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DROUGHT TIP

Drought Strategies for California Walnut Production

ALLAN FULTON, University of California Cooperative Extension Irrigation and Water Resources Farm Advisor, Tehama, Glenn, Colusa, and Shasta Counties; and RICHARD BUCHNER, University of California Cooperative Extension Orchard Farm Advisor, Tehama County

California walnut production currently totals about 325,000 acres of bearing and nonbearing orchards. California growers and handlers are recognized worldwide for the production and marketing of high-quality in-shell and shelled walnuts. When walnut production is profitable, planted acreage increases by converting lower-value crops or previously nonirrigated lands to walnut orchards. Some new orchards are developed at more marginal locations. Precision irrigation technology has allowed planting at locations previously thought to be unsuitable for walnut production. Most important, the success of California walnut production depends upon irrigation.

This Drought Tip discusses tree and walnut development stages and corresponding water use, along with the impacts that water deprivation can have on production, and suggests strategies and practices to make the most effective irrigation decisions with the available water.

Evapotranspiration (ET), Tree Growth, and Fruit Development

Walnut trees that consistently produce economical yields with good kernel quality require about 40 to 42 inches (3.3 to 3.5 acre-feet) of water per acre annually (Goldhamer 1998; Lampinen et al. 2004; Buchner et al. 2008). Most of that water is transpired through the leaves, while some is lost through evaporation from the soil surface. The sum of these two processes is evapotranspiration (ET).

Leaves trade water for carbon under full sun to make carbohydrates, the raw material for tree growth and fruit development. Maximum carbohydrate production occurs in leaves exposed to full sunlight with an adequate water supply. If transpiration is limited by lack of water, photosynthesis declines, compromising tree growth, walnut yield, and quality.

The walnut growing season in California begins about April 1 and ends by mid November (fig. 1). Phenology dates depend on the variety, year, and location. Tree growth and walnut development occur simultaneously during the season.

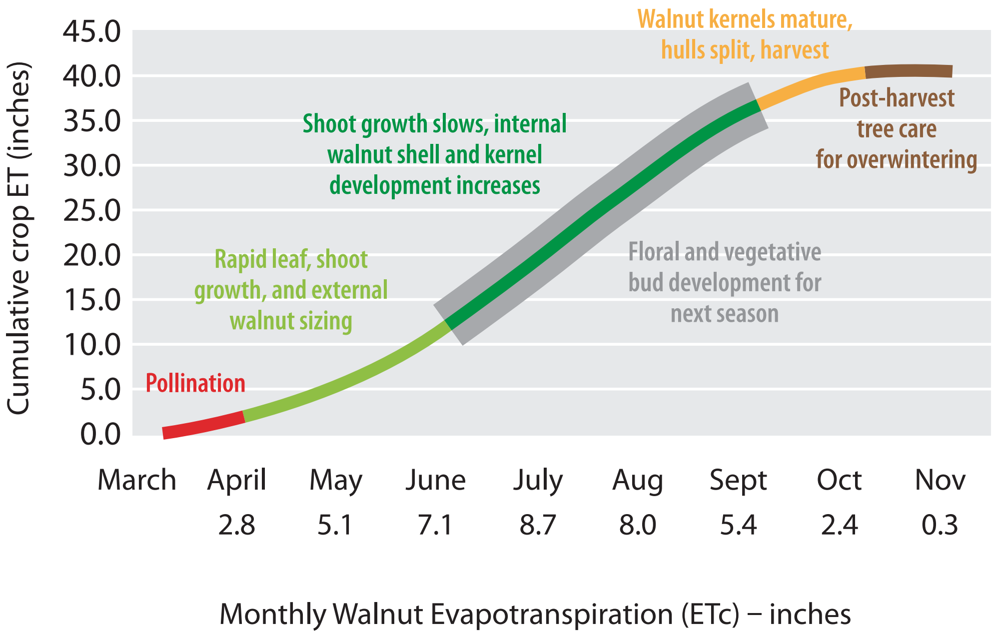

Figure 1. Cumulative and monthly breakdown of average annual crop evapotranspiration (ET) for walnuts and the corresponding tree growth and walnut development stages.

The season begins with flowering and pollination (see fig. 1). Chandler, a major walnut variety, generally blooms about April 1, depending on the year and location in the state. Other walnut varieties may bloom as early as March 15 or as late as April 15. In most years, Chandler pollination is usually completed by mid April. Nut growth follows pollination, and the green walnuts reach full external size by early June. Shell hardening determines final nut size. Kernel fill begins in late June and continues through mid-September. Chandler walnuts generally reach maturity by mid to late September, when the packing tissue surrounding the kernel turns brown. About 3 weeks after kernel maturity, the green hulls split. Mechanical harvest begins in early to mid October.

Walnut differs from other deciduous trees such as stone fruits in that leaves emerge and the canopy develops before and during pollination. Most leaves are fully expanded by the end of May, resulting in full ET, with crop coefficients at or above 1.0.

New tree shoots grow in May and June. This growth is important for walnut production because it supports new flower buds for the following year. Water stress and/or leaf defoliation as a result of underirrigation during these summer months has been shown to reduce the number of floral buds and walnut production for the following season. Shoot growth usually decreases in late June as developing walnuts become the principal demand, or sink, for carbohydrates. After harvest, healthy leaves photosynthesize and replace carbohydrates and nutrients that have been used to produce walnuts. These reserves are critical to prepare trees for dormancy and to support growth and production the following year.

Irrigation management affects all phases of nut and tree development. Beneficial drought-management strategies must minimize the interruption of plant transpiration and photosynthesis and its effect on tree and nut development.

Effective Drought Management Strategies

Regulated deficit irrigation (RDI) strategies, which withhold water at specific growth stages, have not proven to be as effective in walnut as in other perennial crops such as almond, pistachio, prune, wine grape, or oil olive. For these crops, properly timed and controlled levels of water deficit have decreased the amount of water applied and benefitted production or crop quality. In walnut, water curtailments at any growth stage affect crop productivity and quality.

Frequently irrigated Serr walnut trees were compared with nonirrigated trees on a deep clay loam soil with a high water-holding capacity (Brown et.al. 1977). Moisture stress decreased yield by 43% and nut size and kernel quality declined.

A 6-year study showed that the production of Chico walnut declined 20 to 40% when trees were supplied irrigation water at 33% and 66% of ET (about 14 and 28 inches); irrigation cutbacks were applied uniformly throughout the growing season across all tree and walnut development phases (Goldhamer et.al. 1991). Two years of irrigation at full ET were required before the walnut trees returned to near-normal yield potential.

A 6-year study in two Chandler walnut orchards in the Central Valley revealed different responses to irrigation cutbacks (Fulton et. al. 2014). Irrigation cutbacks were imposed in both orchards as bud development and kernel fill stages began in late June and continued through October. The total irrigation water applied ranged from 100% to 52% ET (42 to 22 inches). Conclusions depended on location and tree development. The San Joaquin County experiment involved mature (20- to 25-year-old) unpruned trees at 49 trees per acre on a deep alluvial soil with high water-holding capacity. Irrigation curtailments did not affect walnut yield until the third consecutive year, when yields were 20% lower than trees that had no irrigation cutback. The impacts of withholding irrigation water were swifter and greater in a younger (9- to 14-year-old), mechanically hedged (81 trees per acre) Chandler orchard in Tehama County grown on shallow soils with a lower water-holding capacity. Walnut yield and kernel quality was reduced significantly after 2 consecutive years of cutbacks, and declines in production accumulated to over 40% after 4 straight years of cutbacks.

In the Tehama experiment, when full irrigation was resumed on trees where water had been maintained at 65 to 70% ET for 4 consecutive years, yields recovered close to full production levels in that same (fifth) year. Two years of normal irrigation was not required, as was the case in earlier research (Goldhamer 1991). This appeared to result from sustaining shoot growth through May and June by delaying moderate crop water stress until mid-August through October. Flower buds on the new shoot growth were not fruitful during the seasons in which water was cut back; yields declined, but they appeared to remain viable and became fruitful during the first season that normal irrigation resumed.

A new experiment (Shackel et.al. 2015) is ongoing in a Chandler orchard in Tehama County. This experiment is designed to evaluate withholding irrigation water from pollination through the spring period of rapid shoot growth and external nut sizing. In the first season, the initial irrigation was delayed as much as 50 days and total applied water was reduced to 24 inches, or about 60% of ET. Yield was not immediately affected, but nut size was reduced by 10% in the most extreme cutbacks. Long-term effects of these delays in irrigation startup and cutbacks in total applied water must be evaluated in the future.

Irrigating Walnuts When the Water Supply Can Match 100% ET

The ET for mature California walnut orchards is about 40 to 42 inches annually. Applied irrigation water is typically less than annual ET because soil storage contributions from winter rainfall and in-season precipitation also supply water to meet annual ET. North of Sacramento, annual rainfall ranges from about 12 to 24 inches from November to May. It is possible for about 15 to 35% of the annual ET to be supplied from soil storage and in-season rainfall. Therefore, the maximum annual irrigation water needed by Sacramento Valley walnuts, when the regional water supply is adequate and no deficit is imposed, is about 28 to 36 acre-inches per acre (2.3 to 3.0 acre-feet/acre). Soil storage and in-season rainfall contributions toward the seasonal ET of walnut are likely to be lower in the walnut-growing regions of the San Joaquin Valley or farther south, where annual rainfall is lower (about 6 to 12 inches) and the maximum annual irrigation water needed may be higher, possibly exceeding 36 acre-inches (3.0 acre-feet/acre).

If water is applied to satisfy 100% of ET demands, irrigations should be managed to prevent the measured plant-available soil moisture from dropping below 50% in a root zone of approximately 5 feet. If orchard water stress is measured using midday stem water potential (SWP) with a pressure chamber (fig. 2), crop stress levels should be maintained in the –4 to –8 bar range throughout the season (Fulton 2014).

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

A 10 to 20% reduction in irrigation water supply to walnuts equals a shortfall of 4 to 8 inches (1/3 to 2/3 acre-foot per acre). To minimize impacts on walnut production, gradually withhold water and allow slightly more crop stress during kernel development, nut maturity, harvest, and postharvest. The ET in an unstressed walnut orchard from early July through November is about 24 inches, so the strategy would be to gradually curtail irrigation by 4 to 8 inches during

Figure 2. A pressure chamber on which the digital gauge shows –6.6 bar tree stress. Some walnut growers use this device to detect tree water stress and determine irrigation needs. *Photo: R. P. Buchner.*

this time. Monitoring orchard stress with a pressure chamber and keeping tree stress in the –5 to –9 bar range can save 4 to 8 inches of water while minimizing the impacts to the trees and crop. The most likely effect of this level of irrigation shortfall spread across the summer and fall months would be a higher incidence of darker kernels and slightly lower edible kernel yields.

Irrigating Walnuts 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 (2/3 to 13/4 acre-feet per acre) less available water. The probability of impacting long-term walnut yield and decreasing the current year's nut quality is more likely as the water shortfall increases. If the reduction in water supply is closer to 20%, implementing the previously described deficit irrigation strategy (gradually reducing irrigation during kernel filling, harvest, and after harvest) may still be effective.

As the available water supply is reduced and approaches 50% ET, cutbacks during kernel fill, harvest, and after harvest may need to be to be larger. Monitoring orchard stress with a pressure chamber and keeping tree stress in the –6 to –10 bar range can realize 12 to 14 inches of water savings while minimizing the impacts to tree growth and nut production. Higher incidence of darker kernels and lower edible kernel yields are distinct possibilities with this level of deficit. Bud fruitfulness in next year's crop may also decline as a result of the water shortage.

If even greater cutbacks in applied water must be made to manage a 50% curtailment, an additional 4 to 6 inches of water may be saved, for a total of 16 to 20 inches of water savings, by delaying the beginning of irrigation in the spring from late April or early May for 2 to 3 weeks until late May. Monitoring orchard stress with a pressure chamber and delaying irrigation until the tree stress approaches –6 to –8 bars can achieve this early-season water savings. Water deprivation at the start of the season will likely reduce nut size and result in a higher percentage of medium and small walnuts at harvest. By implementing this strategy, water cutbacks will be avoided in late May and June. Encouraging shoot growth and early bud development might lessen the recovery time to full production when adequate irrigation water supplies become available.

When available water is severely limited, an economic assessment of each orchard's performance may be appropriate. The production history of each orchard and the cost of production should be evaluated. The goal is to identify orchards that consistently produce higher yields of large, sound walnuts per acre-foot of water and other production inputs. Decisions would then be made to prioritize limited water supplies to the more efficient orchards to sustain their production. Lesser-producing orchards would be lower in priority to receive limited water. The main goal in lower-producing orchards may become to manage tree health with less emphasis on walnut yield and quality.

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

At severe reductions in water, impacts on walnut tree growth and crop yield and quality are unavoidable. A simple management strategy is to allocate the available water supply proportionally across all tree and walnut development phases during the season. For example, if the irrigation water availability is 21 inches per acre

Figure 3. Mini-sprinkler irrigation, a common method of irrigating walnuts. *Photo: A. Fulton.*

(1.8 acre-feet per acre, or about 50% of ET), the strategy might be to apply 50% of the monthly ET levels shown in figure 1. Also, consider monitoring tree water stress and attempt to keep pressure chamber levels between −8 to −12 bars as much as possible.

Irrigation water supply reductions of this magnitude inevitably affect orchard production. The best strategy may be to manage tree condition and orchard survival until water supply conditions improve. Walnut production would not be the main objective when faced with this level of water supply curtailment. If an orchard is subjected to this level of reduction in water supply, it will take 2 or more years of normal irrigation to achieve yields similar to those achieved prior to the drought.

Other Drought Management Options

If research in almonds is a reasonable indicator for walnut, when growing walnuts under a severe water supply curtailment, the best strategy may be to do nothing drastic in terms of pruning. Pruning scaffolds to reduce the canopy size and transpiration surface may not show any advantage in managing the drought and may delay the recovery of trees to their full production potential after the drought ends. New shoots and fruitwood must to be grown to return the walnut trees to their original size and fruit-bearing surface. Applications of light-reflecting materials did not make a difference in almond crop stress, and a similar response is anticipated for walnuts.

Severe, extended droughts may also represent a period to consider removing lesser-producing orchards and preparing the land for replanting at a later date to establish more-productive orchards. In situations where the water supply reliability has become very tenuous, annual crop production may make more sense than replanting a permanent crop such as walnuts. With annual crops, fallowing a proportion of the farmland is an option for enduring droughts.

Cover crops and ineffective weed control increase orchard ET levels, so orchard floor vegetation management is an important consideration when managing drought. Water use can be as much as 25% higher when vegetation is growing vigorously in the orchard middles.

Proper irrigation system design coupled with regular system checks and maintenance are essential to managing scarce water supplies. A pressurized irrigation system that is not properly designed or maintained can apply more than twice as much water in areas of the orchard close to the pump and filter than in areas of the orchard farther away. This can result in serious overirrigation in some parts of the orchard and severe underirrigation in others. Monitor for pressure losses across the irrigation system, check and fix broken parts regularly, and flush hose lines often. Consider the need for chlorination to control algae and bacteria clogging and acidification to control mineral plugging if these are a concern.

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E-mail: anrcatalog@ucanr.edu

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