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Fog interception. Photo courtesy Sandro Tedde Photography.

DROUGHT TIP

Fog Contribution to Crop Water Use

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How much water should be applied per irrigation depends on the crop water use, also called crop evapotranspiration (ETc). The ETc is made up of water vaporized from the plant and the soil surface (evaporation) and water vaporized inside the plant leaves and diffused through leaf pores to the ambient air (transpiration). The rate at which evaporation and transpiration occur depends principally on the amount of energy available to vaporize (evaporate) the water. This energy comes from directly from sunlight and indirectly as heat from the air and soil.

- If the plant surfaces are dry, the energy is used for transpiration, and most of the evaporation comes from the soil.
- If the plant surfaces are wet, a portion of the available energy is used to vaporize surface water, so there is less energy for transpiration, and the reduced transpiration diminishes the loss of soil water from the root zone.

The quantity of water vaporized from the plant surfaces is related to when the plant surfaces dry off during the day. The longer that plant surfaces are wet during the day, the more that fog contributes to ETc.

As fog passes through a crop, some of the water is intercepted by and coats the plant, much like light rainfall. In fact, the fog contribution to crop water use should be considered effective rainfall, since it contributes to ETc. In some regions, fog interception by crops can be appreciable and should be taken into account in determining how much irrigation water is needed for a crop. Evaporation of intercepted fog reduces transpiration losses because the energy is used to vaporize water on the surface rather than water inside the leaves that comes from the soil. Thus, during foggy periods, using the ETc to directly estimate the loss of soil water will result in an overestimation of how much irrigation to apply.

No known scientifically based method exists to measure fog contribution to crop water use, but since all fog intercepted by the crop contributes to crop ET, an estimate of the fog contribution can be made from the daily ET rate and from the time of day that fog interception dries from the crop.

Estimating Fog Contributions

Figure 1 shows an approximation for normalized daily cumulative ETc and the time of day (PST) that intercepted fog dries off a crop. The cumulative ETc was normalized so that easy adjustments can be made for changing ETc rates during the year. The figure 1 model was tested using reference ET (ETo) data from thirty CIMIS sites in California (see Moratiel et al. 2012), assuming that ETo and ETc are somewhat similar.

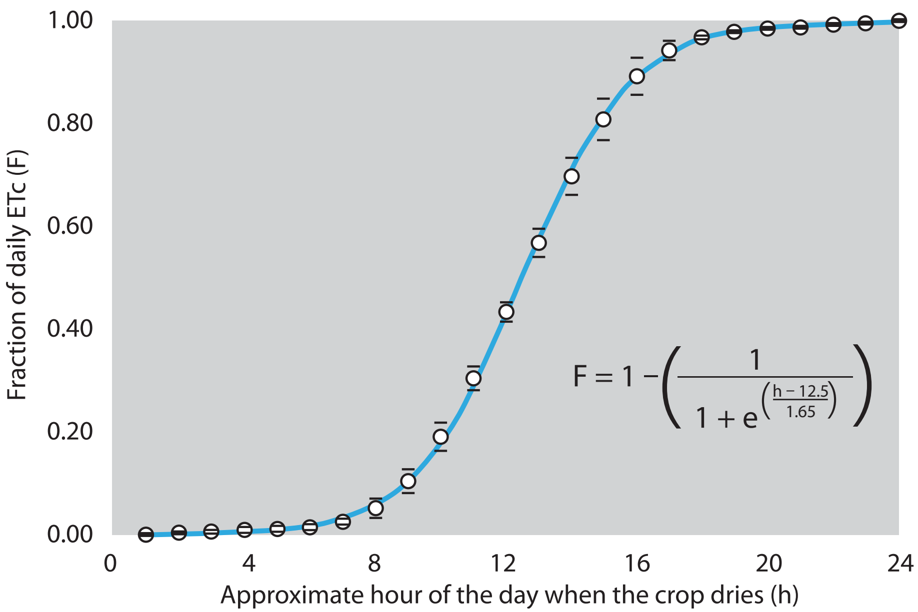

Figure 1. Fog contribution fraction (F) corresponding to the hour of the day (h) that intercepted fog dries off a crop.

Fog contributions can be estimated on a daily, weekly, monthly, or seasonal basis for planning irrigation water needs using cumulative ETc over the period of interest. An estimate of ETc is determined using reference evapotranspiration (ETo) and the proper crop coefficient (Kc) as

$$ETc = ETo \times Kc. \quad [1]$$

Crop coefficient (Kc) values for many California crops are available in the BIS irrigation scheduling program. The BIS program, which is written in MS Excel, can help with the calculation of daily crop coefficient (Kc) values and crop evapotranspiration (ETc). The BIS program and documentation are available at the U.C. Davis Biometerology Program website, http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm.

Average ETo data are publicly available online through the California Irrigation Management Information System (CIMIS) website, http://wwwcimis.water.ca.gov/. A user can select a weather station close to their site and retrieve data, which include measured parameters such as ETo, solar radiation, air temperature, soil temperature, relative humidity, and wind speed, and derived parameters such as vapor pressure and dew point temperature.

To estimate fog contributions, follow these steps:

- Step 1. Observe the approximate time of day that the intercepted fog dries from the crop surfaces.
- Step 2. Using the fog contribution graph (fig. 1), determine the fraction (F) of daily ETc corresponding to the time of day when the plant leaves dry.
- Step 3. Calculate the daily fog contribution to ETc as

$$C = F \times ETc. \quad [2]$$

Monthly or seasonal fog contributions are calculated the same way, using average ETc and average drying time for the time period of analysis.

If part of the available energy for ET is used to evaporate intercepted fog from the surface of a crop, there is an equivalent reduction in water loss due to transpiration (vaporization that occurs inside of the leaves). The water for transpiration is withdrawn from the soil by the roots, so reducing transpiration leads to a decline in the loss of soil water. Therefore, if the ETc and the fog contribution to ET is known, the daily change in soil water content (ΔSW) is estimated as

Design: the code Δ stands for an uppercase Greek letter delta, which looks like a triangle.

$$\Delta SW = ETc - C. \qquad [3]$$

To simplify the determination of ΔSW, we can combine equations 2 and 3 to get

$$\Delta SW = ETc\ (1-F). \qquad [4]$$

The daily ΔSW values are totaled between irrigation dates to estimate the cumulative soil water depletion.

The required net irrigation needed equals the cumulative soil water depletion, unless a different target dryness level is selected. This is the amount one would need to apply if water were distributed equally over the entire area. Because irrigation systems do not apply water evenly across a field, however, additional water is commonly applied to ensure that the entire crop receives adequate irrigation.

Sample Calculations

Sample 1

Given: A crop has an ETc of 0.20 inches per day and fog interception from the previous night that dries by about 10:00 a.m.

The fraction of ETc from the fog contribution in Figure 1 is F = 0.20. From eq. 2, the fog contribution is

$$C = 0.20 \times 0.20 = 0.04 \text{ inches.}$$

Using eq. 4,

$$\Delta SW = 0.20\ (1 - 0.20)$$
$$= 0.16 \text{ inches.}$$

Sample 2

Given: A crop has an average ETc of 0.15 inches per day over a 30-day period and the fog interception typically dries off the leaves at about 11:00 a.m.

The fraction of daily ETc from the fog contribution in figure 1 is F = 0.30, and the fog contribution is

$$C = 0.30 \times 0.15 = 0.045 \text{ inches}$$

and the mean daily ΔSW from Eq. 4 is

$$\Delta SW = 0.15\ (1 - 0.30)$$
$$= 0.105 \text{ inches per day.}$$

The soil water loss over 30 days is

$$\Delta SW = 30 \times 0.105 = 3.15 \text{ inches.}$$

Drought Tips on Irrigation Scheduling

The ΔSW information is used to determine irrigation schedules. Guidelines on how to schedule irrigation are described in "Drought Tips" available from the University of California Cooperative Extension. A link to the listing of "Drought Tips" is at the website http://www.anrcatalog.ucdavis.edu/Items.aspx?hierId=260525. Additional documents and programs on irrigation scheduling are also available at http://biomet.ucdavis.edu/irrigation-scheduling.html.

References

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