BEST PRACTICES IN RESPONSE TO HUANGLONGBING IN CALIFORNIA CITRUS

UPDATED JUNE 10, 2019

PURPOSE

The following voluntary grower actions were endorsed by the Citrus Pest & Disease Prevention Committee on May 29, 2019 in order to provide California citrus growers recommended best practices for responding to a nearby CLas detection (the bacterium that is associated with Huanglongbing (HLB) beyond the required regulatory response. The recommendations represent the most effective tools known to the citrus industry at this time, and growers are encouraged to use as many methods as are feasible for their operation in order to limit the spread of the Asian citrus psyllid (ACP) and HLB, as the cost to manage the Asian citrus psyllid is far less than any potential costs or loss to the industry should HLB take hold throughout our state.

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FUTURE UPDATES

The suggested actions listed in this toolkit will be actively updated and modified as conditions warrant, or as new information, data and tools become available. For example, Early Detection Technologies (EDTs) are under development, and as they become available and growers gain confidence in them, they should be used to determine which trees are in the early stages of CLas infection.

CDFA REGULATORY RESOURCES

The following recommendations are supplemental to the CDFA regulatory response to an HLB-positive tree or a CLas-infected ACP. Details on CDFA's response can be found at https://tinyurl.com/CDFAProtocol

Mitigations required to move bulk citrus between ACP or HLB quarantine zones can be found at https://tinyurl.com/hlbmitigations

BRIEF DEFINITION OF TERMINOLOGY

Candidatus Liberibacter asiaticus (CLas): Bacteria that are associated with huanglongbing (HLB) or citrus greening in many citrus-producing areas around the world.

Asian Citrus Psyllid (ACP): An insect that can transmit CLas. It is considered invasive in California.

Huanglongbing (HLB): Also known as citrus greening, HLB is the most devastating disease of citrus plants worldwide. In California, it is spread by CLas-infected Asian citrus psyllids (ACP) . HLB was formerly known as citrus greening.

PCR: A biochemical test used to determine if a tree or psyllid contains CLas.

EDT: Early Detection Technology; any test that detects CLas sooner than PCR.

EXPLANATION OF AREAWIDE ACP TREATMENT PROGRAM

The Areawide ACP Treatment Program is an organized, coordinated insecticide treatment among neighboring orchards with the goal of achieving greater psyllid control than if the orchards were treated individually at different times. Insecticide treatments are applied during the winter (Dec–Jan) and again in the late summer and fall months (1–2 treatments, depending on the region, in Jul–Aug and Sep–Oct). Carefully comply with application instructions to ensure chemical effectiveness. Growers should work closely with their local PCD/Task Force regarding treatment timing and review the UC IPM Guidelines for Citrus for the choice of insecticide. Additional treatments should be applied by growers when psyllid populations increase between the coordinated treatments. Perimeter treatments in mature orchards can be used in Scenario 1 (see below) if the borders have low ACP densities (<0.5 nymph/flush) and the center of the orchard is demonstrated to be free of psyllids. Young orchards and orchards where ACP are not aggressively managed must be sprayed in their entirety.

- Two fall treatments are recommended for Ventura, Santa Barbara, San Bernardino and central Riverside.
- One fall treatment is recommended for Coachella, Temecula, San Diego and Imperial.
- Two organic treatments are applied for every conventional treatment.

RECOMMENDATIONS

These recommendations for psyllid and HLB control are designed for regions of Southern California where ACP are well-established and areawide management programs are in progress, which includes Santa Barbara, Ventura, Riverside, San Bernardino, San Diego, Orange and Imperial counties.

The San Joaquin Valley, the northern coast and inland areas are still using a local eradication strategy and ACP are not well-established. In these regions, growers are reminded to stay aware of the situation by participating in seminars and communicating with grower liaisons, scouting for psyllids, complying with coordinated treatments, using ACP effective insecticides for treatments, and supporting efforts to locally eradicate psyllids. The situation in the central and northern regions could change and, if so, the areawide scenarios would then apply. As mentioned above, the best practices listed will be actively updated and modified as conditions warrant.

The following recommendations are broken into four scenarios with different actions for each one.

Scenario 1	Orchards beyond the 5-mile quarantine.
Scenario 2	Orchards within the 5-mile quarantine, but farther than 1 mile from an HLB detection.
Scenario 3	Orchards within 1 mile of an HLB detection, but not known to be infected.
Scenario 4	PCR-positive plant material or a PCR-positive ACP is found in an orchard.

SCENARIO 1: ORCHARDS OUTSIDE A 5–MILE QUARANTINE

Recommended Actions

- ☐ **Awareness:** Communicate regularly with local Grower Liaisons, Cooperative Extension, Pest Control Districts (PCD), County Agricultural Commissioners (CAC), Pest Control Advisors (PCA), and others for the most up to date information and best practices. Get to know your neighbors, attend industry meetings and sign up for alerts on CitrusInsider.org to stay informed.
- ☐ **Scout for ACP Nymphs:** Deploy trained scouts to look for ACP every 2 weeks. Sample for nymphs by examining 10 tender flushes (1 per tree) on each of the four borders (first row or tree) and one row in the center of the orchard. Be extra vigilant in sampling young trees. Treatments are recommended when ACP are present and before they reach 0.5 nymphs/flush.
- ☐ **Control ACP with Insecticides:**
  - Participate in areawide treatment programs and strive to eliminate psyllids, or at least reduce their numbers below 0.5 nymphs per flush by applying winter and fall treatments. Apply additional treatments (within label limits) if populations start to increase before a scheduled areawide treatment.
  - Treat the border before the center of the orchard and, if possible, make applications at night when psyllids are inactive to avoid driving psyllids out of the orchard.
  - When treating for other pests, utilize insecticides known to have efficacy against ACP whenever possible.
  - According to University of California, conventional broad spectrum pyrethroid and several neonicotinoid insecticides have been shown to be most effective in controlling ACP because of their long residual life. If softer insecticides or oils are used for ACP management, increase the treatment frequency to every 2 weeks, when psyllids are present.
- ☐ **Young Trees/Replants:** Young citrus is highly attractive to ACP. When planting citrus, consider applying additional protectants (kaolin, insecticides) and/or cover the citrus trees with psyllid-proof mesh bags.
- ☐ **Barriers/Repellents:** Psyllids infest the edges of groves first and prefer the edge when their densities are low. Create barriers such as fencing with psyllid-proof screening or windbreaks to block ACP arrival and/or apply repellents to limit ACP establishment on the perimeter of the orchard. There may be regional differences in the suitability of these tactics.
- ☐ **Visual Survey for HLB:** Conduct a visual survey for HLB symptoms in the border row/trees and in the uppermost part of tree canopies by whatever means possible once a year, during late spring or late fall. Have any suspicious tissue tested via PCR.
- ☐ **Tree Health:** Ensure appropriate nutrient and water applications to tend to your orchard's leaf and root health.

SCENARIO 2: ORCHARDS BETWEEN 1 AND 5 MILES FROM AN HLB DETECTION

Recommended Actions

- ☐ **Awareness:** Communicate regularly with local Grower Liaisons, Cooperative Extension, Pest Control Districts (PCD), County Agricultural Commissioners (CAC), Pest Control Advisors (PCA), and others for the most up to date information and best practices. Attend citrus industry meetings to stay informed and sign up for alerts on CitrusInsider.org. Help educate your neighbors about the seriousness of the situation and be prepared to help with communications and spray applications.
- ☐ **Scout for ACP Nymphs:** Deploy trained scouts to look for ACP every 2 weeks. Sample for nymphs by examining 10 tender flushes (1 per tree) on each of the 4 borders (first row or tree) and 1 row in the center of the orchard. . Be extra vigilant in sampling young trees. If ACP are found, treat with insecticides before they reach 0.5 nymphs/flush in any area of the orchard.
- ☐ **Control ACP with Insecticides:**
    - Treat the entire orchard a minimum of 3 times per year (regional differences no longer apply) with an ACP-effective, long-residual insecticide (once in winter during Dec–Jan, and twice in fall during Jul–Aug and again from Sep–Oct). Coordinate with your liaison, PCD, and/or local Task Force for precise treatment timing.
    - Between the 3 minimum applications, apply additional insecticides (within label limits) before psyllids reach 0.5 nymphs/flush. These extra treatments can be applied to the perimeter of mature orchards if the center of the orchard is demonstrated to be free of psyllids.
    - Treat the border before the center of the orchard and, if possible, make applications at night when psyllids are inactive to avoid driving psyllids out of the orchard.
    - When treating for other pests, utilize insecticides known to have efficacy against ACP whenever possible.
    - According to University of California, conventional broad-spectrum pyrethroid and several neonicotinoid insecticides have been shown to be most effective in controlling ACP because of their long residual life. If softer insecticides or oils are used for ACP management, increase the treatment frequency to every 2 weeks.
- ☐ **Young Trees/Replants:** Young citrus is highly attractive to ACP. In young orchards, or when replanting citrus, apply additional protectants (such as kaolin or insecticides) and/or cover the citrus trees with psyllid-proof mesh bags. Young orchards should be treated in their entirety.
- ☐ **Barriers/Repellents:** Psyllids infest the edges of groves first and prefer the edge when their densities are low. Create barriers such as fencing or windbreaks to block ACP arrival and/or apply repellents to limit ACP establishment on the perimeter of the orchard. There may be regional differences in the suitability of these tactics.
- ☐ **Visual Survey for HLB:** Conduct a visual survey for HLB symptoms in the two border rows/trees and in the uppermost part of tree canopies by whatever means possible twice a year during late spring and late fall. Test any suspicious tissue via PCR.
- ☐ **Direct CLas Detection Protocol:** Test foliage and psyllids from 10 trees in each corner of the block (total 40 trees) using direct methods of detection of the bacterium using a laboratory permitted by CDFA or a commercial kit (such as PCR or ELISA-based kits).
- ☐ **Tree Health:** Ensure appropriate nutrient and water applications to maximize leaf and root health.
- ☐ **If HLB is Detected**: Grower voluntary response changes to scenario 4.

SCENARIO 3: ORCHARDS WITHIN 1 MILE OF AN HLB DETECTION, BUT NOT KNOWN TO BE INFECTED

Recommended Actions

- ☐ **Awareness and Coordinated Efforts:** Communicate regularly with local Grower Liaisons, Cooperative Extension, Pest Control Districts (PCD), County Agricultural Commissioners (CAC), Pest Control Advisors (PCA), and others for the most up to date information and best practices. Attend citrus industry meetings to stay informed and sign up for alerts on CitrusInsider.org. Help educate your neighbors about the seriousness of the situation and be prepared to help with communications and spray applications. Offer to lead your psyllid management area's communication network. HLB control needs to be a group effort — you can't do it on your own.
- ☐ **Scout for ACP:** Deploy trained scouts to look for ACP every 2 weeks. Sample for nymphs by examining 10 tender flushes (1 per tree) on each of the four borders (first row or tree) and 1 row in the center of the orchard. If ACP are found, treat before psyllids reach 0.5 nymphs/flush in any area of the orchard. Pay special attention to vigorously flushing trees and areas under high ACP pressure. For example, monitor where the orchard edges border residences or where ACP populations have been found in the past.
- ☐ **Control ACP with Insecticides:**
  - Treat the *entire* orchard a minimum of 3 *times per year* (regional differences no longer apply) with an ACP-effective, long-residual insecticide (once in winter from Dec–Jan, and twice in fall during Jul–Aug and during from Sep–Oct). Coordinate with your liaison for treatment timing.
  - Between the 3 minimum applications, apply additional insecticides (within label limits) before psyllids reach 0.5 nymphs/flush. Treat the whole orchard.
  - Treat the border before the center of the orchard and, if possible, make applications at night when psyllids are inactive to avoid driving psyllids out of the orchard.
  - When treating for other pests, utilize insecticides known to have efficacy against ACP whenever possible.
  - According to University of California, conventional broad spectrum pyrethroid and several neonicotinoid insecticides have been shown to be most effective in controlling ACP because of their long residual life. If softer insecticides (such as oils) are used, increase treatment frequency to every 2 weeks.
- ☐ **Young Trees/Replants:** Practice exclusionary treatments for young trees or replants such as ACP-proof mesh covers. Replant with tolerant or resistant rootstocks or scions as they become available.
- ☐ **Barriers/Repellents:** Psyllids infest the edges of groves first. Create barriers such as fencing with psyllid-proof screening or windbreaks to block ACP arrival and/or apply repellents to limit ACP establishment on the perimeter of the orchard. There may be regional differences in the suitability of these tactics.
- ☐ **Visual Survey for HLB:** Conduct a visual survey for HLB symptoms in the entire orchard, including the uppermost part of tree canopies by whatever means possible twice a year, during late spring and late fall. Test any suspicious tissue via PCR.

- [ ] **Direct CLas Detection Protocol:** Test foliage (and any psyllids found) from 100% of trees in the perimeter row/tree using direct methods of detection of the bacterium such as PCR. CDFA will test tree borders and psyllids within 400 meters of an HLB detection. Test additional trees through an approved laboratory or commercial kit (such as PCR or ELISA-based kits). Report any self-conducted positive test results from a direct method to CDFA, who will then take regulatory action.
- [ ] **Tree Health:** Ensure appropriate nutrient and water applications to maximize root health.
- [ ] **If Huanglongbing is detected:** Grower voluntary response changes to scenario 4.

SCENARIO 4: PCR-POSITIVE PLANT MATERIAL OR A PCR-POSITIVE ACP IS FOUND IN AN ORCHARD

Recommended Actions

- [ ] **Awareness:** Communicate regularly with local Grower Liaisons, Cooperative Extension, Pest Control Districts (PCD), County Agricultural Commissioners (CAC), Pest Control Advisors (PCA) and others for the most up to date information and best practices. Attend citrus industry meetings to stay informed and sign up for alerts on CitrusInsider.org. Help educate your neighbors about the seriousness of the situation and be prepared to help with communications and spray applications. Offer to lead your psyllid management area's communication network. HLB control needs to be a group effort — you can't do it on your own. Alert neighboring homeowners to organizations that assist homeowners with citrus tree removal.
- [ ] **Scout for ACP:** Deploy trained scouts regularly (every 2 weeks) to look for ACP. Sample flush for nymphs on border rows (first row or tree). Examine 10 flushes per border or center row. If ACP are found, treat *before* psyllids reach 0.5 nymphs/flush in any area of the orchard. Pay special attention to young and flushing trees, and areas under high ACP pressure. For example, monitor where the orchard borders residences or where ACP populations have been found in the past.
- [ ] **Control ACP with Insecticides:** **<u>Effective psyllid control is the most important tool to manage HLB spread.</u>**
    - Treat the *entire* orchard a minimum of 3 *times per year* (regional differences no longer apply) with an ACP-effective, long-residual insecticide (once in winter from Dec–Jan, and twice in fall from Jul–Aug and again from Sep–Oct). Coordinate with your liaison for treatment timing.
    - Between the 3 minimum applications, apply *additional* insecticides (within label limits), before psyllids reach 0.5 nymphs/flush. Treat the whole orchard.
    - Treat the border before the center of the orchard and, if possible, make applications at night when psyllids are inactive to avoid driving psyllids out of the orchard.
    - When treating for other pests, utilize insecticides known to have efficacy against ACP whenever possible.
    - According to University of California, conventional broad-spectrum pyrethroids and several neonicotinoid insecticides have been shown to be most effective in controlling ACP because of their long residual life. If softer insecticides (such as oils) are used, increase treatment frequency to every 2 weeks.
- [ ] **Young Trees/Replants:** Practice exclusionary treatments for young trees or replants, such as ACP-proof cloth covers. Where ACP are present, unprotected replants are highly likely to be infected. Replant with tolerant or resistant rootstocks or scions as they become available.
- [ ] **Barriers/Repellents:** Psyllids the edges of groves first. Create barriers such as fencing with psyllid-proof screening or windbreaks to block ACP arrival and/or apply repellents to limit ACP establishment on the perimeter of the orchard. There may be regional differences in the suitability of these tactics.
- [ ] **Visual Survey for HLB:** Conduct a visual survey for HLB symptoms in the entire orchard, including the uppermost part of tree canopies, by whatever means is possible twice a year, in late spring and late fall. Any suspicious tissue should be tested via PCR.

- [ ] **Direct CLas Detection Protocol:** Test foliage (and any psyllids found) from 100% of trees in the perimeter using direct methods of detection of the bacterium such as PCR. CDFA will test perimeter trees and psyllids in the first 400 meters of an HLB detection. Test additional trees through an approved laboratory or commercial PCR or ELISA-based kit. Report self-conducted tests with positive detections to the CDFA, which will then take regulatory action.
- [ ] **Tree Health:** Ensure appropriate nutrient and water applications to maximize root health.

Actions taken if an HLB-positive tree is found by PCR in a commercial orchard

- [ ] **Treatments at the time of an HLB detection:** When HLB is detected, the current CDFA regulations require pesticide treatment of entire orchards with broad-spectrum insecticides within a ¼ mile (400 meters) of the find site. Growers are strongly urged to extend voluntary treatments with ACP effective insecticides to 1 mile (1600 meters) from the detection site. Work with liaisons/PCD/Task forces and CDFA to determine subsequent treatments.
- [ ] **PCR positive infected tree removal:** If an infected tree or nymph (juvenile ACP) is detected by direct methods, remove the infected tree or the tree the nymph was collected from, within 1 week of test result notification, following an ACP treatment with an effective foliar neonicotinoid or pyrethroid insecticide. When removing the tree, excavate as much of the root system as possible. Plant material can be chipped in place or burned. The chippings do not present a risk of infection and can be moved safely. If stump removal is not possible, it should be ground and treated with an herbicide to prevent growth of potentially infected suckers.

ADDITIONAL CONSIDERATIONS

Isolated Orchards

Isolated orchards that are far removed from residences with HLB host plants will be easier to manage and more likely to succeed with ACP disinfestation and HLB management than orchards neighboring residences.

Organic Insecticides

The level of psyllid control needed to minimize HLB spread will be difficult to achieve with organic insecticides because of their short residual nature. In scenarios 2–3, a shift to conventional insecticides or intensified frequency of applications of organic treatments (Pyganic, Entrust, oils) are strongly recommended by University of California. The University of California recommends thatorganic treatments be applied every 2 weeks; however, if psyllid nymphs are demonstrated to remain below 0.5 nymphs/flush this duration could be extended. Conventional insecticides will be required in scenario 4 based on CDFA's mandatory 400-meter treatment in response to an HLB detection.

Early Detection Technologies (EDTs) as Emerging Tools

There are currently no EDTs broadly available that have completed the process of rigorous scientific review. However, should that process be completed in the future, using EDTs to quickly test whole orchards, or orchard perimeters, for HLB would undoubtedly be a valuable tool. EDTs currently under review include canine-based detection, protein-based detection, and altered metabolic, volatile organic compound, or microbial community profiles. Some of these EDTs will be considered "indirect" tests; in other words, the test detects some secondary change related to the infection rather than the bacteria itself. Should a tree test positive with an indirect EDT, tree removal is not currently required, but growers should take additional action.

At this time, if plant material is moved off-site to be tested with any EDT, the testing agency is required to report that information, and any positive test results, to the CDFA. Self-performed testing with an indirect EDT, which does not involve moving plant material off-site, does not currently require any reporting.

If EDTs become available to detect quiescent (hidden) infections, sample trees in the border row/tree once a year. Research suggests that testing with multiple EDT methods may improve the confidence of the results. While tree removal based on an EDT test is voluntary, take action on any tree that is a suspect positive. Remove the tree or cover it with psyllid-proof material and retest it yearly with a direct method. If an EDT indicates a tree may be infected, reporting that information to CDFA is voluntary if the tested plant material is not removed from the orchard.

A Note about Biological Control:

The biological control agent *Tamarixia radiata* is available commercially, however biological control agents do not suppress psyllid populations low enough year-round to prevent disease spread. Therefore, the grower voluntary response is based on insecticide treatments, barriers, repellents and other methods to reduce psyllids to very low levels.

SCIENTIFIC RATIONALE FOR RECOMMENDED VOLUNTARY GROWER RESPONSE TO HLB

Holly Deniston-Sheets and Beth Grafton-Cardwell

Explanation of Scenario cut-offs:
The triggers for scenario changes are based on data regarding the natural dispersion range of the ACP and/or observed spatiotemporal patterns of ACP and HLB spread.

Scenario 1: Orchards outside a 5-mile quarantine zone
Growers under this scenario should largely be practicing preventative tactics to exclude ACP from their orchards, prevent ACP establishment should incursion occur, and be on guard for the appearance of HLB or ACP. Growers should be vigilant even when finds seem far away, as HLB spread over 50 miles has been documented over the course of one year (Flores-Sánchez et al., 2017).

Scenario 2: Orchards between 1 and 5 miles from an HLB detection
These orchards are at risk for natural psyllid dispersion into the area. Research has shown that psyllids move with some regularity between trees, including between neighboring orchards within a matter of days (National Academies of Sciences, 2018; Boina et al., 2009). ACP is typically detected within about 3 miles from another ACP find (Daugherty, unpublished), and the presence of unmanaged orchards within 2.5 miles virtually guarantees psyllid invasion (Belasque Jr., et al., 2010).

Scenario 3: Orchards within 1 mile of an HLB detection, but not known to be infected
Growers within this zone should be practicing extreme caution, as ACP are capable of continual flight around ¾ mile (National Academies of Sciences, 2018), meaning that incursion of psyllids into neighboring orchards is probable, as it is not limited by their natural flight capacity.

Scenario 4: CLas detected within an orchard
The high latency period of HLB infection means that multiple HLB detections in an orchard are indicative of a much larger cryptic infection. In Brazil, for example, research has shown that more than 90% of an orchard is likely infected if only 28% of an orchard is symptomatic (Craig et al., 2018). Because the edge effect is supported by a wealth of evidence, multiple HLB infections in the interior of an orchard should be considered signs of an advanced infection (Leal, et al., 2010; Luo et al., 2014; Gottwald et al., 2008; Sétamou & Bartels, 2015; Shen et al., 2013).

The following actions have been recommended regardless of proximity to CLas:

Scouting
One adult ACP female can lay over 700 eggs in her lifetime (Liu & Tsai, 2000; Hall , 2008), and an ACP population can double in less than a month (Sule et al., 2012). Regularly scouting for psyllids will ensure that an infestation does not catch growers unaware. Scouting is generally recommended every 2–4 weeks, depending on the season and age of the tree. Young, vigorously growing trees, which are highly attractive to psyllids, could require scouting as often as once a week. Mature trees during periods of psyllid dormancy could be monitored once per month. Every 2 weeks is suggested as the normal protocol during periods of flushing, especially during the fall when psyllids are most common (Grafton-Cardwell, et al., Revised continuously; Stansly et al., 2009). Psyllid populations can continually infect orchards from outside areas, so a regular scouting program is imperative (Hall & Gottwald, 2011).

There is an abundance of evidence that psyllids colonize the borders of orchards before the interior (Sétamou & Bartels, 2015; Luo et al., 2014; Gottwald et al., 2008). To maximize the chance of psyllid detection, as well as minimize unnecessary labor costs, this is where sampling should take place. One center row should also be sampled, to determine if psyllid movement farther into the orchard has occurred. Sample a single flush from each of 10 trees along each border. Flush should be sampled to detect psyllids because psyllids require flush to feed and lay eggs (Grafton-Cardwell, et al., Revised continuously). Research has shown this is an appropriate number of samples to detect psyllids (Sétamou et al., 2008). In regions where areawide control is practiced, treatment is recommended before psyllids reach 0.5 nymphs per flush, or 2 of 10 flushes are infested (Grafton-Cardwell, personal communication).

Visual Survey

Most scientists recommend regularly identifying and removing infected trees (Hall & Gottwald, 2011). Because PCR testing of entire orchards is fiscally and logistically prohibitive, visual scouting for disease symptoms is recommended. Confirming HLB in trees is difficult, but symptoms can be used to detect leaves that are more likely to contain CLas bacteria (Louzada et al., 2016). Symptoms are irregularly distributed and CLas has been found in higher concentrations farther from the trunk, so visual surveys need to view aerial parts of the canopy (Teixeira et al., 2008).

Barriers

Although other agricultural pests may be tolerated until an economic threshold is reached, the presence of any ACP should not be tolerated, as HLB can be spread even at low insect densities (Gutierrez & Ponti, 2013; Bassanezi, et al., 2013). Although aggressive ACP control is always suggested, methods to prevent the entry of ACP into an orchard should also be considered a valuable tool.

Research has shown that 96% of adult psyllids fly at heights less than 7 ft, and >99% of ACP fly at less than 9 ft. Fencing with ACP-impermeable mesh on the perimeters of an orchard, which extends above these heights, has been shown to substantially reduce psyllid introduction into orchards (Setamou et al., 2018). Live windbreaks at borders, while potentially not as effective as fencing, have also been shown to reduce psyllid numbers in orchards (Martini et al., 2015). These 2 techniques could also be combined, with fencing being implemented as windbreaks mature.

These techniques do not need to be implemented around the entire perimeter of the orchard to be beneficial. Perimeter exclusion methods installed only on the sides of the orchard most likely to be invaded by psyllids (e.g. those closest to roads, residential areas, etc.) have been shown to successfully reduce psyllid incursion (Setamou et al., 2018).

Other methods to prevent psyllids from settling or feeding on leaves have also been investigated. Products formulated with kaolin clay have been shown to reduce psyllid numbers on flush by 60% (adults) to 78% (nymphs) (Hall et al., 2007). Individual protective tree covers have also been effective by physically excluding psyllids from trees (Graham et al., 2018). These methods should be considered especially for young trees (such as new plantings or replants), as they are more susceptible to a rapid decline following HLB infection (Gottwald, 2010) and tend to flush more frequently, which attracts the psyllids (Stansly & Rogers, 2006; Stansly et al., 2017).

Tree health

CLas colonizes roots before leaves, leading to root damage even before foliar symptoms appear (Johnson, Wu, Bright, & Graham, 2014). HLB infections lead to significant root mass loss, which could make trees more susceptible to other stressors, such as freezes and droughts (Graham, Johnson, Gottwald, & Irey, 2013). Such stressors could negatively impact yield and quality, so appropriate nutrient and water management should be practiced to potentially offset these effects (National Academies of Sciences, 2018). It should be noted, however, that not all peer-reviewed literature directly supports this recommendation. It is possible that any benefits of such treatment are not seen in short-term studies.

The following items are differentially recommended depending on the situation.

Insecticides

Aggressive ACP control with broad-spectrum insecticides is still considered the best method of limiting HLB spread (Boina & Bloomquist, 2015; Grafton-Cardwell et al. 2013; McCollum, personal communication). Extensive screening of insecticides has been conducted in Florida and California (Grafton-Cardwell, Stelinski, & Stansly, 2013; Qureshi & Stansly, 2009) and pyrethroids and neonicotinoids (thiamethoxam and imidacloprid) have proven extremely effective. They also have the added benefit of having the longest residual effect, especially the systemic formulations, (Boina & Bloomquist, 2015; Qureshi, Kostyk, & Stansly, 2014). These treatments have been shown to locally eradicate psyllids in the San Joaquin Valley for periods of up to several years. Consequently, it is recommended that their use be continued as necessary. In southern California, rotating pyrethroids as winter sprays and neonicotinoids as fall treatments should also be continued, as this sort of practice is considered more effective than any other (Boina & Bloomquist, 2015). Organic insecticides, in contrast, have little to no residual time, and therefore much more limited efficacy compared to conventional treatments (Qureshi, Kostyk, & Stansly, 2014; Technical Working Group, 2009). These treatments allow psyllids to escape and/or reinvade orchards rapidly (Boina & Bloomquist, 2015; Tofangsazi et al., 2018) and are not recommended.

Orchards with HLB finds within 400 meters are required to use broad spectrum insecticides, as part of the CDFA regulatory response. Orchards beyond 400 meters, but within 1 mile of an HLB detection, are recommended to use broad-spectrum treatments. Treatments may be applied to just the perimeter of mature orchards in scenarios 1 and 2 if sampling demonstrates that the psyllids reside exclusively on the borders. In scenarios 3 and 4, the whole orchard is treated to protect the trees from disease spread. Young orchards should always be treated in their entirety.

Although only 1 fall treatment is recommended in Coachella, Temecula, San Diego and Imperial, 2 fall treatments are recommended for Ventura, Santa Barbara, San Bernardino and central Riverside. In the latter areas, 1 fall treatment did not sufficiently suppress psyllids in 2017 (Grafton-Cardwell 2019) and task forces and PCDs in these regions have shifted to two fall treatments.

When other citrus pests require treatment, use an insecticide which is also effective against ACP whenever possible (Rogers, 2008).

PCR Testing (or other direct)

The presence of the bacteria that causes HLB can be directly confirmed by PCR, which is the current industry standard for testing (Li et al., 2006). Other direct testing methods could be utilized should they be developed.

EDTs

There are currently no EDTs broadly available that have completed the process of rigorous scientific review. However, should that process be completed in the future, using EDTs to quickly test whole orchards, or orchard perimeters, for HLB would undoubtedly be a valuable tool. EDTs currently under review include canine-based detection, protein-based detection, and altered metabolic, volatile organic compound, or microbial community profiles. Some of these EDT's will be considered "indirect" tests; in other words, the test detects some secondary change related to the infection rather than the bacteria itself. Should a tree test positive with an indirect EDT, tree removal is not currently required, but growers should take additional action.

At this time, if plant material is moved off-site to be tested with any EDT, the testing agency is required to report that information, and any positive test results, to the CDFA. Self-performed testing with an indirect EDT which does not involve moving plant material does not currently require any reporting.

Infected tree removal

Tree removal has historically been part of the management program for HLB. The intent of tree removal is to reduce the amount of inoculum available to contaminate uninfected psyllids (Craig et al., 2018; National Academies of Sciences, 2018) . A lack of on-farm management, both not rogueing trees and not controlling psyllids, increases HLB incidence for the farmer as well as for their neighbors. The presence of farms without rigorous ACP/HLB management threatens the whole citrus industry (Belasque Jr. et al., 2010). In California, where disease incidence is currently at low levels, rogueing infected trees is always recommended and should be combined with aggressive ACP control.

Mathematical models based on HLB epidemiology have shown that once detectable infections occur in 5% of trees within an orchard, it is likely that 90% of the orchard is infected (Craig et al., 2018), even in the presence of control.

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