Heatwaves and Avocados

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It is undeniable that our climate is changing and as a result our weather is becoming more erratic. For California avocado growers this is resulting in more frequent, hotter and longer duration heat waves. It is true that heat waves are nothing new to California avocado groves, but these events used to occur a few times per season with temperatures peaking over 100°F for a few hours in the afternoon. In recent years, heat events have become more common, often lasting for several days in a row, and temperatures have been documented to reach 100°F and stay above that temperature for 8 hours or more in numerous groves.

What Happens to an Avocado Tree During a Heatwave?

Under normal conditions, an avocado tree is extracting water from the soil through its roots, which moves through the tree and exits through leaf pores known as stomates. Stomates can open and close to regulate the flow of water vapor out of a plant and the entry of carbon dioxide for photosynthesis. The opening and closing of stomates is driven by plant hydration, temperature, relative humidity and wind. The loss of water from a plant's leaves through the stomates acts as an evaporative cooler, maintaining leaf temperature close to that of air temperature.

The purpose of closing leaf stomates under high temperature and/or low humidity is to slow the movement of water from the soil, through the plant, to the atmosphere. If this "flow" is too rapid, the water column — which is under very high tension — can snap, resulting in the formation of an air bubble (embolism) in the water conducting tissue (xylem) of the plant. These air bubbles are nearly irreversible and can lead to permanent damage to the plant.

Avocados evolved in a very moderate subtropical climate where temperatures rarely exceed 85°F and rainfall is abundant. As a result, they are poorly adapted to the high temperatures and low humidity that is common in California. Research conducted in California and Australia looked at the leaf function of avocados in Irvine, Riverside (Hass) and in the Murray Valley, Victoria (Fuerte). What they found is that avocado photosynthesis dropped off and stomates closed during the afternoon when air temperatures rose above about 85°F (Figure 1).

During a heatwave, the avocado tree's response is to close its stomates to prevent excess water loss and the development of embolisms. This results in leaf temperature increasing because the evaporative cooling has been reduced. Under

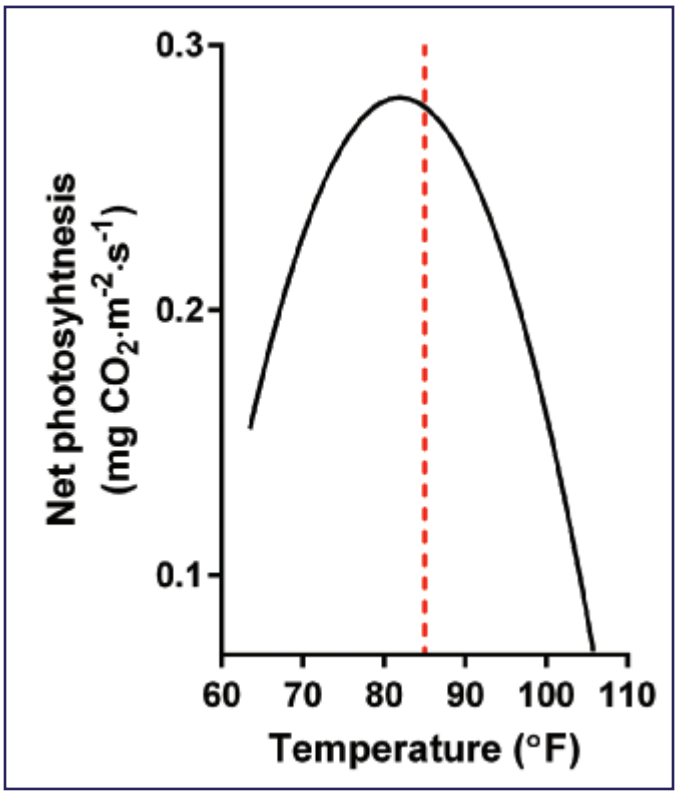


Figure 1. The relationship between air temperature and net photosynthesis of Fuerte avocado in the Murray Valley, Victoria, Australia. The vertical red line is at 85°F. Redrawn from: Scholefield et al. 1980 California Avocado Society Yearbook 64:93-106.



Figure 2. A 4-year-old tree showing heat damage primarily on the top and west sides of the tree.

extreme conditions, the leaves and small stems of the tree will overheat and literally cook. When trees are gradually and routinely exposed to high temperatures they can acclimate to a certain level, but when heat events occur in the early or late season, when the trees are acclimated to "normal" temperatures, they suffer more severe damage.

Heat Damage

Young trees are often more severely damaged during heatwaves than mature trees. The greater space between young trees, compared with mature trees, allows the heat to fully surround the trees, exposing them to high temperatures from all sides. Young trees also have less mass and smaller diameter branches. As a result, they have less water content relative to surface area and heat up much more quickly than large trees. Lastly, young trees simply don't have the extensive root system and reserves to tolerate extreme weather events and likely close their stomates sooner than mature trees. Damage to mature trees is usually primarily across the top of the canopy and on exposed sides of the trees.

As leaf temperature rises after the stomates close, wilting will occur. Once leaves wilt, they expose fruit and branches that were previously shaded. This results in sunburn damage to small and, in some cases, large branches. These damaged branches may sprout in time, but without some intervention they will never be healthy, fully functional branches in the tree canopy.

Fruit can suffer both direct and indirect damage from heat. Mature fruit exposed to heat can become very hot. Under normal conditions, thermal imaging cameras have been used to document fruit surface temperatures in bins of harvested fruit. Bins placed in the shade have fruit surface temperatures of about 75°F, whereas unshaded bins have fruit surface temperatures approaching 110°F. This demonstrates how quickly fruit can heat up when exposed to direct sunlight. There also is some evidence that severe heat can cause changes in the composition of the various oils in the avocado, resulting in decreased fruit quality.

Young developing fruit for next season, like young trees, have very little mass and heat up very quickly. This fruit can quickly reach at least ambient temperature all the way to the center of their developing seed and may even exceed ambient temperatures. As a result, the fruit become soft, their developing seeds die, and they are no longer viable. In addition, many of these young fruit can be severely sunburned as the surrounding leaves wilt and expose them to direct sunlight.



Figure 3. Young avocado fruit damaged during a heat event showing a dead seed.

Recovery

Many growers have probably heard the analogy: treat it like a freeze, wait and see. While this is true, there are some nuances missing in this analogy. Following a freeze, it is difficult to know the full extent of the damage and where the dead tissue ends and live tissue starts. Thus, the common advice is to wait until the tree begins to regrow, indicating where the living tissue is, and then prune back to this new growth. In the case of a freeze, this usually takes several months since we're not in an active period of growth for the tree. And that is the big difference — trees are usually in an active state of growth when heat events occur.

In most cases, trees damaged by heat will sprout quickly and show you where the living tissue is. Once this new growth appears, it is safe to come in and prune the dead and damaged wood from the tree. However, sunburn protection is critical. It is very important to pay attention to the weather forecasts and use your best judgement before pruning. If another hot spell is coming, it would be best to wait until temperatures return to more normal levels.

Whitewash **must** be applied the day of pruning — it takes



Figure 4. A heat damaged limb on a tree with new growth emerging near the base (circle). This branch should be pruned back to this new growth.

only a very brief exposure to full, mid-day sun for previously shaded branches to burn. Some growers prefer to whitewash their trees prior to pruning. They do this to prevent the whitewash from coating the pruning wound and inhibiting the normal wound healing response of the tree. If using this approach, be sure that all exposed branches are protected after the pruning is complete and apply additional whitewash if needed. Typical whitewash is a diluted latex paint — use 1-part paint to 1- up to 3-parts water — but some growers, particularly those who are certified organic, prefer to use a natural kaolin clay product (e.g., Surround®).

For young trees, those less than about 3 years old where most of the canopy may be damaged, the goal should be to get leaves back on the trees before the end of the growing season. These trees are unlikely to bloom the following spring. Once these trees are growing, prune away the dead and damaged branches and whitewash the tree. Be judicious with your water and fertilizer application. Remember, the leaf area on these trees has been drastically reduced and thus, so has their water need. Hand fertilizing with a good quality water-soluble complete fertilizer, rather than fertigation, would be a good way to nurse trees through recovery. This will allow you to tailor the amount of fertilizer applied to each tree based on its level of damage and regrowth.

For larger trees (about 4 years old and older) and mature trees, where only a portion of the canopy is damaged, it's likely there will be some bloom next year. These trees also should be pruned once new growth starts and whitewashed as needed. However, unlike with young trees, the reserves of these larger trees will result in a more rapid regrowth. It will still be important to modify irrigation schedules to account for canopy loss to ensure these larger trees are not over-watered, but their greater size provides some buffering capacity and regular fertilization can resume once new growth starts.

The damaged tissue from heat is going to provide a massive opportunity for avocado branch canker (*Botryosphaeria* and *Colletotrichum* fungi) pathogens to enter the trees. It is critical that the damaged branches be removed from the trees before the possibility of winter rains arrive. The damaged tissues are essentially open wounds in the trees. When we get rain, or even high moisture from heavy fog, the avocado branch canker pathogens will release their spores into the air, which will land on the damaged leaves and branches, forming latent infections. When conditions are right, those spores will germinate, and we will see severe cases of avocado branch canker. Thus, it is critical to begin the cleanup process now to prevent more severe damage down the road.

Preventing Heat Damage

The only way to prevent heat damage from occurring during extreme heat events is to modify the microclimate of the grove. And the only somewhat viable means of doing this is with water. When water is applied to a grove, there are three ways that it can cool the environment:

- Convective cooling: when water evaporates in air (either under the tree or overhead) there is a temperature drop that results in air circulation (convection) within the grove.
- Hydro-cooling: water applied directly to the leaves and fruit absorbs the sensible heat from the plant tissues and carries it away in "runoff."
- Evaporative cooling: water applied directly to leaves and fruit removes sensible heat to latent heat transfer during evaporation (this is how water loss through stomates cools leaves).

All applications of water in the grove will cool trees in one or more of these ways. Factors such as climatic conditions, water application rates, application uniformity and system operation will dictate how much each mechanism contributes to cooling.

The evaporation of water requires large amounts of energy (910 BTU/lb water at 86°F). When cooling a grove using evaporative methods such as canopy irrigation, this energy (heat) comes either from solar radiation and/or from the surfaces (i.e., plant tissues) the water contacts. To prevent sunburn damage, it is best if this energy (heat) comes from the plant tissues of which one is trying to prevent sunburn.

In the Pacific Northwest where orchard cooling has been used in apple production, rates of overhead water application range from 8 gallons per minute per acre (gpm/ac) to over 80 gpm/ac. Typically the lower rates are used for continuous application and the higher rates are used in pulsing applications — 15 minutes on, 15 minutes off.

A complete discussion of orchard cooling can be found in the article "Potential for Heat Mitigation by Overhead Irrigation in Avocado Groves" in the Winter 2021 issue of *From the Grove.*

The unfortunate reality of the changing world we live in is that the weather is becoming more erratic with extreme temperature events becoming more common. There is little growers can do to adapt to these events. The best prevention is to maintain optimum tree health so the trees are as well prepared as can be for these extreme events.