Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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Effectiveness of Asian Citrus Psyllid Management in Huanglongbing Treatment Zones in Residential Southern California

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Background

Major cities and other population centers often play an important role in the early phases of biological invasions and can be challenging environments in which to implement effective integrated pest management strategies. The Asian citrus psyllid (ACP), *Diaphorina citri*, a vector of the bacterial pathogens associated with the fatal citrus disease huanglongbing (HLB), also known as citrus greening, has emerged as an example of such an urban invasive species, which has broadly impacted California citrus production. The disease occurs in citrus and is caused by the bacterium, Candidatus Liberibacter asiaticus (CLas), which is only spread by the insect vector.

ACP was first detected in California in a residential area of San Diego County in 2008, followed by Los Angeles and Imperial counties in 2009. Over the next few years ACP spread rapidly throughout Southern California, particularly into interior regions with more favorable climates and abundant residential citrus. The first detections in commercial citrus groves occurred in 2011. Those groves invaded earliest were located near to residential citrus with ACP. Since then, ACP has continued to invade commercial citrus, including the San Joaquin Valley in 2012, and areas further North in recent years. The first case of HLB was detected in a residential area of Los Angeles County in 2012. Since then, more than 7,000 additional residential citrus trees have been confirmed as infected, grouped into five quarantine zones across Southern California that encompass portions of Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura counties (Fig. 1). Thus far, no cases of HLB have been found in commercial groves.

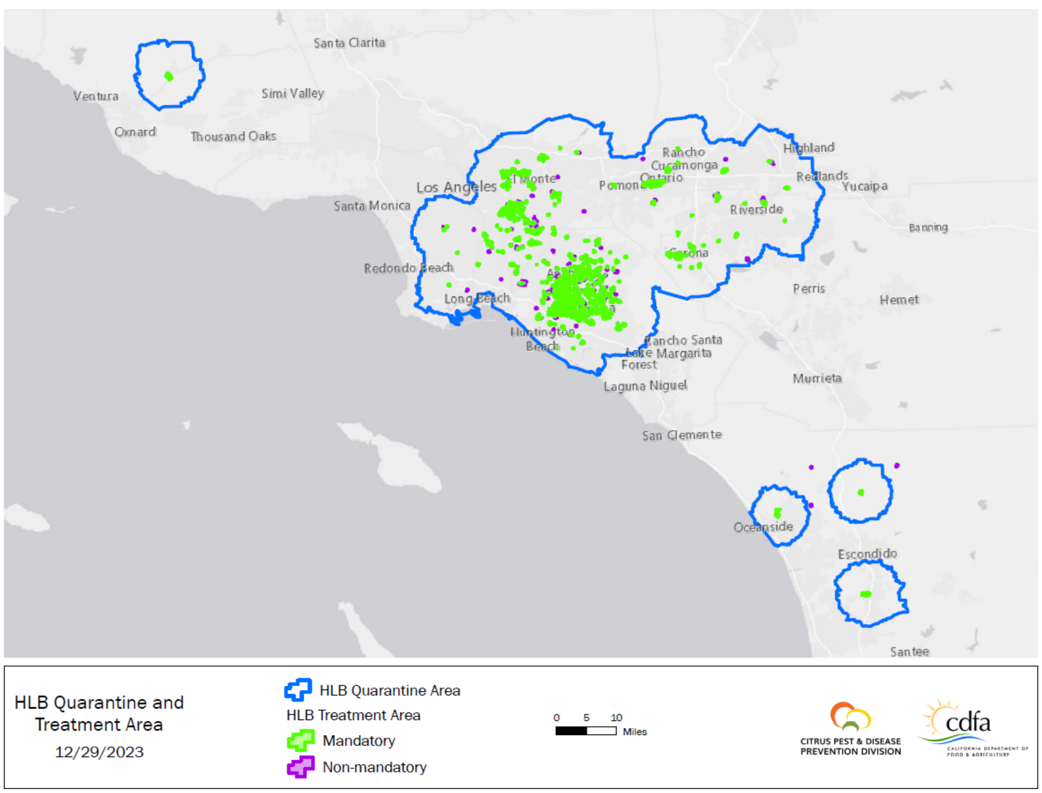

Figure 1. Location of HLB quarantine zones and treatment areas in California as of December 2023. Map courtesy of the CDFA

In response to the invasion of ACP and HLB in California, an action plan was established that includes extensive surveillance for ACP and HLB, establishment of quarantines that restrict movement of plant material, removal of infected trees to limit pathogen supply, and vector control. Details of the response have changed over time, particularly those associated with vector and disease control in residential areas. Currently, following confirmation that a tree is infected with *C*Las, the tree is removed and all ACP host plants on the property and those adjacent properties within 250 m receive insecticide applications. The goal of the treatments is to reduce ACP populations in the neighborhood surrounding HLB detections to limit pathogen spread. The treatment program consists of a combination of a soil application of a systemic neonicotinoid (Merit 2F or CorTect) and a foliar application of a pyrethroid (Tempo SC Ultra).

The other element of vector control in residential citrus is a biological control program employing the parasitoid *Tamarixia radiata*. This small wasp preferentially attacks and kills ACP, especially late-instar nymphs, leaving behind “mummies” (Fig. 2). After initially being imported from a region of Pakistan, it is being mass-reared and released throughout Southern California, including within and surrounding HLB treatment zones. Post-release surveys showed that the parasitoid readily establishes in residential Southern California, spreads naturally, and can strongly reduce ACP populations – especially if ants are excluded from trees. *T. radiata* may explain in part the apparent declines in ACP abundance over the last several years.

Although this residential ACP control program has been in place for more than a decade, limited information exists regarding its success in suppressing ACP, especially for the insecticide treatment element of the program. Here we report the results of a multi-year survey of residential properties in HLB treatment zones to capture the combined impact of treatments and biocontrol on ACP.

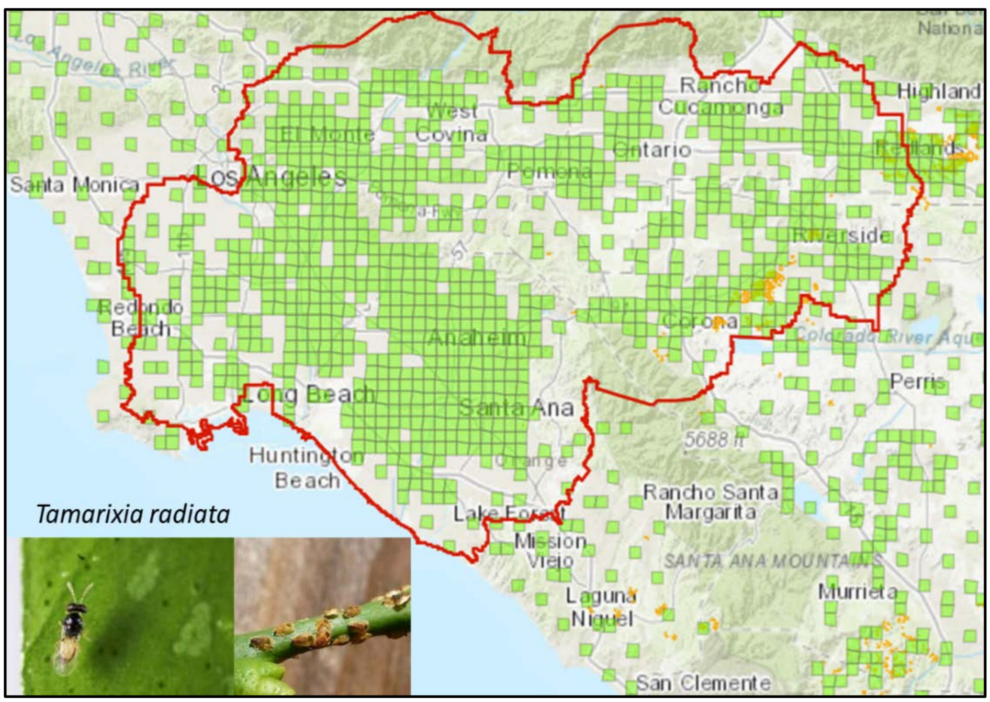

Figure 2. *Tamarixia radiata* release locations (green pixels) for a portion of Southern California. Parasitoid photos courtesy of Michael Lewis, UCR

Study design and results

Our analysis focused on multiple years of monitoring conducted by CDFA staff on a monthly basis at 35 residential properties spread throughout treatment zones in portions of Los Angeles, Orange, and Riverside counties. At each census, the frequency of new foliage (“flush”) favored by ACP was estimated, timed visual counts of the number of ACP adults were conducted, Argentine ant (*Linepithema humile*) presence was recorded, and shoot samples were collected and inspected under the microscope to count ACP eggs and nymphs. Collectively, more than 7500 censuses were made among these properties between 2018 and 2023.

Using CDFA treatment data, we determined whether each site was within an active HLB treatment zone and over what time period. Treatment zones shifted over time due to new HLB finds or after the expiration of treatments. Thus, the treatment histories of the 35 residential sites varied substantially. We also considered the potential effect of *T. radiata* releases in the area surrounding each site. A CDFA database of releases was used to calculate the number of unique releases and total number of parasitoids released within 1 km (0.6 mi) of each site.

Overall, ACP abundance was low. Nonetheless, analyses showed that the frequency of flush had significant and positive effects on all ACP lifestages. The life history of ACP is strongly tied to flush production in citrus. ACP nymphs can only develop successfully on tender new foliage. Therefore, adult females preferentially target flush for egg laying. ACP abundance also differed among citrus cultivars, which could stem from greater attraction or better performance by psyllids. Regardless, this general result is consistent with prior research on ACP showing differences among cultivars. Conversely, we found little evidence of Argentine ant presence.

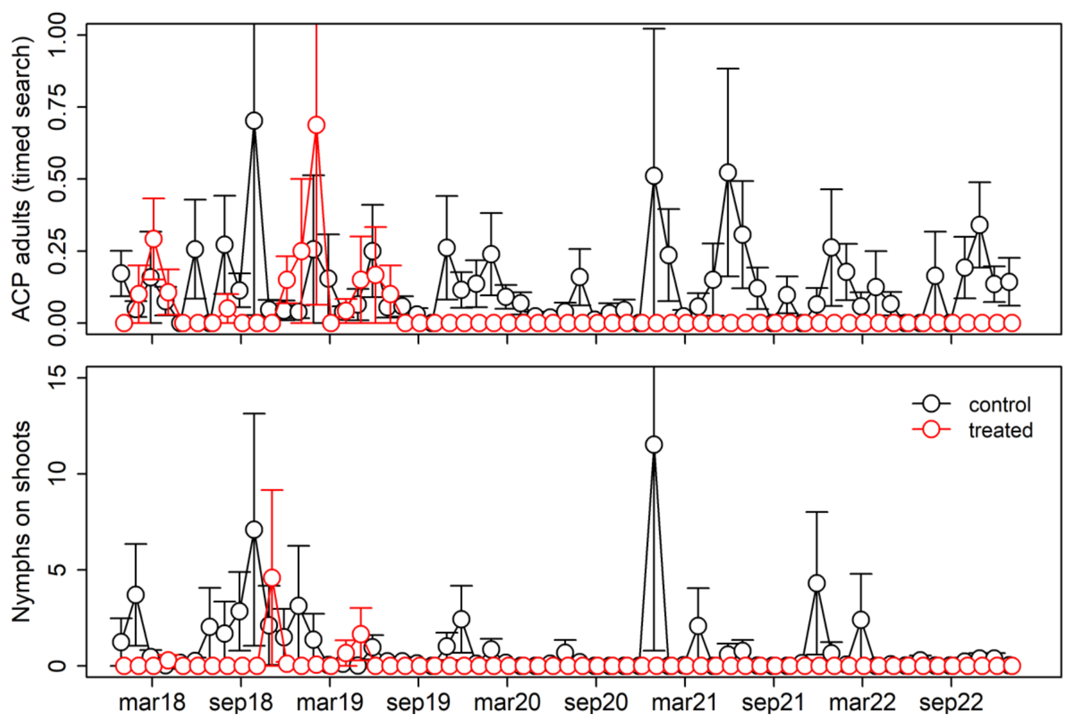

Figure 3. ACP abundance was substantially lower on citrus trees at treated residential sites compared to untreated control sites, especially after Summer 2019

affected ACP abundance, which is inconsistent with prior research that ant tending can disrupt biocontrol and favor ACP.

Those sites in active HLB treatment zones had significantly lower densities of ACP adults and nymphs than untreated control sites, and the difference became more pronounced over time (Fig. 3). By the end of Summer 2019, ACP was extremely rare in treated sites. This suggests the HLB treatments are achieving their intended effect. It is also interesting that the trends are consistent with a cumulative effect of sustained control over time. The precise mechanism driving this apparent decline is not clear but may in part be attributable to broader regional declines in ACP abundance over the last several years.

Although parasitism reached as high as 50%, it was only observed at 5 of the 35 sites and averaged 13%. The relatively low parasitism may stem from a lack of suitable ACP stages for parasitism (i.e. late-instar nymphs) over much of the study. Nonetheless, some effects of *T. radiata* releases are apparent in the study (Fig. 4). ACP adult counts were negatively associated with a greater number of total parasitoids released, and ACP nymphal counts were negatively associated with a greater number of unique parasitoid releases. Sites that had three or more releases the previous month had no detectable ACP nymphs (Fig. 4). These measurable effects of parasitoid release, despite limited evidence of parasitism, may reflect the extent to which *T. radiata* engages in host feeding that has been documented in prior research.

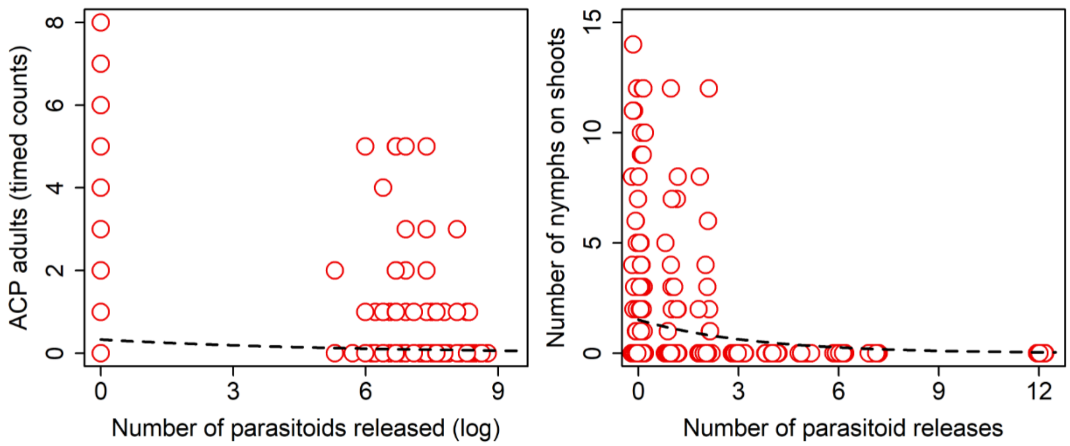

Figure 4. Modest, but detectable declines in ACP abundance associated with a greater number of unique releases or total number of *Tamarixia radiata* released nearby residential sites.

Conclusions

Residential citrus played a central role in the initial invasion of ACP and, more recently, HLB incidence in Southern California. Attempts to slow HLB spread in the region rely on removal of infected trees, to limit inoculum supply, and vector control via insecticide treatments of infected neighborhoods and parasitoid releases. Our analysis provides direct evidence that the treatments have strongly suppressed ACP populations. Moreover, despite modest parasitism rates, *T. radiata* releases significantly reduced ACP abundance – likely due to host-feeding by this species. Indeed, our estimates of parasitoid impact in treatment zones are likely conservative due to insecticide treatments near-complete exclusion of ACP lifestages required by parasitoids. Additional research is needed to determine whether the level of vector suppression is sufficient to achieve the ultimate goal of reducing HLB incidence and spread.

For more information

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Managed Honeybees in a Wet Year

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California experienced higher than average, and sometimes extreme, rainfall the past two winters (2022-23 and 2023-24). These El Niño conditions affect many aspects of farming. Here we explore what this high rainfall might mean for beekeepers and grove managers maintaining the colonies of honeybees that are employed as pollinators for subtropical crops including avocados and some citrus.

Managed colonies of European honeybees, *Apis melifera*, are kept by farmers globally as livestock: domesticated animals raised in an agricultural setting to provide labor and/or produce consumable goods, food or other products. Feral honeybee colonies are also established throughout California, including the subspecies *Apis melifera scutellata* (East African lowland honeybee), which is not usually kept by farmers due to its higher tendency to abscond (abandon the hive) when food is scarce and for defensive behaviors that can be dangerous.

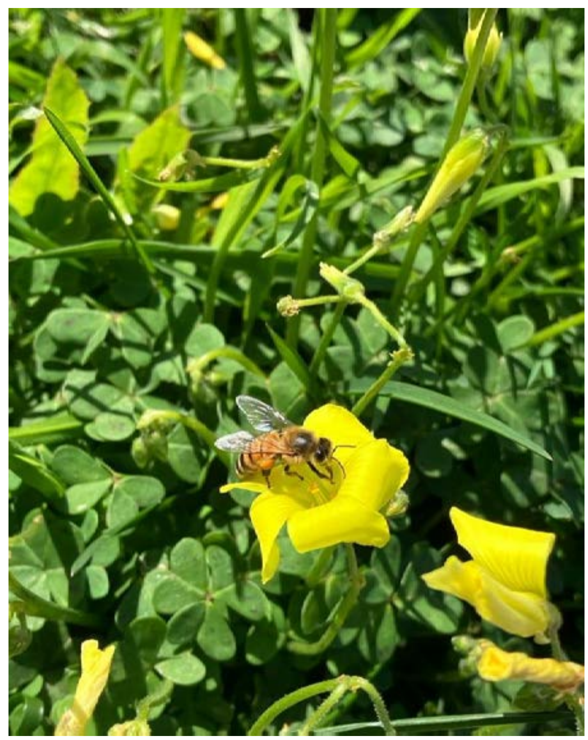

Figure 1. A honeybee on a flower of *Oxalis pes-caprae* (sour grass or Bermuda buttercup), a non-native perennial that was prevalent in southern California this year.

Beekeepers in California face many challenges including lack of forage, conflicts at the urban-agriculture interface, and pests and diseases. For managed honeybee hives, beekeepers and the property owners of land on which managed hives are kept, are regulated by local County Ordinances in addition to the California Department of Food and Agriculture (CDFA) Apiary Protection Program through the California Food and Agricultural Code Division 13, Chapter 1, Sections 29000-29322. These regulations help protect the beekeeping industry, nearby residents and environment through public education, pest, disease, and safety compliance monitoring, and conflict resolution for sensitive sites and complaints about bees. In a wet year, these challenges may be exacerbated directly by the temperature and rainfall, and indirectly by changes in plant growth and populations of other non-livestock bees. Be prepared for:

1. **More weed maintenance**

More rain means more weeds. For fire safety, weeds and other combustible vegetation need to be cleared from the area immediately around beehives, and from the road used to drive to and from sites where hives are kept.

- Using a power tool such as a weed whacker to clear vegetation around hives may agitate bees. For safety purposes consider trimming weeds at dusk while wearing a bee suit. Near hives, consider using hand tools such as a hoe to clear weeds and vegetation. The area should be avoided afterwards to allow bees to settle overnight.
- Be sure to check applicable ordinances for where you plan to have hives located to ensure all regulatory requirements are followed, including firebreaks. For example, in most areas within the San Diego County region, hives must be placed at proper distances from residences, public rights-of-way and sensitive sites (locations deemed as having a higher risk of harm).
- Even with weeds properly cleared, always practice good fire safety including using a noncombustible smoker plug and secondary container for bee smokers, and always carrying firefighting supplies such as a shovel and fire extinguisher or backpack firefighting pump sprayer.

1. **More floral resources**

Beyond the firebreak, better conditions for diverse flowers in the landscape mean managed bees may have easier access to more nutrient diverse diets (Figure 1). Hopefully, this will help support healthy, robust hives this year. This may mean less need to supplementally feed managed bees, and that they are better prepared to ward off pests and diseases. To encourage pollinator-supportive habitats and pollinator islands, consult with organizations working with growers and landowners, such as:

- Project Apis m. Seeds for Bees,
- Resource Conservation District Greater San Diego County – Working Lands for Pollinators Program, and
- USDA Natural Resources Conservation Service – Environmental Quality Incentives Program.

2. **More unmanaged hives**

On the contrary, more flowers also mean more resources for feral honeybees, which could increase in number during spring, then become defensive as they guard their stored resources as the environment dries out in summer and fall. These unmanaged, non-native honeybees can spread pests and diseases including Nosema and varroa mite, and rob honey from managed colonies. In southern California, the subspecies that are commonly present in the environment can be hazardous due to their higher tendency for resource guarding behaviors. Exercise caution using noisy power tools and engines (e.g. mowers, chainsaws, etc.) around unmanaged hives as this can agitate defensive bees and cause them to attack. High populations of unmanaged bees can increase the tension between beekeepers and residents at the urban-ag interface; so, it is a good time to survey the area for unmanaged hives, and to run through your Best Management Practice checklist to ensure the health and integrity of your managed colonies.

3. **Water source maintenance**

As the weather heats up, it is still important to always maintain an adequate and accessible supply of fresh water for bees. A flowing stream or natural water site is ideal, or standing water source such as a well with landing sites that is replenished and cleaned frequently. Even following record-breaking rain events, fresh water sources can dry up quickly, and are essential for bee survival.

Both beekeeper and property owner are responsible for maintaining safe and healthy bee rearing conditions. If you have further questions, contact the UC California Master Beekeeper Program (CAMBP) or your local Apiary Program/Department of Agriculture listed therein.

Threats to Citrus Orchards in California by Synergistic effects of Dry Root Rot and Phytophthora Root and Crown Rot

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First identified and named in California in 1920, Citrus Dry Root Rot (DRR), caused by the fungus *Fusarium solani*, has become a global threat (Bender 1985; Labuschagne et al. 1987; Broadbent 2000; Graham et al. 1985). Originally documented in major citrus-producing regions like the US, Australia, the Middle East, India, and South Africa (Bender 1985; Labuschagne et al. 1987; Broadbent 2000; Graham et al. 1985), DRR is now a concern with a wider global reach. DRR is becoming more problematic due to several factors. **Climate change** has been correlated with increased disease outbreaks in some areas and DRR is no exception. Higher temperatures are linked to a rise in DRR incidence and intensity (Ezrari et al. 2022). Additionally, various **biotic stresses** weaken trees and make them more susceptible to DRR. These stresses include nematode infections and prior infections by Phytophthora root and crown rot (Ezrari et al. 2022) as well as damage from burrowing rodents (Bender 1985). Finally, several **abiotic stresses** contribute to the problem such as drought, root asphyxiation from overwatering, high temperatures, poor drainage, fluctuating soil pH, mechanical root damage, and excessive fertilization. These factors can weaken trees, allowing *Fusarium solani* to infect roots (Ezrari et al. 2022). By understanding these factors, researchers can develop effective management strategies to protect citrus crops from DRR.

Fusarium species pose a wider threat to citrus and other plants' health (Sndoval-denis et al. 2018). These fungi are commonly found in soil samples and can cause various diseases beyond DRR, including twig rot, root and stem rot, twig blight, and vascular wilt (Sndoval-denis et al. 2018). Notably, while *F. solani* is the primary culprit behind DRR in California, other *Fusarium* species can also be involved. For instance, *F. oxysporum f. sp. citri* has been identified as the causative agent in some Tunisian orchards (Hannachi et al. 2014). Additionally, reports highlight *F. proliferatum* and *F. sambucinum* as potential contributors to DRR (Labuschagne et al. 1987; Malikoutsaki-Mathioudi et al. 1987). Despite the long history of DRR in California citrus groves, research on its identification, development, and management has been limited and sporadic.

Potential role of DRR in citrus decline in California:

Over the past year, a concerning trend has emerged in lemon orchards in some parts of California. Field observations in various locations, including Santa Paula, Ventura County, and the Central Valley, revealed that previously healthy lemon trees are undergoing sudden wilting and collapse as described below:

- **Root discoloration:** Unearthed root systems display black, purple, or grayish discoloration, with some brown vascular discoloration visible in cross-sections of the rootstock stem.
- **Foliar wilt and decline:** Leaves turn yellow and then brown, followed by rapid dieback and wilting (as shown in Figure 1).
- **Bark and crown decay:** Infected trees often exhibit decay on the bark and lower crown.

These symptoms primarily affect the crown, roots, and cross-sections of the trunk, resembling those of Phytophthora root rot. However, DRR differs by impacting larger roots and the trunk below the bud union, without the characteristic oozing gum.

Growers report a worrying phenomenon: rapid tree death during hot summer months. This suggests that when environmental conditions favor DRR, it may progress more aggressively than Phytophthora root rot. Our observations align with Adesemoye et al. (2013), who described a similar rapid disease progression in hot seasons, particularly following the first spring heat wave after the rainy season (Adesemoye et al. 2013). This suggests a potential link between seasonal variations and DRR activity. Increased root growth and activity in spring and summer may create a favorable environment for the pathogen to thrive and spread in the rhizosphere (the zone of root influence). Additionally, high temperatures in May and June might enhance the pathogen's development.

Figure 1. Dry root rot disease in lemon orchard planted on Carrizo citrange rootstock in Santa Paula, **(a)** Lemon trees with yellow foliage (Exeter, CA); **(b)** impacted crown, roots and vascular system and unusually abundant fallen fruit (Santa Paula); **(c)** wilted dead tree (Exeter, CA).

Carrizo Citrange and susceptibility to DRR: A hypothesis emerges.

Our recent observations raise a significant question about rootstock susceptibility to Dry Root Rot (DRR). In California's Central Valley and Santa Paula regions, lemon trees grafted on Carrizo citrange experienced sudden death from DRR, while adjacent lemon blocks on Trifoliate or C-35 rootstocks remained healthy despite similar management and environmental conditions. We hypothesize that Carrizo citrange may be more susceptible to DRR compared to Trifoliate and C-35 rootstocks. Selecting healthy and Fusarium/Phytophthora-tolerant rootstocks is crucial for preventing these diseases in new orchards. The rootstock's tolerance protects the entire plant against the pathogen.

While numerous studies address rootstock susceptibility to Phytophthora root and crown rot, data on DRR susceptibility or combined infection with both diseases is lacking. Existing knowledge suggests most citrus rootstocks are susceptible to DRR. However, Sour orange, a popular Mediterranean rootstock, exhibits high stress tolerance, which might explain the rarity of DRR in that region. Trifoliate orange (*Poncirus trifoliata*) and its hybrid Swingle citrumelo are considered tolerant to *Phytophthora nicotianae*, while Carrizo citrange shows intermediate tolerance to *Phytophthora* spp. (Graham 1995).

Our ongoing research project is dedicated to exploring multiple management strategies for nurseries and orchards, with a focus on the crucial role of resistant rootstocks in integrated disease management. Additionally, the potential for combined infections with other soil-borne pathogens like Phytophthora complicates DRR diagnosis and hinders accurate assessments of disease incidence and severity in California citrus production.

Combating Citrus Dry Root Rot: A multifaceted approach

Managing soil-borne pathogens like *Fusarium solani*, the cause of DRR, is complex due to interactions with the rhizosphere microbiome and the influence of abiotic stress factors. Focusing on preventative measures through cultural practices and sanitation becomes crucial.

Here are key strategies for combating DRR:

- **Minimize Root Injury:** Avoid damage to the crown and root system, especially during wet periods. This includes cautious use of machinery and proper timing of pesticide and fertilizer applications. Let exposed crown areas dry completely.
- **Sanitation:** Remove severely infected trees to prevent further spread. While effective, consider the environmental impact and potential for resistance before resorting to chemical control.
- **Integrated Pest Management:** Since no single solution exists, an integrated approach is recommended. This might involve:
    - **Fungicides:** Research suggests some fungicides, like methyl thiophanate, can be effective (Khanzada et al. 2016; Haq et al. 2014). However, resistance development is a concern (Al-Sadi et al. 2015).
    - **Rootstock Selection:** Planting citrus varieties on rootstocks resistant to Fusarium or Phytophthora can offer long-term benefits.
    - **Testing:** When encountering sudden tree death, test the soil for nematodes and Phytophthora, as these can weaken trees and increase DRR susceptibility.
- **Cultural Practices:** Promote healthy root growth and reduce stress on trees:
    - **Irrigation Management:** Ensure proper drainage and avoid prolonged contact between water and the crown/trunk.
    - **Fertilization:** Implement balanced fertilization practices.
    - **Certified Nurseries:** Purchase citrus seedlings from reputable nurseries to minimize the risk of acquiring infected plants.
    - **Soil Health:** Maintain well-aerated, well-drained, and loose soil around trees. This can help prevent dormancy-breaking fungal spores from attacking damaged roots.

By implementing these strategies, citrus growers can proactively manage DRR and protect their crops.

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Microbial Safety in Avocado Farms

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While the United States is a significant avocado producer, several other countries hold the title of leading producers globally. More than 90% of USA avocado production comes from California, which has around 47,000 acres. A single California avocado tree can produce more than 100 avocados, contributing to an annual harvest of around 277 million pounds in 2022 in California alone. The remaining avocado production comes from Florida and Hawaii.

Food safety in avocado production and consumption is a critical concern to ensure public health. Microbial safety risks in avocado farms have become a significant concern due to the potential for contamination at various stages of production. Avocados are particularly susceptible to microbial growth due to their high lipid and moisture content, low carbohydrate levels, and non-acidic pH. These factors create an environment that supports microbial proliferation. Moreover, avocados and avocado products are often consumed raw, without a ‘kill step’ such as cooking that would eliminate pathogens. Fresh-cut avocado products carry additional risks because piercing the avocado’s skin can transfer pathogens from the skin to the pulp during cutting with subsequent growth during refrigerated storage.

According to the Centers for Disease Control and Prevention, there were about 15 outbreaks of foodborne illness related to avocados, processed avocado products or guacamole products between 2000 and 2022. In outbreaks where the cause was identified, *Salmonella* was the most implicated pathogen, accounting for 50% of cases, followed by norovirus at 33%, and *Bacillus cereus* at 17%. There have also been instances of avocado and avocado product recalls due to potential contamination with *Salmonella* and *Listeria,* even in the absence of reported illnesses. Processed avocado products, including avocado that is fresh cut, refrigerated and frozen, may be packaged and consumed without undergoing a 'kill step' beforehand. Previous studies have reported that *Salmonella, Escherichia coli* O157:H7 and *Listeria monocytogenes* can survive or grow on avocados and freshly cut avocado products held at temperatures between 39°F and ambient temperature (~68°F). The pathogens may also survive on frozen products held at - 4°F for several weeks up to 60-weeks.

One of the primary sources of microbial contamination is the use of untreated or improperly treated water for irrigation. Avocado farms often rely on surface water sources, which can be contaminated with pathogens such as *Escherichia coli* and *Salmonella* from animal feces or runoff from nearby agricultural activities. If contaminated water is used to irrigate the avocado trees, the microbes can transfer to the fruit's surface, posing a risk to consumer health.

Another critical point of microbial contamination is during the harvesting process. Workers handling the avocados can introduce pathogens if they do not follow proper hygiene practices. For instance, improper hand washing, or the use of contaminated tools and equipment can result in the transfer of harmful bacteria and viruses to the fruit. The harvesting bins could be a potential source of the cross-contamination of foodborne pathogens. Moreover, it is important to note that leaving avocados on the ground before collection is not advisable, as it can expose them to soil-borne pathogens and fecal matter from wildlife, significantly raising the risk of contamination.

Post-harvest handling and processing also present significant microbial safety risks. Once avocados are harvested, they often go through various stages of washing/hydro-cooling (if used), sorting, and packaging. If the facilities and water used for these processes are not adequately sanitized, there is a high likelihood of cross-contamination. Pathogens can spread from contaminated fruits to clean ones through contact surfaces, leading to widespread contamination of batches. Proper sanitation protocols and regular monitoring are essential to mitigate these risks and ensure the microbial safety of the avocados.

Transportation and storage conditions are additional factors that can influence microbial safety in avocado farms. Avocados need to be stored and transported under conditions that minimize microbial growth. Inadequate temperature control can create an environment conducive to the proliferation of bacteria and mold. Moreover, the physical handling of avocados during loading and unloading can introduce new contaminants if hygiene practices are not strictly followed. Implementing robust cold chain management and strict hygiene standards during transportation and storage is crucial to maintaining the microbial integrity of avocados from farm to table.

For growers and packers of fresh avocados, it is a priority to ensure safe products reach the hands of consumers. From farm to table, every step in the supply chain must adhere to stringent safety protocols to minimize risks of contamination. On the farm, good agricultural practices (GAPs) are implemented to maintain the hygiene of the growing environment, including proper use of fertilizers and irrigation. During harvesting and post-harvest handling, avocados must be carefully cleaned and stored to prevent microbial contamination.

The Food Safety Modernization Act (FSMA), enacted by the U.S. Food and Drug Administration (FDA), plays a pivotal role in enhancing food safety standards for avocado farms. The FSMA rule emphasizes preventive controls and proactive measures to ensure the safety of produce, including avocados. Under FSMA, farms must comply with the Produce Safety Rule, which sets forth standards for growing, harvesting, packing, and holding produce. This rule addresses critical areas such as worker hygiene, agricultural water quality, biological soil amendments, and equipment sanitation. By adhering to these standards, avocado farms can significantly reduce the risk of contamination and ensure their produce is safe for consumption.

Worker training and education are integral components of maintaining food safety on avocado farms. Under the Produce Safety Rule, every produce farm must have an individual employed who has completed an FDA-approved Produce Safety Rule Grower Training, or equivalent course. In addition, all personnel engaged in the supervision of personnel who handle/contact covered produce or food contact surfaces must receive training as specified in the Rule. Farm workers must be trained on health and hygiene practices to prevent contamination. This includes understanding the importance of handwashing, using sanitary facilities, and recognizing signs of illness. Regular training sessions and up-to-date educational materials help reinforce these practices and ensure compliance with food safety standards. Additionally, having designated food safety coordinators on farms can help monitor and enforce these practices, ensuring that all workers adhere to the necessary protocols. Regional training sessions for food safety are often held for growers and packinghouses. It is advisable to attend these training sessions to be informed regarding these regulations and safe handling practices.

Moreover, record-keeping and traceability are crucial aspects of food safety in avocado farming. The FSMA rule requires farms to maintain records that document compliance with safety standards, such as water testing results, cleaning and sanitation logs, and worker training records. These records not only demonstrate adherence to food safety regulations but also facilitate traceability in the event of a contamination outbreak. Efficient traceability systems enable quick identification and recall of affected produce, minimizing the impact on public health. By integrating these practices, avocado farms can uphold high food safety standards, protect consumers, and maintain trust in their produce.

For more information:

https://www.fda.gov/fsma-final-rule-produce-safety
https://www.cdc.gov/foodborne-outbreaks
https://www.fda.gov/fda-sampling-fresh-herbs-guacamole-and-processed-avocado
https://www.fda.gov/Microbiological Sampling Assignment: Whole Fresh Avocados
https://www.fda.gov/ Microbiological Sampling Assignment: Processed Avocado and Guacamole

If you have any questions or concerns related to food safety in your farm/packing facility or for FSMA Produce Safety Rule training, contact the author.

How Much Fruit is Up there?

- Author: Ben Faber

Old crop, new crop. What's up there in the trees? Are they big enough to sell? Is there a good set for next year? These are questions every avocado grower has every year, and often all year long. What is up there in the trees is confounded by what is called the "Avocado Illusion". And boy was I reminded of the issue the other day when harvesting a GEM planting density trial. You don't see GEMs, you feel them, sense them being somewhere near your hand. There's a mass that's different from all the leaves near your hand, and you reach for it with your clipper and by golly you got a live one. But how many have you missed? You really need to search.

In a Science Magazine Letters to the Editor in Dec 1990, Paul Sandorff commented on a book written by Maurice Hershenson called *The Moon Illusion*. In the book Hershenson described the illusion of why the moon seemed so much larger when it was on the horizon than when it rose to its zenith on the same night. http://science.sciencemag.org/content/250/4988/1646.1

Sandorff said that this illusion applied to avocados since it was so hard to gauge the size of avocados when they were in the tops of the tree canopy. It is the surrounding environment that puts a context to size according to this theory of illusion.

Hershenson added to this observation in the March 1991 Science letters section with the comment that the leaves surrounding the fruit changes our depth perception and so changes our idea of the fruit size. A further addendum to the avocado illusion theory is that since the fruit are the same color as the leaves (they are both dark green and the fruit unlike most other fruit continues to photosynthesize), it is hard to make out the fruit. You can be looking right at the fruit and not see it, confusing it with a leaf.

This illusion makes for difficult fruit estimation. To compensate for this illusion, I will eye the canopy in quadrants, counting the number of fruit, then arbitrarily doubling that total number. It usually gives a pretty close number to the real number of fruit that are in the tree. With all the low-down fruit in the skirt and with the wet winter, there were a heck of a lot of snails in the canopy dining on fruit.

Photo:

Can you count the number of fruit in this Hass canopy?

Photo: a mess of GEM fruit revealed hiding in the skirt.

Tiny Troublemakers: How Geminiviruses Are Affecting California's Crops

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In 2022, California's agricultural industry thrived, with the market value of products sold reaching $59.0 billion. This represents a significant increase of $13.8 billion from 2017. Among the state's top 10 most valuable crops were tomatoes, carrots, grapes, almonds, and pistachios. According to the International Committee for the Taxonomy of Viruses (ICTV), the *Geminiviridae* family holds the title of the largest plant virus family, boasting over 520 identified species. These viruses primarily target tropical and subtropical plants including citrus, grapes, nut trees, fiber crops like cotton, legumes, solanaceous vegetables (chili peppers, eggplants, tomatoes, and potatoes), and cucurbit vegetables (including zucchini, pumpkin, melon, and squash). So many different geminiviruses are reported in California, each causing specific diseases in numerous host plants.
This family comprises 14 genera containing a total of more than 500 species which have double strand DNA genome. The Begomovirus genus is the most diverse genera, with over 440 identified species, in the family. These viruses are transmitted by insect vectors including whiteflies, leafhoppers, treehoppers, and aphids.

In areas with many different geminiviruses, especially those that infect the same plants, these viruses can utilize genetic recombination. This can create entirely new virulent virus types that can infect a wider range of plants. This makes controlling these diseases very difficult, especially if we rely on plants being resistant to the original viruses.

How do a geminivirus affect Crops?

The symptoms of a geminivirus infection can vary depending on the specific virus and the type of plant it infects. Some common signs include:

- **Stunted growth:** The plant may grow slower than usual, staying small and underdeveloped.
- **Yellowing and vein bound leaves:** Leaves may turn yellow or pale, indicating the plant isn't getting the nutrients it needs.
- **Rolled and deformed leaves:** Leaves might become puckered, curled, or misshapen.
- **Poor fruit quality:** Fruits may be smaller, misshapen, or have a bitter taste.

These symptoms can significantly reduce crop yields, hurting farmers and impacting the availability of fresh produce for consumers.

Which California Crops are more at risk?

A range of economically important California crops, including subtropical trees and vegetables, are susceptible to infection by geminiviruses. These susceptible crops include:

- **Citrus:** the citrus chlorotic dwarf-associated virus (CCDaV) initially identified in Turkey and China, continues to threaten citrus production in Mediterranean countries. Citrus trees infected with chlorotic dwarf disease exhibit a range of leaf deformities, including curling, inverted cupping, and chlorosis across various citrus cultivars such as ‘Eureka' lemon, pomelo cultivars ('Ruby Green,' 'Thailand Green,' and 'Sanhongyou'). Although CCDaV itself hasn't been detected in the US, its potential vector, the bayberry whitefly (*Parabemisia myricae*), is already established in California and Florida. The presence of the CCDaV vector, in California and Florida necessitates increased vigilance to prevent the disease from impacting citrus production in the US. **The disease is not currently present in California.**

- **Tomatoes:** Tomato yellow leaf curl virus (TYLCV) is a major concern, causing significant yield losses and impacting the quality of tomatoes.
- **Cucumbers and melons:** Squash leaf curl virus (SqLCV) can infect these cucurbit crops, leading to stunted growth, misshapen fruits, and reduced yields.
- **Beans:** Bean golden mosaic virus (BGMV) can cause yellowing, blistering, and stunting in bean plants.
- **Vegetables:** Beet curly top virus (BCTV) is a virulent type which can infect a high range of vegetables and perennial shrubs and cause quality and quantity loss of crops.

Why are geminiviruses so successful and keep getting more diverse in the world?

- **They can mix and match their genes:** they are good at exchanging parts of their genetic code with each other. This creates new variations that can be even more harmful and contagious.
- **They team up with extra DNA satellites:** These viruses pick up snippets of DNA from other sources as they evolve. This extra DNA can give them new abilities and more pathogenicity power.
- **Wild plants are their hideout:** Wild plants act as a reservoir for these viruses, allowing them to survive and mutate.
- **They don't have a picky appetite:** they can infect a wide variety of plants, increasing their chances of spreading and mixed infections.
- **Their hitchhikers travel far:** The insects that carry these viruses are moving to new areas, bringing these viruses with them.

Fighting back against the Tiny Villains

Scientists and farmers are working on several strategies to combat geminiviruses:

- **Developing resistant varieties:** By breeding plants with natural resistance to geminiviruses, researchers hope to create crops that are less susceptible to infection.
- **Insect control:** The transmission of geminiviruses largely relies on tiny, active insects known as leafhoppers and whiteflies. Implementing strategies to manage these insect populations can be a crucial step in hindering the spread of the virus.
- **Sanitation affairs:** Removing infected plants and weeds can help prevent the spread of geminiviruses within a field.
- **Biotechnology approach:** Scientists are exploring ways to use genetic engineering to create plants that are immune to specific geminiviruses.

The Importance of Research

Understanding geminiviruses and developing effective control methods is crucial for protecting California's agriculture industry. By working together, scientists, farmers, and policymakers can find ways to minimize the impact of these tiny troublemakers and ensure the continued success of California's diverse and vital crop production.

Citrus Leprosis Disease – Staying Alert on Potential Threat to California's Citrus Industry

Sandipa Gautam, UCCE Area Citrus IPM Advisor
Kris Godfrey, UCD Project Scientist

California's citrus is renowned for its premium quality fresh citrus production, contributing significantly to the state's economy. However, citrus is susceptible to many diseases making it a constant challenge to protect the crop from insects, diseases and vectors that can transmit these diseases. Fortunately, not all pathogens that can cause serious citrus disease are present in California. Entry of any exotic disease increases production costs, additional regulations to contain and eradicate the problem before it becomes endemic. Huanglongbing and its vector insect, Asian citrus psyllid is one such threat that was found in California in 2012 and since then that has rallied all resources to prevent the spread of disease. There are other citrus diseases that can also cause great economic losses to the California industry, citrus leprosis disease is one of the most serious and poses an imminent threat.

What is citrus leprosis?

Citrus leprosis is a viral disease caused by a non-systemic virus that produces local chlorotic and necrotic lesions on leaves, branches, and fruit which is vectored by mites. Heavy infestation leads to fruit drop, twig dieback, and loss of yield. All citrus varieties are prone to this disease, but sweet oranges and mandarins are the most susceptible varieties. Recent studies have shown that twelve viruses from three genera can cause citrus leprosis systems. The disease is described to be of two different types, Cytoplasmic type – where the virus affects cytoplasm, CiLV-C and nucleus type, CiLV-N, where the virus attacks the cell's nucleus. Leprosis does not spread systemically through the whole plant, but rather appears as discrete lesions in a localized area where mites feed and the virus viral particles are introduced.

Where is this disease present?

Citrus leprosis is a serious threat in citrus growing regions in Brazil and Argentina and is present in many countries in South America (Figure 1). It was first reported in North America in 2005 in Mexico and in 2020 in Hawaii. Recent studies have found that mites that transmit orchid fleck virus (OFV) can transmit the same virus to citrus causing citrus leprosis disease. These findings and the fact OFV were detected in South Africa and Hawaii underlines that it is a global threat to the citrus industry.

Year	Country
1920	Argentina
1933	Brazil
1974	Venezuela
1995	Guatemala (reported in 2007)
1995	Panama (reported in 2000)
2000	Columbia
2001	Costa Rica
2004	Chiapas Mexico
2005	All central America Except Belize
2005	Tabasco, Mexico
2005	Bolivia, Paraguay
2007	Oaxaca, Mexico
2009	Campeche, Mexico
2020	Hilo, Hawaii

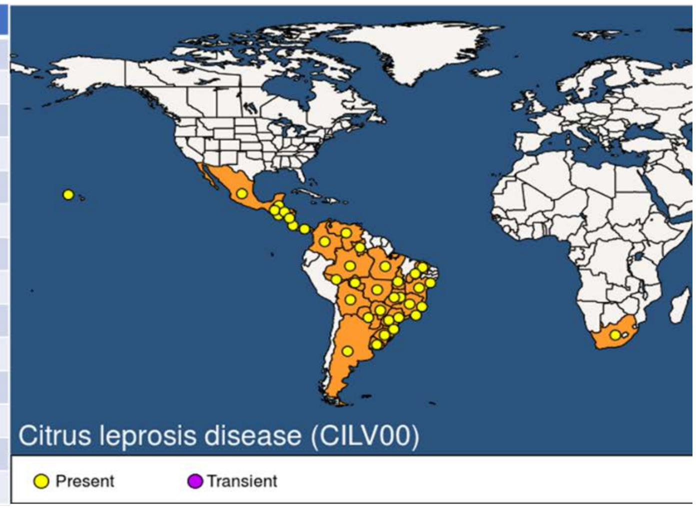

Figure 1. Timeline of disease progression from South to North America and its distribution. (figure taken from EEPO global database)

What are the disease symptoms?

Leprosis produces symptoms on leaves, fruit, and stems. These symptoms can be variable depending on the citrus variety, type of leprosis (CiLV, or CiLV-N), progression of the disease. The C-type is considered more aggressive and is more widespread than the N-type. On leaves, symptoms begin as a roundish yellow area that eventually develops a central brown spot (Figure 2). Symptoms look similar on fruit (Figure 3) and branches and can appear as raised areas that are darker. If there are more points of virus entry, symptoms developed at each point of entry will grow and coalesce.

How is citrus leprosis transmitted?

Citrus leprosis is mainly transmitted by several species of *Brevipalpus* mites. Four species in this genus, namely, *B. phoenicis*, *B. californicus*, *B. obovatus*, and *B. yothersi* are known vectors of the disease. However, which mites transmit each of the 12 different viruses associated with citrus leprosis is not well understood. The disease can only spread if both the virus and mites are present. The *Brevipalpus* mites feed on the foliage, stems, and fruit, and are widespread in California. All active stages of the *Brevipalpus* mites can acquire and transmit the viruses, but they do not replicate inside the mites, and they are not transmitted to the mite's eggs. It is important to note that one of the potential vectors, *B. californicus*, is a minor pest in California citrus systems. **A recent study by Dr. Godfrey and her group have demonstrated that *B. californicus* mites cannot transmit the citrus leprosis causing virus that was reported from Mexico.**

Figure. 2. Symptoms of citrus leprosis disease on citrus leaves. Photo by T. Pitman.

Figure 3. Early symptoms appear as green lesions (left) and symptoms grow necrotic as fruit matures (right). Photo by T. Pitman.

What can growers do?

Prevention is better than cure. The disease is not currently present in California. However, California's climatic conditions, citrus varieties grown here, and presence and wide distribution of *Brevipalpus* mites makes it highly suitable for establishment of the pathogen. As the disease can come through propagative material, avoid bringing propagation materials from areas where the disease is currently present. Staying informed about the disease symptoms on both leaves and fruit will help the industry to quickly detect the disease if it should be introduced. If growers suspect that trees may have leprosis like symptoms, growers are encouraged to report samples to local County Agricultural Commissioner offices, Cooperative Extension Specialists and Advisors in their region.

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Topics in Subtropics

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