drought tips

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Irrigating Up Crops Efficiently With Sprinklers

How much water should be applied during a sprinkler irrigation — and therefore how long the run time should be — can be easily calculated if the crop evapotranspiration rate and reference evapotranspiration rates are known.

Evapotranspiration

When water evaporates (vaporizes) from a crop, the process is called *evapotranspiration*. Water evaporating from the plant surface or soil surface, is called *evaporation*. Water vaporizing inside the plant leaves and diffusing through leaf pores to the ambient air is called *transpiration*. Evapotranspiration (ET) is the sum of evaporation (E) and transpiration (T).

The evapotranspiration rate for a particular crop (ETc) is usually determined from the reference evapotranspiration (ETo) rate, which is an estimate of the evapotranspiration of a 4- to 6-inch-tall, cool-season grass transpiring at its maximum rate.

Reference evapotranspiration (ETo) rates are a measure of the evaporative power or demand of the environment. In addition to weather, irrigation frequency, plant height, plant roughness, canopy ground shading, plant-water relations, and crop age all affect ETc rates. Table 1 gives ETo historical averages for the areas shown on the California evaporative demand map (figure 1). Current ETo rates are available from the California Irrigation Management Information System (CIMIS). Local farm advisors can advise on how to obtain CIMIS data.

The ETc is calculated with the following formula, which adjusts the ETo to ETc with a crop coefficient (Kc):

$$ETc = ETo \times Kc. \qquad (1)$$

When ETc is calculated, ETo rates adjust for weather factors (evaporative demand) and crop coefficients adjust for other physical and biological factors.

Irrigation and rainfall frequency affect the ETc rate during the initial growth period — the period from planting until the crop canopy shades approximately 10 percent of the soil surface area. Together, the ETo rate and the presence of water on or near the soil surface are the principal factors determining ETc rates during the initial growth period. When the soil surface is wet, the ETc rate is typically at or slightly above the ETo rate. However, as the soil surface dries, less water is available for surface evaporation and the ETc rate drops relative to the ETo rate. When the evaporative demand is high, the soil dries rapidly and, as a result, the ETc rate declines relative to the daily ETo rate.

Calculating Net Applications

Initial growth period ETc rates for sprinkler-irrigated crops can be calculated using tables 1 and 2. First, find the appropriate evaporative demand area on the California map. Then, using table 1, estimate the ETo rate corresponding to that area and the initial growth period of the crop. Using table 2, find the ETo value in the left-hand column and locate the irrigation and/or rainfall recurrence interval (days to the next irrigation) at the top of the table. Select or interpolate to find the ETc value corresponding to the selected ETo and recurrence interval.

The net amount of water to apply is calculated by multiplying the selected ETc rate in inches per day by the irrigation frequency in days. If the irrigation water could be applied uniformly over the entire field, the required net application would be the amount to apply. But, since sprinklers do not apply water uniformly throughout the field, additional water must be applied to ensure that all areas receive adequate water. The gross amount of water to apply is determined from the required net application and an estimate of application efficiency.

Calculating Run Times

Calculate the gross amount of water to apply by dividing the required net application by an estimate of the sprinkler system's application

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efficiency, expressed as a fraction. Assuming no runoff occurs and the required net application is correctly determined, a sprinkler uniformity calculation can be used as an estimate of application efficiency. Many water districts, private consultants, and some public agencies will perform sprinkler system evaluations to determine sprinkler uniformity. Contact the local Cooperative Extension office for information on who performs sprinkler evaluation or for publications on how to perform your own tests. After the gross application amount has been calculated, the system run time is found by dividing the calculated gross application amount by the sprinkler application rate.

Sample Calculations

Given: Location: South Coast Interior Valleys
Initial growth period: April 1 - April 30
Sprinkler recurrence interval: 5 days
Application rate: 0.2 inches per hour
Application efficiency: 77 percent

ETo = 0.14 in/day (from table 1)
ETc = 0.10 in/day (from table 2)
Net application = (0.10 in/day) x 5 days = 0.50 inches
Gross application = (0.50 in)/0.7 = 0.65 inches
Run time = (0.65 in)/(0.2 in/hr) = 3.25 hours

Given: Location: Central Coast Coastal Valleys and Plains
Initial growth period: Sept. 15 - Oct. 15
Sprinkler recurrence interval: 7 days
Application rate: 0.2 inches per hour
Application efficiency: 70 percent

ETo = 0.12 in/day (from table 1)
ETc = 0.07 in/day (from table 2)
Net application = (0.07 in/day) x 7 days= 0.49 inches
Gross application = (0.49 in)/0.70 = 0.70 inches
Run time = (0.70 in)/(0.2 in/hr) = 3.5 hours

Additional Recommendations

The guidelines presented here will help irrigators avoid applying more sprinkler water than necessary during a crop's initial growth period. If the soil profile is wet, water applied in excess of what the soil can hold will percolate below the crop root zone and not contribute to crop production. These recommendations may reflect application amounts considerably below those used by many growers. Where this is true, run times should be gradually shortened and the crop and soil water content closely observed to ensure that crop yield or quality is not affected by the reduced application amounts.

Tensiometers are useful for monitoring the soil water status while run times are being shortened. If the tensiometer readings do not rise significantly and if no adverse crop effects are observed, the system run time can continue to be shortened. However, application totals should not fall below the amounts calculated from the procedure described in this leaflet. In high-salinity regions, gross application should be increased by 5 to 10 percent to provide for salt leaching.

References

California Department of Water Resources (DWR), 1975. *Crop Water Use in California.* Bull. 113-3, California Department of Water Resources. Sacramento, CA 94236-0001

Doorenbos, J. and Pruitt, W. O., 1977. *Crop water requirements.* FAO Irrigation and Drainage Paper 24. United Nations FAO, Rome.

Pruitt, W.O.; Fereres, E.; Kaita, K.; and Snyder, R. L., 1987. *Reference evapotranspiration (ETo) for California.* UC Bulletin 1922.

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Table 1. Estimated reference evapotranspiration (ETo) rates (inches/day) for geographic areas shown on the California evaporative demand map*

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	ETo (inches/day)											
1. North coast, coastal valleys and plains	0.02	0.04	0.06	0.08	0.11	0.12	0.11	0.11	0.09	0.05	0.04	0.02
2. North coast interior valleys	0.03	0.05	0.08	0.11	0.16	0.20	0.21	0.19	0.15	0.09	0.04	0.02
3. Northeastern mountain valleys	0.02	0.04	0.07	0.12	0.16	0.19	0.25	0.23	0.16	0.09	0.03	0.02
4. Sacramento valley floor	0.04	0.06	0.10	0.15	0.19	0.24	0.26	0.22	0.17	0.11	0.05	0.03
5. San Joaquin valley floor	0.03	0.06	0.10	0.15	0.21	0.25	0.25	0.21	0.16	0.11	0.05	0.02
6. Central coast interior valleys	0.05	0.08	0.11	0.14	0.18	0.21	0.22	0.19	0.16	0.12	0.08	0.05
7. Sierra Nevada foothill valleys	0.04	0.06	0.09	0.14	0.19	0.24	0.26	0.23	0.18	0.11	0.05	0.03
8. Central coast, coastal valleys and plains	0.06	0.08	0.10	0.13	0.15	0.16	0.17	0.15	0.13	0.10	0.07	0.05
9. South coast, coastal valleys and plains	0.06	0.09	0.10	0.13	0.15	0.17	0.18	0.18	0.15	0.11	0.09	0.06
10. South coast interior valleys	0.05	0.09	0.11	0.14	0.16	0.20	0.22	0.22	0.17	0.12	0.08	0.06
11. Southern California desert	0.09	0.13	0.19	0.25	0.33	0.38	0.37	0.31	0.28	0.20	0.12	0.06

* Actual ETo rates vary within each zone and can be adjusted upward or downward depending on the local climate relative to average for the region. A monthly ETo rate more than 10 percent above or below the values listed would be unusual. ETo values for winter months in snow-covered high Sierra valleys are lower than those listed in the table. The evaporative demand map was developed by the California Department of Water Resources (DWR). Sources for the ETo data include: DWR Bulletin 113-3 and Pruitt et al. (1987).

Table 2. Daily crop evapotranspiration (ETc) rates (inches/day)* for young (< 10% cover), sprinkler-irrigated crops for a range of reference evapotranspiration (ETo) rates and irrigation and/or rainfall frequency.

	Average irrigation and rainfall frequency - days									
ETo	2	4	6	8	10	12	14	16	18	20
(in/day)	ETc (inches/day)									
0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02
0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.02
0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
0.08	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03
0.09	0.09	0.08	0.06	0.04	0.04	0.04	0.04	0.04	0.03	0.03
0.10	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04
0.11	0.11	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04
0.12	0.11	0.09	0.08	0.06	0.05	0.05	0.05	0.04	0.04	0.04
0.13	0.12	0.10	0.08	0.07	0.05	0.05	0.05	0.04	0.04	0.04
0.14	0.03	0.11	0.09	0.07	0.04	0.05	0.05	0.05	0.04	0.04
0.15	0.14	0.11	0.09	0.07	0.06	0.05	0.05	0.05	0.04	0.04
0.16	0.14	0.12	0.09	0.07	0.06	0.05	0.05	0.05	0.05	0.04
0.17	0.15	0.12	0.10	0.07	0.06	0.06	0.05	0.05	0.05	0.04
0.18	0.16	0.13	0.10	0.08	0.06	0.06	0.05	0.05	0.05	0.04
0.19	0.17	0.13	0.10	0.08	0.06	0.06	0.05	0.05	0.05	0.04
0.20	0.17	0.14	0.11	0.08	0.06	0.06	0.05	0.05	0.05	0.04
0.21	0.18	0.14	0.11	0.08	0.06	0.06	0.05	0.05	0.05	0.05
0.22	0.18	0.14	0.11	0.08	0.06	0.06	0.05	0.05	0.05	0.05
0.23	0.19	0.15	0.11	0.08	0.06	0.06	0.05	0.05	0.05	0.05
0.24	0.20	0.15	0.12	0.08	0.06	0.06	0.06	0.05	0.05	0.05
0.25	0.20	0.16	6.12	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.26	0.21	0.16	6.12	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.27	0.22	0.17	0.12	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.28	0.22	0.17	0.13	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.29	0.23	0.17	0.13	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.30	0.23	0.18	0.13	0.09	0.06	0.06	0.06	0.05	0.05	0.05
0.31	0.24	0.18	0.13	0.09	0.06	0.06	0.06	0.06	0.05	0.05
0.32	0.24	0.19	0.14	0.10	0.06	0.06	0.06	0.06	0.05	0.05
0.33	0.25	0.19	0.14	0.10	0.07	0.06	0.06	0.06	0.05	0.05
0.34	0.26	0.19	0.14	0.10	0.07	0.06	0.06	0.06	0.06	0.05
0.35	0.26	0.20	0.14	0.10	0.07	0.07	0.06	0.06	0.06	0.05

*The ETc rate depends on the average ETo rate (from table 5) and irrigation or rainfall frequency. The daily ETc rate is multiplied by the number of days since the last irrigation to yield the net irrigation requirement (from figure 6 in Doorenbos and Pruitt [1977]). An irrigation or rainfall of 2, 4, 6, etc.indicates that irrigations or rainfall occur every second, fourth, or sixth day.

Figure 1. California evaporative demand map