

DROUGHT TIP

Drought Strategies for California Prune Production

In 2014, about 50,000 acres of prunes were grown in California (California Dried Plum Board, 2014). The Sacramento Valley is the leading prune growing area in the state, producing about 80 percent of the crop. Madera, Fresno, and Tulare Counties in the San Joaquin Valley also produce prunes.

California growers and handlers are recognized worldwide for production and marketing of large, high-quality prunes. The growing season is warm with little or no rainfall. Consequently, large amounts of irrigation water are required. When water availability is less than the amount of water desirable to produce the crop, carefully regulated deficit irrigation (RDI) becomes critical to production of the best crop possible. An RDI strategy minimizes the impacts of a water shortage on fruit size, yield, and quality. Under severe water shortages, RDI may not be feasible and the primary objective might be to simply keep the trees alive. In this Drought Tip, we discuss strategies that can help prune growers make the most effective irrigation decisions for using the water they have. The discussion will encompass a wide range of water supply availabilities, from no shortage to severe shortages.

Evapotranspiration (ET), Tree Growth, and Fruit Development

A Sacramento Valley prune orchard with a commercial yield of 3 to 4 dry tons per acre (Buchner et al. 2012a) will use about 42 inches of water (3.5 acre-feet) per acre per year (Fulton et al. 2014). Most of the water is transpired through the leaves during photosynthesis and some is lost through evaporation from the orchard floor. The sum of these losses is called *evapotranspiration (ET)*.

Leaves “trade” water to acquire CO₂, with which they make carbohydrates, the raw material for tree growth and fruit development. Maximum carbohydrate production occurs in leaves that are exposed to full sunlight when soil moisture is not limiting. When transpiration is limited by a reduction in soil moisture available to the tree’s roots, photosynthesis declines. Tree growth, yield, fruit size, and fruit quality may be negatively affected, depending upon the severity of the stress.

Fruit development begins with bloom and pollination (figure 1). “Improved French” prune, the main variety grown, generally begins to bloom about March 1 to 20, depending upon location in the state. In most years, the bloom period is

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compact, lasting about 7 to 10 days if the previous winter resulted in adequate chill accumulation and if warm temperatures occur at bloom. Near the end of bloom, small green fruit are visible as the “jackets” fall and they begin to grow in April and May. Fruit sizing (dry weight accumulation) continues at a relatively steady rate through June, July, and August, and then plateaus at harvest, which occurs from mid-August to early September depending on location and year. Fruit are mature when fruit sugar peaks and the fruit soften to the point that only 3 to 4 lb of pressure is needed to puncture the skin of the fruit. No sugar is transported to the fruit once it is mature, but dehydration may cause the sugar concentration to increase slightly before harvest.

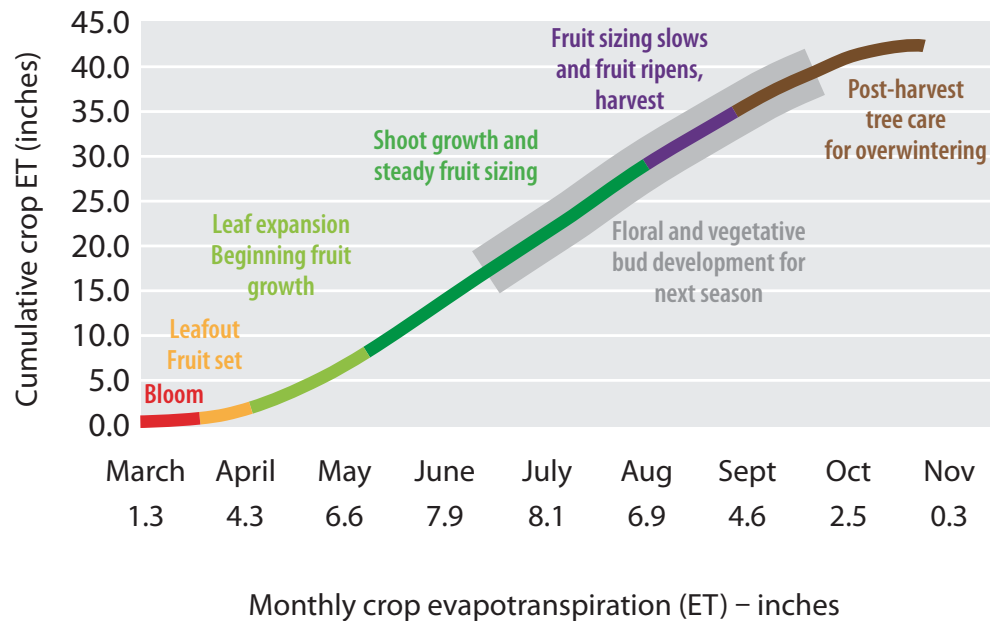


Figure 1. Cumulative and monthly breakdown of average annual crop evapotranspiration (ET) for prunes and the corresponding tree growth and fruit development stages.

Vegetative development begins shortly after full bloom (figure 1), usually in late March. Vegetative buds break and leaves, shoots, and spurs grow and mature. Leaves with spurs are fully expanded by April 30, bringing the trees up to their full orchard ET. Shoot elongation decreases by early June as fruit sizing becomes the dominant sink for carbohydrates. New fruit and flower buds are initiated in June and July on current-season growth. New bud development renews fruit wood and sustains consistent production. Preventing leaf drop during the season is also important to prevention of branches from sunburn. Sunburned limbs form cracks and wounds that are common entry points for fungal disease.

After harvest (figure 1) in mid-September and until leaf drop in late October or early November, healthy leaves are still photosynthesizing and, with nitrogen absorbed by the trees’ roots, building carbohydrate and nutrient storage within woody tissue. These reserves are important for winter tree health and for growth the following spring. Sufficient carbohydrate storage also influences the next season’s bloom and subsequent fruit retention.

Irrigation management affects all of these different phases of tree and fruit development, as well as preparation of trees for overwintering by enabling water to transpire out and carbon to enter the trees. Beneficial drought management strategies will minimize the interruption of plant transpiration and photosynthesis and its effect on tree and crop development.

Prerequisite for Drought Management: Evaluating Green Fruit Set and Crop Thinning

Prune trees typically “over-crop,” setting too many green fruit to allow for good fruit size and quality at harvest. Over-cropping occurs when the prune tree canopy cannot capture adequate sunlight to generate enough carbohydrates to adequately nourish the developing crop. An individual tree may set in excess of 10,000 green fruit. In comparison, depending upon the orchard, the tree’s canopy and leaf area may only be able to supply sufficient carbohydrates to size 2,500 to 3,500 green fruit to commercially acceptable levels. Consequently, California prune growers thin the fruit in May to balance the crop load with the trees’ performance potential.

Water management is critical to successful commercial prune production. An over-cropped prune orchard with limited water application may generate a sparse leaf canopy, producing small prunes of poor quality. Large amounts of low-quality and low-value fruit add weight on the tree limbs that compromises tree structure, expose bearing limbs to sunburn, and create entry points for diseases to infect the trees and threaten their long-term viability. Prune crop load is a key component and can be manipulated to make any drought management strategy more successful. Crop thinning (figure 2) is a practice that improves fruit quality and value so that, even though the crop yield may be limited by a water shortage, the trees will still produce valuable, marketable fruit. Crop load management also prevents damage to the trees' structure and a higher potential for diseases that may persist long after the drought ends.



Figure 2. Green fruit removal from a representative prune tree to assess thinning needs. Fruit are hand-picked and dropped on to canvas tarps. They are gathered and weighed. The total number of fruit on the tree is estimated based upon the total weight of all fruit picked from the tree and the weight of a 100-fruit subsample.

Irrigating Prunes When the Water Supply Is Enough to Match 100% ET

ET for a productive prune orchard is about 42 inches annually (figure 1). Applied irrigation water is typically less than seasonal ET, since soil storage contributions from winter rainfall and in-season precipitation also supply plant-available water. In the main prune production regions of the Sacramento Valley, annual rainfall ranges from about 12 to 24 inches and is concentrated between November and May. Therefore, the maximum annual irrigation water requirement for prunes, when the regional water supply is adequate and no deficit is imposed, is usually about 32 to 36 acre-inches per acre (2.7 to 3.0 acre-feet/acre). Soil storage and in-season rainfall contributions are likely to be lower in the prune-growing regions of the San Joaquin Valley, where annual rainfall is lower (about 6 to 12 inches), so the maximum annual irrigation water requirement there may be higher, in excess of 36.0 acre-inches (3.0 acre-feet).

If soil moisture is monitored and used to determine the amount of irrigation required to satisfy 100% of ET demands, irrigations should be managed to prevent plant-available soil moisture from dropping below 50% of ET demand in an approximate 3-foot root zone. If orchard (tree) water stress is measured with a pressure chamber on the basis of midday stem water potential (SWP), crop stress levels should be sustained above -12 bars (Fulton et al. 2014).

Irrigating Prunes with a 20% Reduction in Water Supply (80% ET)

A 10 to 20% reduction in irrigation water supply to prunes works out to a reduction of about 4 to 8 inches ($\frac{1}{3}$ to $\frac{2}{3}$ acre-foot per acre). This level of reduction can be managed to have relatively minor impacts on prune production if you choose the stages of tree and fruit development that are least sensitive to reduced irrigation and target those stages for irrigation cutbacks.

Mid-August, when the fruit mature, is the period least sensitive to deficit irrigation (Goldhamer et al. 1990; Lampinen et al. 1996). Fruit sizing is complete at this point in the season and research has shown that deficit irrigation during this period

can increase soluble solids (sugar content) in the fruit and reduce drying costs at the fruit dehydrator. ET in an unstressed prune orchard during the last 2 weeks of August is about 3.5 inches (figure 1). Imposition of an RDI strategy during this phase has the potential to save 2 to 3 inches of irrigation water, with no harm to the crop. Monitoring orchard stress with a pressure chamber and keeping tree stress in the -16 to -20 bar range is a reliable way to realize this water savings while guarding against too much tree water stress, which might affect bud development or cause canopy defoliation.

Continuing deficit irrigation for 2 to 4 weeks after harvest presents an additional opportunity to manage with limited water supplies. The fruit have been harvested and are not at risk. ET in an unstressed orchard in September and the first 2 weeks of October will total about 6.0 inches (figure 1). By employing regulated deficit irrigation, you can save 3 to 4 inches of water during this phase of tree growth. Care should be taken to limit extreme water stress (MSWP of -20 to -30 bars) after harvest in order to discourage disease infection and spread as well as poor carbohydrate allocation. A brief window of opportunity for water reduction has also been identified in late April and early May, after pollination and prior to the onset of steady fruit sizing, when irrigation may be delayed to conserve water (Goldhamer et al. 1990). While the negative effect of deficit irrigation during this stage of fruit development is relatively low in comparison to deficit irrigation later on in fruit sizing (in June and July), final fruit size was still about 10% smaller than with 100% ET.

Irrigating Prunes with a 20 to 50% Reduction in Water Supply (50 to 80% ET)

A 20 to 50% curtailment in irrigation water supply equates to 8 to 21 inches ($\frac{2}{3}$ to $1\frac{3}{4}$ acre-feet per acre) less plant-available water. The probability that these levels of reduction will impact long-term prune yield and decrease current-year fruit quality increases as water deprivation increases. If the reduction in water supply is closer to 20% of full ET, implementation of the previously described deficit irrigation strategy—reduced irrigation in the weeks just

ahead of and just after harvest—may still be effective at minimizing impact on commercial production. However, additional strategies will need to be implemented if the water shortage approaches 50% of full ET.

As the available water supply is reduced, more after-harvest irrigation may need to be limited. For example, you may need to limit irrigation to 1 to 2 inches in September following harvest and then terminate irrigation entirely for the rest of the year. This has the potential to save about 6 inches of water during the late phase of the season (figure 1). For larger water cutbacks, irrigation after harvest may need to be eliminated completely in hopes that fall rainfall will be sufficient for the trees. It may even be necessary to start the period of deficit irrigation in early August or even late July (when the green fruit are in their later phases of fruit sizing). This would have the potential to save approximately 10 to 12 inches of water (figure 1). When faced with water supply reductions nearer to 50 percent, earlier decisions concerning crop load management become very important to achieving marketable fruit size, preventing exposed tree branches, reducing sunburn, and avoiding disease issues.

As available water becomes severely limited, an economic assessment of each orchard's performance may be appropriate. The production history of each orchard and its cost of production should be evaluated. The goal is to identify those orchards that consistently produce higher yields of larger prunes per acre-foot of water and other production inputs. Decisions would then be made to apply more of the limited water supplies to the more efficient orchards in order to sustain their production. Lesser-producing orchards would have a lower priority for receiving limited water, and the principle goal for those orchards may become simple survival of the trees rather than prune production.

Severe Reductions in Water Supply for Prunes (0 to 50% ET)

Irrigation water supply reductions of this magnitude will inevitably affect orchard production. Possibly the best strategy would be to simply have orchard survival as your goal until water supply conditions improve. Fruit production would not be the main

objective when facing this level of water supply curtailment. An orchard that is subjected to this level of reduction in water supply will take two or more seasons of normal irrigation to get back to prune production levels similar to those achieved prior to the drought.

If field research conducted in almond (Shackel et al. 2012) is a reasonable indicator, it may be possible for a prune tree to survive a season with as little as 6 to 8 inches of water. In the Sacramento Valley prune production regions, soil moisture recharge from winter rains may provide this minimum amount of water. In lower-rainfall production regions of the San Joaquin Valley, however, about $\frac{2}{3}$ acre-foot irrigation water per acre may be required to achieve tree survival. Any supplemental irrigation that can be provided to an orchard beyond this bare minimum for tree survival should be allocated proportionally to ET throughout the season in order to minimize the incidence of extremely high levels of water stress.

Thinning fruit more than normal to lessen the crop load and weight on tree limbs is even more important to maintaining tree structure in severe drought conditions, but it will not reduce the orchard's ET. Thinning should help shade fruit-bearing wood for the next season and protect it from sunburn and secondary diseases.

Other Drought Management Practices

When growing prunes under a severe water supply curtailment, the best strategy may be to do nothing drastic in terms of pruning or other practices that you might expect would relieve water stress. In almonds, the pruning of scaffolds to reduce the canopy size and transpiration surface did not give the trees any advantage in managing the drought and it delayed the trees' recovery to their full production potential after drought conditions ended, since new shoots and fruit wood had to grow in order to return the trees to their previous size and fruit-bearing surface. Applications of light-reflecting materials did not make any difference in almond crop stress, and a similar lack of response is likely for prunes.

Severe, extended droughts may also prompt you to consider removal of lesser-producing orchards, with an eye toward preparing the land for eventual replanting and establishment of more productive orchards. In situations where the reliability of the water

supply has become very tenuous, annual crop production may make more sense than a permanent crop like prunes. With annual crops, you have the option of fallowing a portion of the farmlands during an enduring drought.

Cover crops and excessive weeds will increase an orchard's ET as they compete for plant-available water, so orchard floor vegetation management is an important consideration when managing for drought. Water use can be as much as 25 percent higher when vegetation is growing vigorously in the orchard middles.

Proper irrigation system design, coupled with regular system checks and maintenance, is essential to managing scarce water supplies. A pressurized irrigation system that is not properly designed or maintained has the potential to apply more than twice as much water in areas of the orchard closest to the pump and filter pad than in areas of the orchard furthest away. This has the potential to result in serious overirrigation in some parts of the orchard and severe underirrigation in others. Monitor for pressure losses across your irrigation system, check and fix broken parts regularly, and flush hose lines often. Consider the possible need for chlorination to control algae and bacteria clogging and for acidification to control mineral plugging of micro-irrigation emitters if you find problems with water flow and application uniformity.

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