2021 Pistachio Irrigation: Mitigation Strategies for Drought

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The San Joaquin Valley is in the midst of another drought and pistachio growers are bracing for another hot, dry growing season. Areas on the west side of San Joaquin Valley, got as little as 4 inches of precipitation from fall 2020 until April 2021. With such low moisture reserves, many growers may be seeing signs of stress early. In Westland's Irrigation District, some managers are reporting water delivery costs higher than $1200 per acre foot. For those using groundwater on the west side, pumping costs can range between $200-500 per acre foot depending on production of the well and water levels. Additionally, drought conditions lower canal levels and increase the salt concentration of what is normally high-quality water. Decreasing flowrates, and changes to the chemical and biological characteristics of the water may impact the actual application rate and distribution uniformity of microirrigation systems.

Limited water supplies and increasing costs will lead to tough decisions about when is the most beneficial time to irrigate. Pistachios are known for their ability to withstand drought, but the severity and length of a dry spell can result in high percentages of blanks, low shell splitting percentages, and reductions in overall yield. These negative impacts can be partially mitigated through good water budgeting strategies, monitoring tree water stress levels, and implementing drought management techniques such as proportional decreases in water application throughout the season or regulated deficit irrigation at different stages in crop development.

Water budgeting plus soil moisture monitoring is an irrigation management strategy that is useful during normal precipitation years and during drought to minimize water stress damage to tree health, growth, and nut crop quality. A water budget considers the amount of irrigation needed to replace water losses from transpiration by trees and vegetative cover and evaporation from the soil surface, known in combination as evapotranspiration (ET). Irrigation is needed when estimated or actual ET exceed water inputs, and soil moisture storage. The goal of the water budget is to apply the correct amount of water, at the right timing and frequency to maintain soil 'available water' between field capacity, and 'overdraft' stress levels below management allowable depletion (MAD) that will adversely impact the crop (Figure 1).

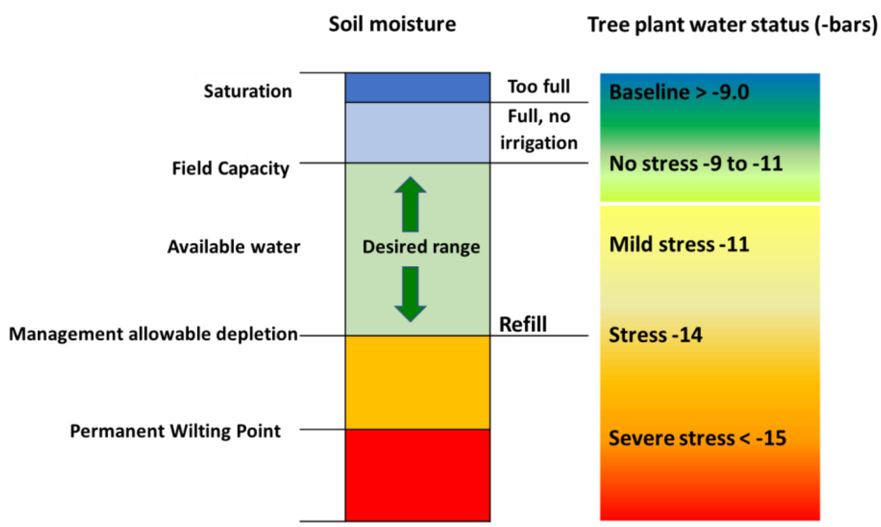

Figure 1. Relationship between different levels of soil moisture availability and plant water stress. Water budgeting techniques aim to maintain soil moisture in the desired range between field capacity and ~50% total soil available water. Severe drought limitations may require moisture just above the threshold of management allowable depletion.

Table 1. Average available water-holding capacity (W_a) for various soil textures. Adopted from the UC ANR Drought tips "Field Irrigation water management in a nutshell" *https://anrcatalog.ucanr.edu/pdf/8571.pdf*

Soil		W_a (inches of water per foot of soil)
General description	**Texture class**	
light, sandy	coarse sand	0.5
	fine sand	0.9
	sandy loam	1.2
medium, loamy	fine, sandy loam	1.5
	loam	1.8
	silt loam	2.0
heavy, clay	clay loam	2.2
	clay	2.4
	peat/muck	6.0

Source: Modified from U.S. Bureau of Reclamation, Agrimet Irrigation Guide website, (https://www.usbr.gov/pn/agrimet/irrigation.html).

In drought conditions, managers may attempt to proportionally decrease water applications to maintain soil moisture levels just above the MAD threshold for crop limiting water stress. For fruit and nut trees, the MAD value is estimated to be 50% of total available water.

Developing an efficient irrigation schedule requires knowledge of the soil characteristics of the site. The depth of soil considered for a water budget changes dependent on the 'effective rooting depth', the portion of soil from which trees extract most of their soil moisture and nutrients. For pistachios grown with microirrigation, this is generally the top 3 feet of soil. Available water holding capacity within the 'effective rooting depth' is an important consideration for water budget irrigation scheduling. The amount of 'available water' to the plant, is commonly shown as the inches of soil moisture per foot of soil (inches/foot). Inches of available moisture varies dependent soil texture (Table 1). Sandy loam soils, for example, hold less water (1.5 inches/foot) than clay loam soils (2.2 inches/foot), and will require a shorter time interval between irrigation sets to maintain soil moisture levels in the desired range (above the MAD) to avoid severe tree stress. Applying more water than the soil can hold or at a faster rate than it can infiltrate may lead to leaching, water logging, runoff from berms, and increase water loss from evaporation.

In addition to texture, soil structure, sodicity and salinity levels, the presence of restrictive layers in the subsoil, the soil rock content, soil organic matter content, and spatial variability of these characteristics across the orchard also influence available soil water. Knowledge of these characteristics for a particular orchard site is important to accurately schedule irrigations. Locations with high levels of spatial variability of soil properties may have uneven soil moisture availability. These sites can be managed by adjusting the frequency and depth of water applied for individual designated zones to maximize water use efficiency and productivity across the orchard. A site-specific soil analysis for the effective rooting zone (top 3') will provide the most accurate information, but online resources can also provide a useful broad characterization of the location. The UC Davis California Soil Resource Lab "Soilweb" application provides general soil texture with an interactive Google map https://casoilresource.lawr.ucdavis.edu/gmap/.

Online Water Budgeting and Irrigation Scheduling Resources

There are several online resources available to make the water budgeting and irrigation scheduling decision making much easier. CropManage is an online decision support and management tool that can be customized to site-specific conditions of an individual orchard and can track fertilizer and irrigation applications throughout the year. Forecast ET_o (FRET) National Weather Service is another useful tool that anticipates the coming week's atmospheric water demand, helping growers to adapt to week-to-week weather variability. Another option developed through a cooperation between the Department of Water Resources (DWR) and UCCE provides weekly ETc reports for a variety of orchard trees and other major crops. The reports deliver the previous weeks ETc and the projected ET for the following week based on historical records from CIMIS weather stations throughout the Central Valley. Contact your local UCCE farm advisor for more information about how to access the DWR-UCCE weekly ET reports.

Monitoring tree stress levels

Irrigating according to a water budget and soil moisture monitoring does not provide information about how orchard trees respond to the applied water schedule. Pressure chambers and other newly available automated technologies offer a plant-based approach to understand if plant stress is within acceptable levels. These tools deliver a measure of the negative pressure of water in the tree, known as mid-day stem water potential (SWP), which is compared to known values for water stress. At high soil water content, tree roots easily extract soil moisture. As the soil dries moisture becomes increasing difficult to extract, increasing plant stress.

The range of tension measurements for pistachio is generally between -6.0 and -20.0 bars, where a more negative value indicates increasing water stress. At field capacity, pistachios in moist soil may have tree mid-day SWP values between -9 and -11 bars. As the soil dries, mild stress develops between -11 and -14 bars. Values more negative than -15 bars point to growth and yield reducing levels of moisture stress (Figure 1). However, research suggests the threshold for stress tolerance under deficit irrigation management may be lower (more negative) at different stages of crop development (see next section).

When measured just prior to watering, mid-day SWP can be used to determine if soil moisture storage from the previous irrigation was sufficient to carry the trees through to the next irrigation set without reaching potentially detrimental stress levels. After watering, they can also confirm whether the prescribed irrigation adequately relieved stress. When used to fine tune irrigation scheduling in multiple regulated deficit irrigation studies in different regions and varieties of pistachio, pressure chamber measurements allowed decreasing water applications by 18-23% without a reduction in nut yield or quality. More information about the pressure chamber and its operation can be found in UC ANR publication 8503 https://anrcatalog.ucanr.edu/pdf/8503.pdf

Regulated deficit Irrigation

Throughout the growing season, different stages of crop development are more or less sensitive to water stress. Multiple studies have found controlled deficit irrigation during shell hardening (Stage II) from the middle of May until the end of June, and during the post-harvest period had little or no negative impact on production. The right level of deficit will vary depending on many factors, but in general about 50% of ETc (the maximum crop ET with no water limitation for a well- drained soil) with mid-day SWP values between -15 and -18 bars during this time could result in significant water savings without adverse yield impacts. Water stress should be minimized during the shell expansion (Stage I), which occur during the first two weeks of May, and the nut filling (Stage III) phase of crop development beginning around late June. Severe stress from late June through mid-September will likely reduce harvestability and can also decrease shell splitting. More information can be found on the UC Drought Management webpage:
http://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Pistachios/

Saline locations

Pistachio trees are known for their salt tolerance and much of the acreage they are grown on have naturally high salt levels. However, these trees do have salt tolerance limits. Irrigation water exceeding 4.5-7 dS/m EC is probably not sustainable for the long term, especially if salinity challenges are coupled with poor soil drainage. Shifting water quality and limited supply in a drought year can intensify salinity problems. Recent UC research found salt affected soil resulted in lower yields but also lower water use. When salinity levels are very high, trees are subjected to osmotic stress, meaning they are working harder to take up and transpire water. As salt concentrations increase around the roots there is less solute differential between the root sap and the soil water, which reduces the ability of the root to pull in water by osmosis. More information about understanding soil and water reports and managing salinity can be found here: http://www.wcngg.com/2020/08/06/choosing-amendments-for-effective-salinity-management/

Saline-sodic conditions reduced average daily actual ET (ET_a) by about 33% in a salt affected site compared to non-saline orchards. However, the differences in water use were not constant throughout the growing season. Salt-affected trees had the same ET_a as non-saline sites earlier in the season through shell hardening (Stage II), but then the water use per unit of canopy cover decreased during kernel fill through the postharvest season. Despite the potentially lower water requirements during the growing season, salt affected orchards will require additional water to leach salts from the rootzone during dormancy. Therefore, the overall amount of water needed to produce a crop in salt-affected areas needs to account for the necessary leaching fraction.

Irrigation System Evaluation and Maintenance

Commonly used in pistachio plantings, microirrigation systems allow for careful management and timing of water and nutrient applications. Although highly efficient, there are almost always varying levels of distribution uniformity (DU) in different areas across an orchard block. The small openings of micro-emitters make these irrigation systems highly susceptible to clogging and require routine maintenance. Changes in water sources during drought years can result in unexpected problems stemming from poor water quality. Annual water tests are recommended to make informed decision on water treatment to keep irrigation systems performing adequately. Irrigation system evaluations are mainly advised to determine the actual application rate (in/hr) and DU for accurate irrigation scheduling and water applications. Doing so will also enable managers to address small problems in a timely manner and ensure the best water use efficiency possible. http://micromaintain.ucanr.edu/

Summary

Pistachios are known for their ability to withstand drought, but severe water shortages during critical stages of crop development can result in high percentages of blanks, low shell splitting percentages, and reductions in overall yield. Regulated deficit irrigation targeted at different stages in crop development may significantly reduce water use and mitigate detrimental water stress impacts to the crop. Much of pistachio growing acreage is located on salty ground. Saline sites have recently been shown to reduce water use by one-third relative to the amount used by pistachios growing on non-saline ground. Irrigation managers should consider site specific information about salt levels and soil texture when creating an irrigation schedule. Water budgeting, soil moisture and tree water stress monitoring techniques, irrigation system evaluations and routine maintenance should be implemented to increase irrigation scheduling precision. There are free online resources available to schedule and track irrigation applications throughout the year. Contact your local UCCE farm advisor for more resources to implement water-saving techniques during drought.