Better Growing

By Tim Spann, PhD
Spann Ag Research & Consulting

Potential for Heat Mitigation by Overhead Irrigation in Avocado Groves

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. Recently, 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. These events are unprecedented.

This has caused many growers

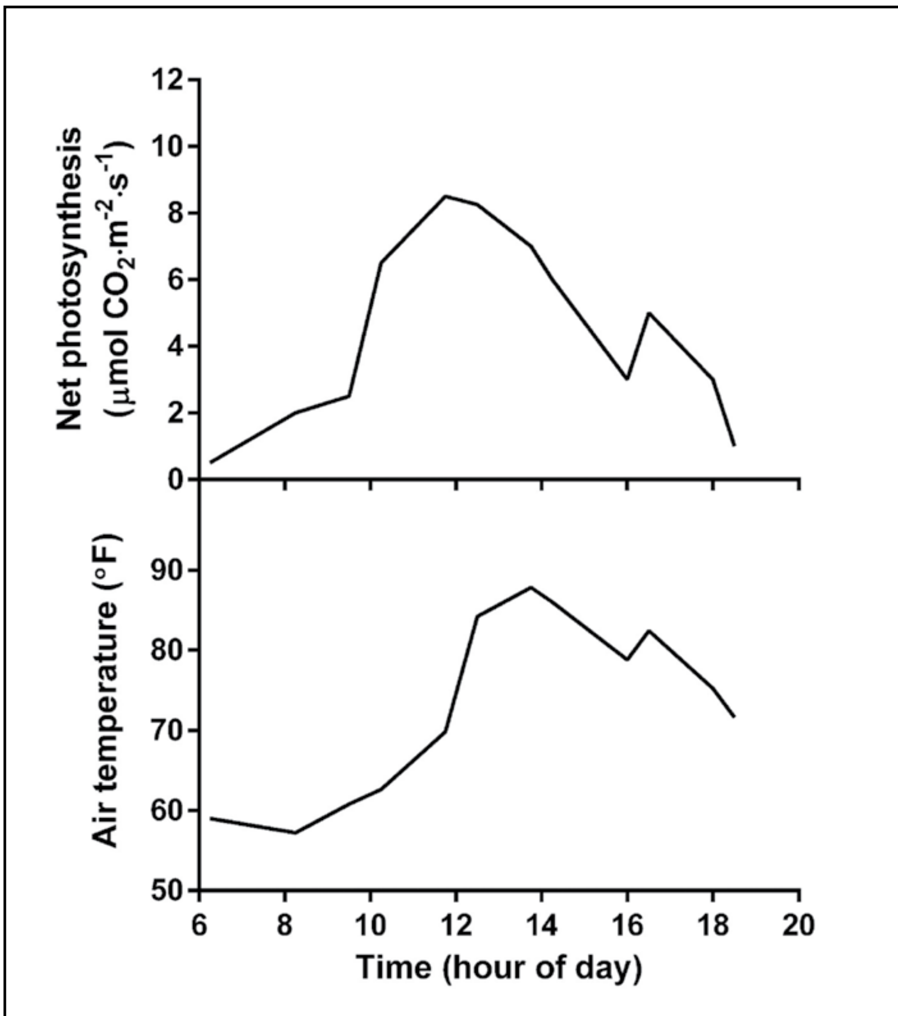

Figure 1. Air temperature (lower graph) over the course of a day at the South Coast Research and Extension Center, Irvine, CA, and corresponding net photosynthesis of 'Hass' avocado leaves. Redrawn from: Liu et al. 2002. Acta Horticulturae 575: 865-875.

to ask if it is possible to cool avocado groves using overhead irrigation. The short answer is yes. This technique is relatively common in deciduous fruit orchards in some of the hot dry areas of the northwestern U.S. as well as in other countries such as Spain and Australia. However, there is no research data available for implementing this technique in avocados in California; although, I have heard of a few growers installing some test systems.

In this article I want to review what happens to avocados when temperatures reach extreme levels, some things to consider if you want to try overhead irrigation for cooling your trees, and some potential risks to consider.

How Does Heat Affect Avocados?

To understand how avocados are affected by heat, it's important to remember where avocados originate. The avocado is native to the subtropical forests of southern Mexico, Central America, and northern South America where it lives primarily as an understory tree (growing in the shade of larger trees). In these areas temperatures rarely exceed 85°F, rainfall is abundant, and the trees are rarely exposed to intense sunlight — quite different from the environment they're grown in commercially.

As a result of evolving in these idyllic conditions, the avocado tree has little tolerance for high temperatures. This can be seen by looking at what happens to photosynthesis as the air temperature increases. The accompanying figure (**Figure 1** on page 34) shows air temperature data over the course of a day at South Coast Research and Extension Center in Irvine, California. These graphs clearly show how 'Hass' photosynthesis declines when afternoon temperatures exceed about 85°F.

The other accompanying figure (**Figure 2**) is data from the Murray Valley in Victoria, Australia and shows how 'Fuerte' photosynthesis responds to temperature. Again, when temperature exceeds about 85°F photosynthesis declines and continues to decline to the point of fully stopping when temperatures exceed 100°F.

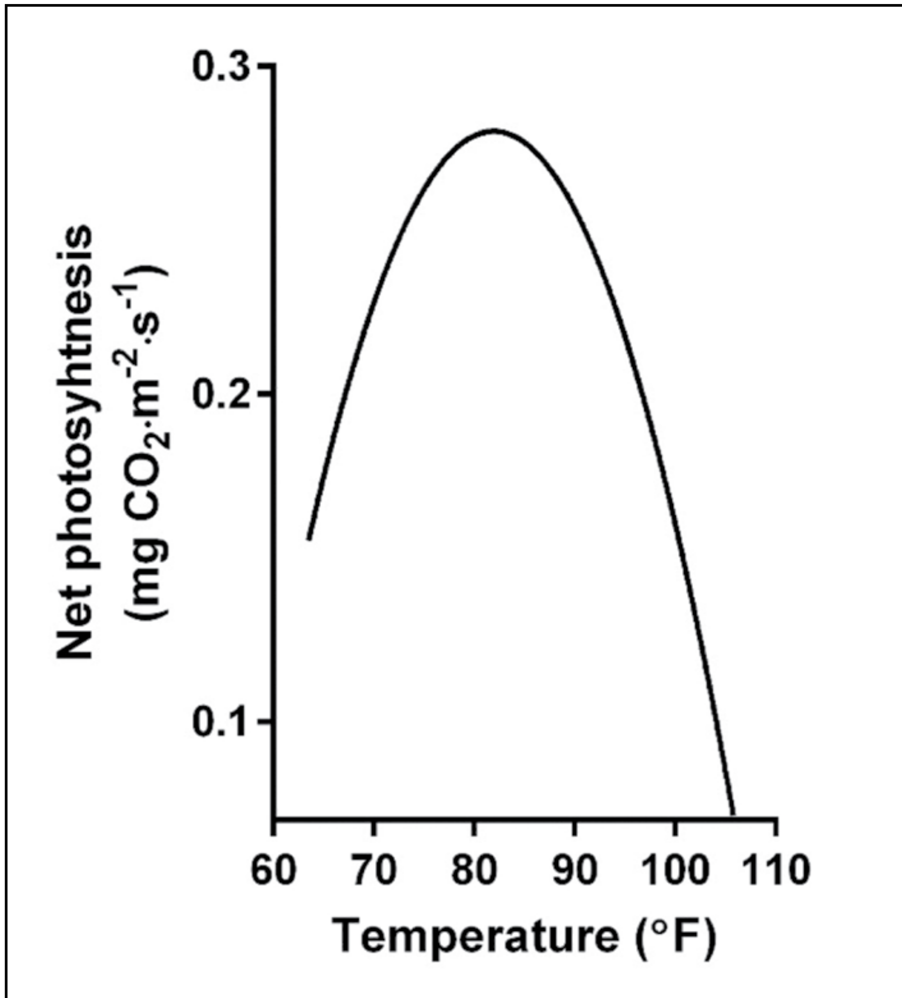

Figure 2. The relationship between air temperature and net photosynthesis of 'Fuerte" avocado in the Murray Valley, Victoria, Australia. Redrawn from: Scholefield et al. 1980. California Avocado Society Yearbook 64:93-106.

Why does photosynthesis decline at high temperatures? Photosynthesis and plant water usage are directly connected. There are pores in plant leaves called stomata. When plants take up water from the soil, that water moves through the plant and exits through the stomata. It is the difference in vapor pressure between the leaf and the atmosphere that actually drives water movement through the plant. The inside of the leaf is essentially at 100% relative humidity and the atmosphere is usually at a lower relative humidity. Thus, the drier the air is, the greater the vapor pressure gradient, and the greater the flow of water is through the plant. Water vapor leaving leaves through the stomata reduces the leaf temperature through evaporative cooling. So, when stomata close, the leaf temperature begins to increase.

However, water is not the only thing that moves through the stomata. Carbon dioxide (CO_2) also enters the plant through the stomata to supply photosynthesis, which is the process of chemically combining CO_2 with water

(H_2O), using the energy of sunlight to produce carbohydrates (CH_2O) and oxygen (O_2). The carbohydrates (sugars) are the plant's energy source to grow.

When the vapor pressure difference between the plant's leaves and the air becomes too great (or available water becomes limited because the soil becomes too dry), the plant responds by closing its stomata to prevent excess water loss. This also cuts off the supply of carbon dioxide for photosynthesis. Thus, when air temperatures climb above a plant's threshold – approximately 85 °F for avocados – the stomata begin to close thereby reducing the rate of photosynthesis.

What happens next is a cascade of events. Wilting will begin to occur, which is the plant's attempt to reduce the amount of sunlight being intercepted by the leaf, thus avoiding heating up. If the stress is not relieved, the leaf temperature will continue to climb until the leaf tissue cooks. This is seen later as scorching on the leaves. In addition, wilting allows sunlight to penetrate to normally shaded parts of the canopy leading to sunburn of the fruit and stems. If the high heat conditions continue long enough or occur on successive days, parts of the canopy can die back and young trees can be killed.

Using Water to Cool a Grove

There are three ways in which water applied to a grove can result in cooling:

1. 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.
2. Hydro-cooling: water applied directly to the leaves and fruit absorbs the sensible heat from the plant tissues and carries it away in "runoff".
3. Evaporative cooling: water applied directly to leaves and fruit removes sensible heat to latent heat transfer.

How much water is needed to cool a grove?

The following is excerpted from: *Evans, R. G. 1999.*
OVERTREE EVAPORATIVE COOLINGSYSTEM DESIGN AND OPERATION FOR APPLES IN THE PNW. USDA-ARS
-Northern Plains Agricultural Research Laboratory, Sidney, MT.

"[The] heat "load" on fruit that is exposed to the sun has two principal components: 1) direct radiative heating from the sun; and, 2) advective heating from hot air originating from outside the block moving through the orchard. Taking a simple physical chemistry approach, we can make some calculations to give us the relative magnitude of the amount of water required for effective overtree evaporative cooling of exposed fruit. Assuming that we want to cool apples under conditions where the incoming solar radiation has an intensity of 800 W m^{-2} and that we have an air temperature of 95°F (reasonable numbers for the middle of a summer day). To equal (neutralize) the energy from the incoming solar radiation would require the complete evaporation of about 21 US gal/min/ac above the tree canopy (assuming: 8.36 lb/US gallon of water, 1040 Btu/lb is the latent heat of vaporization, 8695 Btu to evaporate 1 US gallon of water, and 1 W/m^2 = 0.3170 Btu/hr/ft^2). However, there is also an advective (wind) component that is typically at least equal to the solar radiative heating during periods of high air temperatures, low humidities and low wind speeds. This means that at least 40 gpm/ac [2,400 gallons per hour per acre] would have to be continuously applied over the tree during this period to just equal the incoming both radiative and advective heat energy and maintain the exposed fruit surface at ambient temperatures (in this case 95°F) under these assumed conditions. Cooling the exposed fruit below ambient temperature would require the application of additional water. These calculations are supported by field data measuring actual exposed fruit temperatures on hot summer days in south central Washington of cooled and uncooled fruit. Higher wind speeds and/or higher air temperatures would increase the amount of water required for effective evaporative cooling."

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.

Risks of Evaporative Cooling in Avocado Groves

There are numerous potential risks to using overhead irrigation to cool your avocado grove. The first one is thinking you can use your existing irrigation system. Most growers' irrigation systems are not designed to deliver the volume of water needed for the durations needed to the entire grove in order to effectively cool the trees. Thus, a separate system will need to be engineered and installed to effectively cool the grove. To avoid excess water use, pulsing would probably be the most efficient method to use and appropriate controllers and valves are needed to make that happen.

A sufficient water supply is needed to supply both overhead cooling and irrigation needs. Remember, the water being applied to cool the grove is evaporating; that is how it cools. You will also need to apply irrigation to maintain soil moisture, so the trees have water available for uptake. After all, the point of cooling is to keep temperatures down, allow photosynthesis to continue, and prevent tissue damage.

Water quality can become a major issue in applying overhead irrigation. When the applied water evaporates, the dissolved salts will be left behind. This can result in salt buildup on fruit and leaves and potentially lead to severe burn from the salt accumulation.

Lastly, the potential for disease outbreaks must be considered. We are fortunate in California that we have very few issues with foliar and fruit disease issues. However, this is because of our dry climate and not because the pathogens aren't present. The application of water directly to foliage and fruit, and the increased humidity resulting from that application — particularly during a multiday heat event — could cause disease issues such as fruit rot.

This article is not meant to discourage anyone from testing overhead cooling systems for avocados, but hopefully it gives you pause to consider some of the risks involved and what would be required to implement such a system. If you decide to test overhead cooling in your grove I would be very interested in hearing about your experiences.