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Dreaming in Reality

Reuben Hofshi
Del Rey Avocado Co.

The world's avocado markets are rapidly expanding and merging into a single integrated global market. The future price of avocados in the US, for example, will increasingly reflect not only the local availability of avocados but also the global supply and demand condition. California growers are used to experiencing significant price fluctuations between "on" years and "off years; the same scenario is likely to occur globally. In previous years, high-production, low-priced years were followed by medium to low crop years coupled with moderate to high prices. This price fluctuation is largely due to the alternate bearing characteristic of the avocado triggered by a catastrophic event such as an industry-wide freeze or a severe and prolonged hot spell during fruit set. Most growers were able to make ends meet and even profit through multiple year income averaging. Under today's global reality, low production years in California will attract a greater flow of fruit from foreign sources. This in turn will lower the returns to local growers due to increased overall supply. The income-averaging scheme, which many growers use to keep their enterprises viable, will deteriorate under this situation. As producing countries continue to plant thousands of new acres annually, a point of global market saturation will eventually be reached. When the supply exceeds demand, it will trigger a worldwide reduction in price, which may be of a substantial magnitude. The California avocado growers are likely to experience a prolonged recession, similar to the period during the expansion years in California of the early 1980's and, therefore, the viability of their venture may be threatened.

With this outlook in mind some growers are searching for a means to change their practices in order to withstand an extended financial downturn. Another future cycle of profitability will probably follow the "bad" times, as supply will once more lag behind demand. The return to profitability is likely to result from: a) increased global demand and consumption of avocados resulting from low prices at the consumer level; b) increasing consumer awareness of the high nutritional and health value of the avocado; c) effective advertising campaigns especially in densely populated areas with low historical usage of avocados; and d) the attrition of marginal growers with a high cost to production ratio.

What strategies can a grower take to improve the chances for survival and profitability?

Many variables can significantly affect productivity, which is the underlying prerequisite to long-term financial gain. The following discussion examines some cultural practices growers may want to implement. How cost effective, if applicable at all, will these efforts be? Obviously, there will be variability among regions and their associated microclimates, and the amount of capital, thought and effort the individual farmer is willing to invest to improve the enterprise. Five suggested improvements for better farming are:

• Salinity tolerant rootstocks

• Pollination

• High density plantings

• Reflective mulches

• Evaporative cooling

Salinity tolerant rootstocks

Saline irrigation water has a major negative effect on the productivity and health of the avocado orchard. One acre-foot of Colorado River water contains an average of 1,548 Ibs. of total dissolved solids (TDS, 569 ppm or mg/L; Source: Metropolitan Water District). The TDS includes approximately 234 Ibs. chlorides and 240 Ibs. sodium (86 and 88 ppm or mg/L respectively). When water of this quality is applied to saline sensitive Mexican rootstocks, varying degrees of tip-burn may result, especially in periods of water stress. The avocado is classified among plants that are very sensitive to salts (Allison et al, 1954). To reduce the risk of tip burn and the negative effect of salinity on the nutritional status of the avocado tree through ionic imbalance, growers resort to leaching in varying quantities and frequencies (Shalhevet, 1994; Hoffman and Van Genuchten, 1983; J. Oster, UC, Riverside, personal communication). Most growers do not have the means to monitor the soil EC (electrical conductivity) in the root zone. EC is a measure of the total salt level in the soil and hence could be used as an indicator of when to leach (relatively inexpensive EC meters are available for such analysis). The salinity level of the irrigation water, soil type, irrigation regime and the type of the irrigation system influence the salinity level in the root zone (rhizosphere) (M. Zilberstaine, Extension Specialist, Israel, personal communication). Growers can consider a number of approaches to leaching and can be guided by consultants, published literature (Allison et al, 1954; Mission Resource Conservation District, Fallbrook; R. Marroco, Fallbrook Ag Lab Bulletin) and others (see the irrigation calculator on the California Avocado Commission's website at http://www.avocado.org and the UCR Avocado Info website at http:// www.ucavo.ucr.edu). Leaching requires large amounts of water, much of which is wasted, to drive the accumulated salts away from the root zone. There is the added fear of ground water contamination by leached nitrates and other salts. Leaching is a costly but a necessary practice to keep the trees efficiently productive by minimizing tip burn (A.W. Whiley, Dept. of Primary Industries, Qld. Australia; R. Marrocco, Fallbrook Ag Lab, personal communication).

An alternative, especially if a tree replacement scheme is contemplated (Hofshi, 1999a, 1999b), is to use salinity tolerant rootstocks (Mickelbart and Arpaia, 1996; Oster and Arpaia, 1991). There are differences in the mechanisms by which rootstocks respond to salinity and this in turn influences the reaction of the scion variety (Oster and Arpaia, 1991). Their study showed that 'Hass' grown on clonal 'Duke 7' and 'Toro Canyon' were the least affected by chloride and sodium when compared to 'Hass' grown on 'Thomas', 'Parida', 'G755B' and 'Barr Duke' clonal rootstocks. Another study comparing 'Hass' avocado on clonal Thomas', Toro Canyon' and 'Duke 7' found similar results (Mickelbart and Arpaia, 1996). The search for salinity tolerant rootstocks was spearheaded in 1982 by A. Ben-Ya'acov in Israel based on findings made by C. Oppenheimer and A. Kadman in Israel and by W. Cooper and A. Haas in the US. In Israel, the central aqueduct, even in rainy years, carries irrigation water with a chloride level of over 200 ppm. This is a much higher chloride level than the Colorado River water (80 - 90 ppm). In Israel, Ben-Ya'acov and others have promoted the use of West Indian rootstocks due to their higher inherent salinity tolerance. Major differences among the West Indian rootstocks were found and many were eliminated because of sensitivity to chlorosis, the sunblotch viroid and poor soil aeration (Ben-Ya'acov, 1995). This later characteristic, good aeration, is a critical prerequisite for most West Indian selections (Ben-Ya'acov, 1995). Limited evaluation trials of West Indian rootstocks under California conditions were carried out by Haas (1950) and by Halma(1954). The West Indian rootstocks as a potential source of improved rootstock material for *Phytophthora cinnamomi* tolerance were abandoned in California mostly due to sensitivity to cold in areas where Mexican rootstocks managed to survive (J. Menge and G. Zentmyer, UC, Riverside; personal communication). According to A. Ben-Ya'acov (Volcani Research Institute, Israel, personal communication), it was Halma's work during the 40's and early 50's with the West Indian cultivar 'Waldin' that brought about the West Indian predicament in California. Ben-Ya'acov does not consider 'Waldin' to posses any exceptional traits.

Rejecting this valuable group of rootstocks overlooked a number of important considerations:

a) Salinity can be a major limiting factor to productivity through tip-burn and ionic imbalance.

b) Water quality in most water districts in southern California is marginal to bad. Plentiful groundwater in many localities is barely usable for avocado irrigation with existing rootstocks.

c) The cost of water is the most expensive segment of farming avocados in California. If a potential leaching fraction of 10 - 20% and possibly more is added, the cost of growing the crop is also increased.

d) Only a relatively narrow band of the total area where avocados are grown in California is in areas prone to freezing. In young trees (< 2 years of age) freeze damage is more likely to occur below the bud union; this is why the use of tree wraps is so important in young trees. Ben Ya'acov (personal communication) believes that once the tree is established that the most "cold sensitive" portion of the tree during a freeze is the leaves, even on "cold tolerant" varieties. The leaves will suffer more damage than the trunk of "cold sensitive" rootstocks such as the West Indian varieties. Many growers have taken a much greater risk, therefore, by replacing within a "cold zone", cold tolerant cultivars such as 'Bacon', 'Fuerte' and 'Zutano' with the more cold sensitive 'Hass' and 'Gwen' cultivars.

e) During rootstocks selection there is a greater likelihood to find among West Indian rootstocks root rot tolerance than either among the Mexican or Guatemalan races (A. Ben-Ya'acov; personal communication).

f) Some West Indian selections have a tendency for "dwarfing". This trait can be very important to those interested in canopy management and high density plantings of avocados (A. Ben-Ya'acov; Y. Regev, Farm Advisor, Western Galilee, Israel; Grant Thorp, HortResearch, New Zealand; personal communication).

Recently, there has been a renewed interest in both salinity tolerance and the West Indian rootstocks by researchers at UC, Riverside including T. Chao, D. Crowley, C. Lovatt and J. Menge. If positive findings emerge, this could help many California avocado growers by reducing the need for frequent leaching while their trees remain tip-burn free. It can also help those who have been reluctant to use their saline underground water for avocado irrigation.

Pollination

The avocado requires an insect vector to set fruit. Based on the experience of most farmers in semi-arid environments such as southern California, this need is obvious (Clark, 1923; Ish-Am and Eisikowitch, 1998a; Stout, 1933). The insect most commonly found in avocado orchards is the European honey bee, *Apis mellifera* L. (Vithanage, 1990). It is the practice, therefore, of many, but not all avocado growers to have a beekeeper place hives (usually one or less beehives per acre) to help pollinate their avocado trees. Honey bees seem to prefer other food sources such as wild flowers, citrus and mustard to the avocado (Ish-Am and Eisikowitch, 1998b). Since pollination efficiency is measured as the number of honey bees per quadrant in a medium size tree (Hofshi, 1995) and is a function of visitation rate (Shoval, 1987), strategies are needed to increase the number of visitations. One sure method for more visitations is to increase the colony density per acre. The author's experience has been that very good fruit set occurred when large numbers of honey bees visited each tree (3-4 hives per acre). When honey bees are abundant, the same flower can receive multiple visits thus increasing the chance for cross pollination. This in turn can increase the efficiency of pollination, fertilization, fruit set and fruit retention processes. In years when plentiful rains produce abundant wildflowers, and citrus bloom is in synchrony with avocado flowering, as many as four strong hives per acre may be necessary (Hofshi, 1995). Alternatively, if citrus flowers before the peak avocado bloom and wild-flowers are in short supply, visitation rates may be very adequate with a lower number of colonies per acre (G. Ish-Am, Hebrew University of Jerusalem, Israel, personal communication regarding the unusually high initial fruit set in Israel in spring 1999).

Prior to the unfortunate introduction of the Varroa mite into California from South East Asia, feral (wild) honey bees were abundant in canyons and hillsides surrounding avocado orchards. Since feral honey bees have almost disappeared, growers are increasingly dependent on the services of the beekeeper. Beekeepers customarily send their colonies for almond pollination in the San Joaquin Valley during February to early March, since it is an important source of income for them. They usually leave the colonies in the almond orchards until the end of March or even later. This leaves avocado groves almost entirely devoid of honey bees in the winter and early spring. Avocado growers could suffer economically from the lack of honey bees, since pollination and fruit set opportunities may arise at any time during the flowering period. Avocado bloom may extend from February through June in 'Hass' and even longer in 'Pinkerton' which can begin to bloom as early as December. Open avocado flowers, during late winter and early spring, a period when there is minimal alternative pastures for the honey bee, constitute a highly desirable food source for them. Very good early fruit set could occur if windows of adequate day-night temperatures occur. The spring 1999 in most localities in California is an example of a cold spring when there were only a few days of satisfactory temperatures for fruit set. By the time honey bees were brought in from the almond orchards in March and April, cold weather all but destroyed a potential 'on' year for the industry.

It is advantageous for serious growers, who want to minimize any hindrance to setting a good crop, to consider obtaining honey bee colonies, equivalent to 4 "strong" honey bee colonies per acre, either through a beekeeper or by personal ownership (Hofshi et al,1999). Pollination is less likely to be a limiting factor to fruit set with such high bee densities in the orchard. A strong honey bee hive would be one which has at least 8 frames of brood and a colony population of approximately 40,000 honey bees. The hives, in order to maximize the potential for fruit set, should be placed strategically in groups, throughout the grove during the entire flowering period. One negative aspect is the cost of keeping honey bees in the grove for such extended periods with no guarantee of fruit set during the colder segment of the bloom. The avocado grower will need to compensate the beekeeper for not taking the colonies to areas of greater demand (i.e. almonds), for the services provided by placing honey bee colonies throughout the avocado grove, and for keeping the hives in the orchard for prolonged periods in years when the bloom is delayed due to cold or unusual weather.

Another aspect of pollination is the placement of sufficient numbers of pollenizer trees within the grove. Avocado flowers can either be self pollinated, close pollinated, or cross-pollinated (Hofshi, 1995). The average number of pollen grains deposited per visit is 4 - 6 in "close" pollination and 1 - 2 in "cross" pollination while 20 pollen grains per stigma are needed for successful fertilization (G. Ish-Am; personal communication). Self pollination occurs only within a single flower in the male stage. Although, multiple pollen grains are easily found on the stigma in the male stage, it does not lead to "self fertilization" in semi-arid environments (G. Ish-Am; personal communication). The pollen tubes, even when large numbers of pollen grains are present, will only penetrate past the stigmatic surface but are stopped along the way before fertilization can take place (Shoval, 1987). In some environments such as south Florida, which is more humid and where West Indian varieties dominate, Davenport (1989) and Davenport et al (1994) have reported that self pollination and fertilization can occur and possibly accounts for most of the fruit set in that environment. Close pollination occurs when there is "overlapping bloom" within the same tree or within a group of trees of the same variety during the "self bisexual overlapping" period (G. Ish-Am; personal communication). This may account for much of the fruit set in large, single variety blocks found in some groves in Santa Barbara County. Cross-pollination occurs when the pollen of one variety pollinates another variety (Stout, 1923). Cross-pollination confers hybrid vigor to the resulting fruitlets and appears to be a major contributing factor to productivity and fruit retention in most years (Degani et al 1989; Ish-Am, 1994). Research in Israel has shown that most avocados that persist to harvest are ones that are the progeny of cross-pollination especially when 'Ettinger' was the pollen donor. It is the author's experience that grouping together clusters of "B" flower types (such as 'Zutano', 'Bacon' and 'Ettinger') every 5th tree and every 3rd row may provide a better pollen source for "A" flower types (such as 'Hass' and 'Pinkerton') for cross-pollination than single variety pollenizers planted in rows. The area which honey bees visit during foraging flights seldom exceeds three adjacent trees. Therefore, close proximity of the pollenizer trees to the flowers which require pollination may be highly advantageous (Ish-Am and Eisikowitch, 1998c). Although it makes harvesting the pollenizer varieties somewhat difficult, there is a better chance that the peak-bloom period of at least one of the pollenizer varieties will synchronize with the peak-bloom of the variety to be pollinated.

High density plantings

Strategies for higher productivity are necessary in order to remain competitive in the global avocado market. An alternative to planting new groves in conventional spacing, or rejuvenating existing aging groves through tree removal, stumping or severe pruning, is planting new trees in high densities (Hofshi, 1999a; H. Arditi, Farm manager, Israel; M. L. Arpaia, UC, Riverside; Y. Regev, Farm Advisor, Israel; M. Zilberstaine; personal communication). Planting in high density is a common practice in many fruit trees. This practice takes advantage of precocity (early bearing) and juvenile vigor.

Some researchers (Köhne and Kremer-Köhne, 1991, 1992; Razeto et al, 1998; Snijder and Stassen, 1997; Stassen et al, 1995, 1998) have studied the concept of high density plantings of avocado. With a better understanding of how and when to prune avocados for efficient light management, and the usage in some countries of PGR's (plant growth regulators); it is possible to maintain high density orchards for over ten years from planting (P. Stassen, ITSC, South Africa; G. Thorp, personal communication). These investigators have shown that in the first few years there is a significant advantage to high density planting in terms of early high yields. Advantage could be taken of the precocity of particular cultivars, when it is grafted on an appropriate rootstock (Ben-Ya'acov, 1992) and cinctured (P. Stassen, personal communication) to produce a measurable yield within 2 years of planting. Growers who have the type of terrain, which allows them to plant in a north-south orientation, can plant their trees in hedgerows such as 4.1 ft (1.25m) between trees and 13 ft (4m) between rows, as recommended by P. Stassen. The height of the trees should not exceed 13 ft (4m) and preferably should be no higher than 80% of the distance between the rows (i.e. 10.5 ft or 3.2m). It becomes much more complex when one has to deal with hillsides with diverse row orientations due to contour plantings, often within the same block. Hedgerows may not be a solution in this condition and more upright, single or double leader trees in a cylindrical shape would probably do best (G. Martin, avocado grower, CA; P. Stassen; G. Thorp, personal communication). Given the possibility of obtaining reasonably priced quality clonal trees (Hofshi, 1999b), ultra-high density planting is economically feasible. A grower has several options to deal with the trees as they crowd. One option is to remove every other tree within the row before overcrowding takes place; for instance a 10' x 15' spacing would become 20' x 15' and eventually end up, after further thinning, with a 20' x 30' spacing. A second option is to let the trees remain in a tight, well-pruned hedgerow trained to a single leader. The trees should be trained to a pyramidal shape; that is, the tree width is narrower at the top of the tree than its base. The canopy would be maintained at a specific width and height; this approach is made easier when plant growth regulators are available. A final option is to grow the trees to a certain age, such as 8 - 12 years, and manage the tree size and shape using canopy manipulation techniques, and then replace the trees with new ones. This scheme takes advantage of developments in rootstock and scion varieties and the precocity and juvenility of a new orchard (Hofshi, 1999a,).

Growers are often fearful of trying something new and untested. The industry and surviving growers can not wait to react to competition; they need to meet it head on through high production. High density planting is one sure way to significantly increase productivity.

Reflective mulch.

If you were to drive by the nectarine, peach, plum and 'Fuji' apple orchards of the San Joaquin Valley prior to harvest, a new feature that is increasingly observed is reflective mulch. It is called "mulch" because it is laid on the ground, but its purpose is not to add organic matter to the soil or for weed control but to reflect solar radiation, which would otherwise be mostly absorbed by the soil, to the inside of the canopy. The 5 foot wide strip of polyethylene film is highly reflective and enhances color in apples, peaches, nectarines, plums, pomegranates, and persimmons (Andris, 1996; Andris and Cristosto, 1996; Andris et al, 1997; Andris et al, 1998; Thorp, 1994; H. Andris, UC Farm Advisor; personal communication). The benefits are mostly noted on the interior fruit, where fruit color and fruit size are normally delayed due to shading and limited sunlight penetration. The introduction of these mulches has helped to produce interior fruits of better color which result in earlier harvesting and a reduced number of harvests. Most "soft fruit" orchards are harvested by color and size. The use of reflective mulch allows the number of picks to be reduced from 4 or 5 to 3. The grower benefits, therefore, from early season high prices and reduced harvest cost.

M. L. Arpaia, B. Faber, and H. Andris are trying these mulches in avocado orchards. The goal of these preliminary experiments is to observe the potential benefits to be gained from placing reflective mulch in avocado groves. Some potential benefits for the avocado are extending fruit photosynthesis by reflecting light into the interior of the tree and onto fruit, which are shaded by the canopy. This may result in larger fruit size. By reflecting light to the tree's interior, the photosynthetic capacity of shaded leaves may also be increased. Dormant buds normally remain dormant unless the tree is stumped back and the trunk and branches are exposed to sunlight, which triggers these buds to grow. By reflecting light onto the trunk and scaffold branches, with or without a horizontal cut above the bud, it is possible that some of these dormant buds will be stimulated to grow. Flower induction and flower initiation is light dependant (Salazar-Garcia et al, 1998) and this reflected light may also encourage flowering on shaded interior fruiting wood. We will only know that if reflective mulch is a potential management tool for avocados after more experience is gained from these preliminary experiments.

Research has demonstrated that aphids will fly over vegetable plants planted with the reflective mulch. On susceptible plants the risk of aphid-vectored virus diseases is reduced (Summers et al, 1995; Summers and Stapleton, 1999). Dr. Summers has also documented increased fruit size and yield in treated plots of tomatoes and other vegetables. Because of these observations, M. Hoddle (UC, Riverside; personal communication) is interested in the effect of reflective mulches on the behavior of the avocado thrips. It appears that the light reflected by the mulch in tomato fields confuses migrating thrips to the point that the thrips arrival at the plants may result not from intentionally directed flights but mostly from random flights. Random flights account for only 20-25% of total thrips flights. It is believed that the reflected light from the mulch causes the thrips to be disoriented. The additional heat generated above the surface of the mulch may also prove fatal to the thrips.

There are some negative aspects related to the use of reflective mulch. These include:

1) The mulch costs about $130 for a 5' x 4000' roll, not including placement, and is used only once.

2) Disposal after usage can be a problem since it must go to a landfill.

3) The mulch will cool the soil by 3 - 7 °F (H. Andris; David Williamson, Sonoco Corp.; personal communication) and this may be important in the winter and spring when warmer soils are needed for soil nutrient pickup by the roots and for root growth (Zamet; 1993). New reflective materials produced in New Zealand, although significantly more expensive than the materials used in California, are alleged to actually warm the soil by 4 - 6 °F (G. Thorp; personal communication).

4) Workers complain of added heat and even some sunburn if a person remains for some time in the path of the reflected rays. There are some concern that it may impact workers' vision since the reflected light is so bright. Some growers supply eye protection to those spreading the material in the field (H. Andris, personal communication).

Evaporative cooling.

Weather is the major factor influencing the productivity of avocados in any given year. "Favorable" weather is likely to be conducive to a good crop. Cold temperatures during bloom produce low yields (Sedgley, 1977). A few days of hot, dry weather during the bloom and fruit set period, and the potential set you had could vanish. Conversely, a freeze can be severe enough to destroy the crop for a season and may also affect the following year's potential for fruit set.

Can growers intercept weather to better protect their crop? The answer is sometimes, yes! The following is an example of how adverse weather could be dealt with by innovative growers.

A large percentage of the total dry weight of a mature avocado is oil. Oil production by plants is energy expensive and is much costlier in terms of demand for resources than producing sugars in fruits such as citrus. What generates energy in any green plant is the complex process of photosynthesis. Photosynthesis uses light energy from the sun to convert atmospheric carbon dioxide (CO_2) and plant water into the simple sugars such as sucrose, fructose and glucose, which are needed for the growth and maintenance of the tree and its fruit.

Two major factors, light and stomatal conductance limit the rate of photosynthesis. As the amount of light available to the leaf drops, the rate of photosynthesis decreases. Leaves that are shaded, such as those on the interior of the tree are less efficient at photosynthesis. Stomatal conductance is a measure of the degree to which the stomata are opened. Stomata are the small pore-like openings that are typically found on the bottom surface of leaves. They are also found on avocado flowers and developing fruit. The function of the stomata is to facilitate the intake of CO_2 that is necessary for photosynthesis and to allow the passage of water vapor from the plant into the atmosphere, a process known as transpiration. When the avocado tree is subject to stressful conditions such as high temperature and low humidity, the stomata will begin to close to reduce the loss of water from the plant This is a defense mechanism by the tree against water deficit stress. When the leaf temperature reaches a certain threshold, especially during periods of high temperature, low humidity, intense sunlight and windy conditions, the atmospheric water deficit increases, causing excessive water loss from the leaf (Unrath and Sneed, 1974; Kotzé et al, 1987). The tree protects itself and its progeny against water deficit stress by reducing stomatal conductance (X. Liu, UC, Riverside; A. W. Whiley, personal communication). Each time this occurs the tree's photosynthetic output is reduced and it may be completely halted. A. W. Whiley remarked that when stomatal conductance was decreased by half, there was a proportional reduction in the assimilation rate of carbon dioxide (Hofshi, 1995). The reduction in photosynthesis is further aggravated if the soil water potential (how much water is available to the plant) is low due to lack of adequate and timely irrigation. Finally, the nutritional status of the tree, particularly Mg (magnesium) and K (potassium), are critical to efficient photosynthesis and stomatal performance, respectively. Magnesium is an integral component of the chlorophyll molecule, which is the green pigment that absorbs solar radiation. The mechanism of opening and closing of stomata is not fully understood. The turgidity of two kidney-shaped guard cells, which surround each stoma, is responsible for the opening and closing of the stomata. Potassium, through changes in the electrical potential inside and outside of the guard cells, is critical to the functioning of the stomata.

We do not yet have all the data needed to pinpoint the exact threshold for stomatal closure in avocado. According to Xuan Liu, stomatal closure in avocados occurs when temperatures are in the low 90's (32.2° C). Typically, stomata in avocado open early in the morning and on warm days begin to be restricted sometime after sunrise and reach maximum stricture in the early afternoon hours. As the weather cools down in the afternoon the stomata will become much less restricted. By this time, however, solar radiation is reduced, which in turn lowers the photosynthetic rate. Figure 1 demonstrates the relationship between net photosynthesis, stomatal conductance and the leaf vapor pressure deficit. The rate of net photosynthesis is influenced by the amount of photosynthetically active radiation (note the lack of photosynthesis on the overcast morning of June 10,1999), leaf temperature (note the reduction in photosynthesis on June 17, 1999 during the early afternoon), stomatal conductance and the leaf to air vapor pressure deficit. Continued work to define the environmental parameters involved in stomatal closure will be performed at the ACW ranch in De Luz by X. Liu and R. Hofshi. The information learned will be provided to all interested growers. We hope to develop a model to predict photosynthetic performance under different stress conditions.

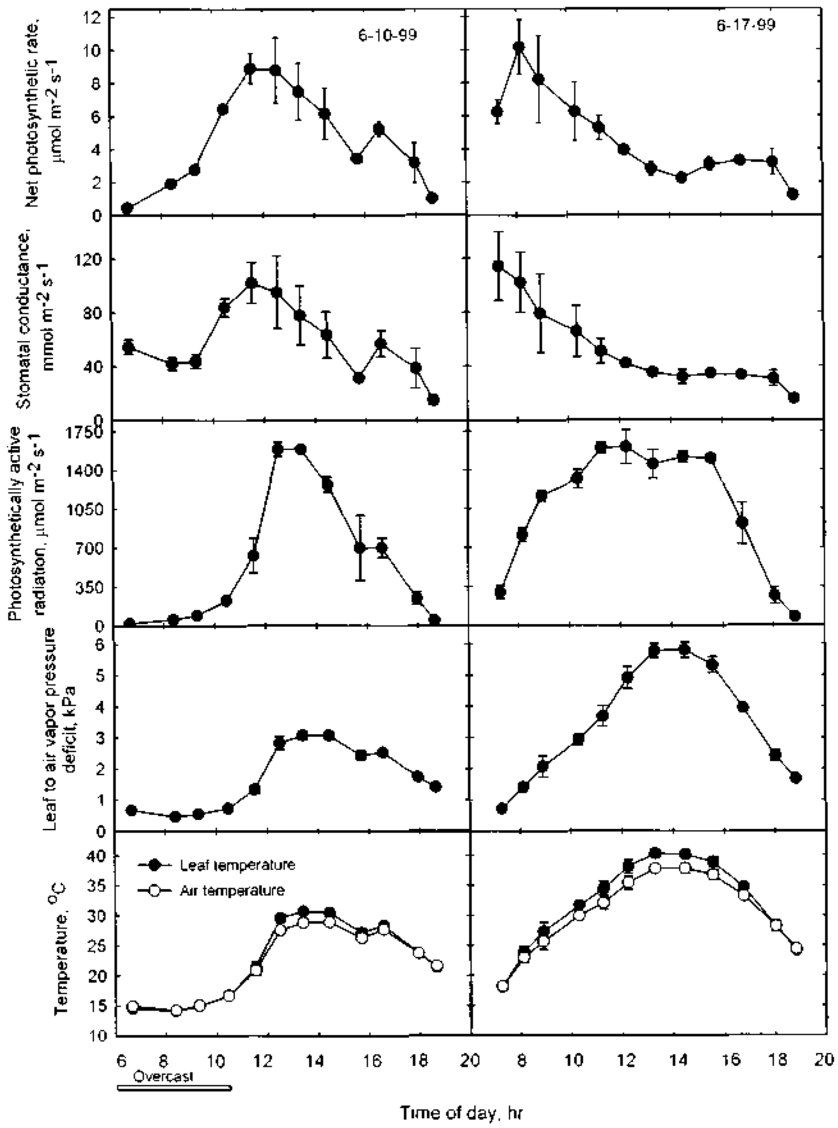

Figure 1. Diurnal patterns of 'Hass' avocado leaf photosynthetic performance, measured at the University of California (UC), Riverside campus on 2 days in June 10 and 17, 1999, respectively. On June 10,1999, the weather was overcast in the morning hours as compared to the second date (June 17, 1999) which was drier and clear from sunrise (Unpublished data from X. Liu and M. L. Arpaia, Department of Botany and Plant Sciences, UC Riverside).

Can the avocado photosynthetic "factory" be improved under Southern California arid conditions? Very likely, by using evaporative cooling.

The purpose of evaporative cooling in avocado is to decrease leaf and ambient temperatures and increase air humidity during periods of restricted stomatal conductance. Evaporative cooling is used in 'Red Delicious' apples grown in Washington to reduce fruit temperature, minimize sunburn on the fruit and enhance coloring (K. Lewis, WA State University Farm Advisor; personal communication). This is accomplished by installing an additional above-canopy low volume sprinkler irrigation system (Evans, 1998; Sneed and Unrath, 1972). Work with overhead irrigation in pears conducted by Lombard et al (1966) indicates that it is possible to increase air humidity by 25%, and to reduce air temperature in the shade by 10 °F. Other researchers were able to lower leaf temperature in grapes by 15 to 25 °F. Evaporating water is expected to remove one-third of the heat energy from incoming radiation if the free water surface is present all day (Allan, 1976). The system could operate with any one of several triggering mechanisms such as a timer, leaf temperature thermocouple, air temperature and humidity sensors, etc. Any one of the sensors or the timer will turn on a hydraulic valve for a certain length of time (usually 15 minutes), and then keep the system off for 30 to 45 minutes (exact on-off periods for avocado are not known). An additional benefit for such a system is its potential use for freeze protection and as a means to apply certain pesticides and foliar nutrients efficiently and inexpensively.

The minimum requirements for an effective evaporative cooling system are:

1. Water should be low in salts to minimize salt precipitation on the leaves. It should be particularly low in calcium carbonate (R. Stevens). Otherwise, the water needs to be treated prior to application to lower the lime deposition potential, which indicates the maximum quantity of lime that can precipitate from water if it evaporates to dryness on a given surface. This may sound ridiculous, but many apple growers in eastern Oregon and Washington remove carbonates from their water before applying onto the leaves (K. Lewis; G. Witney, WA State University, Farm Advisor, personal communication).

2. The system is likely to require 45 - 60 gallons per minute per acre to be effective (Evans, 1998). Many groves may not have this capacity in their mains and sub-mains. For those who do have the infrastructure and water volume capacity, and also in new installations, which could be adequately designed, this could be incorporated into the hydraulic configuration. Normal irrigation scheduling will need to be adjusted to the early morning, evening or night hours to accommodate the additional demand for water.

3. Installation of a long-riser per tree with a mini-sprinkler with an output of 25 to 30 gallons per hour (0.5 gal/min).

4. A hydraulic valve which is activated by a sensor or a timer. The potential negatives to the use of overhead irrigation to increase evaporative cooling are:

1)The cost and quality of the water used. Evans (1998) who has done extensive work on this method in Washington concluded "Evaporative cooling is not a water conservation measure and will require extra water. Total seasonal water application amounts will be from 25% to 40% greater than historical irrigation requirements since the cooling is a very "inefficient" use of water and, by design, much is lost to the atmosphere".

2) If the system is activated very frequently, which is not likely, in orchards with root rot the fungus could spread or in areas with heavy soils root affixation may occur. A different strategy, therefore, may need to be considered.

3) Some post harvest diseases such as anthracnose may pose a problem due to the elevated moisture on the fruit (Ploetz et al., 1994; Ben Faber, UC Farm Advisor, personal communication).

In conclusion, however, the potential for improved productivity in my view is great, if a system as described above could be installed in an inland avocado grove.

This paper is the product of several years of interaction with some of the people at the forefront of change in the exciting field of avocado productivity. There are many other innovative approaches to this subject both familiar and unfamiliar to the author. In the effort to have a successful enterprise, we often think of untried ideas, which make common sense and we have a gut feeling that they will work well. Making reality of these dreams is likely to bring both financial gain and mental reward.

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Salinity.

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