates offset the effect of the faster advance on the irrigation uniformity.

WATER CONSERVATION FOR LANDSCAPES

John Karlik, Environmental Science/Environmental Horticulture Advisor

In urban residential areas, about half of household water use is for outdoor purposes, and of that fraction about half is used for landscape irrigation. Since an increasing number of us have water meters, and as urban areas increase in size accompanied by needs for water, landscape water conservation becomes a greater priority both individually and collectively. It is usually possible to significantly reduce water consumption without major changes to a landscape or irrigation system. Class discussions and conversations indicate people often think first of changing plants to save water, but irrigation scheduling is actually more important, since even with a landscape composed entirely of drought-tolerant plants the irrigation schedule will determine how much water is used. In the following discussion, I offer considerations and suggestions for reducing landscape irrigation amount beginning with the most effective steps.

The irrigation system should be run periodically when the operator can check valve operation and make adjustments, such as modifying direction of sprinkler heads or raising them. A system check also includes repairing missing sprinkler heads, cleaning screens in the heads, and fixing leaks.

The simplest and easiest way to conserve irrigation water is to reduce the application amount. With an automatic irrigation system, clock adjustments should be made at least quarterly during the year. With normal winter rainfall, irrigation systems may be shut off during winter. Water use by plants changes tenfold from winter to summer throughout Kern County, and if summer settings are not altered water is wasted during most of the year. Fall and spring are transition times when careful managers may want to adjust clock settings every month. Some clocks have a water budget feature allowing a percentage change for all circuits, so watering times can be easily increased or decreased during weeks of usually warm or cool weather. When irrigating, it is best to wet the entire root zone of plants, if possible, and so changing the number of days per week rather than the runtimes per zone is preferable for making seasonal adjustments.

In a landscape, the manager may have little idea of what the initial time settings ought to be. A simple water audit can establish baseline information from which future schedules can be calculated. To perform a water audit in a small landscape, sprinklers are run for a specific time, with water caught in cans or coffee mugs spaced across the delivery area. The water depth is measured to give a precipitation rate in units of depth per time, such as inches per hour. If the precipitation rate is known, it can be compared to plant water needs. In general, average per-day water requirements for landscapes are 0.25, 0.16, 0.02, and 0.15 inches per day for summer, autumn, winter and spring, respectively, in the valley portion of Kern County.

Soil and plants should be monitored and irrigation adjusted accordingly. Plants indicate moisture stress by color change, or in more advanced condition, by wilting. Soils can be occasionally checked with a soil probe or screwdriver to gauge the depth of water penetration. If runoff occurs, multiple short cycles may be necessary to apply the needed amount of water. Some types of turf heads, such as stream rotors, offer low precipitation rates for soils with low infiltration rates. Early morning is the best time of day to irrigate to minimize water loss from wind and evaporation. Mulching around plants can reduce soil evaporation and help provide more uniform moisture.

A non-uniform irrigation system, especially on turf, can waste large amounts of water, because it is common for homeowners to irrigate until the driest spot is wet, which may result in twice as much water as needed in other areas. In general, the output from a sprinkler should reach the adjacent sprinkler (head-to-head coverage). High overall uniformity can be obtained with single-stream heads, stream rotors, or impact sprinklers. Fan-sprays are more difficult to work with to achieve high coefficients of uniformity but are needed for irregularly shaped areas. For shrubs, groundcovers and trees, drip irrigation is often a useful method for water delivery.

The landscape design, including the irrigation design, often sets limits on water conservation. Plants do differ in irrigation requirements, with turfgrasses often the plant type with greatest water needs in a typical landscape. Warm season turfgrasses, such as bermudagrass, require less water than do cool season grasses, such as tall fescue. Plants with similar water requirements should be in the same irrigation zone, and plants on the same irrigation line should need similar amounts and frequency of irrigation. For example, in a residential landscape, turf should be irrigated from one or more lines, shrubs and groundcovers on others, fruit trees on others, and so forth. These plant types may need different frequencies of irrigation, in other words, more or fewer days per week. Low-priced irrigation controllers used for home landscapes may not allow setting days on/off independently for each valve. Improved controllers are now available that allow greater flexibility in scheduling. For a drip system, one cost-effective solution is to have two inexpensive irrigation controllers, one for valves operating most days per week, and a second for valves operating once or twice per week for long periods of time.

MAXIMUM WATER USE EFFICIENCY IN A DROUGHT YEAR

Blake Sanden, Irrigation Management/Agronomy

The Federal project water allocation has been cut to 40% (even less if your in Westlands Water District) and State water supplies from the California Aqueduct have been slashed to 35%. Snowpack and reservoir storage across the state as of the beginning of June was 50 to 69% of normal. In many areas of Kern County, groundwater pumping levels have dropped 20 to 50 feet; meaning your old dependable 1200gpm well might only be yielding 1000 gpm.

Okay, we know it's bad, now what can we do about it? Following is a list of practices and resources to help you get the most out of every drop of water. The following topics are too extensive to explain in one newsletter, so they are only introduced here as a general category (with a couple exceptions) with links to other newsletters or tables posted on our Kern Cooperative Extension Website http://cekern.ucdavis.edu (and a few others) so you can get more info on the topic of your choice.

NORMAL YEAR CROP WATER USE, EVAPOTRANSPIRATION (ET) and CIMIS

From May through August we are blessed with very predictable weather in the San Joaquin Valley, where the "reference crop potential evapotranspiration" (basically unstressed pasture grass water use, ETo) varies no more than 5% from one year to the next. This makes it possible to estimate average crop ET for a given week based on the "normal year" ETo multiplied by a crop coefficient (Kc) for that stage of crop development. These average SSJV ET values and Crop Coefficients can be found at: http://cekern.ucdavis.edu/files/53222.xls

These are a combination of published values and my personal observation from Kern County trials. Additional references are also listed. More detailed Excel tables can be downloaded for the below crops:

- Almonds: Almond ET- Age-Week-Month http://cekern.ucdavis.edu/files/53223.xls
- Citrus: Citrus ET by age http://cekern.ucdavis.edu/files/53224.xls
- Forage: Forage ET http://cekern.ucdavis.edu/files/53225.xls
- Grapes: Grape ET http://cekern.ucdavis.edu/files/53226.xls
  Estimating vineyard crop coefficients http://cekern.ucdavis.edu/files/53263.doc
- Pistachios: Pistachio ET by Age http://cekern.ucdavis.edu/files/53227.xls

The data given in these tables is my best estimate for the southern San Joaquin Valley. You can update these tables with the current year's ETo by accessing the CIMIS website and following these steps:

Website Address: http://www.cimis.water.ca.gov/

Non-Members:

1. Select Data tab on header
2. Sample Daily or Monthly report
3. Select County
3. Submit – gives last 7 days for all stations in county

Signing up for membership is free, can be done on the website and allows many more options for data access.

KERN COUNTY CIMIS STATIONS

5	Shafter/USDA
54	Blackwell's Corner
125	Arvin-Edison
138	Famoso
146	Belridge
172	Lost Hills NW

There are many other publications available with suggested crop water use tables (browse UC irrigation publications: http://anrcatalog.ucdavis.edu/Search/irrigation.aspx and our current UC Drought Management Website: http://ucmanagedrought.ucdavis.edu/almonds.cfm); not all of them agree. My numbers for almonds are higher than nearly any other reference, but are the result of 7 years of various trials and observations in more than 40 almond blocks across Kern County and they also reflect a higher estimate of San Joaquin Valley ETo than the one we used 10 years ago. Remember, these tables are just guidelines to get you started. Depending on salinity impacts, crop load, the overall vigor of your field and irrigation uniformity your actual crop water requirement (ET + non-uniformity + leaching) may be less or as much as 10 to 20% greater than the table values. Checking field soil moisture (next section) and actual crop stress will tell you whether you are on target or not.

FLOOD SYSTEM MANAGEMENT – know your soil water holding capacity, use higher flows and tailwater return for better uniformity and efficiency

Flood systems usually offer the greatest possibilities and biggest challenges for "saving" water. It is much more important to know the mechanics and interaction of soil water holding capacity, infiltration, run times, tailwater management/return and field distribution uniformity for flood systems than micro systems. A well designed fanjet system puts out a 92% uniform application rate on the sandy part of the field as on the clay loam area, and it doesn't matter if there is a "low belly" in the middle of the run. With a flood system you may get anything from as little as 0.6 inch depth of water infiltrated in a Wasco sandy loam irrigated with snow-melt water that has "sealed over" by mid-season to as much as 7 inches on a Milham sandy loam irrigated with well or Aqueduct water. A Buttonwillow cracking clay may take in 5 to 8 inches in a 24 hour set, then seal up when the cracks close and not take a drop more. Of course the path of greatest water use efficiency is the cross road of timing the irrigation to just infiltrate the depth of water the plant has used since the last irrigation and before experiencing undesirable stress. Coming back too soon with too much water will push water and fertilizer out the bottom of the rootzone (deep percolation) and possibly cause waterlogging and increased disease potential. Tailwater losses can also increase.

So the first step is to know your dirt, okay soil. The available water holding capacity (AWHC) may be as little as 0.75 inches of water/foot in a coarse loamy sand to 2.5 inches/foot in a fine textured silt/clay loam to clay, which means your reserve moisture available to say a corn or alfalfa crop over a 5 foot rootzone an range from 4 to 12 inches total. For an annual crop like corn you also need to consider the increasing rooting depth as the crop grows. The forgiving aspect of flood irrigation is that most of our ag soils from a fine sandy loam to a clay loam will give up 4.5 to 6 inches of water before crop stress ocurrs (about a 50% depletion), assuming a six foot rootzone. Table 1 shows typical irrigation intervals for different soil textures over the season, which somewhat confirm the old standard of irrigate 3 weeks apart early season and every 2 weeks midseason and that will get you close to what you need.

Table 1. Calculated irrigation interval (days of moisture reserve) by month, soil texture and rooting depth.

110 day silage corn plant 4/14		Roots1.5' Apr	Roots 3 ft May	Roots 4.5' Jun	Roots 6 ft Jul	Aug
Soil Texture	**Avg Daily ET**	**0.06**	**0.15**	**0.26**	**0.3**	**0.26**
Available Soil Moisture to 6 feet @ 50% depletion	**(in)**	**Days of Moisture Reserve for Average Daily ET by Month and Root Delopment**				
Sand	**2.1**	9	7	6	7	8
Loamy Sand	**3.3**	14	11	10	11	13
Sandy Loam	**4.2**	18	14	12	14	16
Loam	**5.4**	23	18	16	18	21
Silt Loam	**5.4**	23	18	16	18	21
Sandy Clay Loam	**3.9**	16	13	11	13	15
Sandy Clay	**4.8**	20	16	14	16	18
Clay Loam	**5.1**	21	17	15	17	20
Silty Clay Loam	**5.7**	24	19	16	19	22
Silty Clay	**7.2**	30	24	21	24	28
Clay	**6.6**	28	22	19	22	25

Well, if you're irrigating with $200 water (or even $100 water) then "close" is no cigar. Over irrigating by 6 inches/acre costs you $100, or underirrigating by 6 inches could lose you a ton of alfalfa or 3 to 5 tons of silage. The only way you'll know is by checking soil moisture by hand or with various sensors or contract irrigation scheduling services. By using a flowmeter for the field and hand checking to 4 feet (head and tail) before and after the irrigation you will have a better idea of the depth of water the field not only "takes", but actually "stores". If your calculation of stored water is significantly less than what the flow meter measured then you're losing a lot of water out the tail ditch or to deep percolation.

For a handy guide on UNDERSTANDING ESSENTIAL SOIL TEXTURE/MOISTURE STORAGE & DISTRIBUTION UNIFORMITY FOR EFFICIENT FLOOD IRRIGATION download:

- **Flood irrigation soil moisture and scheduling** **http://cekern.ucdavis.edu/files/53297.doc**

The Center for Irrigation Technology has an on-line water balance scheduling spreadsheet and webiste that might also be helpful: **http://www.wateright.org**.

TAILWATER RETURN & ENERGY EFFICIENCY – improve irrigation uniformity and save water

For most ag soils, the "on time" water needs to be applied to the tail end of the field should be at least 25 to 35% of the total on time that the head end received to get a reasonable "distribution uniformity" (DU) of infiltrated water of 70 to 80%. Except for coarse sandy soils, about 60 to 80% of the maximum infiltration over 24 hours occurs in the first 3 to 6 hours. This is why we can produce fairly uniform yields in cotton with a ¼ mile run, 24 hour set, 16 to 18 hours to get out and 6 to 8 hours to run on the tail. The resulting tailwater may be about 15% of the total applied.

Whether borders in hay, wheat, almonds, grapes or furrows in cotton, corn and beans the faster you run the water (avoiding heavy erosion) for a given set time, the better uniformity you'll have AND the more tailwater you'll generate.

Table 2. TAILWATER PIT COSTS & RETURNS (April 2008)
Average energy cost, kwh over season: $0.14

Crop: ALFALFA	**Acreage: 80**		**Crop ET (in): 52**		
Item	**$**				
2900 feet, 8 inch pipeline @ $4/ft installed	**11,600**				
0.5 ac-ft pit (50x100x5)	**1,500**				
Concrete pump stand/sump	**3,000**				
7 HP turbine pump	**6,000**				
Electrical panel	**3,500**				
TOTAL	**$25,600**				
Return flow (gpm): 700			**Pumping Head (ft): 20**		
Field Distribution Uniformity	**65 %**	**70 %**	**75 %**	**80 %**	**85 %**
Pumping Efficiency	**50 %**	**50 %**	**50 %**	**50 %**	**50 %**
Required Applic (in)	80.0	74.3	69.3	65.0	61.2
Required Applic (ac-ft)	533.3	495.2	462.2	433.3	407.8
Runoff (%)	**10%**	**15%**	**20%**	**25%**	**30%**
Total Water without Return (ac-ft)	586.7	569.5	554.7	541.7	530.2
Tailwater (ac-ft)	**53.3**	**74.3**	**92.4**	**108.3**	**122.4**
Hours On for Season	414	577	717	841	950
Sump HP Reqd	7.1	7.1	7.1	7.1	7.1
Sump KWH/ac-ft	41	41	41	41	41
Total Sump KWH	2183	3040	3783	4433	5007
Total Energy Cost	$306	$426	$530	$621	$701
Reservoir Maintenance	$200	$200	$200	$200	$200
Depreciation (20 yrs)	$1,280	$1,280	$1,280	$1,280	$1,280
Annual Water Cost ($/ac-ft)	**$33**	**$26**	**$22**	**$19**	**$18**

Kern County probably has more field specific tailwater return systems than any other county in CA due to the cost of our water, but there are still lots of fields in Kern Delta, Buena Vista and some other districts that just dump the tailwater back into the district ditch and you lose it. Table 2 shows the breakdown of costs, required water applied to meet ET, tailwater generated and your final $/ac-ft for recycled tailwater for an 80 acre block of alfalfa for different field distribution uniformities. Of course these numbers are theoretical calculations and I don't know of any hay field in Kern County where somebody puts on 80 inches trying to keep the dry end of the field wet. Most fields get 50 to 60 inches, and the best yielding fields always have some runoff to avoid drowning out the ends. So … BOTTOM LINE: better field uniformity = less total applied water required = better yield = more tailwater. For a 20 year system life: if you return 100 ac-ft/year of tailwater to the field your cost is about $20/ac-ft, if it's only 60 ac-ft/yr the cost is about $30/ac-ft – a real bargain these days, especially with reduced allocations. You can get the Excel spreadsheet for Table 2 and plug in your own numbers by downloading: **Pump-Tailwater Energy Efficiency Compare** http://cekern.ucdavis.edu/files/53301.xls

Groundwater pumping and well efficiency

With declining groundwater levels and the increased dependence on pumping it is imperative to get your well checked to make sure you are at top efficiency, and there are substantial grants available to help. The Center for Irrigation Technology Cal State Fresno administers $millions in free pump testing payments and substantial well repair/maintenance cost share in cooperation with the California Energy Commission and other power companies. To get the details go to: http://www.pumpefficiency.org/

If your power costs $0.14/kwh and you improve the pump efficiency from 50 to 65% you can save about $3000 for the water required to irrigate 80 acres of pistachios. Improving the field uniformity with the increased flow by 15% can save another $4000 dollars in reduced water requirement and pumping. This spreadsheet is part of the above Excel file.

MICRO-IRRIGATION SYSTEMS MANAGEMENT FOR MAXIMUM EFFICIENCY

Okay, your irrigation designer/dealer guaranteed you a 92% distribution uniformity (DU) for your new micro-sprinkler orchard system. This means that when you apply a 1 inch average to the field that the wettest 25% of the field with the most pressure gets an average 1.09" and the driest 25% averages 0.92". Now it's 2 to 4 years later and you haven't checked the in-field pressure on the automatic subunit regulators (They're automatic, right?!), you haven't cleaned the hose screens at the "Tee", and you only flush hoses twice a year. A pilot valve on one of the regulators has silted up and is now unresponsive and the valve runs 10 psi higher than before. The exit port on another valve is partially plugged and causes the valve to partially close and drop the pressure to these hoses by 10 psi. Now your uniformity is down to 75%. Doesn't sound too bad until you realize that the wet area now gets 1.33" and the dry area only gets an average of 0.75". The driest 10% of the field will get less than 0.7" and the wettest 10% double that amount. This is a formula for "hull rot" and phytophthora in the wet area and defoliation in the dry area. I have seen this happen.

Most of Kern's irrigation districts help support the Mobile Irrigation Lab run by Brian Hockett of the NW Kern Resource Conservation District. This **FREE** service will evaluate the uniformity of your system and identify problems and possible corrections. Call Brian Hockett, 661-336-0967 ext. 138. For some tips on **Micro Irrigation Systems Tune-up** the link is: http://cekern.ucdavis.edu/files/53302.doc

SOIL MOISTURE and OTHER MONITORING TECHNOLOGY

In the study mentioned above we are using the neutron probe, Watermark electrical resistance sensors, Enviroscan capacitance probes connected to a PureSense data logger with a cell phone upload to the Internet, 2 different types of "above-the-canopy-heat-flux" weather station methods of estimating almond ET and we will cap it off with monthly satellite estimates of ET at the end of the season. Sounds like overkill? This is only a handful of what's out there. Five years ago, Google showed about 50,000 sites for *soil moisture monitoring*, now you get 549,000.

Whether you're hand probing, using tensiometers or any of the other "snapshot" techniques to estimate your water status, or you're using data loggers and get a picture of the dynamic changes of water movement in the soil you are mainly checking for two things: 1) The cycling of sufficient penetration and plant root extraction of water; usually to 3 feet for most permanent crops. 2) At least occasional monitoring of the lower end of the rootzone (say about 5 feet) to make sure you aren't saturated (over irrigation) or drying out (deficit irrigation).

A comparison of 8.4 gph versus 10.7 gph fanjets (2/tree) in almonds illustrated this concept perfectly. Irrigations were 24 or 48 hours. The soil was a Panoche sandy clay loam. We installed separate Watermark sensors (18, 36 and 60 inch depths) and an AM400 logger recording readings every 8 hours under each of the different flow rates. Starting the beginning of May there was not enough applied water from the 8.4 gph fanjets to penetrate to 18" in a 24 hour set given the high water use by the tree. The soil moisture tension (and water content) kept decreasing resulting in more stress, along with the 5 foot depth starting in June until the field receives a 48 hour set after harvest and the weather cools off. For the 10.7 gph fanjets the 18" depth showed clear wetting and drying all season but even with the increased flow the soil moisture at the 36 and 60" depths decreased starting in June and didn't fully recover until post-harvest. However, the soil moisture decrease at the 60" depth was very slight compared to the 8.4 gph jets – indicating that the 10.4 gph trees probably didn't stress and almost no water was lost to deep percolation. Readings for these charts were logged every 8 hours but hand auguring and tensiometers that you read once/week **and write down on a chart** could tell you the same thing.

Continuous monitoring with loggers is probably the most convenient and can be helpful in identifying pressure differentials in blocks and small losses to deep percolation that you can't see with "spot-check" methods; especially for shallower rooted veg crops or citrus. For a discussion of these benefits and a table of the different types of sensors download:

- **Making Sense of Soil Moisture Sensors** http://cekern.ucdavis.edu/files/53305.doc

REGULATED DEFICIT IRRIGATION (RDI)

The concept here is to find physiologic periods of crop development where water stress won't hurt the crop and can even benefit the development of certain characteristics. Wine grapes are the most famous for this as color and flavor of the grapes can be improved for most varieties by mild to severe stress in some cases. Of course, the more the stress the less the tonnage. Reduced ET means reduced CO2 assimilation and reduced carbohydrate production. This is why deficit irrigation for annual forage crops is not even an option since you get paid on the tonnage you produce.

RDI pros: Water stress through RDI has been shown to be helpful on increasing fruit set in canning tomatoes, decreasing "puff and crease" in late navels, reducing hull rot and advancing hull split in almonds and possibly weakening shell seal in pistachio to increase split percentage.

RDI cons: Deficit irrigation has also been shown to decrease second year yields of Early Beck navel oranges in Kern County (Craig Kallsen and I achieved this dubious result last year.), decrease nut size in the current year almond crop and decrease nut load the following year. It has also been shown to decrease split % and nut size/yield in pistachios.

Bottom line: RDI in almonds for decreasing hull rot is tricky. You have to put the trees into moderate stress (-14 to -16 bars) from the end of June to Nonpareil harvest, but it's easy to go too far and have the stress continue when you're trying to set next year's crop. Pistachios have the best window (right now, actually) to cutback on ET before nut-fill in August. You can save as much as 12" of water by using only a couple inches post harvest as well. Citrus growers usually manage their trees to get around 36 to 39" of water in a normal year. So you're not going to save much here. For a full discussion and additional links download:

- **Almond-Pistachio-Citrus Regulated Deficit Irrigation** http://cekern.ucdavis.edu/files/53306.doc

VEGETABLE IRRIGATION IN A DROUGHT YEAR

Joe Nunez, Vegetable Crops/Plant Pathology Advisor

With the potential of periods of power outages and the announcement of reduced water deliveries this year, proper irrigation of all crops is going to be challenging. Generally speaking, vegetables must receive adequate irrigation or yields will be reduced when crops become too stressed for water. The compounding effects of improper irrigation of vegetables due to periods of power shortages and reduced water deliveries will therefore be particularly difficult. However, there are some strategies that can be taken to minimize the impact of these upcoming problems.

- Vegetable yields can be severely reduced from insufficient water. Instead of using less water to irrigate the same amount of acreage, it may make more economic sense to reduce the planted area and use sufficient water on the reduced acreage.
- Select fields to plant with the best water-holding capacity. Heavy textured soils can hold more water, thus reducing the likelihood of water stress in the event of a power shortage that prevents a timely irrigation.
- Select fields that allow for good irrigation efficiency. Saline soils, fields with improper slopes, or fields with low spots are not efficient to irrigate, and it would be better to use the water wisely on land which can be irrigated more efficiently.
- Consider the efficiency of the application method. Furrow irrigation efficiency is greatest with rows of proper length. Rows which are too long may lead to over-irrigation of the ends of the field when sufficient water is applied to irrigate the center of the field, so shorter rows may allow more efficient irrigations. When using sprinklers, make sure that the sprinkler heads are in proper working order, that worn nozzles are not being used, and that all the nozzles are of the same size. Also replace any worn or torn rubber gaskets on the joints so water is not being wasted. These efforts will insure that water is being applied uniformly throughout the field, and is also critical for efficient chemigation.
- Weed control is always important, but during the trying times of reduced water deliveries and unexpected power outages, it becomes even more critical. Weeds compete with crops for nutrients, sunlight, and water. Water is too short in supply and too expensive to apply to share with unwanted weeds.
- Use tailwater recovery systems to reuse tailwater when possible. Tailwater is best used in furrow irrigation systems rather than drip or sprinkler systems.
- Irrigate according to the crop needs. Many vegetable crops are swallow-rooted and do not need to be irrigated much below a depth of twelve inches. Some crops, such as melons, are deep-rooted and can mine water from greater areas, requiring less frequent irrigations but longer application periods. Apply only enough water to refill the root zone. Irrigation budgets can be calculated using various charts and tables for different soil types and crops.

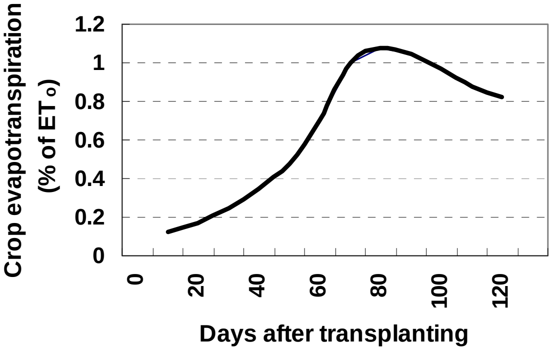
DEFICIT IRRIGATION STRATEGIES FOR PROCESSING TOMATOES

Tim Hartz CE Vegetable Crops Specialist, UC Davis. Submitted by Joe Nunez, Advisor

A variety of research projects on tomato irrigation conducted over the past 20 years can provide guidance to processing tomato growers looking for ways to stretch water resources. Here is a brief discussion of some important points:

1) What constitutes full irrigation? The consumptive use of processing tomatoes (the total amount of water transpired by the crop or evaporated from the soil) typically runs between 24-28 inches. Daily water use is driven by environmental factors [accurately represented by reference evapotranspiration (ET_o) values available for many Central Valley locations], and the degree of ground cover by crop foliage (heating by sunlight interception is a primary driving force for plant transpiration). Fig. 1 shows the typical pattern of crop evapotranspiration (ET_c) for a drip-irrigated processing tomato crop on which no water stress is imposed. The major difference with non-drip irrigated fields is that in the early season (before there is substantial foliage cover) sprinkler or furrow irrigation will increase evaporation from the wetted soil surface. By midseason crop water use can be slightly higher than ET_o, but as the crop matures water use tends to decline.

Fig. 1. Crop evapotranspiration of a drip-irrigated tomato field as a percentage of reference evapotranspiration (ET_o).



2) Imposing deficit irrigation: A tomato crop is most sensitive to water stress during fruit set, and attempting to save water by reducing irrigation during fruit set is strongly discouraged. Even moderate levels of soil moisture deficit during fruit set can substantially reduce that set, and induce blossom end rot. However, once fruit set is complete (roughly the time that the earliest fruits are reaching the mature green stage, typically 5-6 weeks preharvest), a substantial level of moisture stress can be imposed with minimal loss of productivity. Fresh fruit yield may decline a few tons per acre, but an increase in soluble solids concentration usually results in little or no decline in brix yield.

The degree of deficit irrigation possible without loss of brix yield depends on a number of factors, primarily soil water holding capacity and the presence or absence of a shallow water table. As is clear from Fig. 1, the average crop water use during the fruit ripening period in a fully watered field is approximately 80-90% of ET_o. Most fields can tolerate irrigation of only 40-60% of ET_o during this period with minimal problems; fields with high water holding capacity and good rooting depth may be able to deal with as little as 25% of ET_o over the final 6 weeks.

The ability to precisely control irrigation during the fruit ripening depends on the irrigation system used. For drip fields, controlling deficit irrigation is easy; simply reduce the hours of run to deliver the desired % of ET_o. Within the last 10-14 days before scheduled harvest drip irrigation can be terminated in most fields without severe stress. During deficit irrigation root intrusion in buried drip systems can be a problem, so be vigilant. If harvest is delayed, small irrigations can be made to keep the vines up.

With furrow irrigation it is more difficult to precisely control irrigation volume, and consequently the primary tool for late season water management has been manipulating the irrigation cutoff date, thereby saving one or more irrigations. Extensive trials in clay loam soils in Fresno County have shown that cutting off furrow irrigation as much as 40 days preharvest will have minimal effect on brix yield (although, as previously stated, fruit yield may suffer a small decline). Even on these forgiving soils, however, earlier cutoff can lead to substantial yield loss. In fields with soil of lower water holding capacity even 40 days preharvest can be too severe a treatment. Using an early cutoff strategy can be risky, particularly if harvest is substantially delayed.

3) Using a groundwater table: In fields with a water table within 2-3 feet of the surface, deficit irrigation can result in the crop drawing as much as several inches of water from the water table, allowing for a more severe irrigation cutback or earlier cutoff than would otherwise be appropriate for the field. If the water table is non-saline, late-season deficit irrigation poses little risk of serious yield decline. However, if the water table is saline, a much larger yield loss is possible with an aggressive irrigation cutback; also, deficit irrigation at the end of the 2008 season will leave the root zone with high EC, thereby increasing next year's water requirement.

4) Use of poor quality irrigation water: San Joaquin groundwater can be poor quality, making its use problematic for some crops. However, after the crop has been established, tomatoes are quite tolerant of high salinity irrigation water. Research at the UC Westside Center showed that, once flowering had begun, irrigating with drainage water of 8.0 EC did not affect fruit yield. The limited supply of high quality water can be used on other, less tolerant crops. Similarly, tomatoes are more tolerant of boron than most other common Central Valley horticultural crops, with water B concentration up to several parts per million causing little loss of productivity.

The bottom line is that irrigation reduction strategies for processing tomatoes should focus on water management during the fruit ripening period; any attempt to reduce irrigation earlier in crop development is likely to result in significant reduction in yield and/or fruit quality. Growers can take advantage of the relative salinity and boron tolerance of tomato by substituting lower quality groundwater, saving higher quality water for more sensitive crops.

VINEYARD MANAGEMENT IN A DROUGHT YEAR

Jennifer Hashim-Buckey, Viticulture Advisor

Water is a precious resource that is in short supply to San Joaquin Valley growers due to several consecutive years of below-average rainfall, low snow-melt runoff and a court-ordered restriction on water transfers to help save the Delta smelt. It is unclear what lies ahead for most Kern County grape growers regarding drought conditions, but some growers will have to make tough decisions about water use and crop production. Water management will be a key factor in efficiently using the limited supplies available. The following are some concepts to consider when tailoring irrigation programs to the current situation.

Grapevine water use varies throughout the growing season and is highly dependent upon canopy development and evaporative demand. Maximum vine water use is dependent on the final size of the canopy which is a function of the trellis and vine vigor; therefore, large vines grown on gable or overhead systems will have a higher requirement than vines with small canopies using a 1 or 2-wire system or small cross-arm.

Canopy development and the timing of fruit growth (for table grape vineyards) must be taken into account in developing a deficit irrigation strategy for vineyards. Water use by grapevines begins with bud break in early April and gradually increases as the canopy develops and evaporative demand increases. Vines require approximately 2.0 – 3.0 acre-inches of water from bud break to bloom in order to support canopy development. A full canopy should be developed before imposing a moderate water stress. This is particularly important for varieties that are susceptible to sunburn such as Redglobe and Thompson Seedless.

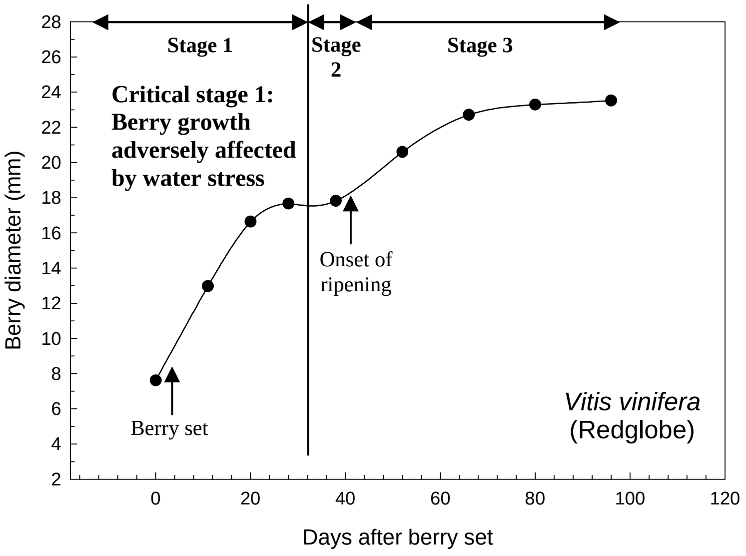


Fig. 1. The developmental pattern of fruit diameter (*V. vinifera* L. cv. Redglobe). Stage 1, 2 and 3 refer to the three stages of berry growth: 1, the initial phase of rapid growth; 2, the lag phase of slow or no growth; and 3, the final phase of resumed growth and ripening.

The degree to which berry growth is affected by water deficits is dependent upon the time when water stress is imposed. From bloom (early May) to veraison (late June-early July), grapevines use about 7.0 (small canopy) - 12.0 (large canopy, gable system) acre-inches of water. Proper water management is critical from bloom to approximately four weeks later, as berry growth is most susceptible to water stress during this period because cell division and expansion are occurring in young berries (Fig. 1). Therefore, if cell division is reduced by water stress at this time, final berry size and yield at harvest is reduced. Extra water applied later will not overcome a stress imposed during this critical period of berry growth.

The ripening phase covers the period from veraison to harvest and water use during this time varies greatly by variety and harvest date. For example, this period for Flame Seedless grown in early districts may only last 2-2.5 weeks ending with harvest the first week of July, while the period for Crimson Seedless in late districts may be as long as 2.5-3 months. Thompson Seedless, when harvested in early September, uses about 8.0 to 11.0 inches (depending on crop level and trellis system) during the 8 weeks it is in this phase. Regardless of variety, berry growth during this time is due primarily to cell expansion. It has been demonstrated that irrigations may be cut back (approximately 75% of full crop evapotranspiration (ET_c)) to pose a moderate stress subsequent to veraison with minimal or no effects on berry size or sugar accumulation. Therefore, if water supply is short and deficit irrigation is necessary during the ripening period, final yield and fruit quality will be less affected than if vines are stressed during the period of bloom to 4 weeks later. Furthermore, mild water stress during this period may be beneficial to promote color development and reduce berry cracking and bunch rot.

Water use during the post-harvest period, which concludes with dormancy (about mid-November), again varies with trellis type, variety and harvest date. Typical water use during this period for Thompson Seedless (harvested in early-September) ranges from 4.0 to 7.0 acre-inches of water. Water use during the post-harvest period is higher for varieties harvested earlier and lower for late-season varieties. In any case, irrigations at this time should be applied in amounts to maintain canopy but not encourage growth. Moderate water stress may be beneficial by stopping shoot growth and promoting wood maturity; however vines should not be allowed to defoliate. It is also worth noting the importance of a heavy irrigation during the dormant period in order to replenish the soil-water reservoir. Failing to irrigate post-harvest, whether by necessity or practice generally leads to poor bud break in the spring.

In conclusion, the total season's water requirement of a mature vineyard can vary greatly from 22.0 – 45+ inches depending on the variety, canopy size and trellis type and it is apparent from the discussion above that **the only time one does not want to impose a water stress is the period from bloom to four weeks later**. Furthermore, studies conducted on Thompson Seedless in the San Joaquin Valley have shown that there is a linear increase in berry weight as the amount of applied water increased from 0 to 80% of full ET when irrigating at that level all season long. It was also found that no additional increase in size is achieved when water was applied in amounts greater than 80% of full ET_c. Therefore, maximum berry size in Thompson Seedless can be obtained under mild water deficits.

A detailed Excel table featuring water use information for wine grapes, Flame Seedless and Thompson Seedless and Crimson Seedless on a gable trellis system grown in the southern San Joaquin Valley can be found online at http://cekern.ucdavis.edu/Irrigation%5FManagement.
