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DROUGHT TIP

Irrigating Citrus with Limited Water

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Citrus is an evergreen perennial tree fruit that covers about 260,000 commercial acres in California, with 140,000 acres of navel orange cultivars and nearly equal acreages (about 40,000 acres each) of Valencia oranges, lemons, and mandarins (USDA 2015). Citrus is also one of the state's most common backyard fruit trees. As an evergreen in California's Mediterranean climate, with wet winters and dry summers, citrus requires some water all year long. In wetter areas of the state, much of this water requirement may be met by winter rainfall; but in most of the state for much of the year, citrus must have supplemental water. Depending on the cultivar and rootstock, citrus can sustain certain levels of drought stress (Romero et al. 2006). Proper irrigation system design, installation, maintenance, and scheduling, combined with applying adequate water during critical periods while reducing water during less-critical periods, can help citrus orchards continue production during times of water shortage or drought.

Irrigation Requirements for Citrus

Plants open their stomata to take up carbon dioxide, which also allows the release of water by transpiration. There is a one-to-one relationship between plant growth and water loss: plants must lose water in order to grow. Any time a plant is water stressed, its growth is reduced. With fruiting plants, the yield and size of the fruit is closely tied to the plant's total biomass. During certain periods of a plant's growth, some water stress can be sustained without reducing fruit yield or quality. In some cases, water stress may improve fruit quality, such as by reduced creasing and granulation of the fruit (Goldhamer and O'Connell 2006).

Citrus is sensitive to salinity, both total salinity and specific salt elements such as boron, chloride, and sodium. Water applications must not only meet the transpiration needs of the crop but also must leach the accumulated salts from previous irrigations, as well as naturally occurring soil salts, from the root zone. Depending on irrigation water quality, the total applied water may represent as much as 25% more than the transpirational water needs of the citrus crop. As drought persists, the quality of well water often diminishes, and greater amounts of water must be allocated to leaching; also, salt from irrigation water accumulates faster because there is less high-quality rainwater for leaching in the winter months.

Depending on the location and weather patterns, a significant portion of citrus trees' water needs can be met by rainfall and even fog in some areas along the coast. In most cases, however, it must be met by supplemental water through irrigation. In the Central Valley and desert regions, weather patterns tend to be more consistent, and in many years irrigation can be almost on a calendar schedule; however, along the coast, weather tends to be more erratic, and scheduling is less easily done by calendar. Irrigation requirements for citrus can be 4 acre-feet per acre in the desert regions, 3.5 acre-feet per acre in the Central Valley, and 1.5 acre-feet per acre along the coast.

Irrigation System Design and Maintenance

To meet the needs of citrus trees and to help save limited water, an irrigation system must be properly designed and evaluated. Evaluation of the system should occur at least once a year and certainly after harvest, when damage to emitters is common. In areas where there is damage from coyotes, gophers, rabbits, and other animals, evaluation must be part of regular maintenance.

An irrigation system design should include pressure regulation, especially in uneven topography. Irrigation blocks should be created so that similar-sized trees with similar water requirements are irrigated together. If the system is too large and there is too much pressure loss, the system should be resized or new valves installed so that pressure is even throughout the blocks.

The efficiency of an irrigation system is indicated by its distribution uniformity (DU). A DU of 100% means that every emitter is putting out exactly the same amount of water. If the DU is low, the system must run longer to provide all trees with enough water, but this will cause some trees to get more water than they need, which may not be good for the trees and also wastes water. Pressure losses in lines and uneven terrain can make it impossible to achieve 100% DU, but 80% is attainable and 95% is not unheard-of. Even in well-designed new systems, clogging and leaks can rapidly reduce DU; the way to ensure a high DU is through annual monitoring and regular maintenance. It is critical that the irrigation system be maintained to ensure that the DU of each emitter is satisfactory. This means fixing clogged, broken, or damaged emitters; cleaning filters in a timely fashion; and pruning tree skirts to create an even spray pattern. Many irrigation districts and resource conservation districts have mobile labs that will come to a farm and measure irrigation system performance, often at no charge. (For a further discussion of DU and how it is measured, see Faber and Goldhamer 2014.) Finally, it goes without saying that water should be kept on the orchard, so eliminate runoff. If there is runoff, find out why. Are there gopher or ground squirrel holes? Is the application rate higher than infiltration? Are lines or emitters broken? Is the wind or canopy disrupting the spray pattern? Are weeds or windbreaks competing with the trees? Correct the situation to ensure that the applied water is going to the trees.

Irrigation System Management and Scheduling

Irrigation scheduling is critical. Do not apply more water than the tree's root zone can hold: the extra water cannot be used by the tree and also leaches nutrients from the root zone. Key in knowing how much water to apply is knowing the rooting depth of the trees. Depending on the rootstock, citrus can be fairly deeply rooted, but the bulk of the active roots are in the top 2 feet of soil. Deeper roots can mine water from winter rains, but active irrigation depths should rarely exceed 2 feet unless irrigation is being applied for leaching. A soil sampler or steel rod can be used to assess the depth of an irrigation by inserting it into the soil and following the wetting profile. When the wetted area exceeds 2 feet deep, it is time to turn the irrigation off. The depth of irrigation needs to be assessed only a few times in order to determine the depth of infiltration for a given irrigation run time.

Monitoring sensors such as tensiometers or conductance sensors can help time irrigation to match the tree's water need and the amount of water applied. The sensors should be placed so that a shallow one tells you when to begin irrigation and a deeper one tells you when to stop. Scheduling can also be done using evapotranspiration information, for example, from the California Irrigation Management Information System (CIMIS, http://www.cimis.water.ca.gov/) or your own personal weather station or atmometer. Some growers also use plant-based measures such as dendrometers or leaf water potential devices, which tend to be more labor intensive. Various other soil moisture measuring devices, such as tensiometers, conductance and capacitance probes, have also been used to determine irrigation schedules; a discussion of these tools can be found in Faber 2014.

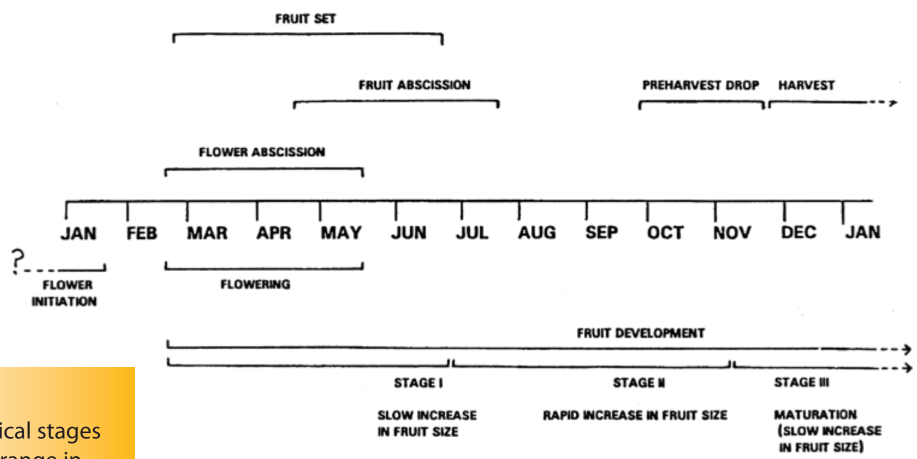

Figure 1. Phenological stages of navel orange in California. *Source:* Lovatt 1999.

Regulated Deficit Irrigation

Citrus responses to irrigation water deficit have demonstrated that the sensitivity of yield to water stress depends on the physiological phase in which water stress was applied (fig. 1). Adequate water supply is of major importance during citrus flowering and fruit set. A second critical period coincides with rapid fruit growth, from fruit set to harvest. Water stress in the first period increases abscission of flowers and young fruit, and water stress in the second period reduces fruit size. In the first period, soil moisture from even scanty winter rain might be sufficient to help reduce tree water stress. However, irrigation may be necessary during this period, and it will certainly be required during the period of rapid fruit growth.

When faced with water shortages due to drought, you can supply 50 to 75% of the crop evapotranspiration estimates during the tree and crop development phases, when trees are most sensitive to water stress, in an effort to minimize the impacts on production. Ensuring adequate water during the critical periods while reducing water during less-critical periods is called regulated deficit irrigation.

For navels and mandarins, it is possible to identify the critical periods when water is required. In other citrus cultivars, however, the critical periods may overlap. For example, Valencia orange can have two crops on the tree at the same time from spring into summer harvest, and coastal lemons can have fruit in all stages from fruit set to fruit maturity at all times of the year. In the case of navels, reducing applied water by 25% or more has resulted in no reduction of fruit yield when the water reductions occur during non-critical periods (Goldhamer 2006; Domingo 1996; Hutton et al. 2007). Water reductions during the rapid expansion period can result in significant fruit size reduction, though, and water should not be withheld during this period if fruit size is critical to marketing (Goldhamer 2006; Hutton et al. 2007).

In the case of coastal lemons, water stress should be avoided during the period of rapid expansion, to ensure that the most profitable crop, the summer one, is least affected. Each grower should identify the time of year in which the most profitable fruit size is important. Growers in areas that have more summer heat than the coast might practice a "Verdelli" irrigation practice, in which water is withheld for a time in order to force flowering that can often yield more summer fruit for harvest the following year (Maranto and Hake 1985).

Although the full range of soil and plant monitoring devices has been used to assess water stress in trees, the most accurate tool for identifying stress is a pressure chamber. This device can be used on leaves to ascertain when and how much stress the trees are sustaining. Once the level of stress has been determined, an irrigation schedule can be designed to avoid water stress in the critical periods.

Regulated deficit irrigation has been somewhat limited in the field because of the need to install and maintain instruments, sample trees on a regular basis, and interpret the data to decide when to apply water. Often, water deliveries or the needs of other irrigated areas do not allow for the flexibility needed to use this technique.

More Drastic Measures

Canopy Management

Canopy management can reduce the rate of water use because transpiration is essentially a function of the amount of leaf surface present. With no leaves, there is no transpiration and no water use. The extreme case is tree removal. When canopies are pruned, water use is reduced. Most citrus produces terminal flowers, so pruning also reduces yield, but pruning also typically increases fruit size as competitive fruit growing points are removed. There is a balance between yield reduction and tree water use; typically, a 25% canopy reduction results in a 25% decrease in tree water use (Romero 2006).

The severity of the drought will determine how severely the canopy should be trimmed. For example, with no irrigation, the trees can be skeletonized so that only the main structural branches are left (the trees should be whitewashed to prevent sunburn). As the trees leaf out, gradually apply water in small amounts, checking the soil moisture to make sure the trees do not get too much or too little water. If trees are pruned in the winter, they usually flower a year later in the spring, but it can take 3 years for the trees to recover their previous yields.

Skeletonizing should be practiced first on the poorest-producing orchards. Citrus orchards that get too much wind and have substantial wind scarring or elevated water use are the most prone to frost damage and other problems such as fruit theft. In areas that are healthy and a new cultivar has been contemplated, topwork and replace the old cultivar (fig. 2). Also, remove orchards that have produced poorly due to disease.

Canopy sprays of kaolinite clay have shown some promise in reducing transpiration with negligible yield reduction (Skewes 2013; Wright 2000). If kaolinite clay is used, it should be done under the advisement that the packing house can remove the clay.

Figure 2. Navel orange trees skeletonized, whitewashed, and grafted. *Photo:* D. Rosen.

With a reduced canopy often come other benefits besides water reduction. Spray coverage for pest control is improved. Because new growth is generated by the root system, fertilizer applications can be significantly reduced or eliminated altogether for a year until fruit set recommences.

Replanting

When faced with the uncertainty of water supply and cost, growers must decide whether an orchard is economically feasible. Is it prone to frost, disease, or wind scarring? Has it been a poor producer? A production cost study from the UC Davis Department of Agricultural Economics may help in this decision (see http://coststudies.ucdavis.edu/en/current/).

When replanting an orchard, it may be necessary only to remove individual unproductive trees. If the whole orchard is to be removed and a new crop is be planted, the best decision from a disease-prevention standpoint is to plant a crop subject to a different group of diseases, such as almond, walnut, pomegranate, etc.

When interplanting an orchard or replacing an orchard with more citrus, rootstock should be a major consideration. Each rootstock has its strengths and weaknesses (see the UC Riverside Citrus Variety Collection website, http://www.citrusvariety.ucr.edu/citrus/rootstocks.html). Take drought tolerance into special consideration. Rootstocks with greater rooting volumes and depths typically have more drought tolerance; for example, Swingle citrumelo has a greater drought resistance than trifoliate (Romero et al. 2004).

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