Topics in Subtropics Newsletter

University of California Cooperative Extension

Fresno, Kern, Madera, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara,Tulare,&Ventura Counties

News from the Subtropical Tree Crop Farm Advisors in California

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California inundated with invasive fruit flies

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California is experiencing an unusually high number of invasive fruit fly infestations. There are seven active regional quarantines in different areas of the state for four different species of exotic fruit flies in the family Tephritidae: Medfly (*Ceratitis capitata*) and Tau fly *(Zeugodacus tau*) in Los Angeles, *Queensland* fruit fly (*Bactrocera tryoni*) at the border of Ventura/Los Angeles, and f*our* separate quarantine areas for the Oriental fruit fly (‘OFF’; *B. dorsalis*) in Riverside/San Bernardino, Contra Costa, Sacramento, and Santa Clara counties. A quarantine just ended following the successful eradication of an infestation of Mexfly (*Anastrepha ludens*) *in* San Diego County.

The OFF infestation in San Bernardino/Riverside is especially serious in terms of the unprecedented number of flies found and the many acres of commercial production affected. For this species, six male flies/one mated female/one larva triggers a quarantine, but here we have detected more than 500 adult flies and are still finding more, even during winter. The affected area, including more than 550 square miles, encompasses not just residential properties but an important agricultural region with commercial farms. Farmers in the area are bringing in more trained pesticide applicators, and facing crop losses, delayed harvests, disruption to integrated pest management practices for other pests, and increased costs as they act to mitigate the damage. The unfortunate proximity of the epicenter of the outbreak to agricultural production is necessitating some problem solving and adaptation of mitigation protocols as we race to stop the fly population from establishing.

The quarantine boundary is also approaching the edge of the California Citrus State Historic Park and the University of California Riverside campus, with fly finds less than two miles from active subtropical fruit and biological control research plots, the Givaudan Citrus Variety Collection, and citrus trees of historical importance. Researchers are gauging how the infestation and mitigation protocols might impact current experiments being conducted, including delayed harvest dates, and scrambling to adapt research plans accordingly.

Usually, we have one or two small exotic fruit fly quarantines per year, so the current situation is a strain on resources statewide. The number of areas invested and the severity of the OFF infestation in San Bernardino/Riverside are stretching resources thin as the Department of Agriculture pulls insect detection specialists and staff from other projects to help place more traps, enact compliance agreements, and visit residential properties. San Bernardino County is providing yard signs to help encourage residents not to move produce while the quarantine is in effect.

Exotic fruit flies are one of the most serious threats to food production in the state, with the estimated economic cost of any one of these Tephritidae species becoming established running into the $100 of millions through crop losses, additional pesticide use, and collapse of export markets. These flies are of concern because the larvae/maggots feed on fresh fruit and vegetables prior to harvest. The immature flies chew through the fresh fruit, and it rots on the tree or vine, or drops prematurely to the ground. Fruit infested with large maggots is not marketable to consumers and not fit for human consumption. They are much more damaging than other flies, like smaller *Drosophila* species that develop on fruit that has already matured, been harvested and is in compost. Tephritidae flies are also highly polyphagous, with some species attacking more than 100 types of fruit, vegetables, and nuts, including the major food crops produced in the state; citrus, avocado, dates, tomatoes, bell peppers, figs, grapes, cucurbits and many specialty crops are all at risk.

We have a long-standing success record of keeping fruit flies out of the state, and fully expect to achieve eradication of all the current infestations through an approach that consists of biological control (mating disruption by sterile insect release), chemical control (targeted pesticide baits), and physical control (destruction of infested fruit from the current season and restrictions on movement of fruit from infested areas). If you have questions about a fruit fly quarantine/eradication, or if you think you have fruits and vegetables infested with fruit fly larvae, call the CDFA Exotic Pest Hotline at 1 (800) 491-1899, contact your local Agricultural Commissioner, or the University's Cooperative Extension. More information specifically for growers is available at regional Farm Bureau meetings and on the CDFA website: https://www.cdfa.ca.gov/plant/PE/InteriorExclusion/current_grower_info.html#INTRO

Satellite-based irrigation tools to manage irrigation water more precisely in avocado groves

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Introduction. The water requirement of a crop must be satisfied to achieve optimum potential yields. The crop water requirement is called crop evapotranspiration and is usually represented as ETc. By combining reference evapotranspiration (ETo) and the proper crop coefficient (Kc), crop water use (ETc) can be determined as $ETc = ETo \times Kc$. ETo is an estimation of evapotranspiration for short grass canopy under a well-managed, non-stressed condition. ETo is the main driver to estimate or forecast crop water needs. There are user-friendly satellite-based irrigation tools available that may assist growers to schedule irrigation more effectively. These tools provide ETo forecast for up to six days in the future or/and actual ET at the scale of individual fields. This article introduces three satellite-based irrigation tools including FRET, IrriSAT, and OpenET. A comparison of the estimated daily crop water needs utilizing OpenET tool and actual ET measured for a period of 150-day is also presented for an avocado grove in the San Pasqual Valley, Escondido.

FRET (Forecast Reference EvapoTranspiration)

A new alternative to weather station ET is forecast reference ET or FRET (Fig. 1). The National Weather Service offers FRET data on the Graphical Forecasts page of their website. FRET is one option in the digital forecast database display, and you can zoom in to find ETo data for your field up to six days in the future. In other words, FRET will assist growers to have forecast ETo up to the next six days and more effectively schedule irrigation. FRET is currently available at https://digital.weather.gov/. This tool is particularly very useful to forecast crop water needs and schedule running hours of irrigation system ahead of heat waves in avocado orchards.

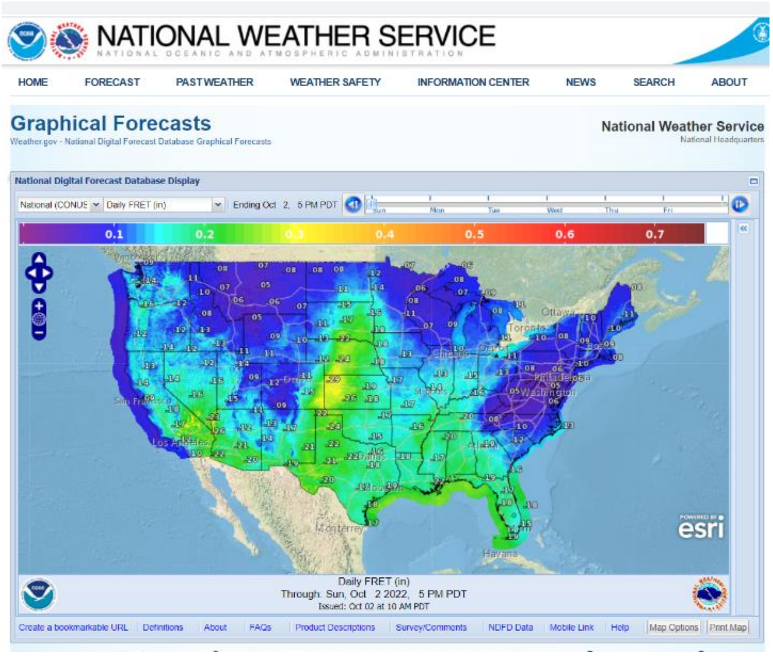

Fig. 1. A screenshot of the FRET ETo map for the entire United States issued on October 2, 2022.

IrriSAT irrigation decision support system

IrriSAT is a weather-based irrigation management and benchmarking technology that uses remote sensing to provide site specific crop water management information across large spatial scales (Fig. 2). It uses satellite imagery to estimate crop coefficients (Kc) at a 30 m resolution. IrriSAT calculates Kc from a linear relationship with satellite derived Normalized Difference Vegetation Index (NDVI). Daily crop water use is determined by simply multiplying Kc and ETo observations from a nearby weather station. A beta version of the app is currently available at https://irrisat-cloud.appspot.com/, developed using Google App Engine.

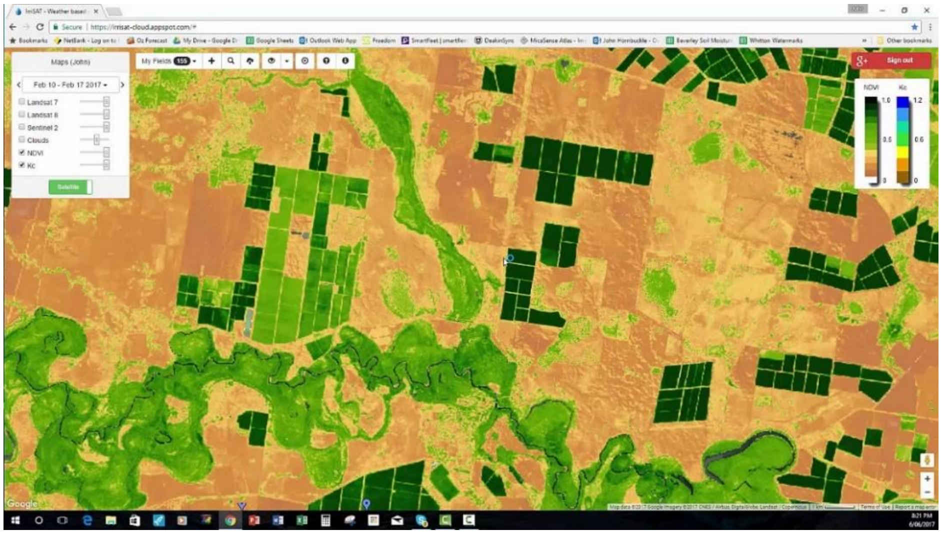

Fig. 2. A screen dump of crop coefficients calculated by the IrriSAT Google App. By combining reference evapotranspiration and the Landsat derived crop coefficient, crop water use can be determined on a 30m x 30m basis such that: ETc = ETo × Kc.

OpenET

OpenET is a new online platform that uses satellites for mapping evapotranspiration (actual ET) at the scale of individual fields, and currently can be used in 17 western states (Fig. 3). OpenET is produced at a spatial resolution of 30m x 30m (0.22 acres). Daily, monthly, and cumulative ET data are now available on the OpenET Data Explorer. OpenET is currently available at https://openetdata.org/.

OpenET currently includes seven models that are developed based on full or simplified implementations of the surface energy balance (SEB) approach or relies on surface reflectance data and crop type information to compute ET as a function of canopy density using a crop coefficient approach for agricultural lands. The model acronyms are *eeMETRIC*, *geeSEBAL*, *DisALEX*I, *SSEBop*, *PT-JPL*, and *SIMS*. In addition, OpenET provides the OpenET ensemble values calculated from an ensemble of the above six models.

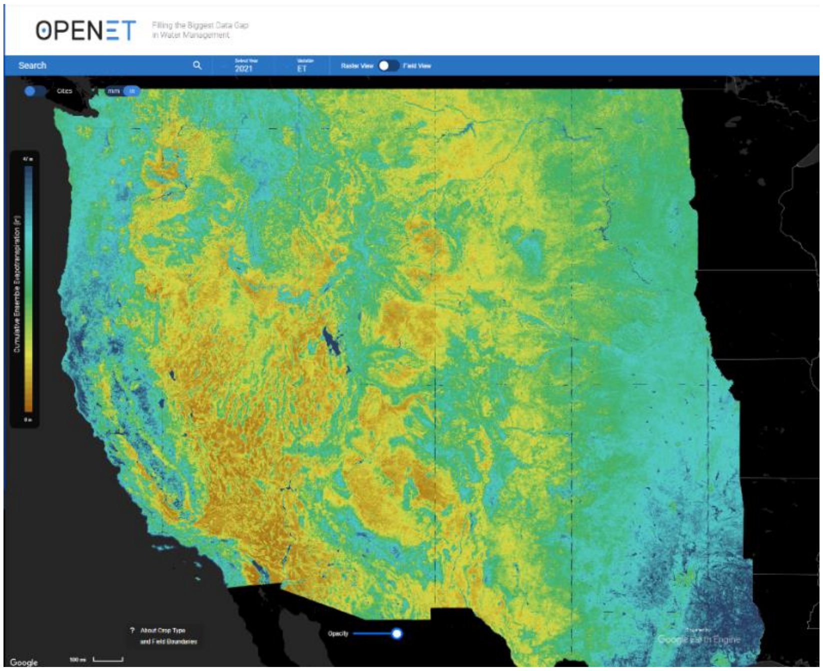

Fig. 3. A screen dump of cumulative ET (inch) for the entire western states in 2021. You may zoom on the OpenET map to find your orchard for a specific time (daily, monthly, yearly) and explore the data.

OpenET to estimate crop water needs of avocados. A case study was conducted to estimate daily ET values in an avocado grove in the San Pasqual Valley, Escondido over a 150-day period (May 1st, 2022, through September 327th, 2022). The experiment was carried out in nearly 3-acre (south facing row orientation) of this 8-acre avocado grove. The ET estimated from the OpenET models, and the OpenET *Ensemble* were evaluated versus the actual ET measured using the residual of energy balance approach (Fig. 4) with a combination of surface renewal and eddy covariance equipment.

Fig. 4. Ground view of surface renewal and eddy covariance ET station at the avocado site in Escondido.

The actual ET (measured) varied widely throughout the study period. The ET ranged between 0.03-inch d^{-1} (May 20th and September 9th) and 0.23-inch d^{-1} (May 13-14) (Fig. 5). The cumulative ET, average daily ET, and maximum daily ET were 26.78, 0.18, and 0.23-inch, respectively (Table 1).

Comparing the cumulative ET and daily ET values estimated from the OpenET models and measured from the surface renewal equipment indicated that both *geeSEBAL* and *SIMS* models provide an accurate estimation of ET for the experimental site (an average of 2% cumulative ET difference). All other OpenET models and the OpenET *Ensemble* overestimated the ET of the avocado site from 11-12% (*Ensemble* and *eeMETRIC* models) to 51% (*DisALEXI* model).

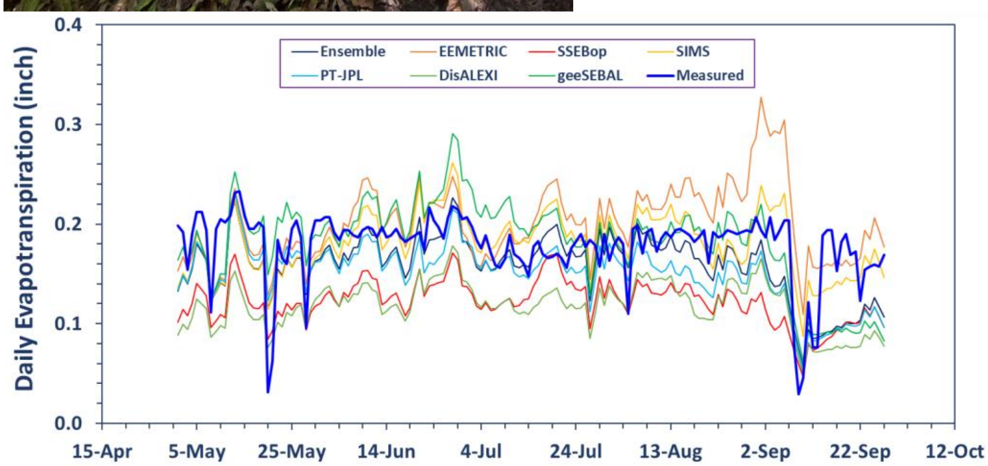

Fig. 5. Daily ET estimated by the seven OpenET models and measured using surface renewal equipment in an avocado orchard the San Pasqual Valley, Escondido.

Recommendations. While more comprehensive efforts will be conducted to evaluate the accuracy of OpenET under different canopy features, row orientations and environmental conditions for avocado orchards, this case study demonstrates a good agreement between the results of OpenET (*geeSEBAL* and *SIMS* models) and field measurements for an avocado site. As a user-friendly satellite-based irrigation tool, it is recommended growers consider using OpenET to manage water and fertilizer more efficiently in avocado orchards. More comprehensive evaluation and information to adopt OpenET in avocado orchards under various circumstances will be developed and shared in the next future.

Excess irrigation can be considered beneficial water use for salinity management in avocado groves. In other words, 26.7-inch actual ET measured for the experimental avocado site over the 150-day study period is only avocado crop water use over the period. The amount of additional irrigation water to effectively drain salt from the crop root zone depends on the soil conditions and effective rainfall. The irrigation water that needs to be applied in an individual orchard over the season depends on crop water requirements, effective rainfall, irrigation system efficiency, and salt leaching requirements.

Table 1. Cumulative ET, maximum daily ET and average daily ET estimated by the seven OpenET models and measured using surface renewal equipment in an avocado orchard the San Pasqual Valley, Escondido. The comparison was conducted for a 150-day period (May 1st, 2022, through September 27th, 2022). The ET values are reported in inch.

	Ensemble	***eeMetric***	***SSEBop***	***SIMS***	***PT-JPL***	***DisALEXI***	***geeSEBAL***	**Measured**
Cumulative ET	23.84	30.10	18.36	27.16	22.70	17.70	27.47	**26.78**
Maximum Daily ET	0.23	0.33	0.17	0.26	0.23	0.18	0.29	**0.23**
Minimum ET	0.06	0.11	0.05	0.09	0.05	0.05	0.06	0.03
Average Daily ET	0.16	0.20	0.12	0.18	0.15	0.12	0.18	**0.18**

Managing citrus mealybug – does ant control help?

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Starting 2019/20 season, pest control advisors started noticing citrus mealybug infestations in multiple citrus varieties that continued to increase in acreage in the San Joaquin Valley. Although present in the citrus systems, mealybugs were considered to be a minor pest and kept well under check by natural enemies until recently.

What are mealybugs?

Mealybugs are soft, oval, flat, distinctly segmented insects whose body is covered in white mealy wax. Citrus mealybug, *Planococcus citri* is the most common species associated with citrus. Females lay ~600 eggs in egg sacs loosely held by white cottony flint (Fig. 1A, 1B). Crawlers are yellowish, and can move or be carried by ants, birds, or the wind to start new infestations. Crawlers feed by sucking sap using straw-like stylets and soon develop a waxy covering (Fig. 1C). Like California red scale, females molt and stay as third instars until mated by a male. Males go through a pupal stage and emerge as adults with wings that fly to seek a mate (Fig. 1D).

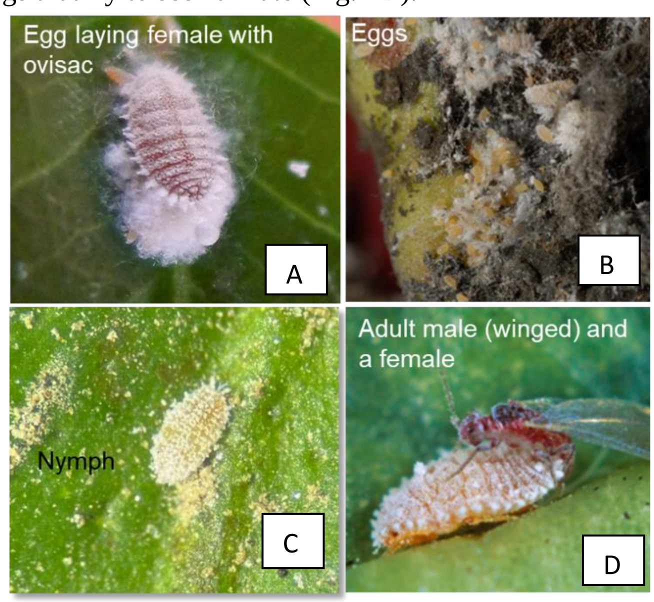

Figure 1. Adult female with egg sac underneath (A), eggs- amber yellow and oval (B), nymph (C), and male (winged) mating with female (D).

Mealybugs prefer the inside canopy of the tree and can be found under dense leaves, between clusters of fruits, or in other cryptic places where they can be difficult to find, especially when the population is low. As the season progresses and the tree flushes, blooms, and fruit develops, mealybugs move to the parts of the tree where nutrients flow. Ongoing research on seasonal phenology suggest that there are 5-6 generations in the San Joaquin Valley. The first generation starts from overwintering adult/egg populations in late March/early April. The second-generation crawlers/nymphs move to fruit in June/July. The remaining generations each year primarily feed and multiply on the fruit.

Mealybugs produce nutrient rich honeydew that is an attractive food source for ants. Ants have been reported to defend insect colonies from predators and parasitoids. In an early infestation, ant trails can be used as an indicator to locate mealybug infestations or other sap sucking pests. Managing sugar feeding ants in citrus orchards has shown increased biocontrol of sap sucking insects (McCalla et al. 2023). It is plausible that loss of chlorpyrifos as an ant control tool may have aggravated ants thereby aiding to increase mealybug pressure in recent years.

As mealybugs have become a reoccurring pest in citrus orchards, University of California researchers-initiated studies to work towards developing strategies to manage this pest. Research funded by Citrus Research Board and led by Gautam lab is investigating biology, field ecology, and management of mealybugs (Gautam 2023, Gautam et al. 2023). During field visits, our observations have shown that various ant species of were present throughout the growing season attending mealybug colonies (Fig. 2).

Figure 2. Ants attending a mealybug colonies.

Does managing ant help suppress mealybug?

UC researchers have documented that managing sugar feeding ants increases biocontrol, thereby reducing the pest pressure of sap sucking insects. When ant densities are were reduced >90%, there was ~90% less mealybug on twigs and complete elimination of mealybug was reported from fruit (McCalla, 2023). However, managing ants has been a challenge since the use of chlorpyrifos was banned. To address this need, UC researchers have worked to develop and test different types of hydrogel beads for delivering insecticide products to sugar-feeding species of ants (Haviland et al. 2024).

Research led by David Haviland has focused on the experimental use of commercially-available polyacrylamide hydrogel beads for large field-scale applications. In 2023 a large-scale field trial was conducted in a 20-acre grapefruit block in Sanger, California. Two applications of hydrogel beads laced with insecticides were made on Aug 2 and August 30, 2023. Post-treatment evaluations for ant density were done on 24 trees/plot by counting the number of ants that passed through a graft union for 15 secs weekly for 4 weeks after each application. The effects of ant suppression on mealybug densities was evaluated in October 2023 by counting the number of fruits infested with mealybugs (presence/absence) on 30 fruits from the inside canopy. Insecticide treatments had variable results on ant density, with lowest ant density consistently found in plots treated with thiamethoxam (Fig. 3). Similarly, plots treated with thiamethoxam had the lowest populations of mealybugs (Fig. 4).

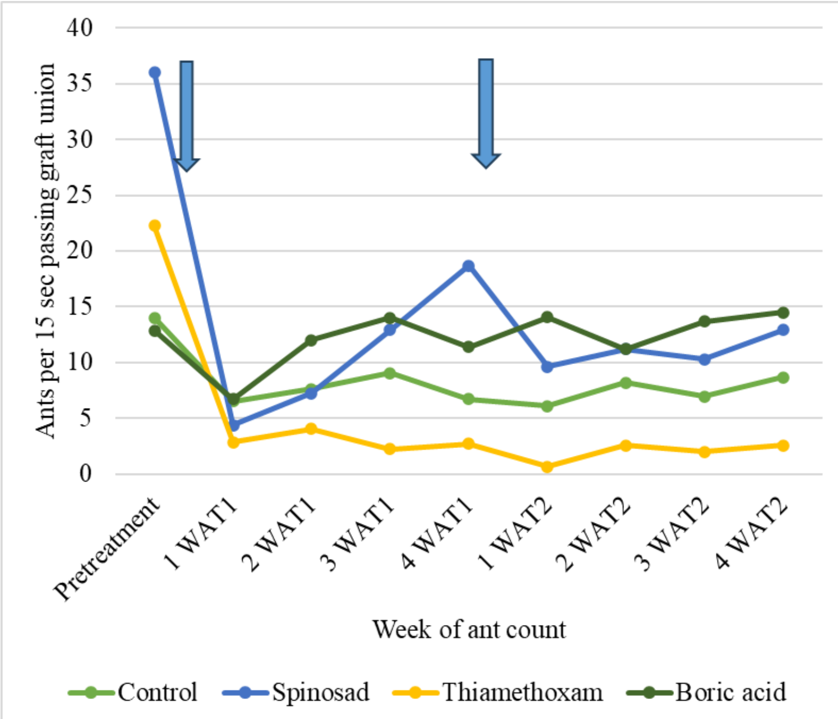

Figure 3. Ant density passing a graft union/15 sec. Arrows indicate timing of insecticide applications. The first application was made on Aug 2 and second application was made on Aug 30.

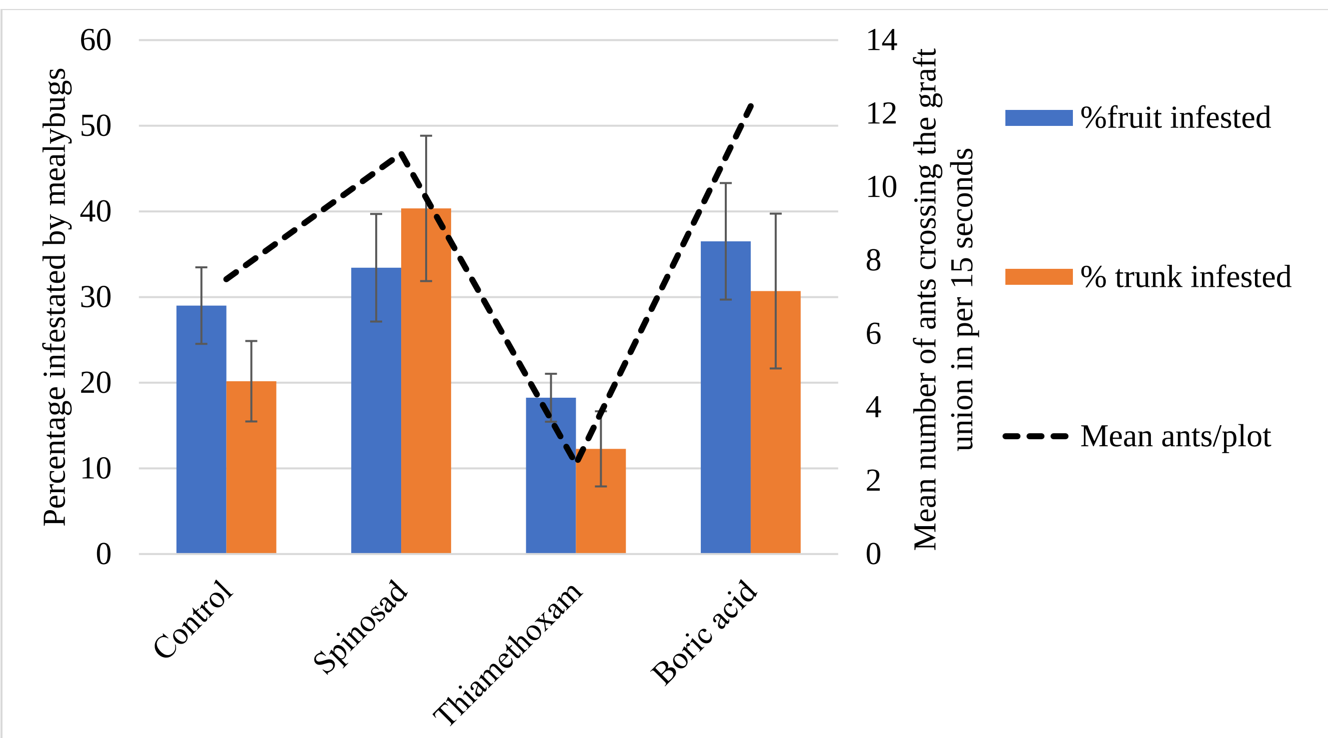

Figure 4. Effects of ant treatments on the number of foraging ants on the trunk, and on the percentage of trunks and fruit infested by mealybug.

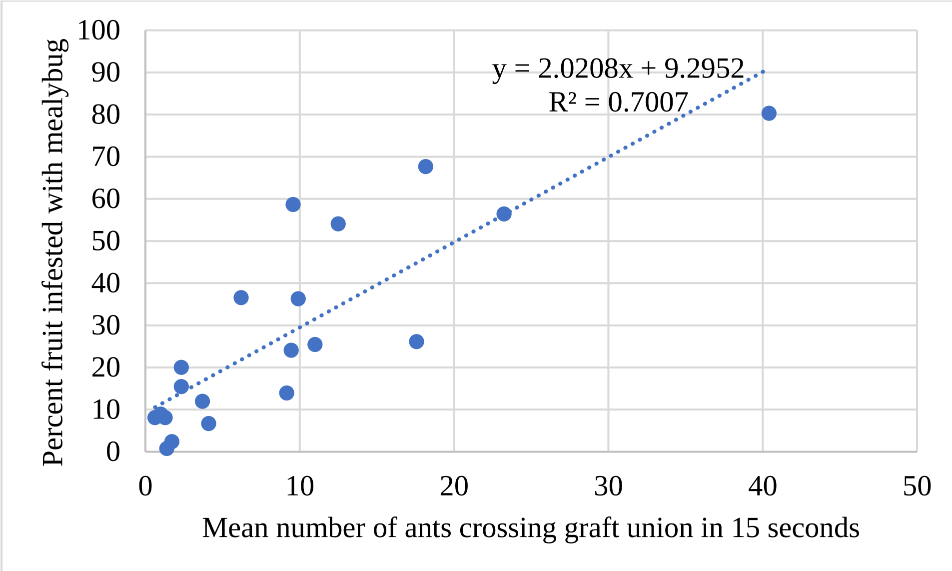

Figure 5. Scatterplot showing the relationship between ant density in tree and fruit infestation with citrus mealybug.

While there were remarkable variations in the percentage of fruit infested with citrus mealybug among plots, the plots treated with Thiamethoxam had least ant density and mealybug infestation across the field. There was positive co-relation between ant density in tree and percentage of fruit infested with citrus mealybug incidence Fig. 5. Starting ant management early in the season prior to mid-June as the second generation of mealybug starts emerging may help suppress mealybug pressure.

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Understanding fruit fly quarantines

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There are several species of fruit fly in the family Tephritidae that are considered serious agricultural pests. These flies, including Mediterranean Fruit Fly, Queensland Fruit fly, Tau fruit fly and Oriental fruit fly, lay eggs that hatch into maggots inside the fruit from over 100 different crop species. Not only do the maggots tunnel through fruit, but they introduce decay organisms and facilitate tissue breakdown. Some species will attack flowers and plant stems as well. Fruit flies are prolific breeders and adaptable to different climates, making them a threat to a wide variety of California commodities. To stem the attack of fruit flies, CDFA maintains an array of detection and monitoring devices to establish distribution indices for these flies. Regions then exceeding thresholds fall under a quarantine. These fruit flies have triggered quarantines throughout southern California in recent months, in Contra Costa, Sacramento, San Bernadino, Santa Clara, Ventura, and Los Angeles. As we monitor the fruit fly issue and expansion of regional quarantines, growers throughout the state can get ahead of the curve by learning more about how these fruit fly quarantine restrictions and regulations work.

Growers can track the expansion of quarantine zones on CDFAs website to see how near they are to a quarantine zone. Should they fall under quarantine, they are required to hold their crop for the duration of one fruit fly life cycle. This life cycle holding period will vary based on the fruit fly species and the weather. For example, the life cycle of the Queensland Fruit Fly is around 90 days in the winter and 30 days in the summer. Growers can view the fruit fly life cycle lengths at the CDFA pre-harvest treatment schedules website. During this holding period, growers must treat their crop repeatedly with a bait spray until the holding period expires. Bait sprays consist of a food attractant and an insecticide and are applied at low volumes along a field perimeter and at spaced intervals throughout a field to kill flies. One option is to treat with Malathion + NuLure every 6-14 days for the duration of the holding period, although growers may need to notify their county agricultural commissioner and register for special local need usage. Growers can also use GF-120 Spinosad bait every 7-10 days for organic control. Treatment choice involves assessing tradeoffs between efficacy, cost, and pre-harvest interval restrictions. For example, spinosad baits have very short pre-harvest intervals, making them suitable when harvesting on a frequent basis, but they are more expensive).

One additional option that growers have is participating in a pre-quarantine program. These are offered and overseen by each individual county, so growers should check in with their local county agricultural commissioner's office to see if they are eligible for participation. The way these programs work is that growers can voluntarily opt to apply fruit fly bait spray treatments. Should that grower fall under quarantine later, the treatments they applied count towards the holding period and they will be able to move harvested product more quickly. If a grower is very close to a quarantine zone and anticipates economic losses due to a long holding period (particularly in winter months, when holding periods are longer), they may want to consider participating in a pre-quarantine program as a proactive measure.

While fruit flies are among the world's most destructive agricultural pests and will likely continue to pop up periodically in California, quarantines and associated regulations have historically been successful at eradicating them in California. If you have any questions about how these quarantines impact your grower operations, contact your local UCCE office.

Phytoplasma Diseases of Palms in the USA

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Phytoplasmas are plant pathogenic bacteria that lack cell walls and have reduced genomes. Their taxonomy has historically been based upon 16S ribosomal gene sequences. Since they have not been cultured to date, they are classified as *Candidatus* Phytoplasma spp. Phytoplasmas of various taxonomic designations have been associated with or shown to cause diseases in a wide range of cultivated and wild plant species. In recent years, long-established and newly reported declines or diseases of palms have been associated with phytoplasmas. Although there are reports of phytoplasma-associated diseases of palms in both the Eastern and Western Hemispheres, this brief review will focus on reports from the United States.

The earliest reported disease of palms that was later associated with Phytoplasma infection was Lethal Yellows (LY). LY is a disease which attacks and kills coconut palms (*Cocos nucifera*). LY was first reported in Jamaica in 1891 and much later (1972) associated with a phytoplasma (Tsai and Harrison 2003), which was later identified as being in the taxonomic sub-group 16SrIV-A (Harrrison *et al.* 2002a). An epiphytotic of LY occurred in southern Florida in the 1960's to 1970's (Tsai and Harrison 2003). During this outbreak *Phoenix* spp., which in Florida were planted as ornamentals or present in germplasm collections or botanic gardens were also shown to be susceptible. This was evidenced by the presence of mycoplasma-like bodies observed in tissues via electron microscopy (Thomas 1974, 1979; Howard *et al.* 1979). *Phoenix dacytlifera* was more susceptible to decline than other *Phoenix* spp., being equivalent in this regard to *C. nucifera* (Howard and Barrant 1989), although the symptomology was distinct compared to that in *C. nucifera* (McCoy et al. 1983). The vector of LY in Coconut palm was demonstrated to be the planthopper *Haplaxius crudus* van Duzee, and this was assumed to be the vector transmitting LY to *Phoenix* spp. as well (Howard *et al.* 1983, 1984).

In the late 1970's, *Phoenix* spp. palms growing in the Lower Rio Grande Valley of south Texas were observed to be declining in a manner similar to declines observed in *Phoenix* spp. in south Florida that had been associated with phytoplasmas, and it was assumed without proof that phytoplasmas were also the cause of the declines in Texas (Miller *et al*. 1980; McCoy *et al*. 1980 a, b). A separate outbreak of declines of *Phoenix* spp in south Texas in 2001 with similar symptomology was found to be associated with phytoplasmas of the taxonomic sub-group 16SrIV-D and was designated as "Texas Phoenix Palm Decline" (TPPD) (Harrison *et al*. 2002b). However, Harrison *et al*. (2002b) stated that it was not clear whether the source of this decline was the previously reported decline in Texas of had been introduced from a different area. The vector of TPPD was unknown and was not considered to be *H. crudus* (Elliott and Harrison 2007). In 2007, declining trees with symptoms similar to those of LY and LB were detected in Florida and found to be associated with the TPPD phytoplasma (Harrison *et al.* 2008). Recently, *H. crudus* was shown to be a competent vector of the 16SrIV-D phytoplasma (Mou et al. 2022). TPPD is now generally referred to as "Lethal Bronzing" Disease (LBD) (Bahder and Helmick 2019).

Both the LY and LBD phytoplasmas infect a wide range of palm species, with differing symptomology amongst the different genera (Bahder and Helmick 2018, 2019). The largest economic impact of the palm phytoplasma diseases is associated with coconut palm. LY has had a devastating impact on the coconut industries of several countries in the Caribbean Basin. If fruit is present (that is, the palm is an adult and the disease occurs during the fruit development cycle), the first symptom is a premature fruit drop (Figure 1). This in itself would present an economic hit to the Coconut industry, but LY can and does kill coconut palms. In addition to the premature fruit dehiscence, LY can cause necrosis of inflorescences. Foliar symptoms are a chlorosis (yellowing) of the leaves in the canopy, starting with the older leaves and advancing to the younger leaves (Figure 2). For many selections of coconut palms, the leaves turn a golden-yellow, while in other types the leaves turn a reddish- to grayish-brown. Chlorotic leaves initially remain erect but eventually necrose and hang down around the crown of the tree before falling off (Figure 3). Eventually the apical bud is killed and the palm dies. This generally occurs when 50 – 75 % of the crown has become chlorotic.

This same pattern is observed in other palm genera, while still others, including *Phoenix,* show a different pattern of disease. In these palms, fruit drop is not observed. Leaves, starting from the older and proceeding to the younger, turn a reddish-brown to dark brown or gray (Figure 4). As with other genera of palms, eventually the apical meristem is killed and the tree dies. However, *Phoenix* species generally die when only about 33 % or less of the leaves are discolored. The symptoms for LY and LBD are similar, and host ranges are similar. For LY and LBD, death of the tree generally occurs within 3 to 5 months after initial infection.

In Florida, LY has generally been reported from the southern tier of the state, but more recently there have been reports from as far north as Gainesville. LBD was initially detected in the central tier and later in the southern tier. At this time, in the United States, LY has been reported from Florida, whereas LBD has also been reported from Texas and Louisiana. Similar palm declines associated with these and other related phytoplasmas have also been reported from Mexico and other countries in the Caribbean Basin.

In Florida, Texas, and Louisiana, palms are grown for ornamental purposes. In California, palms are also popular ornamental trees, but dates, produced by the date palm, are a locally important crop in the low desert areas of California and Arizona. The potential threat of phytoplasmas to the date industry has been recognized since the reports of LY in Florida in the 1970's, particularly since it was noted to affect *Phoenix* species in germplasm collections and botanic gardens (McCoy et al 1976, 1982). Howard et al (1985) established a small experimental planting of 5 date palm cultivars in southern Florida in the early 1980's. All were found to be hosts to the vector, *H. crudus*, although it was present in lower populations than on nearby coconut palms. Howard (1992) reported that 94.1 % of the five cultivars established ('Deglet Noor', 'Zahidi', 'Thoory', 'Medjool', and 'Halawy') developed symptoms of LY and phytoplasmas were observed in 'the phloem of all symptomatic palms. 'Halawy' palms survived infection longer than the other cultivars. As *P. dactylifera* is also susceptible to LBD, which may also be either more widely established further north in the Western Hemisphere or be vectored by more northerly established insects, LBD (and possibly other phytoplasma-associated palm declines) can also be considered a potential threat to the U.S. date industry.

In 2014, the LBD-associated phytoplasma was detected in date palm samples from Riverside County by researchers in Florida. However, the official diagnostic testing by the California Department of Food & Agriculture did not confirm this result. Thus, no palm decline-associated phytoplasmas have been officially detected in California (Harrison and Elliot 2016). Apparently, there have been no follow ups to this report. Declining date palms in the Coachella and Imperial Valleys do not exhibit symptoms consistent with phytoplasma-associated declines. In addition, the vector *H. crudus* is not known to occur in California (T. Perring, personal communication). It is possible that other planthoppers in California are able to transmit the pathogen, but this is not known. The climates of the low desert and the Caribbean Basin are very different, and it is possible that the high summer temperatures in the low desert would not be conducive to phytoplasma survival. It is also possible that, due to the climatic differences, the epidemiology and symptom expression would be different than in the Caribbean Basin.

It is also possible that the phytoplasma-associated diseases could become established in ornamental palm plantings in the coastal region of southern and central California or the Central Valley. However, again, symptoms consistent with LY or LBD infections from the Caribbean Basin have not been observed, nor the vector reported.

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Figure 1. Fruits that prematurely dropped from Coconut palm due to Lethal Yellows. Photo credit: NA Harrison

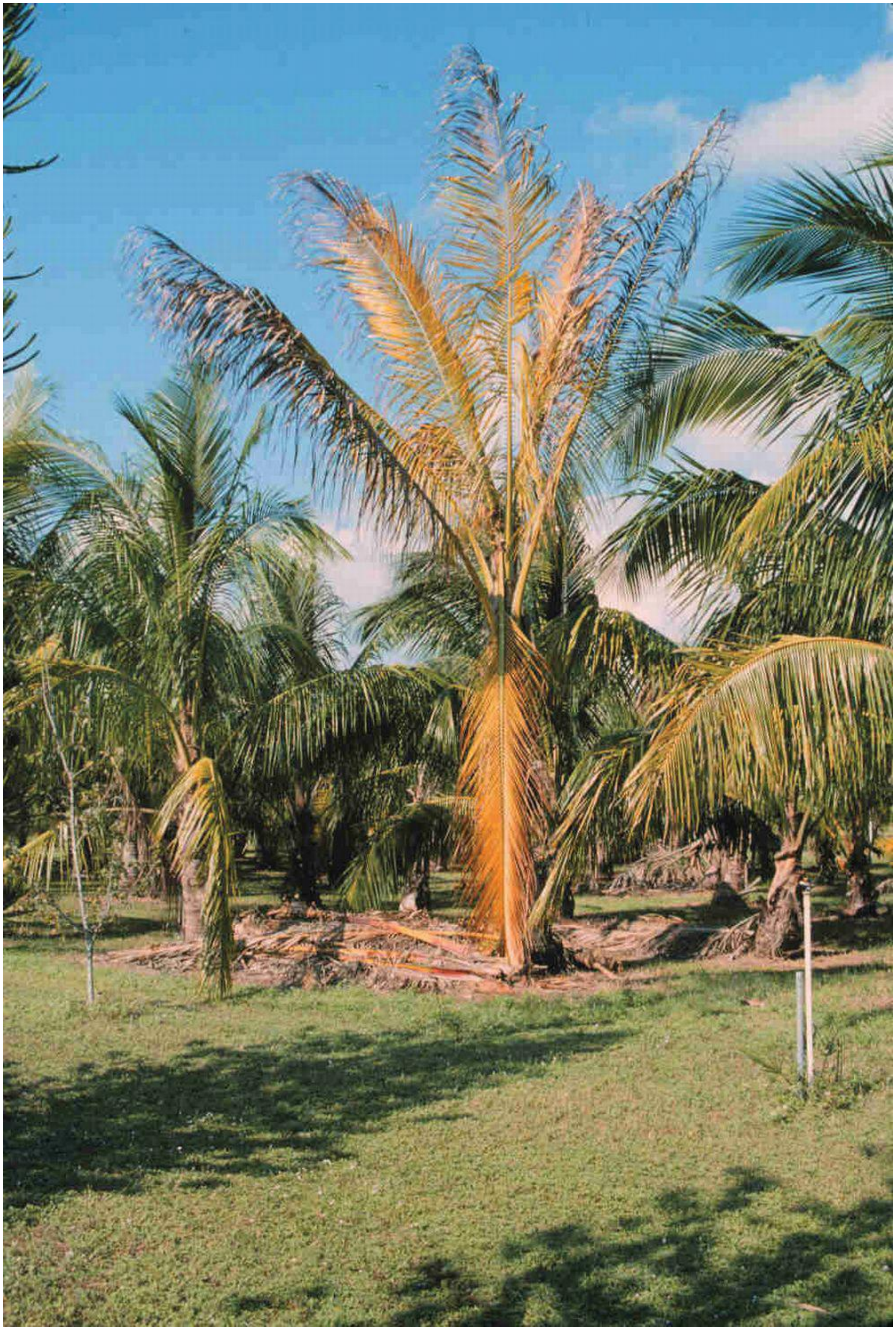

Figure 2. Foliar yellowing symptoms of Lethal Yellows on Coconut palm. Photo credit: NA Harrison

Figure 3. Lethal Yellows symptoms on Coconut palms. Palm on left exhibits solitary chlorotic leaf near apex with dead leaves hanging down around trunk. Photo credt: TK Broschat

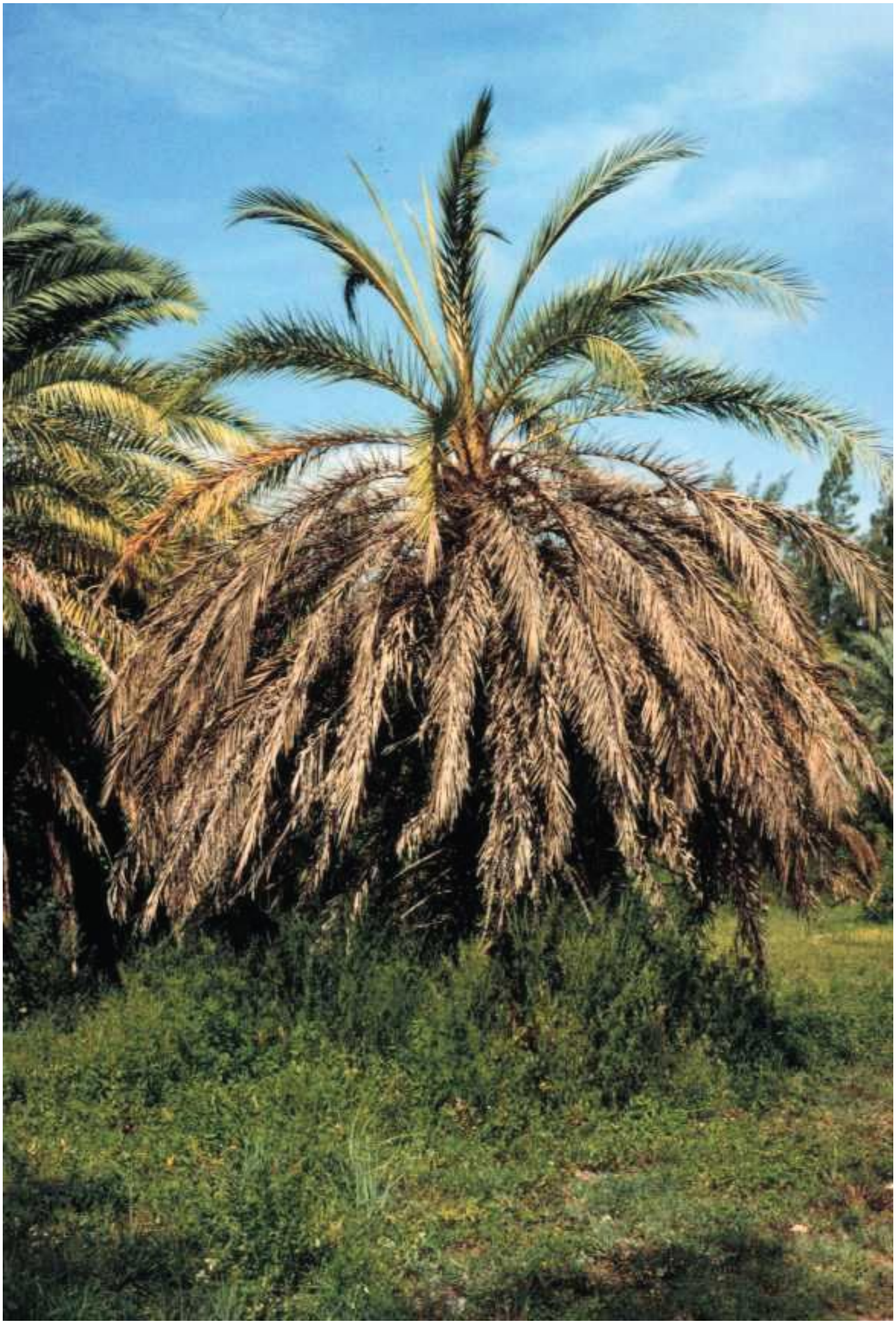

Figure 4. Date palm exhibiting foliar browning symptoms of Lethal Yellows. Photo credit: NA Harrison

Cultivating Citrus Resilience to HLB in California

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Huanglongbing (HLB), also known as citrus greening disease, is caused by the bacterium Candidatus Liberibacter asiaticus, which is transmitted by the Asian citrus psyllid. The bacterium harms citrus trees in several ways, leading to severe physiological and structural damage.
After the infection, the HLB bacterium invades the phloem, the vascular tissue responsible for transporting nutrients throughout the tree. HLB causes a disruption in nutrient uptake and transport within the tree. This leads to nutrient deficiencies, particularly in essential elements such as nitrogen, phosphorus, and potassium. As a result, the tree experiences stunted growth, yellowing of leaves (chlorosis), and overall nutrient imbalance. The bacterium affects the root system, leading to root loss and dieback. This compromises the tree's ability to take up water and nutrients from the soil, exacerbating the impact of nutrient deficiencies and water stress. Additionally, it affects the photosynthetic process in citrus trees. The bacterium's presence disrupts chloroplast function, reducing the tree's ability to convert sunlight into energy. This results in decreased photosynthesis, further contributing to nutrient deficiencies and overall tree decline. One of the characteristic symptoms of HLB is the yellowing of leaves, often referred to as citrus greening. The bacterium affects the chlorophyll content in leaves, leading to a mottled appearance. This yellowing occurs unevenly on the tree and is a clear indicator of HLB infection. HLB-infected trees experience stunted growth due to the disruption of normal physiological processes. The overall health of the tree declines, leading to a reduction in fruit production and quality. Infected trees may produce smaller, misshapen, and discolored fruit. HLB-infected trees often exhibit premature fruit drop, where fruit drops from the tree before reaching maturity. This is a significant economic impact for citrus growers, as it reduces the yield and marketable fruit. Over time, HLB-infected trees undergo a general decline in health. The combination of nutrient deficiencies, reduced photosynthesis, and compromised vascular function can lead to the death of the tree. The lifespan of infected trees is significantly shortened compared to healthy trees.
It's important to note that there is currently no cure for HLB, and managing the disease involves a combination of strategies. While researchers from all over the world are working hard to get a cure for that disease, citrus growers are increasingly turning to cultural practices (a diverse set of agricultural strategies) as a sustainable and holistic approach to mitigate the profound impact of this relentless disease. Cultural practices encompass a nuanced and multifaceted array of agricultural techniques and approaches used in citrus groves. In the realm of citrus and HLB management, a comprehensive strategy is imperative to create an environment that not only minimizes the likelihood of disease transmission but also nurtures the robustness of citrus trees and makes them more resilient to HLB.

Various agencies in California are making significant efforts on Psyllid monitoring and management, a first defense line to stop the spread of the disease. Regular Monitoring: Instituting a meticulous and frequent monitoring system for Asian citrus psyllid populations is paramount. This proactive approach enables growers to detect infestations early, facilitating targeted interventions to halt the spread of HLB. In addition to Psyllid monitoring and management, harnessing the power of nature through the introduction of beneficial insects establishes a delicate ecological balance. These natural predators act as biological control agents, keeping psyllid populations in check without resorting to chemical pesticides. Swift identification and removal of HLB-infected trees are critical components of disease management. The prompt destruction of infected trees eliminates potential bacterium reservoirs, mitigating the risk of further psyllid transmission to healthy trees. Utilizing beneficial microorganisms as soil inoculants enhances root health and improves nutrient uptake, potentially bolstering the tree's ability to withstand HLB stress.
Another method is to isolate the trees from the Psyllid through growing the Citrus trees Under

Protective Screen (CUPS). The system is a closed screenhouse built on a number of acres from 1-5 acres. The system is currently used by some growers in Florida; however, the response of the Californian varieties to grow under such conditions is not known. The first CUPS structure was established at UC Lindcove research and extension center, and we are currently evaluating the performance of some varieties under this structure.

Recognizing that weeds can serve as alternative hosts for psyllids, implementing rigorous weed management practices eradicates potential habitats and minimizes the presence of psyllids in citrus groves. Studies in Florida and California showed a beneficial effect of using wood chip mulching on root growth and weed control. We are collecting more data on these trials, and it will be available for the growers during the next season.

Managing nutrients with precision is vital for supporting citrus tree health. Tailoring fertilization to the unique needs of the orchard ensures trees receive optimal amounts of essential nutrients like nitrogen, phosphorus, and potassium. This fortification enhances natural defenses against HLB. Additionally, implementing consistent and well-timed irrigation practices is crucial. Effective water management alleviates stress on citrus trees, reducing susceptibility to HLB and other stress-related diseases.

Further, incorporating HLB-resistant rootstocks is a crucial aspect of disease management. Selecting rootstocks that exhibit resistance or tolerance to the bacterium contributes significantly to orchard health. Ongoing research endeavors focus on identifying citrus varieties that exhibit inherent resistance or tolerance to HLB. The strategic planting of these varieties adds an extra layer of protection against the disease and its associated symptoms, contributing to the overall health and productivity of citrus orchards. Currently, we are evaluating the effect of a number of HLB resistant rootstocks on the tango mandarin growing under California conditions. These rootstocks include US942, US897, and X639. The evaluation of the resistant rootstock and varieties will continue in collaboration with worldwide researchers.

In the face of the formidable challenge presented by HLB disease, cultural practices emerge as a promising, sustainable, and sophisticated approach to mitigation. By embracing a comprehensive strategy that intertwines vigilant psyllid management, optimization of tree health, meticulous sanitation measures, selective varietal planting, and collaborative initiatives, citrus growers can fortify the resilience of their orchards. The integration of cultural practices, including rootstock selection and proper fertilization, not only contributes to HLB control but also nurtures the long-term sustainability of citrus farming, ensuring a future where citrus crops not only survive but thrive in the face of adversity. As our understanding of cultural practices evolves, the citrus industry can anticipate a resilient, vibrant, and flourishing future.

It is worth mentioning that California is hosting the next international HLB conference in Riverside, California, on March 26-29, 2024, and registration is open at this link: https://web.cvent.com/event/7c12d9c3-01db-4e6e-b781-aafeb0f7109a/summary. Researchers from all over the world will share their experience and the latest update on citrus HLB.

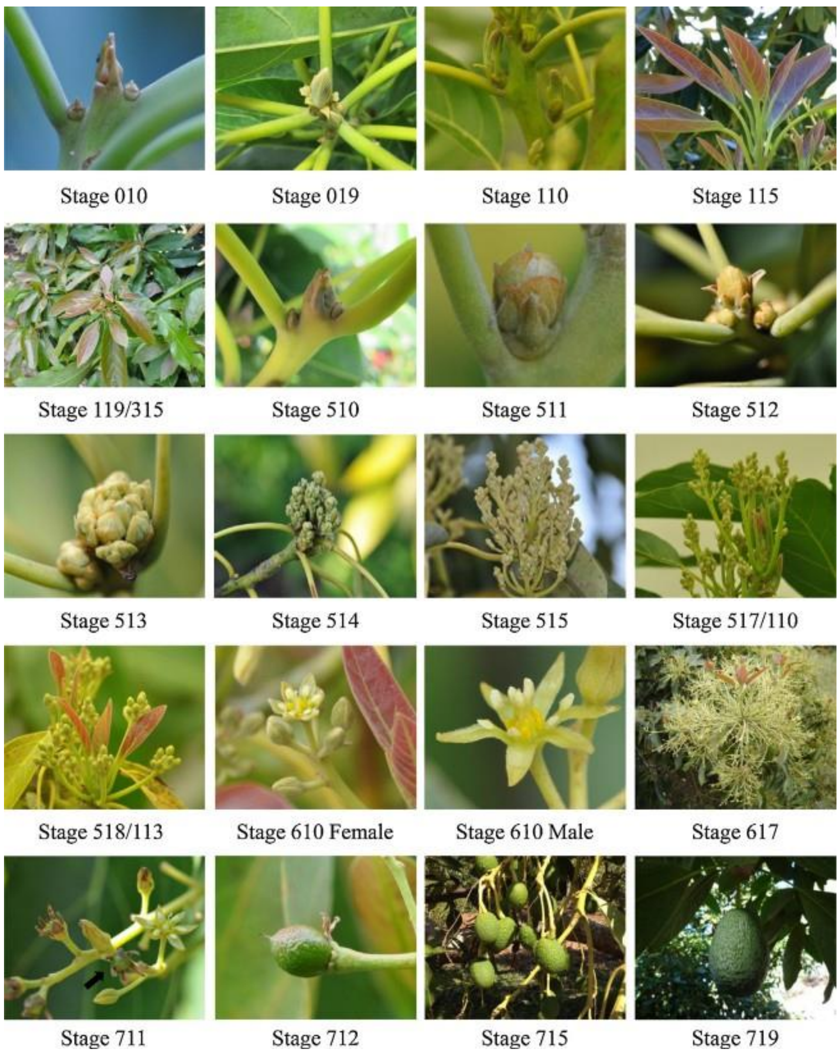
Phenology and the Avocado

Ben Faber

Farm Advisor UCCE Ventura County

Plants, therefore avocados, go through different growth stages, so called phenological stages, regular periods where they grow and differentiate from seed to various vegetative stages, flowering and finally seed production. Avocado has a preset pattern of phenology that occurs depending on variety and where it is grown, driven by light, temperature, water availability and often by different stresses, such as cold, heat, and heavy or light crop load.

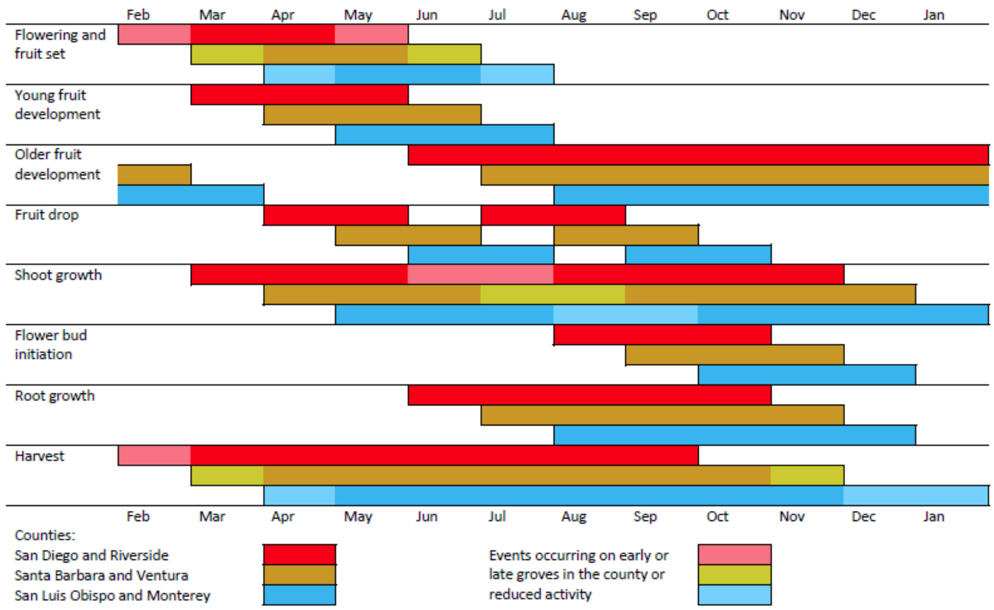
The successive stages of avocado phenology are demonstrated in the photomontage below, from bud break to harvestable fruit:



Main phenological growth stages of 'Hass' avocado according to the extended BBCH scale. From: http://avocadosource.com/journals/elsevier/scientiahort_2013_164_434-439.pdf

And, depending on where in California the avocado is growing, the latitude, or on what side of the slope (in the shade or full sun, on the top of the slope, etc.), the tree will go through these successive stages at different times of the year, offset by weeks or even months. A general plan for the California coastal region was developed from accumulated experiences and tests by a variety of groups and is shown below:

The average seasonal phenology of avocado trees, typically of the Hass variety, across a single year for the main growing regions in southern California. Individual trees and groves may be earlier or later than the average, and the precise timing of phenological events depends on a number of factors, including: cropping history of the trees, the cultural-management practices used on the grove, prevailing weather conditions and harvesting decisions.



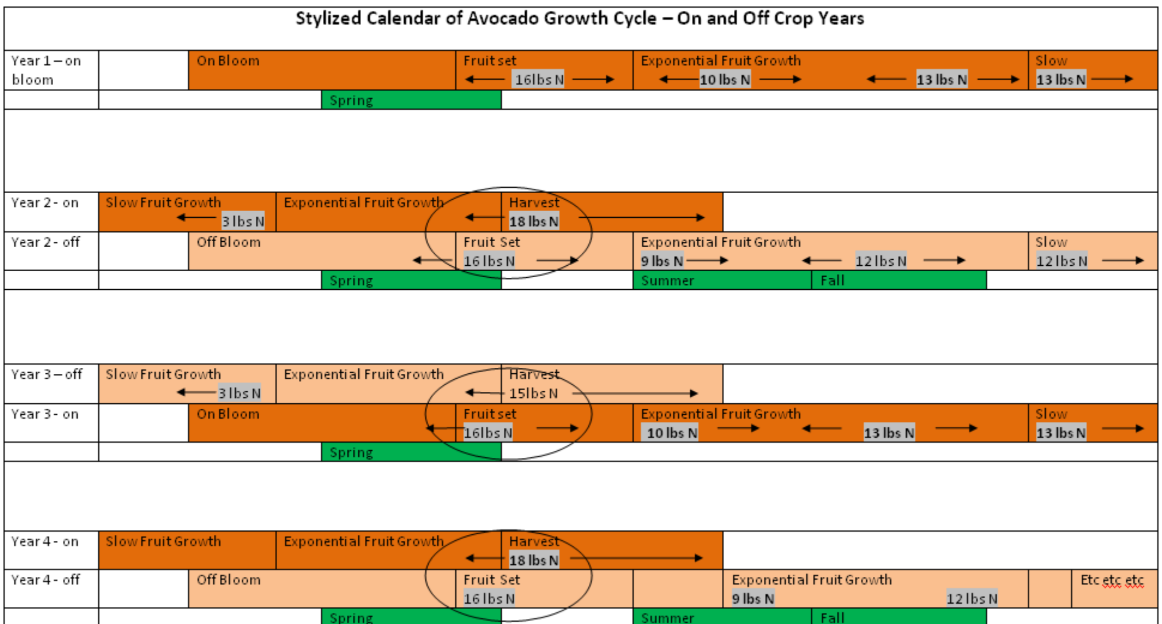
Redrawn from: Integrated Pest Management for Avocados UCANR Publication 3503

Research-based information that allows producers to anticipate the regionally appropriate times for major phenological evets is limited in California. From work conducted at South Coast Research and Extension Center in Irvine, the onset of flowering in early March extends into May, normally, and the main fruit set period is between mid-April and May. I later work from the same location, a mean beginning bloom date for "on" and "off" crop years differed between Julian date 66 (March 7) and 80 (March 21), respectively. From avocado research in Carpinteria, flower abscission (as a measure of bloom) during "on" and "off' crop years peaked on two different Julian dates, (May 4 and June 2). Mid-June has been reported as the middle of the commercial 'Hass" season for the Irvine area. Harvest in Santa Barbara and San Luis Obispo Countries may just be staring in mid-June and continue through November in the most northern growing areas.

Difference in crop development impact the timing of cultural practices, such as fertilization, irrigation, phytophthora treatment, pollination and gibberellin sprays. For instance, nitrogen fertilization is often recommended by month of the year, rather than growth stage of the tree. Several recent efforts indicated that the timing of nitrogen fertilizer may have significant impacts on yield and that two times the fertilizer rates in April and November may result in substantial yield increase. Available information indicates the April timing might correspond to fruit set for the Irvine area compared to early bloom for Santa Barbara and San Luis. By November, Irvine's current year's crop may have been harvested three months previously. In San Luis Obispo, harvest may have just ended. So just going by date is insufficient for guiding many horticultural activities.

California's trees often have two crops maturing at the same time. It becomes especially pronounced the further north the production. The management of multiple crops on each tree becomes more important and more confusing as the length of time the fruit remains on the tree. Carrying two and even three loads of crop increases the potential for alternate bearing. Reduction in alternate bearing has been determined to be an important strategic requirement for California's growers. Understanding the impacts of cultural practices on alternate bearing is important. For example, the chart below demonstrates a stylized calendar of the avocado growth cycle for California. Rate and application timing of nitrogen as predicted by the Avocado Nitrogen Model proposed by Rosecrance et al. (2013 and Calculator) are noted for a 15,000 per acre yield outcome. The "on" year suggests nitrogen rate for the late fruit growth/harvest/summer and fall flush period is 15 lbs. This application coincides with the fruit set timing for 16 lbs of N for the "off" bloom crop during the later bloom/fruit set/spring shoot growth phase. Rates and timings to support these crops ought then be combined and represent the 2X fertilizer rate that Lovatt (2001) found to have significant effects on yields.

Calendar of avocado growth cycles with both "on" and "off" years represented when they overlap, and suggested nitrogen fertilization timings and amounts.



16 lbs e.g. Rosecrance recommendation

Taking into account the actual phenology, what is happening in your trees, then is important for assessing when to make N applications. In the winter and spring of 2023, it seems like everything was on a different cycle. Thrips delayed their appearance, flowering was erratic. Honeybees seemed to have found somewhere else to hang out, because they were not flying in the avocado trees. And then suddenly, we had some fruit set in Ventura in late June. This is a really clear example of the problem of following a cookbook to farming avocados. The point here is that just going by the calendar is not going to meet the needs of the tree. The phenological stages of the tree in your environment needs to be taken into consideration.

Notes:

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Calculator: https://rrosecrance.yourweb.csuchico.edu/Model/AvoModel/Avo2NKModel.html

http://www.ipni.net/publication/bettercrops.nsf/0/F2E59118B155B269062579AC005AE171/$FILE/Better%20Crops%202012-1%20p.12-13.pdf

The Annual California Avocado Society Meeting

Gary Bender Farm Advisor Emeritus UCCE San Diego County
and Ben Faber, Farm Advisor UCCE Ventura County

If you made it to the annual California Avocado Society meeting on October 14, 2023, congratulations! You are interested in the latest developments in our industry, and you are trying to keep your grove profitable in an era where we are pressed by rising costs and competition from Mexico. If you missed the meeting, you missed a good one. We suggest it is important to make it to next year's meeting and to join the California Avocado Society if you are not already a member.

This year's event was hosted by Brokaw Nursery in Ventura at their Long Canyon Ranch. The 184 attendees were bussed from the nursery up through the canyon and dropped into the middle of one of the finest looking groves we have ever seen. From there the group was sorted into three groups and routed to three stations with speakers at each station. After an hour the attendees went a little higher into the grove and then routed around through another set of three speakers. We will attempt to recap what we learned at each station.

Girdlinng and Pruning by Nathan Lurie and Samuel Garibay, Brokaw Ranch.

Nathan described how the ranch will go through and girdle one branch on each tree in the fall to stimulate that branch to set fruit heavily in the following spring. The best time to girdle is from Oct 15 to Nov 15. According to Samuel, the girdle is made with a girdling knife or saw blade with small teeth, and the cut is not any deeper than about 2mm. The cut should not go into the wood; it should go just through the bark and phloem. The cut completely encircles the branch in an area that is straight without knobs or smaller side branches. The reason this is effective is because the cut blocks the flow of sugars from the leaves to the roots and possibly re-routes them to the future flower buds. There might be some plant growth hormones involved also, but this is undetermined.

They cautioned that the entire trunk should not be girdled because this would block all sugars going to roots and could kill the tree.

Then after the fruit on this branch is harvested in a year and half, this branch is removed as part of the pruning program. This process continues each year with girdling in the fall.

In a discussion with Rob Brokaw, the owner of the nursery, he told us in a heavy crop year the girdling doesn't always make much difference when compared to non-girdled trees, but in a light crop year, the girdling definitely makes the trees more productive and profitable compared to non-girdled trees. And, of course, in a light crop year the prices for fruit are higher. Rob said he thinks this girdling/pruning process is worth it and the ranch will continue in this program.

Irrigation Scheduling by Ryan Giacolone, Phytech

Ryan discussed irrigation scheduling by using the Phytech system, a result of new technology combined to create a better method for growers to determine when and where to water so that trees don't get stressed by under-watering or over-watering. Their technology consists of four elements.

Dendrometer. This is a device that wraps around the trunk and measures expansion and contraction of the trunk diameter during the day. This measurement, measured in microns, goes up to a maximum daily shrinkage where a need for irrigation is indicated. A colored chart is created showing the expansion/contraction, dark green indicates the trees have too much water and red indicates the tree is dry and in danger of dropping fruit.

Pressure sensor soil probe. This probe gives soil moisture readings at every 6" depth down to 3ft deep. This information goes into a formula that supplies the grower with the amount of water needed to irrigate in inches/acre.

Fruit sensor. This sensor is applied to fruit that is growing and will help predict when the grower will be able to size pick harvest. The company claims that this can determine when the majority of the crop will reach size 48, or size 60 for example.

Ambient temperatures monitor. Temperature information is also used in the formula for predicting when to irrigate.

All this information is uploaded to a formula and information when to irrigate and how much to irrigate can be downloaded into the grower's computer. In answer to a question, Ryan indicated that these devices are linked together and leased to the grower for $1625/year and could take care of an irrigation block on any grove.
Editor's note: this presentation was very interesting but this scheduling method has not been tested by UCCE.

<u>Growing Hass for High Productivity</u> by Matt Purcell, Brokaw Nursery.
Matt described a **high density** growing system that Brokaw has adopted for increasing Hass production. This includes four elements and could be used (and probably should be used) by everyone no matter how big your grove is.
Berms. They build a continuous berm that looked to be about 18' to 24" high and about 4 ft to 5 ft wide. The trees are planted at the top of the berms. There is a 6.5 ft spacing between the trees along the top of the berms, and a 16.5 ft spacing between the rows of trees. Their land is flat enough where the berms are built with small tractors. These berms reduce the saturation and poor drainage, gives a good uniformity of soil texture and stabilizes the soil temperature.
Drip irrigation. A drip line is laid down on each side of the planted tree. These have inline drippers every 18 inches. At their ranch the water pressure in the lines is set at 60 psi.
Pruning. Good production is all about getting light into the sides of trees and not letting the trees form a canopy. Pruning also stimulates new growth for flowers in the following spring. Pruning creates space for bees to fly down the rows and pollinize the flowers. He conceded that it is difficult to find a time to prune because there is always something going on in the tree, flowers, fruit set or growing fruit. He made a comment that you can't just use anybody for pruning, he said "You need the right people at the right time".
He added that you should try to harvest as early as possible and do periodic side pruning to keep light coming into the lower branches.
Girdling. This was described in the first talk by Nathan Lurie.
Matt also said the grower needs an irrigation plan and a fertilizer plan. In their case they use Phytech for the irrigation plan and they do a leaf analysis in the fall and have the lab help them with a fertilizer plan.
<u>On the Record: Irrigation Fertilizer and Pollination</u> by Ben Faber (UCCE Ventura County) and Arnon Dag (Volcani Agricultural Institute, Israel).
The only problem with this talk is they had so much good information that you just can't condense it into 15 minutes. But I will give you some tidbits.
Arnon said that research done by other researchers in the past and confirmed recently showed that Hass pollinated by B flower trees (such as Fuerte, Bacon, Zutano, Ettenger) stuck on trees during stress. Hass pollinated by Hass tended to fall off during stress. Growers in California really need to pay attention to this point because stress in our groves seems to be increasing.
Another benefit of having other cultivars in the grove is that the other cultivars tend to have more nectar in their flowers than Hass, bringing more bees into the grove.
Ben said Michael Clegg from UC Riverside studied pollinizer trees and found that Zutano was the best one for Hass in San Diego, Bacon was the best one in Ventura and Fuerte was the best one in Morro Bay. A study across all pollinizer trials in all years showed that having pollinizer trees in groves increased yield by 15%.
Arnon said that the grower might try bringing bees into the grove sequentially. This is because when bees are first brought in the scout bees in the morning instruct the rest of the hive to start working in the avocados close by but soon the scout bees find other trees to work and they start to lose interest in the avocados. So, when you bring in new bees again these hives will start working the avocados again.
He also suggested that a pollinizer tree should be planted every third tree in every third row. This equates to about 10% of grove as pollinizers.
There are other pollinator insects in the groves including a lot of fly species. But honeybees carry the most pollen. It is important to bring a lot of pollen into to flowers because it takes 7 pollen grains to pollenate a flower, not just one as many people think.
In response to a question, bee attractants that are sold at the farm supply stores do not work. Sometimes they seem to induce bees to fly around the trees more, but they don't increase flower visitation. As for

pollen sprayers, Arnon said he doubts they work but he didn't cite any evidence. This sounds like an interesting area for more research.

And for a question about how many hives per acre you should have, Arnon said 1-2 hives per acre but they have to be good hives, not just boxes. Make sure each hive has at least 7 brood frames and the rest of the frames are full.

Another thing that might be of interest would be to plant alyssum flowers around the grove. These are highly attractive to syrphid flies which have been shown to pollinate avocado flowers.

Some new information about fertilizers and pollination: in a study using high doses of various types of fertilizers it was shown that high potassium rates tended to repel bees from flowers. Arnon suggests that potassium should not be applied until after fruit set. You don't want to repel bees from your flowers!

A Practical Approach to Avocado Rootstock and Field Trials by Kamille Garcia-Brucher, Brokaw Research and Development.

Kamille showed us the rootstock trials being conducted by Brokaw's own research department. The nursery receives new rootstocks from various programs in Israel, South Africa, and other countries, in addition to new rootstocks from UC Riverside. They want to know which ones work best in their environment, so they plant them out in a randomized replicated trial and rate them from 0 (healthy) to 4 (almost dead). Kamille noted that VC 804 is looking very good as a rootstock. This rootstock is from the Volcani Center in Israel.

The next step will be to try to understand exactly why certain rootstocks do not do well. Unfortunately, they do not have a test going with saline water, because they do not have salty wells. But they are interested in doing a trial with a cooperating grower who does have saline water.

What Does Your Grove Need? by Gerardo Aldunate, International Grove Consultant.

Gerardo mentioned many of the things that were covered in other talks, but he wanted the growers in the audience to always be aware of what's happening in the grove. For instance, he asked people to describe what was happening right now (in October). The answer: there is a small leaf flush going on and the buds are changing internally to either shoot buds or flower buds for the next spring. That is a good reason not to prune in the fall because you will be cutting off flower buds.

Conclusion of the Meeting.

The meeting ended with a tri-tip barbeque luncheon (delicious!) and a presentation of honors from the Society.

The Oliver Atkins award presented by Ben Faber to Samuel Garibay of Brokaw Farms for his outstanding educational contributions to the industry in CA and world-wide.

The Award of Honor presented to Rob Brokaw by Carl Stucky for so much that he has done over the years to support the industry.

The Award of Honor presented by Leo McGuire to Ed McFadden late of CA and now Alaska for his quiet contributions to research, the direction of our industry and his good sense.


Photo: Greg Alder

Pre-bloom foliar boron application on olive may improve yield

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Olive orchards entering an OFF year in 2024 may benefit from pre-bloom foliar boron (B) applications to support reproduction and yield. Because the 2023 California olive crop varied widely both within and between olive-growing regions, the value of boron applications should be considered at the individual orchard level. For example, in the southern San Joaquin Valley, the 2023 'Manzanillo' table olive crop was OFF due to the high temperatures at bloom whereas many oil cultivars in the region were unaffected by the heat and had heavy production. Those orchards that had a heavy ON crop in 2023 may benefit from pre-bloom boron application in the 2024 season.

Boron is an essential micronutrient for plant growth and reproduction. Boron deficiency affects plant reproduction by reducing pollen viability and germination and limiting pollen tube growth. Deficiency also limits the proportion of flowers that set fruit and reduces the retention of developing fruit. The influence of boron deficiency on multiple stages of reproduction may negatively impact yield. Boron also plays a role in vegetative growth and metabolism, ensuring cell wall and membrane integrity and facilitating sugar transport and cell division. Because boron plays a crucial role in reproduction, boron is translocated from vegetative tissues to reproductive tissues resulting in higher concentrations of the

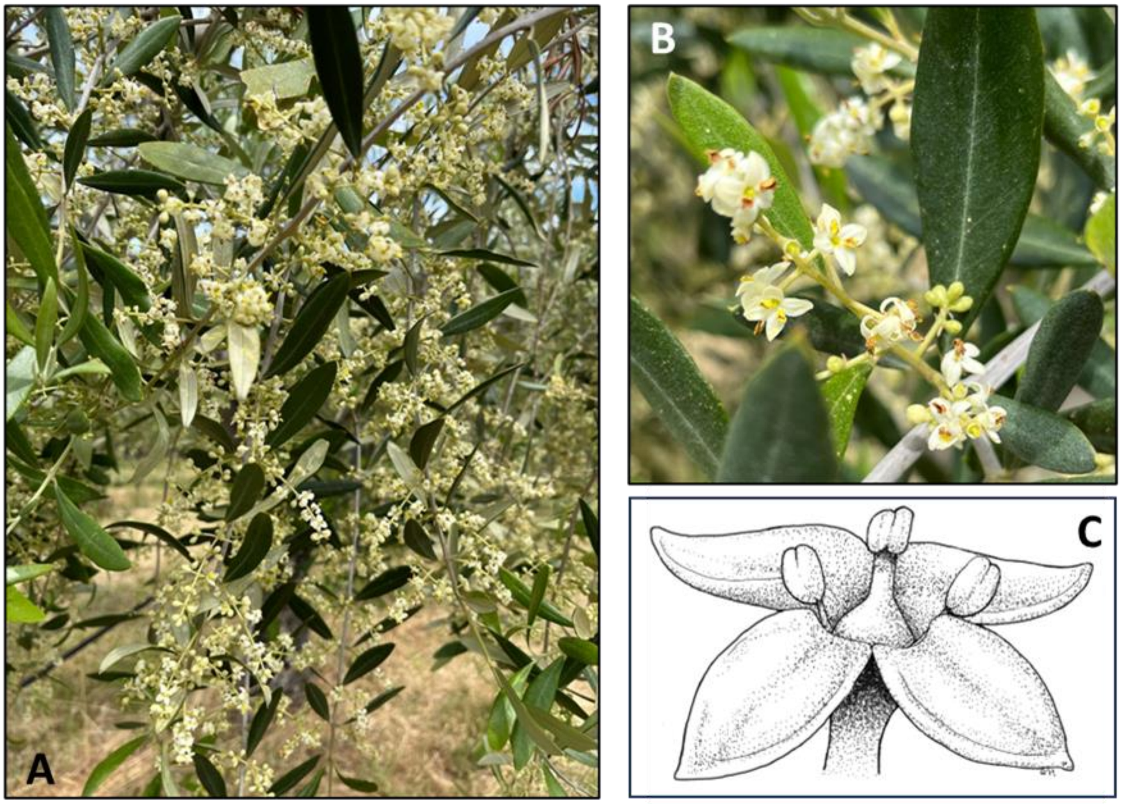

Figure 1. Olives produce numerous small flowers (A) on panicles (B). Each panicle contains 12-20 flowers (B). Perfect flowers contain two anthers and a pistil in the center (C). Photos: E. Andrews. Illustration: S. Hishinuma.

nutrient in reproductive organs than leaves. Due to this high demand, reproductive boron deficiency can occur even when vegetative boron and available soil boron are sufficient.

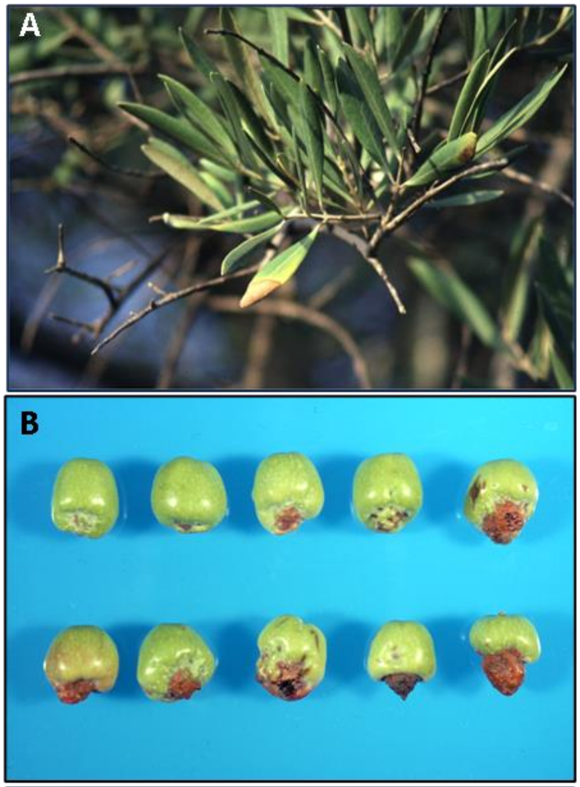

Figure 2. Symptoms of boron deficiency in olive include dead leaf tips with a characteristic yellow band and a green leaf base (A) and misshapen fruit (B). Photos: J. Connell.

Studies conducted across numerous global olive-growing regions demonstrate the beneficial effects of foliar boron application on yield, particularly in advance of an OFF crop. The influence of boron application on productivity in olive orchards may relate to increases in photosynthesis, an increase in the number of perfect flowers (those with both male and female reproductive parts) (Figure 1), and an increase in pollen viability, or pollen tube growth. Olives are considered andromonoecious, a reproductive strategy in which plants bear both hermaphroditic (perfect) flowers and male flowers. Stress prior to bloom may cause pistil abscission in a fraction of buds resulting in a higher percentage of male flowers. Several research studies have demonstrated that pre-bloom foliar boron application can increase the percent of perfect flowers on trees, thus increasing the number of flowers capable of producing fruit. In olive, boron is readily mobilized from both young and old vegetative growth to support flower and fruit production; therefore, a portion of boron applied throughout the year may be utilized to support reproductive processes. During the pre-bloom season, however, cool temperatures and the corresponding reduced physiological activity may limit the uptake and translocation of boron in olive. Additionally, flowers are not as strong a boron sink as fruit; therefore, the pre-bloom foliar application may render the micronutrient available at a short-lived, yet critical, time in crop development.

Both oil olives and 'Manzanillo' table olives have been shown to benefit from foliar boron applications. For example, 'Arbequina' receiving pre-bloom foliar application of boron exhibited increased bloom and a 27% increase in yield in an OFF year. In the 'Arbequina' study, no value of boron was observed in an ON year, and boron was found to have no effect on vegetative growth. In another study, boron applications to 'Frantoio' resulted in increased concentration of chlorophyll and soluble sugars, as well as changes in the profile of endogenous plant growth regulators within the leaves. In California, pre-bloom boron applications on 'Manzanillo' resulted in increased percentage of perfect flowers and improved fruit set and yield, particularly during an OFF year.

The recommended foliar boron concentration for olives ranges from 19-150 ppm. Values below 14 ppm boron may result in boron deficiency, whereas values above 185 ppm may result in boron toxicity. A foliar nutrient analysis only provides a snapshot of the status of the plant at the time of leaf collection; however, low boron status of leaves has been found to correlate well with symptoms of deficiency. Symptoms of boron deficiency in olive include dead leaf tips with a characteristic yellow band and green leaf base, as well as twig and limb dieback (Figure 1). Boron deficiency may first become apparent in the meristems, the growing tips of shoots. Boron deficiency may also result in misshapen and defective fruit (Figure 1), low fruit set, and premature fruit drop. The value of boron application for improved fruit set is not limited to orchards with visual symptoms of boron deficiency or foliar boron levels below the recommended range. In fact, the numerous research studies that demonstrate the value of pre-bloom foliar boron applications for enhanced fruit set and yield were conducted in orchards with no boron deficiency. Based on these findings, foliar analysis alone may not be a useful predictor of benefits from pre-bloom foliar boron application.

Table 1. Common fertilizer sources of boron

Common Name(s)	Compound Name	Chemical Formula	Boron Content
Solubor®	Disodium octaborate tetrahydrate	$Na_2B_8O_{13} \cdot 4H_2O$	20.5 %
Boric Acid	Boric Acid	H_3BO_3	17.5 %
Borax	Disodium tetraborate tetrahydrate	$Na_2B_4O_7 \cdot 10H_2O$	11.3 %
Sodium borate	Disodium borate pentahydrate	$Na_2B_4O_7 \cdot 5H_2O$	20 %

Boron is typically introduced to orchards either as a solid mineral broadcast on the soil surface, or in solution as a foliar spray. The pre-bloom foliar application is designed to specifically enhance fruit set and yield and should be applied three weeks prior to bloom. Boron is generally sold as borax, sodium borate, sodium tetraborate, boric acid, or Solubor® (Table 1). The boron content varies between formulations; therefore, all calculations should be based on the equivalents of active ingredient (ie. pounds of boron). For example, for soil-applied boron in olive, 5-10 lbs/acre of boron is broadcast, which equates to approximately 45-49 lbs/acre of borax (11% boron) or 24-48 lbs/acre Solubor® (20.5% boron). In California, foliar application of boron three weeks prior to 'Manzanillo' bloom, particularly in OFF years, at rates of 1 or 2 lb./acre Solubor® in a 100 gallon/acre (246 or 491 mg/L boron at 935 L/hectare) was demonstrated to improve yield by approximately 30%. The baseline boron level in this California study site was 16 ppm boron, a level just below the established critical level, but high enough to avoid deficiency symptoms.

The value of boron applications on orchard health and economic return varies based on the status of the alternate bearing cycle in the year of application, the baseline boron status of the tree and soil, and other climate factors that may influence yield. Plants have a narrow range between boron deficiency and toxicity. Be sure to read the product label carefully to avoid over-application and conduct annual leaf tissue analyses to gather baseline information on the boron status of orchards. More information on fertilizer rates for olives and other California crops may be found on the CDFA FREP California Crop Fertilization Guidelines website (https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/).