CALIFORNIA CITRUS PEST AND DISEASE PROTECTION PROGRAM

Science Advisory Panel Review. April 2022

Executive Summary

The Citrus Pest and Disease Prevention Program (CPDPP) requested that an independent Science Advisory Panel (SAP) review the status of the program's tactics, recognizing the situation regarding the Asian citrus psyllid (ACP) and Huanglongbing (HLB) in California is quite different from when the program was initiated. The SAP Review has been a recurrent interval activity with the last review conducted in 2016-17. Following review and discussion of extensive information and data, the SAP provided a series of recommendations in response to the eight questions posed for the review. The most important recommendations address the need to modify Southern and Central/Northern California program focus and priorities regarding commercial and residential detections and actions. The SAP offers a suite of important recommendations to address this issue: **1) split the Central/Northern and Southern California Risk-Based Surveys (RBS) into two separate surveys, 2) increase the proportion of residential citrus near commercial citrus in the Residential RBS, 3) invoke the Commercial RBS in Southern California, 4) collect asymptomatic, as well as symptomatic plant tissue and pool samples to increase the volume of samples and detection success, 5) stimulate the creation of nonregulatory labs to process a greater quantity of samples, and 6) test entire citrus blocks – not just perimeters – when a find occurs in or near a citrus block.** These recommendations also suggest that rebalancing of resources will necessarily accompany changes in program direction, but SAP did not make specific recommendations on finances. In all likelihood, *Candidatus* Liberibacter asiaticus (*C*Las) has already infected commercial citrus orchards and the current CPDPP processes may not be surveying sufficient insects and plant material to find it. The greater detailed discussion and additional recommendations may be found in the body of the report. These recommendations include better coordination of data collection and analysis from various participant activities to enhance use of the information. In addition, SAP emphasized more frequent evaluation of the program by a standing SAP and consideration of developing a new set of questions that can guide future directions of the CPDPP.

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Introduction

Citrus Huanglongbing (HLB) is a bacterial citrus disease that has gained a significant foothold in global citrus regions over the past two decades. The pathosystem is comprised of the bacterium, *Candidatus* Liberibacter asiaticus (*C*Las), the insect vector *Diaphorina citri*, Asian citrus psyllid (ACP), and cultivated citrus plants. Essentially all cultivars of citrus show disease susceptibility and some degree of disease response to infection. In addition to vector transmission, the disease can be spread through vegetative propagation from infected material. HLB has proven to be widely adapted to citrus growing geographies and environments, and generally results in progressive tree decline and associated reduction in fruit yield and fruit quality.

Limited opportunities to disrupt or reverse HLB disease impacts once it is established reinforce the importance of preventing introduction of elements of the disease into a new area and to take aggressive actions to forestall establishment and disease spread once introduced.

Situation in California

Following in the trend of invasion of other US citrus producing areas, the ACP was first detected in Southern California (San Diego) in 2008, followed by the first *C*Las+ tree detection in Los Angeles County in 2012. Immediate reactions to these detections were initiated. Drawing upon experience from HLB introductions in Brazil, Florida, Texas and beyond, a coordinated and well-funded response was initiated, engaging the California Department of Food and Agriculture (CDFA), U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS), Federal and University researchers, commercial citrus growers, and residents whose dooryard citrus trees were vulnerable to attack.

Initial efforts by the coordinated response were facilitated by the limited areas in which the ACP and later, *C*Las+ trees were detected. Intensive delimiting surveys and comprehensive searches for new infestations or infections in backyard citrus trees were conducted frequently in the focal areas. Similarly, communication to affected parties and follow-up responses to positive finds were managed in a timely fashion.

The expansion and establishment of ACP/HLB during the past decade in interior and coastal Southern California and the periodic detection and local eradication of the ACP in Central and Northern California has required considerable expansion of search and response areas and accompanying regulated areas. Regions of the state vary considerably in their level of invasion by the ACP from generally infested (coastal and interior Southern California) to yet undetected (areas of Central and Northern California). HLB has currently been detected only in Southern California residential trees. Geographic and climatic differences, as well as grower practices, influence the ability of the disease and its vector to affect citrus in residential and commercial landscapes. In short, the initial response to ACP and HLB detections in California has evolved from a few very intensive, focused areas to a broader, more extensive response that incorporates all the known factors that contribute to the current and expected future dynamics of ACP/HLB in the state.

The dynamic and variable nature of ACP/HLB pressures in California requires the Citrus Pest and Disease Prevention Program (CPDPP) and other response programs to be flexible and nimble in response while pursuing aggressive search and infected tree removal strategies. As the dynamics of ACP/HLB change in California, needs and expectations for the program are also changing and the scope of the program is expanding as more individuals and communities are impacted. Program response requires reallocation of strategies and resources to meet these dynamics. It also demands that all entities involved work closely in a concerted effort to address the greatest risks to HLB infection of commercial citrus.

As ACP spread and became established in Southern California interior and coastal areas, efforts shifted from locating and responding to every potential new psyllid to 1) managing psyllids in commercial citrus, 2) protecting against movement of psyllids out of Southern California, 3) surveys to test psyllids for *C*Las followed by delimitation of areas after infected psyllids were found, and 4) surveys for *C*Las+ trees. This strategy has resulted in 450 *C*Las+ ACP detections and more than 3300 *C*Las+ residential trees detected and removed in Southern California. Focused attention in the form of plant and insect survey and testing has been paid to core regions of infection (initially Los Angeles and Orange County residences and later Riverside, San Bernardino and San Diego County residences). As the core areas expand and approach commercial citrus, it is critical for the program to focus on the leading edge of the HLB infections and find the "first" new infections in novel areas and commercial citrus rather than the "next" HLB infected tree in the core residential areas.

Finally, it is worth noting that the presence of ACP/HLB in portions of California has led to a complex matrix of required formal regulatory responses that are aimed at restricting further advance of the disease in California that could occur through natural or human-assisted means. These responses include delimitation surveys to detect *C*Las+ ACP and trees, insecticide treatments, and tree removals. Those impacted by regulatory responses include most obviously citrus growers and residents who enjoy backyard citrus trees but extends well beyond to those who provide citrus nursery stock for planting in commercial settings as well as through retail outlets to residential planting. Many challenges and unintended consequences are being experienced by citrus nursery stock producers and nursery plant movement is impacted. In the same manner, the post-harvest movement of citrus fruit by transporters, downstream packing, and transportation channels are being subjected to regulations surrounding commercial and dooryard citrus fruit movement within and outside of quarantines as the situation changes.

Rationale for a Science Advisory Review of the CPDPP

The response to ACP/HLB in California has been built based on the best possible information available and is reactive to the science surrounding HLB and its occurrence in other parts of the world. Fortunately for those engaged in creating and implementing the response program in California, there are many examples to study, since HLB has aggressively expanded across a significant portion of global commercial citrus areas during the 21st century. Extensive research is underway to expand the knowledge and develop management tools for this disease. Drawing from this growing body of research and the experience of the introduction responses to HLB in Florida, Texas, Brazil, and beyond, California has a valuable base on which to imagine and deploy the necessary responses.

History of Establishment of the Citrus Pest and Disease Protection Program (CPDPP)

An effort was initiated by California citrus growers to mount an aggressive program that brought together the above groups with significant commitment of funding shortly after the 2008 detection of ACP. CA AB281 was passed in October of 2009 to establish an industry-funded program to assist in combating citrus specific diseases, vectors, and pests when found in California. The CPDPP was formalized to coordinate the activities of HLB response within the California Department of Food and

Agriculture (CDFA) with the other entities involved, and to provide grower oversight of the program via the Citrus Pest and Disease Protection Committee (CPDPC). https://legiscan.com/CA/text/AB281/2009

The building blocks for the development of the CPDPP utilized existing programs that were directed to the specific needs of California. These included:

- USDA-APHIS Citrus Health Response Program (CHRP) and National Emergency Response Programs. CHRP supports multi-pest surveys in commercial and residential citrus areas to identify early infestations of exotic citrus pests, regulates the interstate movement of nursery material, and ensures quarantine boundaries accurately reflect infested areas.
- CDFA's existing citrus and other regulatory response programs
- Engagement with regulatory response agencies in other states (Florida Department of Agriculture and Consumer Services and Texas Department of Agriculture)
- Research and extension programs within California which had already joined the ACP/HLB global community and were developing information and strategies to combat the disease. This included the University of California and USDA-ARS personnel.
- Citrus industry organizations, notably California's Citrus Research Board that funded research on the ACP and HLB and California Citrus Mutual, that provides growers with representation on a range of legislative, regulatory, and funding issues.
- Citrus growers and affiliated groups who had knowledge and experience with HLB from their broad engagement in the citrus community, and who had local knowledge important to development and implementation of a response program.

Science-based input into and review of CPDPP

- A technical Advisory Committee was engaged in 2013 to bring the best available science to the effort and utilized the scientific community to assist in establishing program response approaches.
- A formal mechanism was established by the CPDPP to aid in assembling data and providing science-based responses to questions emerging from the program. The Data Analysis and Tactical Operations Center (DATOC) was established and funded by the CPDPP as a standing support group who could recruit ad-hoc expertise as needed to provide science-based answers to questions asked by the Citrus Pest and Disease Prevention Committee (CPDPC). It was not envisioned that DATOC would provide SAP review support to the program.
- A Science Advisory Panel (SAP) was convened in December 2013 and May 2017 to review the status of ACP/HLB in California and the CPDPP response.
    - The SAP meeting in December 2013 generated a report which outlines a series of recommendations that address actions needed in response to the CPDPP survey finds, and details of the size of treatment areas within quarantine zones. This report can be found in Appendix 1.
    - The May 2017 report of SAP provided a set of general recommendations, as well as a series of specific recommendations by region for Southern California and the San Joaquin Valley. The recommendations are not reproduced here but can be found in the full May 2017 report found in Appendix 2.

- Since 2017, the dynamics of the ACP and HLB in California have changed dramatically in the size of the affected ACP/HLB areas, imposition of regulatory controls related to HLB, and potential improvements in understanding from the research community. Thus, it appears that the timing is right for another incremental review of the CPDPP.

2022 SAP Review Planning Process

Planning for the SAP Review of the CPDPP began in late 2021 between the CPDPC and CPDPP, culminating in a review scheduled for Spring 2022. Correspondence from California's Secretary of Food and Agriculture, Karen Ross, to SAP panelists stated, "As part of Citrus Pest and Disease Prevention Committee's (CPDPC) commitment to continue evaluation and improvement, the California Department of Food and Agriculture (CDFA) is establishing a Science Advisory Panel (SAP) to review the activities being conducted by the Citrus Pest and Disease Prevention Division (CPDPD)… Panel members will review current program activities to evaluate efficacy and efficiency, validate those activities that are still appropriate and recommend improvements where needed."

The goals and objectives of the review as envisioned by the planning group were:

Goal: To keep Huanglongbing (HLB) out of California's commercial citrus groves.

Objectives:

1. Evaluate whether the program's existing strategies/activities – with a focus on the key questions outlined below – are still the most effective for meeting our goal.
2. Evaluate the efficacy of the strategies by region:
    a. Southern California – Imperial, San Diego, Riverside, Orange, San Bernardino, Los Angeles
    b. Central Coast – Ventura, Santa Barbara, San Luis Obispo, Monterey
    c. Central Valley – Kern, Tulare, Fresno, Madera
    d. Northern California
3. Are the identified strategies in each region the most efficient use of resources to meet our goal?
4. How might the strategies be improved in each region to increase efficiency, while still being as effective as possible?

The SAP thus convened to:

1. Look at key questions surrounding the ACP/HLB situation and CPDPP as it now exists.
2. Evaluate the program from a scientific perspective.
3. Offer an assessment and recommendations that can be considered as the CPDPP looks ahead.
4. Provide a written report of findings that can be shared widely with the program and stakeholders.

While the charge to the SAP did not specifically request information about program funding or administration review, these elements are intermingled with the other questions being asked, as resources are finite and may change with time. Planning forward within the dynamic of spread in California must take these factors into consideration.

Formulation of Issues to be Addressed

The specific targets for attention by the SAP were assembled within a SAP planning team, canvassing various communities for questions about program details, approaches and successes recognizing that the CPDPP must continue to evolve to be successful. Questions from within the program focused on how advances in detections and other science areas could improve efficiency and timeliness of the program. Grower questions were funneled through the CPDPC, while the CPDPP outreach group captured general questions posed to the program from other groups. These questions were collated, clarified, and organized into a set of overarching topical questions under which the more detailed questions could be grouped.

The Planning Group necessarily deferred on some of the questions posed to the 2022 SAP, as they were not likely to be appropriately addressed by the science-based panel. For example, recognition of this limitation is specifically addressed in Question 8 on regulatory activities.

The emerging overarching topics/questions to be addressed are presented here, but the more complete set of questions and sub-questions can be found in Appendix 3.

<u>Overarching Questions for Review by the SAP</u>

1. **Can we determine the role that the program is playing in keeping HLB out of commercial groves?**
2. **Is the Risk-Based Survey adequately addressing HLB detection?**

There are different strategies for HLB response in Southern California versus Central/Northern California.

<u>Central/Northern California</u>

3. **Is the ACP/HLB management program protecting the San Joaquin Valley well enough? (Kern, Tulare, Kings, Fresno, Madera)**

<u>Southern California (including the coastal areas)</u>

4. **Is the ACP/HLB management program in Southern California managing HLB well enough?**

Note: Some commentary may be necessary here to address Central/Coastal California as it is distinguished from Southern California and from San Joaquin Valley citrus.

5. **What does the future management of HLB in Southern California look like?**
6. **Production nurseries are regulated to prevent the spread of ACP and HLB. Does the California program provide sufficient protection at the retail level?**
7. **Is there sufficient access by growers and homeowners to real-time information on the locations of HLB and are there incentives to stay engaged in the program?**
8. **Regulatory Issues: Viewed as a topic to be addressed from a science perspective, but the panel is not constituted to provide in-depth review of regulatory issues.**

Perspectives on the California ACP/HLB Situation and CPDPP:

The CPDPP and its activities are subject to a range of perspectives that are important to acknowledge as a review is undertaken. It is also worth noting that the situation with ACP/HLB emerged in California through no fault of the impacted groups. Among these points-of-view are:

- Residents statewide who have historically had the freedom to grow and enjoy fresh citrus from their yards, and who are being directly impacted.
- Commercial citrus interests who are concerned about the impacts of HLB infection in commercial orchards. It is important to understand perspectives from growers who:
  - Are already threatened by orchard proximity to ACP/HLB residential situations
  - Are remote to current infestation/infection but likewise concerned
  - Will be become more concerned when HLB approaches their production areas
- Other elements of the citrus industry (e.g., nurseries, packers, transporters) who are being impacted by the presence of ACP/HLB and the response programs.
- CPDPP program principals, those responsible for making best efforts to implement regulatory and management strategies, deploy resources, and respond to the wide array of expectations from the program.
- Funders, policy makers, citizens, and others who are tangentially engaged and who are watching the campaign and its results.

Assembly of Team and Background Information

The planning group considered the selection of a team of scientists experienced with the science surrounding ACP/HLB and the current situations with HLB around the USA and world. A blend of panelists from within and outside of California would provide both local familiarity and a more objective view of questions from those not directly involved in the California program. A panelist with epidemiological experience related to other systemic vectored diseases was included to bring another perspective to the review. A team of eight participated in the program review:

Harold Browning; co-chair of the SAP; Innovation Director, Premier Citrus, Florida; Emeritus Professor of Entomology, University of Florida

Elizabeth E Grafton-Cardwell; co-chair of the SAP; Emeritus Extension IPM Specialist, University of California, Riverside

Rodrigo Almeida; Professor of Emerging Infectious Disease Ecology, Hildebrand-Laumeister Chair in Plant Pathology, Chair, Division of Organisms & Environment, Department Of Environmental Science, Policy and Management, University Of California, Berkeley

David Bartels; Quantitative Analyst, Data Analysis, Risk, and Targeting Team, USDA-APHIS-PPQ Field Operations

Don Seaver; National Science Program Coordinator, Domestic and Emergency Scientific Support, USDA-APHIS PPQ S&T

Mamoudou Setamou; Professor of Agronomy and Resource Sciences, Texas A&M University-Kingsville Citrus Center

Robert Shatters; Research Leader and Research Molecular Biologist, Subtropical Insects and Horticulture Research Unit, U. S. Horticultural Research Laboratory, USDA, ARS

Georgios Vidalakis; Professor & UC Extension Specialist in Plant Pathology; Director, Citrus Clonal Protection Program (CCPP), Presidential Researcher, CRB & UC ANR Endowment for Sustainable Citrus Clonal Protection, University of California, Riverside

Pre-meeting reading materials were considered a valuable resource to familiarize panelists with the issues, program elements and results associated with the CPDPP, as well as some of the background science that had been considered in program development and evolution. Extensive materials are available on HLB in general and specifically on the CPDPP, and an effort was made to balance the volume of pre-read materials. Ultimately, the assembly of about 50 resources were provided to panelists in advance of the site meeting, as listed below. White papers developed by DATOC were helpful for summarizing the progress of the program. Note that these materials were organized according to how they may inform the general review or assist with background on specific question topics. Only limited excerpts or specific documents from this list are reproduced in this report or in the appendices. The list of topics and full content links are presented in Appendix 4.

The diversity of elements of the CPDPP that collectively address presence and population status of ACP and HLB among residential and commercial citrus plantings became evident as the SAP planning group constructed questions to be considered in the review of the California program. For example, assessment of the ACP is provided by an array of activities that use trapping, visual observation, and ancillary collections during related activities, all generating different kinds of data dependent upon the goals of the activity, location in the state, and the entity performing the activity. In some cases, the ACP is recorded as present/absent, while in others, psyllids are enumerated. ACP are collected in some cases for analysis of *C*Las presence and titer. Similarly, surveys for HLB-infected trees are conducted using different methods.

Results of these monitoring activities are used in different ways, and may trigger response activities (e.g., ACP in a region it has not established or *C*Las+ ACP or citrus outside known areas of infection). A Regional Activity Summary Sheet (Appendix 5, Also Item #3 on Pre-read Materials) was developed to characterize CPDPP monitoring activities for ACP and HLB by region and the response that might be triggered. This table was instructive in familiarizing the SAP with details of each activity, and where and how it was conducted. It also highlighted the variability of focus in areas of the state and the potential challenges associated with different data and sampling methods coming from the suite of activities. Note that this sheet also provides information on commercial citrus activities that are conducted outside of the CPDPP.

During discussion, it became apparent that the summary sheet would have value even to those close to the program that many not be familiar with all the moving parts.

SAP Meetings

Two weeks prior to the on-site review session, a virtual CPDPP orientation meeting was conducted to assist in creating a common understanding of the program and results to date.

During this virtual orientation, an overview presentation by the CPDPP was provided from program resources (Appendix 6) with follow-up discussion. In addition, presentations by Subject Matter Experts (SMEs) were given to highlight specific topics in greater detail. An example of the SME presentations was information on the Risk-Based Survey models and how they contribute to overall survey and detection for ACP and HLB. An additional presentation on ACP monitoring research in commercial citrus orchards was provided. Links to these SME presentations are provided in the pre-read list (Appendix 4).

On-Site SAP Review Meeting

The on-site meeting of the SAP was conducted in Sacramento on April 20-22, 2022. Participants in the on-site meeting in addition to the SAP included leadership of the CPDPP, representatives of the outreach program arm of the CPDPP who facilitated the planning and execution of the review, and CDFA Citrus Pest and Disease Prevention Division (CPDPD) leadership. During the course of the review, additional SMEs were recruited to join sections of the agenda to provide additional insight or to answer questions from the SAP. During discussion and in follow-up, additional resources were identified as useful background to the review (Appendix 7).

The agenda for the SAP on-site meeting is provided in Appendix 8. Day one of the review began with a closed session of SAP to discuss the process, review questions, and suggest leads to facilitate notes and first draft summaries of each question.

Introduction and opening comments in the general session were provided by CPDPD Director Victoria Hornbaker, the CPDPP Vice-chair Dr. Etienne Rabe and CPDPP Secretary/Treasurer Keith Watkins. An overview of comments from Dr. Etienne Rabe is provided in Appendix 9.

The bulk of the two-day meeting was devoted to discussion of the questions among the SAP, CPDPP representatives, and Victoria Hornbaker. SMEs (Dr. Neil McRoberts, Dr. Frank Byrne, Aaron Dillon, Dr. Subhas Hajeri) were engaged virtually to participate in clarifying discussions in some questions (refer to meeting agenda Appendix 5). Audio/visual, capture of notes and other meeting support was provided by Nuffer, Smith, Tucker (Price Adams and Natalie DeAngelo).

The following sections present the SAP assessment and recommendations for each of the overarching questions.

Question #1: Can we determine the role that the program is playing in keeping HLB out of commercial groves?

Introductory Statement

The CPDPP focused intensively on hot spots from the beginning of ACP and HLB reports in Southern California, necessarily targeting residential citrus trees where initial detections occurred. Several complementary and overlapping strategies for sampling and survey were developed, each with a goal and set of tactics that included discovery/monitoring and treatment. Combining knowledge of HLB disease biology and spread with safeguarding regulatory responses, the CPDPP moved outward from these initial finds to suppress infestation and infection while also surveying to find new hot spots.

The program expanded in geography consistent with finds and reached out beyond the known area of infestation (ACP) and infection (HLB) to provide lower-level surveillance across areas not known to be infested. Expanded survey was used in both ACP and HLB monitoring and included regions outside of known occurrence in the Central Valley and Northern California. Protections against human-assisted dispersal of HLB via plant or fruit movement were put in place consistent with imposition of quarantines, and models evolved to predict highest risk for movement and thus focus for CPDPP activities.

A decade later, the presence of ACP in California has increased geographically, particularly in Southern California interior and coastal areas where both residential and commercial citrus occur, often in proximity. The ACP could be described as endemic in most of these areas, with consistent population development over time and space, particularly in residential areas. Data shared with the SAP indicated that the ACP is being suppressed via insecticide treatments, particularly when coordinated across large areas in commercial or residential citrus. Since 2016, a decline in overall densities of the ACP have been observed in both residential and commercial citrus likely due to a combination of climatic and biological factors. It is not possible to determine the relative contributions of these factors that affect ACP populations. However, surveys of uncontrolled populations of ACP in commercial citrus occasionally reveal very high densities of ACP, indicating that biological control is insufficient and insecticide control is needed. In Central/Northern California, ACP finds continue to appear periodically but are sporadic and when treatments are applied are suppressed below detectable levels.

Similarly, HLB detections have expanded since initial finds in 2012, and the rate of new finds has increased over time, likely reflecting the focused efforts to detect infections in core areas in combination with increasing local spread. Location and removal of HLB positive trees has the goal of limiting buildup of *C*Las reservoirs and appears to be working as indicated by the low percentage (0.1%) of ACP carrying *C*Las collected from survey and sampling efforts.

Science Advisory Panel Assessment

The extent to which the ACP and *C*Las have spread in California can best be described as a combination of climatic factors specific to this state, in combination with the effectiveness of efforts to suppress movement and buildup of populations. In total, the progression of ACP movement and infection by *C*Las is very slow in comparison to that experienced in other citrus regions, notably Florida, Texas, and Brazil. The presence of natural topography separating California citrus growing regions surely contributes to the limited long-range movement and defines quite variable climatic growing regions in the state. These regions vary from extreme summer heat and cold winters that reduce flushing necessary for vector reproduction and disease transmission (Central California) to conditions that are highly favorable for citrus flushing, psyllid development, and disease transmission throughout the spring, summer, and fall (inland and coastal Southern California). The geophysical environment of California, experiencing drought conditions, predicts slow and restricted spread compared to a more uniform tropical, highly favorable environment not dissected by geographic barriers.

The SAP discussed at length how the program has evolved from highly intensive, focused "search and destroy" on a few foci early on to a more diffused, extensively tiered system that attempts to continue to monitor the core of infestation and infection, while looking outward to the edges and beyond. The balance of effort and resources across this wide landscape encompassing much of California was a topic that was repeatedly visited. The conversation often acknowledged that the CPDPP cannot continue to or need to find every *C*Las+ psyllid or tree in the core residential areas of Southern California. Extended time of exposure to ACP and *C*Las will increase the risk of outward spread, requiring modified strategies to find and suppress the vector and pathogen on the margins of its known distribution and beyond, and to focus considerable effort on the commercial/residential buffer areas to protect against intrusion into commercial plantings.

The CPDPP and allied agencies and entities interested in managing HLB in California have a daunting task that increases with time-in-residence of the pathosystem in California and requires diligent evolution of strategies. The SAP applauded the initiation of the response program and the significant resource commitment that drives it**. Deliberations throughout the meeting focused on how the program and overall response can shift to be more effective and resource responsive under the evolving threat that the disease poses as it establishes and slowly spreads.** Parts of the overall assessment presented here will be repeated as subsequent, more focused questions below. This section is intended to provide a global view of the key issues and gaps that should be addressed by the program, and likewise, the recommendations are more general to the overall effort.

The SAP identified gaps that when overcome would increase the effectiveness of the program and overall response.

1. Collaborating agencies are currently not harmonized: It is an expected response that multiple entities engage in response to a threat such as that posed by HLB in California. Responsibilities, capabilities, and resources of each entity vary, but in composite, magnify the effort. However, to take greatest advantage of these efforts, they must be harmonized to complement and support one another to the highest degree possible. The SAP felt that with the CPDPP providing the focal point for the response and encompassing the regulatory, biological monitoring, and treatment elements, along with grower oversight, direction, and funding, is naturally able to facilitate harmonization. **Specifically, all entities should be encouraged to coordinate in their planning, strategies, tactics, and implementation of CPDPP programs to achieve specific and overall success. This coordination must trickle down to methods for data collection, data analysis and sharing, and ultimately shared responsibilities to replace redundancy with complementarity where relevant. This will be addressed more specifically in subsequent questions.**

2. Develop the ability to test massive amounts of commercial grove plant samples for *C*Las: The SAP concluded that there is an imbalance in the level of effort going forward between managing the known core areas of HLB positive residential citrus trees, and diligence in finding incursions of HLB into commercial citrus areas as early as is possible. Shifting of resources and strategies towards testing commercial plantings and rebalancing other strategies will provide more assurance that incipient infection of commercial citrus has not occurred and is escaping detection.

3. Deploy Commercial RBS in Southern California: One gap that should be addressed immediately in Southern California is the deployment of the Commercial RBS model that has been developed in tandem with the Residential RBS model deployed early in the program. Conducting commercial survey via the RBS will initiate testing in commercial citrus and emphasize the buffer areas between residential and commercial citrus in Southern California, especially where *C*Las has been detected. This would improve the likelihood of early detection of HLB in commercial citrus adjacent to residential areas with history of *C*Las+ ACP and *C*Las+ infected trees.

Recommendations

1. Increased coordination and sharing of data. While recommendation #1 should be accomplished within the CPDPP most easily, the effort to coordinate, leverage, and share data should extend to all other entities that are engaged in obtaining data on ACP and HLB in the California landscape. Among the agencies that have affiliation, but not necessarily data sharing and coordination goals with the CPDPP, are DATOC, Geographic Information Systems (GIS) efforts, California Citrus Tristeza Eradication Agency (CCTEA), CDFA, USDA, Citrus Research Board (CRB), and University Research and Extension programs to name a few. Coordination of data collection and sharing should be specified in all CPDPP subcontracting.

2. Genotyping and better understanding of disease elements. This applies to both *C*Las and to ACP and will be detailed in other questions that follow.
    a. Lack of understanding of vector and pathogen diversity (genotypic and phenotypic) limits our understanding of HLB spread in California and could impact the success of the program. If genetic variants exist, as evidence suggests, understanding the biological implications of this variation should guide survey and response efforts.
    b. Assumptions are being made that the pathogen behaves similarly to populations in Florida and Texas and that may not be true.

3. Formulate a new set of questions to be answered with the program survey and trapping over the next 5 years. The CPDPP is a very robust, resource-intensive program. While many of the SAP suggested changes can be implemented in the short term to adjust the program to be more reactive to recent conditions and realities of ACP and HLB in California, an effort also should be made to evaluate how the questions that drive CPDPP activities have changed. Developing a set of questions focused on the current situation and looking forward 5 years likely would define new or greatly modified approaches that CPDPC should implement to keep pace with the changing HLB picture in California. For example, is there a more systematic, broader way that staff can cover a larger sample size to increase the opportunity to find early HLB infection in or near commercial citrus?

a. Develop a flow chart to lay out suggested revisions to program organization. SAP members found it difficult to become familiar with all of the program strategies and tactics as they are differentially implemented in regions of the state and between residential and commercial citrus plantings. As a first step, develop a flow chart of the current program that will familiarize everyone involved with how the program is functioning at an operational level. A revised flow chart could be drawn as CPDPC considers and implements recommendations from this review and/or a new set of questions guide additional changes in strategy and resources allocation.

4. Create a standing technical group of experts not directly affiliated with the CPDPP that meets periodically, as needed and on a scheduled basis (minimum every 2 years), to review the CPDPP from an outside perspective. It is likely that changes to the ACP/HLB movement and spread will continue and perhaps accelerate, requiring more frequent evaluation and adjustment as conditions change.

5. Program materials (planning, assessments, reports) should be updated regularly and made available publicly to the extent possible and linked to one location. The program should determine intervals for reviewing/updating internal management documents, noting revision history for those tracking the program over time.

Areas in Need of Additional Discussion

The difference in the number of infections and the rate of spread of disease in residential trees between Los Angeles and Orange counties bears investigation. While there are similarities between Orange County and Los Angeles County residential characteristics with regards to citrus plantings, they experience very different rates of establishment and spread of HLB. Possible factors influencing the differences discussed included time of first infection (not detection), genotypes/phenotypes of *C*Las/ACP, microclimate differences, prevailing wind direction for vector spread, and risk factors for human-assisted spread. That there is such a difference in the intensity of HLB infection between these primary counties may inform program strategies going forward, lessening efforts in some regions and intensifying efforts in others, if it can be determined what the causes for this difference are.

Question #2: Is the Risk-Based Survey adequately addressing HLB detection?

Introductory Statement

The Risk-Based Survey (RBS) model to predict exotic pest and disease introductions was initially based primarily on introduction risk (census travel), +CLas locations, ACP density, citrus density, climate suitability, nurseries, citrus transportation corridors, as well as military and Native American lands, and was developed by the USDA ARS team near the beginning of the ACP/HLB program in California. The initial model has been adapted to consider these and additional ACP and HLB risk factors, such as packing houses, farmers markets, and organic citrus. The complete list of risk factors that have been considered in the RBS model and their historical weighting are found in Appendix 10. The algorithm is recalibrated to account for new information before each survey cycle by adjusting the weighting of all factors. The Residential RBS Model currently covers the entire state, and the focus is on detecting HLB in residential areas. A separate version of the model has been developed that focuses the sampling on commercial citrus. This version has been used by the CCTEA for *C*Las survey work in the Central Valley but has not yet been incorporated into CPDPP sampling.

Science Advisory Panel Assessment

Overall, the Residential RBS model used in the HLB program is one of the most comprehensive and scientifically sound survey designs used in a pest management program. The panel feels it has and will continue to focus the limited survey resources in an efficient manner. At this time, there are imbalances in the weighting of the factors that make up the residential model that should be adjusted. For example, the presence of *C*Las in ACP or plant material causes the survey to potentially focus more heavily on the core areas of infection rather than the leading edge or the area between residential and commercial citrus. In addition, there are significant differences in the progression of the HLB epidemic between Southern and Central/Northern California (defined as being separated by the Tehachapi Mountains between Los Angeles and Bakersfield). The ACP is considered endemic in Southern California and there is a concentration of HLB positive trees in Los Angeles and Orange counties and detections in Riverside, San Bernardino, and San Diego counties. In Central/Northern California, ACP populations are sporadic and HLB has not been detected in citrus. We feel the use of the model should be changed to account for these differences and the Commercial RBS Model should be invoked in Southern California.

Recommendations

1. Split the Residential RBS model into separate Central/Northern and Southern Region models and adjust weighting separately for each of the two regions.
    a) With this modification, the Southern California Residential RBS should be reweighted to shift from an over-emphasis on historic finds in the core Los

Angeles Basin residential areas to residential areas proximal to commercial citrus in Southern California (change weighting factors for historic vs. buffer area weighting). This re-weighting should allow continued residential tree survey within the core infection areas of the Los Angeles Basin, while looking more closely at the residential/commercial interface that is of value to detect early HLB in or near commercial orchards.

b) The Central/Northern California Residential RBS Model weightings should revert to focusing more on initial introduction factors (census and travel) as well as ACP finds. Possible new factors to include would be citrus worker movement, equipment movement, and worker housing.

2. Invoke use of the Southern California Commercial RBS.
   a) The initiation of the Commercial RBS model will add critically needed sampling efforts in citrus groves. Weighting within the Commercial RBS will identify mile x mile areas where commercial citrus occurs near *C*Las+ ACP or *C*Las+ tree finds in nearby residential areas. The execution of this recommendation would provide more emphasis on commercial trees in the areas of high likelihood of spread from residential to commercial citrus (discounting long-range movement) and moves the momentum of survey from the core residential areas to commercial citrus and the periphery of the known infestation/infection.

3. Upon the first *C*Las confirmation in Central/Northern California, invoke the Commercial RBS for that region. Further evaluation using simulation runs of these models once split will be necessary to determine how to balance the Central/Northern California residential and commercial surveys in identified mile x mile squares, and how resources should be rebalanced.

4. Utilize the ARS agent-based and Cambridge spread models to proactively look at scenarios where the HLB hotspots in the urban centers are not intensively managed to determine the potential impact on spread into commercial citrus. This will assist in understanding the impact of reduced emphasis on urban center activities (do hot spots develop because of a larger reservoir of infection in the core areas?), and how resulting ACP/HLB presence in the urban centers could affect short and long-range spread to commercial citrus.

5. Incorporate HLB genetic strain typing into the weighting factors for the model if the data becomes available and there are biological differences that affect sampling and response.

Additional Information Requested by SAP

- Provide a table of the risk factors used within both the residential (Central/Northern California and Southern California) and commercial citrus (Southern California) RBS models and the weighting used over time.

- Clarify methodology that would be used to determine where samples would be taken in the selected survey squares of the Commercial RBS, i.e., X number of perimeter trees in the orchard and residential trees within X meters of the orchard, and how pooled sampling may be used to sample a greater number of trees in the orchard.

- The SAP requested a visual of a current run of both Residential and Commercial RBS models where the two portions of the state were split and adjusted for weighting in each portion. The split model results would provide value in determining the value of adopting recommendation #1 above.

List of Materials Referenced either from the pre-read or additional supporting information

- Genotyping HLB references

Areas in Need of Additional Discussion

- If the focus in the Central Valley remains eradication of ACP and HLB, which model would provide the most likely detection of early ACP populations?
- What are the regulatory implications of conducting regular surveys within commercial citrus? What would the delimitation protocol be for an HLB positive tree within an orchard?
- Should the random selection of low-risk areas to be surveyed be increased from the current 5%? Should it be different between Central/Northern and Southern California? This is an important check on the RBS missing new infections in areas of low risk based on risk factors.

Question #3: Is the ACP/HLB Management Program Protecting the San Joaquin Valley Well Enough?

Introductory Statement

The San Joaquin Valley is the major commercial citrus producing region of California, and it is separated from the southern citrus producing regions by the Tehachapi Mountain range. North of the Tehachapi Mountains, psyllids make periodic incursions and occasionally have established reproducing populations; however, insecticide treatments in infested residential areas and coordinated treatments over large areas of commercial citrus, combined with a relatively inhospitable environment (rapid flush hardening), appear to locally eradicate ACP and limit re-establishment. Areas around Bakersfield in the southern end of that region consistently have ACP detections, and Risk-Based Survey (RBS) models should capture this information. To date, no *C*Las has been detected in psyllids or citrus trees in this region. The SAP responses in this section focused on 1) what is working to limit the movement of psyllids into this citrus producing region and what can be done to improve this, and 2) description of the major risk factors that could lead to the spread of *C*Las into commercial production groves and how this knowledge should be used to mitigate these risks.

Science Advisory Panel Assessment

1. Risk-Based Survey. Major risk factors in this region are from *C*Las that may already be present in urban residential areas, invasion of ACP into these areas and secondary spread of *C*Las by the psyllids. Thus, the CPDPP is emphasizing residential citrus and human-assisted movement in/from these areas. Such an overlap could create an ACP infestation that could acquire the *C*Las and carry it into commercial citrus areas.

2. Psyllid movement from the south into the San Joaquin Valley.
    a. A likely contributor to movement of ACP into the central San Joaquin Valley is human-assisted movement. In the early days, before tarping regulations were instituted, ACP spread was likely assisted by bulk citrus, green waste, nursery material, and other human-assisted movement. Measures were taken to tarp citrus truck loads and regulate movement of plant material. More recently, the movement of citrus workers and their equipment between the areas north and south of the Tehachapi Mountain range appears to be a dissemination method.
    b. Monitoring/survey strategies for the ACP do not consider 1) seasonal variation in psyllid abundance, 2) migration and seasonal variation in laborer movement between regions, or 3) selection of citrus types that are more precocious flushing citrus like mandarins and lemons as potential hosts for the ACP. Logistics of conducting broad surveys statewide interfere with sampling Central and Northern California sites at optimal times of year (tree phenology and ACP/HLB prevalence and visibility), as well as when workers and equipment are most likely

to be moving. Efforts should be made to address this issue in trying to find incipient populations or disease.

Recommendations

1. Modifications to RBS were discussed under question #2 for Central/Northern California. In this region, do not reduce the focus on residential citrus. It should remain as a major factor until the ACP becomes endemic and/or *C*Las+ ACP or *C*Las+ trees are found. Other CPDPP and non-CPDPP activities can be adjusted to complement the residential RBS in Central/Northern California to maximize commercial citrus monitoring.

2. Integration of various survey data. It became apparent that data collection from different "groups" (i.e., CDFA, CRB, CCTEA) may be complimentary, but integration of these data sets is not part of the protocol. Better coordination and data integration will allow more efficient monitoring and enrich the data that are driving the risk models and other tactics.

3. Recognizing that ACP traps are not highly effective in detecting commercial citrus ACP, develop a campaign to engage pest control advisors and scouts to conduct visual surveys for ACP. Improve sampling strategies to consider biological factors that influence psyllid activity and greatly expand the efforts in commercial citrus.

4. Consider testing and use of "non-messy traps" for ACP to reduce dust and debris and increase effectiveness and efficiency of trapping.

5. Continue to support and promote coordinated large area treatment for psyllids. This is likely a major contributor to the lack of ACP establishment in commercial citrus in the San Joaquin Valley to date. Examine the 50 or 400-meter treatment areas for residential citrus in the Central region and discuss the feasibility of harmonizing the delimitation area to the same area used in Southern California.

6. Review and update sampling and response strategies in the written action plan for when *C*Las+ trees or *C*Las+ ACP are found in residential and commercial citrus. For example, perimeter testing of citrus orchards by itself is insufficient to detect *C*Las in commercial citrus –an alternative sampling strategy is needed. Involvement of a technical advisory committee is important.

7. Improved educational components to the public may reduce southern incursions of psyllids and improve effectiveness of detecting both ACP and *C*Las. Amplify the program's efforts to educate laborers on personal and equipment sanitation.

Additional Information Requested by SAP

- Provide information on the treatment and delimitation response program for reproducing psyllid populations in residential citrus and the rationale for the delimitation and 50-meter treatment areas.

List of Materials Referenced Either from the Pre-Read or Additional Supporting Information

- Risk-Based Survey Presentations and DATOC discussions (Neil McRoberts)
- CTV Survey team discussion (Subhas Hajeri)

Areas in Need of Additional Discussion

- How to adapt the RBS model to support the concerns specific to the San Joaquin Valley with respect to psyllid incursions and potential for *C*Las movement (not incorporated into the whole California analysis).
- Improvements in the action plan for when *C*Las is detected in either ACP or in commercial citrus trees.
- Use of dogs for detection of psyllids seemed successful in southern desert areas where ACP populations are low, and detection is sporadic. This is the same situation in the San Joaquin Valley and therefore may be of benefit. However, management of dogs requires use of live psyllids to reinforce the training. Is there a mechanism to allow the reinforcement training that does not create a risk of bringing psyllids into this citrus production area?

Questions 4 and 5 address the present and future of HLB management in Southern California: Is the current management program in Southern California managing HLB well enough and what does the future of HLB look like?

Questions #4 and #5 are related, as they both address managing HLB in Southern California and implications beyond, both short and long term. Question 4 centers around elements of the CPDPP that are focused primarily on residential citrus and the monitoring of both ACP and *C*Las using a variety of methods and approaches. The sub-elements discussed by the SAP focused on how well survey and sampling are tracking the changes in appearance and abundance of ACP and HLB in this region, and how the activities can be made more effective. The topic of removal of HLB positive trees in the core residential areas as a continuing necessary step was discussed, including how long this will remain practical if residents are replanting citrus into sites where *C*Las+ removals occurred.

Question 5 focuses more broadly on how the Southern California program, which is increasing in geographic scope and complexity, is positioned to continue to protect commercial citrus in both Southern California and Central/Northern California from spread and establishment of HLB. This question looks forward to outcomes of changes in scope or emphasis of the program in Southern California and how that would impact spread. The SAP considered the level of preparedness in the program to respond when first HLB finds occur in commercial citrus orchards, including management of response actions, information flow, and follow-up program activities that are triggered. Resource questions are raised in each of these, as it can be imagined that the program cannot continue to grow in scope within current resources or under uncertain future funding conditions.

Introductory Statement

In Southern California, reproducing ACP populations are endemic both in urban citrus and commercial groves, thus increasing the risks of HLB presence. Currently, HLB detection and eradication efforts focus primarily on residential citrus, while only a relatively small number of citrus trees are surveyed in commercial groves (sentinel grove survey and crop survey). Furthermore, these commercial citrus HLB survey efforts are based on sampling of symptomatic leaf tissue, hence likely to miss asymptomatic latent infection in trees. Residential citrus testing in the core infection areas has revealed asymptomatic trees that tested positive for *C*Las, indicating the need for asymptomatic tissue testing. Finally, the grower voluntary response plan and CDFA survey that focus on citrus orchard perimeter trees are insufficient responses to an *C*Las infection near or in a commercial citrus orchard. Pooling asymptomatic and symptomatic citrus leaves for testing will be a critical next step for sampling more trees (entire orchards) and detecting early infections by *C*Las.

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Given that many commercial citrus groves in Southern California are interfaced with urban neighborhoods and HLB-infected trees and *C*Las+ psyllids have been detected in some of these residential areas, it is of paramount importance that the HLB survey program in Southern California shifts its focus to include commercial citrus surveys. This recommendation will require changes to surveillance strategies and collection methods, as well as preparedness for *C*Las detections in commercial orchards. The expectation that *C*Las will be detected in commercial orchards provides an opportunity for substantial change and significant reorganization of the HLB efforts in Southern California. Such reorganization will require the inclusion of various stakeholders, a harmonization of surveillance programs, the easy exchange of data, large scale pathogen monitoring, increased outreach to citrus industry members, and a clear vision as to what the goals of the program are. This topic was introduced in Question 1 with the recommendation that reorganization begin with a group effort to develop a new set of questions or objectives that the program should address with surveillance and response activities.

Recommendations

1. **Commercial Risk-Based Survey (RBS)**. The Commercial RBS should be immediately initiated for Southern California, as was discussed in Question 2. This survey will give weight to groves immediately adjacent to urban areas with positive HLB detections and will direct surveying specifically to commercial trees in these buffer areas, complementing the buffer-weighted residential RBS.

2. **Massively increase asymptomatic as well as symptomatic leaf tissue collection.** There is a need to change the *in planta* HLB survey strategy and methodology by collecting and testing both symptomatic and asymptomatic leaf tissue for early detection purposes. Pooling leaf samples collected along border trees of groves will allow the covering of more ground, thereby increasing the chances for early detections. Similar benefits could accrue in residential sampling along or beyond the known perimeter of HLB presence. Any positive pooled samples would not invoke a regulatory action, but would be followed up by more intensive, single tree sampling, that would then potentially lead to regulatory action. The goal is to sample vastly more trees and find the infections in the early stages. Protocols will need to be developed specifically for this program. Data analysis is needed to determine the maximum number of leaf samples that can be combined to detect *C*Las and sampling procedures adjusted for this new approach.

3. **Grower sample submission**. The SAP also recommends that growers in Southern California voluntarily submit additional leaf samples for testing, beyond the RBS or grove surveys currently conducted. Such a strategy will require the development of a sample submission protocol and the establishment of a network of non-regulatory labs to increase testing capacity within the state. Providing leaf tissue testing free of charge for

grower-submitted samples will incentivize participation. Consequently, the SAP recommends exploring ways to make grower sample submission and testing cost-free for the grower. This recommendation would have the impact of increasing the likelihood of finding early HLB infections, especially in commercial citrus.

4. **Commercial citrus response plan improvements**. It is expected that *C*Las will be detected in commercial orchards in the near future. A clear response plan to HLB detections needs to be laid out for psyllid treatment, tree removal, and delimiting surveys within groves. The current protocol of testing only the perimeter trees of groves will not be sufficient for groves that have positive trees or are near positive trees. This sampling scheme was established based on a single tree/test and needs to be revised with the adoption of a pooled sample approach allowing for vastly more trees to be tested. In addition, there is a need for the development of a clear protocol to follow in case of HLB detection in commercial groves, including a pathway for immediate reporting to CDFA. It was unclear but assumed that the CPDPP would play a lead role in responding to commercial orchard HLB detections.

5. **Grower preparedness when HLB finds occur**. Stakeholders must be prepared for those initial positive detection events. Outreach efforts must develop more detailed information on what will happen when *C*Las detection occurs in a commercial orchard. The importance of developing or updating readiness plans cannot be understated. The current response plans for commercial HLB detection should be reviewed and updated.

6. **Residential Risk-Based Survey (RBS).** The SAP recommends adjusting the residential RBS model to select a greater proportion of residences strategically and tactically near commercial groves and the leading edge of the infection versus the core.

7. **Data collection methods harmonization.** Beyond the RBS, there are multiple *C*Las and ACP surveillance programs, including the CDFA, CRB, CCTEA, and the University, with each agency using its own methodology and maintaining its own dataset separately. Such diverse data collection systems are complex, leading to redundancy of efforts and resource allocation, and inhibiting coalescing data from various sources into models and reporting. Apart from providing context and situational awareness, it was not apparent how the massive datasets collectively helped advance HLB management in the state. Therefore, to save resources and optimize HLB surveys in the state, the SAP recommends the harmonization and standardization of plant and insect data collection. Such streamlined data collection approaches will facilitate the integration into a data repository that will be easier to access by the CPDPP and other agencies, and to be used for impactful outreach programs.

8. **Data storage and sharing**. All surveillance programs should use the same formatting for their data; all data should be fully made publicly available possible in a timely manner given the expanding nature of the epidemic. Public (password protected) data

repositories would help the program analysts develop better strategies for managing HLB and engage scientists to conduct higher levels of analysis.

9. **Additional modeling.** Spread modeling of various scenarios must be performed to consider implications of changes to the surveillance effort in Southern California. This does not preclude the inclusion of commercial orchards into current surveillance programs.

Areas in Need of Additional Discussion

1. Robust psyllid monitoring year-round to get a picture of the benefits of residential buffer insecticide sprays.
2. An adjustment of *C*Las-testing in ACP and leaf tissue for sentinel groves during periods of high risks such as fall.
3. The continuation of HLB surveys in the core urban areas, but at a reduced scale and intensity.
4. Reducing surveillance efforts in urban areas of Southern California may have consequences that should be carefully considered. First, increased *C*Las incidence in urban areas may increase the likelihood of long-distance dispersal events into other regions of California. Second, pathogen spread modeling of different scenarios is necessary to infer potential dispersal pathways and how other parameters may be impacted by reduced *C*Las surveillance. Third, it remains unclear what the genetic and phenotypic diversity of *C*Las in California is, and how increased pathogen populations may lead to adaptation to biotic and abiotic pressures, potentially resulting in more virulent genotypes with increased dispersal rates. Finally, given the complexity of HLB and the urban-rural interface in California, it remains important to study how stakeholders will respond to HLB findings, and how those responses will impact management strategies, through the lenses of the social sciences and the humanities.

Question #6: Production nurseries are regulated to prevent the spread of ACP and HLB. Does the California program provide sufficient protection at retail level?

Introductory Statement

The propagation of clean citrus nursery material is an integral part of the three-pronged approach (pathogen free material, vector control, and tree removal) to contain and control HLB. To achieve this goal, citrus production nurseries in California follow guidelines outlined in the USDA Citrus Nursery Stock protocol (CNSP) and the CDFA Citrus Nursery Stock Cleanliness Program (CNSCP). Additional interior quarantine restrictions are imposed by the Host Nursery Stock Regional Quarantine Zones (HNSRQZ). The CNS and CNSCP are complimentary and follow a systems approach for producing certified citrus material that is free from known pests and pathogens. This is achieved through a combination of pathogen free foundation material, propagation in insect resistant structures (IRS), routine inspections of structures and plant material, documented use of insecticides (CNS only), and biannual diagnostic testing. Once nursery stock leaves the controlled production environment and enters the retail market, the protections of both the state and federal programs (IRS, inspections, insecticide applications, and testing) are no longer in place. This loss of regulatory oversight and protection for citrus material at the retail level is a substantial concern to the production nursery industry and phytosanitary security at-large given the long retention time and lack of continued insecticide application (Byrne, et. al., 2018). As part of the overall verification of a systems approach, the CNS and the CNSCP also outline steps to evaluate and mitigate breaches to an IRS. These "critical control point" (CCP) assessments are a joint effort between PPQ and CDFA, whereby structural and/or procedural breaches are evaluated, and appropriate mitigations implemented. These steps ensure the continued propagation of clean nursery material.

Science Advisory Panel Assessment

Clearly, the CNS and CNSCP have served the overall program well since their inception in 2012-13. There have been no detections of HLB in any certified IRS and clean nursery material has entered the commerce stream (Dillon, 2022). However, there is a gap in phytosanitary security once citrus nursery stock enters the retail environment. This could have profound effects on eradication/control efforts, particularly in the Southern California area, through unmitigated exposure to the ACP vector (Byrne, et.al., 2018). The risk assessments and subsequent mitigations following a breach at production facilities cause a substantial impact on nursery operations. The additional testing periods delay shipping and increase the costs to produce material while in the most extreme cases, the nursery loses market access for all material produced in the breached structure. The CNSP requirement for insecticide application period is not supported by the most recent science (Byrne, et.al., 2020). This has a direct impact on the duration of protection afforded citrus nursery material once it reaches the retail market (Byrne, et.al., 2018; Byrne, et.al., 2020). Availability of clean nursery material in quarantine areas is limited by the HNRQZ. This could work against the program's goals if illicit material is sought in these areas.

Recommendations

1. The program should establish a working group that includes industry, retail businesses, and regulators to develop a risk reduction strategy for retail locations within quarantine areas.
2. Ensure risk assessments are consistent between risk assessment teams, as well as state and federal partners. Uniformity of inspections and risk assessments is encouraged when breaches occur or at points where transport or post-production display of nursery citrus plant is important to limiting spread through these channels. Breaches of IRS pose significant risk to the normal operation of a citrus nursery. What can be done to develop a more scientific approach to determine the actual risk posed by an IRS breach, considering California's environment and pest pressure? Can the response be based on the size and temporal existence of a breach?
3. USDA should revise the pesticide application period to reflect the most recent science regarding nursery tree uptake and retention time.
4. The program should develop a protocol that supports availability of disease-free and insecticide-protected nursery material within HLB quarantine regions to make available residential retail nursery trees in those regions and to discourage citrus plant acquisitions from outside sources.

List of Materials Referenced either from the pre-read or additional supporting information

- Assessing the risk of containerized citrus contributing to Asian citrus psyllid spread in California – Byrne, et.al., 2018
- Rapid uptake and retention of neonicotinoids in nursery citrus trees as a safeguard against Asian citrus psyllid infestation – Byrne, et.al., 2020
- Citrus Nursery Perspective – Aaron Dillon, Four Winds Growers
- Citrus Nursery Stock Protocol – USDA APHIS PPQ
- CDFA Citrus Nursery Stock Pest Cleanliness Program
- ACP State Interior Quarantine | Regional Quarantine Zones

Areas in Need of Additional Discussion

- Does the current regulation regarding retail citrus in HLB Quarantine areas still make sense? Could the inside of a retail location be considered a resistant structure?
- Could we have intensive trapping around a nursery to try and declare the area as not infested with the psyllid?

- Breaches of IRS pose significant risk to the normal operation of a citrus nursery. What can be done to develop a more scientific approach to determine the actual risk posed by an IRS breach, considering California's environment and pest pressure?

Question #7: Is there sufficient access by growers and homeowners to real-time information on the locations of HLB and are there incentives to stay engaged in the program?

Introductory Statement

The CPDPP outreach program is conducted by Nuffer, Smith, Tucker (NST) in collaboration with UC Cooperative Extension, grower liaisons, CDFA, and others.

General public: The goal of general public outreach is to garner support for program activities occurring in residential areas including detection trapping, delimiting visual surveys, testing for *C*Las in psyllids and plant material, insecticide applications to eradicate or reduce psyllid populations, and tree removal when *C*Las is found. Communications range from door hangers, home visits and public meetings, to public service announcements, news alerts, local papers, large signage, social media, and booths at citrus fairs. The californiacitrusthreat.org website provides general information for the public.

Citrus industry: The goal of citrus industry outreach is to educate the growers, packers, haulers, PCAs, nurseries and other industry members about the program and keep them abreast of events, regulations, and activities that they may need to engage in. NST supports citrus industry meetings that are conducted by UC cooperative extension, Pest Control Districts, ACP task forces, CDFA, CPDPC, and other organizations as needed. The citrusinsider.org website serves as a central location for reporting news, regulations, maps, and downloadable information for growers, packers, haulers, pest control advisors, and nurseries, as well as provides links to other sites.

Science Advisory Panel Assessment

The time to alert growers and the public when ACP or HLB require a response is sufficiently rapid. Keeping the citrus industry and public and engaged is the challenge. The role of NST has grown and evolved over more than a decade to meet the many communications needs of the ACP/HLB CPDPP program. A significant challenge for communication to the public is reaching the large population of Californians, many of whom have backyard citrus, over a wide geographical area. To add to the complexity, there are many cultural responses to the situation and many different languages involved. NST has responded by producing print materials in several major languages and utilizing native speakers for a number of public presentations. NST relies heavily on experts to communicate to the citrus industry and collaborates to produce web and print materials to support them. Analysis of the success of the NST communications outreach program is limited to numbers of impressions, web traffic to web pages, and discussions about the success of various initiatives based on levels of participation. Analysis of surveys of grower adoption and acceptance of ACP/HLB management practices have been conducted and published by UC faculty and students. These surveys indicate a lack of concern about HLB by growers in some areas of the state because of the relatively slow spread of the disease and confidence in the program, and therefore, there has been a reduction in participation in coordinated insecticide treatments in some areas of the state.

Recommendations

1. Engage a data analysis expert to work with NST to conduct broad quantitative and qualitative analyses of outreach trends and successes targeting the range of audiences.
    a) as a result, suggest changes in outreach strategies needing greater emphasis.
    b) shift toward predictive outreach strategies instead of reactive.
2. Enact an outreach program to engage growers in submitting leaf samples to non-regulatory labs.
3. Provide updated details of what a grower will need to do if HLB is found in or near an orchard.
4. Support an educational program to encourage pest control advisor adoption of monitoring for ACP as part of their regular pest surveys statewide. This could include collection of ACP for testing.
5. Continue coordination of outreach efforts between the CPDPP program, UC and other entities.
    a) Conduct regular strategy sessions to proactively expand outreach in response to changes in the program.

List of Materials Referenced either from the pre-read or additional supporting information

Websites

NST

  https://citrusinsider.org
  https://californiacitrusthreat.org

University of California

  https://ucanr.edu/sites/ACP/

CDFA

  https://www.cdfa.ca.gov/citrus/

Publications

McRoberts, N., S. G. Figuera, H. Densiton-Sheets and E. Grafton-Cardwell. 2019. Grower surveys reveal diverse opinions about managing ACP and HLB. Citrograph 10 (4):22-24.

Garcia-Figuera, S., E. E. Grafton-Cardwell, B. A. Babcock, M. N. Lubell and N. McRoberts. 2021. Institutional approaches for plant health provision as a collective action problem. Food Security 13:273-290.

Garcia-Figuera, S., H. Deniston-Sheets, E. Grafton-Cardwell, B. Babcock, M. Lubell and N. McRoberts. 2021. Perceived vulnerability and propensity to adopt best management practices for huanglongbing disease of citrus in California. Phytopathology 111:1758-1773.

Areas in Need of Additional Discussion

- Engaging the public and areas where the disease occurs.

Question #8 Regulatory Issues:

The SAP was asked to provide perspective on several issues surrounding regulations that are associated with the presence of ACP and HLB in California. These are stated below as they were provided to the SAP.

1. Is there scientific validation for these regulations?
    a. Tarping, nursery, HLB quarantine enforcement, regulated entities.
2. Is there an alternative to insecticide treatments for moving bulk citrus?
3. How are quarantine regulations affecting organic operations?
4. Do the nursery screenhouse breech policies have scientific validation? What factors and milestones should be considered before operations may resume?
    a. Are there different trapping strategies that could be used around nurseries to aid in this decision-making?
5. What milestones/requirements would a region need to meet to be removed from an existing ACP quarantine area? From a scientific perspective, what would an effective exit strategy look like?

While there are scientific elements implicit in these questions, the SAP realized that the regulatory aspects of ACP/HLB in California fall under federal and state purview. The regulations are based on available information and have been formulated within the broader context of pest and disease prevention, detection, and interventions.

During preliminary discussions, it became obvious to the SAP that the panel selected to provide the CPDPP review were neither fully versed in the breadth and depth of the regulations surrounding an invasive pest/disease system, nor was the panel composed of experts in the relevant fields. Rather than take on this topic alone, we engaged in brief discussions within each question when regulations played a role in directing the program or resulted from program detections. In those few cases, the responses within each question reflect the findings of the SAP.

Recommendations:

1. As reported under Question 6 (Nursery), the SAP recommends a working group composed of stakeholders and the regulatory experts be established to identify more clearly where the interface of CPDPP surveillance and response actions is creating difficulties, and to determine if there are resolutions that can be implemented to minimize the impacts of regulatory issues. As time advances, new issues surrounding regulatory components of California's response to HLB may arise and will require attention.

SAP Review Summary

The CPDPP and CPDPC are to be commended for the foresight, coordination, and momentum which resulted in the formation of the Citrus Pest and Disease Protection Program as a centralized unified response to detection of ACP and HLB in California. Assembling plans and resources from among institutions, growers, homeowners, and government allowed for a response program which was calibrated to the early threat of these detections, and which focused on preserving the health of dooryard citrus in Southern California and protecting the important commercial citrus businesses in California from threat of HLB expansion.

The 2022 CPDPP Science Advisory Panel Review of the program and the circumstances in which it now operates recognized immediately the geographical and logistical expansion of the response program as it reacts to broader movement of the vector and pathogen in Southern California and into Central and Northern reaches of the state. The original CPDPP strategies and tactics served well during the focused establishment and early spread of ACP and HLB in Southern California when the area of detections was limited, and the activities were intensive in a small area. The SAP observed that over time, the CPDPP implemented more control actions and expanded program boundaries as spread occurred and conditions changed. This was largely done within the original strategies and tactics, and adjustments were made within that environment which focused primarily on residential citrus trees and their infestations.

The increase in breadth and magnitude of ACP-infested areas, especially in Southern and coastal California, and acceleration in the numbers of *C*Las+ trees in residential landscapes, the SAP summarized that the program considers a shift in emphasis to get ahead of the frontier of the expansion, rather than follow the ACP/HLB front as it continues to grow. That does not mean abandonment of the core area of infection, but rather a rebalancing of activities and resources to the residential/commercial interface which represents a high risk of local spread and into the main commercial citrus growing areas, which are not reported infected but are not receiving much surveillance. A parallel general recommendation based on the expanding differential between ACP and HLB in Southern versus Central/Northern California is that the program should split models that provide guidance on detection and control actions in these different portions of the state's citrus regions and rebalance the levels of effort important to each region and between residential and commercial properties, particularly where the two interface.

The SAP concluded that CPDPC and CPDPP should adopt improvements to the program in the face of the current situation that will increase efficiency, further safeguard against commercial citrus infection.

Toward the general recommendation regarding assessing regions and residential versus commercial activities, the **SAP provides our most emphatic recommendations to address this issue: 1) split the Central/Northern and Southern high-risk surveys into two separate surveys, 2) increase the proportion of residential citrus near commercial citrus in the Residential Risk-Based Survey (RBS), 3) invoke the Commercial RBS in Southern California, 4) collect asymptomatic as well as symptomatic plant tissue, pooling it to increase the volume of samples and detection success, 5) stimulate the creation of nonregulatory labs to process a greater quantity of samples, and 6) test entire citrus blocks (not just perimeters) when a find occurs in or near a citrus block.** In all likelihood, *C*Las has already infected commercial citrus orchards and the SAP concluded that the CPDPP and industry are not surveying sufficient insects and plants to find it. Commercial citrus testing is a critical need, and it is our opinion that the CPDPP must make the changes necessary to address it quickly. Additionally, the current response plan for commercial citrus is not sufficient.

It became apparent that data collection from different "groups" (i.e., CDFA, CRB, CCTEA) may be complimentary, but integration of these data sets is not part of the current protocol. Better coordination and data integration will allow more efficient monitoring and enrich the data that are driving the risk models and management tactics.

The SAP provided a lengthy list of recommendations while addressing each of the questions assigned with variable scale and ease of implementation. They are provided in detail within the body of this report. For the purposes of this summary, we highlight the following as perhaps most important for immediate consideration.

1. **Greatly increase commercial citrus testing and response to *C*Las+**
    a) Invoke the Commercial RBS model to intensify surveys of commercial citrus near where *C*Las+ psyllids and trees have been found.
    b) Use sample pooling to vastly increase the number of trees being tested
    c) Develop nonregulatory testing labs and engage PCAs in collecting samples and growers in submitting sampled.
    d) Develop a more comprehensive grower response (whole orchard testing) to *C*Las+ in or near orchards.
2. **Change the strategy for the Residential RBS survey**
    a) Separate the Central/Northern Survey from the Southern Survey as they have different goals.
    b) De-emphasize the core infection areas, but maintain sufficient survey to determine the impact of reduced surveillance.
    c) Increase attention to the leading edge of infection areas and the buffer areas between commercial citrus and residential citrus.
    d) If genetic typing relative to the biology of the insect and pathogen is available, incorporate it as a factor.
3. **Develop a new set of questions based on current and anticipated ACP and HLB dynamics that can drive further program redirection and focus.** This should be engaged to follow implementation of the shorter-term recommendations contained in the report.
4. **Harmonize data collection and management between agencies and individuals**
    a) Allow greater access of data for analysis and recommendations by scientists.
    b) SAP meet a minimum of every 2 years to review program progress and formulate new recommendations.
5. **Address nursery issues to ensure clean plant material is available to growers and the public**
6. **Conduct a deeper quantitative and qualitative analysis of outreach milestones and successes to shift the program toward predictive rather than reactive messaging.**

Acceptance and adoption of the recommendations provided by the SAP review comes with the need for assessment of resource allocations and balance of effort with new compared to former activities. This should be accomplished with an eye to future resource needs and limitations, as it can be expected that the program needs will continue to change. While the SAP did not delve deeply into resource issues, it was recognized that implementing the recommendations will necessarily lead to resource discussions, and resources, may ultimately play a role in scaling the recommendation as they are implemented along with retention of those activities that are viewed as critical to continue.

The continued collaborations and flexibility that exists within the CPDPP will be essential to keep pace with the biological realities of this citrus disease threat.

CPDPP SAP Review Report Appendices

Appendix 1: Report from CPDPP SAP Meeting, February 2014

https://www.cdfa.ca.gov/citruscommittee/docs/reports/SAP-Report-and-Meeting-031814.pdf

March 18, 2014

Dear Citrus Industry Stakeholder:

Subject: Asian Citrus Psyllid and Huanglongbing Science Advisory Panel Report

The California Department of Food and Agriculture's (CDFA) Asian Citrus Psyllid (ACP) and Huanglongbing (HLB) Ad Hoc Science Advisory Panel (SAP) is a group of scientists selected by the Secretary to provide scientific advice to the Department to ensure that we are using the best science available when developing program policy and protocols. These scientists consist of experts from states that have already experienced the sequence of events associated with ACP/HLB infestation, as well as California-based scientists with local knowledge to ensure a diverse perspective.

The panel met in December 2013 and was tasked with providing recommendations on a series of non-regulatory questions vetted by CDFA. This report contains the list of questions and the answers from the ACP-SAP. In addition, the report contains the SAP's comments and recommendations for consideration in the development of ACP/HLB programs in California.

The SAP made program-wide recommendations that fall under the area of responsibility of not just CDFA, but also collaborating agencies and stakeholders. Therefore, we intend to review the SAP recommendations jointly with all affected entities including the Citrus Pest and Disease Prevention Committee, United States Department of Agriculture, Citrus Research Board, Agricultural Commissioners, and the nursery industry, in order to ensure a common understanding of those recommendations that can be implemented by the agency and/or stakeholders responsible.

The stakeholder meeting is scheduled for March 26, 2014 from 1:00 p.m. to 4:00 p.m. at CDFA headquarters, 1220 N Street, Room 133, Sacramento, CA 95814. Call in information will be furnished upon request.

If you have any questions or concerns, please do not hesitate to contact our Citrus Program Manager, Victoria Hornbaker at 916-654-0317 or via email at Victoria.Hornbaker@cdfa.ca.gov.

Yours truly,

Nick Condos
Director

ACP SAP Questions & Answers. Questions for the ACP/HLB SAP sent to the SAP 10-3-13 by Jason Leathers from California's ACP/HLB Programs. **Answers from the SAP are in bold text.**

1) What is the appropriate size of treatment areas around ACP find sites in eradication zones under a variety of scenarios?
   a) An urban area where no HLB has been detected – **Treating all urban ACP hosts within 400 m as is currently done seems appropriate as well as any commercial citrus grove that falls within 400 m.**
   b) An urban area where HLB has been detected – **Treat 800 m for urban ACP hosts as well as any commercial citrus groves that falls within 800 m. In addition, background checks should be done to try and determine why HLB was likely present. All infected trees should be removed rapidly and trees in the area should be tested for CLas using the best detection methods available at that time, especially during the spring and fall when titers are highest. Because transovariole transmission of CLas within ACP occurs at low rates, detection of CLas in ACP nymphs from an urban tree is proof that the tree is infected with CLas (i.e. it then falls under category 1b).**
   c) A commercial grove where no HLB has been detected – **Treat that grove and any grove or urban ACP hosts that fall within 400 m.**
   d) A commercial grove where HLB has been detected – **Treat that grove and any grove or urban ACP host that falls within 800 m. In addition, background checks should be done to try and determine why HLB was likely present. All infected trees should be removed rapidly and trees in the area should be tested for CLas using the best detection methods available at that time, especially during the spring and fall when titers are highest. Once the cumulative number of infected trees in that grove has reached 2%, all trees in the grove should be removed. Because transovariole transmission of CLas within ACP occurs at low rates, detection of CLas in ACP nymphs from a commercial tree is proof that the tree is infected with CLas (i.e. it then falls under category 1d).**

2) To mitigate risk of natural spread of HLB we currently treat ACP detections in a 2-mile wide buffer on either side of the border with Mexico. What is the minimal width of such a buffer that will mitigate the natural movement of HLB? -- **Two miles on either side of the border (four miles total) appears to be a suitable minimal width.**

3) Are the early HLB detection methods in development (sniffer, root survey, metabolite analysis) appropriate for use now, are they truly accurate? -- **Research is underway in the UC Davis Containment Facility to try and answer this question. It is urgent that this work continues as fast as possible. The close agreement (on three separate trees, three different methods each indicated presumptive "positive" for CLas) of several very different experimental methods on trees chosen around the Hacienda Heights Ground Zero tree are highly suggestive that several of these methods are accurate.**

4) Would it be beneficial to freeze dry leaves from asymptomatic, VOC positive trees for future analysis, when technology improves? -- **In part, this is a matter of resources and their best use for answering scientific questions. In some cases, such leaves should be collected on ice (one method) or dry ice (three of the methods), delivered to the Citrus Research Board Dimitman Laboratory for processing, and then stored at -80°C for later analysis. Consult with the CRB lab (Dr. Polek) to see if this process can be streamlined.**

5) Beyond what level of HLB survey will we see diminishing returns? -- **Right now is an absolutely critical time period with respect to finding and eliminating CLas infected citrus trees in California. Based on experience from Florida, once one passes 2-8% CLas tree infection, one sees diminishing returns.**

6) What role should tree nutrition play in ACP/HLB management? Is phosphoric acid a viable treatment for ACP? -- **Proper nutrition is essential to citrus tree health and most commercial growers in California already practice good tree nutrition. The SAP absolutely rejects the concept that CLas should be allowed to spread and that this disease can be managed through enhanced nutrition – unfortunately, many growers in Florida have taken this approach and are beginning to see dramatic negative impacts (e.g., very high levels of fruit drop this year; negative impacts on flavor which can be mitigated to some degree with blended juice but ruins a fresh fruit market like California's). No – phosphorous (phosphite or H3PO3) acid treatments are absolutely not the way to manage ACP or HLB.**

7) What methods should growers use to facilitate the establishment of *Tamarixia radiata* and other biological control agents when they are introduced in and around groves? Will agents require refugia? – **Management of Argentine ant and other ants that interfere with biological control is essential to establishment of *T. radiata* in urban areas and to high levels of parasitism that will allow this parasitoid to spread as much as possible. Research and trials by pest control advisors and growers will help us learn which natural enemies can survive under various treatment programs in both organic and non-organic citrus. Leaving refugia of uncontrolled ACP in place is not wise.**

8) The California ACP/HLB Task Force and USDA TWG recommended a time period of 24 months to declare eradication of ACP from an area. This is to allow for the passage of 3-4 flushing cycles of citrus. Should the length of the quarantine be reconsidered in conjunction with the treatment program and a lack of finds? – **If 24 months pass and monthly traps and visual surveys do not reveal an additional ACP find, the SAP considers that a good time period to declare eradication a success.**

9) In lieu of the field cleaning process, chemical treatments are now considered sufficient to mitigate risk of spreading ACP on bulk fruit, stems, and leaves from commercial groves in areas of low ACP prevalence.
   a) What criteria should be used to determine areas of low pest prevalence? – **Based on science, the SAP considers southern California to no longer be an area of low pest prevalence and this will likely soon be true of other areas such as the San Joaquin Valley. Given the current HLB situation, the SAP does not believe chemical treatment is sufficient to reduce levels of ACP that might be carrying CLas in shipments of fruit from southern California and coastal areas into the SJV. Instead, the SAP recommends that all fruit be run through a wet packing house wash / brushing before movement to the SJV and fruit should be moved in enclosed or tarped trucks. No treatment should be needed for movement of fruit within a quarantine zone. For movement of fruit from within a SJV quarantine zone to a non-quarantine area, the current list of chemical treatments appears adequate except the SAP further suggests two approved organic spray could be substituted for each approved traditional spray unless the treatment is deemed 'eradication' and then there are no organic treatments deemed eradicative.**
   b) Is there a different set of chemicals that would be sufficient for high prevalence areas? – **For the reasons stated above, the SAP does not consider any insecticide treatment to be sufficient for movement from southern California (because of the risk of moving CLas inoculative ACP) into either a non-quarantine area or low-density area such as the SJV sufficient. Instead, all such fruit should be run through a wet packing house wash / brushing before movement and should be moved in enclosed or tarped trucks.**

10) In addition to the treatments listed in Attachment 1, are there other efficacious alternatives for control or eradication of ACP in commercial organic groves? – **The SAP has modified the chemicals listed under Attachment 1 below to include four products deemed appropriate to list at present. The SAP does not know of sufficient efficacy data to add additional chemicals to the list at this time. It is important that additional organic testing be done so that the strongest products can be selected for use in organic citrus. The SAP does not consider organic products to be eradicative, but they may be used where eradication has been replaced with an areawide treatment program.**

11) With most of the ACP detections in Tulare County being on traps placed on poles rather than within the canopy, should we change trap placement for the ACP program? – **Trials are currently underway to compare adult ACP trapping on cards hung using protocols used for GWSS vs. by CPDPC vs. by CDFA in urban citrus. Pending the outcome of those trials, data should be submitted to the SAP so that a recommendation can be made.**

12) On March 23, 2014 we will be 2 years without a HLB detection in California. What should be our exit strategy? – **The SAP believes an HLB exit strategy does not make sense given that is it extremely unlikely the Hacienda Heights infected tree is the**

only one in that area and the likelihood that CLas inoculative ACP are becoming more moving northward from Mexico towards California. The long latency period between when a tree is infected with CLas and when HLB symptoms appear (can be as long as 3-4 years depending on variety, size of the tree, time of the year, etc.) must be considered.

Attachment 1

University of California – KAC Citrus Entomology – Organic Treatments

Laboratory and field research is underway to increase knowledge of the organic products available for managing Asian citrus psyllid. The following is a list of products that have demonstrated efficacy. In all cases, direct contact with the insect is required and residual activity is short (days) - that is why frequent applications are necessary.

- Pyganic + oil
- Oils (petroleum spray oils, TriTek, JMS stylet oils, others)
- PFR-97 (*Isaria fumosoroseus* fungus)
- Trilogy (neem oil)

ACP SAP Questions & Answers – Winter 2014

The ACP SAP convened via conference call on January 16, 2014 to discuss questions related to whether or not ACP is established in areas of Tulare County. On the call were Matt Ciomperlik, Ed Civerolo, Tim Gottwald, Beth Grafton-Cardwell, Charla Hollingsworth, Joe Morse, Mamoudou Setamou, Georgios Vidalakis. Mark Hoddle was not able to call in.

Unincorporated Tulare County East of Richgrove (Map 1)

Detections: On November 4, 2013 one adult male ACP was identified. On December 23, 2013 four additional ACP were trapped: 3 were on 2 yellow panel traps inside the 800m eradication area and the 4th was at a residence approximately 2km northeast. On December 30, 2013 two additional ACP were trapped just outside the eradication area.

Treatments: At least 3 groves in the original 800m area were not treated subsequent to the November 4 detection. One grower has indicated his/her intentions to refuse treatment for several additional months.

Questions:

1) Is this pattern of detections consistent with evidence of an established population, or does it indicate repeating introductions of ACP to the area?
   Answer: This is consistent with evidence of an established population.
2) Are the detections of ACP just outside the 800m eradication area and 2km to the northeast across a host-free area evidence that ACP have spread beyond the original 800m area?
   Answer: This could be argued either way.

Dinuba (Map 2)

Detections: On August 13, 2013 two single male ACP were found on two yellow panel traps in the city of Dinuba. On September 9, 2013 a third male ACP was trapped at one of these two sites and visual survey revealed that a breeding population of hundreds to thousands of individuals of all life stages of was present on multiple small trees at an adjacent residential property. In January 2014 a single ACP was trapped outside a juicing facility less than 2km north of the previous detections.

Trace Back Investigation: Trace back investigation revealed that the trees had been planted at the property for at least nine months.

Questions:

3) Is this pattern of detections consistent with evidence of an established population, or does it indicate repeating introductions of ACP to the area?
   Answer: This is consistent with evidence of an established population.
4) Is it likely that ACP may have spread beyond the 800m eradication area before treatments were applied?
   Answer: Yes, growers should engage in area-wide control measures CDFA should follow-up with continued survey and residential psyllid control in the urban area.

Porterville

Detections: On June 26, 2013 four ACP were found on a yellow panel trap south of Porterville. Two additional ACP were found within a 5km radius on June 26th and October 3rd.

ACP SAP Questions & Answers – Winter 2014

Questions:

5) Is this pattern of detections consistent with evidence of an established population, or does it indicate repeating introductions of ACP to the area?
Answer: As ACP is capable of traveling long distances in short times it is splitting hairs to worry about establishment in individual areas. An established ACP population should be considered present throughout Tulare County.

Asian Citrus Psyllid / Huanglongbing Ad Hoc Science Advisory Panel Report

From SAP Members: Edwin Civerolo*, Timothy Gottwald, Beth Grafton-Cardwell (co-chair), Mark Hoddle, Joseph Morse (co-chair), Mamoudou Setamou*, and Georgios Vidalakis (* = not present at the Dec. 3-4 meeting but contributed to this report)

Executive Secretary of the SAP: Jason Leathers
Advisor to the SAP: Mathew Ciomperlik

Background

A meeting of the ACP HLB SAP was convened in Ontario, CA December 3-4, 2013 (Agenda = Appendix A). Prior to the meeting, the SAP was provided a list of 12 questions (ACP SAP Questions & Answers, answers from the SAP in bold type) that California's ACP/HLB programs asked be addressed.

December 3 (morning) -- In an open meeting, the SAP and interested parties listened to a series of presentations by Celestina Galindo and Nawal Sharma of the CDFA and MaryLou Polek of the Citrus Research Board updating the group on the status of the ACP and HLB situation and responding to a number of questions that SAP members had submitted prior to the meeting. Presenters responded to questions from the SAP and the public during and/or after their presentations. Following the presentations, all those present were provided an opportunity to pose questions of the SAP or others present or to make statements voicing their concerns.

December 3 (afternoon) and December 4 (morning) -- The SAP met in closed session with Jason Leathers and Mathew Ciomperlik to discuss the ACP/HLB situation in California and develop the framework for their report. At 11 a.m. on December 4, the SAP met with the public to share the highlights of their draft recommendations and receive feedback.

Following the meeting, the SAP developed this report, made sure all SAP members had a chance to review the draft and suggest changes, and then submitted the report to CDFA.

SAP Comments and Recommendations

The SAP organized the report around topic concepts. ACP SAP Questions & Answers contains answers (bold type) to the specific questions the SAP members were asked to address.

A. Rapid Detection of HLB Infected Trees and/or Psyllids

The SAP recommends that the absolute top priority of the program should be rapid detection of HLB-associated Liberibacter(s) and HLB, and elimination/reduction of CLas.

A1. Survey for HLB twice a year. Combining the information that was provided to the SAP; information about HLB spread in Florida, Brazil, and Texas; and the experience of the SAP panel members, the SAP considers that it is almost certain that HLB-associated Liberibacter(s) (e.g., CLas) are currently present in one or more citrus trees in California. Every effort should be made to rapidly find these infected trees and to remove them so as to reduce the potential for spread. The SAP feels it is important that that surveys are done in the most effective and efficient manner possible and as new information is obtained it be provided rapidly to relevant parties (e.g., to Tim Gottwald) so that it can be used to update both urban and commercial citrus risk based surveys.

Based on information discussed at the SAP meeting and the presentations in the morning on December 3, Tim Gottwald plans to update his urban risk analysis survey protocol, including an update of a density driven analysis around Hacienda Heights and East Los Angeles (identified at the meeting as an additional high risk area). He will also provide his latest commercial citrus survey protocol to CDFA. CPDPC and other relevant parties need to discuss what funds are available for expanded surveys. The SAP recommends that HLB surveys be done with the objective of covering trees identified by the density-based Gottwald system twice a year (e.g., not every tree around Ground Zero but instead those identified by the Gottwald risk based system which will naturally weigh those around Ground Zero highly). It is the opinion of the SAP that focusing on high-risk locations twice a year with the existing funding is better than trying to survey more locations less frequently. The SAP feels this is important because the appearance of HLB visual symptoms vary markedly over the year and two sweeps provide a higher likelihood that at least one of the surveys will be done during a symptom-optimal time of the year. In addition, there needs to be greater flexibility in changing the structure of the sampling protocol based on the changing situation in the field. The operational protocol for the HLB survey should be reviewed by the SAP panel yearly and whenever significant changes are made.

A2. Rapid exchange of information. It is certain that CLas is going to be found in California again. Anticipating this, involved parties need to develop a communication system whereby the details on what sites have been sampled and the results (positive vs. negative) are communicated rapidly to Tim Gottwald so that he can update the HLB survey model and communicate modifications back to those who are conducting the surveys. The time to develop and fine-tune this system is now rather than later. The SAP cannot suggest how this communication system is best improved but it is critical that it be improved.

A3. Re-training. The visual symptoms of HLB infection in dooryard citrus are easy to miss. Survey personnel (both CDFA and CPDPC) need to be trained and retrained (re-familiarized with visual HLB symptoms) on a regular basis so that they can best detect the visual symptoms of HLB infection. This retraining should be done every six months by sending survey leaders to Florida to view the field symptoms. We suggest that Tim Gottwald and/or Mike Irey be consulted for advice regarding how this training/re-training is best done.

A4. Hacienda Heights Experimental CLas survey. The SAP understands that the CPDPC has authorized the funding of a "Transect Survey" using several of the non-PCR early detection methods (VOC sniffer, metabolomics, etc.) in a 5-mile area around the "Ground Zero" Hacienda Heights CLas positive tree. **The SAP feels that this is an extremely important survey and that it needs to be done as soon as possible.** The results of this transect survey will help determine the density of CLas presumptive positive trees.

The SAP suggests that Tim Gottwald's risk-based analysis be used to suggest which locations be sampled based on a density-driven analysis in this 5-mile area using a sector format (contact Dr. Gottwald for further details), rather than the proposed format (similar to spokes of a wheel). For example, if it is determined that funding is available for 48 samples, then instead of selecting the 48 sample locations based on symmetry, they should be selected using risk analysis. The SAP also suggests that 48 sample locations are not nearly enough. VOC-or metabolomic-positive trees should also be used as foci for risk based sampling. Such sampling should also be done in the East Los Angeles area where ACP has been present for quite some time and census data (e.g., population ethnicity and density) predicts high risk.

The SAP also suggests that an operational protocol for the Hacienda Heights/ East Los Angeles surveys be written and presented to the SAP for review and comment.

A5. Commercial grove CLas sampling. The SAP suggests that a high priority of the CPDPC is sampling and testing for CLas in psyllids (and perhaps plant material when suspicious symptoms are present) in commercial citrus groves. Obviously, funding is limited and CLas sampling in the urban areas of Los Angeles is a very high priority. But the SAP also suggests that commercial citrus sampling should be initiated, especially in areas where areawide ACP management programs have begun and ACP is established.

A6. Expanding capacity for CLas sampling. The SAP believes that processing a large number of samples in a timely manner is critical and the volume of this work is going to increase exponentially in the future. Thus, the processing capacity needs to be expanded substantially. A suggestion of the SAP is that the CDFA lab continue testing all leaf and root samples and the CRB lab assume the processing of all ACP samples, including those collected in Zones 1, 2, and 3 around Hacienda Heights and other high risk areas. The SAP also suggests that the current Zone 1-3 plant samples continue to be collected per the current protocol (Appendix C).

A7. ACP treatments/sampling in Hacienda Heights. Because of the existence of the CLas positive citrus tree (Hacienda Heights "Ground Zero") and the neighboring HLB suspect trees (based on sampling using experimental methods), it is critical that two objectives be met simultaneously: (1) improved control of ACP in the Hacienda Heights area and (2) as many ACP nymphs be collected for CLas testing as possible (collections timed just prior to treatments and especially at times of the year when titers in ACP might be highest – e.g., after the fall flush). The SAP believes that CLas positive ACP nymphs collected from a tree may be the best way to confirm a tree is HLB positive.

Beth Grafton-Cardwell and Joseph Morse have volunteered to work with CDFA in developing an optimal ACP treatment program. Imidacloprid treatments need to be timed better than they have in the past because there is poor imidacloprid uptake into the tree during the spring. Two suggested changes are to apply imidacloprid only June – September and to make multiple lower rate applications to smaller trees. Second, it appears no beta-cyfluthrin treatments were applied in 2013 – at least three treatments should be applied annually. Third, other treatment options need to be developed for urban trees. For example, if there are bloom concerns, spraying with oil would be better than no foliar sprays at all. Given the risk of HLB in the area, the SAP considers the current low level of ACP control unacceptable.

Three trees have tested presumptively positive in the Hacienda Heights area using experimental methods and are still in the ground (#913, #948, and #7911). The SAP suggests that whatever method was used successfully previously to enlist homeowners to voluntarily remove trees also be used for these three trees and they are removed as soon as possible.

A8. Voluntary removal of Hacienda Heights citrus trees. Depending a good deal on the results of the expanded CLas survey in the Hacienda Heights region using experimental non-PCR methods, the SAP suggests it is prudent to enlist homeowners in Zone 1 of Hacienda Heights (400 m around Ground Zero) to voluntarily remove their citrus trees if they are found to be positive by one or more experimental method. The SAP understands there are ca. 565 citrus trees in Zone 1. If this plan of action is successful, removal should then be expanded to Zone 2.

Such a removal project should be done carefully, with advanced planning, and by enlisting the public in a positive manner so that this is a positive public relations experience.

B. Longitudinal Study Being Conducted in the UC Davis Containment Facility

The overall goal of this in progress study is to validate the sensitivity and reliability of the currently available experimental HLB-associated Liberibacter non-PCR early detection methods (volatile organic compounds by Cristina Davis et al., UC Davis Dept. of Mechanical &Aerospace Engineering; metabolomics by Carolyn Slupsy et al., UC Davis Dept. of Nutrition; elicitors by Wenbo Ma et al., UC Riverside Dept. of Plant Pathology & Microbiology; proteomics by Michelle Cilia et al., USDA-ARS Boyce Thompson Institute at Cornell Univ.; and small RNAs by Hailing Jin et al., UC Riverside Dept. of Plant Pathology & Microbiology) as soon as possible.

B1. Varieties, replication, timing. The SAP feels that the "experimental" non-PCR early detection methods currently being developed are critical to winning the war against HLB. The SAP applauds the Citrus Research

Board, other agencies funding such work, and involved researchers in moving these methods forward towards acceptance of one or several of these methods for regulatory use in the near future. It is critical that the reliability and level of sensitivity of each of the non-PCR methods is evaluated as soon as possible.

The SAP has several suggestions regarding the longitudinal study. First, Georgios Vidalakis should be consulted regarding the choice of citrus varieties that are utilized in the studies. The SAP also feels it is important that sufficient replications of each variety be included so that analysis can be done on the frequency with which false positives and false negatives result. Second, the study should be replicated over time (first inoculation with CLas is planned for February 1, 2014). Citrus grows best during the summer. Infection is slower due to the lower metabolism of the plant and is less receptive to CLas infection during winter months. The SAP suggests that there should be another round of inoculations later in 2014 and that the study be replicated three times in order to take into account seasonal effects. Mike Irey should be consulted to suggest what time of year is the best to inoculate potted citrus with CLas in a greenhouse environment.

B2. Other Strains of CLas. Logically, the UCD longitudinal study (B1) is using the Hacienda Heights strain of CLas and our understanding is that the containment facility is able to house only one CLas strain at a time. However, the SAP is concerned that it is likely that a different strain of CLas is moving northward from Mexico towards California. The SAP suggests that it is prudent to plan several tests of the most promising methods from the longitudinal study on HLB-positive citrus trees in Mexico and/or to expand tests done in Texas.

C. Potential for Movement of CLas Infected ACP with Fruit Movement

The goal is to limit the spread of ACP and CLas via fruit movement. There are already mechanisms in place to clean fruit, however the methods may not be sufficient to prevent ACP movement on fruit, leaves, and twigs. This will become more important as CLas spreads.

C1. Movement of fruit from Mexico into the U.S. The occurrence of HLB is increasing northward towards California, Arizona, and Texas from Mexico. There is uncertainty regarding exactly where HLB is present in Mexico. The SAP does not feel fully informed and would like to hold a conference call with Prakash Hebbar (National Coordinator, Citrus Health Program, USDA/APHIS/PPQ/Plant Health Programs), who may be able to inform the SAP regarding National Agricultural Release Program (NARP) guidelines and current protocols. Based on that conference call, the SAP may have suggestions regarding what might be done to reduce the likelihood that CLas-inoculative ACP move with fruit shipments into California. We believe David Bartels has done work on this topic and perhaps he could be asked to join a conference call with Prakash Hebbar and the SAP.

C2. ACP treatment buffer along the California – Mexico border. The SAP suggests that the current treatment program two miles south into Mexico and two miles north into California be continued until such time that the Mexican strain of CLas is determined to be present in California at multiple locations and eradication seems unlikely.

C3. Movement of fruit from southern California into the San Joaquin Valley. Given the current HLB situation and the likelihood this will become worse with time, the SAP strongly believes that in-field dry brushing or preharvest pesticide treatments in southern California are inadequate with respect to removal of ACP from fruit loads which might be CLas-inoculative. This is because the densities of ACP in some areas of southern California are high, will continue to increase, and with in field dry brushing, some adult ACP are likely to resettle in pack bins. Field applied pesticide treatments without leaf/stem removal are inadequate because it is difficult to achieve perfect coverage and live ACP are likely to be present on trash leaves in the bins following such treatments. The SAP believes it is time that all fruit shipments (including culls going to juice plants) from southern California going into the SJV first go through a packing house wet wash and brushing and that trucks shipping such fruit be enclosed or tarped. The SAP realizes there are economic and/or political consequences but at this time, this is what makes biological sense. The SAP feels that the risk of moving ACP into the San Joaquin Valley that are CLas-inoculative is too high to continue with current protocols.

D. Recommendations Regarding Areawide ACP Treatment Programs

Areawide ACP management is a critical method of reducing HLB spread until a cure/treatment for HLB is found. Areawide 'CHMAs' (Citrus Health Management Areas) need to be established in all areas of California as soon as possible. The SAP is of the opinion that a statewide coordinator is needed as soon as possible to interface with and help coordinate the treatment liaisons.

D1. Optimal size of areawide treatment programs. Using Florida data and a landscape analysis for California, Tim Gottwald can provide recommendations by June 2014 regarding the optimal size and configuration of California areawide treatment programs. This will be especially important for the San Joaquin Valley where there are large contiguous areas of commercial citrus. There may be logistical reasons why program areas may be different from what is recommended (a strong component of local input in setting boundaries for treatment areas makes sense) but regardless, such information should be considered and will help to define treatment areas needed by treatment liaisons.

D2. Commercial ACP treatments. There will be differences between Florida, Texas, Arizona, and California regarding the specific design or components of an optimal areawide treatment program and this will also vary across different citrus growing regions of California. Involved parties need to initiate and optimize areawide treatment programs in California as quickly as possible.

The SAP has several recommendations at this point. First, the winter dormant period (roughly December – February) when mostly adult ACP are present and it is cold enough so that there is limited adult movement is a critical time for coordinated areawide treatments. Note there may be some varieties, e.g., lemons or limes that flush some during the winter; coastal areas may be warm enough so that some adult movement occurs. All treatments within the areawide program should go on over a 2-3-week period, regardless of season, and if ground treatment is used and it is feasible, growers should treat first the perimeter two trees/rows and then treat the center of the grove.

Second, additional insecticide treatments are applied during the field season, especially during the early stages of flushing and utilizing insecticides that are ACP-effective and needed for other pests.

It is essential that research continue to identify the best organic treatment options and that organic growers be included in areawide treatment programs. Because of the short residual activity of organic products identified to date, two organic sprays should be applied for each traditional spray, ideally with one organic treatment applied both at the beginning and the end of a particular non-organic treatment spray timing.

D3. Urban treatments around commercial citrus. The current CDFA protocol is to treat urban areas 400 m around commercial citrus, only if that commercial citrus is part of an effective areawide treatment program. The SAP believes this practice is sound and should be continued in all regions of California. If issues such as the presence of bees arise, alternatives to pyrethroids and neonicotinoids such as oil should be used rather than not treating.

D4. ACP sampling within areawide programs. The SAP believes that consistent ACP sampling will be essential to the success of areawide treatment programs. The sampling should be standardized and occur at approximately monthly intervals as well as before and after treatments to demonstrate efficacy of insecticides. In Florida, sampling data are displayed on a web site visually and the presence of groves with high levels of

ACP provides peer pressure inducing recalcitrant growers to treat. That SAP suggests that the Citrus Research Board accelerate their efforts to assist areawide grower groups in web-based visualization of sampling data.

D5. Management of abandoned or poorly managed groves. The SAP realizes that where effective areawide management is conducted, a few growers who are unwilling to participate can undermine a great deal of good work that is done by others at a significant cost. The SAP believes that sooner, rather than later, is when areawide management programs should explore mitigation options (e.g., initiate discussions with local County Agricultural Commissioners). Areawide liaisons need to consider how these poorly managed groves can be tracked in the best way.

E. Recommendations Affecting Quarantine Areas

Suggestions regarding current quarantine areas, which may change as these areas change.

E1. Tulare County quarantine area. Based on the known low sensitivity of traps used to detect ACP, the map of ACP finds in the San Joaquin Valley and the overlap of eradication zones in Tulare, the SAP believes that it is no longer feasible to eradicate ACP in Tulare County and all of Tulare County should be quarantined for ACP. If a Tulare ACP find is near the border of another county, then the treatment area should extend 800 m around the find into that neighboring county. Treatments in Tulare and the neighboring county should be coordinated.

The SAP considers that a treatment zone 800 m around an ACP find is appropriate within eradication areas.

E2. ACP trapping methods. The SAP examined preliminary trapping data in which two groves with ACP in southern California were trapped using the current protocols for (a) GWSS trapping, (b) CPDPC commercial citrus trapping, and (c) CDFA (urban citrus) trapping. Data suggest that the CDFA method traps a higher number of psyllids. However, the SAP suggested changes to the trapping experiment to make it more scientifically sound and believes more data are needed before a change can be suggested. Pending the outcome of those trials, data should be submitted to the SAP so that a recommendation can be made.

E3. Citrus cull piles. The SAP does not feel sufficiently well enough informed regarding the handling of citrus cull piles (composted or left as animal feed) and green waste to suggest what should be done. The SAP suggests an industry working group, perhaps containing an SAP member, be put together to develop strategies.

F. Recommendations Affecting Citrus Nurseries

The goal is to provide best management practices for movement and sale of disease-free nursery plant materials within California.

F1. Movement of tissue culture material and cuttings. The SAP perceives extremely low risk of contamination with ACP or CLas during movement of citrus tissue culture material from an approved laboratory facility (even if it is within a quarantine area) to another such laboratory (even if outside of quarantine) as long as the material is transported securely in a sealed container (i.e. it is properly contained and not opened until inside the second laboratory). Similarly, the SAP sees extremely low risk with movement of citrus cuttings from inside an approved enclosed facility (even if within a quarantine area) to other locations (even if outside quarantine) as long as (a) the cuttings contain no leaves or small twigs that might harbor ACP nymphs or adults and (b) the movement is inside a sealed container.

F2. Accelerate movement into protective structures. Outdoor nursery trees are at risk for HLB infection. The SAP recommends that all citrus nursery production (not just mother trees and increase trees), regardless of location in California, be moved into approved protective structures by July 1, 2015 (18 months from now). The deadline for moving seed trees within protective structures might be January 1, 2017 (36 months). There are solid scientific reasons for suggesting this. There is a considerable time lag between when citrus is first infected with CLas and when symptoms appear. Unfortunately, ACP can acquire CLas from non-symptomatic trees. Thus, the mistakes made in Florida should not be repeated allowing the movement of Liberibacter-infected trees without apparent symptoms to spread the pathogen (also see F3-F4 below).

The issues listed below under F3a and F3b are complex enough that the SAP feels an industry working group is needed to develop recommendations that might be presented for consideration to USDA and CDFA. The working group should probably include USDA and CDFA representation so that suggestions conform to what is possible. Thus, ideas listed under F3a and F3b below are only suggestions the working group might consider.

F3a. Storage and sale of citrus nursery trees at retail outlets. It is the opinion of the SAP that the retail outlets are one of the highest risk pathways for the spread of psyllids and HLB-associated Liberibacter(s). This was well demonstrated in Florida. There are several significant problems with how retail nurseries are being currently handled in California: (1) citrus trees are often treated with pesticides long before they reach the retail nursery; (2) citrus trees are being held at retail outlets for long periods of time, often well in excess of 90 days, some times for over a year; (3) trees are often over-watered at retail outlets, resulting in leaching of systemic pesticides so that the expected duration of ACP control is not achieved; (4) CDFA no longer is monitoring or regulating retail outlets; and (5) as CLas spreads in California, it can be carried by ACP into nurseries and spread by consumers purchasing and moving plants.

For the above reasons the SAP believes a working group needs to be appointed as soon as possible to develop a safe system that allows for citrus trees clean of ACP and free of HLB-associated Liberibacter(s) be provided to the public.

SAP does not want to constrain ideas this working group might develop but our recommendations are as follows: (1) Trees should be treated with both an approved systemic and foliar pesticide soon before they leave the production nursery, perhaps no more than 10 days before movement (the regulations currently state 90 days); (2) Trees must be either destroyed or re-treated with both an approved systemic and foliar pesticide if they have not been sold within 90 days of when they left the production nursery; (3) There is a need to ensure that trees are not moved from southern California into coastal areas or the San Joaquin Valley; and (4) The working group may need to entertain novel strategies – one the SAP discussed might involve asking buyers to order citrus trees in advance including prepayment (thus making it likely trees would remain at the retail location for a limited period of time). As noted above, this is a difficult situation and it may not have an easy fix. However, a system must be developed that will generate a ready supply of citrus trees to the public in a safe manner or consumers are likely to obtain unsafe trees from other sources.

F3b. Interim plan for movement of nursery trees until all trees are inside protective structures. The second issue the SAP suggests the working group address is to develop protocols for the movement of different types of plant material within, between, and through quarantine areas within California. These protocols need to focus on potential risk with the goal of reducing pesticide use and maximizing the level of protection of trees where there is high risk of ACP/HLB exposure. These guidelines should be re-examined by the SAP as CLas is found in new areas and/or as quarantines expand.

Movement of plants from an area where CLas has been detected (e.g., widely around the Hacienda Heights area
No movement should be allowed

Movement of plants within a quarantine area
1. Approved structure to approved structure – trees need to be enclosed, no pesticide treatment needed
2. Approved structure to ground (planting) – no restrictions, no pesticides needed

3. Open field nursery (or unapproved structure) to ground – no restrictions, no pesticides needed

Movement of plants from within a quarantine zone through a non-quarantine area to another quarantine area

4. Approved structure to approved structure – trees need to be enclosed, no pesticide treatment needed
5. Approved structure to ground – trees need to be enclosed, no pesticide treatment needed
6. Open field nursery (or unapproved structure) to ground – trees need to be enclosed, approved pesticide treatments required

Movement of plants from a quarantine area to a non-quarantine area

7. Approved structure to approved structure – trees need to be enclosed, no pesticide treatment needed
8. Approved structure to ground – trees need to be enclosed, no pesticide treatment required
9. Open field nursery (or unapproved structure) to ground – movement should not be allowed

Movement of plants from a non-quarantine area to a quarantine area

10. Approved structure to approved structure – trees need to be enclosed, no pesticide treatment needed
11. Approved structure to ground – trees need to be enclosed, no pesticide treatment needed
12. Open field nursery (or unapproved structure) to ground – trees need to be enclosed, approved pesticide treatments required

Movement from a non-quarantine area through a quarantine area to another non-quarantine area

13. Approved structure to approved structure – trees need to be enclosed, no pesticide treatment needed
14. Approved structure to ground – trees need to be enclosed, no pesticide treatment needed
15. Open field nursery (or unapproved structure) to ground – trees need to be enclosed, approved pesticide treatments required

Movement from a non-quarantine area to another non-quarantine area

16. Approved structure to approved structure – no restrictions
17. Approved structure to ground – no restrictions
18. Open field nursery (or unapproved structure) to ground – approved pesticide treatments required

F4. Harmonization of USDA and CDFA regulations. It is essential that USDA-APHIS regulations governing interstate movement of citrus be harmonized with CDFA regulations governing movement of citrus within California. The list of approved systemic and foliar treatments should be the same under both sets of regulations and should be updated as new information is made available. Second, the approved foliar and systemic treatments should be made shortly before shipment (the SAP suggests within 10 days). SAP reasoning is that the foliar treatment will not remain effective for much longer than several weeks and if the systemic treatment is made more than 10 days prior to shipment, the time period treatments will remain effective in controlling young nymphs resulting from eggs laid on foliage after the trees leave the production nursery will be reduced.

F5. Use of solid systemics. The SAP is not aware of efficacy data showing that solid systemic insecticides (e.g., tablets) are effective as ACP management treatments. Thus, the SAP cannot suggest they be added to the list of approved treatments at this time.

Appendix A. Agenda of the Dec. 3-4, 2013 ACP/HLB SAP Meeting

California Department of Food and Agriculture's
Asian Citrus Psyllid / Huanglongbing Ad Hoc Science Advisory Panel
December 3-4, 2013
Holiday Inn Express & Suites
2280 South Haven Avenue, Ontario CA 91761
(909) 930-5555

Purpose of the Meeting: To convene an Asian Citrus Psyllid & Huanglongbing Ad Hoc Science Advisory Panel (ACP HLB SAP) and create draft advisory recommendations.

Tuesday, December 3, 2013 — **Holiday Inn Express & Suites**

California Department of Food and Agriculture Program Overview - Open to the Public

10:00-10:10	Opening Remarks/Housekeeping Introductions & Review Agenda	Jason Leathers
10:10-10:30	Update on ACP in California	Tina Galindo
10:30-10:50	HLB – Hacienda Heights	Tina Galindo
10:50-11:10	Experimental HLB Detection & Hacienda Heights	MaryLou Polek
11:10-11:30	ACP & HLB Nursery Update	Joshua Kress & Nawal Sharma
12:00	Adjourn	

1:00-5:00 **ACP HLB SAP Break-out Session - SAP Members**

2:00-5:00 **ACP HLB Data Sharing/GIS Break-out Session - Open to the Public (Location TBA)**

Wednesday, December 4, 2013 — **Holiday Inn Express & Suites**

08:00-10:30 **ACP HLB SAP Break-out Session - SAP Members**

11:00-12:00 **Report of Preliminary ACP HLB SAP Recommendations - Open to the Public**

Appendix C. Current CDFA Survey Protocol in Response to HLB Find in Hacienda Heights

Task Force / CPDPC Recommendations

Zone One - Collect plant tissue from every host plant (100%) within a minimum of 400 m every other month (6X/year) for 2 years and collect both adult psyllids and nymphs if present. Tissue should be collected from individual trees/single samples (do not pool). CDFA protocol: Adult psyllids are collected by site, nymphs are collected by tree.

Zone Two - 400-800 m survey: Survey and collect a tissue sample from 100% of the host plants by combining (pooling) 4 host plants in one PCR sample. Survey every 4 months (3X/year). If present, collect psyllids (both adults and nymphs).

Zone Three - >800 m/1 – 1.2 km: Survey 50% of the host plants twice/year. Collect plant samples by pooling 4 host plants per sample, at a frequency of twice/year. This zone is based mostly on logistics/practicality. If present, collect psyllids (both adults and nymphs). There is not sufficient information concerning California conditions to limit collections during certain times/seasons of the year.

Appendix 2: Report from CPDPP SAP Meeting, May 2017

https://www.cdfa.ca.gov/citruscommittee/docs/reports/SAP-Mtg-05-31-2017_FinalRecommendations.pdf

SAP Meeting 31 May 2017

SAP members present on the teleconference call: Tim Gottwald, Beth Grafton-Cardwell, Mark Hoddle, Charla Hollingsworth, Joseph Morse, Mamoudou Setamou, and Georgios Vidalakis

Public presentations were made via webinar to the committee and other attendees (9-11 am):
Update on ACP in California - Victoria Hornbaker
Update on HLB in California - Debby Tanouye
ACP and HLB Response Protocols - Debby Tanouye
Nursery Update - Nawal Sharma
Questions and Answers - Jason Leathers

At 11:00 am the public portion ended and the committee members began a discussion of the CPDPC finance committee's request for recommendations. Rather than review the CPDPC's questions point by point, we chose to have a general discussion of how to direct activities and resources to achieve the best control of huanglongbing (HLB) possible given it is an increasing problem and resources are limited. Respectfully, it was not feasible for us to quantify likely outcomes in the way the CPDPC Budget TF Subcommittee requested because there are too many unknowns, especially the current distribution of the bacterium CLas in California. We were uncomfortable in considering costs of activities, but focused on the best control of HLB in light of the current situation.

For the purpose of this discussion, regulatory qPCR positive trees are those whose tests result in <37 CT values with confirmation by APHIS, while an inconclusive category should be added as a non-regulatory, decision threshold for producers and industry at 37-37.99 CT values, and negatives should be represented by CT values of 38-40. For ACP, positive psyllid results have ≤32 CT values, inconclusives have 33-37.99 values and negative psyllids have 38-40 CT values. Note that we are not suggesting that regulatory agencies revise their validated work instruction thresholds, only that industry should consider trying to influence growers and homeowners to take more aggressive action by removing trees at higher, inconclusive CT plant thresholds and/or based on the presence of CLas in psyllid nymphs found on a tree, in addition to actions taken based on the currently mandated regulatory CT levels.

General recommendations:

1. We recognize that detection by PCR lags behind infections because of the difficulty in sampling at a level sufficient to detect CLas and because the current regulatory thresholds for action are conservative. Going forward, tree removal efforts must be expanded beyond regulatory PCR positive trees. That is, the industry must take action against trees or insects with CT values <38 whether or not they are considered regulatory positives. In addition, the citrus industry should use EDT methods when their effectiveness is validated to increase tree removal activities.

2. We suggest that the citrus industry Intensify activities and resources in the San Joaquin Valley where the bacterium and the psyllid have not become well-established and where increased efforts could postpone their establishment. It is critical to protect the citrus in this region by more aggressive psyllid control and expanded tree removal in both urban and commercial citrus.
   - Increase resident CDFA manpower in Fresno, Tulare and Kern counties to be able to respond more quickly.
   - Conduct a higher level of HLB risk survey in the SJV (we recommend 4 cycles/year).
   - More aggressively manage psyllids in both urban and commercial citrus in the SJV with the goals of postponing their establishment and minimizing disease spread.
   - Minimize the human-assisted spread of psyllid and HLB movement from southern California to the SJV in as many ways as possible.
3. Conversely, reduce activities (see below) in many areas of southern California where the disease detection and tree removal is no longer keeping pace with disease spread and instead use those resources in the San Joaquin Valley.
4. Promote the testing and validation of EDTs throughout California, especially when positive or inconclusive decision thresholds of trees are met. Have mechanisms in place to utilize the time between first detection and confirmation of the disease to test the tree with EDTs, prior to tree removal.
5. Growers should be prepared to remove all trees with <38 CT values. As EDTs are verified, they can be used to help make non-regulatory tree removal decisions.
6. Biological control agents: generalist predators and parasitic wasps have not been demonstrated to stop disease spread. There is currently insufficient research to demonstrate that commercially-reared predators would reduce ACP levels sufficiently (such research should be done realizing it is unlikely that disease spread will be affected). *Tamarixia* releases should continue in areas of concern in southern California and releases should shift to the San Joaquin Valley as the psyllid becomes established there. It is a bit early to properly evaluate *Diaphorencyrtus* establishment and impact in southern CA, and thus, that work should continue for now.

Southern California

The committee was in agreement, that the increasing number of CT values in the range of 37-37.99 for plants and 33-37.99 for ACP, indicate that the CLas bacterium has spread well beyond Los Angeles and Orange counties and the current activities of testing and tree removal will not stop this spread. The regulatory inconclusive CT values for ACP are frequently leading the sampling teams to the regulatory PCR positive trees, however, lack of removal of the trees with higher decision threshold CTs is likely leaving a reservoir of CLas that is being spread by psyllids. Based on the pattern of inconclusive CT values, HLB is not just found in the HLB quarantine areas, it has spread through much of southern California (Los Angeles, San Bernardino, Riverside, Orange, Imperial and San Diego counties).

Recommendations:

- Reduce the high-risk survey to 1 cycle per year in southern California (inland and the coast), continuing to identify regulatory PCR positive trees and mandatorily removing them.
- Request that homeowners, in addition to the mandated conclusive PCR positive trees, voluntarily remove all decision threshold inconclusive PCR trees (including those with immature ACP <38 CT value) and replant with something other than citrus.
- Stop buffer treatments in residential areas around commercial citrus in Los Angeles, Orange, San Bernardino, Riverside (with the exception of around UCR), and San Diego counties.
- Consider continuing residential buffer treatments in Imperial and Ventura counties for PMAs that have 90% grower participation during areawide treatments and as long as decision threshold inconclusive CT value trees remain at low frequency and regulatory positive trees are not detected. This subject needs more detailed analysis and discussion.
- Increase plant sampling, tree removal activities and ACP urban treatments around the UCR Rubidoux facility, CDFA *Tamarixia* rearing facility, and UC Riverside citrus plantings to preserve precious germplasm and protect research programs.
- Continue the ACP urban buffer treatments along the Mexico border.
- ACP trapping should be stopped in much of southern California, but continue 2 miles north of the Mexico border, Imperial County, Ventura County and around UC Riverside where buffer treatments around commercial citrus occur. This subject needs more detailed analysis and discussion.
- Prepare to shift releases of *Tamarixia* from southern California to the San Joaquin Valley when the ACP population becomes better established in that region.

San Joaquin Valley California

Put greater effort into protecting commercial citrus in the San Joaquin Valley, since the incidence of ACP is still low and PCR positive trees and psyllids (thus far, only regulatory inconclusive PCR positives) are rare. Continue to aggressively reduce psyllids so that they do not become established and do not pick up and spread CLas.

Recommendations:

- Increase the high risk survey for HLB to 4 cycles to improve detection of decision threshold inconclusive and regulatory PCR+ trees and remove both types of trees.
- Increase ACP trapping and treatments around trees with <38 CT values (both urban and commercial citrus) and remove both positive and decision threshold inconclusive CT value trees when found.

- Increase the general program of voluntary residential citrus tree removal in areas where CT values are <38 and/or where psyllids are found repeatedly, as has been done in Kern County.
- Continue treating ALL psyllid find sites (1 or more psyllids triggers a response) and surrounding citrus at the 400 meter distance for residential and 800 meter distance for commercial citrus. There was discussion, but not total agreement, on the subject of expanding the treatment distance around find sites even further (as much as 1.2 miles because of the distance that psyllids can fly) to more aggressively locally eradicate/suppress psyllids in the SJV.
- Treat residential citrus in the buffer areas 400 m around commercial citrus when growers conduct coordinated treatments.
- Release *Tamarixia* and *Diaphorencyrtis* in urban areas in the San Joaquin Valley as ACP populations develop.

Appendix 3: Questions to be addressed by 2022 CPDPP SAP Review

Questions for Review by the SAP

1. **Can we determine the role that the program is playing in keeping HLB out of commercial groves?**
    a. What impacts are biological control, climate and treatments collectively having on overall ACP populations? Can treatments be reduced in the face of lower population levels?
    b. What are the features of Orange County that make it a significant contributor to HLB detections (versus LA County)? How should the program respond to this?
    c. What are the spatial/temporal relationships of HLB finds in S. Calif?

2. Is the Risk-based survey adequately addressing HLB detection?

a. Does it still serve the purpose of safeguarding the commercial industry? (statewide)
b. What additional factors should be included in the risk-based survey? (statewide)
c. The program is heavily focused on residential properties/surveys. Should the program refocus more on commercial citrus and adjoining residential properties in S. California? (S. Calif)
d. Does the risk-based *C*Las survey collect enough information in areas where HLB has been detected near commercial citrus (Riverside, San Bernardino, San Diego)? (S. Calif)
e. How is CLas being genetically typed, and is that information incorporated into spread/risk analyses?

There are different strategies for HLB response in S. California versus central/northern CA.

Central/Northern California

3. Is the ACP/HLB management program protecting the San Joaquin Valley well enough? (Kern, Tulare, Kings, Fresno, Madera)

a. Are there more effective ways to detect psyllids in regions where they have not established?
    i. Is there a need for additional psyllid surveillance? Should survey be an additional PCA (Pest Control Advisor employed by Grower) activity?
    ii. Are there emerging detection technologies (EDTs such as canines) that should be explore as part of this effort?
b. Are eradicative treatments for new psyllid finds effective and can the strategies be improved?
c. Are coordinated grove treatments over wide areas effective and can they be improved?

Southern California

4. Is the ACP/HLB management program in S. Calif managing HLB well enough? (San Diego, Imperial, Riverside, San Bernardino, Ventura)

a. Are there aspects of the grove ACP survey that could be more efficient and/or improve detection of Clas?

b. Following an HLB detection, can we do a more effective job at sampling the surrounding/remaining hosts within the delimitation area? Are there emerging detection technologies (EDTs) that should be explored as part of this effort?
c. Do residential treatments neighboring commercial citrus provide a benefit in terms of ACP reduction and resulting HLB spread?
d. What is the willingness of growers and residents to treat and how is it negatively affecting the program?
e. Should removal of HLB infected hosts be reduced to residential areas adjacent to citrus growing operations? What would the impacts be of leaving infected trees in the ground (biological and regulatory)?

5. What does the future management of HLB in S. California look like?

a. The program has the manpower and budget to handle HLB tree removals right now, but if infections expand significantly, how does the program adjust its response?
b. If the program significantly scaled back activities, what would the growers lose, what would the dangers of ACP and HLB accelerated spread be?
c. What happens when HLB finds its way to the first grove? Is the current proposed response sufficient?

6. Production nurseries are regulated to prevent the spread of ACP and HLB. Does the California program provide sufficient protection at the retail level?

a. What is the regulatory situation with regard to retail nursery stock (treatments and time until sales) and is it sufficient to protect against ACP and HLB spread?
b. As HLB Quarantine areas expand and retail nursery sales are prohibited in these areas, will this restriction lead to more illicit sales of citrus in these regions?

7. Is there sufficient access by growers and homeowners to real-time information on the locations of HLB and are there incentives to stay engaged in the program?

Regulatory Issues:

1. Is there scientific validation for these regulations?
    a. Tarping, nursery, HLB quarantine enforcement, regulated entities.
2. Is there an alternative to insecticide treatments for moving bulk citrus?
3. How are quarantine regulations affecting organic operations?
4. Do the nursery screenhouse breech policies have scientific validation? What factors and milestones should be considered before operations may resume?
    a. Are there different trapping strategies that could be used around nurseries to aid in this decision-making?
5. What milestones/requirements would a region need to meet to be removed from an existing ACP quarantine area? From a scientific perspective, what would an effective exit strategy look like?

Appendix 4: 2022 SAP Review Pre-Read Materials with Links

Science Advisory Panel
Pre-Read Table of Contents
(sourced from www.datoc.us, www.citrusinsider.org, CDFA and subject matter experts)

Draft Agenda for April 20-22

Many of the following resources are white papers from DATOC, the Data Analysis and Tactical Operations Center https://www.datoc.us. The Center is an interdisciplinary team of growers, entomologists, modelers, plant physiologists, data scientists, and other researchers, with input from regulatory personnel. DATOC regularly produces analyses regarding the state of ACP and HLB in California, including policy briefings and program recommendations to the Citrus Pest and Disease Prevention Committee based on current research. Most often, requests for DATOC analyses come directly from the Citrus Pest and Disease Prevention Subcommittees. In addition to the links provided on the preread list, there are quarterly reports on the DATOC website that may be of interest. The role of the SAP will be to identify areas of greatest concern and pose questions for DATOC to follow up on.

Program Background Documents

1. March 29 SAP Virtual Meeting CPDPP Overview
2. CDFA ACP/HLB Action Plan
3. CPDPD Activity Summary Sheet By Region
4. Glossary of Citrus Industry Acronyms and Definitions 2019 – Citrus Research Board
5. Quarterly Updates | DATOC
6. CPDPD Annual Report FY 19-20
7. CPDPD Annual Report FY 18-19

Focus Question 1: Can we determine the role that the program is playing in keeping HLB out of commercial groves?

Focus Question 2: Is the Risk-based survey adequately addressing HLB detection?

8. CA Risk-based HLB/ACP Survey: design, evaluation & analyses – Luo, Posny, McRoberts
    a. Visual Display of Risk Survey Locations - CDFA

Focus Question 3: Is the ACP/HLB management program in the San Joaquin Valley protecting this region well enough?

9. SJV Trapping | DATOC
10. ACP Trap Technology Review | DATOC
11. Report on Asian citrus psyllid populations monitored in commercial citrus orchards during 2016-2019 Grafton-Cardwell
12. Management of Asian Citrus Psyllid in California

12a. Genome-wide analyses of Liberibacter species provides insights into evolution, phylogenetic relationships, and virulence factors - Thapa et al.

Focus Question 4: Is the ACP/HLB management program in S. Calif managing HLB well enough?

a. ACP trapping

13. Time series of ACP Populations | DATOC
14. Spatiotemporal dynamics of the Southern California Asian citrus psyllid – Bayles et al.
15. Report on Asian citrus psyllid populations monitored in commercial citrus orchards during 2016-2019

b. Residential treatment around commercial citrus

16. 7e4267_820c2a7c454740c3bc96f68bbdb46ee3.pdf (filesusr.com)
17. New criterion for buffer zone treatment | DATOC
18. Buffer Treatment Recommendations – M. Rivera
19. Buffer Treatment Efficacy and San Joaquin Valley Trapping – DATOC
20. Residential Activities Analysis | DATOC

c. Grower activities

21. Psyllid Management Areas | Citrus Insider
22. Treatments | Citrus Insider
23. CPDPP Voluntary Grower Response Plan 2019
24. Voluntary Grower Response Plan for Huanglongbing | Citrus Insider
25. Grower voluntary actions | DATOC
26. Management of Asian Citrus Psyllid in California
27. Summary of Grower/PCA Strategies for Managing ACP – Grafton-Cardwell
28. Efficacy of Coordinated Area-Wide Treatments to Control HLB – Babcock, McRoberts, Figuera

d**. HLB detection and spread**

29. Sampling for HLB | DATOC
30. Delimitation Zone | DATOC
31. Treatment area recommendation | DATOC
32. Growth of disease incidence | DATOC
33. Commercial Grove Trapping Locations – Dunn (CRB)
34. Seasonality of Ct values | DATOC
35. EDT Guidelines | DATOC
36. EDT Concluding Report | DATOC
37. Research Using HLB Canine Detection Team – Mauk et al.
38. Infection Density | DATOC
39. Situational monitoring | DATOC
40. State of the state | DATOC

41. 7e4267_80ba161e5be244c9b46d523860eeff4b.pdf (filesusr.com)
42. Clas Genotypes – Lucita Kumagai

Focus Question 5: What does the future management of HLB in S. California look like?

43. CPDPP 2018 Strategic Plan
44. CPDPP Voluntary Grower Response Plan 2019
45. 7e4267_ff36e3d28fa940a882e018cd6da7229f.pdf (usrfiles.com)

Focus Question 6: Production nurseries are regulated to prevent the spread of ACP and HLB. Does the California program provide sufficient protection at the retail level?

46. Citrus Nursery Perspective - Aaron Dillon, Four Winds Growers
    a. Assessing the risk of containerized citrus contributing to Asian citrus psyllid spread in California – Frank Byrne, et. al.
    b. Rapid uptake and retention of neonicotinoids in nursery citrus trees as a safeguard against Asian citrus psyllid infestation – Frank Byrne, et. al.

Focus Question 7: Is there sufficient access by growers and homeowners to real-time information on the locations of HLB and are there incentives to stay engaged in the program?

Misc. Links

47. Recording of March 29 Virtual Presentation – Passcode: @daT37k
48. Science Subcommittee CPDPD Overview PPT
49. Central California Tristeza Eradication Agency - Subhas Hajeri

Appendix 5: CPDPP Regional Activity Summary Sheet

Citrus Pest and Disease Prevention Division					
Regional Activity Summary Sheet					
Region					
		Southern	**Central**	**Northern**	**Statewide**
Activity	***Detail***				
ACP					
Residential ACP Detection Trapping	*yellow sticky cards, 5-16 traps/mile^2 serviced monthly, ▪ 10,000 or more commercial acres – 16 traps per square mile. ▪ 1,000-9,999 acres – nine traps per square mile. ▪ Less than 999 acres – five traps per square mile. • Trap Relocation and Replacement: Traps are relocated and replaced every 4-8 weeks to another host with a minimum relocation distance of 500 feet. • Visual surveys and/or tap sampling are conducted once at each trapping site when the trap is placed.*	No, unless being done to support residential treatments bordering groves or along US/Mexico border	Yes	Yes	No
Grove ACP Trapping (SJV)	*yellow sticky cards, 1 trap/40 acres serviced every 2 wks, ACP collected and tested for Clas*	No	Detection trapping	No	No
Grove ACP (HLB) Survey (southern)	*9,484 sentinel sites visual examination of foliage for ACP and search for symptomatic leaves 2x/yr, ACP collected and tested for Clas*	Yes	No	No	No
ACP Delimitation Trapping (Grove/Residence)	*yellow sticky cards, 50 traps /mile^2 in 4 square miles around the detection, serviced weekly for one month then monthly for 1 year*	No	Yes, in response to ACP detection	Yes, in response to ACP detection	No

Visual ACP Delimitation Survey	*search foliage for ACP and symptomatic leaves 50 meters around detection site, ACP collected and tested for Clas*	No	Yes, in response to ACP detection (trap or live collection)	Yes, in response to ACP detection (trap or live collection)	No
ACP Identification	*Live ACP collected into alcohol or fresh trap samples from uninfested areas sent to CDFA to verify identification*	No	Yes	Yes	No
ACP Clas PCR Diagnostics	*qPCR conducted on live ACP collected into alcohol and ACP from traps collected <2 weeks*	Yes, live ACP that are collected into alcohol are sent to CRB lab for CLas PCR	Yes, live collected ACP and ACP from traps collected less than2 weeks sent to CDFA Lab for Ento and CLas PCR	Yes, live collected ACP and ACP from traps collected less than2 weeks sent to CDFA Lab for Ento and CLas PCR	Yes
ACP Residential treatments for ACP or HLB Q response	*Treatments (Tempo and Merit) are applied to all residences adjacent to an ACP or HLB find, expanded to 400 meters in response to multiple ACP detections*	Yes in response to HLB Detection (250 m)	Yes, in response to ACP detection (trap or live collection)	Yes, in response to ACP detection (trap or live collection)	Yes
ACP Residential treatments around commercial citrus	*Treatments (Tempo and Merit) are applied once/yr to residences within 250 meters of a commercial orchard if the growers in the region have achieved ≥90% participation in areawide treatments and ACP are detected*	Yes	no	no	no
ACP Residential treatments along the Mexico Border	*Treatments are applied to citrus in the area within 2 miles of the Mexico border in response to ACP detections*	Yes	no	no	no

ACP Regulatory, bulk citrus and quarantine enforcement	*Tarping of all bulk citrus, shipping between any of 7 zones requires field cleaning of fruit or ACP preharvest insecticide, in HLB Quarantine area 2 mitigations are required to ship fruit out of the area*	Yes	Yes	Yes	Yes
Nursery Inspection and Enforcement	*All citrus nursery stock has a cdfa tag and is treated every 90 days with insecticides*	Yes	Yes	Yes	Yes
Outreach		Yes	Yes	Yes	Yes
HLB					
Risk Survey (Clas)	*Residential: collect psyllids and symptomatic leaf material (statewide) and test it for Clas. Two surveys are conducted per year.*	Yes, based on USDA risk algorithm	Yes, based on USDA risk algorithm	Yes, based on USDA risk algorithm	Yes, based on USDA risk algorithm
HLB Delimitation Survey around Clas+ (residential)	*when a Clas positive tree or nymph is found, trees are tested within 250 meters (delimitation) and positive trees removed, trees are treated with Tempo*	Yes in response to HLB Detection	No, because HLB not detected in the region.	No, because HLB not detected in the region.	No, because HLB not detected in all regions.
HLB Delimitation Survey around Clas+ (grove)	*when a Clas positive tree or nymph is found in or within 250 m of a grove, perimeter trees of that grove are tested, ACP collected, treatments are applied to the grove, positive trees are removed and the perimeter resampled once/yr*				
CLas PCR Diagnostics	*qPCR conducted on citrus leaves collected from positive tree and neighboring residences during 250 meter delimitaion*	Yes, Plant and Insect for Risk and Delim Survey	Yes, for Risk Survey	Yes, for Risk Survey	Yes

HLB Regulatory Actions	*5 mile radius quarantine triggered with a Clas+ plant sample or ACP nymph*	Yes	No	No	No
Clas+ Tree Removal	*triggered with a Clas+ plant sample or ACP nymph, tree is treated with Tempo insecticide and removed*	Yes in response to HLB Detection	No, because HLB not detected in the region.	No, because HLB not detected in the region.	No, because HLB not detected in the region.
Issue Abatement Warrants		Yes to remove HLB positive refusal trees	No	No	No
Outreach		Yes	Yes	Yes	Yes
Other					
Commodity Survey (20% citrus/yr)	*Grove: collect psyllids and symptomatic leaf material and test it for Clas. 20% of acreage visited/yr. Search for other pests and diseases simultaneously*	Yes	Yes	Yes	Yes
SOS Survey		Yes	No	No	No
SOS Regulatory		Yes	No	No	No
Multi Pest Survey		Yes	Yes	Yes	Yes
3D ACP Trap Pilot Project		Yes	No	No	No
EDTs					
Croptix Survey		Yes	No	No	No
ACP Detector Dogs	*Dogs are trained to detect the psyllid only*	Yes	Yes	No	No

Appendix 6: 2022 SAP Review CPDPP Orientation PowerPoint presentation

https://docs.google.com/presentation/d/1y-mfKHqul3GItdyTHyT4WsmaHEgECZTQ/edit?usp=sharing&ouid=117889308003707121367&rtpof=true&sd=true

Science Advisory Panel
Pre-Meeting Overview Session

Introductions

Science Advisory Panelists:

- Harold Browning
- Beth Grafton-Cardwell
- Mamoudou Sétamou
- David Bartels
- Georgios Vidalakis
- Judith Brown
- Rodrigo Almeida
- Bob Shatters
- Don Seaver

Committee Representatives:

- Mark McBroom – Chair
- Etienne Rabe – VP/Science and Technology Chair

Featured Presenters:

- Neil McRoberts – UC Davis
- Weiqi Luo – NC State University
- Drew Posny – NC State University

CDFA Staff:

- Victoria Hornbaker – Division Director
- Keith Okasaki – Sr. Enviro. Scientist Supervisor

Facilitation:

- Price Adams - NSTPR

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Goals and Objectives

Goal: To keep Huanglongbing (HLB) out of California's commercial citrus groves.

Panel Objectives:

1. Evaluate whether the program's existing strategies/activities – with a focus on the key questions outlined below – are still the most effective for meeting our goal.
2. Evaluate the efficacy of the strategies by region:
   1. Southern California – Imperial, San Diego, Riverside, Orange, San Bernardino Los Angeles
   2. Central Coast – Ventura, Santa Barbara, San Luis Obispo, Monterey
   3. Central Valley – Kern, Tulare, Fresno, Madera
   4. Northern California
3. Are the identified strategies in each region the most efficient use of resources to meet our goal?
4. How might the strategies be improved in each region to increase efficiency, while still being as effective as possible?

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Process

Today's Goal:

- Provide an overview of California activities as a foundation for future discussions

Phase 1: April 20 – 22 Sacramento Meeting

- Drill down on specific programmatic questions
- Hear from subject matter experts
- Deliberate and determine any additional resources/analysis needed for review
- * Agenda and travel confirmations pending

Phase 2: Initial Findings Discussion

- Panel/co-chairs share initial recommendations for review of ad hoc group (packers, growers, regulators, nurseries, etc.) to identify potential impacts (budget, trade, regulatory, etc.).

Phase 3: Finalize Recommendations

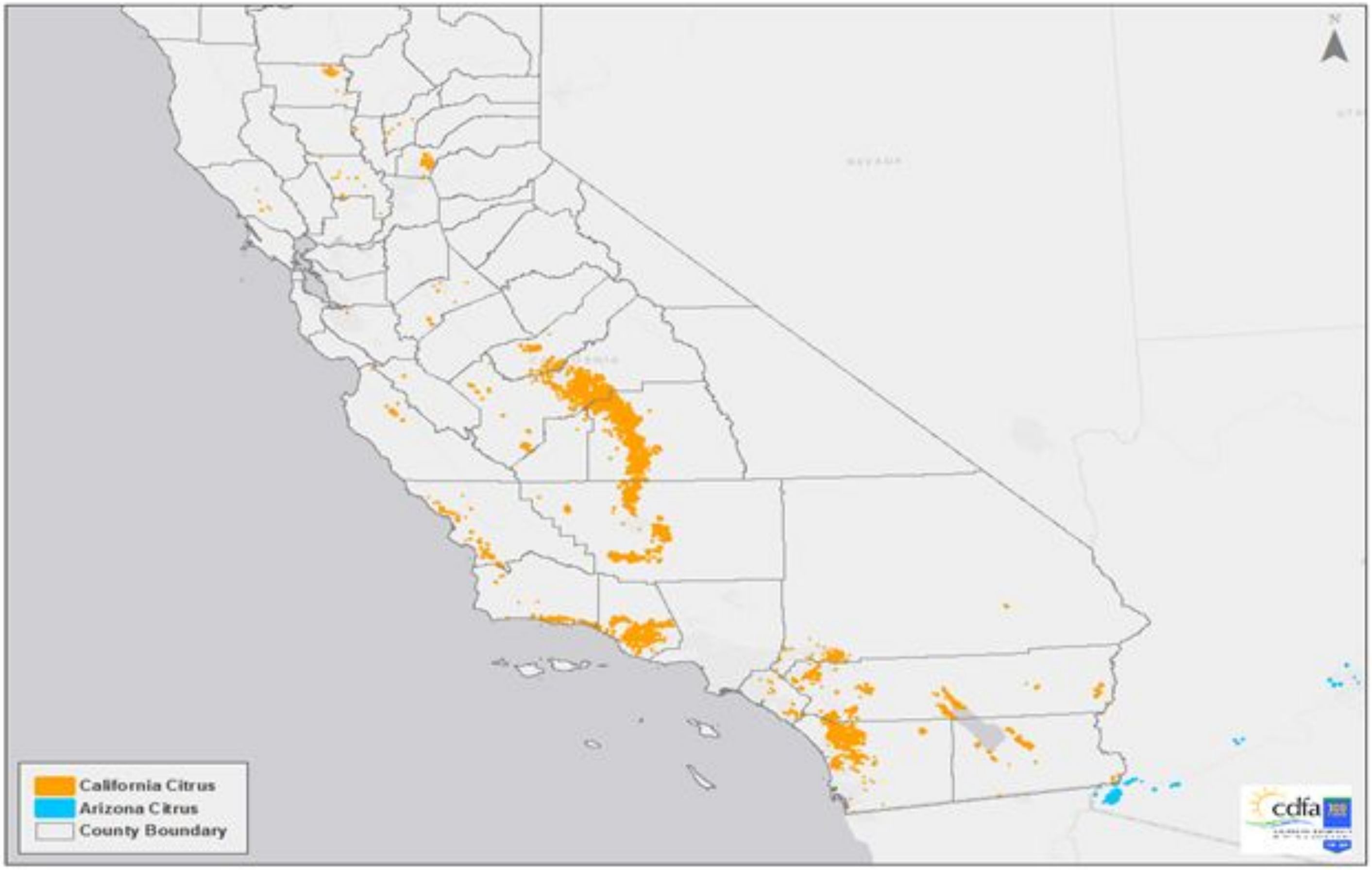
Co-chairs present final recommendations to CDFA/Committee for review.

Travel

- Four Points by Sheraton – Sacramento
  - Hotels will be booked on your behalf
    - Send lodging form to Victoria
    - Indicate your preferred departure date
- Flights to Sacramento – SMF
  - Self Book and submit for reimbursement
  - 4/20 to 4/22

Citrus Pest and Disease Prevention Program Overview

California Citrus Layer



California Citrus by the Numbers

- $3.4 billion in sales
- $7 billion in economic revenue
- 22,000 jobs
- 3,900 farmers
- 292,000 acres of citrus production

California Citrus Pest & Disease Prevention Committee

The Citrus Pest & Disease Prevention Program Committee was authorized through Assembly Bill No. 281, which was signed into law on October 9, 2009.

- Develop a statewide citrus specific pest and disease work plan
- Advise the Secretary on issues pertaining to the implementation of the work plan

Food and Agricultural Code Section 5911-5940

- The prevention and management of citrus diseases is a matter of public interest.
- The provisions of this article are enacted for the protection of the citrus industry … for the purpose of protecting the health, peace, safety, and general welfare of the people of this state.

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2018 Strategic Plan

Five Key Priorities

1. Quickly detect and eradicate diseased trees.
2. Control movement of psyllids around the state and enforce regulations.
3. Suppress psyllid populations.
4. Improve data technology, analysis and sharing.
5. Use outreach and collaboration to encourage homeowner and industry participation.

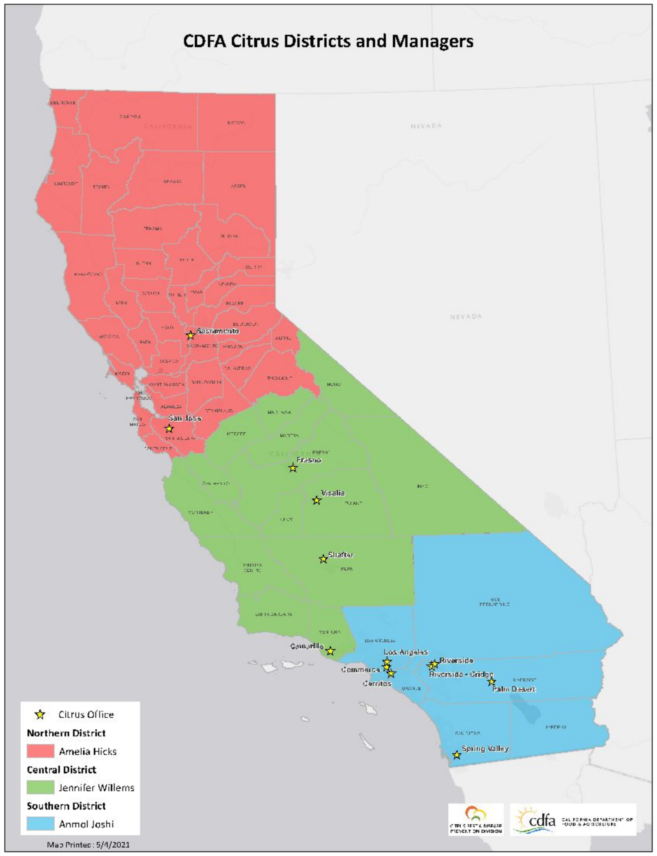
Citrus Pest & Disease Prevention Division

11

field offices across the state

168

division staff members dedicated to supporting the citrus industry



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HISTORY OF HUANGLONGBING IN CALIFORNIA

Huanglongbing (HLB) is a fatal plant disease that kills citrus trees and has no cure. We must all work together to protect our citrus.

2008
First Asian citrus psyllid (ACP) found in California (San Diego)

2009
Citrus Pest & Disease Prevention Committee established

MARCH 2012
First HLB+ tree found in Hacienda Heights

JAN-DEC 2016
19 HLB+ trees found

JAN-JUNE 2017
42 HLB+ trees found

APR 2017
First HLB+ tree found in La Habra in Orange County

JULY-DEC 2017
227 HLB+ trees found

JAN-DEC 2018
699 HLB+ trees found

DEC 2018
1,000th HLB+ tree found in Whittier in Los Angeles County

JAN-AUG 2019
569 HLB+ trees found

AUG 2019
1,500th HLB+ tree found in Garden Grove in Orange County

NOV 2019
First HLB+ tree found in San Bernardino County

DEC 2019
HLB+ trees in Corona expand Riverside HLB quarantine boundary

AUG 2020
First ACP+ found in a commercial grove in Riverside

DEC 2020
First ACP+ found in San Diego County in Fallbrook

AUG 2021
First HLB+ tree found in San Diego County

SEPT 2021
More than 2,400 HLB+ trees found

MARCH 2022
More than 3,000 HLB+ trees found

CPDPP

CALIFORNIACITRUSTHREAT.ORG

(Timeline as of March 2022 and subject to change.)

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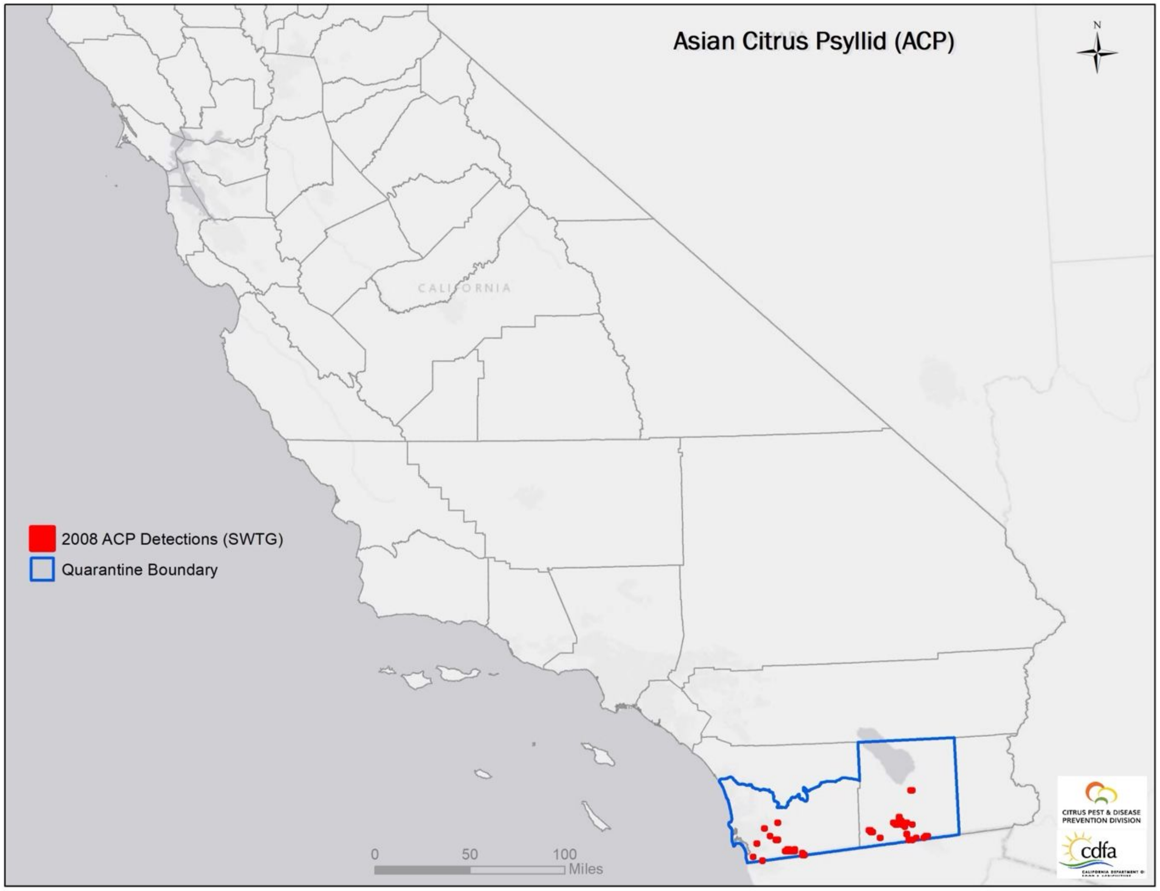
Asian Citrus Psyllid and Huanglongbing Detections

ACP Distribution



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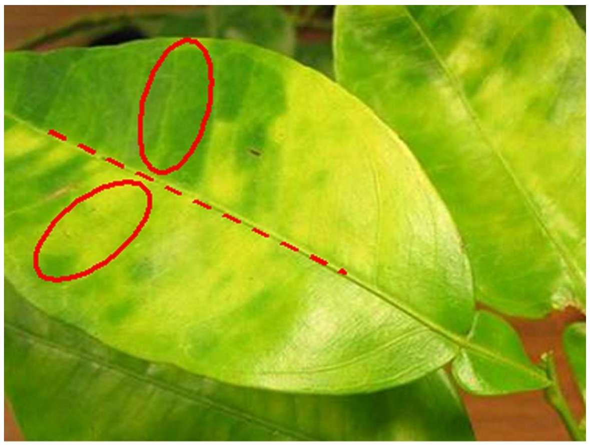
Symptoms of HLB



3,095 HLB-infected trees as of March 4, 2022

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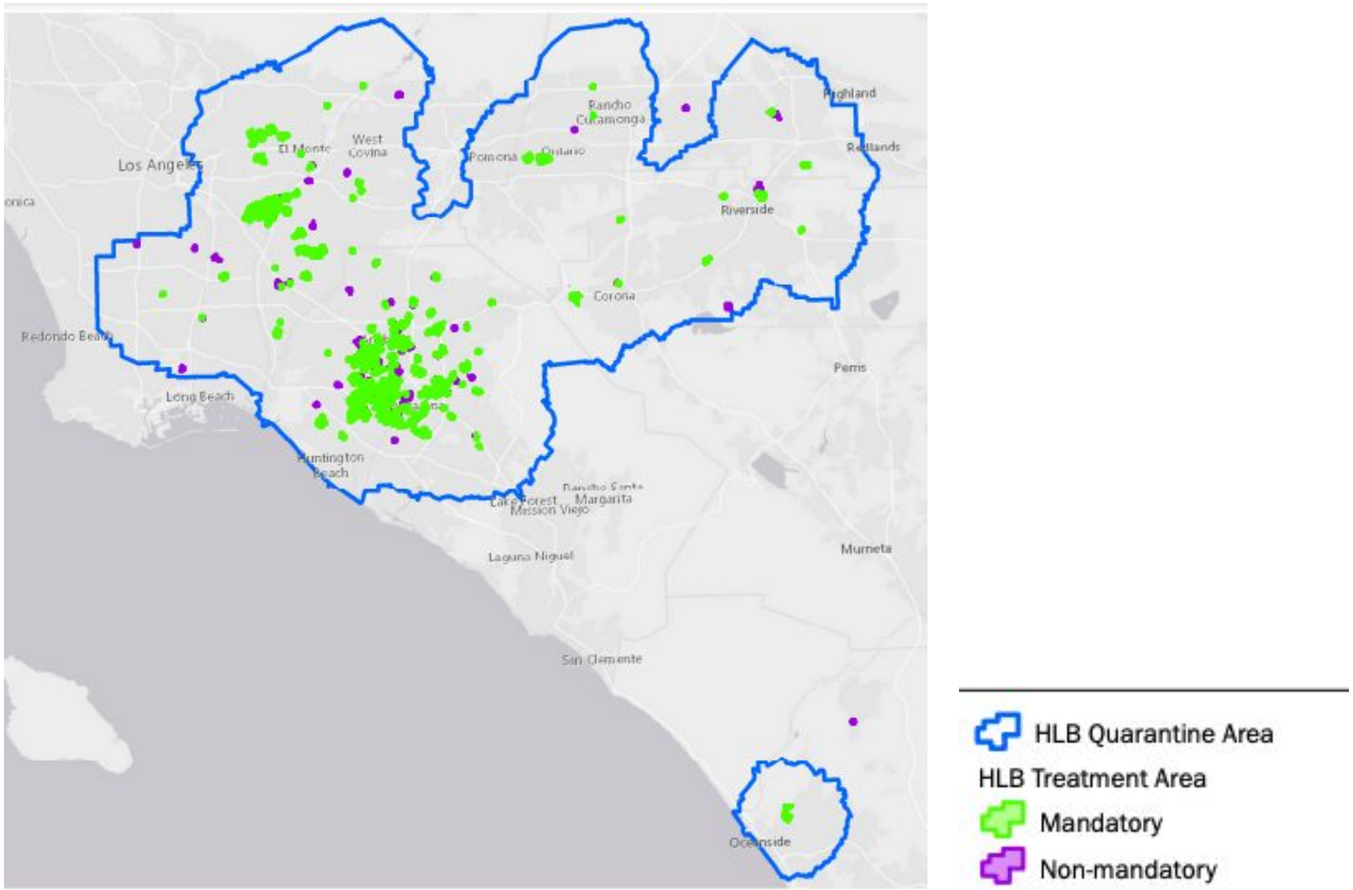
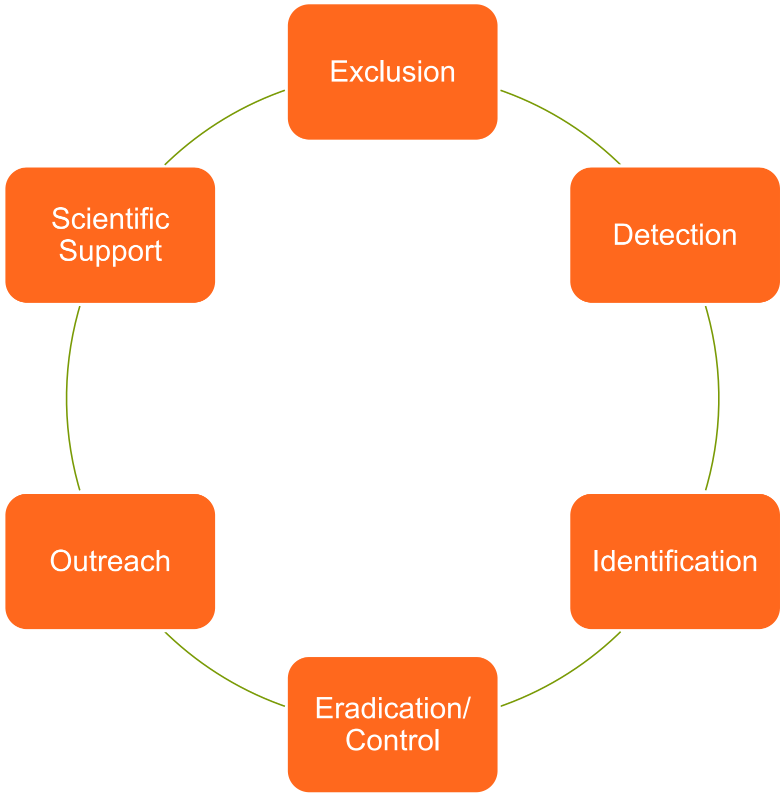
HLB Quarantine and Treatment Areas




Program Field Activities

Pest Prevention System Framework



ACP/HLB Program Activities

- **Exclusion:**
  - Federal and, State Interior and Exterior Quarantines
- **Detection**:
  - Detection ACP Trapping – Residential and Commercial
  - HLB Risk Survey
  - Commodity Survey
  - Delimitation ACP Trapping
  - Delimitation Surveys (ACP and HLB)
- **Identification:**
  - ACP Diagnostics
  - HLB Diagnostics
- **Eradication/Control:**
  - Residential Treatments
  - Commercial Treatments*
  - HLB+ Tree Removal
  - Biocontrol

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CPDPP Statewide Activities

ACP
- *C*Las diagnostics
- Bulk citrus and nursery quarantine enforcement
- Outreach

HLB
- Risk-based survey based on USDA risk algorithm
- Commodity survey (20% citrus per year)
- Outreach
- Diagnostics based on risk-based survey

Other
- Multi-pest survey

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Northern District Activities

ACP

- Residential detection trapping
- ACP identification
- *C*Las testing if live collected or trap collected within 2 weeks
- Delimitation trapping and survey in response to detection
- Residential treatments

Other

- Statewide ACP, HLB, and SOS quarantine administration
- Data analysis and visualization

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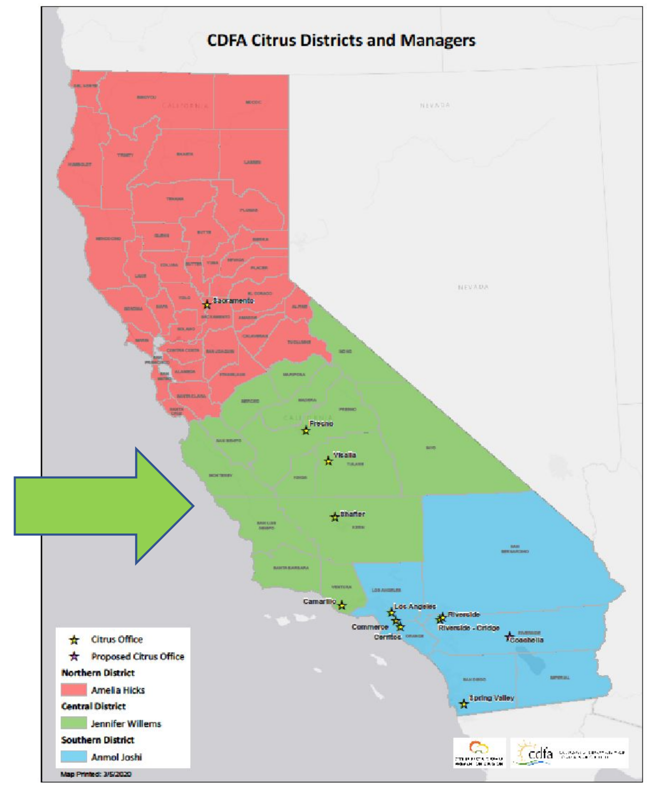
Central District Activities

ACP

- Residential detection trapping
- ACP identification
- *C*Las testing if live collected or trap collected within 2 weeks
- Delimitation trapping and survey in response to detection
- Residential treatments

Other

- ACP detector dogs



Southern District Activities

ACP

- Residential treatment in response to HLB or border detection
- Collect ACP for *C*Las testing
- Grove survey

HLB

- Visual HLB delimitation survey in response to detection
- HLB+ tree removal
- Issue abatement warrants
- HLB quarantine enforcement

Other

- SOS survey and quarantine enforcement
- 3D ACP trap pilot project
- Croptix survey
- ACP detector dogs

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EXCLUSION

Quarantines

- Federal Domestic Quarantine: Title 7 Code of Federal Regulations § 301.76
- State Exterior Quarantine: Title 3 California Code of Regulations § 3435 (Citrus Pests)
- State Interior Quarantine: 3 CCR § 3435 (ACP) and § 3439 (HLB)
  - ACP Quarantine – Bulk Citrus
  - ACP Quarantine – Nursery
  - HLB Quarantine

These regulations specify the quarantine areas, the hosts and possible carriers, and the prohibitions or conditions which enable movement of hosts within or from the quarantine zone.

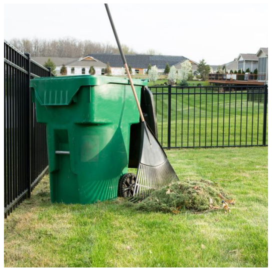
Regulated Entities

Nurseries

(production, wholesale and ail)

Bulk Citrus

(growers, harvesters, packing houses, haulers)



Green Waste Receivers

Yard Maintenance Operations

Swap Meets/ Farmers Markets

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ACP Regional Quarantine – Bulk Citrus

- The bulk citrus regional quarantine zones group counties by risk of spreading ACP to commercial groves.
- Compliance agreements convey the quarantine restrictions and requirements to establishments within a regulated area.
- All transporters/haulers are required to completely safeguard citrus fruit while in transit.
- The ACP-free performance standard must be met to ship to a different zone using a mitigation method, which includes field cleaning by machine, grate cleaning, and preharvest treatment.

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ACP Regional Quarantine – Nursery

- Single ACP detection in a new county triggers a full county quarantine. The county will be added to an ACP regional quarantine zone.
- Production and wholesale nurseries are regulated establishments.
- Nurseries must treat and tag all host plants offered for sale or distribution every 90 days using a foliar and systemic insecticide.
- Outdoor grown treated and tagged host plants must remain within the quarantine zone unless moved under the terms of a special permit.
- Nursery stock produced and maintained within an approved insect-resistant structure may be shipped to any location intra- or interstate.

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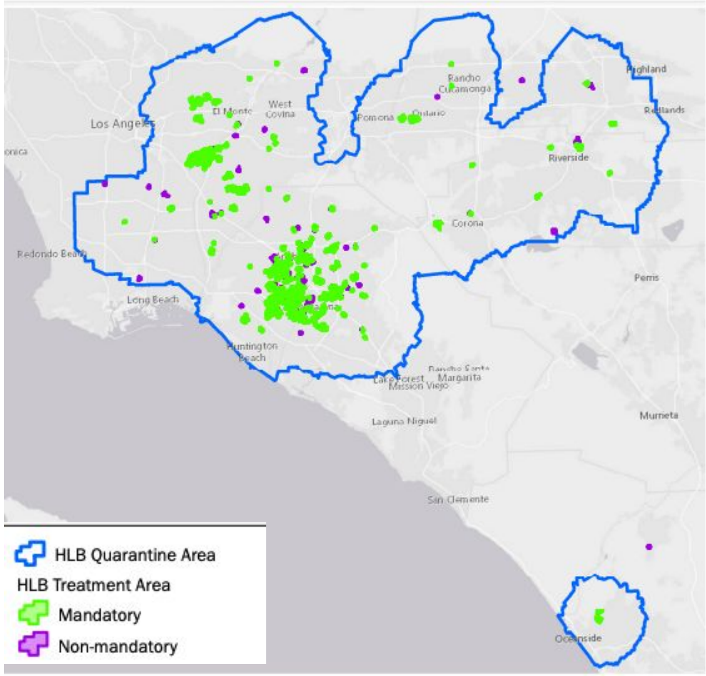
HLB Quarantine – Los Angeles, Orange, Riverside, San Bernardino and San Diego Counties

- The detection of an HLB-positive tree establishes a five-mile radius quarantine area.
- Total area is 1,705 square miles (as of 3/2/2022).
- Host nursery stock may only be sold if maintained within an approved structure. Structures are inspected every 30 days and plants are tested every six months.
- Citrus fruit may be moved to a packinghouse within the same, contiguous HLB quarantine as the grove if a single mitigation is completed. Fruit may be moved to a packinghouse outside, or in a non-contiguous HLB quarantine after a wet wash or if two of the three below mitigations are completed.
    - Field cleaning by machine
    - Grate cleaning
    - Preharvest treatment
- All transporters/haulers are required to completely safeguard citrus fruit while in transit.



As of March 11, 2022

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DETECTION

Detection

- Detection ACP Trapping – Residential and Commercial
- HLB Risk Survey
- Commodity Survey
- Delimitation ACP Trapping
- Delimitation Surveys (ACP and HLB)

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Trapping

Detection ACP Trapping

- Residential - Occurs in all non-infested areas; and in SoCal to support buffer and border treatments only
  - Trap Density: Five to 16 traps per square mile.
  - Trap Servicing Interval: Monthly
- Commercial
  - Trap Density: One trap per 40 acres
  - Trap Servicing Interval: Every two weeks

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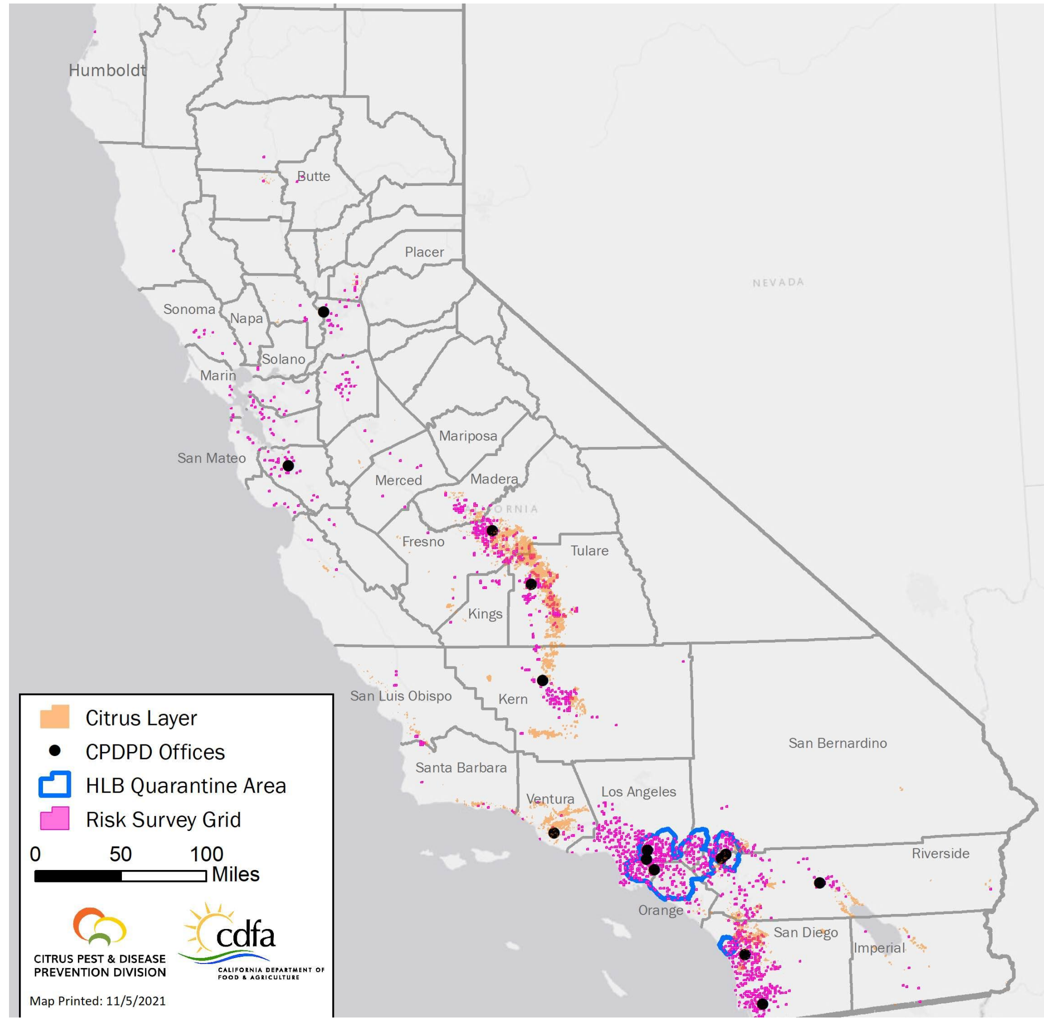
HLB Risk Survey

- Using risk modeling developed by Dr. Tim Gottwald, the following factors are considered when determining risk associated with the Huanglongbing (HLB) disease:
  - Residential citrus population and distribution
  - Ethnic population
  - Weather effects
  - Citrus transportation routes
  - Potential to spread ACP from commercial nurseries, big box stores and citrus green waste
  - Areas infested with ACP
  - Proximity to commercial citrus groves
- Goal is to complete two cycles per year.



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Delimitation Surveys and Trapping

- **ACP Detection (non-infested areas, which excludes Southern California)**
    - Survey all properties within 50 meters of a detection site.
    - Delimitation Trapping:
        - Trap Density: 50 traps per square mile in the 4-square-miles centered on the detection.
        - Trap Servicing Interval: Traps will be serviced weekly for one month and monthly after that for one year past the identification date.
- **HLB Detection (in any area, currently only in SoCal)**
    - Survey all properties and collect samples from all host plants 250-meter radius of a detection site.

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Commercial Grove Survey Southern California 2017-2021

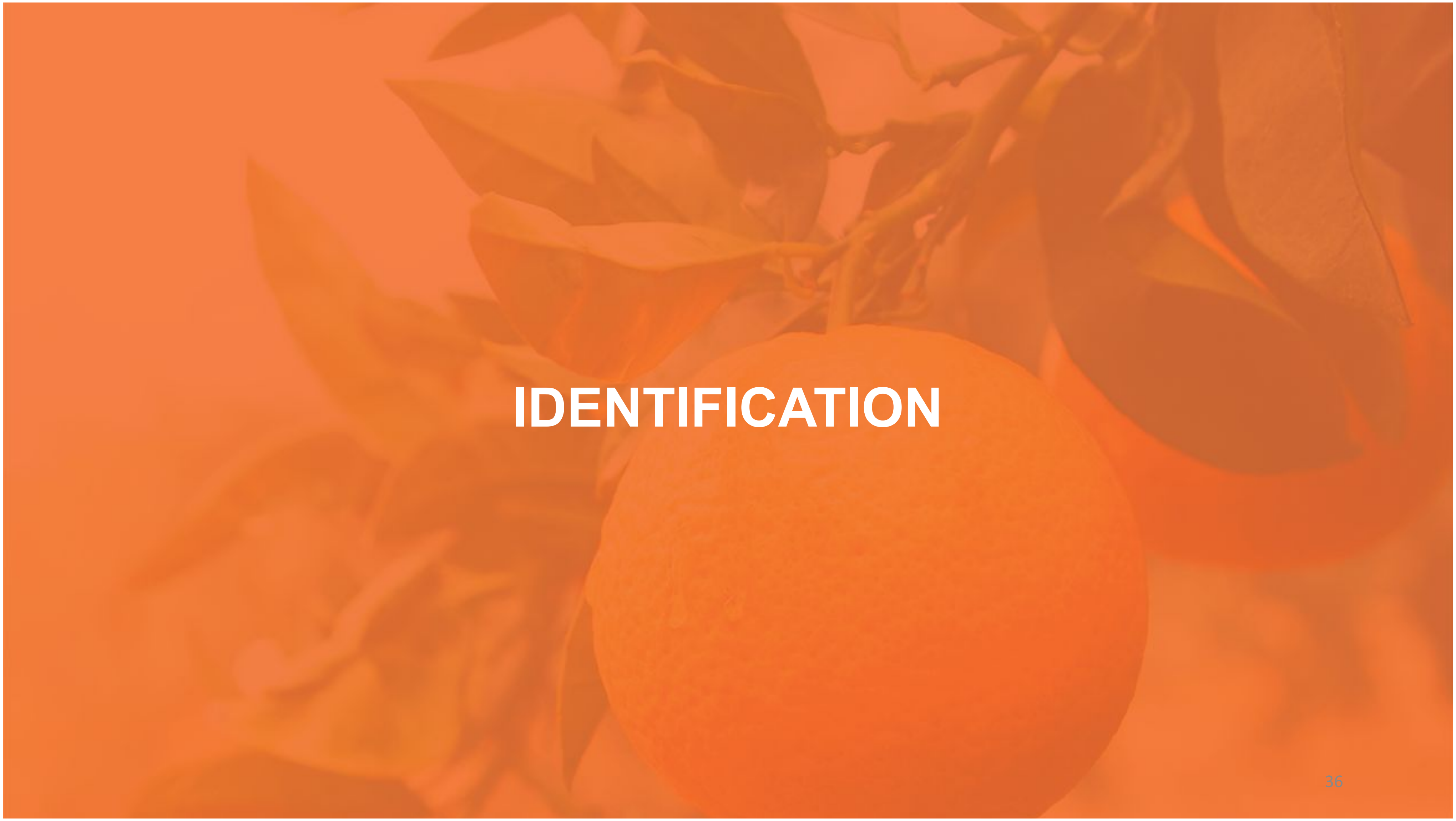
9,331
Active Sentinel Sites

51,642
ACP Samples Collected

23,920
Nymphs Collected

275,279
Adults Collected

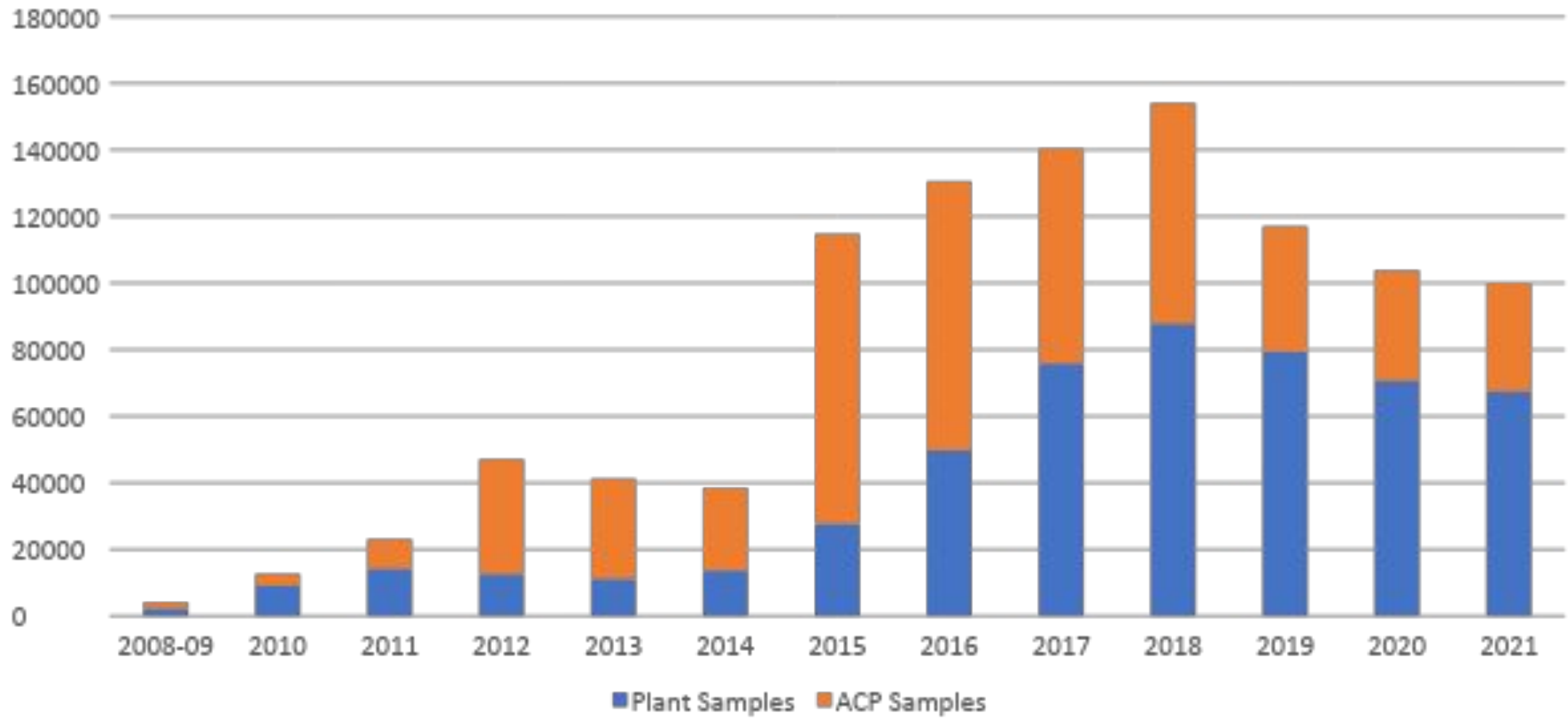
Data as of 12/31/ 2021


IDENTIFICATION

Detection

- Diagnostics:
  - ACP Diagnostics
  - HLB Diagnostics

Number of Samples Submitted for Testing Per Year 2008-2021



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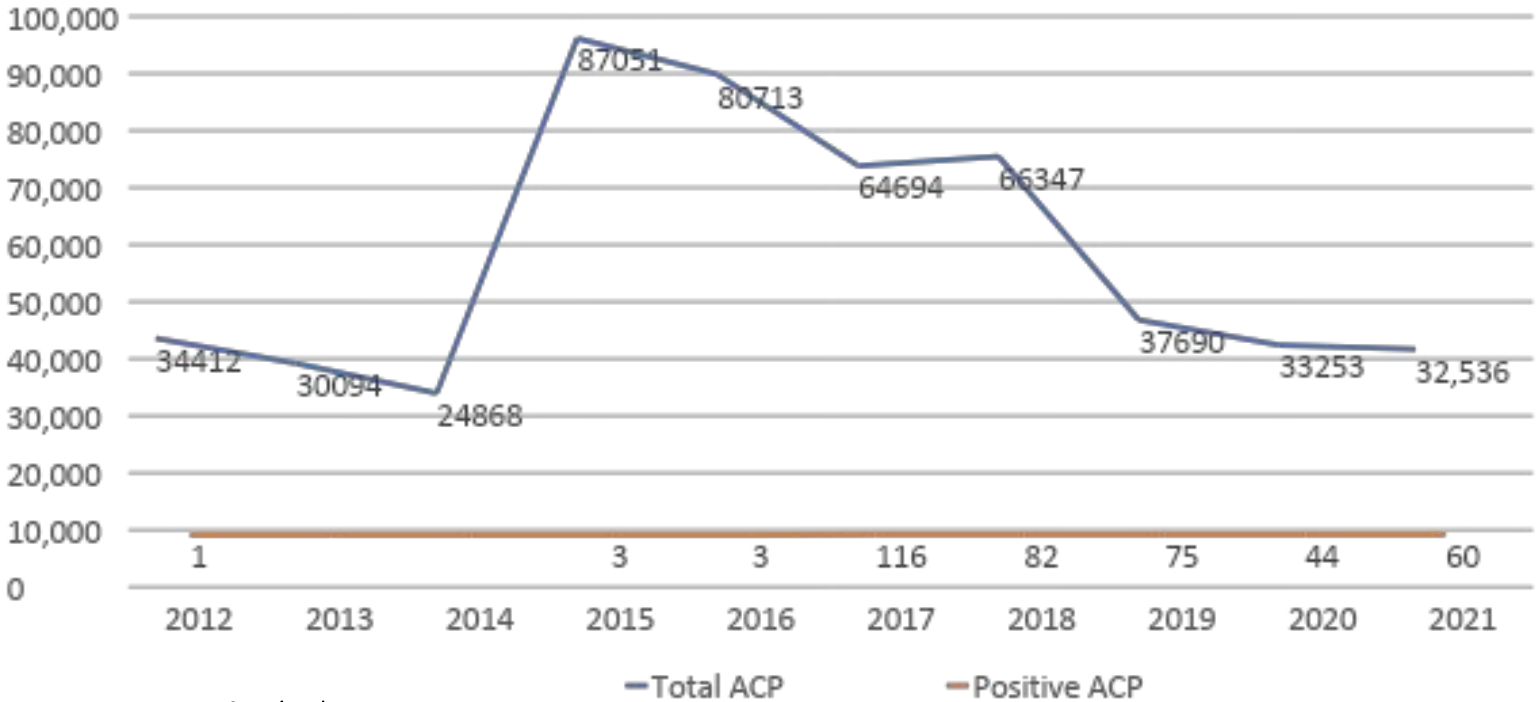
Diagnostics: ACP Samples and Detections

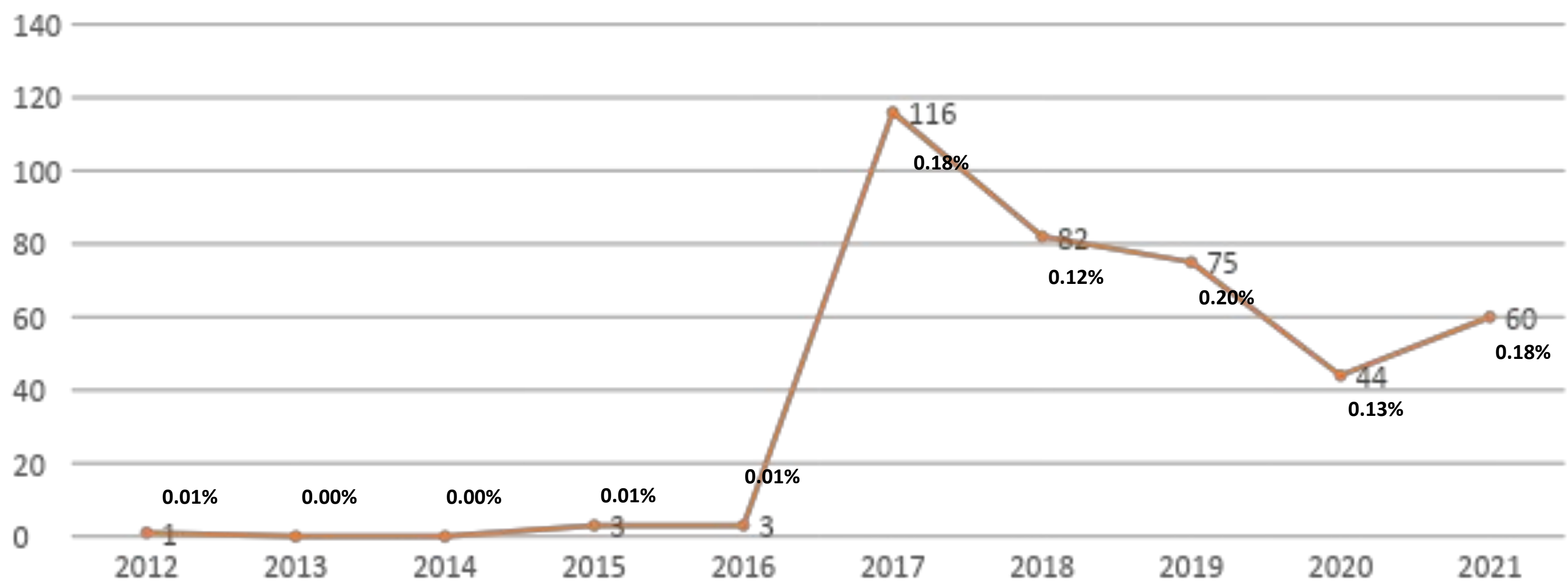


As of 12/31/2021

2018: 400m radius

2020: 250m radius

*C*Las+ ACP Detections

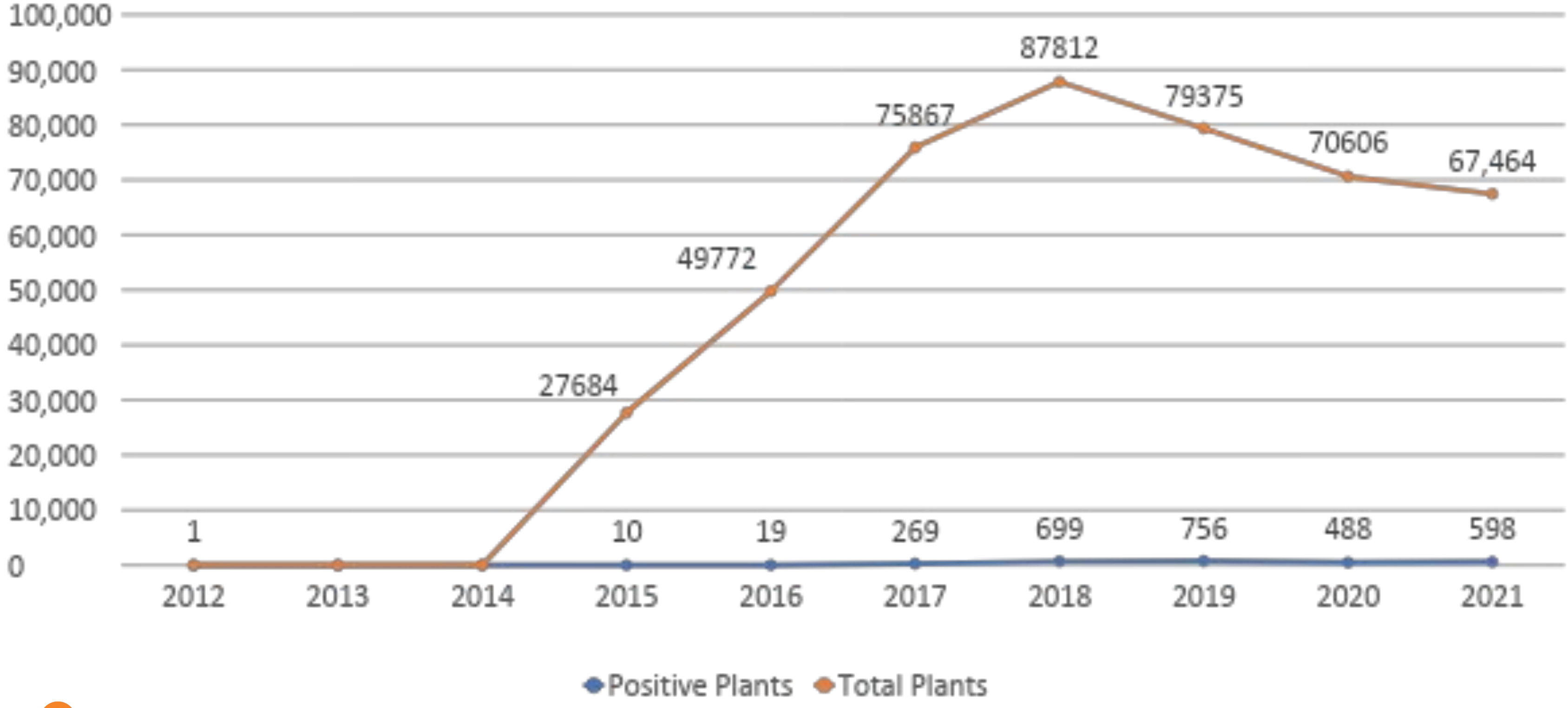


2018: 400m radius

2020: 250m radius

% denotes percentage of total ACP samples tested for *C*Las

Diagnostics: HLB Samples and Detections

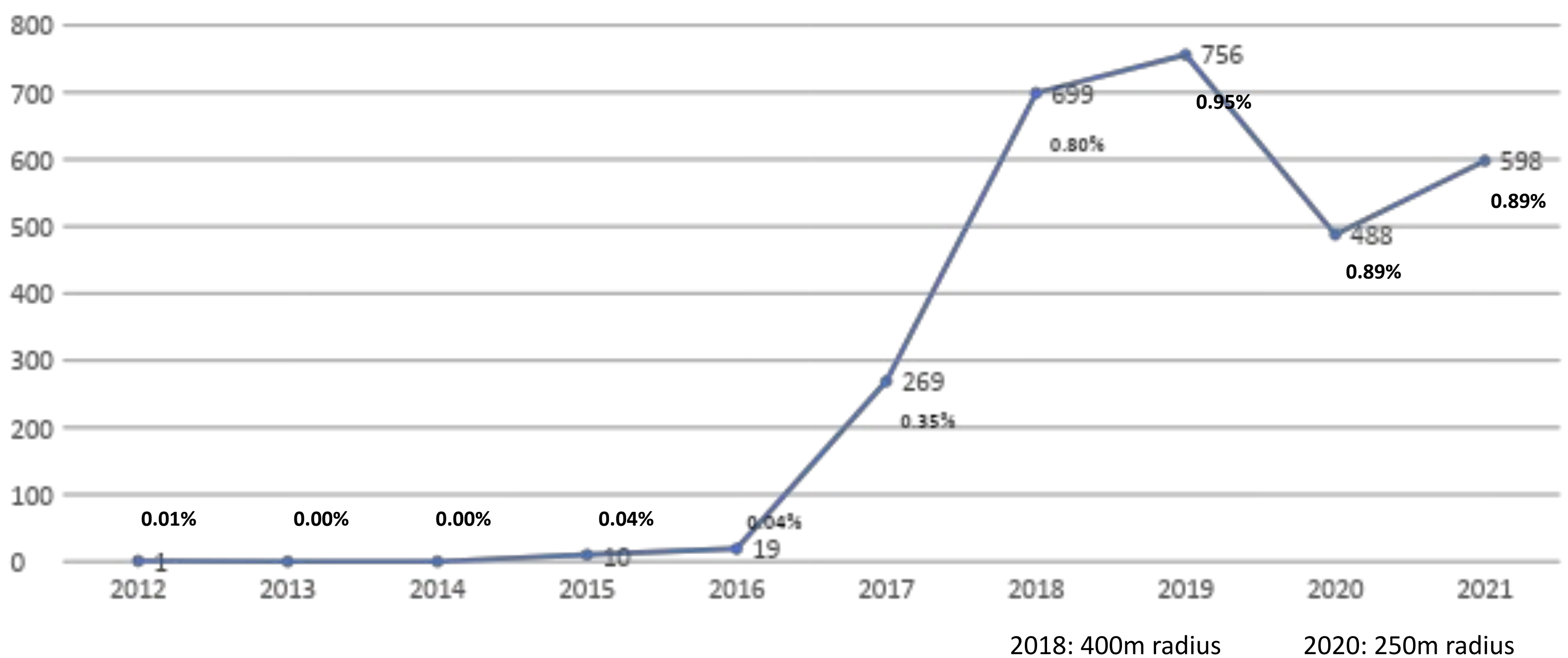


As of 12/31/2021

2018: 400m radius

2020: 250m radius

HLB+ Tree Detections



% denotes percentage of total plant samples

HLB Detections

County	Sites	Positive Trees	Positive ACP
Los Angeles	490	598	96
Orange	1,580	2,358	257
Riverside	51	58	14
San Bernardino	66	121	24
San Diego	6	9	5
Total	**2,193**	**3,144**	**396**

https://maps.cdfa.ca.gov/WeeklyACPMaps/HLBWeb/HLB_Treatments.pdf

As of 3/25/2022

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CONTROL & ERADICATION

Control/Eradication

- Residential Treatments – Voluntary and Mandatory
- Commercial Treatments*** – Voluntary and Mandatory
- HLB+ Tree Removal
- Biocontrol

*** Not funded through CPDPP

Types of Treatment

Voluntary Treatments in Response to ACP in Areas Not Generally Infested (Currently excluding SoCal)

- Find site and adjacent properties are treated in response to one ACP
- Find site and 400 meters are treated in response to multiple ACP detections

Voluntary Treatments Around Commercial Groves (SoCal)

- CDFA treats residential properties 250 meters around commercial properties
  - Only if 90% of commercial citrus acreage is treated in a coordinated manner. Up to two applications per year.
- US/Mexico Border
  - 400-meter treatment area in response to ACP detections within a 2-mile buffer along the US/Mexico border.

Voluntary Treatments in Response to ACP positive for *C*Las - Commercial* and Residential (currently only in SoCal)

- Find site and up to 250 meters around detection site

Mandatory Treatments in Response to HLB (Commercial* and Residential – currently only in SoCal)

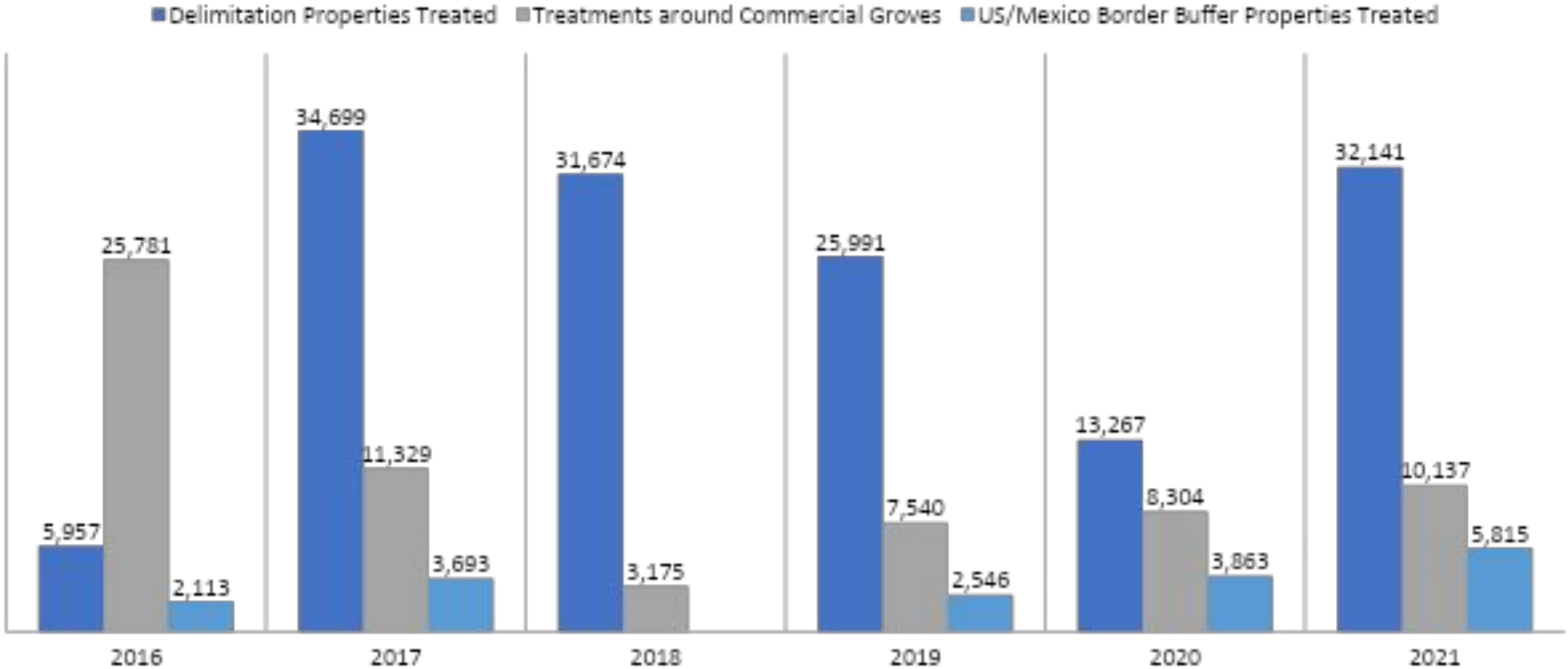
- Find site and 250 meters around detection site

Commercial Coordinated Treatments – Central Valley *

Commercial Area Wide Treatments – Southern California *

*Commercial Grove Treatments not funded by CPDPD

Properties Treated



2018: 400m radius

2020: 250m radius

Residential Treatments

Only host plants are treated

- Foliar treatment with Beta-cyfluthrin (Tempo SC Ultra)
- Soil drench with imidacloprid (Merit 2F)

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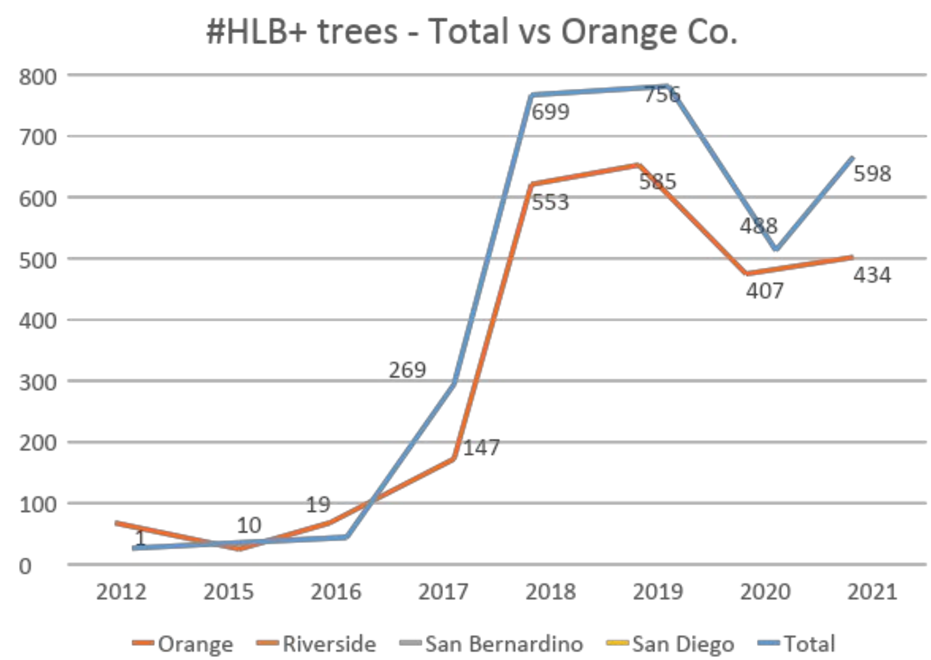
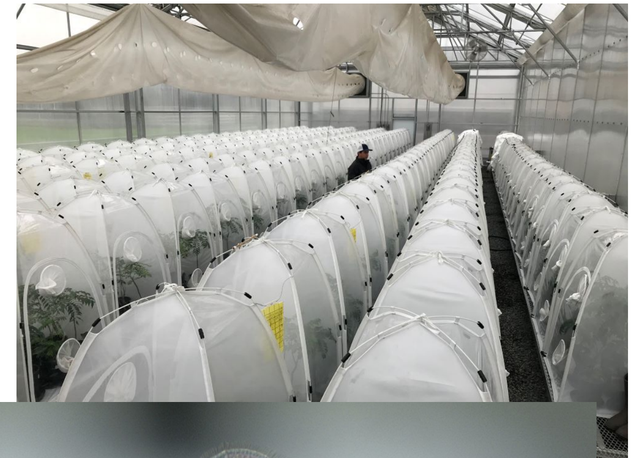
HLB Positive Trees

Year	Los Angeles	Orange	Riverside	San Bernardino	San Diego	Total
2012	1	0	0	0	0	1
2015	10	0	0	0	0	10
2016	19	0	0	0	0	19
2017	119	147	3	0	0	269
2018	146	553	0	0	0	699
2019	150	585	19	2	0	756
2020	56	407	12	13	0	488
2021	60	434	20	75	9	598
Total	**593**	**2,295**	**58**	**114**	**9**	**3,069**



Biocontrol Mass Production

- CDFA has two biocontrol agent rearing facilities
  - Mt. Rubidoux (Riverside County)
  - Cal Poly Pomona (Los Angeles County)
- Release strategy changed from releases across Southern California to more focused releases
  - Around HLB find locations
  - Along borders and trade routes
  - In newly infested ACP areas
  - In buffer areas between urban and commercial citrus



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Monitoring Four Years of ACP Population Decline with *Tamarixia radiata*

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

ELSEVIER

Density dependent mortality, climate, and Argentine ants affect population dynamics of an invasive citrus pest, *Diaphorina citri*, and its specialist parasitoid, *Tamarixia radiata*, in Southern California, USA

Ivan Milosavljević[a,*], David J.W. Morgan[b], Rachael E. Massie[b], Mark S. Hoddle[a,c]

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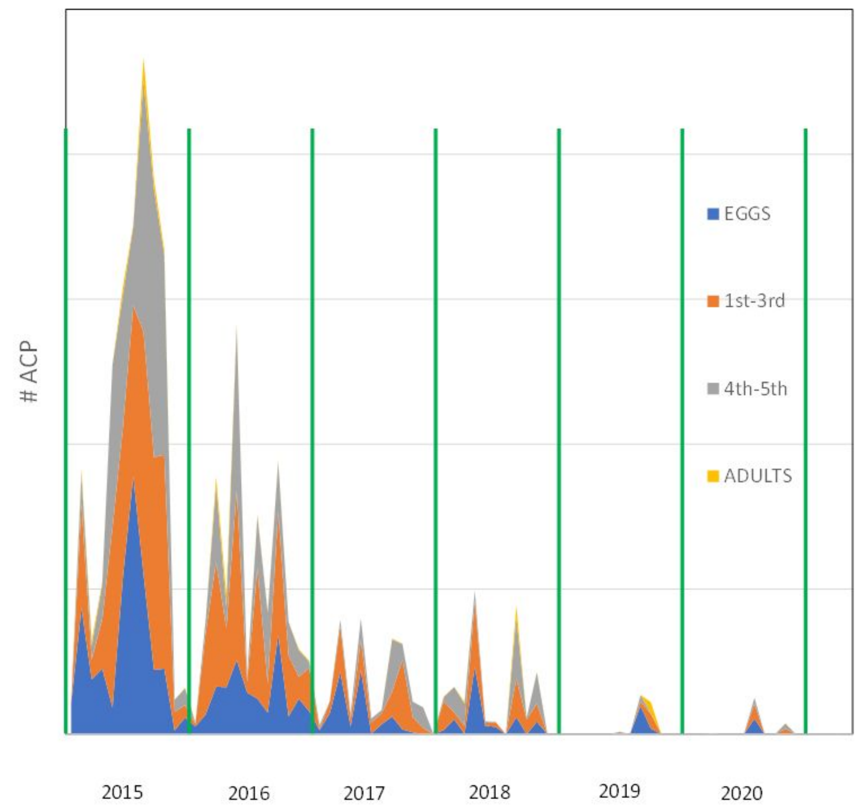
HIGHLIGHTS

- Highest *D. citri* densities were found in intermediate and coastal regions.
- Parasitism rates averaged 25% with lag density-dependent parasitism being detected.
- Parasitism by *T. radiata* was>50% greater when *L. humile* was absent.
- *Diaphorina citri* densities declined by over 75% across all study sites over four years.
- Reduced *D. citri* densities may have slowed spread of *Candidatus* Liberibacter asiaticus in California.



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OTHER PESTS AND DISEASES

Other Pests and Diseases

Multi-Pest Survey – USDA Partnership

- Sweet Orange Scab - Limited portions of Imperial, Riverside, Orange Counties
- Citrus Canker Disease – 2022 USDA identified nursery stock – CDFA destroyed and surveyed adjacent properties

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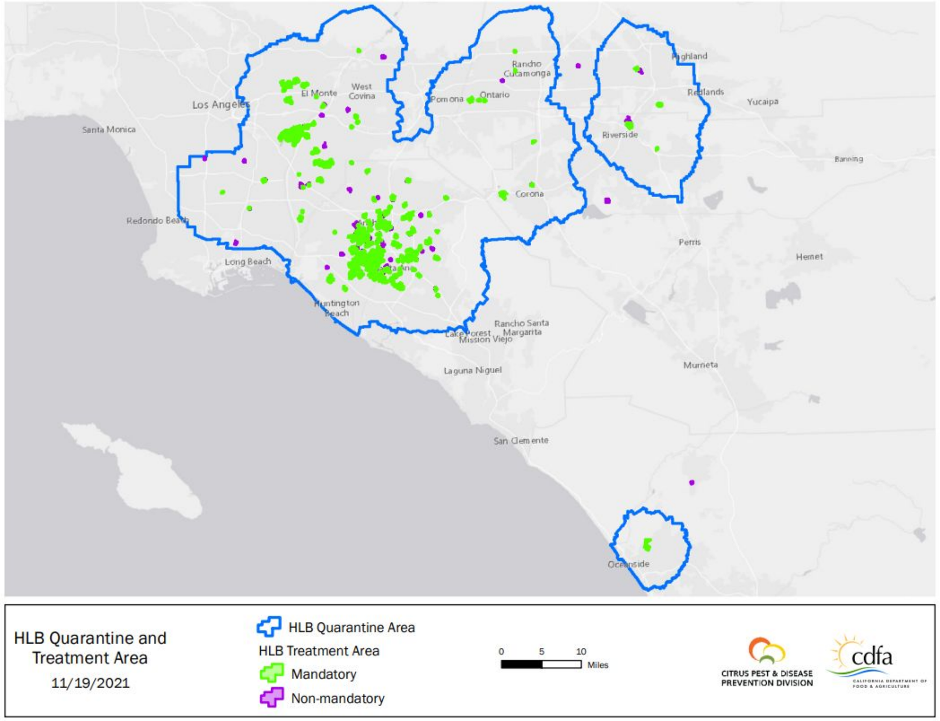
SCIENTIFIC SUPPORT
54

Data Analysis and Visualization Unit (DAVU)

- Manage and analyze detection data for citrus pests and diseases.
- Generate maps for survey, treatment, and regulatory activities.
- Collaborate with USDA to design the statewide HLB risk-based survey program.



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Data Analysis and Tactical Operations Center (DATOC)

- Comprised of growers, entomologists, modelers, plant physiologists, data scientists, and researchers.
- Conducts situational assessments and produces analyses regarding the state of ACP and HLB in California.

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Partners in Research

- ACP Detector Dogs
- HLB Detector Dogs
- Leaf Microbiome
- Metabolomics
- Spectrophotometer Technology
- Tissue & Seasonality of HLB
- Volatile Organic Compounds

California CITRUS MUTUAL

CITRUS RESEARCH BOARD

Citrus Pest Detection Program
Central California Tristeza Eradication Agency

USDA

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

CROPTIX

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OUTREACH

Outreach Overview

Residents

More than 325 million estimated touchpoints via:

- Earned media outreach (1,117 stories/280 million impressions)
- Advertising and public service announcement distribution
- Social media and website management
- 439,159+ views to CaliforniaCitrusThreat.org website(s)
- Community event attendance
- Targeted outreach via direct mail
- Collateral development
- Multicultural outreach


Los Angeles Times

A disease that could devastate citrus growers has reached San Bernardino County

Industry Members

- 150 earned trade media stories garnering 863,600+ estimated impressions
- More than 440,000 approximate overall touchpoints through a variety of activities
- Strategic industry partnerships
- Regional grower and packer meetings
- Training workshops
- Tradeshows and events
- Strategic partnerships
- 110,900+ views to CitrusInsider.org website
- 1,855 subscribers to Citrus Insider's e-newsletter

Elected Officials

- Built relationships and communicated with nearly 4,000 elected officials and representatives
- Conducted 22 desk-side meetings and city council presentations
- Presented 40 Citrus Hero Awards to city and county officials
- Provided content to local governments and elected officials to educate their constituents
- Attended in-person and virtual tradeshows to represent CPDPP

Grower Liaisons

The CDFA employs contractors (Grower Liaisons) in the citrus growing counties.

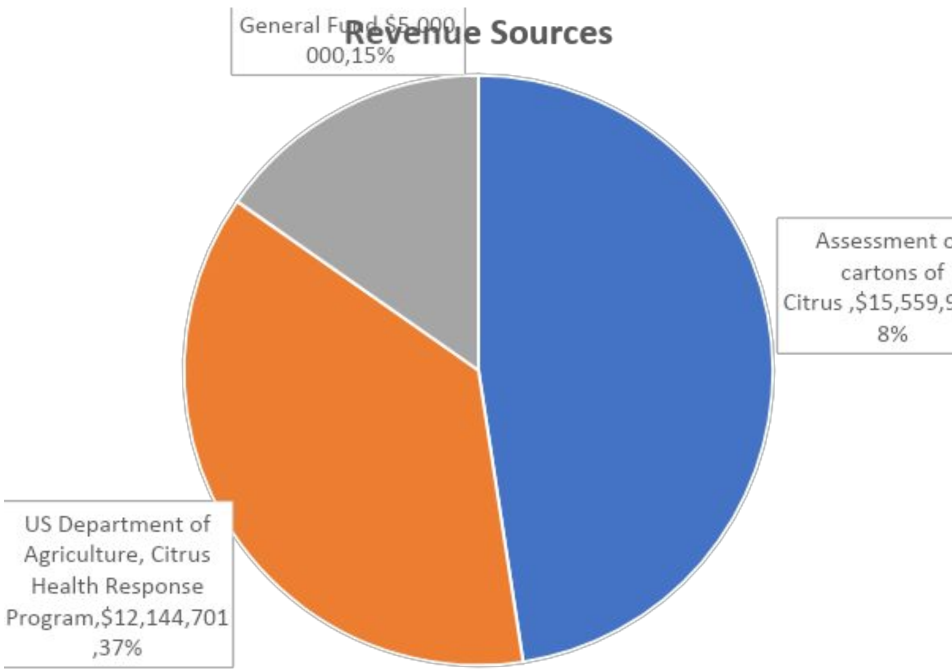
- To help coordinate grower treatment activities.
- To help with outreach and education to the grower community.
- To assist with the detection of neglected and abandoned groves.
- To work with small/residential grove owners to get them involved in the treatment programs.

Visit CitrusInsider.org to find the Grower Liaison(s) in your county.

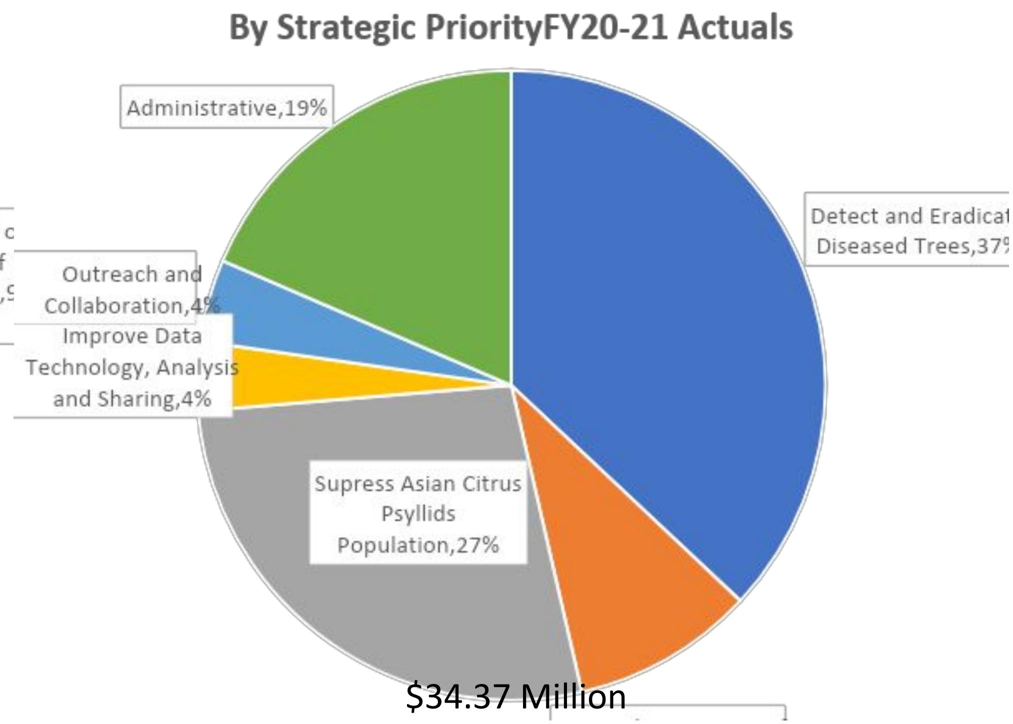





FY 20-21 Budget Overview



$32.7 Million

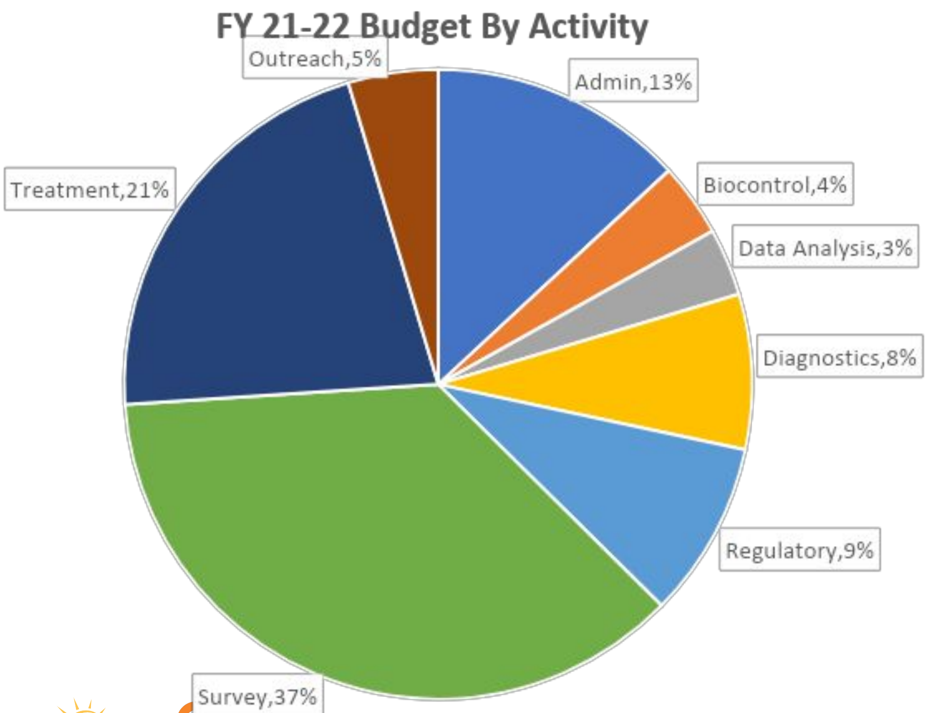


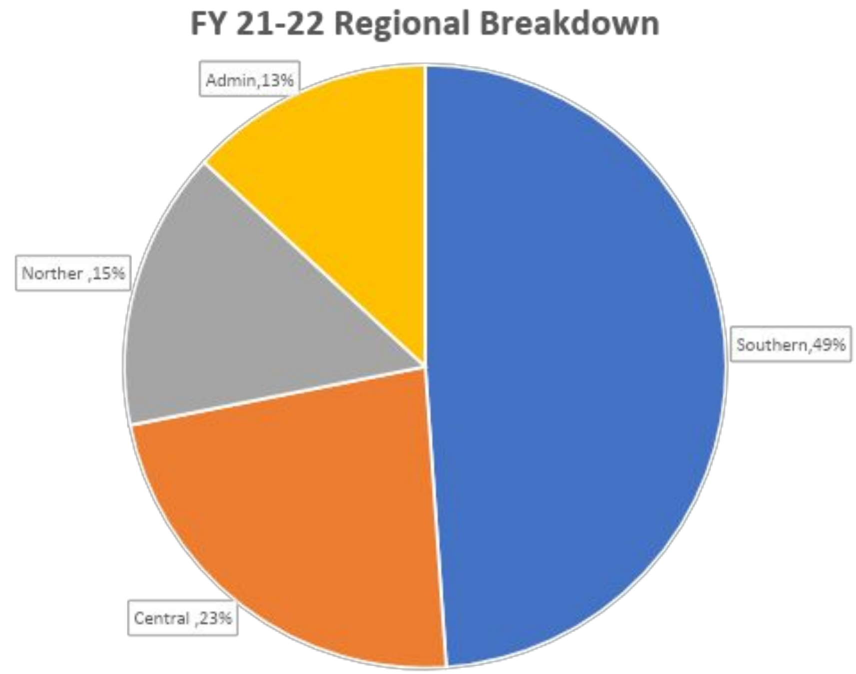
$34.37 Million

FY 21-22 Budget Display October 1, 2021 - September 30, 2022				
#	Group	Region	Activity	Approved Budget
1	ACP Mgmt	Border	Treatment	$ 625,046
2	ACP Mgmt	Central	Survey	$ 2,659,168
3	ACP Mgmt	Central	Treatment	$ 1,290,726
4	ACP Mgmt	Northern	Survey	$ 1,540,124
5	ACP Mgmt	Northern	Treatment	$ 445,718
6	ACP Mgmt	Southern	Treatment	$ 1,815,452
7	ACP Mgmt	Southern	Survey	$ 281,149
8	ACP Mgmt	Statewide	Biocontrol	$ 1,686,369
9	ACP Mgmt	Statewide	Survey	$ 3,000,000
10	ACP Mgmt	Statewide	Regulatory	$ 3,215,894
11	HLB Det	Border	Survey	$ 212,795
12	HLB Det	Southern	Survey	$ 2,084,691
13	HLB Det	Statewide	Survey	$ 6,532,228
14	HLB Det	Statewide	Diagnostics	$ 3,338,979
15	HLB Erad	Southern	Treatment	$ 5,361,616
16	HLB Erad	Statewide	Regulatory	$ 826,945
17	ACP/HLB	Statewide	Admin	$ 5,852,176
18	ACP/HLB	Statewide	Outreach	$ 2,063,377
19	ACP/HLB	Statewide	Data Analysis	$ 1,547,305
20	ACP Mgmt	Statewide	Diagnostics	$ 209,052
				$ 44,588,810

FY 21-22 Approved Budget

FY 21-22 Budget Overview





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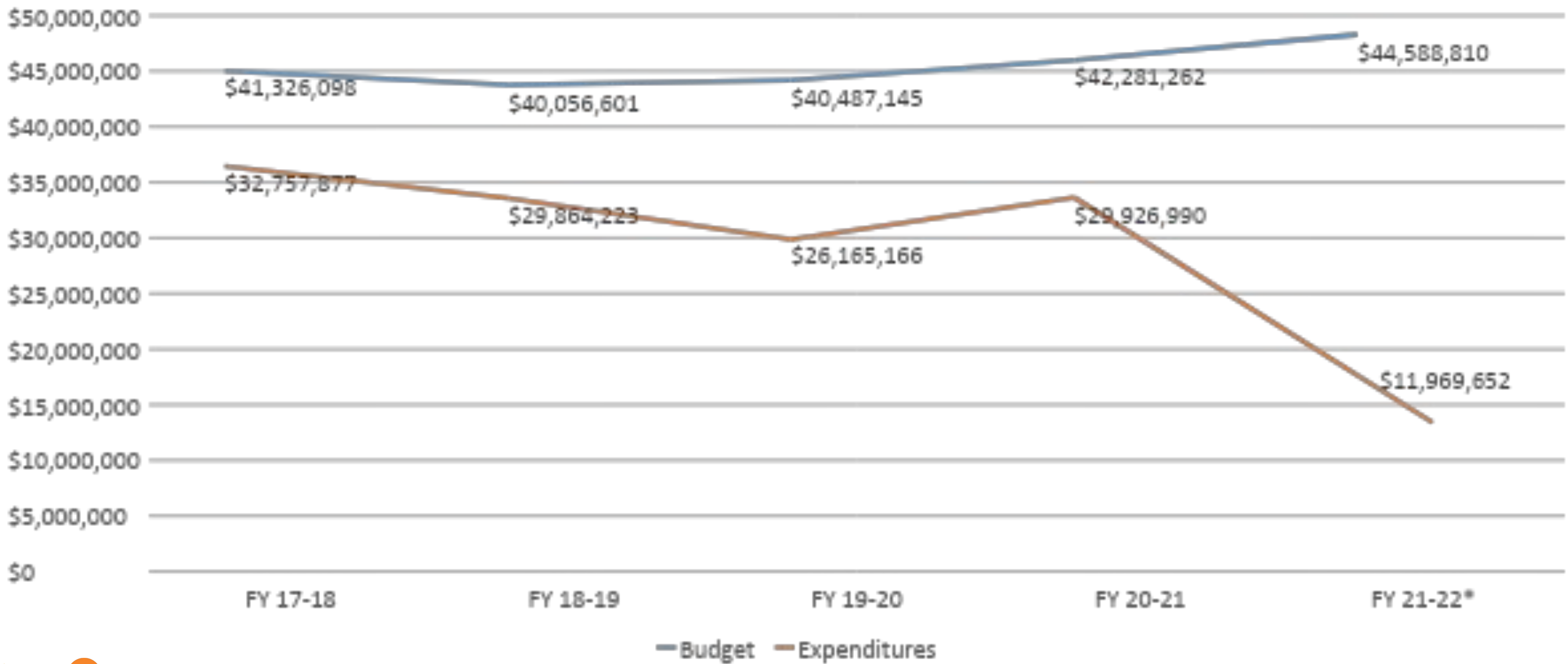
Historical Budget



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*Year to date expenditures through February 2022

Questions


Citrus Pest & Disease
Prevention Program
cdfa
CALIFORNIA DEPARTMENT OF
FOOD & AGRICULTURE

See you in Sacramento!

April 20-22, 2022

Citrus Pest & Disease Prevention Program

cdfa
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

Appendix 7: Additional Resources Considered by 2022 SAP

- Rapid uptake and retention of neonicotinoids in nursery citrus trees as a safeguard against Asian citrus psyllid infestation – Byrne, et.al., 2020
- Citrus Nursery Perspective – Aaron Dillon, Four Winds Growers
- Citrus Nursery Stock Protocol – USDA APHIS PPQ
- CDFA Citrus Nursery Stock Pest Cleanliness Program
- ACP State Interior Quarantine | Regional Quarantine Zones
- McRoberts, N., S. G. Figuera, H. Densiton-Sheets and E. Grafton-Cardwell. 2019. Grower surveys reveal diverse opinions about managing ACP and HLB. Citrograph 10 (4):22-24.
- Garcia-Figuera, S., E. E. Grafton-Cardwell, B. A. Babcock, M. N. Lubell and N. McRoberts. 2021. Institutional approaches for plant health provision as a collective action problem. Food Security 13:273-290.
- Garcia-Figuera, S., H. Deniston-Sheets, E. Grafton-Cardwell, B. Babcock, M. Lubell and N. McRoberts. 2021. Perceived vulnerability and propensity to adopt best management practices for huanglongbing disease of citrus in California. Phytopathology 111:1758-1773.
- Assessing the risk of containerized citrus contributing to Asian citrus psyllid spread in California – Byrne, et.al., 2018

Crop Protection 138 (2020) 105345

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Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Rapid uptake and retention of neonicotinoids in nursery citrus trees as a safeguard against Asian citrus psyllid (*Diaphorina citri*) infestation

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ARTICLE INFO

Keywords:
Imidacloprid
Thiamethoxam
Dinotefuran
Containerized citrus
Asian citrus psyllid
Nursery

ABSTRACT

There are specific regulations in the USA for the inter-state shipment of containerized citrus from production nurseries located within *Diaphorina citri* Kuwayama (Asian citrus psyllid; ACP) quarantine zones. To ensure trees are protected from the insect, nurseries must treat trees with an approved systemic neonicotinoid at least 30 days, and not more than 90 days, before trees can be shipped. The objective of this study was to reevaluate the necessity for a 30-day pre-shipment restriction by providing regulators with further data on the uptake of imidacloprid, thiamethoxam and dinotefuran, during the days immediately following treatments. In previous studies, ACP-effective thresholds were determined for 1-year old containerized citrus trees by correlating residue concentrations in leaf tissue with ACP efficacy. In this study, we used target concentrations to compare the uptake and retention of these neonicotinoids in 4 cultivars of 1-year old containerized citrus trees. ACP-effective thresholds were achieved within 3 days of treatment with the current lowest label rate (6.43 g AI/m^3 soil) of generic formulations of imidacloprid, and within 1 day of treatment with the maximum label rate (97 g AI/m^3 soil) of the name brand formulation Admire Pro®. The establishment of dinotefuran at ACP-effective thresholds was erratic in citrus cultivars, and residues of both dinotefuran and thiamethoxam had largely dissipated before the 30-day pre-shipment period had expired. The uptake and retention of all three neonicotinoids were significantly compromised under excessive watering (400% ET), although ACP-effective thresholds were still achieved with all imidacloprid treatment rates and thiamethoxam within 3 days. Overall, our results strongly support shortening the 30-day pre-shipment restriction to at most 3 days for trees treated with either imidacloprid or thiamethoxam. And, dinotefuran should be removed from the list of systemic insecticides approved for quarantine treatments.

1. Introduction

The Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Hemiptera: Liviidae), is one of the most important pests of citrus in the world (Bove, 2006). It is the vector of the deadly plant-pathogenic bacterium *Candidatus* Liberibacter asiaticus (*C*Las), the causal agent of huanglongbing (HLB), also known as citrus greening (Lafleche and Bove, 1970). There is no cure for HLB, and the disease can kill an infected tree within as little as 5 years. When the ACP was first detected in California in 2008 at a residence in San Diego county (CDFA, 2008), the California Department of Food and Agriculture (CDFA) established a quarantine zone to regulate the movement of ACP host plants from areas known to be infested with the insect (CDFA, 2017; Grafton-Cardwell et al., 2013). Since the initial find, ACP has spread throughout southern California, where it is now well-established in residential and commercial citrus. The devastating impacts of the insect and disease have already been experienced in Florida, where the ACP was first documented in 1998 (Halbert et al., 2000; Halbert and Manjunath, 2004). The unrestricted movement of infested citrus nursery stock was a major factor in the dispersal of this insect to all citrus growing areas within Florida (Halbert et al., 2010). When HLB was subsequently detected in 2005, the pervasiveness of the insect was attributed as a major contributing factor in the rapid establishment of the disease in commercial groves. Estimates of the cost of the HLB epidemic to the Florida citrus industry exceeded $4.5 billion for the five seasons between 2006/07 and 2010/11 (Hodges and Spreen, 2012).

In an effort to avert a similar scenario in California to that which occurred in Florida, state and federal regulators implemented restrictions on the trade of ACP host plants both within and outside of ACP quarantine zones, including inter-state (USDA, 2019; Grafton-Cardwell

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Available online 8 August 2020

Table 1
Citrus tree production for the neonicotinoid field trial.

Cultivar	Rootstock	Budding Date	Repotting Date
'Parent Washington' navel orange*Citrus sinensis* (L.) Osbeck		June 30, 2017	June 15–20, 2018
'Frost Owari' Satsuma mandarin*C. unshiu* Marcovitch	C-35 citrangeX *Citroncirus* spp		
'Rio Red' grapefruit*C. paradisi* Macfadyen			
'Limoneira 8 A' lemon*C. limon* L. Burm. F.	Carrizo citrangeX *Citroncirus* spp.		

et al., 2013). Currently, all citrus nursery stock must be treated no more than 90 days prior to shipping with an approved foliar contact insecticide and a soil systemic insecticide in order to receive a 90-day certification (CDFA, 2017). During this certification period, plants may be shipped from production facilities to retail outlets. However, in addition to the maximum 90-day pre-shipment requirement, all shipments destined for regions outside of quarantine areas, including inter-state shipments, must be treated no less than 30 days prior to the shipment date (CDFA, 2017). The 30-day restriction was mandated by the USDA-APHIS at a time when nursery trees were produced outdoors rather than in approved insect-proof screenhouses, and when imida- cloprid was the predominant systemic neonicotinoid used by nurseries (Byrne et al., 2018). The decision to implement the restriction was based on the best knowledge available at that time on how quickly imidaclo- prid treatments could disinfest trees of psyllids. No data were available for the uptake and persistence of neonicotinoids in containerized citrus trees, which are typically sold when they are 1 year old. In mature citrus trees, however, imidacloprid uptake was known to take several weeks before it became fully systemic (Castle et al., 2005). This delay likely influenced the decision to instigate a 30-day hold on nursery stock, despite their smaller size and protection in screenhouses, to ensure that the insecticide was distributed throughout the tree, and all potential life stages of ACP were killed prior to shipment.

Once trees have shipped to a retail outlet, there are no requirements that trees be retreated once the 90-day certification has elapsed, since the certification rules only apply at production facilities. However, recent data showed that citrus trees often remain in retail for periods well in excess of the certification period (Byrne et al., 2018). During these long residencies, there is a serious risk of trees becoming infested with ACP and acting as conduits for the further spread of the insect and disease when the trees are eventually sold to homeowners or landscapers. Clearly, it is imperative that the protective effects of the two mandated pre-shipment insecticide treatments are maximized in order to limit the possibility of plants becoming infested by ACP while awaiting sale at retail. While the approved foliar contact treatments are highly effective against all ACP life stages (Bethke et al., 2015, 2017; Morse et al., 2016), they do not provide long residual control (Tofangsazi et al., 2017); the bulk of the long-term protection is provided by the systemic treatment (Byrne et al., 2017, 2018; Rogers and Shawer, 2007). Therefore, unnecessary delays in shipping after the treatments have been applied at the production nurseries will shorten the period of time that trees at retail are protected by those systemic treatments. Previous research (Byrne et al., 2017, 2018) has shown that containerized citrus trees treated systemically with imidacloprid could be shipped within two weeks of treatment, when peak residues were established within trees. Since those studies were completed, USDA-APHIS has updated quarantine regulations (USDA, 2019), primarily in response to the detection of HLB in California in 2012 (Kumagai et al., 2013). All citrus produced within an area quarantined for ACP and/or HLB, and destined for another citrus-producing state, must now be produced within a USDA-APHIS-approved structure, and must undergo stringent inspection and permitting measures before shipment is approved. However, despite the requirement that all citrus be produced within insect-proof structures, pre-shipment treatment requirements for production nurseries have not changed, and the 30-day restriction remains in place. Before considering any further changes, additional studies were required that focused on early uptake within the first week following treatment of imidacloprid, since this information was lacking (Byrne et al., 2018). Furthermore, evaluations of additional imidacloprid treatment rates were needed. Several generic formulations of imidacloprid are approved for use as pre-shipment treatments (CDFA, 2017). However, the treatment rates for many of the generic products are lower than the name brand product, Admire Pro®. Therefore, the use of different products by separate production nurseries could potentially result in different levels of protection for citrus trees.

The overall goals of this study were to address the concerns of state and federal regulators regarding how rapidly imidacloprid and other approved neonicotinoid quarantine treatments become fully systemic within nursery trees at concentrations known to be effective in preventing the colonization of trees by ACP (Setamou et al., 2010). The uptake and retention of imidacloprid were compared at four treatment rates that span the recommended label rates for the name brand and generic imidacloprid formulations. In addition, we conducted further evaluations of the neonicotinoids thiamethoxam and dinotefuran. Based on previous research, we expressed concerns on the use of dinotefuran as a quarantine treatment, and the exclusion of thiamethoxam from the inter-state treatment schedule (Byrne et al., 2017). Therefore, we included these two chemicals in our studies and evaluated their early uptake under two irrigation regimes. Over-watering could be especially problematic for the efficacy of these highly water-soluble compounds if insecticides were leached from the potted trees. In particular, excessive irrigation at retail outlets could lessen the protective effect of the treatments applied by production nurseries (Byrne et al., 2018).

2. Materials and methods

2.1. Trees

Details on the production of the 4 citrus cultivars used in this study are summarized in Table 1. Four hundred citrus trees were propagated on June 30, 2017 by budding one of four cultivars on C35 or 'Carrizo' citrange rootstocks growing in 12.7 cm diameter treepots (Stuewe & Sons; cat # CP512CH). The trees were maintained in a protective structure free of any insecticide treatments at the Lindcove Research and Extension Center (LREC) in Exeter, CA until they were approximately 1 yr old. Trees were transported to a lathe house at the University of California's Citrus Research Center-Agricultural Experiment Station (CRC-AES) on May 21, 2018, and were replotted on June 15–20, 2018 into 18.9 L pots. The latter is the predominant pot size used by California nurseries for the production of citrus trees for sale at retail outlets. The soil mix consisted of a modified formulation of UC Soil Mix #1 (http://agops.ucr.edu/soil/) with 10% sand, 60% redwood bark, 15% moss, 15% coconut fiber. All other constituents were included at the standard level of UC Soil Mix #1. The trees were top-dressed as needed with a granular fertilizer (Vigoro® Citrus & Avocado Plant Food) over the course of the experiment. Two weeks after replotting (July 3, 2018), the trees were transferred from the lathe house to a field plot, where they were laid out in a 16 25 grid pattern with 1.5 m spacing between potted trees.

2.2. Irrigation

Each tree was provided with drip irrigation designed to deliver one of two watering levels. The irrigation regimes were implemented using

Table 2
Neonicotinoid insecticides and treatment rates.

Insecticide	Active Ingredient	Treatment Rate
Admire Pro 0.55 kg AI/l (suspension concentrate)	Imidacloprid	6.4 g AI/m^3 soil (121 mg/tree) 19.4 g AI/m^3 soil (368 mg/tree) 64.3 g AI/m^3 soil (1.21 g/tree) 97 g AI/m^3 soil (1.84 g/tree)
Flagship 25 WG25% water dispersible granule	Thiamethoxam	5.90 g AI/m^3 soil (118 mg/tree)
Safari 20 SG20% soluble granule	Dinotefuran	8.50 g AI/m^3 soil (170 mg/tree)

adjustable DIG® emitters, whose output was verified at the outset of the study. The watering levels were established based on measures of daily evapotranspiration (ET) on a subset of 5 trees from each cultivar that were chosen randomly from the experimental trees. This involved watering them to capacity, then weighing the entire potted tree within the next hour and again 24 h later to calculate the daily change in mass. ET measurements were repeated three times over consecutive days. Based on this value we selected two irrigation rates that we refer to as replacement watering (100% ET) and overwatering (400% ET). There were no appreciable differences in ET measurements between cultivars.

Dinotefuran and thiamethoxam uptake and retention were evaluated at both irrigation levels in all 4 cultivars, since there were no data available for containerized citrus showing the impact of over-watering on these insecticides. In previous work, we showed that overwatering did impact imidacloprid performance (Byrne et al., 2018); however, we were interested in determining whether the effects were consistent across a range of treatment rates, so we tested this in the mandarin cultivar.

2.3. Insecticide treatments

On Aug 27, 2018, trees were treated with one of three systemic applications of neonicotinoids - Admire Pro (imidacloprid; 0.55 kg active ingredient (AI) L ^{1} suspension concentrate), Flagship 25 WG (thiamethoxam; 25% AI water-dispersible granule) and Safari 20 SG (dinotefuran; 20% AI soluble granule). Imidacloprid was evaluated at 4 rates, while thiamethoxam and dinotefuran were applied at their recommended label rates. For each treatment, or treatment rate, 10 replicate trees for each cultivar were treated. In Table 2, treatment rates are summarized in terms of active ingredient (AI) per m^3 of soil for easy comparison between chemicals used in this study, and other products available on the market. Pots were pre-irrigated for 15 min to ensure adequate wetting of the soil mix prior to insecticide application. The formulated insecticides were diluted in water, and then administered to each pot in a final volume of 250 mls using a measuring cylinder, followed by an additional 1 L from a watering can to ensure the insecticide permeated below the soil mix surface into the root zone. The daily drip irrigation regime at each of the two water volume levels was implemented 24 h after the insecticides were applied.

2.4. Chemical quantification of neonicotinoid insecticides

Residues of imidacloprid (QuantiPlate Kit for Imidacloprid, cat. # EP 006; Envirologix, Portland, ME, USA), dinotefuran (SmartAssay Dinotefuran Test Kit, cat. # 306–33989; FUJIFILM Wako Chemicals USA Corp, Richmond, VA) and thiamethoxam (SmartAssay Thiamethoxam Test Kit, cat. # 300–34009; FUJIFILM Wako Chemicals USA Corp, Richmond, VA) were quantified using commercially available enzyme-linked immunosorbent assay (ELISA) kits. The lower limits of quantitation (LOQs) of residues in citrus leaves for the three ELISAs were set at 850 ng dinotefuran, 75 ng imidacloprid, and 90 ng thiamethoxam g ^{1} leaf tissue. LOQs for each ELISA system were determined empirically by spiking citrus leaf extracts with known concentrations of insecticide and then determining the required dilution to eliminate matrix effects and optimize recovery (Byrne et al., 2005). ELISA absorbance (at 450 nm) readings were determined using an accuSkan GO microplate reader (Fisher Scientific Company, Hanover Park, IL, USA). Samples of young leaf flush tissue were collected from each tree at each cardinal direction, immediately prior to treatment, and then on 13 sampling days after the trees were treated (1, 3, 5, 7, 10, 14, 21, 28, 60, 90, 120, 150 and 180 d). Tissue samples of 0.5 g from each tree were placed in vials, chopped into small pieces using scissors and then extracted by the addition of 5 mL of absolute methanol. Extracts were shaken on an orbital shaker for 12 h at 25 C. An aliquot (10 L) of each extract was dried completely in a TurboVap LV evaporator (Caliper Life Sciences, Hopkinton, MA, USA) and then dissolved in a 0.05% aqueous solution of Triton X-100 prior to analysis by ELISA. A TLC purification step for imidacloprid was used to eliminate imidacloprid metabolites from the extracts (Nauen et al., 1998) that could potentially cross-react with the ELISA kit antibody (Byrne et al., 2005).

2.5. Data analysis

Imidacloprid uptake and retention for all replicate trees irrigated at the 100% ET level over the full (180 d) duration of the study were compared using a linear mixed-effects model (LMM; Crawley, 2009). Specifically, we analyzed imidacloprid concentrations, that were log (x 1) transformed to meet test assumptions, with fixed effects of citrus cultivar (navel orange, lemon, grapefruit, mandarin), imidacloprid treatment rate (6.43, 19.4, 64.3, and 97 g AI/m^3 potting media), and sampling day post-treatment (from 1 through 180 d). A random effect of tree replicate identity was included to account for autocorrelation stemming from repeated measurements of the same trees on each sampling day (Crawley, 2009).

A similar model was used to analyze imidacloprid residues in the potted mandarin trees irrigated at the two different irrigation levels. We used a LMM on log (x 1) transformed imidacloprid concentrations that included fixed effects of irrigation regime (100% or 400% ET), imidacloprid treatment rate, sampling day post-treatment, all interactions, and a random effect of replicate identity due to multiple measures of each tree.

We compared the frequency of ACP-effective residues for each of the three neonicotinoids at 100% ET watering for the 60-d duration of measurement for dinotefuran and thiamethoxam. We had anticipated sampling the dinotefuran and thiamethoxam trees for 180 d, but terminated sampling of these trees at 60 d, when analysis of the 30-d and 60-d samples showed titers in most samples were either well below ACP-effective thresholds or at non-detectable levels. Rather than include presumptive data that would zero-inflate the thiamethoxam and dinotefuran datasets, imidacloprid data for the four treatment rates were truncated to allow direct comparison of the three insecticides over the same timeframe. Effective residues for imidacloprid were based on prior research showing 220 ng imidacloprid/g leaf tissue were required for high ACP nymphal mortality (Setamou et al., 2010). We used previously determined thresholds for dinotefuran and thiamethoxam of approximately 900 ppb and 150 ppb, respectively, that were associated with low ACP colonization rates in a field study (Byrne et al., 2017). We used a generalized linear mixed-effects model (GLMM) with binomial error (Pinhero and Bates, 2009) on the fraction of samples with ACP-effective residues, with fixed effects of citrus cultivar, sampling day post-treatment, and insecticide treatment (4 imidacloprid rates, thiamethoxam, dinotefuran), and a random effect of replicate identity. Due to problems with model convergence, the maximum model evaluated included main effects and no interactions.

In a final analysis, the effects of watering regime on dinotefuran and thiamethoxam were examined in the four citrus cultivars. This analysis

Table 3
Statistical results for effects of citrus cultivar, imidacloprid treatment rate (rate), sampling day post-treatment (sampling day), and their interactions, on imidacloprid concentration.

Source	^{2}	df	P
citrus cultivar	4.705	3	0.1947
imidacloprid treatment rate	1607.07	3	<0.0001
sampling day post-treatment	28046.5	12	<0.0001
cultivar*rate	12.049	9	0.2106
cultivar*sampling day	353.644	36	<0.0001
rate*sampling day	2874.18	36	<0.0001
cultivar*rate*sampling day	1720.80	108	<0.0001

again considered the fraction of trees with ACP-effective residues using a binomial GLMM, with fixed effects of treatment (insecticide type), citrus cultivar, irrigation level (100 or 400% ET), sampling day post-treatment, and a random effect of tree replicate identity. The maximum model considered for the GLMM included all main effects and the two-way interactions cultivar x treatment and treatment x sampling day post-treatment. Replication within the mandarins treated with dinotefuran and irrigated at 400% ET was limited to 3 trees due to mortality or poor plant growth during the experiment. Therefore, some caution should be used when interpreting the results of that treatment combination.

3. Results

3.1. Effect of treatment rate on imidacloprid residues in 4 citrus cultivars under replacement irrigation

Results for imidacloprid concentration in all four citrus cultivars receiving replacement watering (100% ET) showed significant main effects for treatment rate and sampling day post-treatment, and significant cultivar x sampling day, cultivar x treatment rate, and cultivar x treatment rate x sampling day interactions (Table 3). In general, imidacloprid residues increased sharply after 1 day post-treatment, peaked at 3–4 weeks post-treatment, and declined sharply after 2 months for all 4 citrus cultivars (Figs. 1 and 2). Indeed, mean imidacloprid residues for all cultivars at all rates were above the ACP-effective concentration (220 ppb; 2.34 on a $\log_{10}$ scale) between at least 3 days and 2 months post-treatment (Figs. 1 and 2b). One day after treatment, mean residues exceeded the ACP-effective concentration at the highest two treatment rates in navel orange, lemon and mandarin, and all but the lowest rate in grapefruit (Fig. 2a). From 3 months onward, differences in imidacloprid concentrations were more apparent among cultivars and treatment rates. In grapefruit and mandarin, concentrations declined to zero at the lowest two rates while concentrations at the highest two rates exceeded the ACP-effective concentration through 6 months post-treatment (Fig. 1). For navel orange and lemon, concentrations also declined to zero at the lower two rates, while effective concentrations were maintained for 5 months at the second highest rate, and for 6 months at the highest rate (Fig. 1).

3.2. Uptake and retention of four rates of imidacloprid in mandarins under two irrigation regimes

Results for imidacloprid concentration in mandarins irrigated at two levels showed significant main effects and all interactions except for the interaction irrigation level x sampling day post-treatment (Table 4).

In general, the higher watering level resulted in reduced imidacloprid residues, although the magnitude of reduction depended on treatment rate and sampling day post-treatment (Figs. 2 and 3). After 1 day post-treatment, imidacloprid residues increased sharply and stayed relatively high for approximately 2 months, regardless of the irrigation regime (Fig. 3). Under both irrigation regimes, mean ACP-effective concentrations were reached within 3 days at all treatment rates (Fig. 2). At the two lowest treatment rates (6.43 g and 19.4 g AI/m^3), imidacloprid was not detected from 3 months post-treatment under either irrigation regime (Fig. 3). At the two higher treatment rates (64.3 g and 97 g AI/m^3), from 3 months post-treatment onward the higher

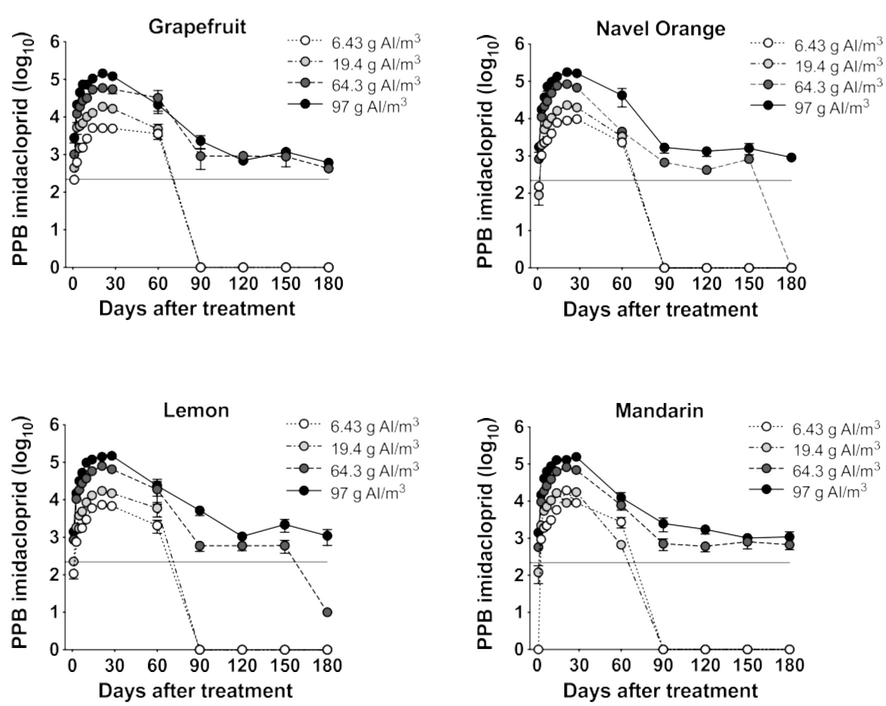

Fig. 1. Imidacloprid concentrations (log10 (x)‾±SE) in leaf tissue samples collected from 4 citrus cultivars (10 tree replicates per cultivar) treated at 4 different treatment rates (Table 2) and sampled for up to 6 months post-treatment. The horizontal line denotes the ACP-effective concentration (2.34 on a log10 scale). Residue data for 1 day and 3 days post-treatment are shown in more detail in Fig. 2.

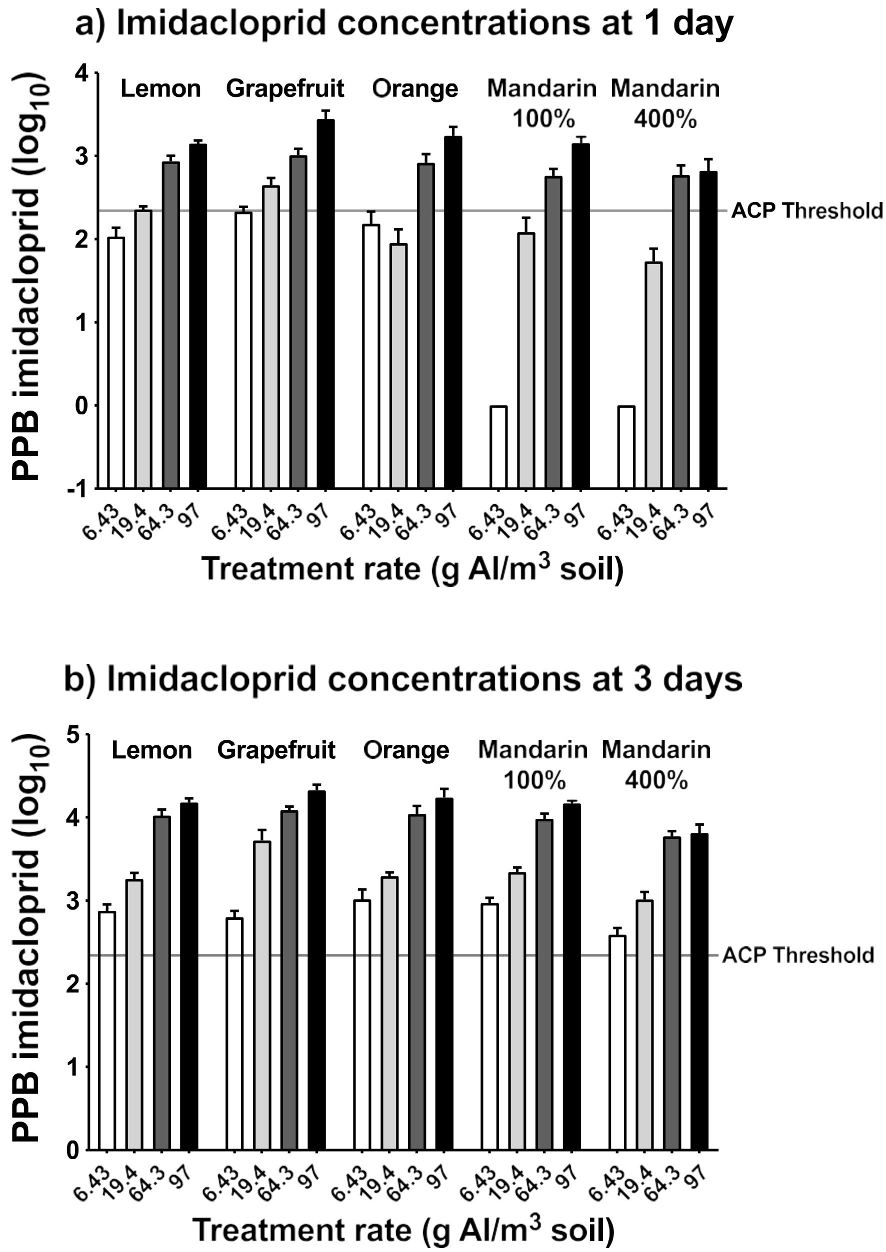

Fig. 2. Imidacloprid concentrations (log$_{10}$ ($\bar{x}$) SE) in 4 citrus cultivars (10 tree replicates per cultivar) at a) 1 day, and b) 3 days after treatment with 6.43, 19.4, 64.3, and 97 g AI imidacloprid/m^3 soil. All cultivars other than mandarins were watered at 100% ET. Residue data for the entire 180 day monitoring period are shown in Fig. 1.

Table 4

Statistical results for effects of irrigation level (water), imidacloprid treatment rate (rate), sampling day post-treatment (sampling day), and their interactions, on imidacloprid concentrations in young mandarin trees.

Source	^{2}	df	P
water	51.818	1	0.0001
imidacloprid treatment rate	484.11	3	0.0001
sampling day post-treatment	7249.9	12	0.0001
water*rate	10.513	3	0.0147
water*sampling day	19.516	12	0.0768
rate*sampling day	659.93	36	0.0001
water*rate*sampling day	74.985	36	0.0001

irrigation rate generally reduced imidacloprid residues near or below ACP-effective concentrations compared to the lower irrigation rate (Fig. 3).

3.3. Uptake and retention of imidacloprid, dinotefuran and thiamethoxam in 4 citrus cultivars under replacement irrigation

The comparison of the uptake and retention of the three insecticides over 60 d post-treatment showed significant effects of cultivar, treatment, and days since treatment (Table 5). In general, thiamethoxam resulted in the most consistently rapid uptake, dinotefuran exhibited substantial variability in both uptake and retention, and imidacloprid resulted in the longest retention over time (Fig. 4).

More specifically, for all cultivars, the lower 3 imidacloprid rates did

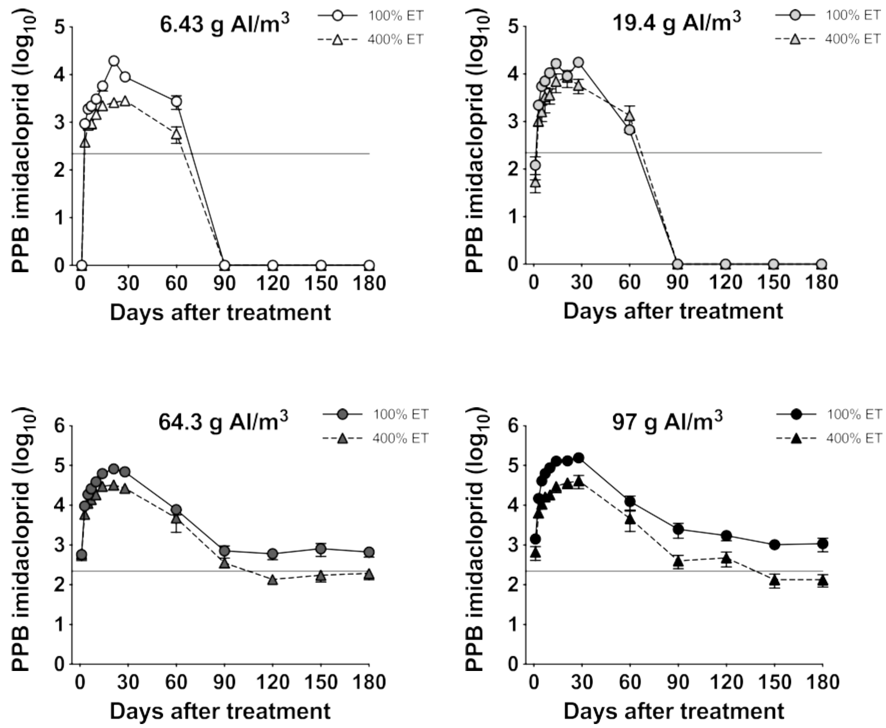

Fig. 3. Imidacloprid concentrations ($\log_{10}$ ($\bar{x}$) SE) in leaf tissue samples collected over 6 months from young mandarin trees following treatment with 6.43, 19.4, 64.3, or 97 g AI imidacloprid/m^3 soil and irrigated at either 100% or 400% evapotranspiration rate (ET). The horizontal line denotes the ACP-effective concentration.

Table 5
Statistical results for analyses on the proportion of trees with ACP-effective residues of imidacloprid, thiamethoxam or dinotefuran (treatment), among 4 citrus cultivars, and sampling day post-treatment. Data for all treatments were included in the analysis up to 60 d post application.

Source	^{2}	df	P
citrus cultivar	12.902	3	0.0049
treatment	195.98	5	0.0001
sampling day post-treatment	322.79	8	0.0001

not result in 100% uptake to ACP-effective concentrations after 1 day. However, after 3 days at these rates, all trees had ACP-effective residues except for 1 lemon tree treated with the second lowest rate and 1 mandarin tree treated with the second to highest rate. Once ACP-effective imidacloprid residues were reached in all trees, they were maintained for at least 60 d post-treatment at all rates in orange and grapefruit, and at the two higher rates in lemons and mandarins. At the highest imidacloprid rate all trees reached ACP-effective concentrations within 1 d post-treatment.

Dinotefuran showed more substantial variation in the fraction that reached ACP-effective concentrations. For 3 of the 4 cultivars, uptake was not at 100% after 1 d. Indeed, in lemons, no more than 80% of trees ever attained effective residues (Fig. 4). Moreover, dinotefuran retention was generally poorer than the other neonicotinoids, with noticeable declines approximately 30 d after treatment.

Thiamethoxam applications resulted in 100% of trees with effective residues after 1 d, and remained at that level for approximately 21 d in all cultivars, after which a clear decline occurred (Fig. 4).

3.4. Uptake and retention of dinotefuran and thiamethoxam in 4 cultivars of citrus under two irrigation regimes

The final analysis of the effects of irrigation regime on dinotefuran and thiamethoxam uptake and retention showed significant main effects and significant interactions between cultivar x treatment and treatment x sampling day post-treatment (Table 6). Trees treated with dinotefuran showed substantial variability within the first month following treatment, with a relatively high fraction of lemon and grapefruit trees having residues that were below the ACP-effective concentration (Figs. 4 and 5). In contrast, thiamethoxam treatments resulted in a consistently higher proportion of trees with ACP-effective concentrations over the first three weeks, after which the proportion dropped sharply (Figs. 4 and 5). Higher irrigation levels were associated generally with reduced dinotefuran uptake and retention during the first 2 weeks following treatment, and reduced thiamethoxam uptake during the first few days following treatment (Fig. 5).

4. Discussion

This study provided a comprehensive assessment of how different treatment rates of imidacloprid and irrigation regimens affect insecticide uptake and retention in containerized citrus. The purpose of the treatments is to protect trees from infestation by ACP, and thereby disrupt the spread of psyllids on nursery trees. Therefore, it is essential to interpret residue levels in a manner appropriate to that goal. Although we did not establish the efficacy of the treatments directly against ACP in this investigation, prior studies provide sufficient data to allow an assessment of the relevancy of residue levels at preventing the establishment of colonies. Byrne et al. (2017) showed that 2 varieties of 1-year old containerized citrus trees treated with the 6.43 g rate of imidacloprid did not become infested with ACP until residues had declined to at least 75 ng g ^{1} of leaf tissue, whereas untreated control trees became infested much sooner. There are no other data available relating residue and efficacy data for ACP on containerized citrus. However, in an orchard study conducted on 3- and 4-year old non-bearing 'Rio-Red' grapefruit trees (the same grapefruit variety used in this study), imidacloprid residues of 220 ng g ^{1} prevented the establishment of ACP colonies on trees (Setamou et al., 2010). Both of these studies rated treatment efficacy on the ability of ACP to establish

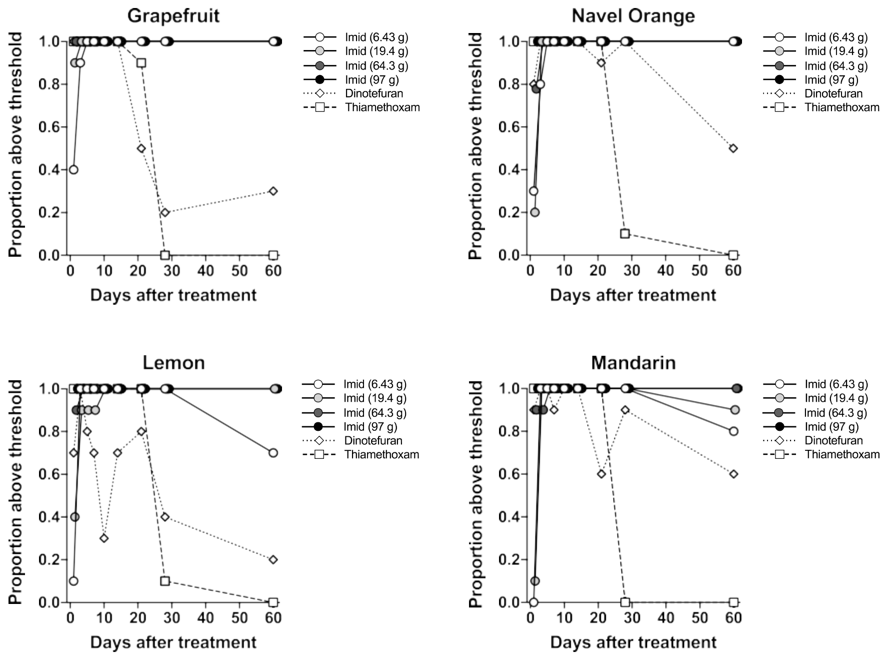

Fig. 4. Proportion of citrus trees (4 cultivars) with ACP-effective concentrations of imidacloprid (treated at four different treatment rates; Table 2), dinotefuran, or thiamethoxam over 60 d post-treatment. All trees were irrigated at 100% ET. Symbols at each time-point are offset slightly for clarity.

Table 6
Statistical results for analyses on the proportion of trees with ACP-effective residues of thiamethoxam or dinotefuran (treatment), among 4 citrus cultivars (cultivar), 2 irrigation levels (water), and days since treatment (sampling day).

Source	^{2}	df	P
citrus cultivar	13.779	3	0.0032
treatment	6.891	1	0.0087
water	16.339	1	<0.0001
sampling day post-treatment	676.61	8	<0.0001
treatment*cultivar	15.602	3	<0.0001
treatment*sampling day	179.23	8	<0.0001

colonies on treated trees, and are, therefore, the most relevant measures of the efficacy of systemic treatments for production nurseries. Other approaches have accessed residue levels on the basis of their ability to prevent adult feeding, and thereby disrupt the transmission of HLB, or to kill adult ACP. Langdon et al. (2018b) assessed the efficacy of imidacloprid treatments in grove trees based on artificial ingestion bioassays (Langdon and Rogers, 2017), and concluded that the highest leaf tissue concentrations measured in field-treated citrus trees (1000 ng g^{-1}) would be ineffective at reducing ACP feeding activity. Unfortunately, no data were provided in that study on the efficacy of the treatments at preventing the establishment of active ACP colonies. In the same way, Byrne et al. (2017) showed that considerably higher concentrations of imidacloprid were required to kill adult ACP in bioassays when insects were exposed to leaves sampled from systemically-treated trees, compared with concentrations measured at the time insects began to establish colonies. The apparent disconnect between the acute mortality residue levels measured under the artificial conditions of laboratory bioassays, in which the insects are required to feed over a (relatively) short period of time on a treated substrate, and those determined at the time ACP begin to colonize treated trees, has been discussed in some detail (Byrne et al., 2017). In particular, bioassays of imidacloprid systemic activity are difficult to interpret because of confounding sublethal and anti-feedant behavioral effects. Such effects are known to occur in many different species of insects, including ACP (Boina et al., 2009), and could potentially increase efficacy thresholds, if adult mortality was the only acceptable measure of efficacy. The latter would render most field treatments as ineffective, and would necessitate the use of the maximum imidacloprid label rate by production nurseries in order to reach those thresholds.

In this study, the results show that imidacloprid uptake is rapid in four citrus cultivars, with mean residues surpassing required ACP-effective thresholds in trees within as little as 3 days. In fact, based on the ACP-effective concentration of 220 ng g^{-1} leaf tissue (Sėtamou et al., 2010), full protection to trees was achieved in all cultivars within 1 day of treatment with the current highest label rate (97 g AI/m^3 soil) for imidacloprid. In mandarins, over-watering of trees dramatically reduced the overall titers of imidacloprid, and slowed the initial rate of uptake. Yet, even with over-watering conditions of 400% ET, uptake of insecticide was rapid enough to protect trees within 3 days at all rates. Protection beyond 60 d was only achieved at the higher treatment rates. Thus, we have provided further evidence that the requirement for a 30-day delay between treatment with imidacloprid and shipping to retail is unnecessarily long, and may be counter-productive to the overall goal of preventing infestations of ACP on containerized citrus. More significantly, the delay in treatment before shipment shortens the protective effect that the systemic treatments will ultimately have on trees awaiting sale in retail. Without any regulation of residency times, treatment rates, or irrigation levels for containerized citrus trees in retail outlets, trees that lose their protection while in retail become vulnerable to infestation by ACP (Byrne et al., 2018), and become potential reservoirs for the HLB pathogen (Halbert et al., 2012).

There are several generic formulations of imidacloprid available on the market. For nursery stock that is destined for markets outside of quarantine areas, including inter-state markets, any generic formulation of imidacloprid is approved for use (CDFA, 2017). One potential problem, however, is that the pesticide label rates on many of the generic products are not consistent, meaning that the choice of product used by a production facility will impact the amount of active ingredient applied to a tree. The lowest rate evaluated in this study is the maximum treatment rate allowed by the labels for the majority of generic formulations. Based on prior estimates of concentrations required to prevent ACP colonization (Byrne et al., 2017; Sėtamou et al., 2010), our data

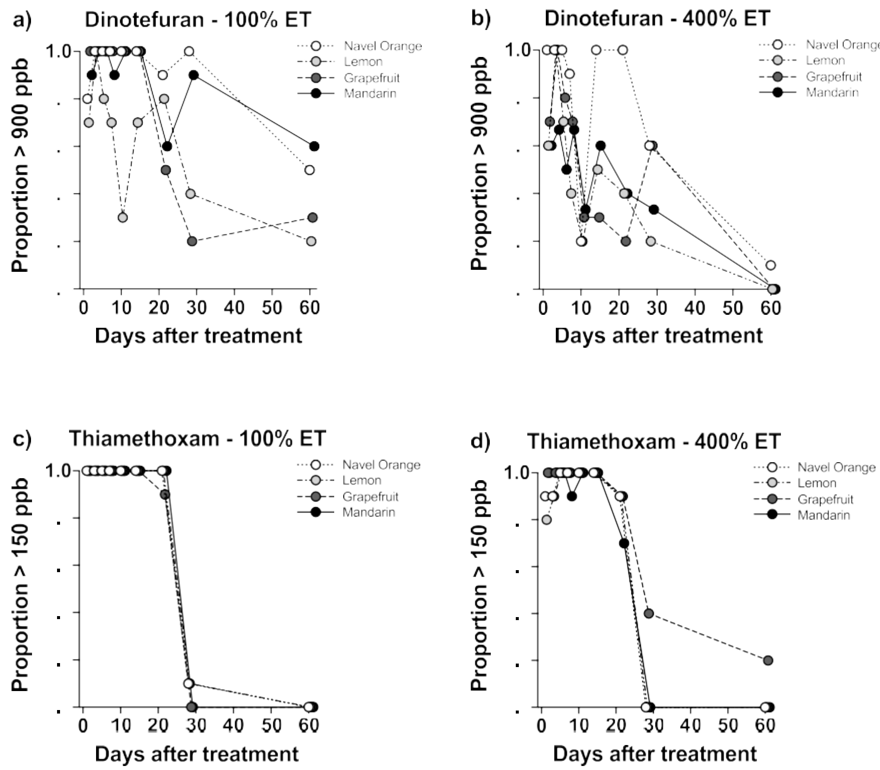

Fig. 5. Proportion of citrus trees over time with residues above approximate ACP-effective concentrations following treatment with dinotefuran [a, b] or thiamethoxam [c, d] and irrigation at 100% [a, c] or 400% of evapotranspiration [b, d]. Symbols at each time-point are offset slightly for clarity.

show that this treatment rate (6.43 g AI/m^3 soil) will deliver ACP-effective concentrations to trees within 3 days, although retention of effective residues will be dramatically reduced compared with higher treatment rates permitted by other formulations. There are very few imidacloprid products that permit treatment rates above our lowest test rate. Therefore, while the majority of products may protect trees relatively quickly, they will not protect trees beyond 90 days. One option to consider would be to limit quarantine treatments to products that permit higher treatment rates. By so doing, trees would acquire ACP-effective concentrations more rapidly, as quickly as 1 day, and be protected for a longer period once they are shipped. From a production nursery perspective, the need to wait 30 days before shipping represents a logistical challenge. Once a new order is received, nurseries would prefer not to have to put a 30 day hold on delivering that order while waiting for a treatment to take effect. Therefore, many nurseries have now resorted to the costlier exercise of treating nursery stock every 90 days. By so doing, nurseries have certified stock available that has been treated within the 90-day maximum treatment window, and satisfies the minimum 30-day pre-shipment requirement. However, this strategy complicates the ability to protect nursery trees effectively once they are shipped to retail, since trees could potentially be shipped in as little as 1 day before the expiration of the 90-day certification period, when a large proportion of the insecticide has already dissipated. At lower treatment rates, trees would be vulnerable to infestation sooner once they left the protective environment of the screen house.

Both thiamethoxam and dinotefuran are recommended as approved treatments for the movement of nursery stock within ACP quarantined areas (CDFA, 2017), while dinotefuran is the only active ingredient, other than imidacloprid, that is approved for use on nursery stock that will be shipped outside of quarantined areas. Our data show that dinotefuran is wholly unsuitable as an effective quarantine treatment. Although uptake was very rapid, and higher titers of dinotefuran were established within trees compared with either imidacloprid or thiamethoxam, the lower inherent toxicity of dinotefuran (Byrne et al., 2017) ultimately meant that ACP-effective concentrations were not always reached in trees. Furthermore, over-watering of trees treated with dinotefuran, which is a likely scenario at retail outlets (Byrne et al., 2017), further reduced the efficacy of this treatment, and resulted in extremely erratic residue patterns in the 4 cultivars.

Thiamethoxam was a more effective treatment than dinotefuran. Previous data showed that it is inherently quite toxic to ACP, with significantly lower concentrations needed to protect trees from ACP colonization (Byrne et al., 2017). ACP did not establish on containerized trees until concentrations of thiamethoxam exceeded 163 ng g $^{-1}$. Again, significantly higher concentrations were required to achieve outright adult mortality in short duration bioassays (Byrne et al., 2017), and to lower the probability of finding an infested leaf flush to practically zero (Langdon et al., 2018a). As with imidacloprid, we regard the more appropriate measure of the efficacy of systemic thiamethoxam for quarantine treatments in terms of their ability to prevent colonization.

The time to achieve ACP-effective concentrations of thiamethoxam was delayed by over-watering; however, residues reached fully effective ACP thresholds within 1 day in trees under replacement irrigation. Interestingly, thiamethoxam was applied at 70% of the treatment rate used for dinotefuran (Table 2), and yet was superior in uptake and marginally so in retention. While the rate of uptake for both thiamethoxam and dinotefuran are equally impressive, both the greater inherent toxicity of thiamethoxam and its rapid establishment at ACP-effective concentrations make this chemical more suitable as a pre-shipment treatment than dinotefuran. For both compounds, however, under current regulations, the 30-day pre-shipment requirement means that neither thiamethoxam nor dinotefuran treatments would protect trees from a potential infestation once the trees leave a production facility, since residues have already dissipated by the time the trees are legally ready to ship.

5. Conclusions

The data generated in this study are in response to a request by federal regulators for additional information on the performance of neonicotinoids during the initial days following the treatment of containerized citrus trees. The results strongly support shortening the current pre-shipment restrictions that have been implemented in California. Although three neonicotinoids are approved for use in quarantine treatments, imidacloprid was the most effective neonicotinoid of those tested in terms of both acquisition and retention of effective thresholds. Even at its lowest treatment rate (6.43 g AI/m^3 soil), which closely matched label rates of thiamethoxam and dinotefuran, imidacloprid out-performed its neonicotinoid counterparts, and was the better of the three options. Irrigation level was clearly influential on the performance of the neonicotinoids, both in terms of initial uptake, and in terms of overall retention of ACP-effective levels within trees.

We suggest the adoption of either a fixed 3-day pre-shipment treatment rate of 6.43 g imidacloprid/m^3 soil, or a 1-day pre-shipment treatment rate of 97 g imidacloprid/m^3 soil. Either of these rates would be highly beneficial to the industry as they would minimize post-treatment delays in shipping, and ensure that all trees were afforded the maximum protection when they left the production facility. Furthermore, without any regulations for retail outlets, the 90-day certification period established at the time of treatment at the production facilities should still be retained as an indication to retail outlets of when unsold trees should be discarded.

CRediT authorship contribution statement

Frank J. Byrne: Conceptualization, Methodology, Investigation, Writing - original draft, preparation, Visualization, Funding acquisition. **Matthew P. Daugherty:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Elizabeth E. Grafton-Cardwell:** Conceptualization, Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 8: Agenda for 2022 CPDPP Onsite Review, April 20-22, 2022

Citus Pest & Disease Prevention Program
Science Advisory Panel Meeting
April 20-22, 2022 – Sacramento, Calif.

Hotel:
Four Points by Sheraton Sacramento
4900 Duckhorn Dr, Sacramento, CA 95834

April 20, 2022 – Travel and Group Dinner
Hotel provides airport shuttle service, on request, every 30 minutes. Reservations are not accepted. Call 916-263-9000 upon arrival at Sacramento Airport.

5:30 p.m. Departure - 6 p.m. Working Dinner @ Hawks Public House – hosted by Wonderful Citrus

1525 Alhambra Blvd, Sacramento CA 95816 *(Complimentary parking in Sutter Medical Plaza, entrance on Stockton Blvd.)*
Panelists will gather in the lobby at 5:30 p.m. and either carpool or ride share to the restaurant.

Discussion of purpose, objectives and key questions

April 21, 2022 – Meeting Day One – The Rivers (East) Conference Room
Breakfast buffet ($13) available from 6 - 10 a.m.

7:30 a.m. SAP Closed Session: Review of objectives, timeline and focused questions

8:30 a.m. Meeting Begins – *Coffee Service hosted by California Citrus Nursery Society*
- Introductions

9 a.m. Question 1: Can we determine the role that the program is playing in keeping HLB out of commercial groves?

10 a.m. Question 2: Is the Risk-based survey adequately addressing HLB detection?
SME: Neil McRoberts - Outputs of HLB Risk-Based Survey Model

Noon – BREAK
12:15 p.m. – *Working Lunch - hosted by TreeSource Citrus Nursery*

1 p.m. Question 3: Is the ACP/HLB management program protecting the San Joaquin Valley well enough? (Kern, Tulare, Kings, Fresno, Madera)

3 – 3:15 p.m. BREAK

3:15 p.m. Question 6: Production nurseries are regulated to prevent the spread of ACP and HLB. Does the California program provide sufficient protection at the retail level?

SME: Aaron Dillon - Nursery perspective
SME: Frank Byrne, UCR - Nursery regulations

4:15 p.m. Question 7: Is there sufficient access by growers and homeowners to real-time information on the locations of HLB and are there incentives to stay engaged in the program?

5:30 p.m. Departure - 6 p.m. Working Dinner @ Mayahuel – co-hosted by Bloom to Box and Copeland/Gorden Farming

1200 K Street, Sacramento, CA 95814
Panelists will gather in the lobby at 5:30 p.m. and either carpool or ride-share to the restaurant.

Recap Day One - Additional Resources/Perspectives Necessary

April 22, 2022 – Meeting – The Rivers (East) Conference Room

Breakfast buffet ($13) available from 6 - 10 a.m.

8:30 a.m. SAP Closed Session Resumes – *Coffee Service hosted by California Citrus Nursery Society*

- Recap of Day One

9 a.m. Question 4: Is the ACP/HLB management program in S. Calif managing HLB well enough? (San Diego, Imperial, Riverside, San Bernardino, Ventura)

SME: Neil McRoberts – DATOC Analysis of Southern California Activities
SME: Neil McRoberts - Density of Spatial and Temporal Finds (priority focus on HLB)

Noon to 12:15 p.m. BREAK
12:15 p.m. – *Working Lunch – hosted by TreeSource Citrus Nursery*

1 p.m. Question 5: What does the future management of HLB in S. California look like?

3 p.m. Regulatory Activities

- Discuss next steps

3:30 p.m. Preliminary review of findings

- Program Priorities to Continue
- Adjustments to Program
- New Elements to Explore
- Program Elements to Deprioritize

4:30 p.m. Discussion of Draft Conclusions/Assignments

5 00 p.m. Meeting Adjourns

Appendix 9. Opening Comments from Etienne Rabe, Grower and CPDPC member

Notes to SAP, Sacramento 21 April 2022.

1. Setting the scene:
    a. The CPDPP is a large program embedded in the CDFA (168 permanent positions, 60 hourly, many compliance agreements with counties, etc.). $40m plus budget
    b. The Science Subco started to delve into the components of the very large Southern California component of this program to determine whether all the actions can be scientifically justified. It soon became clear that the entire program should be audited from a scientific point of view by a group of experts
    c. There has been previous SAPs. The last one at least 8 years ago, I believe. The CDFA Sec of Ag graciously agreed that it is time to reconvene a panel.
    d. I am NOT speaking for the entire CPDPP Board. There are obviously different opinions which is good, varying from spending as much as it takes to attain the objective to spend justifiably where it makes scientific and economic sense. The former is not a sustainable path in my view. There still is a lot of goodwill from the grower community to support sensible efforts to combat HLB spread and find solutions. My sense is, however, that the political will might start to wane and so will government funding. We as a CA Citrus industry need to ensure that grower funding, if it ever comes to that, alone can sustain a sustainable program.
    e. While you are not asked to evaluate the justification for the program spend, the scientific underpinning forms the basis for all decisions and thus indirectly address resource needs
    f. We are 12 years plus down the road since the formation of the CPDPP and a lot has changed in the knowledge base. However, in many instances we seem to still be doubling down on specific objectives which may or may not be justified any longer. We put our trust in you to provide us that guidance
    g. In 2013 some of the leading voices in our industry, during the heyday of the early detection technology boom, predicted the demise of the CA Citrus industry in the following 3 years. Thus by 2016. This obviously has not come to pass, and we have learnt a lot in terms of the differences of CA to Fla and TX [Climate one of the main points of difference]. To what extent has our program contributed to the current situation?
    h. I am going to outline a few aspects that is forefront for me, some of which are being posed to you as questions as well
2. Risk-based survey: this encompasses a large part of manpower and resources. It causes us to remove trees many miles from commercial citrus. To what extent has the removal of a total of about 3000 trees to date made the industry safer? This in light of models indicating a reservoir of up to many hundreds of thousands of asymptomatic and symptomatic undetected trees in residential areas in SoCal.
3. ACP populations: the current low level of ACP populations compared to the past, also in Socal, unlikely can be ascribed to treatment effects, at least in SoCal residential regions since this is a one-time treatment, leaky at best due to all the un-controllables (tree condition, watering cycles, some refusals, etc.), Climatic, cyclical, or due to increased biological control?
4. Rate of refusals: this is a very serious matter. In some cases, relative to the area-wide residential buffer management around commercial citrus, this has been reported as around 20% on average and in some counties can be up to 35%

5. To get back to the program today: we have neglected to engage people like you over the recent years. As stated, the program is a major undertaking, by any definition. It cannot continue to grow infinitely. While you are not asked to address financial issues nor the program management, it will surely come up in your discussions and you should not be afraid to respectfully express opinions in this regard. If you find certain parts of the program not to be of strategic importance to the overall objective, it will certainly affect the program extent and, hence, staffing. Again: the Committee will need to know this and will hopefully hear from you if you deem this important
6. In summary: we as a Committee and the industry at large are extremely indebted to you all for availing us of your time and expertise. We are looking forward to your deliberations.

10 Year Battle Against ACP and HLB California Citrus Nursery Prospective

2012-2022

WHAT IS WORKING AND WHAT CAN BE IMPROVED

BY: AARON DILLON, FOUR WINDS GROWERS

CCR 3701. California Citrus Nursery Stock Pest Cleanliness Program

2009 – California citrus nurseries agree to self-regulate in advance of widespread pressure from ACP or HLB

CCR 3701 required mother trees (2012) and increase trees (2013) to be grown inside of an insect-resistant structure (IRS)

- Established schedule for mother tree testing and inspection of IRS

Program tests for viroids and all other citrus diseases which have been largely eliminated from California citrus nurseries

HLB has never been discovered in a certified nursery in California

What is Working

California citrus nurseries are complying with CCR 3701 which requires a significant financial investment on the part of participating nurseries

As a result, citrus nursery stock from California participating nurseries is not serving as a vector to spread ACP or HLB

California citrus growers are starting with clean trees – key component of a healthy citrus industry

CDFA and California citrus nurseries have a good working relationship. Together they have found ways to streamline regulatory activities and develop protocols that have improved efficiency of compliance requirements while continuing to mitigate risk – i.e. shipment self certification

Nursery xtock in California is regulated separately from citrus fruit production – very important to maintain separation between nursery and fruit regulations

What Can Be Improved – ACP Quarantine Boundaries

2018 – CDFA moved to a regional quarantine structure and quarantined **entire** counties where ACP was detected, rather than five-mile radius quarantines around detections.

- USDA has stated that counties do not have a way to show that they are free from ACP because existing traps aren't very effective
- As a result, once a county goes into quarantine it **can not ever** come out. No exit strategy from quarantine.
- This can lead to serious consequences for California citrus nurseries in the event of a breach on an IRS.
  - One nursery has had their mother plants put on hold for 1 year while they await negative HLB test results, even though no ACP has ever been detected near the nursery

Question for SAP: Can a protocol be developed to declare the area around a nursery or county to be free from ACP? Possibly using high density traps (including live ACP traps) or other means to determine that ACP is not present around a citrus nursery or in a county after a specified amount of time from the previous detection.

What Can Be Improved – Risk Assessment Team Methodology

"All structure breaches, quarantine violations, and other regulatory incidents are reviewed by the CDFA-USDA cooperative citrus risk assessment team"- https://www.cdfa.ca.gov/citrus/pests_diseases/acp/nurseries.html

The Risk Assessment Team is made up of members from CDFA and USDA

Recommended breach protocol (2016) does not consider California's environment and ACP/HLB activities. California and other HLB-infested states are considered equal.

http://phpps.cdfa.ca.gov/PE/InteriorExclusion/pdf/Recommended_ACP_Breach_Protocol.pdf

Question for the SAP: Breaches of IRS pose significant risk to the normal operation of a citrus nursery. What can be done to develop a more scientific approach to determine the actual risk posed by an IRS breach, considering California's environment and pest pressure?

What Can Be Improved – Retail Sales of Citrus Trees in HLB Q Areas

Sale of citrus nursery stock is prohibited in an HLB Q unless maintained within an approved structure.

Approved structure requirements are not equivalent to production IRS.

2017 – California citrus nurseries enlisted researchers from UCR to conduct a pilot project for retail nursery citrus to determine the efficacy of required chemical treatments used on citrus nursery stock.

As the HLB Q grows in California, there is a larger area of the sate that does not have access to the clean citrus nursery stock being produced inside of certified citrus nurseries and treated with the required soil and foliar chemical applications. This leads to an increase in the risk of "black market" sales of citrus since consumers have extremely limited access to clean citrus nursery stock in these quarantine areas.

Question for the SAP: Does the current regulation regarding retail citrus in HLB Q areas still make sense? Could the "inside" of a retail location be considered a resistant structure?

Summary of Citrus Nursery Program in California

The Citrus Nursery Stock Pest Cleanliness Program is a **mandatory** program for California citrus nursery sources

California citrus nurseries are producing clean trees that are not servings as vectors to spread HLB or other citrus diseases

The biggest issue with the program is breach protocols/response. Required responses to breaches is not always consistent.

- IRS Breach protocol should be reviewed to account for California's situation

As the area in California quarantined for HLB continues to grow, consumer access to clean citrus trees, produced in accordance with the mandatory program, continues to decrease. This leads to greater incentive for unregulated "black market" citrus production.

Citrus Nursery Stock

The citrus nursery stock protocol provides standards and requirements for the interstate movement of citrus nursery stock from areas quarantined for citrus canker, huanglongbing, and/or Asian citrus psyllid. All interstate movement of citrus nursery stock is prohibited unless the conditions in the protocol are met.

The survey protocol for citrus nursery stock describes the rates of inspection, sampling, and testing required by the nursery stock protocol.

Please contact your local Citrus Health Response Program office if you have questions about the protocol.

- **Citrus Nursery Stock Protocol**
  - **Summary of Comments and APHIS' Summary**
- **Survey Protocol for Citrus Nursery Stock Protocol**

Citrus Nursery Stock Flickr Album

How to Help Save Our Citrus

Threats to Citrus

Asian Citrus Psyllid

Huanglongbing (HLB) is spread by a tiny insect, the Asian citrus psyllid (ACP, *Diaphorina citri*). First detected in Florida in 1998, ACP spread to Texas in 2001, California in 2008, and Arizona in 2009. ACP is now present in all citrus growing regions of the United States.

ACP reproduce on newly developing leaves, and while the insect itself causes little direct feeding damage, the insect can carry the bacteria that causes huanglongbing (*Candidatus* Liberibacter asiaticus*, CLas*)*.* ACP can transmit HLB to uninfected citrus trees as it feeds.

Citrus Black Spot

Citrus black spot (CBS), which is caused by the fungal pathogen *Phyllosticta citricarpa* (previously known as *Guignardia citricarpa*) was first found in south Florida, near Immokalee, in March 2010. CBS symptoms on fruit include hard spot, cracked spot, false melanose, freckle spot or early virulent spot, and virulent spot. Symptoms of CBS are easiest to observe during color break, when fruit turns from green to ripe coloration. When trees are severely infected, CBS can cause premature fruit drop before harvest, resulting in significant yield loss.

CBS is spread when wind-borne spores embed in the leaf litter under trees and are carried long distances by air currents. Rain splash may move spores short distances from infected fruit and/or leaf litter. Human-assisted movement of fruit and infected nursery stock is the main form of long distance movement.

Citrus Canker

Citrus canker is a disease caused by the bacterium, *Xanthomonas citri* subspecies *citri*. Infection causes lesions on the leaves, stems, and fruit of citrus trees. Typical lesions of the disease are raised, tan to brown in color, and have a water-soaked margin and yellow halos. The bacteria propagate in the lesions, which ooze bacterial cells that are dispersed by windblown rain, contaminated equipment, and movement of infected plants.

While not harmful to humans, uncontrolled canker infection can significantly affect tree health, causing leaves and fruit to drop prematurely. A fruit infected with canker is safe to eat, but its appearance can decrease its marketability.

Canker originated in southeast Asia. Citrus canker was first detected in the United States in 1910 and was eradicated in 1933. It was discovered again in 1995 in Miami-Dade County, Florida. Despite an aggressive tree removal program, USDA

was not able to eliminate canker in Florida a second time and ended eradication efforts in 2006. Canker is present in Florida, Louisiana, and parts of Texas.

Citrus Greening

Huanglongbing (HLB, also known as citrus greening) is the most serious citrus disease in the world and is caused by the bacterium *Candidatus* Liberibacter asiaticus. There is no cure for this disease once a tree is infected. While the disease poses no threat to humans or animals, it has devastated millions of acres of citrus production around the world, including in the United States.

HLB has been known in Asia since 1900, and Africa since 1920. The first detection of HLB in the Americans was in Brazil in 2004. The first detection of HLB in the United States was in Florida in 2005. HLB has been detected in all the major citrus growing states in the United States, except Arizona.

Once a tree is infected with the bacteria, the tree can remain without detectable symptoms for months or years. During this symptomless phase, the tree can serve as a source of bacteria to infect other trees. Over time, an infected tree will start producing fewer fruit that are smaller, shaped irregulary, and taste bitter. Affected trees have leaves with blotchy mottling, stunted growth, root die-back, and are prone to dropping fruit before it is ripe. Trees infected with HLB will eventually succumb to the disease.

Sweet Orange Scab

Sweet orange scab (SOS) is a disease caused by the fungus *Elsinöe australis*, which results in scab-like lesions primarily on fruit. The fruit are safe to eat, but the blemishes result in reduced marketability in the fresh fruit market. SOS can cause premature fruit drop and stunt young nursery trees and new field plantings.

SOS was first detected in the United States in 2010 in Texas. SOS is now confirmed in Louisiana, Florida, Mississippi, Texas, Arizona, and parts of California.

How to Help Prevent Citrus Diseases

Moving citrus trees is the fastest way that citrus diseases are spread. When you move citrus trees, you risk losing America's citrus.

You Can Help Prevent Citrus Disease

Citrus Story Map

Report Signs of Citrus Disease

If you think you have identified an infected plant, report it immediately. To avoid spreading the disease, do not move your plant. Complete the "Report It" form below or call your local USDA State Plant Health Director's office.

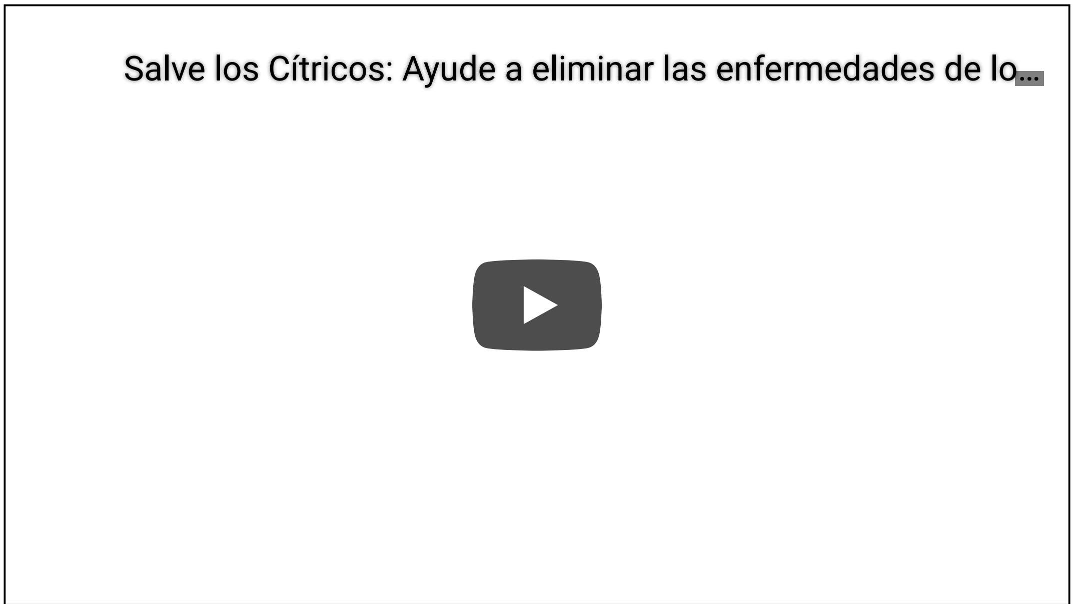
Report It Form (English)	**Report It Form (Espanol)**

If you are younger than 18 years of age, please ask a parent, guardian or trusted adult to help you complete the form.

Thank you for helping stop the spread of citrus disease!

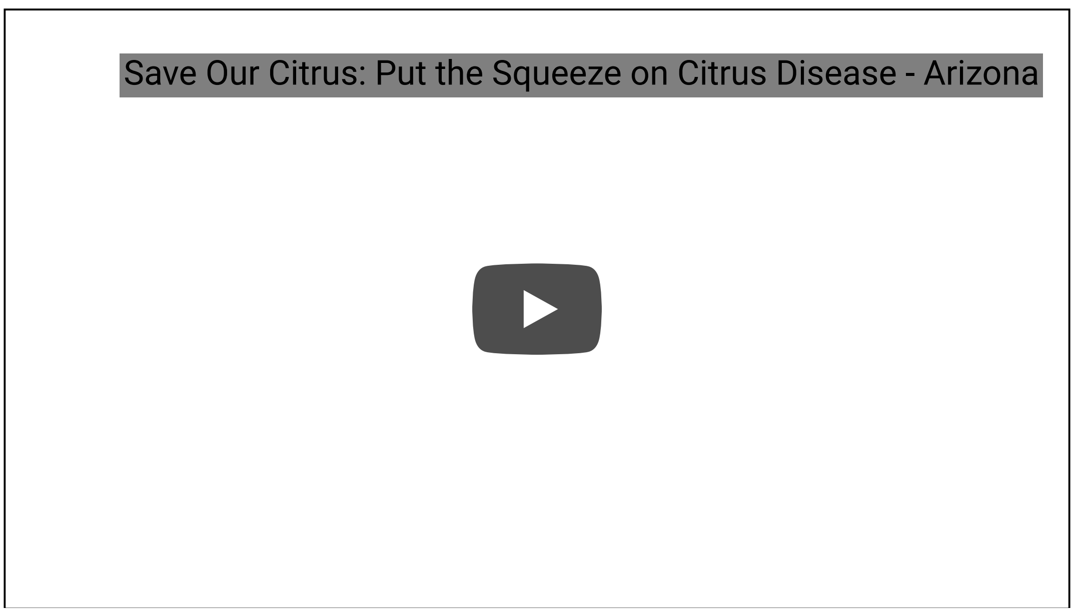
Videos

Salve los Cítricos: Ayude a eliminar las enfermedades de los cítricos



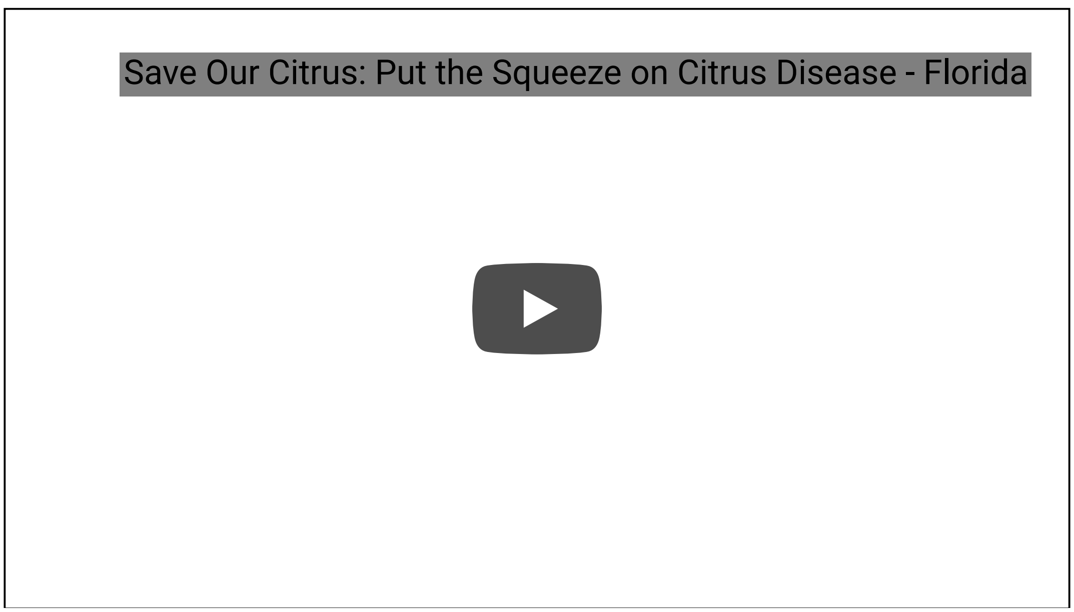
Save Our Citrus: Put the Squeeze on Citrus Disease

Arizona

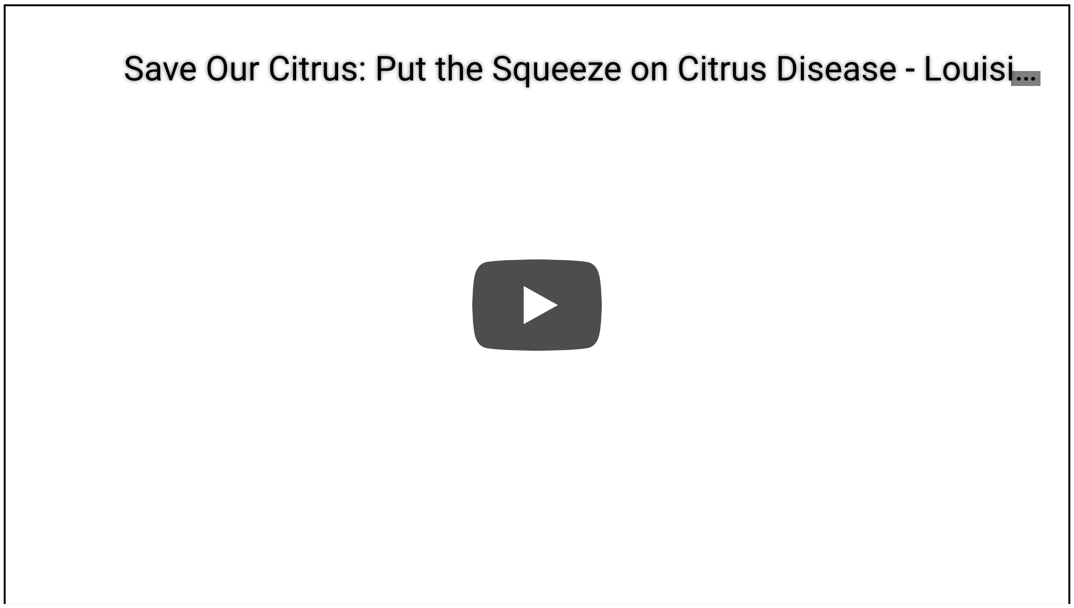


California

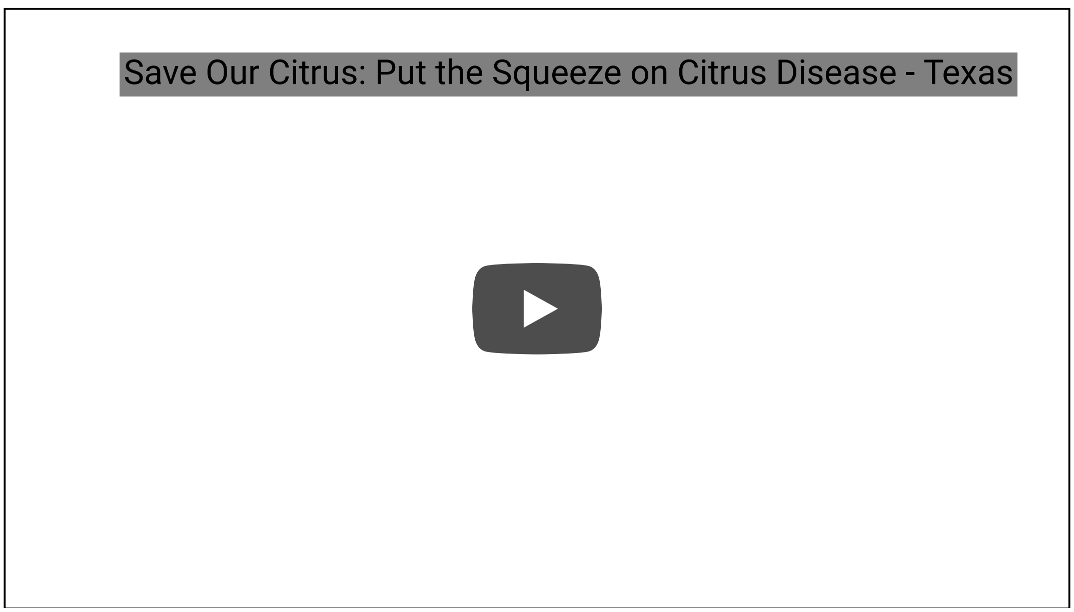
Florida



Louisiana



Texas



[Photo Galleries]

Nursery

[Citrus nursery:] Citrus nursery stock protocol provides standards and requirements for the interstate movement of citrus nursery stock from areas quarantined for citrus canker, huanglongbing, and/or Asian citrus psyllid. All interstate movement of citrus nursery stock is prohibited unless the conditions in the protocol are met. Protocols include monthly structural inspections, treatment logs and sampling.

Citrus Disease

Citrus Black Spot: Citrus black spot is a citrus disease caused by a fungus, which affects citrus plants throughout subtropical climates, reducing both fruit quantity and quality. Symptoms can be found on fruit and leaves, but are easiest to identify on mature fruit. Fruit are susceptible to infection for six months following fruit set. Leaves typically do not show symptoms, but foliar lesions can be observed on highly susceptible varieties, such as lemon, or on stressed trees. On lemon, fruit pedicels may also show symptoms. All citrus varieties are susceptible to citrus black spot, making strict regulation and management necessary to prevent spread of this disease.

Citrus Canker: Citrus canker is a citrus disease caused by a bacteria. While not harmful to humans, canker significantly affects the vitality of citrus trees, causing leaves and fruit to drop prematurely. Citrus canker causes lesions on citrus leaves, stems, and fruit. Characteristic lesions are raised and brown, have water-soaked margins, and usually have a yellow halo surrounding the lesion. Older lesions appear corky. Symptoms generally appear within 14 days of exposure to the canker bacteria. The bacteria remain viable in old lesions and on plant surfaces for several months. A fruit infected with canker is safe to eat but has reduced marketability as fresh fruit.

Citrus Greening: Huanglongbing (HLB), also known as citrus greening is the most serious citrus disease. It is caused by a bacteria which is spread by the Asian citrus psyllid (ACP), a tiny insect that transmits the bacteria to the tree when feeding. ACP transmits the bacteria to the tree when feeding on new shoots. There is no cure for this disease and all commercial varieties of citrus are susceptible to HLB. Symptoms of HLB-infected trees include blotchy mottle leaves, stunted growth, reduced fruit size, premature fruit drop, corky veins, and root decline. It is difficult to identify HLB-infected trees because they may remain asymptomatic for months to years after infection. HLB eventually kills the tree.

Sweet Orange Scab: Sweet orange scab is a disease caused by a fungus, which results in scab-like lesions primary on fruit and less frequently on leaves and twigs. The initial symptoms of sweet orange scab form on very young fruit as lesions that are slightly raised and pink to light brown. As the lesion expands, it becomes cracked or warty. The lesion color changes to yellowish brown and eventually to dark gray. Sweet orange scab can cause premature fruit drop and stunt young nursery trees and new field plantings, but has little impact on fruit quality. While there is no danger to humans, the blemished fruit has reduced marketability. Sweet orange and tangerine are common hosts, however all Citrus species are vulnerable.

Citrus Pest
Asian Citrus Psyllid: **Asian citrus psyllid is a tiny insect that feeds on citrus. While the insect causes little damage, it can carry a bacterium that causes the disease huanglongbing (HLB), also known as citrus greening. HLB is the most serious threat to U.S. citrus. Asian citrus psyllid is now present in all citrus growing regions of the United States.**

Bicontrol
Citrus Biocontrol: **USDA and our State partners currently release Tamarixia in Arizona, California, Florida, Louisiana, and Texas to protect America's citrus crops. These measures are used to control the population citrus pests such as the Asian citrus psyllid.**

Operations
Citrus Operations: **Citrus operations include biocontrol, regulatory activities in nurseries for interstate movement, multi-pest surveys for pest detection and delimiting surveys to control pest propagation. Other regulatory activities include packinghouse protocols for decontamination and treatment.**

Sampling
Citrus Sampling: **APHIS conducts multiple surveys and collects citrus samples to identify any new pest or disease incursions or find signs of citrus pathogens and disease already known to exist in the United States. Samples are taken from both dooryard and nursery sources during these surveys.**

Multi-Agency Response

Huanglongbing Multi-Agency Coordination (MAC)

Contact Us

State Citrus Contacts

CDFA Home ⁞ Plant Health ⁞ Pest Exclusion ⁞ NSC ⁞ Nursery Services ⁞ Citrus Nursery Stock

Citrus Nursery Stock Pest Cleanliness Program

The Citrus Nursery Stock Pest Cleanliness Program is a **mandatory** program for citrus nursery sources. All source trees for citrus propagative materials must meet the testing and maintenance requirements for this program.

Any citrus nursery stock production that does not meet the requirements of this Program may be subject to enforcement action by CDFA or the County Agricultural Commissioner.

General

- Citrus Nursery Stock Pest Cleanliness Program Regulations
- Annual Application and Lab Fees Notification 2021
- Annual Application for Registration of Citrus Trees 2021
- UCR Citrus Clonal Protection Program (CCPP)

Program Master Permits

Citrus Nursery Links

Quick Links

Online Nursery License Renewal

Nursery License Application Form

Nursery Inspection Procedures Manual


Directory

Nu

Pest Hotline: 1-800-491-1899

Contact Us

Nursery, Seed, & Cotton Program
1220 N Street, Room 221
Sacramento, CA 95814

Nursery Services
Ph: (916) 654-0435
Email: nurseryservices@cdfa.ca.gov

Seed Services Ph: (916) 403-6715
Email: seedservices@cdfa.ca.gov

Pest Exclusion

PE Home

Exterior Program

Interior Program

NSC Program Links

Home

Nursery Services

Seed Services

Registration and Certification

Improvement Advisory Board

Cotton Program

Nursery Services Staff List

Seed Services Staff List

Meeting Notices

County Contacts

California Food and Agricultural Code

California Code of Regulations

USDA Animal and Plant Health Inspection Service (APHIS)

California Agricultural Commissioners and Sealers Association (CACASA)

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Citrus Nursery Stock Pest Cleanliness Program

The following sections are extracts from the California Code of Regulations. They have been prepared by the Nursery, Seed, and Cotton Program, Pest Exclusion Branch, California Department of Food and Agriculture. These extracts are provided for information purposes only. For the official text, the user should consult the California Code of Regulations published by Barclays Law Publishers.

California Code of Regulations
Title 3. Food and Agriculture
Division 4. Plant Industry
Chapter 4. Plant Pathology
Subchapter 6. Plant Disease Control

3701. Citrus Nursery Stock Pest Cleanliness Program.

The following definitions apply to this section.

(a) “Applicant” means any person whose application has been submitted to but not yet accepted by the Department.

(b) “Authorized agent” means any person who has been granted authority by the Department to test plant and/or insect samples for the purposes of these regulations.

(c) “Breach” means any detectable opening of a size approximately 0.3 square millimeters inadvertently made in an insect-resistant structure.

(d) "Citrus" means "citrous" and any plants of the genera Citrus, Fortunella, Poncirus, and all hybrids having one or more of such as parents that could host any disease for which testing is required in Section 3701.6.

(e) “Citrus Clonal Protection Program” (CCPP) means the University of California at Riverside, Department of Plant Pathology & Microbiology.

(f) “Citrus Clonal Protection Program Tag Number” or “CCPP Tag Number” means the unique identifying number assigned by CCPP to a tree.

(g) “Citrus tree” means a rooted citrus plant.

(h) “Department” means the California Department of Food and Agriculture.

(i) “Department registration number” means the unique identifying number assigned by the Department to each registered mother tree, mother line or seed tree.

(j) “Foundation stock” means propagative materials collected or taken from trees maintained by the CCPP.

(k) “Infected” means that the presence of a pathogen listed in these regulations was detected using the testing methods specified in Section 3701.6.

(l) “Micro-propagation” means vegetatively propagating plant material in vitro by means of nodal cuttings

(m) “Official sample” means a sample collected by the Department.

(n) “Participant” means any person who agrees to fulfill the responsibilities of the participant described in

Section 3701.2, who has submitted an application to the Department and whose application has been accepted by the Department.

(o) "Propagative materials" means seeds, cuttings, buds, budsticks, graft sticks or micro-propagated materials taken from a citrus tree.

(p) "Registered" means the Department has approved a citrus tree or propagative material that has been propagated, planted, inspected, tested, and documented in accordance with the provisions of these regulations.

(q) "Registered increase tree" means a citrus tree, propagated using propagative materials from CCPP, or a registered mother tree or mother line, for the purpose of rapidly producing budwood, and that the Department has determined to be in compliance with the inspection, testing and other requirements specified in these regulations.

(r) "Registered mother line" means in vitro material introduced into culture from nodal cuttings at a particular time and from a single tree, to be used as a source of vegetative propagating material; and that the Department has determined to be in compliance with the inspection, testing and other requirements specified in these regulations and to which the Department has assigned a tag bearing that line's departmentally assigned registration number.

(s) "Registered mother tree" means a citrus tree, used as a source of vegetative propagating material, that the Department has determined to be in compliance with the inspection, testing and other requirements specified in these regulations and to which the Department has attached a tag bearing that tree's departmentally assigned registration number.

(t) "Registered seed tree" means a citrus tree, used as a source of seed only, that the Department has determined to be in compliance with the inspection, testing and other requirements specified in these regulations and to which the Department has attached a tag bearing that tree's departmentally assigned registration number.

(u) "Retesting" means that the Department has determined that additional samples will be collected and tested.

(v) "Target vector" means an insect vector of Tristeza or Huanglongbing.

(w) "Tested" means any test procedure using plant material or its extracts to determine the presence or absence of a disease or disease agent in or on the tested plant material. For the purposes of these regulations, testing will be in accordance with the procedures adopted by the Department for diseases and disease agents listed in Section 3701.6.

(x) "Topworking" means budding or grafting of another variety on top of existing stock.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code.
Reference: Sections 407, 2801, 5802, 5803, 6940 and 6941, Food and Agricultural Code.

3701.1. General Provisions.

(a) Participation in and compliance with the requirements of these regulations is mandatory for any person, with the exception of the Citrus Clonal Protection Program, who by any method of propagation, produces any citrus nursery stock propagative material. Under California Food and Agricultural Code Section 5803, it is unlawful for any person to bud, graft, or otherwise propagate or grow any citrus in violation of these regulations or to sell as nursery stock any bud, budsticks, or plant which is so produced.

(b) The participant shall annually sign and file a California Nursery Stock Registration and/or Certification Program Agreement, provided by the Department, acknowledging the responsibilities of participation in this program according to Title 3, Division 4, Section 3069, California Code of Regulations.

(c) Approvals, supervision, inspections, determinations and registration shall be conducted by the Department. Tests may be conducted by the Department or its authorized agents.

Note: Authority cited: Sections 407, 25801, 5802, 5803 and 6946, Food and Agricultural Code. Reference: Sections 407, 5801, 5802, 5803, 5310, 5311, 6940, 6941 and 6945, Food and Agricultural Code.

3701.2. Program Responsibilities.

(a) Responsibilities of the Participant

(1) Paying all fees as described in Section 3701.8.

(2) Providing the labor to collect samples for testing under the supervision of the Department.

(3) Submission of a completed, signed compliance agreement as required in Section 3701.4.

(4) Applying for the registration or re-registration of plants grown under the provisions of these regulations.

(5) Selecting tree(s) or mother lines for testing, and the proper maintenance of any plants being grown under the provisions of these regulations.

(6) Procuring qualified propagative materials for planting.

(7) Using propagation, farming, and sanitation practices as required in Section 3701.4.

(8) Removal of citrus trees or mother lines from insect-resistant structures when no longer eligible to be maintained within the structure.

(9) Maintain, and upon request, provide within five business days to the Department a record of all mother trees, mother lines, seed and/or increase trees registered by the participant, or other trees maintained in the same structure with registered material.

(A) For all mother trees, mother lines, seed trees, increase trees and nursery stock, the records shall include the sources(s) of the vegetative propagative materials used to produce the trees or mother lines and the date propagated, and shall be maintained for a minimum of five years from date of propagation.

(B) For all citrus vegetative propagative material that is produced from registered mother trees, mother lines, or increase trees and used for propagation or sold as propagative material, the records shall include disposition of such material including name and address of customer if applicable, Department registration number or CCPP tag number as applicable, quantity and kind of units of propagative material, and cultivar, and shall be maintained for a minimum of five years from date the material is produced.

(10) Taking precautions to guard against the introduction and spread of pests and diseases to plants entered in this program.

(11) Proper use of registration tags provided by the Department, including removal within five working days, of registration tags from citrus trees that have died, for which the Department issues a cancellation of registration notice, or that otherwise are no longer eligible for registration, maintaining control of registration tags issued to the participant, and ensuring that tags are not applied to plants or propagative materials that are not eligible.

(12) Proper use, maintenance and submission of Department-supplied insect monitoring traps.

(13) Notifying the Department at least 24 hours in advance of any pest control treatments in

plantings using a pesticide that has reentry or worker safety requirements that would create a health hazard for the Department's employees, or in any manner interfere with the Department's ability to conduct scheduled inspections or other field activities. This subsection only applies when the Department has notified the participant of the date of a planned inspection or other program-related action that would bring the Department's representative(s) into a treated area or into contact with treated plants.

(14) Notifying the Department of any trees for which registration is requested that are known to be infected with the citrus variant of the HSVd, citrus viroid IIa (CVd-IIa, Non-cachexia variant).

(15) Meeting the requirements of Title 3, Division 4, California Code of Regulations, Section 3060.4(a)(1)(D) when selling any propagative material infected with the citrus variant of the HSVd, citrus viroid IIa (CVd-IIa, Non-cachexia variant).

(b) Responsibilities of the Department.

(1) Maintain records of all registered mother trees, mother lines, seed and increase trees.

(2) Specify, in the registration record, those trees that are infected with the citrus variant of the HSVd, citrus viroid IIa (CVd-IIa, Non-cachexia variant).

(3) Process applications from applicant and/or requests for records from applicant within 10 business days of receipt.

(4) Release results of disease tests to participants within 5 business days of receiving final test results from the facility performing the diagnostics.

(5) Require that the facility performing the diagnostics include in its protocol a method of conducting additional diagnostic procedure(s) for any sample for which the results were inconclusive or positive.

(6) Require that the facility performing the diagnostics notify the Department within three business days of any inconclusive or positive test results.

(7) Upon receiving notification from the diagnostic facility, notify the affected participant within three business days of any inconclusive or positive test results.

(8) Approve insect-resistant structures.

(9) Inspect and test participants' citrus trees and mother lines in accordance with the provisions of these regulations and as required by the Department.

(10) Cancel registration of citrus trees and mother lines that are found to be infected with diseases listed in Section 3701.6, using tests prescribed in Section 3701.6, and/or the trees or mother lines have been produced out of compliance with the provisions of these regulations.

(11) The Department may issue special permits exempting researchers or others from compliance with any or all of the provisions of these regulations. The permit shall state any and all provisions under which citrus propagation will be allowed.

Note: Authority cited: Sections 407, 5705, 5801, 5802 and 6946, Food and Agricultural Code. Reference: Sections 407, 5310, 5311, 5705, 5801, 5802, 5803, 6940, 6941 and 6945, Food and Agricultural Code.

3701.3. Eligibility Requirements.

(a) Registered mother trees, registered mother lines and registered seed trees.

(1) Citrus trees registered under Title 3, Division 4, Chapter 3, subchapter 2, Article 1 before the effective date of these regulations may maintain their registration as long as they meet the maintenance requirements of Section 3701.4 and the testing requirements of Section 3701.6.

(2) Until July 1, 2011, mother trees and mother lines not previously registered, may be eligible for registration provided they have tested negative for Tristeza and Huanglongbing in the previous twelve months; and seed trees not previously registered may be eligible for registration.

(3) Other than as described in 3701.3(a)(1) and (a)(2), mother trees, mother lines and seed trees for which registration is requested shall have been propagated using scion materials obtained from or tested by CCPP in accordance with Table 1, or from registered mother trees; and rootstock shall be from registered seed sources or propagated vegetatively from registered sources.

(4) Registered mother trees may be topworked and thereafter re-registered, provided that the topworking was performed using only registered materials.

(5) Registered mother trees infected with the citrus variant of the HSVd, citrus viroid IIa (CVd-IIa, Non-cachexia variant), that otherwise meet the testing requirements of Section 3701.6 may be registered.

(b) Registered increase trees

(1) Propagative materials used in the production of increase trees shall be foundation stock, registered mother stock, registered mother line stock or registered seed tree stock.

(2) Registered mother trees may be topworked using registered materials to establish a registered increase tree.

(3) Until January 1, 2013, registered field-grown increase trees may be used as a source of propagative materials for a period of 18 months, beginning with the date the tree was propagated, with no additional testing.

(4) Registered increase trees, maintained in departmentally approved insect- resistant structures that meet the requirements of Section 3701.5, may be used as a source of propagative materials for a period of 48 months from date of propagation with no additional testing.

(5) Notwithstanding Section 3701.3(b)(4), no plant shall be maintained for a period longer than 72 months within an insect-resistant structure that also contains registered trees, unless that plant has been tested for Tristeza and Huanglongbing within the previous 72 months.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code.
Reference: Sections 407, 5310, 5311, 5801, 5802, 5803, 6940, 6941 and 6945, Food and Agricultural Code.

3701.4. Planting Location and Maintenance Requirements.

(a) Registered trees shall be located as follows:

(1) Mother trees and the rootstock used in their production may be field grown until January 1, 2012. To be eligible for registration after January 1, 2012, mother trees and the rootstock used in their production shall be maintained in departmentally approved insect-resistant structures that meet the requirements of Section 3701.5.

(2) Increase trees and the rootstock used in their production may be field grown until January 1, 2013. To be eligible for registration after January 1, 2013, increase trees and the rootstock used in their production shall be maintained in departmentally approved insect-resistant structures that meet the requirements of Section 3701.5.

(b) Notwithstanding Section 3701.4(a), any plant meeting the eligibility requirements of this program may be moved from one approved structure into another approved structure provided the plants are in the process of being actively relocated. Any plant moved during daylight hours shall be covered in a manner to protect against target vectors. If a screen covering is used, no openings shall be larger than approximately 0.3 square millimeters.

(c) Maintenance Requirements

(1) All plants entered in this program shall be kept in good growing condition and pests shall be kept under effective control.

(2) Only those plants meeting the eligibility requirements of these regulations, or nursery stock derived therefrom, may be planted or maintained inside a departmentally approved insect-resistant structure. After January 1, 2013, only nursery stock that has been propagated and maintained within a departmentally approved insect-resistant structure at all times is eligible to be maintained in a structure that also contains registered mother, seed or increase trees.

(3) Each participant maintaining an insect-resistant structure shall sign a compliance agreement with the Department that includes a plan developed by the participant and approved by the Department for meeting the following performance standard:

(A) Ensure proper utilization of entryways.

(B) Establish procedures that are sufficient to prevent entry or spread of diseases and/or target vectors.

(C) Maintain structural inspection schedule that is sufficient to ensure the integrity of the structure is maintained.

(D) Participant's response to structural breach.

(E) Ensure appropriate nursery personnel are trained in pest identification and plant inspection techniques.

(F) Ensure proper use of Department supplied traps.

(G) Participant's plan for major structure maintenance or replacement.

Note: Authority cited: Sections 407, 5705, 5801, 5802 and 6946, Food and Agricultural Code. Reference: Sections 407, 5310, 5311, 5705, 5801, 5802, 5803, 6940, 6941 and 6945, Food and Agricultural Code.

3701.5. Insect-Resistant Structures Performance Standard.

(a) Each insect-resistant structure shall be approved by the Department prior to planting or moving stock into it. Structures under construction or completed prior to the adoption of these regulations may be grandfathered in provided they meet the performance standards outlined below.

(b) All insect-resistant structures shall be enclosed with a covering to exclude target vectors and shall have entryways that prevent the entrance of target vectors.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code. Reference: Sections 407, 5310, 5311, 5801, 5802, 5803, 6940, 6941 and 6945, Food and Agricultural Code.

3701.6. Inspection and Testing Procedures.

(a) Except as otherwise provided, inspection and testing activities described in this section shall be made by the Department, or its authorized agents which, for the purposes of testing, include the Citrus Clonal Protection Program, the Central California Tristeza Eradication Agency and the Jerry Dimittman Laboratory. Official samples submitted to a facility that is certified by the United States Department of Agriculture to perform specific test(s) shall be eligible to fulfill those specific testing requirements of this program. All inspection and testing procedures shall be conducted at times determined suitable by the Department.

(b) Upon submittal of laboratory protocols, and Department review and acceptance thereof, agents may be granted authorization for performing any of the specific laboratory tests required by these regulations. Any change(s) in protocol(s) must be submitted to the Department for review and acceptance prior to their use in this program.

(c) The diseases and associated disease agents of concern to this program and approved test methods are listed below in Table I. Additional inspections and tests other than provided in this section may be required by the Department.

Table I: Diseases, Disease Agents of Concern and Approved Test Methods/Indicators

Diseases of Concern	**Disease Agent(s)**	**Test/Indicator Plant**
Viruses		
Infectious Variegation, Leaf rugose, Crinkly leaf	*Citrus variegation ilarvirus* *Citrus leaf rugose ilarvirus* *Citrus crinkly leaf ilarvirus*	Sour orange Etrog Citron
Leaf blotch Dweet mottle	*Citrus leaf blotch virus* (CLBV) aka *Dweet mottle virus* (DMV)	Dweet tangor
Leprosis	*Citrus leprosis rhabdovirus*	Sweet orange
Psorosis A & B (Ring spot)	*Citrus psorosis ophiovirus* (CPsV)	Sweet orange Dweet tangor
Satsuma Dwarf	*Satsuma dwarf virus* (SDV) group	Satsuma mandarin, Dweet tangor, White sesame (*Sesamum indicum*), ELISA
Tatter leaf-Citrange stunt	*Apple stem grooving capillovirus* (ASGV) aka *Citrus tatter leaf virus* (CTLV)	Rusk citrange/RL Citrus excelsa
Tristeza (Quick decline, Stem pitting, Seedling yellows)	*Citrus tristeza closterovirus* (CTV)	Mexican lime, ELISA, Immunoimpression Direct tissue-blot immunoassay
Yellow mosaic	*Citrus yellow mosaic badnavirus*	Sweet orange, pummelo, ELISA
Viroids		
Various citrus growth abnormalities and symptomatologies related to citrus viroids including exocortis and cachexia	*Citrus exocortis viroid* (CEVd), *Hop stunt viroid* (HSVd), Citrus variants of HSVd, *Citrus viroid-IIa* (CVd-IIa): Non-cachexia, CVd-IIIb & -IIc: Cachexia, *Citrus bent leaf viroid* (CBLVd) aka CVd-I, *Citrus dwarfing viroid* (CDVd) aka CVd-III, *Citrus bark cracking viroid* (CBCVd) aka CVd-IV, *Citrus viroid V* (CVd-V), *Citrus viroid VI* (CVd-VI) aka CVD-OS	Etrog citron Arizona 861-S1/RL and sPAGE,Imprint Hybridization

Procaryotes		
Citrus variegated chlorosis	*Xylella fastidiosa*	PCR and sequencing
Huanglongbing (Citrus greening)	*Candidatus* Liberobacter sp.	Sweet orange PCR Source plant observation
Stubborn	*Spiroplasma citri*	Culture Sweet orange
Witches' broom	*Candidatus* Phytoplasma aurantifolia	Mexican lime, PCR
Unknown		
Australian Dieback	Uncharacterized, probable phytoplasma	Sweet orange, grapefruit
Concave gum	Unknown	Dweet tangor Sweet orange
Chlorotic dwarf	Unknown	Sour orange, rough lemon
Cristacortis Impietratura	Unknown	Dweet tangor Sweet orange
Vein enation	Unknown, probably Luteovirus	Mexican lime Sour orange
Impietratura	Unknown	Dweet tangor. Sweet orange

(d) Testing. Tests shall be conducted as described in Table 1 unless the Department approves or requires changes.

(1) Mother trees and mother lines shall be tested as follows:

(A) Field-grown registered mother trees shall be tested by the Department annually for Tristeza and Huanglongbing, at least once every 36 months for viroids and at least once every 72 months for psorosis.

(B) Registered mother trees and mother lines, maintained in a departmentally approved insect-resistant structure meeting the requirements of Section 3701.5, shall be tested as follows:

1. For Tristeza and Huanglongbing:

A. Prior to their first use as a propagative source but no later than 72 months from date of propagation, the trees and mother lines shall be tested for Tristeza and Huanglongbing, and for the next two consecutive years following this initial testing.

B. Thereafter, to be used as propagative sources, the trees and mother lines shall have been tested within the previous three years for Tristeza and within the previous six years for Huanglongbing unless the disease is detected in the State. If Huanglongbing is detected in the State, the trees shall have been tested within the previous 36 months for Huanglongbing.

C. Registered trees not in current use as propagative sources must be tested at least once every six years to be eligible to remain in the program.

2. For Viroids:

A. Beginning January 1, 2013, to be used as propagative sources, the trees and mother lines shall have been tested within the previous three years, with the following exception,

B. Beginning January 1, 2016, mother trees and mother lines maintained in insect-resistant structures within which no trees have tested positive for viroids shall be tested prior to their first use as a propagative source and at least once every six years thereafter.

3. For psorosis: At least once every six years.

(C) In addition to the above, mother trees or mother lines found to be infected with the citrus variant of the HSVd, citrus viroid IIa (CVd-IIa, Non-cachexia variant) shall be tested to ensure the sequence similarity of the detected CVd-IIa with the Department approved growth modifying Tsn-RNA IIa.

(2) Seed trees shall be tested at least every six years for Huanglongbing, psorosis A & B and citrus leaf blotch virus.

(e) Should any tree within an insect-resistant structure test positive for any disease covered in these regulations, the Department may require additional testing of any tree within that structure. The Department's decision to require additional testing shall be based upon a risk evaluation conducted by the Department which shall be made available to the participant and include the following elements:

(1) Length of time deficiencies existed prior to correction.

(2) Size of breach, if applicable.

(3) Number and type of past actions taken by the Department.

(4) Type of pathogen or vector of concern.

(5) Identification of pathogen or vector.

(6) Test results.

(7) Presence or absence of pathogens, target vectors and hosts in the geographic area of nursery site at such distances or levels that spread of these pathogens or vectors into the nursery is either likely or not.

(8) Degree of infestation or population numbers of target vectors.

(9) Chemical application records supporting appropriate use of pesticides.

(10) Destruction or treatment of infested material.

(11) Interviews with employees or others familiar with operational procedures.

(f) The Department may require re-testing of any tree for which the test results are deemed inconclusive by the facility performing the diagnostics, or at the request of the affected participant.

(g) The Department may approve or require the substitution or addition of other tests, under generally accepted standards of scientific analysis, which are of equal or better reliability in detecting the diseases and disease agents of concern in this section.

(h) The Department shall publish a notice of approval of any test method which is substituted for or in addition to those listed in this section to program participants and on the Department's web site.

(i) Inspection. The Department may perform unannounced inspections of structures and/or plants entered in the program at any time during normal business hours. In addition, each participant nursery shall be subject to an annual inspection of the following:

(1) All required records pertaining to trees entered in the program.

(2) All insect-resistant structures maintained as part of the program.

(3) The participant's compliance agreement for insect-resistant structures.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code.
Reference: Sections 407, 5310, 5311, 5801, 5802, 5803, 6940, 6941, 6943 and 6945, Food and Agricultural Code.

3701.7 Refusal, Suspension or Cancellation of Registration.

(a) Registration may be suspended for any registered tree(s) or registered mother lines if any of the conditions listed below apply.

(1) Tests or visual inspections indicate that the citrus tree(s) or mother line(s), or any citrus tree(s) or mother line(s) within the same structure, are infected with the applicable disease or disease agent of concern listed in Section 3701.6; or

(2) The requirements of these regulations have not been met; or

(3) The pest cleanliness requirements for nursery stock in Title 3, Division 4, Section 3060.2 of California Code of Regulations have not been met; or

(4) The source that the citrus trees or mother lines were propagated from is diseased and the citrus trees or mother lines and their progeny are also suspected of being diseased.

(5) Participant's failure to meet the requirements in the compliance agreement.

(6) Breach of an insect-resistant structure.

(b) Registration may be canceled or refused for any registered tree(s) or mother lines if any of the conditions listed below apply.

(1) The citrus tree(s) or mother line(s) is/are infected with an applicable disease or disease agent of concern listed in Section 3701.6 and detected using a test listed in that section.

(2) The requirements of these regulations have not been met; or

(3) The pest cleanliness requirements for nursery stock in Title 3, Division 4, Section 3060.2 of California Code of Regulations have not been met; or

(4) The source that the citrus trees or mother lines were propagated from is diseased and their progeny are also determined to be diseased.

(5) Participant's failure to meet the requirements in the compliance agreement.

(6) Breach of an insect-resistant structure.

(c) The Department's decision to suspend, refuse or cancel registration of a citrus tree or trees shall be based upon a risk evaluation conducted by the Department which shall be made available to the participant and include the elements as described in Section 3701.6(e).

(d) Disposition of suspended and canceled trees or mother lines.

(1) Suspended trees or mother lines may be retained in the planting.

(2) Suspended trees or mother lines shall be clearly identified and written records maintained.

(3) Propagative materials from suspended trees or mother lines may, at the discretion of the Department, retain their registered status while testing to determine their disease status is in progress.

(4) Propagative materials from canceled trees or mother lines shall not be used.

(5) Trees or mother lines maintained in insect-resistant structures which have tested positive for any of the diseases listed in Section 3701.6(d) shall be removed by the participant within three business days of being notified by the Department that the tree or mother line is to be removed.

(e) Reinstatement of suspended trees or mother lines.

(1) Registration of suspended trees or mother lines and/or propagative materials may be reinstated if the Department determines that the suspension is no longer necessary. The Department may use testing and/or inspections to make this determination.

(2) Registered trees or mother lines may have their registration reinstated if they test negative for disease(s) shown to be infecting the source(s) from which they were propagated.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code.
Reference: Sections 407, 5310, 5311, 5801, 5802, 5803, 6940, 6941 and 6945, Food and Agricultural Code.

3701.8 Application and Fees.

(a) Application to register citrus trees may be made after the trees have been planted. Upon submitting an application the applicant shall consent to the taking of samples or plants from any planting by the Department for inspection or testing purposes. Application(s) shall be submitted as follows:

(1) For mother trees, mother lines, increase trees or seed tree(s), the participant shall submit an application for the initial registration and each year thereafter to request continued registration.

(2) The applicant shall submit an application on a form provided by the Department and provide the following information:

(A) Applicant's name and mailing address;

(B) Applicant's telephone and fax numbers, email address;

(C) Applicant's California Nursery Stock License Number;

(D) County where applicant is located;

(E) Type of planting:

1. Field, including number of trees

2. Insect-resistant structure, including Department-assigned insect-resistant structure number, location, square footage, and number of mother trees, mother lines, seed, increase and/or nursery trees per structure.

(F) Number of mother tree, mother line, seed, increase and/or nursery trees for which testing is requested.

(G) Location of planting, including county

(H) Signature and title of applicant; and

(I) Date application signed.

(b) Fees. Fees are to be used to reimburse the Department for the costs of administering the program, including defraying expenses incurred in the approval, inspection, testing, and registration procedures herein provided and are not to obtain any right or privilege. Fees, in whole or in part, may be waived if the cost of the services rendered is covered by assessment.

(1) Application fees shall be paid by the participant in advance of any work conducted.

(2) The Department may charge additional fees because of conditions or total acreage entered or number of tests performed when established minimum fees will not cover the cost of services.

(3) Fees paid for services that are not rendered shall be refunded to the participant. The amounts refunded may be prorated based on the direct costs incurred by the Department in the administration of the requirements of these regulations.

(4) Provided that the participant provides the labor to collect the samples, the fee schedule shall be:

(A) For mother tree, mother line, increase tree and seed tree registration, the annual application fee shall be $200 plus,

(B) For each tree or mother line to be tested:

1. $35 per tree or mother line for first 100 trees or mother lines, or

2. $3,500 plus $30 per tree or mother line beginning with the 101st tree or line for 101-300 trees or lines, or

3. $9,500 plus $25 per tree or mother line beginning with the 301st tree or line for more than 300 trees or lines,

(C) For insect-resistant structures, an annual program fee of $300 for all structures at one location, plus $.01/square foot.

(D) In addition to the above fees, an additional fee will be assessed equal to the amount charged by the laboratory selected by the Department to do the analyses.

Note: Authority cited: Sections 407, 5801, 5802 and 6946, Food and Agricultural Code.
Reference: Sections 407, 5801, 5802, 5803, 6940, 6944 and 6945, Food and Agricultural Code.

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
Karen Ross, Secretary

September 22, 2021

To: **Citrus Nursery Stock Pest Cleanliness Program Participants**

Subject: **2021/22 Program Fees, Application Timeline, and Laboratory Procedure Updates**

The following is an update regarding program fees, application timeline, and laboratory procedures for the Citrus Nursery Stock Pest Cleanliness Program.

Except as noted below, all scion source trees that require disease testing during 2021/22 will be tested for tristeza (CTV), Huanglongbing (HLB), psorosis (CPsV), and viroids. All seed source trees that require disease testing during 2021/22 will be tested for HLB, CPsV, and leaf blotch (CLBV).

Program Fees and Application Timeline

To cover laboratory costs, the total laboratory fee for testing scion source trees will be $118 per sample. The total lab fee for testing seed trees will be $100 per sample.

These laboratory fees are included on the Application for Registration of Citrus Trees (Form 65-057, revised 09/21), along with the annual application fee, collection fee, and structure fee, in accordance with California Code of Regulations (CCR), Title 3, Section 3701.8.

The application, program agreement (3 CCR Section 3069), and corresponding fees must be submitted annually by participants. Fillable copies of both the application and program agreement can be found on our website at: http://www.cdfa.ca.gov/plant/pe/nsc/nursery/citrus.html.

Fees may be paid via check payable to "**CDFA 90012**", and sent with completed paperwork to:

Cashier
Department of Food and Agriculture
1220 N Street
Sacramento, CA 95814

Applications and fees must be received by the Program **prior** to collection of samples or inspections by Program staff.

Sample collection will begin in October and continue for approximately fifteen weeks. Any required resampling will be performed as needed beginning in February and testing results should be mailed to participants by mid-May.

While preparing testing results reports, the Program will review the prior year's applications and payments and will mail out adjusted billing or reimbursements to those participants where a correction is needed.

For nurseries participating in the Voluntary Pre-Quarantine HLB Sampling and Testing Program:

- We will be working with each nursery to try to prevent duplication of efforts and costs.
- Please notify program staff when contacted to discuss your individual situation and determine the best course of action for your nursery.
- Lab fees will be reduced for those samples that are not submitted by the program for HLB testing.
- Service fees will be charged for any additional samples collected by program staff.

Should you have any questions, please feel free to contact the Nursery, Seed, and Cotton Program at (916) 654-0435 or nurseryservices@cdfa.ca.gov.

Sincerely,

Juan Koponen
Environmental Program Manager
Nursery, Seed, and Cotton Program
Plant Health and Pest Prevention Services

STATE OF CALIFORNIA
DEPARTMENT OF FOOD AND AGRICULTURE
PEST EXCLUSION/NURSERY, SEED & COTTON PROGRAM
Form 65-057 (REV. 09/2021)

APPLICATION FOR REGISTRATION OF CITRUS TREES

Application is hereby made to the DEPARTMENT OF FOOD & AGRICULTURE for the registration of citrus trees and/or mother lines:

APPLICANT		TELEPHONE	NURSERY LICENSE NUMBER
ADDRESS		COUNTY	E-MAIL
CITY	STATE	ZIP CODE	DATE OF APPLICATION

TESTING REQUIREMENTS:

Registered mother trees and mother lines shall be tested for Tristeza and Huanglongbing prior to their first use as a propagative source, and for the next two consecutive years following initial testing. Thereafter, they shall be tested at least once every three years for Tristeza and Huanglongbing.

Mother trees and mother lines shall have been tested for viroids within the previous three years. However, trees and mother lines in insect-resistant structures within which no trees have tested positive for viroids shall be tested prior to their first use as a propagative source, and at least once every six years thereafter.

Mother trees and mother lines shall be tested at least once every six years for Psorosis.

Seed trees shall be tested at least every six years for Huanglongbing, Psorosis A & B, and citrus leaf blotch virus.

Trees not used as a propagative source must be tested for Tristeza and Huanglongbing at least once every six years to be eligible for the program. Only plants meeting the eligibility requirements may be maintained in an insect-resistant structure that also contains registered material.

ATTACHMENT:

Applicant shall include planting information with this application, including type and location of planting, and inventory of registered trees. Additionally, for insect-resistant structures the required information includes: Department-assigned insect-resistant structure number, location, square footage, and number of mother trees, mother lines, seed, increase, and/or nursery trees within each structure.

SCHEDULE FOR THE CALCULATION OF FEES TO BE REMITTED WITH THIS APPLICATION

A. APPLICATION FEE: To be paid by all applicants once a year.	**$200.00**
B. FOR EACH TREE TO BE TESTED **(choose one of the following)**: • For 100 trees or mother lines or less, $35 per tree or mother line. [No. of trees ( ) x ($35)] = • For 101-300 trees or mother lines, $3,500 plus $30 per tree or mother line beginning with the 101st. $3,500 + [No. of trees ( ) – 100 = ( ) x ($30)] = • For more than 300 trees or mother lines, $9,500 plus $25 per tree or mother line beginning with the 301st. $9,500 + [No. of trees ( ) – 300 = ( ) x ($25)] =	$
C. LABORATORY FEES **(for all trees tested in B)**: • No. of Scion Trees and/or Mother Lines tested ( ) x $118 = PLUS • No. of Seed Trees tested ( ) x $100 =	$
D. INSECT RESISTANT STRUCTURES: For insect-resistant structures, an annual program fee of $300 for all structures at one location, plus $0.01 per square foot. [Number of structure locations ( ) X $300 = $ _______] PLUS [Total square footage ( ) X $0.01 = $ _______] =	$
TOTAL (A + B + C + D)	$

This application is for the purpose of testing and/or registration of the trees listed. Applicant agrees to provide the labor to collect the plant material for testing under the supervision of the Department. All inspections and any registration and/or testing shall be in accordance with the regulations adopted by the Secretary of Food and Agriculture. Certification does not express or imply any warranty of the Department regarding the freedom from disease or quality of the nursery stock. The Department is not responsible for any loss resulting from disease, misuse of tags or other indicia of certification, failure to comply with provisions of the regulations, or otherwise.

SIGNATURE	TITLE	DATE

NOTE: Please make your remittance payable to **"CDFA 90012"** and forward with your application to:
CASHIER, DEPARTMENT OF FOOD AND AGRICULTURE
1220 N Street
Sacramento, CA 95814

STATE OF CALIFORNIA

Gavin Newsom, Governor

DEPARTMENT OF FOOD AND AGRICULTURE

KAREN ROSS, Secretary

1220 N Street, Nursery Services
Sacramento, CA 95814
Phone: (916) 654-0435
Fax: (916) 651-1207

CALIFORNIA NURSERY STOCK REGISTRATION AND/OR TESTING OF CITRUS TREES PROGRAM AGREEMENT

Each participant in the California Nursery Stock Registration and/or Testing of Citrus Trees Program is required to sign this agreement as a condition of participation as provided in the California Code of Regulations, Title 3, Section 3069.

PLEASE READ THIS CAREFULLY AND COMPLETELY BEFORE SIGNING

3069. Disclaimer of Warranties and Financial Responsibility; Implementing Agreements and Forms.

(a) Nature of “Registration” and/or “Certification.” The terms “registration” and/or “certification” as used in the Programs mean that Department employees or agents have visually inspected growing grounds and crops thereon as described in this article. The terms do not mean that the Department has inspected or is responsible for nuclear or parent stock, or that the Department has control over the labeling of the stock by Program participants. Registration and/or certification does not guarantee or warrant that the articles to which foundation, registration or certification tags are attached, or which are otherwise represented as foundation, registered or certified are merchantable or fit for a particular purpose.

(b) The Department of Food and Agriculture disclaims all express or implied warranties, including without limitation, implied warranties of merchantability and fitness for a particular purpose, regarding all plants, plant parts, and plant materials under any Nursery Stock Registration and/or Certification Program. The Department is not responsible for disease, genetic disorder, off-type, failure of performance, mislabeling, or otherwise, in connection with these Programs. In any event, Department liability is limited to the cost of purchase price of the plants, plant parts, or plant material involved. No grower, nursery, dealer, government official or other person is authorized to give any express or implied warranty or accept any financial responsibility on behalf of the Department regarding these Programs, except as provided in this section.

(1) The undersigned grower is a participant in the

Citrus Nursery Stock Pest Cleanliness

____

program of the Department of Food and Agriculture. The applicant understands that the following limitations apply:

LIMITS OF LIABILITY

(A) The Department of Food and Agriculture disclaims all express or implied warranties, including without limitation, implied warranties of merchantability and fitness for a particular purpose.

(B) The Department is not responsible for disease, genetic disorders, off-types, failure of performance, mislabeling, or otherwise, in connection with the Program.

(C) In any event, Department liability is limited to the cost of purchase price of the plants, plant parts or plant material.

(D) No grower, nursery, dealer, government official or other person is authorized to give any express or implied warranty, or accept financial responsibility on behalf of the Department regarding the Program, except as provided in California Code of Regulations, Section 3069.

(2) Participant agrees to the above limitations of liability and further agrees:

(A) To waive any and all causes of action for damages, indemnification, or otherwise, which may accrue to the applicant in any manner against the State of California, the Department, its officers, agents, and employees in connection with the Departments participation in the Program;

(B) To indemnify, defend and save harmless the State of California, the Department and its officers, agents, and employees from any and all claims or losses occurring or resulting from the Department's participation in the Program in connection with participants activities;

(C) To attach to each container of foundation, registered or certified nursery stock a tag, accurately and fully completed. In lieu of a tag on each container, a notice, accurately and fully completed, may be printed on or attached to each bulk delivery invoice. Each tag and notice will be in the form provided by California Code of Regulations, Section 3069(b); and

(D) Not to advertise or otherwise represent that the Department certifies freedom from disease, genetic disorder, off-type or any aspect of performance, nor that the Department has any financial responsibility with regard to the Program.

This agreement shall be deemed to incorporate future amendments to the Food and Agricultural Code and California Code of Regulations relating to the Nursery Stock Registration and/or Certification Program.

This agreement shall remain in effect for the current and each succeeding year of Program participation.

____________________ ______________________________________
Date Signature

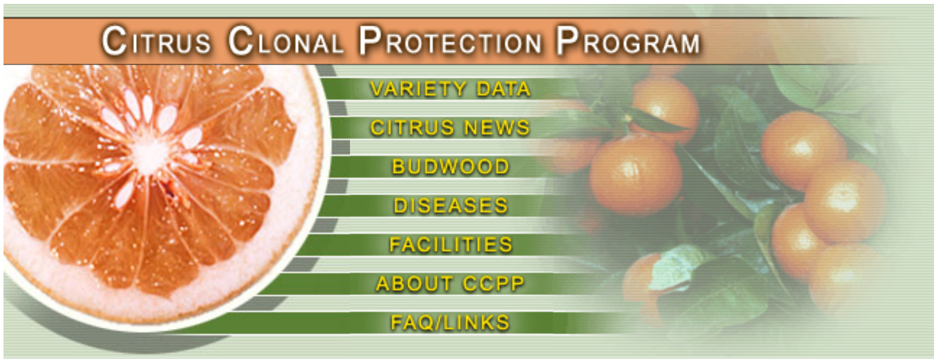
____
Name and Title of Grower Representative

____
Name of Nursery

____
Street Address

____
City and Zip Code

Note: If participant is a sole proprietorship, the owner must sign; if a partnership, a managing partner; if a corporation, an executive officer. Keep a signed copy for you file.



The **Citrus Clonal Protection Program** has its roots in the 1933 original discovery of the virus nature of the citrus psorosis disease by Dr. H. S. Fawcett of the Citrus Experiment Station at Riverside. That discovery triggered the establishment of the Psorosis Freedom Program in 1937. In 1957, the Citrus Variety Improvement Program was inaugurated and it was later renamed to Citrus Clonal Protection Program (CCPP).

Citrus Clonal Protection Program
... starting citrus correctly

Today the CCPP stands as a cooperative program with the University of California, Riverside (UCR)-Department of Plant Pathology and Microbiology, the California Department of Food and Agriculture (CDFA), the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) and the citrus industry of the state of California represented by the California Citrus Nursery Board (CCNB) and the Citrus Research Board (CRB). Since 2009, the CCPP has been a part of the National Clean Plant Network (NCPN) for specialty crops.

-Make a Gift to the CCPP Foundation

-Upcoming Citrus Varieties

-Start a Citrus Variety Introduction Inquiry

-Order Budwood Online

Download the ***CCPP Brochure***

The CCPP provides a safe mechanism for the introduction into California of citrus varieties from any citrus-growing area of the world for research, variety improvement, or for use by citrus enthusiasts and the commercial industry of the state. This mechanism includes, disease diagnosis and pathogen elimination followed by maintenance and distribution of true-to-type, primary citrus propagative material of the citrus varieties.

Get more information about **Citrus Variety Introduction**

CCPP Pathogen Elimination from Citrus Varieties Flow Chart

Start a Citrus Variety introduction Inquiry

The CCPP distributes citrus budwood in accordance to the California Department of Food and Agriculture regulations to anyone interested to propagate citrus trees for commercial or personal use. The CCPP does not distribute citrus seeds, rootstocks, or trees. For such items contact your local nursery or click here for more information.

Download the **CCPP Budwood Flyer**

Order Budwood Online

Event Calendar

Upcoming Budwood Cut Dates

Contact Us

Citrus Clonal Protection Program
Department of Plant Pathology
University of California
Riverside, CA 92521
Voice: (951) 237-0303 for general inquiries
(559) 429-9718 for budwood sales
Fax: (951) 827-4294
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Acknowledgments

The CCPP would like to thank the citrus growers and nurserymen of California for their generous support, financial and otherwise as well as the University of California Lindcove Research and Extension Center for the excellent collaboration and maintenance of the CCPP Foundation Block Operations.

University of California, Riverside

Citrus Clonal Protection Program-Data Management System (CCPP-DMS)

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§ 3435. Asian Citrus Psyllid Interior Quarantine.

A quarantine is established against the following pest, its hosts and possible carriers.

(a) Pest. Asian Citrus Psyllid (*Diaphorina citri*).

(b) Regional Quarantine Zones:

(1) A county or portion thereof shall be included in an appropriate host nursery stock regional quarantine zone and bulk citrus regional quarantine zone when survey results indicate an infestation is present or not, and the Department has evaluated the county based on the pest risk factors in Subsection (b)(2), or the local California County Agricultural Commissioner(s) is notified and requests the county be included into a regional quarantine zone. The Department shall also issue electronic and/or written notification of the regional quarantine zone designation(s) to other California County Agricultural Commissioners and other interested or affected parties and post notification of the designation to its website at: https://www.cdfa.ca.gov/plant/acp/regulation.html. The notification shall include a web link to a map of the host nursery stock regional quarantine zones and bulk citrus regional quarantine zones, a list of the counties or portions thereof in each regional quarantine zone, a written description of the Department's evaluation of the pest risk factors associated with the county or portion thereof, and instructions on the process to appeal the designation of a county or portion thereof into a regional quarantine zone. Automatic notifications of any changes in regional quarantine zone designations will be available through a list serve option. Any individual or local entity may appeal the designation of a county or portion thereof into a regional quarantine zone by submission to the Department of a written request for review of the designation accompanied by clear and convincing evidence justifying a change in the designation. The appeal must be filed no later than ten (10) working days following issuance of the notice of designation by the Department. The Department must respond with a written decision no later than ten (10) working days following receipt of the appeal. During the pending of the appeal, the designation under appeal shall remain in effect.

(2) A county or a portion thereof shall be included in a regional quarantine zone based upon a combination of the following pest risk factors:

(A) The level of Asian citrus psyllid infestation

1. Generally Infested Regions are counties or parts of counties where multiple asian citrus psyllids are routinely detected throughout the area and during every survey period.

2. Partially Infested Regions are counties or parts of counties where asian citrus psyllids have been detected, but are not routinely detected throughout the area or during every survey period

3. Uninfested Regions are counties or parts of counties where asian citrus psyllids have not been detected

(B) The presence of or proximity to Huanglongbing disease detections

(C) The proximity to the United States/Mexico border

(D) Geographical barriers to the natural movement of ACP, such as mountains or host-free areas

(E) Contains a commercial citrus growing region

(F) Whether sufficient citrus commodity cleaning and packing capacity is available to process the majority of citrus grown in a region, as determined by the Department in consultation with citrus industry experts knowledgeable in citrus variety, acreage increase or decrease trends, historical production volumes for different regions, and volume capability of cleaning and packing capacity in different regions.

(3) The following Host Nursery Stock Regional Quarantine zones and Bulk Citrus Regional Quarantine zones will be designated to restrict movement of Asian citrus psyllid host material.

Nursery Stock Regional Quarantine Zone 1 comprises uninfested counties, geographical barriers exist between it and Zone 3, and it is not proximate to the border with Mexico.

Nursery Stock Regional Quarantine Zone 2 comprises counties that are partially infested with ACP, geographical barriers exist between it and Zone 3, HLB has not been detected, and the zone is not proximate to the border with Mexico.

Nursery Stock Regional Quarantine Zone 3 comprises counties that are generally infested with ACP, HLB has been detected in some areas, and the zone is proximate to the border with Mexico.

Bulk Citrus Regional Quarantine Zone 1 comprises uninfested counties where HLB has not been detected, there are no contiguous citrus growing regions, and it is not proximate to the border with Mexico.

Bulk Citrus Regional Quarantine Zone 2 comprises counties that are partially infested with ACP, HLB has not been detected, a geographical barrier exists between it and adjacent citrus growing regions (i.e., Zones 4, 5, and 6), a citrus growing region exists within the zone, sufficient citrus commodity cleaning and packing capacity exists within the zone, and geographical barriers separate it from zones that are generally infested with ACP and where HLB has been detected (i.e., Zone 6).

Bulk Citrus Regional Quarantine Zone 3 comprises counties that are partially infested with ACP, HLB has not been detected, a geographical barrier exists between it and adjacent citrus growing regions (i.e., Zones 2 and 4), a citrus growing region exists within the zone, sufficient citrus commodity cleaning and packing capacity exists within the zone, and geographical barriers separate it from zones that are generally infested with ACP (i.e., Zone 4) or where HLB has been detected (i.e., Zone 6).

Bulk Citrus Regional Quarantine Zone 4 comprises counties that are generally infested with ACP, HLB has not been detected, a geographical barrier exists between it and adjacent citrus growing regions (i.e., Zones 2 and 3), a citrus growing region exists within the zone, sufficient citrus commodity cleaning and packing capacity exists within the zone, geographical barriers separate it from Zone 6 where HLB has been detected, and it is not proximate to the border with Mexico.

Bulk Citrus Regional Quarantine Zone 5 comprises counties that are generally infested with ACP, HLB has not been detected, a geographical barrier exists between it and adjacent citrus growing regions (i.e., Zones 4 and 6), a citrus growing region exists within the zone, sufficient citrus commodity cleaning and packing capacity exists within the zone, a geographical barrier separates it from Zone 6 where HLB has been detected, and it is proximate to the border with Mexico.

Bulk Citrus Regional Quarantine Zone 6 comprises counties, or portions of counties, that are generally infested with ACP, HLB has been detected in some areas, a geographical barrier exists between it and adjacent citrus growing regions (i.e., Zones 2, 4, and 5), a citrus growing region exists within the zone, sufficient citrus commodity cleaning and packing capacity exists within the zone, and it is not proximate to the border with Mexico.

Bulk Citrus Regional Quarantine Zone 7 comprises counties that are partially infested with ACP, HLB has not been detected, there are no contiguous citrus growing regions, and it is not proximate to the border with Mexico.

(c) Articles and Commodities Covered. The following are declared to be hosts and possible carriers of *Diaphorina citri.*

(1) All nursery stock, plants, plant parts, including green waste, and plant products capable of propagation, except seed, extracted from fruit of:

Aegle marmelos (bael, Bengal quince, golden apple, beta, milva)

Aeglopsis chevalieri (Chevalier's aeglopsis)

Afraegle gabonensis (Gabon powder-flask)

Afraegle paniculata (Nigerian powder-flask)

Amyris madrensis (mountain torchwood)

Atalantia monophylla (Indian atalantia)

Atalantia spp.

Balsamocitrus dawei (Uganda powder-flask)

Bergia (=Murraya) koenigii (curry leaf)

Calodendrum capense (Cape chestnut)

X Citrocirus webberi

Choisya arizonica (Arizonia orange)

Choisya ternata (Mexican or mock orange)

Citropsis articulata (Katimboro, Muboro, West African cherry orange)

Citropsis gilletiana (cherry-orange)

Citropsis schweinfurthii (African cherry-orange)

Citrus aurantiifolia (lime, Key lime, Persian lime, lima, limón agrio, limero)

Citrus aurantium (sour orange, Seville orange, marmalade orange, naranja agria, naranja amarga)

Citrus hystrix (Mauritius papeda, Makrut lime)

Citrus jambhiri (rough lemon, jambhiri-orange, limón rugoso, rugoso)

Citrus limon (lemon, limón, limonero)

Citrus madurensis (=X Citrofortunella microcarpa)

Citrus maxima (pummelo, pomelo, shaddock, pompelmous, toronja)

Citrus medica (citron, cidra, cidro, toronja)

Citrus meyeri (Meyer lemon, dwarf lemon)

Citrus x nobilis (king mandarin, tangor, Florida orange, King-of-Siam)

Citrus x paradisi (grapefruit, pomelo, toronja)

Citrus reticulata (mandarin, tangerine, mandarina)

Citrus sinensis (sweet orange, orange, naranja, naranja dulce)

Citrus spp.

Clausena anisum-olens (anis)

Clausena excavata (clausena)

Clausena indica (clausena)

Clausena lansium (wampi, wampee)

Clymenia polyandra (a-mulis)

Eremocitrus glauca (Australian desert lime)

Eremocitrus hybrid

Esenbeckia berlandieri (Berlandier's jopoy)

Fortunella crassifolia (Meiwa kumquat)

Fortunella margarita (Nagami kumquat, oval kumquat)

Fortunella polyandra (Malayan kumquat)

Fortunella spp.

Limonia acidissima (Indian wood apple)

Merrillia caloxylon (flowering merrillia)

Microcitrus australasica (finger-lime)

Microcitrus australis (Australian round-lime)

Microcitrus papuana (desert-lime)

X Microcitronella spp.

Murraya spp. (curry leaf, orange-jasmine, Chinese-box, naranjo jazmin)

Naringi crenulata (naringi)

Pamburus (=Atalantia) missionis (pamburus)

Poncirus trifoliata (trifoliate orange, naranjo trebol)

Severinia buxifolia (Chinese box-orange)

Swinglea glutinosa (tabog)

Tetradium ruticarpum (evodia, wu zhu yu)

Toddalia asiatica (orange climber)

Triphasia trifolia (trifoliate limeberry, triphasia)

Vepris (=Toddalia) lanceolata (white ironwood)

Zanthoxylum fagara (wild lime, lime prickly-ash)

(2) Any other articles which are infested or exposed to infestation by *Diaphorina citri*.

(3) Possible carriers shall include all appliances used in the growing, harvesting, processing and hauling of the host plants and plant parts and any green waste residues including but not limited to tractors, trailers, trucks, planting, picking and pruning equipment and processing machinery and any other article, thing or means of conveyance when it is determined by the Secretary or county agricultural commissioner to present a hazard of spreading live life stages of the *Disphorina citri*.

(4) Citrus fruit in bulk containers or bins or any citrus fruit with leaves and stems attached and associated green waste.

(5) Exemptions. The following articles are exempt from the provisions of this subsection:

(A) Defoliated dormant bare-rooted nursery stock;

(B) Defoliated dormant nursery stock in containers where all leaf litter and any weeds have been removed;

(C) Host fruit commercially cleaned, graded, and packed within a bulk citrus regional quarantine zone may move within or from the quarantine zone;

(D) Non-commercially cleaned host fruit for personal consumption and under 25 pounds in weight may move within and from the bulk citrus regional quarantine zones if free of all stems and leaves;

(E) Green waste of citrus fruit covered in subsection (c)(4) may move within a bulk citrus quarantine zone.

(d) Restrictions.

(1) Host Nursery Stock Regional Quarantine zones.

(A) Articles and commodities covered in subsection (c) (1) and (2) are prohibited movement from Host Nursery Stock Regional Quarantine Zones 2 or 3 except if moved under the terms of a special permit as authorized under Title 3, Section 3154 of the California Code of Regulations. All nursery stock covered in subsection (c) (1) offered for sale or distribution in Nursery Regional Quarantine Zones 2 or 3 shall be cleaned and/or treated in a manner to eliminate all live life stages of *Disphorina citri* to the satisfaction of the Department or county agricultural commissioner and bear a zone-specific label stating that it may not be moved outside of the nursery regional quarantine zone.

(B) Articles or commodities originating in the Host Nursery Stock Regional Quarantine Zone 1 may be moved directly through and delivered to the other Host Nursery Stock Regional Quarantine zones without delay and by a direct route in an enclosed vehicle or container or completely enclosed by a covering to prevent exposure to the *Disphorina citri* while transiting the zone.

(2) Bulk Citrus Regional Quarantine zones.

(A) Articles and commodities covered in subsection (c)(4) are prohibited movement from or within a Bulk Citrus Regional Quarantine Zone except if the article or commodity covered is moved under the terms of a special permit as authorized under Title 3, Section 3154 of the California Code of Regulations or under subsection (d)(2)(B).

(B) Articles or commodities originating in the Bulk Citrus Regional Quarantine Zone 1 may be moved directly through and delivered to the other bulk citrus regional quarantine zones without delay and by a direct route in an enclosed vehicle or container or completely enclosed by a covering to prevent exposure to the *Disphorina citri* while transiting the zone.

(3) Articles and commodities covered in subsection (c)(3) are prohibited movement from any regional quarantine zone except if cleaned and/or treated in a manner to eliminate all live life stages of *Disphorina citri* citri to the satisfaction of the Department or county agricultural commissioner.

Note: Authority cited: Sections 407, 5301, 5302 and 5322, Food and Agricultural Code. Reference: Sections 401.5, 407, 5301, 5302, 5321 and 5322, Food and Agricultural Code.

HISTORY

1. New section filed 9-5-2008 as an emergency; operative 9-5-2008 (Register 2008, No. 36). A Certificate of Compliance must be transmitted to OAL by 3-4-2009 or emergency language will be repealed by operation of law on the following day.

2. Amendment of subsection (b) filed 9-17-2008 as an emergency; operative 9-17-2008 (Register 2008, No. 38). A Certificate of Compliance must be transmitted to OAL by 3-16-2009 or emergency language will be repealed by operation of law on the following day.

3. Amendment of subsection (b) filed 10-29-2008 as an emergency; operative 10-29-2008 (Register 2008, No. 44). A Certificate of Compliance must be transmitted to OAL by 4-27-2009 or emergency language will be repealed by operation of law on the following day.

4. Amendment of subsection (b) filed 12-4-2008 as an emergency; operative 12-4-2008 (Register 2008, No. 49). A Certificate of Compliance must be transmitted to OAL by 6-2-2009 or emergency language will be repealed by operation of law on the following day.

5. Refiling of 9-5-2008, 9-17-2008 and 10-29-2008 orders on 3-4-2009 as an emergency; operative 3-4-2009 (Register 2009, No. 10). A Certificate of Compliance must be transmitted to OAL by 6-2-2009 or emergency language will be repealed by operation of law on the following day.

6. Amendment of subsection (b) filed 3-18-2009 as an emergency; operative 3-18-2009 (Register 2009, No. 12). A Certificate of Compliance must be transmitted to OAL by 9-14-2009 or emergency language will be repealed by operation of law on the following day.

7. Certificate of Compliance as to 12-4-2008 and 3-4-2009 orders transmitted to OAL 5-28-2009 and filed 7-7-2009 (Register 2009, No. 28).

8. Redesignation of portion of subsection (b) as new subsection (b)(1), new subsections (b)(2) and (c)(4), subsection renumbering and amendment of newly designated subsection (c)(5)(A) filed 8-27-2009 as an emergency; operative 8-27-2009 (Register 2009, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-23-2010 or emergency language will be repealed by operation of law on the following day.

9. New subsection (b)(3) filed 9-1-2009 as an emergency; operative 9-1-2009 (Register 2009, No. 36). A Certificate of Compliance must be transmitted to OAL by 3-1-2010 or emergency language will be repealed by operation of law on the following day.

10. Amendment of subsection (b)(1) refiled 9-14-2009 as an emergency; operative 9-14-2009 (Register 2009, No. 38). A Certificate of Compliance must be transmitted to OAL by 12-14-2009 or emergency language will be repealed by operation of law on the following day.

11. Amendment of subsection (b)(1), repealer of subsections (c)(5)(D) and (d)(1)(A)-(C), amendment of subsections (d)(1)-(2) and new subsections (d)(3)-(4) filed 10-30-2009 as an emergency; operative 10-30-2009 (Register 2009, No. 44). A Certificate of Compliance must be transmitted to OAL by 4-28-2010 or emergency language will be repealed by operation of law on the following day.

12. Amendment of subsection (b)(1), new subsection (b)(2) and subsection renumbering filed 11-16-2009 as an emergency; operative 11-16-2009 (Register 2009, No. 47). A Certificate of Compliance must be transmitted to OAL by 5-17-2010 or emergency language will be repealed by operation of law on the following day.

13. Amendment of subsections (b)(1)-(2) and new subsection (b)(5) filed 11-25-2009 as an emergency; operative 11-25-2009 (Register 2009, No. 48). A Certificate of Compliance must be transmitted to OAL by 5-24-2010 or emergency language will be repealed by operation of law on the following day.

14. Certificate of Compliance as to 9-14-2009 order transmitted to OAL 11-25-2009 and filed 1-6-2010 (Register 2010, No. 2).

15. Redesignation of portion of subsection (b) as new subsection (b)(1), new subsection (b)(2) and (c)(4), subsection renumbering and amendment of newly designated subsection (c)(5)(A) refiled 2-26-2010 as an emergency; operative 2-26-2010 (Register 2010, No. 9). A Certificate of Compliance must be transmitted to OAL by 5-27-2010 or emergency language will be repealed by operation of law on the following day.

16. New subsection (b)(3) refiled 2-26-2010 as an emergency; operative 2-26-2010 (Register 2010, No. 9). A Certificate of Compliance must be transmitted to OAL by 5-27-2010 or emergency language will be repealed by operation of law on the following day.

17. Certificate of Compliance as to 10-30-2009, 11-16-2009, 11-25-2009 and 2-26-2010 orders, including further amendments to subsections (b)(1) and (c)(5)(C), transmitted to OAL 4-20-2010 and filed 6-2-2010 (Register 2010, No. 23).

18. Amendment of subsection (c)(1) filed 7-26-2010 as an emergency; operative 7-26-2010 (Register 2010, No. 31). A Certificate of Compliance must be transmitted to OAL by 1-24-2011 or emergency language will be repealed by operation of law on the following day.

19. Certificate of Compliance as to 7-26-2010 order transmitted to OAL 10-12-2010 and filed 11-22-2010 (Register 2010, No. 48).

20. Amendment of subsection (b)(1), new subsections (b)(1)(A)-(B), amendment of subsections (b)(2)-(4) and repealer of subsection (b)(5) filed 12-30-2010 as an emergency; operative 12-30-2010 (Register 2010, No. 53). A Certificate of Compliance must be transmitted to OAL by 6-28-2011 or emergency language will be repealed by operation of law on the following day.

21. Certificate of Compliance as to 12-30-2010 order transmitted to OAL 6-2-2011 and filed 6-22-2011 (Register 2011, No. 25).

22. Repealer of subsection (b)(1)(A) and redesignation and amendment of former subsection (b)(1)(B) to subsection (b)(1) filed 2-6-2012 as an emergency; operative 2-6-2012 (Register 2012, No. 6). A Certificate of Compliance must be transmitted to OAL by 8-6-2012 or emergency language will be repealed by operation of law on the following day.

23. Amendment of subsection (c)(1) filed 4-12-2012 as an emergency; operative 4-12-2012 (Register 2012, No. 15). A Certificate of Compliance must be transmitted to OAL by 10-9-2012 or emergency language will be repealed by operation of law on the following day.

24. Amendment of subsection (b)(2) filed 8-6-2012 as an emergency; operative 8-6-2012 (Register 2012, No. 32). A Certificate of Compliance must be transmitted to OAL by 2-4-2012 or emergency language will be repealed by operation of law on the following day.

25. Certificate of Compliance as to 2-6-2012 order transmitted to OAL 7-10-2012 and filed 8-20-2012 (Register 2012, No. 34).

26. Amendment of subsection (b)(2) filed 9-12-2012 as an emergency; operative 9-12-2012 (Register 2012, No. 37). A Certificate of Compliance must be transmitted to OAL by 3-11-2013 or emergency language will be repealed by operation of law on the following day.

27. Repealer of subsection (b)(1), subsection renumbering and amendment of newly designated subsections (b)(1) and (b)(3) filed 11-15-2012 as an emergency; operative 11-15-2012 (Register 2012, No. 46). A Certificate of Compliance must be transmitted to OAL by 5-14-2013 or emergency language will be repealed by operation of law on the following day.

28. Reinstatement of section as it existed prior to 4-12-2012 emergency amendment by operation of Government Code section 11346.1(f) (Register 2013, No. 3).

29. Certificate of Compliance as to 8-6-2012 order transmitted to OAL 1-30-2013 and filed 2-27-2013 (Register 2013, No. 9).

30. Reinstatement of section as it existed prior to 9-12-2012 emergency amendment by operation of Government Code section 11346.1(f) (Register 2013, No. 14).

31. Readoption of 9-12-2012 emergency action filed 4-2-2013 as an emergency; operative 4-2-2013 (Register 2013, No. 14). A Certificate of Compliance must be transmitted to OAL by 7-1-2013 or emergency language will be repealed by operation of law on the following day.

32. Repealer of section (b)(2), subsection renumbering and amendment of newly designated subsection (b)(2) filed 4-4-2013 as an emergency; operative 4-4-2013 (Register 2013, No. 14). A Certificate of Compliance must be transmitted to OAL by 10-1-2013 or emergency language will be repealed by operation of law on the following day.

33. Repealer of subsection (b)(1), subsection renumbering and amendment of newly designated subsection (b)(1) filed 4-16-2013 as an emergency; operative 4-16-2013 (Register 2013, No. 16). A Certificate of Compliance must be transmitted to OAL by 10-14-2013 or emergency language will be repealed by operation of law on the following day.

34. Readoption of 4-2-2013 emergency action filed 6-19-2013 as an emergency; operative 6-19-2013 (Register 2013, No. 25). A Certificate of Compliance must be transmitted to OAL by 9-17-2013 or emergency language will be repealed by operation of law on the following day.

35. Certificate of Compliance as to 11-15-2012 order transmitted to OAL 5-8-2013 and filed 6-19-2013 (Register 2013, No. 25).

36. New subsection (b)(1) and subsection renumbering filed 7-30-2013 as an emergency; operative 7-30-2013 (Register 2013, No. 31). A Certificate of Compliance must be transmitted to OAL by 1-27-2014 or emergency language will be repealed by operation of law on the following day.

37. Certificate of Compliance as to 6-19-2013 order transmitted to OAL 7-30-2013 and filed 8-12-2013 (Register 2013, No. 33).

38. New subsections (b)(2) and (b)(3) filed 9-20-2013 as an emergency; operative 9-20-2013 (Register 2013, No. 38). A Certificate of Compliance must be transmitted to OAL by 3-19-2014 or emergency language will be repealed by operation of law on the following day.

39. Redesignation and amendment of former subsection (b)(1) as new subsection (b)(1)(A) and new subsection (b)(1)(B) filed 9-30-2013 as an emergency; operative 9-30-2013 (Register 2013, No. 40). A Certificate of Compliance must be transmitted to OAL by 4-1-2014 or emergency language will be repealed by operation of law on the following day.

40. Certificate of Compliance as to 4-4-2013 and 4-16-2013 orders transmitted to OAL 9-3-2013 and filed 10-7-2013 (Register 2013, No. 41).

41. Redesignation and amendment of former subsection (b)(1)(A) to subsection (b)(1), repealer of subsection (b)(1)(B) and amendment of subsection (b)(2) filed 10-14-2013 as an emergency; operative 10-14-2013 (Register 2013, No. 42). A Certificate of Compliance must be transmitted to OAL by 4-14-2014 or emergency language will be repealed by operation of law on the following day.

42. Amendment of subsection (b)(1) filed 11-25-2013 as an emergency; operative 11-25-2013 (Register 2013, No. 48). A Certificate of Compliance must be transmitted to OAL by 5-27-2014 or emergency language will be repealed by operation of law on the following day.

43. Amendment of subsection (b)(1) filed 2-5-2014 as an emergency; operative 2-5-2014 (Register 2014, No. 6). A Certificate of Compliance must be transmitted to OAL by 8-4-2014 or emergency language will be repealed by operation of law on the following day.

44. Certificate of Compliance as to 7-30-2013 order transmitted to OAL 1-21-2014 and filed 2-10-2014 (Register 2014, No. 7).

45. New subsection (b)(4) and subsection renumbering filed 4-4-2014; operative 4-4-2014 (Register 2014, No. 14). A Certificate of Compliance must be transmitted to OAL by 10-1-2014 or emergency language will be repealed by operation of law on the following day.

46. Certificate of Compliance as to 9-20-2013, 9-30-2013, 10-14-2013 and 11-25-2013 orders transmitted to OAL 3-12-2014 and filed 4-24-2014 (Register 2014, No. 17).

47. Amendment of subsection (b)(1), repealer of subsection (b)(2) and subsection renumbering filed 6-2-2014 as an emergency; operative 6-2-2014 (Register 2014, No. 23). A Certificate of Compliance must be transmitted to OAL by 12-1-2014 or emergency language will be repealed by operation of law on the following day.

48. Amendment of subsection (b)(1) filed 6-17-2014 as an emergency; operative 6-17-2014 (Register 2014, No. 25). A Certificate of Compliance must be transmitted to OAL by 12-15-2014 or emergency language will be repealed by operation of law on the following day.

49. Certificate of Compliance as to 2-5-2014 order transmitted to OAL 6-16-2014 and filed 6-24-2014 (Register 2014, No. 26).

50. Amendment of subsection (b)(3) and new subsections (b)(3)(A)-(B) filed 8-25-2014 as an emergency; operative 8-25-2014 (Register 2014, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-23-2015 or emergency language will be repealed by operation of law on the following day.

51. Certificate of Compliance as to 4-4-2014 order transmitted to OAL 9-4-2014 and filed 9-15-2014 (Register 2014, No. 38).

52. New subsection (b)(2)(A) and redesignation and amendment of former subsection (b)(2) as new subsection (b)(2)(B) filed 9-17-2014 as an emergency; operative 9-17-2014 (Register 2014, No. 38). A Certificate of Compliance must be transmitted to OAL by 3-16-2015 or emergency language will be repealed by operation of law on the following day.

53. Amendment of subsection (b)(1), new subsection (b)(2)(C) and amendment of subsection (b)(4) filed 9-25-2014 as an emergency; operative 9-25-2014 (Register 2014, No. 39). A Certificate of Compliance must be transmitted to OAL by 3-24-2015 or emergency language will be repealed by operation of law on the following day.

54. Certificate of Compliance as to 6-2-2014 order transmitted to OAL 9-4-2014 and filed 10-14-2014 (Register 2014, No. 42).

55. New subsection (b)(4) and subsection renumbering filed 10-17-2014 as an emergency; operative 10-17-2014 (Register 2014, No. 42). A Certificate of Compliance must be transmitted to OAL by 4-15-2015 or emergency language will be repealed by operation of law on the following day.

56. Amendment of subsection (b)(2) filed 10-17-2014 as an emergency; operative 10-17-2014 (Register 2014, No. 42). A Certificate of Compliance must be transmitted to OAL by 4-15-2015 or emergency language will be repealed by operation of law on the following day.

57. New subsection (b)(5) and subsection renumbering filed 10-23-2014 as an emergency; operative 10-23-2014 (Register 2014, No. 43). A Certificate of Compliance must be transmitted to OAL by 4-21-2015 or emergency language will be repealed by operation of law on the following day.

58. Certificate of Compliance as to 6-17-2014 order transmitted to OAL 10-14-2014 and filed 11-19-2014 (Register 2014, No. 47).

59. New subsection (b)(6) and subsection renumbering filed 1-2-2015 as an emergency; operative 1-2-2015 (Register 2015, No. 1). A Certificate of Compliance must be transmitted to OAL by 7-1-2015 or emergency language will be repealed by operation of law on

the following day.

60. Amendment of subsection (b)(1) filed 1-16-2015 as an emergency; operative 1-16-2015 (Register 2015, No. 3). A Certificate of Compliance must be transmitted to OAL by 7-15-2015 or emergency language will be repealed by operation of law on the following day.

61. Amendment of subsection (b)(4) filed 1-26-2015 as an emergency; operative 1-26-2015 (Register 2015, No. 5). A Certificate of Compliance must be transmitted to OAL by 7-27-2015 or emergency language will be repealed by operation of law on the following day.

62. Amendment of subsection (b)(3) and new subsections (b)(3)(A)-(B) refiled 2-12-2015 as an emergency; operative 2-12-2015 (Register 2015, No. 7). A Certificate of Compliance must be transmitted to OAL by 5-13-2015 or emergency language will be repealed by operation of law on the following day.

63. Amendment of subsection (b)(1) filed 3-2-2015 as an emergency; operative 3-2-2015 (Register 2015, No. 10). A Certificate of Compliance must be transmitted to OAL by 8-31-2015 or emergency language will be repealed by operation of law on the following day.

64. Amendment of subsection (b)(6) filed 3-20-2015 as an emergency; operative 3-20-2015 (Register 2015, No. 12). A Certificate of Compliance must be transmitted to OAL by 9-16-2015 or emergency language will be repealed by operation of law on the following day.

65. Certificate of Compliance as to 9-17-2014 order transmitted to OAL 3-9-2015 and filed 4-8-2015 (Register 2015, No. 15).

66. Certificate of Compliance as to 9-25-2014 order transmitted to OAL 3-19-2015 and filed 4-9-2015 (Register 2015, No. 15).

67. New subsection (b)(8) filed 4-30-2015 as an emergency; operative 4-30-2015 (Register 2015, No. 18). A Certificate of Compliance must be transmitted to OAL by 10-27-2015 or emergency language will be repealed by operation of law on the following day.

68. Certificate of Compliance as to 10-17-2014 order (amending subsection (b)(4)) and 10-23-2014 order (amending subsection (b)(5)) transmitted to OAL 3-19-2015 and filed 4-30-2015 (Register 2015, No. 18).

69. Editorial correction of History 68 (Register 2015, No. 19).

70. Certificate of Compliance as to 10-17-2014 order (amending subsection (b)(2)) transmitted to OAL 4-10-2015 and filed 5-6-2015 (Register 2015, No. 19).

71. Amendment of subsection (b)(2)(A) filed 5-8-2015 as an emergency; operative 5-8-2015 (Register 2015, No. 19). A Certificate of Compliance must be transmitted to OAL by 11-4-2015 or emergency language will be repealed by operation of law on the following day.

72. Repealer of former subsection (b)(3)(A), subsection relettering and amendment of newly designated subsection (b)(3)(A) filed 5-13-2015 as an emergency; operative 5-13-2015 (Register 2015, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-9-2015 or emergency language will be repealed by operation of law on the following day.

73. Amendment of subsection (b)(2)(A) filed 5-28-2015 as an emergency; operative 5-28-2015 (Register 2015, No. 22). A Certificate of Compliance must be transmitted to OAL by 11-24-2015 or emergency language will be repealed by operation of law on the following day.

74. Certificate of Compliance as to 8-25-2014 and 2-12-2015 orders transmitted to OAL 5-12-2015 and filed 6-22-2015 (Register 2015, No. 26).

75. Amendment of subsection (b)(4) filed 6-24-2015 as an emergency; operative 6-24-2015 (Register 2015, No. 26). A Certificate of Compliance must be transmitted to OAL by 12-21-2015 or emergency language will be repealed by operation of law on the following day.

76. Amendment of subsections (b)(1) and (b)(3)(A) and new subsection (b)(3)(C) filed 7-8-2015 as an emergency; operative 7-8-2015 (Register 2015, No. 28). A Certificate of Compliance must be transmitted to OAL by 1-4-2016 or emergency language will be repealed by operation of law on the following day.

77. Certificate of Compliance as to 1-2-2015 order adopting subsection (b)(6) transmitted to OAL 6-25-2015 and filed 8-4-2015 (Register 2015, No. 32).

78. Certificate of Compliance as to 1-16-2015 order amending subsection (b)(1) transmitted to OAL 7-13-2015 and filed 8-6-2015 (Register 2015, No. 32).

79. Amendment of subsection (b)(2)(A) filed 8-10-2015 as an emergency; operative 8-10-2015 (Register 2015, No. 33). A Certificate of Compliance must be transmitted to OAL by 2-8-2016 or emergency language will be repealed by operation of law on the following day.

80. New subsection (b)(2)(D) filed 8-10-2015 as an emergency; operative 8-10-2015 (Register 2015, No. 33). A Certificate of Compliance must be transmitted to OAL by 2-8-2016 or emergency language will be repealed by operation of law on the following day.

81. Certificate of Compliance as to 1-26-2015 order transmitted to OAL 7-16-2015 and filed 8-20-2015 (Register 2015, No. 34).

82. Amendment of subsection (b)(3)(A) and repealer of subsection (b)(3)(C) filed 8-27-2015 as an emergency; operative 8-27-2015 (Register 2015, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-23-2016 or emergency language will be repealed by operation of law on the following day.

83. Certificate of Compliance as to 3-2-2015 order transmitted to OAL 8-27-2015 and filed 9-16-2015 (Register 2015, No. 38).

84. Certificate of Compliance as to 3-20-2015 order amending subsection (b)(6) transmitted to OAL 9-14-2015 and filed 9-30-2015 (Register 2015, No. 40).

85. Amendment of subsection (b)(2)(A) and new subsection (b)(2)(E) filed 10-29-2015 as an emergency; operative 10-29-2015 (Register 2015, No. 44). A Certificate of Compliance must be transmitted to OAL by 4-26-2016 or emergency language will be repealed by operation of law on the following day.

86. Amendment of subsection (b)(2)(A) and repealer of subsection (b)(2)(E) filed 11-12-2015 as an emergency; operative 11-12-2015 (Register 2015, No. 46). A Certificate of Compliance must be transmitted to OAL by 5-10-2016 or emergency language will be repealed by operation of law on the following day.

87. New subsection (b)(9) filed 11-13-2015 as an emergency; operative 11-13-2015 (Register 2015, No. 46). A Certificate of Compliance must be transmitted to OAL by 5-11-2016 or emergency language will be repealed by operation of law on the following day.

88. Amendment of subsection (b)(2)(A) and new subsection (b)(2)(E) filed 11-24-2015 as an emergency; operative 11-24-2015 (Register 2015, No. 48). A Certificate of Compliance must be transmitted to OAL by 5-23-2016 or emergency language will be repealed by operation of law on the following day.

89. New subsection (b)(10) filed 11-24-2015 as an emergency; operative 11-24-2015 (Register 2015, No. 48). A Certificate of Compliance must be transmitted to OAL by 5-23-2016 or emergency language will be repealed by operation of law on the following day.

90. Certificate of Compliance as to 4-30-2015 order transmitted to OAL 10-21-2015 and filed 12-7-2015 (Register 2015, No. 50).

91. Amendment of subsection (b)(2)(A) filed 12-14-2015 as an emergency; operative 12-14-2015 (Register 2015, No. 51). A Certificate of Compliance must be transmitted to OAL by 6-13-2016 or emergency language will be repealed by operation of law on the following day.

92. Certificate of Compliance as to 5-13-2015 order transmitted to OAL 11-3-2015 and filed 12-15-2015 (Register 2015, No. 51).

93. Certificate of Compliance as to 5-8-2015 order transmitted to OAL 11-3-2015 and filed 12-16-2015 (Register 2015, No. 51).

94. New subsection (b)(2)(F) filed 12-21-2015 as an emergency; operative 12-21-2015 (Register 2015, No. 52). A Certificate of Compliance must be transmitted to OAL by 6-20-2016 or emergency language will be repealed by operation of law on the following day.

95. Amendment of subsection (b)(6) filed 12-30-2015 as an emergency; operative 12-30-2015 (Register 2016, No. 1). A Certificate of Compliance must be transmitted to OAL by 6-27-2016 or emergency language will be repealed by operation of law on the following day.

96. Amendment of subsection (b)(5)(A) filed 1-5-2016 as an emergency; operative 1-5-2016 (Register 2016, No. 2). A Certificate of Compliance must be transmitted to OAL by 7-5-2016 or emergency language will be repealed by operation of law on the following day.

97. Certificate of Compliance as to 5-28-2015 order transmitted to OAL 11-20-2015 and filed 1-6-2016 (Register 2016, No. 2).

98. Amendment of subsection (b)(1), redesignation of portion of subsection (b)(1) as new subsection (b)(1)(A) and new subsections (b)(1)(B) and (b)(11) filed 1-14-2016 as an emergency; operative 1-14-2016 (Register 2016, No. 3). A Certificate of Compliance must be transmitted to OAL by 7-12-2016 or emergency language will be repealed by operation of law on the following day.

99. Certificate of Compliance as to 6-24-2015 order transmitted to OAL 12-7-2015 and filed 1-20-2016 (Register 2016, No. 4).

100. Certificate of Compliance as to 7-8-2015 order transmitted to OAL 12-18-2015 and filed 1-21-2016 (Register 2016, No. 4).

101. Repealer of subsections (b)(2)(A)-(B), subsection relettering and new subsection (b)(2)(D) filed 2-9-2016 as an emergency; operative 2-9-2016 (Register 2016, No. 7). A Certificate of Compliance must be transmitted to OAL by 8-8-2016 or emergency language will be repealed by operation of law on the following day.

102. Certificate of Compliance as to 8-10-2015 order for subsection (b)(2)(D) transmitted to OAL 1-26-2016 and filed 3-8-2016 (Register 2016, No. 11).

103. Certificate of Compliance as to 8-10-2015 order for subsection (b)(2)(A) transmitted to OAL 1-26-2016 and filed 3-9-2016 (Register 2016, No. 11).

104. Repealer of subsection (b)(2)(C), subsection relettering and amendment of newly designated subsection (b)(2)(D) filed 3-10-2016 as an emergency; operative 3-10-2016 (Register 2016, No. 11). A Certificate of Compliance must be transmitted to OAL by 9-6-2016 or emergency language will be repealed by operation of law on the following day.

105. Amendment of subsection (b)(4) filed 3-21-2016 as an emergency; operative 3-21-2016 (Register 2016, No. 13). A Certificate of Compliance must be transmitted to OAL by 9-19-2016 or emergency language will be repealed by operation of law on the following day.

106. Certificate of Compliance as to 8-27-2015 order transmitted to OAL 2-23-2016 and filed 3-29-2016 (Register 2016, No. 14).

107. Repealer of subsection (b)(1)(B) and amendment of subsection (b)(6) filed 4-25-2016 as an emergency; operative 4-25-2016 (Register 2016, No. 18). A Certificate of Compliance must be transmitted to OAL by 10-24-2016 or emergency language will be repealed by operation of law on the following day.

108. Repealer of subsection (b)(2)(B), subsection relettering and amendment of newly designated subsection (b)(2)(B) filed 5-10-2016 as an emergency; operative 5-10-2016 (Register 2016, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-7-2016 or emergency language will be repealed by operation of law on the following day.

109. New subsection (b)(12) filed 5-11-2016 as an emergency; operative 5-11-2016 (Register 2016, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-7-2016 or emergency language will be repealed by operation of law on the following day.

110. Amendment of subsection (b)(2)(B) (as designated in 5-10-2016 emergency filing) filed 5-11-2016 as an emergency; operative 5-11-2016 (Register 2016, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-7-2016 or emergency language will be repealed by operation of law on the following day.

111. Amendment of subsection (b)(3)(A) filed 5-12-2016 as an emergency; operative 5-12-2016 (Register 2016, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-8-2016 or emergency language will be repealed by operation of law on the following day.

112. Amendment of subsection (b)(6) filed 5-12-2016 as an emergency; operative 5-12-2016 (Register 2016, No. 20). A Certificate of Compliance must be transmitted to OAL by 11-8-2016 or emergency language will be repealed by operation of law on the following day.

113. Certificate of Compliance as to 10-29-2015 order transmitted to OAL 4-11-2016 and filed 5-18-2016 (Register 2016, No. 21).

114. New subsection (b)(5)(C) filed 5-23-2016 as an emergency; operative 5-23-2016 (Register 2016, No. 22). A Certificate of Compliance must be transmitted to OAL by 11-21-2016 or emergency language will be repealed by operation of law on the following day.

115. Amendment of subsection (b)(2)(B) filed 5-25-2016 as an emergency; operative 5-25-2016 (Register 2016, No. 22). A Certificate of Compliance must be transmitted to OAL by 11-21-2016 or emergency language will be repealed by operation of law on the following day.

116. Amendment of subsection (b)(2)(B) filed 6-1-2016 as an emergency; operative 6-1-2016 (Register 2016, No. 23). A Certificate of Compliance must be transmitted to OAL by 11-28-2016 or emergency language will be repealed by operation of law on the following day.

117. Repealer of subsections (b)(1)-(b)(1)(A), subsection renumbering and amendment of newly designated subsection (b)(5) filed 6-2-2016 as an emergency; operative 6-2-2016 (Register 2016, No. 23). A Certificate of Compliance must be transmitted to OAL by 11-29-2016 or emergency language will be repealed by operation of law on the following day.

118. Certificate of Compliance as to 11-12-2015 order transmitted to OAL 5-2-2016 and filed 6-13-2016 (Register 2016, No. 25).

119. Certificate of Compliance as to 11-13-2015 order transmitted to OAL 5-2-2016 and filed 6-13-2016 (Register 2016, No. 25).

120. New subsection (b)(1)(C) filed 6-16-2016 as an emergency; operative 6-16-2016 (Register 2016, No. 25). A Certificate of Compliance must be transmitted to OAL by 12-13-2016 or emergency language will be repealed by operation of law on the following day.

121. Amendment of subsection (b)(5) filed 6-22-2016 as an emergency; operative 6-22-2016 (Register 2016, No. 26). A Certificate of Compliance must be transmitted to OAL by 12-19-2016 or emergency language will be repealed by operation of law on the following day.

122. New subsection (b)(12) filed 6-22-2016 as an emergency; operative 6-22-2016 (Register 2016, No. 26). A Certificate of Compliance must be transmitted to OAL by 12-19-2016 or emergency language will be repealed by operation of law on the following day.

123. Amendment of subsection (b)(4)(A) filed 6-28-2016 as an emergency; operative 6-28-2016 (Register 2016, No. 27). A Certificate of Compliance must be transmitted to OAL by 12-27-2016 or emergency language will be repealed by operation of law on the following day.

124. Amendment of subsection (b)(10) and new subsections (b)(10)(A)-(B) filed 6-30-2016 as an emergency; operative 6-30-2016 (Register 2016, No. 27). A Certificate of Compliance must be transmitted to OAL by 12-27-2016 or emergency language will be repealed by operation of law on the following day.

125. New subsection (b)(13) filed 6-30-2016 as an emergency; operative 6-30-2016 (Register 2016, No. 27). A Certificate of Compliance must be transmitted to OAL by 12-27-2016 or emergency language will be repealed by operation of law on the following day.

126. Certificate of Compliance as to 11-24-2015 order amending subsection (b)(2)(A) and adopting subsection (b)(2)(E) transmitted to OAL 5-23-2016 and filed 7-5-2016 (Register 2016, No. 28).

127. Certificate of Compliance as to 11-24-2015 order adopting subsection (b)(10) transmitted to OAL 5-23-2016 and filed 7-5-2016 (Register 2016, No. 28).

128. Amendment of subsection (b)(1)(B) filed 7-7-2016 as an emergency; operative 7-7-2016 (Register 2016, No. 28). A Certificate of Compliance must be transmitted to OAL by 1-3-2017 or emergency language will be repealed by operation of law on the following day.

129. Certificate of Compliance as to 12-14-2015 order transmitted to OAL 6-7-2016 and filed 7-20-2016 (Register 2016, No. 30).

130. Certificate of Compliance as to 1-14-2016 order transmitted to OAL 6-27-2016 and filed 7-21-2016 (Register 2016, No. 30).

131. Certificate of Compliance as to 12-21-2015 order transmitted to OAL 6-17-2016 and filed 7-25-2016 (Register 2016, No. 31).

132. Certificate of Compliance as to 12-30-2015 order transmitted to OAL 6-17-2016 and filed 7-25-2016 (Register 2016, No. 31).

133. Certificate of Compliance as to 1-5-2016 order transmitted to OAL 6-27-2016 and filed 7-25-2016 (Register 2016, No. 31).

134. Editorial correction of subsection (b)(5) (Register 2016, No. 32).

135. Amendment of subsection (b)(5) filed 8-1-2016 as an emergency; operative 8-1-2016 (Register 2016, No. 32). A Certificate of Compliance must be transmitted to OAL by 1-30-2017 or emergency language will be repealed by operation of law on the following day.

136. Further amendment of subsection (b)(5) filed 8-1-2016 as an emergency; operative 8-1-2016 (Register 2016, No. 32). A Certificate of Compliance must be transmitted to OAL by 1-30-2017 or emergency language will be repealed by operation of law on the following day.

137. Repealer of subsection (b)(4)(B), subsection relettering and amendment of newly designated subsection (b)(4)(C) filed 8-2-2016 as an emergency; operative 8-2-2016 (Register 2016, No. 32). A Certificate of Compliance must be transmitted to OAL by 1-30-2017 or emergency language will be repealed by operation of law on the following day.

138. Amendment of subsection (b)(8), repealer of subsection (b)(12) and subsection renumbering filed 8-3-2016 as an emergency; operative 8-3-2016 (Register 2016, No. 32). A Certificate of Compliance must be transmitted to OAL by 1-30-2017 or emergency language will be repealed by operation of law on the following day.

139. Amendment of subsection (b)(11), designation of portion of former subsection (b)(11) as new subsection (b)(11)(A) and new subsection (b)(11)(B) filed 8-23-2016 as an emergency; operative 8-23-2016 (Register 2016, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-21-2017 or emergency language will be repealed by operation of law on the following day.

140. Amendment of subsection (b)(4), repealer of subsections (b)(4)(A)-(B), amendment of subsection (b)(10) and repealer of subsections (b)(10)(A)-(B) filed 8-24-2016 as an emergency; operative 8-24-2016 (Register 2016, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-21-2017 or emergency language will be repealed by operation of law on the following day.

141. Amendment of subsection (b)(2)(A) and new subsection (b)(2)(C) filed 8-25-2016 as an emergency; operative 8-25-2016 (Register 2016, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-21-2017 or emergency language will be repealed by operation of law on the following day.

142. Amendment of subsection (b)(3) filed 8-26-2016 as an emergency; operative 8-26-2016 (Register 2016, No. 35). A Certificate of Compliance must be transmitted to OAL by 2-22-2016 or emergency language will be repealed by operation of law on the following day.

143. Certificate of Compliance as to 2-9-2016 order transmitted to OAL 7-26-2016 and filed 8-29-2016 (Register 2016, No. 36).

144. Amendment of subsection (b)(8) filed 9-14-2016 as an emergency; operative 9-14-2016 (Register 2016, No. 38). A Certificate of Compliance must be transmitted to OAL by 3-13-2017 or emergency language will be repealed by operation of law on the following day.

145. Redesignation of portion of subsection (b)(8) as new subsection (b)(8)(A) and new subsection (b)(8)(B) filed 9-16-2016 as an emergency; operative 9-16-2016 (Register 2016, No. 38). A Certificate of Compliance must be transmitted to OAL by 3-15-2017 or emergency language will be repealed by operation of law on the following day.

146. New subsection (b)(11)(C) filed 9-20-2016 as an emergency; operative 9-20-2016 (Register 2016, No. 39). A Certificate of Compliance must be transmitted to OAL by 3-20-2017 or emergency language will be repealed by operation of law on the following day.

147. Amendment of subsection (b)(3) filed 9-20-2016 as an emergency; operative 9-20-2016 (Register 2016, No. 39). A Certificate of Compliance must be transmitted to OAL by 3-20-2017 or emergency language will be repealed by operation of law on the following day.

148. Certificate of Compliance as to 3-10-2016 order transmitted to OAL 8-26-2016 and filed 9-27-2016 (Register 2016, No. 40).

149. Amendment of subsection (b)(1)(B) filed 9-30-2016 as an emergency; operative 9-30-2016 (Register 2016, No. 40). A Certificate of Compliance must be transmitted to OAL by 3-29-2017 or emergency language will be repealed by operation of law on the following day.

150. New subsection (b)(13) filed 10-6-2016 as an emergency; operative 10-6-2016 (Register 2016, No. 41). A Certificate of Compliance must be transmitted to OAL by 4-4-2017 or emergency language will be repealed by operation of law on the following day.

151. Amendment of subsections (b)(5)-(6) filed 10-13-2016 as an emergency; operative 10-13-2016 (Register 2016, No. 42). A Certificate of Compliance must be transmitted to OAL by 4-11-2017 or emergency language will be repealed by operation of law on the following day.

152. Certificate of Compliance as to 3-21-2016 order transmitted to OAL 9-9-2016 and filed 10-19-2016 (Register 2016, No. 43).

153. Amendment of subsection (b)(3) filed 10-28-2016 as an emergency; operative 10-28-2016 (Register 2016, No. 44). A Certificate of Compliance must be transmitted to OAL by 4-26-2017 or emergency language will be repealed by operation of law on the following day.

154. Amendment of subsection (b)(8)(B) filed 10-28-2016 as an emergency; operative 10-28-2016 (Register 2016, No. 44). A Certificate of Compliance must be transmitted to OAL by 4-26-2017 or emergency language will be repealed by operation of law on the following day.

155. Amendment of subsection (b)(4), repealer of subsection (b)(10) and subsection renumbering filed 11-8-2016 as an emergency; operative 11-8-2016 (Register 2016, No. 46). A Certificate of Compliance must be transmitted to OAL by 5-8-2017 or emergency language will be repealed by operation of law on the following day.

156. Repealer of 5-12-2016 emergency amendments to subsection (b)(6) by operation of Government Code section 11346.1(f) (Register 2016, No. 45).

157. Amendment of subsection (b)(10)(B) and repealer of subsection (b)(10)(C) filed 11-9-2016 as an emergency; operative 11-9-2016 (Register 2016, No. 46). A Certificate of Compliance must be transmitted to OAL by 5-8-2017 or emergency language will be repealed by operation of law on the following day.

158. Certificate of Compliance as to 4-25-2016 order transmitted to OAL 10-11-2016 and filed 11-14-2016 (Register 2016, No. 47).

159. Amendment of subsections (b)(1)(B) and (b)(10)(A) filed 11-17-2016 as an emergency; operative 11-17-2016 (Register 2016, No. 47). A Certificate of Compliance must be transmitted to OAL by 5-16-2017 or emergency language will be repealed by operation of law on the following day.

160. Amendment of subsection (b)(1)(B) filed 12-1-2016 as an emergency; operative 12-1-2016 (Register 2016, No. 49). A Certificate of Compliance must be transmitted to OAL by 5-30-2017 or emergency language will be repealed by operation of law on the following day.

161. Certificate of Compliance as to 5-10-2016 order transmitted to OAL 11-2-2016 and filed 12-5-2016 (Register 2016, No. 50).

162. Certificate of Compliance as to 5-11-2016 order amending subsection (b)(2)(B) transmitted to OAL 11-2-2016 and filed 12-5-2016 (Register 2016, No. 50).

163. Certificate of Compliance as to 5-11-2016 order adopting subsection (b)(12) transmitted to OAL 11-2-2016 and filed 12-5-2016 (Register 2016, No. 50).

164. Certificate of Compliance as to 5-12-2016 order transmitted to OAL 11-2-2016 and filed 12-5-2016 (Register 2016, No. 50).

165. Amendment of subsection (d)(1) and Note filed 12-21-2016 as an emergency; operative 12-21-2016 (Register 2016, No. 52). A Certificate of Compliance must be transmitted to OAL by 6-19-2017 or emergency language will be repealed by operation of law on the following day.

166. Amendment of subsection (b)(10)(B) filed 12-22-2016 as an emergency; operative 12-22-2016 (Register 2016, No. 52). A Certificate of Compliance must be transmitted to OAL by 6-20-2017 or emergency language will be repealed by operation of law on the following day.

167. Certificate of Compliance as to 5-23-2016 order transmitted to OAL 11-18-2016 and filed 1-3-2017 (Register 2017, No. 1).

168. Certificate of Compliance as to 5-25-2016 order transmitted to OAL 11-18-2016 and filed 1-3-2017 (Register 2017, No. 1).

169. Certificate of Compliance as to 6-1-2016 order transmitted to OAL 11-23-2016 and filed 1-3-2017 (Register 2017, No. 1).

170. Certificate of Compliance as to 6-22-2016 order transmitted to OAL 12-19-2016 and filed 1-4-2017 (Register 2017, No. 1).

171. Amendment of subsection (b)(11) filed 1-10-2017 as an emergency; operative 1-10-2017 (Register 2017, No. 2). A Certificate of Compliance must be transmitted to OAL by 7-10-2017 or emergency language will be repealed by operation of law on the following day.

172. New subsection (b)(13) filed 1-10-2017 as an emergency; operative 1-10-2017 (Register 2017, No. 2). A Certificate of Compliance must be transmitted to OAL by 7-10-2017 or emergency language will be repealed by operation of law on the following day.

173. Amendment of subsection (b)(3) filed 1-10-2017 as an emergency; operative 1-10-2017 (Register 2017, No. 2). A Certificate of Compliance must be transmitted to OAL by 7-10-2017 or emergency language will be repealed by operation of law on the following day.

174. Certificate of Compliance as to 6-16-2016 order, including further amendment of subsection (b)(1)(C), transmitted to OAL 12-6-2016 and filed 1-12-2017; amendments operative 1-12-2017 pursuant to Government Code section 11343.4(b)(3) (Register 2017, No. 2).

175. Readoption of 8-3-2016 emergency order amending subsection (b)(8), repealing subsection (b)(12) and renumbering subsections filed 1-30-2017 as an emergency; operative 1-30-2017 (Register 2017, No. 5). A Certificate of Compliance must be transmitted to OAL by 5-1-2017 or emergency language will be repealed by operation of law on the following day.

176. Certificate of Compliance as to 6-30-2016 order amending subsection (b)(10) and adopting new subsections (b)(10)(A)-(B) transmitted to OAL 12-19-2016 and filed 1-31-2017 (Register 2017, No. 5).

177. Certificate of Compliance as to 6-30-2016 order adopting new subsection (b)(13) transmitted to OAL 12-27-2016 and filed 2-2-2017 (Register 2017, No. 5).

178. Certificate of Compliance as to 6-28-2016 order transmitted to OAL 12-27-2016 and filed 2-6-2017 (Register 2017, No. 6).

179. New subsections (b)(14)-(15) filed 2-13-2017 as an emergency; operative 2-13-2017 (Register 2017, No. 7). A Certificate of Compliance must be transmitted to OAL by 8-14-2017 or emergency language will be repealed by operation of law on the following day.

180. Certificate of Compliance as to 7-7-2016 order transmitted to OAL 12-29-2016 and filed 2-13-2017 (Register 2017, No. 7).

181. Readoption of 8-23-2016 emergency action amending subsection (b)(11), designating a portion of former subsection (b)(11) as new subsection (b)(11)(A) and adopting new subsection (b)(11)(B) filed 2-16-2017 as an emergency; operative 2-16-2017 (Register 2017, No. 7). A Certificate of Compliance must be transmitted to OAL by 5-17-2017 or emergency language will be repealed by operation of law on the following day.

182. New subsection (b)(16) filed 2-21-2017 as an emergency; operative 2-21-2017 (Register 2017, No. 8). A Certificate of Compliance must be transmitted to OAL by 8-21-2017 or emergency language will be repealed by operation of law on the following day.

183. New subsection (b)(17) filed 2-24-2017 as an emergency; operative 2-24-2017 (Register 2017, No. 8). A Certificate of Compliance must be transmitted to OAL by 8-23-2017 or emergency language will be repealed by operation of law on the following day.

184. Amendment of subsection (b)(9) filed 3-2-2017 as an emergency; operative 3-2-2017 (Register 2017, No. 9). A Certificate of Compliance must be transmitted to OAL by 8-29-2017 or emergency language will be repealed by operation of law on the following day.

185. Certificate of Compliance as to 8-2-2016 order transmitted to OAL 1-30-2017 and filed 3-7-2017 (Register 2017, No. 10).

186. Repealer of subsection (b)(3), subsection renumbering and amendment of newly designated subsection (b)(14) filed 3-24-2017 as an emergency; operative 3-24-2017 (Register 2017, No. 12). A Certificate of Compliance must be transmitted to OAL by 9-20-2017 or emergency language will be repealed by operation of law on the following day.

187. Amendment of subsection (b)(13) and new subsections (b)(13)(A)-(B) filed 3-28-2017 as an emergency; operative 3-28-2017 (Register 2017, No. 13). A Certificate of Compliance must be transmitted to OAL by 9-25-2017 or emergency language will be repealed by operation of law on the following day.

188. Certificate of Compliance as to 8-24-2016 order transmitted to OAL 2-21-2017 and filed 3-30-2017 (Register 2017, No. 13).

189. Certificate of Compliance as to 8-25-2016 order transmitted to OAL 2-21-2017 and filed 3-30-2017 (Register 2017, No. 13).

190. Certificate of Compliance as to 8-26-2017 order transmitted to OAL 2-21-2017 and filed 4-4-2017 (Register 2017, No. 14).

191. Amendment of subsection (b)(1)(A), repealer of subsection (b)(1)(B) and subsection relettering filed 4-7-2017 as an emergency; operative 4-7-2017 (Register 2017, No. 14). A Certificate of Compliance must be transmitted to OAL by 10-4-2017 or emergency language will be repealed by operation of law on the following day.

192. Readoption of 9-14-2016 emergency order amending subsection (b)(8) filed 4-17-2017 as an emergency; operative 4-17-2017 (Register 2017, No. 16). A Certificate of Compliance must be transmitted to OAL by 7-17-2017 or emergency language will be repealed by operation of law on the following day.

193. Readoption of 9-16-2016 emergency order redesignating a portion of subsection (b)(8) as new subsection (b)(8)(A) and adopting new subsection (b)(8)(B) filed 4-17-2017 as an emergency; operative 4-17-2017 (Register 2017, No. 16). A Certificate of Compliance must be transmitted to OAL by 7-17-2017 or emergency language will be repealed by operation of law on the following day.

194. Amendment of subsection (b)(13), repealer of subsections (b)(13)(A)-(B) and new subsection (b)(17) filed 4-18-2017 as an emergency; operative 4-18-2017 (Register 2017, No. 16). A Certificate of Compliance must be transmitted to OAL by 10-16-2017 or emergency language will be repealed by operation of law on the following day.

195. Certificate of Compliance as to 10-13-2016 order transmitted to OAL 3-28-2017 and filed 4-20-2017 (Register 2017, No. 16).

196. Certificate of Compliance as to 9-20-2016 order amending subsection (b)(3) transmitted to OAL 3-17-2017 and filed 4-24-2017 (Register 2017, No. 17).

197. Certificate of Compliance as to 9-20-2016 order adopting subsection (b)(11)(C) transmitted to OAL 3-17-2017 and filed 4-24-2017 (Register 2017, No. 17).

198. Certificate of Compliance as to 9-30-2016 order transmitted to OAL 3-28-2017 and filed 5-4-2017 (Register 2017, No. 18).

199. Amendment of subsection (b)(1)(A) filed 5-4-2017 as an emergency; operative 5-4-2017 (Register 2017, No. 18). A Certificate of Compliance must be transmitted to OAL by 10-31-2017 or emergency language will be repealed by operation of law on the following day.

200. Certificate of Compliance as to 10-6-2016 order transmitted to OAL 3-28-2017 and filed 5-9-2017 (Register 2017, No. 19).

201. Certificate of Compliance as to 10-28-2016 order amending subsection (b)(3) transmitted to OAL 4-25-2017 and filed 5-15-2017 (Register 2017, No. 20).

202. Certificate of Compliance as to 10-28-2016 order amending subsection (b)(8)(B) transmitted to OAL 4-25-2017 and filed 5-15-2017 (Register 2017, No. 20).

203. Amendment of subsection (d)(1) and Note refiled 6-2-2017 as an emergency; operative 6-2-2017 (Register 2017, No. 22). A Certificate of Compliance must be transmitted to OAL by 8-31-2017 or emergency language will be repealed by operation of law on the following day.

204. Certificate of Compliance as to 8-3-2016 and 1-30-2017 orders transmitted to OAL 4-28-2017 and filed 6-7-2017 (Register 2017, No. 23).

205. Certificate of Compliance as to 11-9-2016 order transmitted to OAL 5-4-2017 and filed 6-8-2017 (Register 2017, No. 23).

206. Certificate of Compliance as to 11-8-2016 order transmitted to OAL 5-4-2017 and filed 6-14-2017 (Register 2017, No. 24).

207. Certificate of Compliance as to 8-23-2016 and 2-16-2017 orders transmitted to OAL 5-15-2017 and filed 6-19-2017 (Register 2017, No. 25).

208. Certificate of Compliance as to 11-17-2016 order transmitted to OAL 5-15-2017 and filed 6-26-2017 (Register 2017, No. 26).

209. Amendment of subsection (b)(11) filed 7-6-2017 as an emergency; operative 7-6-2017 (Register 2017, No. 27). A Certificate of Compliance must be transmitted to OAL by 1-3-2018 or emergency language will be repealed by operation of law on the following day.

210. Certificate of Compliance as to 12-1-2016 order transmitted to OAL 5-30-2017 and filed 7-10-2017 (Register 2017, No. 28).

211. Amendment of subsection (b)(10) filed 7-17-2017 as an emergency; operative 7-17-2017 (Register 2017, No. 29). A Certificate of Compliance must be transmitted to OAL by 1-16-2018 or emergency language will be repealed by operation of law on the following day.

212. Certificate of Compliance as to 1-10-2017 order adopting subsection (b)(13) transmitted to OAL 7-7-2017 and filed 7-20-2017 (Register 2017, No. 29).

213. Certificate of Compliance as to 12-22-2016 order transmitted to OAL 6-13-2017 and filed 7-24-2017 (Register 2017, No. 30).

214. Amendment of subsection (d)(1) and Note refiled 7-31-2017 as an emergency; operative 8-31-2017 (Register 2017, No. 31). A Certificate of Compliance must be transmitted to OAL by 11-29-2017 or emergency language will be repealed by operation of law on the following day.

215. Amendment of subsection (b)(1)(A), repealer of subsection (b)(1)(B) and subsection relettering refiled 8-3-2017 as an emergency; operative 8-3-2017 (Register 2017, No. 31). A Certificate of Compliance must be transmitted to OAL by 11-1-2017 or emergency language will be repealed by operation of law on the following day.

216. Certificate of Compliance as to 1-10-2017 order amending subsection (b)(11) transmitted to OAL 7-7-2017 and filed 8-10-2017 (Register 2017, No. 32).

217. Certificate of Compliance as to 4-17-2017 orders amending subsections (b)(8)-(b)(8)(B) transmitted to OAL 7-7-2017 and filed 8-16-2017 (Register 2017, No. 33).

218. Certificate of Compliance as to 1-10-2017 order amending subsection (b)(3) transmitted to OAL 7-7-2017 and filed 8-17-2017 (Register 2017, No. 33).

219. Certificate of Compliance as to 2-21-2017 order transmitted to OAL 7-31-2017 and filed 9-5-2017 (Register 2017, No. 36).

220. Amendment of subsection (b)(1)(A) filed 9-5-2017 as an emergency; operative 9-5-2017 (Register 2017, No. 36). A Certificate of Compliance must be transmitted to OAL by 3-5-2018 or emergency language will be repealed by operation of law on the following day.

221. Amendment of subsection (b)(13) filed 9-7-2017 as an emergency; operative 9-7-2017 (Register 2017, No. 36). A Certificate of Compliance must be transmitted to OAL by 3-6-2018 or emergency language will be repealed by operation of law on the following day.

222. Certificate of Compliance as to 2-13-2017 order transmitted to OAL 7-31-2017 and filed 9-12-2017 (Register 2017, No. 37).

223. Certificate of Compliance as to 2-24-2017 order transmitted to OAL 8-18-2017 and filed 9-27-2017 (Register 2017, No. 39).

224. Certificate of Compliance as to 3-2-2017 order transmitted to OAL 8-18-2017 and filed 9-28-2017 (Register 2017, No. 39).

225. Certificate of Compliance as to 3-24-2017 order transmitted to OAL 9-20-2017 and filed 10-23-2017 (Register 2017, No. 43).

226. Repeal of 3-28-2017 emergency amendment by operation of Government Code section 11346.1(f) (Register 2017, No. 43).

227. Amendment of subsection (b)(11) filed 11-2-2017 as an emergency; operative 11-2-2017 (Register 2017, No. 44). A Certificate of Compliance must be transmitted to OAL by 5-1-2018 or emergency language will be repealed by operation of law on the following day.

228. Certificate of Compliance as to 7-6-2017 order transmitted to OAL 9-27-2017 and filed 11-6-2017 (Register 2017, No. 45).

229. Certificate of Compliance as to 4-7-2017 and 8-3-2017 orders transmitted to OAL 10-5-2017 and filed 11-9-2017 (Register 2017, No. 45).

230. Amendment of subsection (b)(10) filed 11-20-2017 as an emergency; operative 11-20-2017 (Register 2017, No. 47). A Certificate of Compliance must be transmitted to OAL by 5-21-2018 or emergency language will be repealed by operation of law on the following day.

231. Certificate of Compliance as to 4-18-2017 order transmitted to OAL 10-13-2017 and filed 11-21-2017 (Register 2017, No. 47).

232. Amendment of subsection (b)(14) filed 11-22-2017 as an emergency; operative 11-22-2017 (Register 2017, No. 47). A Certificate of Compliance must be transmitted to OAL by 5-21-2018 or emergency language will be repealed by operation of law on the following day.

233. Certificate of Compliance as to 5-4-2017 order transmitted to OAL 10-27-2017 and filed 12-13-2017 (Register 2017, No. 50).

234. Certificate of Compliance as to 7-31-2017 order transmitted to OAL 10-27-2017 and filed 12-13-2017 (Register 2017, No. 50).

235. Repealer of subsections (b)-(b)(17), new subsections (b)-(b)(3), amendment of subsections (c)(1) and (c)(4)-(c)(5)(C), new subsections (c)(5)(D)-(E), repealer of subsections (d)(1) and (d)(3)-(4), subsection renumbering, new subsections (d)(1)-(d)(2)(B) and amendment of newly designated subsection (d)(3) filed 12-26-2017 as an emergency; operative 1-1-2018 pursuant to Government Code section 11346.1(d) (Register 2017, No. 52). A Certificate of Compliance must be transmitted to OAL by 7-2-2018 or emergency language will be repealed by operation of law on the following day.

236. Certificate of Compliance as to 7-17-2017 order transmitted to OAL 11-30-2017 and filed 1-3-2018 (Register 2018, No. 1).

237. Repealer of subsections (b)-(b)(17), new subsections (b)-(b)(3), amendment of subsections (c)(1) and (c)(4)-(c)(5)(C), new subsections (c)(5)(D)-(E), repealer of subsections (d)(1) and (d)(3)-(4), subsection renumbering, new subsections (d)(1)-(d)(2)(B) and amendment of newly designated subsection (d)(3) refiled 6-28-2018 as an emergency; operative 6-28-2018 pursuant to Government Code section 11346.1(d) (Register 2018, No. 26). A Certificate of Compliance must be transmitted to OAL by 9-26-2018 or emergency language will be repealed by operation of law on the following day.

238. Certificate of Compliance as to 6-28-2018 order, including further amendment of subsection (c)(1), transmitted to OAL 9-26-2018 and filed 11-6-2018; amendments effective 11-6-2018 pursuant to Government Code section 11343.4(b)(3) (Register 2018, No. 45).

This database is current through 6/17/22 Register 2022, No. 24

3 CCR § 3435, 3 CA ADC § 3435

END OF DOCUMENT

CITRUS RESEARCH BOARD

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MAGAZINE

FALL 2019

Attendees at the Palm Desert, California seminar provided their answers via clicker during participation in the interactive talk on the Citrus Pest & Disease Prevention Committee's voluntary action plan.

Grower Surveys Reveal Diverse Opinions about Managing ACP and HLB

Neil McRoberts, Sara García Figuera, Holly Deniston-Sheets and Elizabeth Grafton-Cardwell

Project Summary

The Data Analysis and Tactical Operations Center (DATOC) provides on-going research-based information to the Citrus Pest and Disease Prevention Program (CPDPP) regarding all aspects of the epidemiology and management of huanglongbing (HLB). "Economic Returns to Coordinated Actions to Control HLB" is a collaborative project between the University of California, Riverside and the University of California, Davis, in which biological simulation and economic analyses are used to estimate the economics of coordinated activities, such as area-wide pesticide applications, to control the spread of HLB. For both projects, it is important to understand the actions that individual growers plan to take in response to the threat of HLB, so information about growers' opinions of the proposed voluntary response plan is of interest. The results presented here come from surveys of growers who attended the June 2019 Citrus Research Board Citrus Growers Educational Seminar Series. These survey results provide a snapshot of growers' opinions about various aspects of Asian citrus psyllid (ACP) and HLB management, particularly in relation to the recently released CPDPP "Best practices in response to huanglongbing in California citrus."

Introduction

HLB is a regulated disease in California, so confrmation of a diseased tree through an approved diagnostic method triggers a regulatory response. Regulations stipulate mandatory removal of the tree, establishment of a quarantine zone around the infection and intensive surveying in a 400-meter radius of the infected tree to determine whether additional infected trees are present. However, it is hoped that growers voluntarily will take additional action to help limit the spread of the disease, either individually or in coordination with nearby growers. Recommended best practices were developed by a committee of growers, University of California scientists and other citrus program advisers including members of the DATOC panel, and recently were published by the CPDPP (*https://citrusinsider.org/psyllid-and-disease-control/voluntary- best-practices-for-growers-response-to-huanglongbing/*).

To assess the citrus industry's willingness to adopt these practices, clicker handsets were used to gather attendee responses at the Citrus Growers Educational Seminar Series, conducted this past June in Palm Desert, Santa Paula and Exeter, California *(see page 18)*. Preliminary highlights of the survey results are presented here, while more detailed analyses are on-going.

Who Participated?

The majority of respondents were grove owners or managers; a smaller fraction were Pest Control Advisers. About one-ffth of respondents in each location chose "other" to defne their involvement in the citrus industry (**Figure 1**). In Palm Desert, responses were split between small (less than fve acres) and large (greater than 500 acres) producers. In Santa Paula, 50 percent of respondents farmed 25 acres or less. In Exeter, the majority of respondents farmed 500 acres or more (**Figure 2**). We asked the audience at each seminar to consider the questions in relation to the coming year.

Communication and Risk Perception

The frst voluntary activity in the response plan is for growers to stay aware of the situation in their area. Most people were "likely" or "very likely" to discuss HLB with their grower and/or residential neighbors in the year ahead (**Figure 3**). Similar results (not shown) were obtained when respondents were asked how likely they would be to communicate with their Grower Liaisons.

Respondents were mostly optimistic that HLB would not be detected in their groves in the year ahead. The perceived

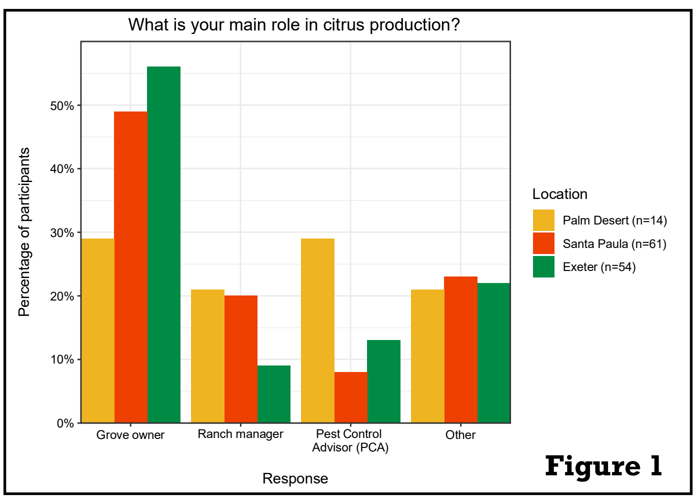

Figure 1

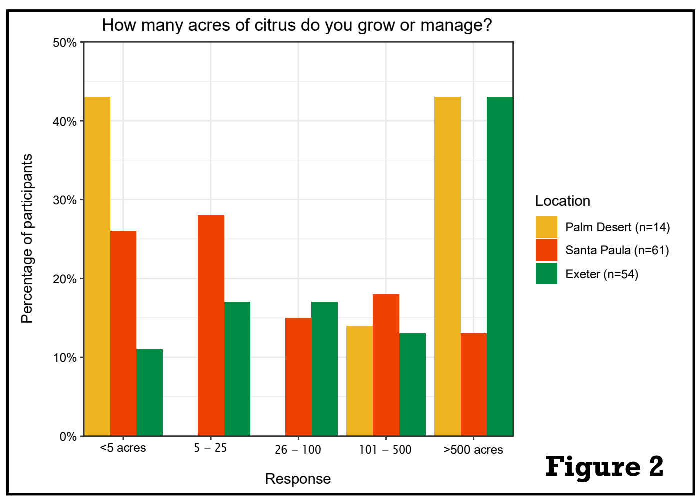

Figure 2

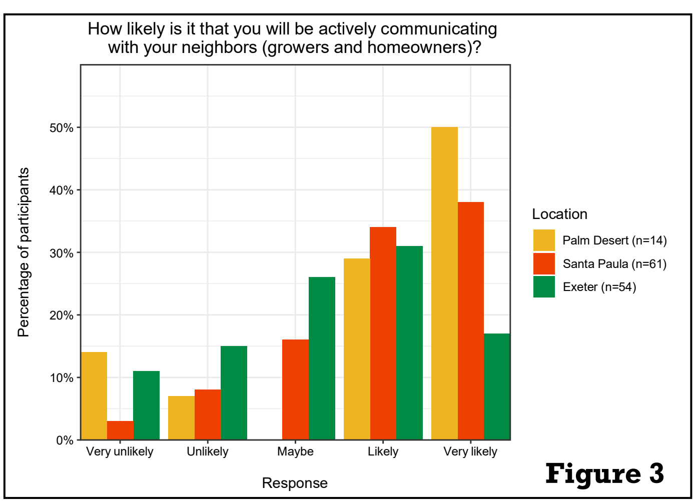

Figure 3

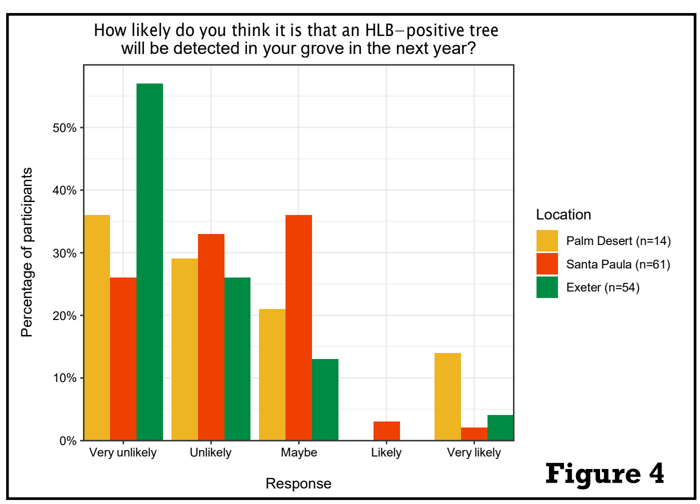

Figure 4

level of threat appeared to correspond with the distance from known HLB detections. In Palm Desert, 36 percent of respondents said that an HLB detection was "very unlikely," while the corresponding "very unlikely" numbers for Santa Paula and Exeter were 26 percent and 60 percent, respectively (**Figure 4**).

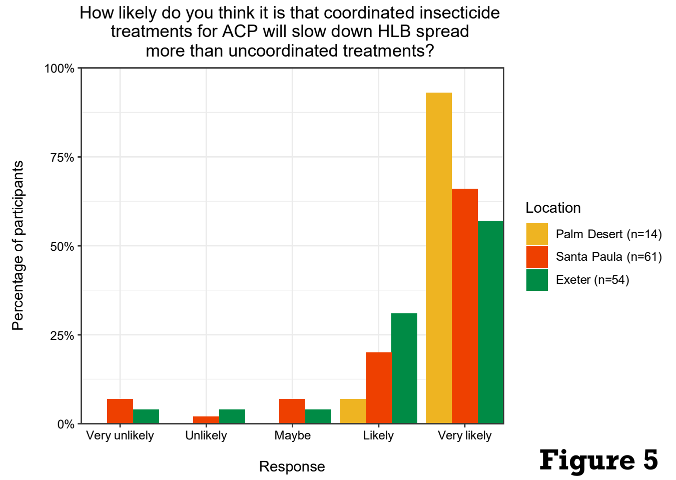

Figure 5

Area-wide ACP Control

The need for area-wide management to control ACP has been a consistent and regular outreach message from the CPDPP for several years. Based on responses from all three seminars, the message largely has been received (**Figure 5**). A majority of respondents at all three locations thought it "very likely" that coordinated treatments would slow down the rate of progress of HLB more than uncoordinated treatments would.

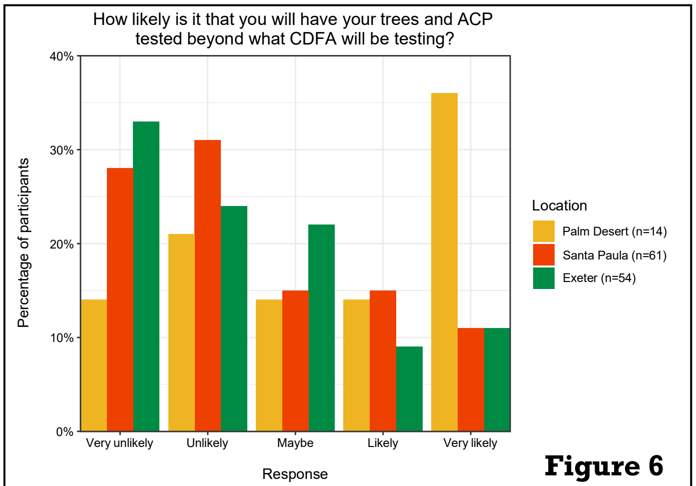

Figure 6

Additional Activities: Testing for HLB, Bactericide Use and EDTs

Growers were more likely to participate in recommended pesticide applications for ACP than to undertake additional actions to fnd disease or protect their trees. In all locations, the majority of respondents were "very unlikely" or "unlikely" to test additional ACP or tree samples for disease beyond the testing conducted by the California Department of Food and Agriculture (**Figure 6**).

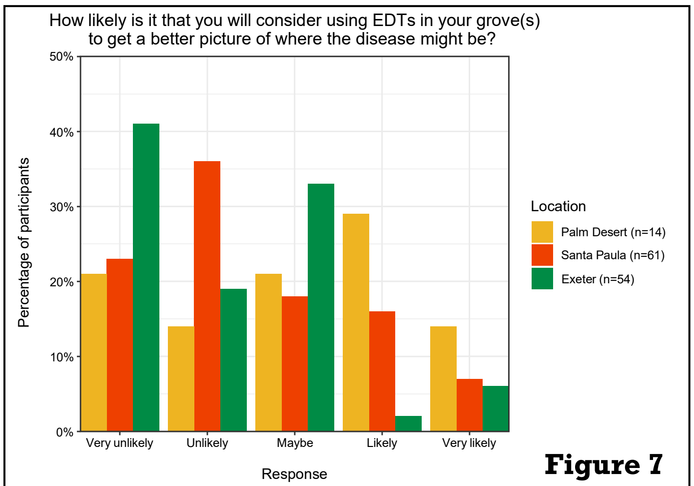

Figure 7

Although Early Detection Technologies (EDTs) and bactericides (two products currently are approved for use on citrus in California) are not recommended in the voluntary plan, we were interested to know if growers and ranch managers are considering using them. At the three locations, just 19 percent of respondents across the three regions indicated that they were "likely" or "very likely" to use bactericides and/or EDTs, suggesting that although some growers may use them in the near future, neither is a popular option at this time (**Figures 7** and **8**). These opinions do not seem to be based on a lack of knowledge about the options; typically (in our experience of administering opinion surveys with growers), respondents to this type of survey select "maybe" when uncertainty is due to a lack of information. This tendency is not strongly refected in the results, although it is more evident in the results for bactericides than EDTs.

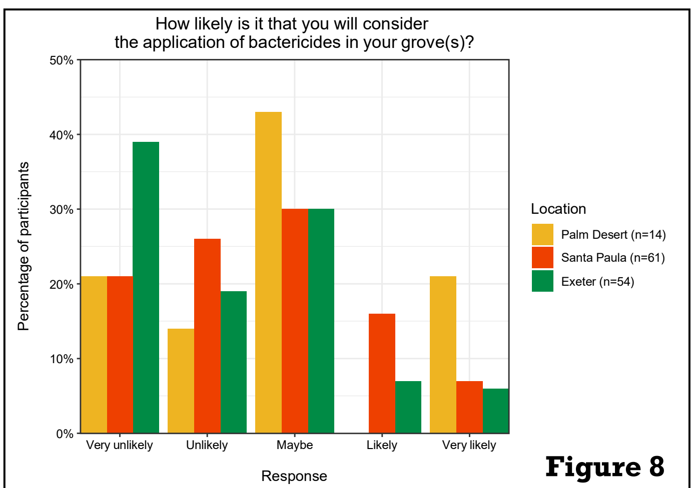

Figure 8

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REVIEW

Institutional approaches for plant health provision as a collective action problem

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Abstract

The provision of plant health has public good attributes when nobody can be excluded from enjoying its benefits and individual benefits do not reduce the ability of others to also benefit. These attributes increase risk of free-riding on plant health services provided by others, giving rise to a collective action problem when trying to ensure plant health in a region threatened by an emerging plant disease. This problem has traditionally been addressed by government intervention, but *top-down* approaches to plant health are often insufficient and are increasingly combined with *bottom-up* approaches that promote self-organization by affected individuals. The challenge is how to design plant health institutions that effectively deal with the spatial and temporal dynamics of plant diseases, while staying aligned with the preferences, values and needs of affected societies. Here, we illustrate how Ostrom's design principles for collective action can be used to guide the incorporation of *bottom-up* approaches to plant health governance in order to improve institutional fit. Using the ongoing epidemic of huanglongbing (HLB) as a case study, we examine existing institutions designed to ensure citrus health under HLB in Brazil, Mexico, the United States and Argentina, and discuss potential implications of Ostrom's design principles for the collective provision of plant health under HLB and other plant diseases that are threatening food security worldwide. The discussion leads to an outline for the interdisciplinary research agenda that would be needed to establish the link between institutional approaches and plant health outcomes in the context of global food security.

Keywords Plant health · Collective action · Public good · Area-wide management · Invasive species · Huanglongbing

1 Introduction

Plant health, the well-being of individual plants and communities in cultivated and natural ecosystems, is increasingly being threatened by plant pests and diseases (Giovani et al., 2020; MacLeod et al., 2010), fostered by climate change and the integration of the global economy (Bebber et al., 2014; Liebhold et al., 2012). Viral diseases vectored by insects such as the whitefly *Bemisia tabaci* or the Western flower thrips *Frankliniella occidentalis* (Gilbertson et al., 2015), fungal diseases such as 'Panama disease', caused by *Fusarium oxysporum* f. sp. *cubense* tropical race 4 (Maymon et al., 2020), or bacterial diseases such as Olive Quick Decline Syndrome, caused by *Xylella fastidiosa* sp. *pauca* (Schneider et al., 2020), are current examples of invasive plant diseases that have been detected outside their native habitat and have triggered costly emergency responses. When introduced into a new territory, invasive plant diseases can pose a significant risk to crop production and ecosystem services (Boyd et al., 2013; Paini et al., 2016; Simberloff et al., 2013), and they can be a major threat to food security, as they can limit the availability, quality and/or economic access to food (Fones et al., 2020; Savary et al., 2017). Because of these threats, many studies have been devoted to understanding the spread of plant diseases and developing management strategies, but fewer studies have examined how people coordinate

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efforts when implementing those strategies (McAllister et al., 2015).

When people face the challenge of protecting plant health from a disease spreading across a region, a *collective action problem* may arise. This occurs when individuals must choose whether to make a costly effort towards achieving some group-level goal, but because they can individually benefit from the efforts of others without bearing the costs, they have an incentive to reduce their effort or withdraw it completely; i.e. to free ride. If enough individuals free ride, the group goal may not be achieved (Gavrilets, 2015). Collective action problems are inherent to situations in which individuals cannot be excluded from the benefits of others' efforts, such as in the provision of public goods (Sandler, 2015).

Preserving plant health from disease has public good attributes because one grower's benefits from low disease pressure does not reduce the ability of others in the affected region to also benefit (i.e., it is *non-rivalrous*), and no grower can be excluded from the benefits of healthy production (i.e., it is *non-excludable)* (Lansink, 2011). Pioneering studies proposed that invasive species management generated environments free of invasive species that also had public good attributes (Perrings et al., 2002; Sumner, 2003), and the concept of reducing invasive species or weeds as a public good has been reviewed recently (Bagavathiannan et al., 2019; Graham et al., 2019, Niemiec et al., 2020). In essence, the notion is that individuals pursuing their own interests by taking actions to ensure plant health on their own properties can benefit from provision generated by nearby properties. Thus, they may be tempted to free ride on others' efforts. This sets up the classic collective action problem outlined above. In the extreme case where a single individual can bring collective benefits to zero by, for example, not taking measures to ensure plant health on their own property and thereby keeping open an avenue for disease spread that defeats the efforts of neighbors, then plant health can be considered a weakest-link public good, in which the level of overall provision would be determined by the least effective provider (Hennessy, 2008; Perrings, 2016). A few recent studies have advanced this conceptualization of provision of plant health as a public good, extending the scope of the collective action problem from the management of *invasive* pests and diseases to *established* plant diseases with great spread potential (Damtew et al., 2020; Sherman et al., 2019). The crucial question that remains is: how can individuals organize effectively to achieve desired levels of protection against disease?

Institutions are the formal and informal rules, norms and conventions that societies use to structure interactions and increase predictability in situations of interdependent choice (Ostrom, 2005). In *top-down* institutional approaches to plant health, governments assume regulatory command of plant health services, establishing rules to prevent disease spread and funding monitoring and management efforts (FAO, 1999). Government intervention is typically justified by *under-provision* of plant health by the sum of individuals' efforts and the need to ensure food security (Epanchin-Niell, 2017; Waage & Mumford, 2008). However, because of high transaction costs of monitoring disease spread and enforcing management efforts across all actors, *top-down* approaches are often insufficient on their own to prevent the spread of emerging plant diseases (Colella et al., 2018; Gottwald et al., 2001). The alternatives are *bottom-up* approaches based on self-organization by the affected communities, or hybrid approaches that combine the expertise and resources of government agencies with community-based initiatives and local knowledge (Epanchin-Niell et al., 2010; John, 2006). Although these alternative approaches are increasingly being exploited (Higgins et al., 2016; Mato-Amboage et al., 2019), there is a lack of institutional guidelines to effectively incorporate them into plant health governance.

We would like to offer further insight to this emerging field by examining the extent to which Ostrom's design principles for the sustainable management of common-pool resources (Ostrom, 1990) can be used as a guiding framework to incorporate *bottom-up* approaches into plant health governance. Plant health institutions must deal with the inherent spatial and temporal variability of emerging pests and diseases. At the same time, they must also be aligned with the preferences, values and needs of the societies affected so that plant production can be sustained. Our goal is to show how Ostrom's (1990) principles can be used to meet these challenges and place the task of institutional design within a broader social-ecological systems framework. To ground our work in a well-documented example, we focus on huanglongbing (HLB) disease of citrus, since it exhibits many of the characteristics of invasive diseases that give rise to a collective action problem, while being widely documented and of sufficient global importance to merit attention in its own right. Using the ongoing HLB epidemic in North and South America as a case study, we explain the collective action problem associated with citrus health under HLB, document the extent to which the institutions designed to manage HLB follow Ostrom's principles, and discuss further implications of collective action theory for plant health in the context of global food security, showing how this approach could be applied to other diseases that threaten food security worldwide.

2 Plant health provision requires collective action

Although the collective action problem associated with plant health has been mostly characterized for invasive species (Graham et al., 2019), certain attributes of endemic plant diseases such as aerial spore dispersal (Damtew et al., 2020; Sherman et al., 2019), insect vector dispersal (Anco et al., 2019) and/or importance of primary and secondary inoculum for disease epidemics (Bergamin Filho et al., 2016) call for regional management approaches that may also give rise to collective action problems. Some of these endemic diseases, such as rice tungro disease (Cabunagan et al., 2001) or cassava brown streak disease (Legg et al., 2017), are a major threat to food security in Southeast Asia and East Africa. Despite the fact that a collective action problem was identified as the most important obstacle to integrated pest management (IPM) adoption in developing countries (Parsa et al., 2014), institutional approaches to promote plant health in these contexts have been rarely characterized (Lansing, 1991). To the extent possible, we will draw parallels between HLB as the focus of our study and endemic diseases in staple crops that also require collective action.

HLB is considered the most severe threat to citrus health worldwide (Bové, 2006). Most commercial citrus cultivars are susceptible to HLB (Ramadugu et al., 2016), and infected trees have reduced yield and fruit quality (Bassanezi et al., 2011; Dala-Paula et al., 2019). Once a tree is infected, there is no cure, and it will typically die (McCollum & Baldwin, 2016). The most prevalent type of HLB is associated with the bacterium "*Candidatus* Liberibacter asiaticus" (*C*Las), which is transmitted by grafting and by an insect vector, the Asian citrus psyllid (ACP), *Diaphorina citri* (Bové, 2006). Both bacterium and vector have spread from Asia to the American continents and threaten citrus production in Brazil, Mexico, the United States and Argentina, which are among the top citrus producers worldwide (Fig. 1).

HLB is difficult to eradicate because ACP is mobile and prolific, *C*Las multiplies in both the insect vector and the tree, and trees are infectious long before detection is possible (da Graça et al., 2016). Vector control is key to disease management because HLB epidemics are driven by ACP that migrate into citrus groves (Gasparoto et al., 2018). Effective vector control requires *area-wide management* (AWM), which consists of time-coordinated insecticide sprays by all growers in a region (Vreysen et al., 2007). Because coordinated treatments benefit the whole group, any grower may be tempted to rely on others' treatments and avoid the cost of spraying, but if a grower fails to coordinate, that property can sustain ACP and spread HLB to the rest (Bassanezi et al., 2013). Thus, like other plant diseases (Damtew et al., 2020; Sherman et al., 2019), the challenge for HLB is how to overcome a collective action problem to ensure citrus health provision (Singerman & Rogers, 2020).

A similar collective action problem arises in the area-wide management of rice tungro disease (RTD), the most important viral disease of rice in South and Southeast Asia. Tungro-infected plants show yellow to orange leaf discoloration and stunted growth, and severe infections may lead to considerable yield losses (Azzam & Chancellor, 2002). RTD is caused by two viruses, *Rice tungro spherical virus* (RTSV) and *Rice tungro bacilliform virus* (RTBV), which are transmitted in a semipersistent manner by six leafhopper vector species, the most important being the green leafhopper, *Nephotettix virescens* (Azzam & Chancellor, 2002). Rice plants can become infectious within 1 week of being inoculated, and the vector can acquire and transmit the viruses within minutes, so insecticide treatments are generally ineffective to prevent RTD epidemics, and the main management practices are the use of resistant rice varieties and area-wide synchronous planting (Savary et al., 2012). Synchronizing the timing of rice planting over a sufficiently large area imposes a non-rice period between harvest and planting when the leafhopper may lose the viruses, it may not able to feed, and transmission from fields planted earlier in the season to newly planted fields may be prevented (Savary et al., 2012). The adoption of synchronous planting in Southeast Asia in the 1970s and 1980s was successful at controlling RTD epidemics in parts of Indonesia and Malaysia, but in other areas it faced significant socio-economic and socio-cultural constraints (Azzam & Chancellor, 2002). Synchronous planting increased hire rates of tractors and labor, it required an efficient irrigation network, and most importantly, it required extensive cooperation among farmers and coordination among government agencies (Cabunagan et al., 2001). Therefore, rice growers trying to synchronize their planting period to prevent RTD epidemics and ensure rice health faced a similar collective action problem to citrus growers trying to coordinate their insecticide treatments against the ACP to ensure citrus health, and parallels between institutional arrangements for RTD and HLB will be illustrated below, data availability permitting.

Likewise, cassava growers in Central and East Africa also face a collective action problem to protect their crops from cassava brown streak disease (CBSD), which is considered the greatest threat to cassava productivity in Africa (Legg et al., 2014). CBSD causes leaf chlorosis, brown streaks on the stem and root necrosis, which has devastating consequences, as cassava roots are a prime food security crop (Mbewe et al., 2020). CBSD is caused by two related viruses, *Cassava brown streak virus* (CBSV) and *Ugandan cassava brown streak virus* (UCBSV), which are transmitted in a semipersistent manner over short distances by the whitefly *B. tabaci* (Maruthi et al., 2017). Because cassava is vegetatively propagated, CBSD can also spread over long distances through trade of infected cassava cuttings. As a consequence, cassava health provision strategies are currently focused on providing certified plant material, improving CBSD surveillance and diagnosis, and breeding or genetically engineering resistant cultivars (Legg et al., 2014). To date, the area-wide use of certified cassava cuttings is one of the most viable options to ensure cassava health, but it requires compliance by most cassava growers in a region to avoid the introduction of inoculum that could be subsequently spread to nearby fields by the prevalent whitefly populations (Ferris et al., 2020). A pilot

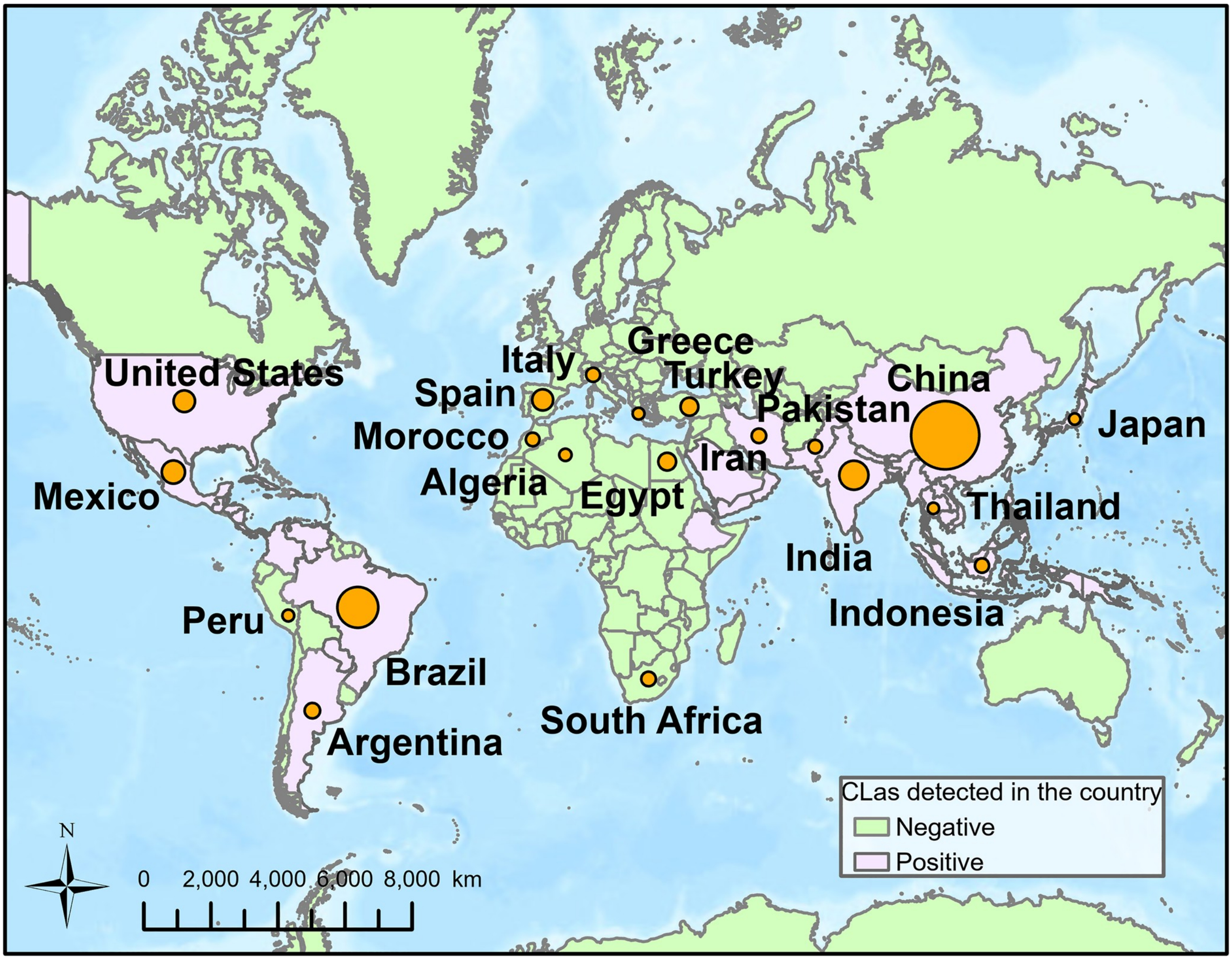

Fig. 1 Current distribution of "*Candidatus* Liberibacter asiaticus" (*C*Las) in citrus-producing countries. Countries that have detected *C*Las are shown in pink, and countries that have not detected *C*Las are shown in green (CABI, 2020a). The orange circles are proportional to the total citrus production (tonnes) of the 20 countries with the highest citrus production worldwide (FAO, 2018), which have been labelled. Eleven of them (Argentina, Brazil, China, India, Indonesia, Iran, Japan, Mexico, Pakistan, Thailand, United States) have detected *C*Las; and nine of them (Algeria, Egypt, Greece, Italy, Morocco, Peru, South Africa, Spain, Turkey) have not detected *C*Las

"community phytosanitation" program for CBSD that involved area-wide removal of infected plants and replanting with certified cassava cuttings was recently implemented in Tanzania (Legg et al., 2017), offering another example of how to address a collective action problem in plant health provision.

3 Institutional arrangements for plant health provision

In order to ensure citrus health, similar institutional arrangements to promote AWM of ACP have emerged in HLB-affected citrus regions in North and South America (Fig. 2), following international guidelines (COSAVE, 2017; FAO, 2013; NAPPO, 2015). Each region has implemented an emergency response to the invasive disease that contains elements of a *top-down* approach, with the National Plant Protection Organization (NPPO) leading monitoring and diagnostic efforts, nursery certification and overseeing other activities. However, each region also relies on the citrus industry and local authorities to coordinate actions, suggesting elements of a *bottom-up* approach. Although the international guidelines stress that successful AWM requires participation by all growers in a region, they do not explicitly characterize it as a collective action problem or provide institutional recommendations to prevent free-riding. Research into these aspects has been scant (NASEM, 2018).

Like citrus health provision, sustainable management of common-pool resources (CPRs), such as forests and fisheries,

Fig. 2 Status of the HLB epidemic in Brazil, Mexico, the United States and Argentina. Countries that have detected CLas are shown in pink, and countries that have not detected CLas are shown in green (CABI, 2020a). In Brazil, Mexico, the United States and Argentina, state/province labels include the year of the first HLB-positive tree detection. For Mexico, only the nine main citrus-producing states have been labeled. The status of the HLB epidemic per state/province was determined according to the categories used by CABI (2020b) with information retrieved from each country (Bassanezi et al., 2020; SENASA, 2020; SENASICA, pers. comm.; USDA-APHIS-PPQ, 2019). Few occurrences (yellow) indicates that HLB has been reported occasionally and its presence is rare or sporadic, which corresponds to less than 100 HLB-positive trees in Argentina and the US; and less than 10% of citrus acreage infected in Mexico. Localized (orange) indicates that HLB is present but does not occur in some suitable parts of the state. Widespread (red) indicates that HLB has been detected practically throughout the state where conditions are suitable

requires collective action (Ostrom, 1990). CPRs are similar to public goods in that they are *non-excludable*, because they are sufficiently large to make it costly to exclude potential users from obtaining benefits from their use. However, unlike public goods, CPRs are *rivalrous*, because consumption of the resource by a user reduces availability for the rest. Both give rise to a collective action problem, which may lead to *over-exploitation* in the case of CPRs and *under-provision* in the case of public goods (Ostrom, 1990).

Observations of community management of CPRs led Ostrom to identify eight institutional design principles (DPs) associated with effective self-organization (Table 1), which have been validated by many studies (Baggio et al., 2016; Cox et al., 2010). Because Ostrom's DPs identify conditions that build trust and reciprocity to foster and sustain collective action, our hypothesis is that the extent to which the DPs are incorporated in the regional institutional arrangements for plant health will provide insight into the likely effectiveness of collective efforts to achieve desired outcomes. The detailed example we discuss concerns HLB, but the extension of the concepts to other plant health threats is straightforward.

We obtained information from a variety of sources about the institutional arrangements for citrus health under HLB in Brazil, Mexico, Argentina, Florida, Texas and California, which are examined below in light of the DPs (Table 2).

3.1 DP1: Clearly defined boundaries

Clear user and resource system boundaries exist for AWM of ACP in Brazil, Mexico, Florida, Texas and California. In Brazil, growers formed voluntary groups to coordinate AWM of ACP (Belasque Junior et al., 2009). Additionally, some large citrus operations have provided citrus health services beyond their boundaries, spraying homeowner citrus trees monthly and offering to replace them with other fruit trees (Johnson & Bassanezi, 2016). The Mexican government defined the boundaries of ACP management areas based on HLB incidence, ACP prevalence, citrus acreage, climatological conditions and geographical barriers (SENASICA, 2012). In Florida, growers were asked to voluntarily coordinate treatments over areas that were designed to achieve local ACP population suppression (Rogers, 2011). Texas citrus growers established pest management zones within which every grower is required to treat in coordination (TCPDMC, 2020a). In California, AWM is organized through Psyllid Management Areas (PMAs) and Pest Control Districts (PCDs). PMAs are voluntary groups of 25–35 neighboring growers who coordinate insecticide applications over 2–3 weeks (Grafton-Cardwell et al., 2015). PCDs are special districts formed by growers to have the legal authority to enforce control measures against pests affecting a specific crop (UCCE, 2005).

3.2 DP2: Congruence between appropriation and provision rules and local conditions

Congruence between rules and local conditions (DP2A) is hard to achieve under *top-down* approaches if plant health rules for an entire country do not account for local circumstances and stakeholders' attributes. In Brazil, a national law requires the removal of symptomatic trees, but AWM rules are defined by the citrus industry (Belasque Junior et al., 2009). In Mexico, national citrus health rules are enforced by federal and state authorities (FAO, 2013; SENASICA, 2019a). In Argentina, there is a national plan for HLB, but rules are established in consultation with the state authorities and the citrus industry (SAGPyA, 2009). In the US, the NPPO provides oversight and funding, regulates the movement of plant material between states, and certifies diagnostic protocols (USDA-APHIS-PPQ, 2019). However, citrus health rules differ among states (Graham et al., 2020), and rule enforcement differs by county within states.

Congruence between appropriation and provision rules (DP2B), i.e. an alignment between who funds citrus health efforts, who implements them and who benefits from them, varies between regions. National funds collected through taxes are used to manage HLB everywhere, but the citrus industry is also providing funds, mostly for monitoring. In Texas, monitoring efforts are funded through assessments collected per acre (TCPDMC, 2020a). In California, the state-wide HLB response is funded through assessments collected at an agreed rate on each carton of citrus fruit harvested, and PCD assessments are collected per acre. Details of the funding arrangements are not available for other regions. Insecticide treatments are paid individually by growers in every region except Mexico, where the federal government supplies insecticides to most management areas (SENASICA, 2019a).

3.3 DP3: Collective-choice arrangements

Evidence of grower participation in rule-making for citrus health at the local level is not available for most regions. A Citrus Sectorial Chamber in Brazil and an Inter-institutional Coordination Unit in Argentina –composed of representatives of the citrus industry, the NPPO, state authorities and scientists– meet periodically to review the status of the HLB epidemic and recommend actions to be regulated (MAPA, 2020; SAGPyA, 2009). In Texas, a non-profit organization funded by the citrus industry plans and operates the AWM program (TCPDMC, 2020a). In California, the State program for HLB is led by a committee of citrus industry representatives, which discusses rules in public meetings, approves them by vote, and enforces them through an agreement with the California Department of Food and Agriculture (CDFA). At the local level, growers choose to coordinate through PMAs, which are voluntary; or PCDs, which are established by a

Table 1 An explanation of Ostrom's design principles illustrated by long-enduring common-pool resource institutions, based on Ostrom (1990) and Cox et al. (2010)

Design principle	Explanation
1. Clearly defined boundaries	This principle refers to the presence of well-defined boundaries around a community of users and around a resource system. The boundaries define who is responsible for collective action and over what area, which reduces the costs of monitoring behavior
2A. Congruence between rules and local conditions 2B. Congruence between appropriation and provision rules	The second principle can be subdivided into two: that both appropriation and provision rules conform to local conditions (DP2A); and that there is congruence between appropriation and provision rules (DP2B). DP2A means that the rules that are established for the management and maintenance of a resource are aligned with the predominant social norms, culture, and agro-ecological conditions in a community. DP2B refers to a correspondence between the rules governing contributions to the maintenance of the resource system, and the rules governing withdrawal of resources from the system
3. Collective-choice arrangements	It was stated as "most individuals affected by the operational rules can participate in modifying the operational rules". If local users who directly interact with one another can define the rules that regulate the day-to-day decisions about the use of a shared resource, they will be in a better position to incorporate local knowledge
4A. Monitoring users 4B. Monitoring the resource	This principle is based on the idea that a community needs to be able to identify users that do not comply with rules; otherwise there can be no credible commitment. Monitoring should be undertaken by the resource users, not by external authorities. Monitoring the resource condition assesses the extent to which collective action is effectively providing public goods or preventing overexploitation of common-pool resources
5. Graduated sanctions	Although sanctioning prevents an excessive violation of community rules, sanctions should be graduated based on the severity and/or repetition of violations to ensure proportionality. And they should be imposed by the resource users or officials accountable to them, to maintain community cohesion
6. Conflict-resolution mechanisms	It was stated as "appropriators and their officials have rapid access to low-cost arenas to resolve conflicts among appropriators or between appropriators and officials". Low-cost conflict resolution prevents the cost of conflict from outweighing the benefits of successful collective action
7. Minimal recognition of rights to organize	It was stated as "the rights of appropriators to devise their own institutions should not be challenged by external governmental authorities". Local institutions are more effective when higher levels of government allow users to self-organize in ways that reflect local social and ecological contexts
8. Nested enterprises	It was stated as "governance activities are organized in multiple layers of nested enterprises", and it refers to the importance of connecting smaller social systems that manage different parts of a larger resource system to facilitate cross-scale coordination

majority vote (≥51% of acreage) and are subject to the rules defined by the elected PCD board of directors (UCCE, 2005).

3.4 DP4: Monitoring

Monitoring growers (DP4A) for compliance with AWM occurs in Mexico, where state coordinators report monthly treated area relative to area targeted for treatment (SENASICA, 2019b) and Texas, where scouts hired by the state program call growers after the AWM treatments to record the percentage of the acreage that was treated coordinately (Sétamou, pers. comm.). In California, regional coordinators track the acreage that was treated under coordination through pesticide use reports. Coordinators have close ties with the citrus community and are accountable to the grower committee.

Monitoring ACP populations (DP4B) is done everywhere to enable better timing of insecticide applications. In São Paulo, the monitoring program is led by the citrus industry (Fundecitrus, 2020b). In Mexico, a technical working group within each state monitors ACP populations and determines

Table 2 Presence of Ostrom's "Design principles illustrated by long-enduring CPR institutions" in the institutional arrangements for citrus health under HLB in different citrus-growing areas

Design principle	São Paulo (Brazil)	Mexico	Entre Rios (Argentina)	Florida (USA)	Texas (USA)	California (USA)
1. Clearly defined boundaries	Regional management groups	Epidemiological Phytosanitary Management Areas (AMEFIs)	–	Citrus Health Management Areas (CHMAs)	Citrus Pest and Disease Manageme-nt Zones	Psyllid Management Areas (PMAs) or Pest Control Districts (PCDs)
2A. Congruence between rules and local conditions	AWM rules defined by the local citrus industry	AWM rules defined by national plan	AWM rules not available	AWM rules defined by growers in collaboration with University of Florida (UF-IFAS)	AWM rules defined by growers in collabora-tion with Texas A&M University	AWM rules defined by the local citrus industry with advice from University of California (UC). Some pre-existing PCDs
2B. Congruence between appropriation and provision rules	AWM funded by individual growers	Insecticides supplied by government to non-autonomous AMEFIs	ACP control funded by individual growers	AWM funded by individual growers	AWM funded by individual growers. Assessmen-ts to the TCPDMC based on acreage	AWM funded by individual growers. Other HLB assessments based on production volume or acreage
3.	Collective-choice arrangements	AWM organized locally through Fundecitrus. Other HLB rules defined at national level in consultation with Citrus Sectorial Chamber	AWM organized at national level	AWM not available. Other HLB rules defined at national level in consultation with Inter-institutional Coordination Unit	AWM organized by growers in collabora-tion with UF-IFAS	AWM organized by the Texas Citrus Pest and Disease Management Corporation (TCPDMC)
AWM organized locally through PCDs or PMAs. Citrus Pest and Disease Prevention Committee (CPDPC) estab-lishes rules for HLB in collabo-ration with the California Department of Food and Agriculture (CDFA)						
4A. Monitoring users	No	Monthly reports of area treated coordinately	–	No	Reports of area treated coordinate-ly after each treatment	Seasonal reports of area treated coordinately
4B. Monitoring the resource	Phytosanitary Alert System by Fundecitrus	Diaphorina Monitoring System (SIMDIA)	Monitoring by citrus industry and Argentine National System for Surveillance and Monitoring (SINAVIMO)	Florida Department of Food and Agriculture (FDACS) with federal funds from Citrus Health Response Program (USDA-CHRP)	ACP monitoring program by TCPDMC. Scouts hired by TCPDMC and growers	ACP monitoring by CDFA, County Agricultural Commissioners (CACs), Citrus Research Board (CRB) and pest con-trol advisors (PCAs) hired by growers

Table 2 (continued)

Design principle	São Paulo (Brazil)	Mexico	Entre Rios (Argentina)	Florida (USA)	Texas (USA)	California (USA)
5. Graduated sanctions	No	No	No	No	No	No
6.						Conflict-resolution mechanisms
–	–	–	–	–	No, but Task Force meetings and other public meetings have been used for addressing conflicts	
7. Minimal recognition of rights to organize	Fundecitrus	AMEFIs and State Plant Health Committees established by the government, but with grower leaders and citrus industry representatives	Federación del Citrus de Entre Ríos	CHMAs imposed on growers, but use of a grower leader	TCPDMC	CPDPC, PCDs, grower leader in PMAs
8. Nested enterprises	Yes	Yes	Yes	Yes	Yes	Yes

Note: The symbol "-" indicates that there is not enough information available to determine whether the design principle is present or not. Information retrieved from Brazil Fundecitrus (2020a), MAPA (2020), Mexico SENASICA (2019b), (2019a), Argentina SAGPyA (2009), (2018), Florida FDACS (2016), National Research Council (2010), Texas TCPDMC (2020a) and California CDFA (2019)

when to spray (SENASICA, 2019a). In Argentina, ACP monitoring is part of a national surveillance system, but also involves the citrus industry (ACC, 2018). In Florida, federal and state authorities monitor ACP populations and the University of Florida suggests treatment times (Rogers et al., 2010). In Texas, the industry organization hired scouts to monitor the ACP population and citrus flush (new foliar growth) to time treatments (Sétamou, 2020). In California, CDFA, county authorities, grower organizations and advisors hired by the growers cooperatively monitor ACP populations, and treatments are decided by local task forces or PCDs in consultation with the University of California. Real-time ACP population data are published online in Brazil, Florida and Texas (Fundecitrus, 2020c; TCPDMC, 2020b; UF-IFAS, 2018).

3.5 DP5: Graduated sanctions

Sanctions on growers who do not comply with citrus health rules are not common. In Brazil, growers who do not inspect regularly and remove infected trees are subject to fees (MAPA, 2008), but they are not sanctioned for non-compliance with AWM. California has opted to incentivize compliance instead of sanctioning. If 90% of the acreage in a PMA or PCD is treated within a specific time frame, the CDFA will treat nearby residential areas if given consent by homeowners (CDFA, 2019). In some of the PCDs, if growers cannot prove compliance with AWM they do not receive reimbursement of PCD assessments. The board of directors of the PCD has the right to enter their property and treat on their behalf, billing them later.

3.6 DP6: Conflict-resolution mechanisms

We found no reference to conflict-resolution arenas in any of the areas. In California, CPDPC, PCD and Task Force meetings are public, providing a potential arena for discussing conflicts over provision of citrus health.

3.7 DP7: Minimum recognition of rights to organize

Stakeholder rights to devise institutions to ensure citrus health under HLB have been recognized in all areas. In São Paulo, AWM for ACP is coordinated by Fundecitrus, an association funded by growers and juice manufacturers (Bassanezi et al., 2013). In Mexico, the committees that coordinate efforts at the state level already existed for other crops. Although ACP management areas were imposed on the citrus growers by federal or state authorities in Mexico and Florida, they rely on local leaders to coordinate efforts (Rogers, 2011; SENASICA, 2019a). In Texas, the citrus industry voted to establish the Texas Citrus Pest and Disease Management Corporation, which was authorized to lead the HLB response under the supervision of the Texas Department of Agriculture (TCPDMC, 2020a). Similarly, a committee composed of elected industry representatives leads the HLB response in California in collaboration with CDFA. At the local level, growers have the right to decide whether to coordinate through PMAs or PCDs.

3.8 DP8: Nested enterprises

Because HLB is an invasive disease that can spread quickly over different jurisdictions, international guidelines stress the importance of coordinating activities across institutional scales. NPPOs have established a national plan that is implemented by State authorities through coordination with regional authorities and collaboration from the citrus industry. However, the governance network is adapted to each area, and cross-scale interactions vary. For instance, Brazil and Florida rely on local organizations to coordinate AWM, while federal and state organizations monitor or enforce regulations. In contrast, Mexico, Argentina, Texas and California state-level committees coordinate HLB management, gathering local information to transmit to the higher scales while orders and funds are transferred from the national and state authorities to the local scales.

4 Implications of Ostrom's design principles for plant health

With the increasing global threat to food security from plant pests and diseases, there is a need to better understand what institutional approaches might be more appropriate for provision of plant health in different social-ecological systems. This will only be achieved by examining the performance of institutions in different contexts and developing a theory of when particular institutional arrangements seem to lead to better ecological and social outcomes (Epstein et al., 2015). We chose to focus on HLB because it is a well-documented example of an invasive disease that is threatening citrus production worldwide and has triggered parallel responses amid different ecological and social contexts, but a similar approach could be employed for other plant diseases that are threatening food security in other parts of the world, as illustrated in Table 3. As observed with RTD (Cabunagan et al., 2001) and recently with CBSD (Legg et al., 2017), epidemiological studies have proven that collective action is key to limiting HLB spread and ensuring citrus health (Bassanezi et al., 2013). Consequently, institutional arrangements were made following international guidelines to promote AWM of ACP and ensure *ecological fit* between institutions and the spatial and temporal dynamics of HLB. Fewer recommendations were made to ensure *social fit* between institutions and the societies affected.

Using Ostrom's DPs as a diagnostic tool to examine plant health institutions across different geographical areas is a necessary step towards applying collective action theory to plant health governance in order to improve *social fit*. Our study shows that Ostrom's DPs have been incorporated in all HLB-affected areas' institutions, suggesting implicit recognition of the collective action problem associated with citrus health provision, even though there is no evidence that it was explicitly considered. Because the DPs reduce the transaction costs of searching for mutually beneficial solutions; bargaining over the costs and benefits of those solutions; and monitoring and enforcing management actions (Wilson et al., 2013), collective action theory predicts that citrus-growing areas that incorporate more DPs will be more effective in engaging affected communities, promoting self-organization, and securing participation in AWM that ultimately helps slow HLB spread. These concepts seem to be general enough that they can be expected to apply to a wide range of plant health threats.

Indeed, the apparent relationship between DPs, as implicitly understood and operationalized on an ad hoc basis, and plant health provision suggests the DPs might be a useful reference to improve *social fit*, and consequently *social-ecological system fit* (Epstein et al., 2015). For example: HLB was first detected in Brazil and Florida, and the epidemics have followed very different trajectories. In Brazil, the citrus industry self-organized through Fundecitrus and is leading the AWM program, fulfilling most of Ostrom's DPs. In the states of São Paulo and Minas Gerais, the percentage of HLB-positive orange trees has stabilized around 18% and citrus production survives at a profitable level (Bassanezi et al., 2020). This "success" is commonly attributed to the large size of citrus operations and the adoption of control measures as soon as HLB was detected, fostered by a national law that required surveying and removing infected trees (Bové, 2012). By contrast, many growers in Florida were reluctant to voluntarily remove infected trees and, despite ACP control, HLB spread quickly to 12 counties in 2 years (Bové, 2012; Shimwela et al., 2018). ACP management areas defined by experts set clear boundaries for collective action (DP1), but growers lacked experience in coordinating activities (no DP2A or DP7), participation was not monitored (no DP4A), sanctions were not imposed on noncompliant growers (no DP5), and there was no state-level industry-led organization coordinating efforts (no DP8). A recent study concluded that the AWM program in Florida has been unsuccessful and

Table 3 Presence of Ostrom's "Design principles illustrated by long-enduring CPR institutions" in the institutional arrangements for rice health under rice tungro disease (RTD) in Southeast Asia and cassava health under cassava brown streak disease (CBSD) in East Africa

Design principle	RTD	CBSD
1. Clearly defined boundaries	Irrigation blocks of 1000–2000 ha, considering vector dispersal range (Loevinsohn et al. 1993)	Two study areas in different parts of Tanzania chosen by researchers based on importance of cassava to the communities and relative CBSD severity Legg et al. (2017)
2A. Congruence between rules and local conditions	Coordination required for synchronous planting is similar to coordination required for water management, but rice irrigation systems favor asynchronous planting Goodell (1984)	One-year long period of sensitization with farmers, research institutions, non-governmental organizations and extension services prior to community phytosanitation study. Local leaders raised awareness about the initiative Legg et al. (2017)
2B. Congruence between appropriation and provision rules	Mostly *top-down* programs with government funding Litsinger (2008)	Study conducted with grant funding. Removal of all existing cassava plants by community members. Provision of disease-free cassava planting material by the research team. Free maize seed and sweet potato planting material supplied as an incentive for compliance Legg et al. (2017)
3. Collective-choice arrangements	No evidence in most areas, except for some irrigator associations in the Philippines Goodell (1984)	Farmers removed plants in existing cassava fields, and the process was supervised by local task forces (Legg et al., 2017)
4A. Monitoring users	In some studies, the percentage of rice area planted synchronously was monitored by researchers Sama et al. (1991)	Local task forces composed of extension workers and farmer representatives ensured that farmers did not plant local varieties and removed plants that showed CBSD symptoms Legg et al. (2017)
4B. Monitoring the resource	Not recommended. Studies suggested that monitoring the vector population was not useful to predict RTD epidemics Chancellor et al. (1996)	Community members monitored the fields and removed symptomatic plants. Researchers collected vector, disease and harvest data for the study Legg et al. (2017)
5. Graduated sanctions	The Malaysian government threatened to withhold irrigation from growers that were late in following the recommended planting dates	-
6. Conflict-resolution mechanisms	-	-
7. Minimal recognition of rights to organize	Asking rice field neighbors to collaborate was problematic, because groupings of rice growers in Southeast Asia tended to be based on residential neighborhood proximity or kinship, not rice field proximity. Only in some areas there was a precedent for collaboration through irrigator associations Goodell (1984)	-
8. Nested enterprises	-	National Cassava Steering Committees created to bring together stakeholders involved in cassava production, including the ministries of agriculture and cassava traders. The committees serve as coordination networks and they regulate the movement of planting materials FAO (2013a)

Note: The symbol "-" indicates that we could not find enough information to determine whether the design principle is present or not. Specific sources of information are indicated in the table

highlighted the need for alternative institutional arrangements (Singerman & Rogers, 2020).

In Mexico, Texas, California and Argentina, HLB was detected later, so institutional arrangements benefited from the experience acquired in Brazil and Florida. In Mexico, 26% of the commercial citrus acreage is affected by HLB and AWM programs are ongoing in 24 states, with some successful cases (Martínez-Carrillo et al., 2019). ACP management areas (DP1) were designed based on epidemiological criteria, but they are coordinated through state committees that already existed (DP7, DP8). The government supplies insecticides to the growers and tracks participation in AWM (DP4A), and workshops are held regularly to raise awareness and promote participation.

In Texas, the AWM program is led by the citrus industry (DP3, DP7). AWM zones (DP1) were established by an industry-led organization that collects assessments per acre (DP2B), runs an ACP monitoring program (DP4B), and tracks participation in AWM (DP4A). Although participation has increased over time, a favorable climate and the abundance of residential citrus trees have fostered HLB spread throughout the state, and the disease is now established. However, citrus yields have not declined dramatically and the AWM program continues, adapting to the new conditions (Graham et al., 2020).

In California, HLB has progressed very slowly and is still confined to residential properties in four counties 8 years after first detected. Although this is due to a complex mixture of factors, the institutional arrangements for citrus health under HLB follow Ostrom's DPs remarkably closely. Acceptance of self-imposed regulations by the citrus industry, continuous interactions with the scientific community for policy guidance (McRoberts et al., 2019), and resources targeted for HLB detection, along with California's Mediterranean climate, have all probably limited HLB spread. Nevertheless, HLB-positive trees are detected every week and ACP is established in southern California, where participation in AWM has been uneven. Interdisciplinary research is needed to identify barriers to collective action, because a *C*Las-positive ACP was just detected in commercial groves (CPDPP, 2020) and *C*Las-positive trees might be detected soon.

In Argentina, HLB has only been detected in a few towns and ACP is not widespread, so AWM has not been fully implemented (SENASA, 2020). Early monitoring efforts, heavy involvement of the citrus industry in management activities (DP2, DP3, DP7, DP8), and learning from other regions might help facilitate collective action.

To show how this diagnostic approach could be applied to other diseases, we retrieved information about the institutional arrangements for RDT management in Southeast Asia (Table 3) and found that most of Ostrom's principles were not part of the area-wide synchronous rice planting programs that were implemented in the 1970s and 1980s. As in the HLB case, an area-wide approach was strongly recommended by international guidelines (Brader, 1979), and many countries implemented national programs to promote its adoption, but in this case, they were heavily based on a *top-down* approach (Litsinger, 2008). Synchronous planting was imposed by government agencies within designated ~1000 ha blocks (DP1) through law enforcement and sanctions to noncompliant growers, who in many cases were not used to coordinating activities with field neighbors (no DP2), so grower organizations and collective-choice arrangements were scarce (no DP3, no DP7) (Goodell, 1984; Loevinsohn et al., 1993). Due to the dependency of rice planting on water availability, *top-down* success cases such as the Muda irrigation scheme in Malaysia required investment by the government in irrigation infrastructures, mechanized plowing, timely credits and close supervision of grower groups (Goodell, 1984). Still, success was conditioned by the collective action problem associated with water management, itself requiring complex institutional arrangements (Johnson & Handmer, 2003). Alternatively, the *subaks*, local water-user groups in Bali (Indonesia), provided an example of *bottom-up* institutional arrangements that had evolved over centuries of rice cultivation to optimize pest and water management (Lansing et al., 2017; Lansing, 1991).

In Central and East Africa, international guidelines have also promoted the implementation of "community phytosanitation" to ensure cassava health in CBSD endemic areas, but few recommendations have been made in terms of the institutional arrangements that could favor collective action (Legg et al., 2014). In line with Ostrom's principles, the guidelines recognized that local communities that are currently affected by CBSD, or could potentially be affected, would have to establish and implement community-based regulations and by-laws (Legg et al., 2014). A recent study provided an example of how this type of approach could be implemented through local task forces (DP3) and community monitoring (DP4), but more work will be needed to scale it up (Legg et al., 2017). Our hope is that this analysis will point towards possible approaches to favor *bottom-up* initiatives within cassava-dependent communities in Africa.

5 Discussion

Our analysis suggests that Ostrom's DPs are a valid reference to promote collective action for plant health provision, but more work is needed to establish relationships between institutional arrangements and plant health outcomes. In the same way that the DPs were deduced from case studies of CPRs, further examination of plant health institutions should lead to identification of more tailored design principles. In our case studies, we observed that conflict-resolution arenas, monitoring of compliance with AWM and graduated sanctions on non-compliant growers are not common, which is consistent with previous studies that suggested that not all of Ostrom's design principles might be as important for plant health provision as for CPRs (Graham et al., 2019; Kruger, 2016). The need to prevent *over-exploitation* in CPRs might call for institutions that are not essential for plant health, where the need is to ensure provision of the public good.

Turning to specific methodological needs, institutional studies could be complemented with social and ecological studies to better understand the advantages and disadvantages of *top-down* vs. *bottom-up* approaches to plant health in different social and ecological contexts.

Participatory studies and surveys could provide insight into the attitudes and norms that drive collective action in societies facing plant health threats(Mankad & Curnock, 2018) and improve our understanding of the role of social learning and communication (Damtew et al., 2020; Nourani et al., 2018). Agent-based model simulations could be used to estimate the economic benefits of collective plant health provision in different landscapes (Rebaudo & Dangles, 2011), which would help characterize the collective action problem from a game theoretical perspective and point towards potential institutional arrangements (Bodin, 2017).

Beyond the individual and regional scales, network analysis could be used to evaluate if there is an alignment between the governance network that has been built in response to a plant health threat and the characteristics of the ecological and social systems governed (Lubell et al., 2017; McAllister et al., 2015). This type of analysis would bridge the gap between social network analysis and network approaches taken by ecologists and plant pathologists (Garrett et al., 2018), advancing the integration of social and ecological networks studies of how societies face emerging threats (Barnes et al., 2019).

We hope this study has illustrated the potential of addressing plant health provision as a collective action problem, within a social-ecological systems framework that gives equal research priority to ecological and social systems (Ostrom, 2009). Only an interdisciplinary research agenda will allow us to establish the link between institutional approaches and outcomes, and determine which institutions will be more robust to facilitate collective action and ensure plant health to achieve global food security.

6 Conclusions

Although the social and economic dimensions of plant health have received increasing attention in recent years, incorporating them into the design of plant health institutions to improve *social-ecological system fit* is still a challenging interdisciplinary frontier. With the increasing global spread of plant pests and diseases, there is a need to better understand the collective action problem associated with plant health provision, and how to combine institutional approaches along the *top-down* to *bottom-up* continuum to ensure the sustainability of food production. This need is particularly urgent in the case of HLB, which is threatening the future of citrus production worldwide, but it is also a persistent necessity to ensure food security in developing countries. Our hope is that this study will show the potential of bringing collective action theory to plant health governance to mitigate the impact of HLB and other damaging diseases.

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Disease Control and Integrated Management

e-Xtra*

Perceived Vulnerability and Propensity to Adopt Best Management Practices for Huanglongbing Disease of Citrus in California

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ABSTRACT

Huanglongbing (HLB) disease of citrus, which is associated with the bacterium '*Candidatus* Liberibacter asiaticus', has been confined to residential properties in Southern California 8 years after it was first detected in the state. To prevent the spread of HLB to commercial citrus groves, growers have been asked to adopt a portfolio of voluntary best management practices. This study evaluates the citrus industry's propensity to adopt these practices using surveys and a novel multivariate ordinal regression model. We estimate the impact on adoption of perceived vulnerability to HLB, intentions to stay informed and communicate about the disease and various socio-economic factors, and reveal what practices are most likely to be jointly adopted as an integrated approach to HLB. Survey participants were in favor of scouting and surveying for HLB symptoms, but they were reluctant to test trees, use early detection technologies (EDTs), and install barriers around citrus groves. Most practices were perceived as complementary, particularly visual inspections and some combinations of preventive practices with tests and EDTs. Participants who felt more vulnerable to HLB had a higher propensity to adopt several practices, as did those who intended to stay informed and communicate with the coordinators of the HLB control program, although this effect was modulated by the perceived vulnerability to HLB. Communication with neighbors and the size of citrus operations also influenced practice adoption. Based on these results, we provide recommendations for outreach about HLB management in California and suggest future directions for research about the adoption of plant disease management practices.

Keywords: Huanglongbing, biosecurity, adoption, best management practices, integrated pest management, risk perception

Since Huanglongbing (HLB) was first detected in the state of California in 2012 (Kumagai et al. 2013), the citrus industry has taken a proactive role in dealing with this devastating disease. In response to lobbying by and discussions with citrus industry leadership, the state legislature passed a bill in 2009 requiring the Secretary of Agriculture to establish the California Citrus Pest and Disease Prevention Committee (CPDPC). The CPDPC is composed of citrus industry representatives who make recommendations to the California Department of Food and Agriculture (CDFA), which then implements activities under its regulatory jurisdiction (De Leon 2009). Activities enforced by the CDFA, which include detection and removal of HLB-positive trees, are primarily funded by grower assessments of each carton of fruit harvested; however, because funds are limited, voluntary activities by commercial growers are also encouraged. A task force of grower representatives and researchers was appointed to collaboratively develop a *Voluntary Grower Response Plan for Huanglongbing*, which contains the best management practices recommended by the CPDPC to control the spread of HLB (CPDPP 2019). The voluntary plan was presented to the California citrus industry for the first time in 2019, at a series of industry seminars. We took the opportunity offered by those seminars to assess how likely it was that those practices would be adopted, evaluate what practices within the portfolio might be adopted together, understand what factors might influence adoption, and identify potential targets for outreach.

The adoption of best management practices by growers has been the subject of many studies and reviews (Liu et al. 2018; Prokopy et al. 2019). A common approach is to organize surveys, participatory workshops or interviews to assess the growers' willingness to adopt best management practices while gathering information about their personal and farm operation characteristics or other contextual factors that could help predict adoption (Prokopy et al. 2019; Puente et al. 2011). The adoption of agricultural practices in general has been found to be influenced by growers' attitudes toward the practices, financial motivations, problem awareness, information-seeking behavior, previous adoption of related practices, farm size, and income (Prokopy et al. 2019). For integrated pest management (IPM) in particular, early studies determined that IPM adoption by vegetable growers in the United States was influenced by farm size (Fernandez-Cornejo et al. 1994), whereas IPM adoption by coffee growers in Colombia was influenced by education and wealth (Chaves and Riley 2001). Over the years, other contextual factors have been found to impact IPM adoption, such as farm location and pest intensity (Kaine and Bewsell 2008), social networks and trusted sources of information (Hillis et al. 2016; Sherman and Gent 2014), and cost efficacy of the practices (Hillis et al. 2017).

Fewer studies have examined the socioeconomic and contextual factors that influence the adoption of management practices for invasive pests and diseases, which require quick decision-making to

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prevent spread but are associated with great uncertainty about risk and lack of previous experience (Simberloff et al. 2013). The two components of risk (likelihood of spread and establishment and potential negative impact) are commonly unknown at the time management decisions about invasive pests or diseases need to be made, which may lead to perceptions of risk to be subjectively constructed (McRoberts et al. 2011).

In the human disease literature, early behavioral models proposed that risk perception, comprising *perceived vulnerability* (how susceptible an individual felt to a communicated threat, related to likelihood) and *perceived severity* (how serious the individual believed the threat would be, related to impact), was a key factor in the decision to adopt self-protective behavior (Sheeran et al. 2017). One of the most widely accepted models, the protection motivation theory, proposed that the more vulnerable individuals perceived themselves to be to a threat, and the more serious they believed it to be, the more likely they would be motivated to protect themselves (Rogers 1975, 1985). Assuming that a similar cognitive process drove the intention to adopt protective behavior against plant and animal diseases, risk perception was also considered a key factor in predicting the adoption of management practices for these threats (Heong and Escalada 1999; Ritter et al. 2017).

However, the limited evidence available provides inconsistent support for a positive relationship between risk perception and adoption of management practices for invasive plant diseases. A Netherlands study showed that the adoption of management practices for several invasive diseases varied by crop, and that risk perception was negatively correlated with adoption (Breukers et al. 2012). The authors' interpretation was that growers who said they had experienced invasions and adopted management practices probably felt more protected, and thus perceived a lower risk of future invasions (Breukers et al. 2012). This negative feedback loop between protective behavior and risk perception had already been observed in studies of human diseases (Weinstein and Nicolich 1993). For example, people who received the Lyme disease vaccine showed a greater decline in their perceived risk of getting the disease than people who had not been vaccinated (Brewer et al. 2004).

As a result, three different hypotheses emerged in the human disease literature to describe the relationship between risk perception and self-protective behavior. The *behavior motivation hypothesis*, heir to the protection motivation theory, proposed that risk perception had a causal effect on the health behavior of individuals, so that a higher risk perception at one point in time would lead to increased health behavior in the future, as evidenced by a positive correlation between both factors in a longitudinal or experimental study (Brewer et al. 2004). The *risk reappraisal hypothesis* proposed that if an action were believed to reduce risk, then individuals who performed the action would subsequently lower their risk perception in the future, thus explaining the negative correlations found in the Netherlands study (Breukers et al. 2012) and the Lyme disease study (Brewer et al. 2004). Finally, the *accuracy hypothesis* proposed that individuals who engaged in risky behavior at a given point in time were at higher actual risk and would perceive a higher level of risk, as evidenced by a negative correlation between protective behavior and risk perception at that point in time (Brewer et al. 2004).

These three complementary hypotheses that emerged to explain positive or negative correlations between risk perception and protective behavior against human diseases highlight the importance of the time point when studies are conducted for interpreting results (Gaube et al. 2019); this has been rarely considered in the context of plant diseases. A study involving banana growers during the first few months after an outbreak of the invasive Panama tropical race 4 (TR4) disease in Australia showed that growers perceived a high level of risk, but it was not significantly correlated with proactive action against the disease (Mankad et al. 2019). The authors' interpretation was that fear of Panama TR4 was not the main motivation to engage in control, and other factors such as income dependency on bananas and perceived self-efficacy could be stronger predictors of the propensity to act. Considering the protection motivation theory and the adoption literature, these authors recommended that further studies should be performed to understand drivers of engagement in control against invasive plant diseases (Mankad et al. 2019).

This article uses HLB as a case study to examine the relationship between perceived vulnerability and grower adoption of management practices against invasive plant diseases at a unique point in time. HLB is an invasive bacterial disease that poses a major threat to citrus production worldwide (Wang 2019). Most commercial citrus cultivars are susceptible to HLB, and infected trees experience a rapid decline characterized by blotchy mottle symptoms on foliage, premature fruit drop and poor fruit quality, which lead to considerable economic losses before the eventual death of the tree (McCollum and Baldwin 2016). The most prevalent type of HLB is associated with the bacterium '*Candidatus* Liberibacter asiaticus' (*C*Las), which is transmitted by grafting or by an insect vector, the Asian citrus psyllid (ACP), *Diaphorina citri* (Grafton-Cardwell et al. 2013). HLB has spread from Asia to the main citrus-producing regions in North America and South America, where it has had a devastating impact in Brazil (Bassanezi et al. 2020), Florida (Graham et al. 2020), Mexico (Robles González et al. 2018), and Texas (Sétamou et al. 2020).

HLB was first detected in California in 2012. Since then, >2,000 HLB-positive trees have been detected and removed from residential properties in Los Angeles, Orange, Riverside, and San Bernardino counties (CPDPP 2020b). Commercial citrus production is distributed between the Coastal and Southern counties, where the ACP is widespread, and the Central Valley, where there have been a few isolated ACP detections that have been quickly eradicated (Grafton-Cardwell 2020). Although HLB-positive trees have not yet been detected in any commercial citrus groves, a *C*Las-positive ACP was detected in a commercial grove in Riverside (CPDPP 2020a), and there is fear that positive tree detections will soon follow.

We contribute to the emerging interdisciplinary literature on the adoption of management practices for invasive plant diseases by assessing the California citrus industry's propensity to adopt a portfolio of voluntary management practices to prevent the spread of HLB. Through a survey distributed to 300 participants in three different grower meetings, we analyze adoption in a perennial cropping system after introduction of an invasive disease that cannot be eradicated, but before it has had an impact on commercial production. At this unique point in time, characterized by high risk and high uncertainty, we assess the citrus industry's perceived vulnerability to HLB, validate its accuracy based on geographical proximity to HLB detections, and show how it has changed over the course of the HLB epidemic in California, thus providing an update to a previous study (Milne et al. 2018). More importantly, we show how a multivariate ordinal regression model can be used to simultaneously evaluate the propensity to adopt a portfolio of management practices rated on an ordinal scale, assess the relationships among perceived vulnerability, information, communication, and propensity to adopt, and reveal which practices are more likely to be adopted together. Given the developing HLB situation in California, information to support strategic planning of the response is urgently needed. Based on the results of this study, we provide recommendations for outreach about HLB management in California and suggest future directions for research about the adoption of plant disease management practices more generally.

MATERIALS AND METHODS

Voluntary Grower Response Plan. The CPDPC appointed a task force of grower representatives and University of California (UC) researchers to assemble a set of voluntary best management practices that would be provided to the growers as a toolbox from which to choose practices to prevent the spread of HLB. Four hypothetical scenarios were defined by proximity to confirmed HLB detections to facilitate grower visualization of possible contexts for adoption. Specific protocols to implement the practices varied depending on the scenario. The *Voluntary Grower Response Plan* *for Huanglongbing in California* was officially published in May 2019 (CPDPP 2019); it was presented to the citrus community by the third author immediately before the survey that is the subject of this study.

The task force decided that early detection technologies (EDTs), which comprise any technology that can detect *C*Las before the regulatory quantitative polymerase chain reaction (qPCR), should not be included in the portfolio of recommended practices because none of the EDTs was commercially available at the time when the plan was published. However, we decided to include EDTs in this study because at least one of them would be imminently available and evaluated (Gottwald et al. 2020), and at least that one was probably going to be considered by the citrus industry. For the same reason, we decided to also assess the propensity to use bactericides approved for *C*Las control, which have been tested against HLB and used in Florida (Al-Rimawi et al. 2019; Hu et al. 2018), even though they were not included in the *Voluntary Grower Response Plan*.

Theoretical framework. The propensity to adopt the recommended management practices for HLB in California was studied as a function of a set of predictor variables selected from the protection motivation theory, the technology adoption-diffusion literature, and similar studies of plant disease management.

The HLB management practices recommended by the *Voluntary Grower Response Plan*, with the addition of EDTs and bactericides, are the dependent variables in our regression model. To frame our analysis in the context of the IPM literature, eight selected practices were simplified and grouped into three categories: monitoring, prevention, and suppression. Monitoring and the proper identification of pests and diseases are considered the basis for IPM decisions (Farrar et al. 2016); this category includes scouting for ACP nymphs on flush, conducting visual surveys for HLB symptoms, voluntarily sending citrus leaves and ACP to be tested by an approved laboratory using a direct method of detection such as qPCR, and using EDTs. Prevention is defined as the practice of keeping a pest or disease from infesting a field or site (Farrar et al. 2016); this category includes adopting extra measures such as bags or repellents to protect new citrus plantings, using physical barriers such as mesh or windbreaks around the groves, and applying extra pesticides and repellents to the grove perimeters. Suppression is defined as the control of infestations or epidemics to prevent pest or disease levels from becoming economically damaging (Farrar et al. 2016); this category only includes the use of bactericides.

To align this study with the adoption literature, staying informed and communicating with the grower liaisons and communicating with neighbors, which are recommended by the *Voluntary Grower Response Plan*, were selected as explanatory factors related to actively seeking information and interacting with social networks, both of which have been found to be important determinants of the adoption of agricultural practices (Prokopy et al. 2019). The HLB control program in California has established a formal information network in which grower liaisons (individuals with local connections and experience as managers or advisors for the citrus industry) were hired as coordinators and knowledge brokers between the statewide program and citrus growers at the county or regional level. Therefore, we specifically chose to identify them as the main source of information about HLB. At the same time, informal networks have been repeatedly identified as relevant sources of information about agricultural practices (Hoffman et al. 2015); therefore, we included a question about communication between neighbors to test if informal information networks could be a relevant factor in the adoption of HLB management practices in California, as has been the case for other plant diseases (Maclean et al. 2019; Sherman et al. 2019).

A core hypothesis and four complementary hypotheses shaped the design of this study. According to the protection motivation theory, we expected the perceived vulnerability to HLB to have a positive impact on the propensity to adopt the recommended practices (H1). We chose to focus on the likelihood component of risk (i.e., perceived vulnerability) because we assumed that the citrus industry in California would be familiar with the high impact associated with HLB epidemics based on the widespread knowledge of the devastating consequences of HLB in Florida (Kuchment 2013). Compared with previous studies that measured the impact of risk perception on invasive plant disease management (Breukers et al. 2012; Mankad et al. 2019), this study was conducted at a time when participants already knew about the potential impact of an HLB epidemic in California. However, they did not have any experience implementing the recommended practices in commercial groves; therefore, we did not expect the accuracy hypothesis and the risk reappraisal hypothesis to be relevant to this case (Gaube et al. 2019). Therefore, we did not expect a negative relationship between perceived vulnerability and practice adoption.

We first aimed to evaluate whether the perceived vulnerability to HLB was accurate, and we compared it with the results of a previous survey conducted in 2015 (Milne et al. 2018). Then, we expected the participants' perceived vulnerability to HLB to have a positive regression coefficient for the eight practices considered in the multivariate ordinal regression model because they would all improve the level of protection against HLB. In particular, we expected perceived vulnerability to have a positive impact on the adoption of monitoring practices because people who feel more vulnerable to HLB might have a greater need to know the status of the disease in their fields.

In line with previous adoption studies, we expected the propensity to stay informed and communicate with grower liaisons to have a positive impact on the propensity to adopt the recommended practices (H2). Again, a positive relationship could be expected for all the practices considered; however, we expected it to be particularly noticeable for some of the monitoring practices because the HLB control program and the grower liaisons have been promoting these practices since the beginning of the HLB epidemic in California. In fact, this hypothesis allowed us to examine the level of acceptance and potential effectiveness of the grower liaisons as sources of information and promoters of the HLB control program.

Because HLB is an invasive disease that can rapidly spread across a landscape and requires coordination beyond property boundaries for effective control (Bassanezi et al. 2013; Graham et al. 2020), we expected communication with neighbors to have an impact on the propensity to adopt some of the recommended practices for HLB (H3), and we were interested in determining the sign of the coefficient for this impact for different practices. Communication between neighbors might facilitate sharing positive experiences and ultimately foster the adoption of beneficial practices (Sherman et al. 2019); however, at the same time, lack of intention to communicate with neighbors might indicate distrust and motivate the adoption of practices to provide protection against inoculum coming from neighbors (Maclean et al. 2019). We were also interested in identifying what practices were positively impacted by communication with neighbors because they might be more likely to be adopted in a coordinated manner. Previous studies have shown that face-to-face communication is essential to develop trust and reciprocity to coordinate efforts in plant disease management (Sherman et al. 2019). Growers who were active participants in their community were more willing to cooperate to control pests than those who were not active members (Stallman and James 2015).

Individual socioeconomic factors were expected to modulate the propensity to adopt some of the recommended practices (H4). Land tenure has been identified as a determinant of the adoption of many agricultural practices (Prokopy et al. 2019); therefore, we expected grove owners to have a different propensity than other citrus stakeholders to adopt some practices. In particular, grove owners might be less willing to invest in adopting practices that are more expensive, such as installing barriers along the grove perimeter, which would require the removal of productive trees to make space for the barriers. Also, if voluntary tests lead to the identification of an HLB-positive tree that would trigger a quarantine, then it might have significant economic consequences for the owner; therefore, we hypothesized that grove owners might be less willing to test. Farm size has been consistently associated with increasing levels of adoption for many agricultural practices because larger farms have more financial capital and may have lower adoption thresholds in relation to cost and time to a return on their investment (Prokopy et al. 2019). Therefore, we expected farm size to have a significant and positive impact on the propensity to adopt the recommended practices for HLB. In line with previous studies (Prokopy et al. 2019), we expected that age would have a negative impact on adoption because older growers might consider shorter time horizons and be less willing to make investments to protect themselves against HLB. The general feeling among the citrus industry in California is that conventional and organic growers differ in their approach to control citrus pests and diseases; therefore, we were interested in testing whether this factor had a significant impact on the adoption of HLB management practices. Finally, we expected that participants who obtained a higher percentage of their income from citrus would have a higher propensity to adopt practices to manage HLB, as noted by previous studies (Mankad et al. 2019; Stallman and James 2015).

Because the *Voluntary Grower Response Plan* was conceived as a toolkit for HLB management, we expected the adoption of HLB management practices to be interdependent (H5), which would be indicated by significant correlations between the adoption equations for different practices in a multivariate ordinal logistic regression model. Our expectation was that some of the practices belonging to the same IPM category would have a higher propensity to be adopted together, which would be indicated by significant positive correlations for the equations within each group. For example, within the category of monitoring practices, we expected people who were likely to scout for ACP nymphs on flush to also be likely to conduct visual surveys for HLB symptoms because both practices could be implemented simultaneously and they provide complementary information about the vector and the disease. Because EDTs are a new technology for citrus growers, we were interested in determining if they were being perceived as complementary to other monitoring practices such as surveying for symptoms or testing. For preventive practices, it was unclear a priori if installing physical barriers along the grove perimeter would be perceived as complementary or a substitute for applying pesticides and repellents to the perimeter or taking extra measures to protect new plantings.

Survey design. The survey to assess the citrus stakeholders' propensity to adopt HLB management practices was designed by the authors and consisted of 20 questions (Supplementary text S1). The first six questions referred to the participants' social and economic background and were based on available data (USDA-NASS 2018) or previous similar studies (Mankad et al. 2019; Milne et al. 2018; Singerman et al. 2017; Stallman and James 2017). For these questions, participants were asked to select from a list the categorical responses that most closely represented their situation. First, they were asked to indicate their role in citrus production, choosing among grove owner, ranch manager, pest control adviser (PCA; who is a professional consultant licensed by the State of California to provide pest management recommendations), pest control operator (PCO; who is a person or company licensed to apply agricultural pesticides to crops), and other. Second, participants were asked to indicate how many acres of citrus they grew or managed (farm size), choosing among <5, 5 to 25, 26 to 100, 101 to 500, and >500 acres. Third, they were asked about their age group (younger than 35, 35 to 50, 51 to 65, and older than 65 years). Fourth, they were asked to indicate any California counties in which they had managed or currently managed groves, choosing between Fresno, Imperial, Kern, Madera, Riverside, San Bernardino, San Diego, Santa Barbara, Tulare, and Ventura. Fifth, they were asked to indicate whether they grew citrus conventionally, organically, or both (management system). Finally, they were asked to indicate what percentage of their income came from citrus (0 to 25, 26 to 50, 51 to 75, and 76 to 100%).

To assess their perceived vulnerability to HLB, participants were asked, "How likely do you think it is that an HLB-positive tree will be detected in your grove in the next year (July 2019 to June 2020)?" This question was in line with those asked in human disease studies (Brewer et al. 2004), and it was based on a similar question asked in 2015 (Milne et al. 2018) to provide an update to the citrus stakeholders' perceived vulnerability to HLB 4 years into the epidemic. The rest of the questions assessed the participants' propensity to adopt the best management practices recommended by the CPDPC. The wording of the practices was simplified for the survey, as indicated in the previous section, and the propensity to adopt was assessed as "How likely is it that you will … ?". Ordinal responses were provided using a 5-point scale of very unlikely, unlikely, maybe, likely, and very likely. For two of the questions (8 and 17), a sixth option (*do not know who the liaison is* and *do not have enough information*, respectively) was added to identify participants who thought they lacked enough information to make a choice.

The research protocol was submitted to the Institutional Review Board (IRB) at University of California Davis, and it was granted exempt status because it entailed low risk for the participants.

Survey distribution. The survey was distributed at three grower meetings that were part of the Citrus Growers Educational Seminar Series organized by the Citrus Research Board (CRB) in conjunction with the University of California Cooperative Extension (UCCE) in June 2019 in Palm Desert (southeast California), Santa Paula (coastal California), and Exeter (Central Valley). These are annual seminars organized by the CRB/UCCE that provide attendees with continuing education units and certified crop adviser hours. The availability of these credits tends to result in a larger than usual attendance for grower workshops, thereby reducing selection bias toward only those with a particular interest in a given topic. Selection bias was further limited by the fact that the annual election of citrus industry representatives for the CRB was scheduled on the day of the seminars in Palm Desert and Exeter. The three meetings had the same format. The survey was distributed directly after a presentation of the *Voluntary Grower Response Plan for Huanglongbing*. At the time when the meetings were held during a single week in June 2019, 1,484 trees had been confirmed to be infected with HLB in California since the first detection in 2012; all of them were on residential properties (7 in Riverside County, 387 in Los Angeles County, and 1,090 in Orange County) (CPDPP 2020b).

The survey was introduced to the participants as voluntary and anonymous, in compliance with IRB regulations. It was presented using the TurningPoint add-in for Microsoft PowerPoint (Microsoft, Redmond, WA, U.S.A.), and the responses were collected using clicker handsets from TurningPoint (Turning Technologies, Youngstown, OH, U.S.A.) that had been given to each participant before the seminar started. Participants were given approximately 1 min to answer each question. When the polling time was closed for each question, a summary of the responses (percentage of participants who had chosen each response) was shown to the audience and briefly discussed before moving to the next question.

In total, we collected responses from 300 participants. The average number of responses for any question of the survey was 225 (an average response rate of 75% per question). In Palm Desert, there were 95 registered attendees of the meeting, and responses were collected from 59 participants. In Santa Paula, there were 131 registered attendees, and responses were collected from 91 participants. In Exeter, there were 219 registered attendees, and responses were collected from 150 participants. Across the three meeting locations, 160 people answered a sufficient number of questions (perceived vulnerability, communication, relevant socioeconomic factors, and at least one practice) to be considered for statistical analysis.

Descriptive statistics of the survey respondents. The respondent sample provided reasonable coverage of the citrus industry in California (Table 1). Among the 160 people who answered a sufficient number of questions in the survey to be considered for analysis, 44% were grove owners, 18% were ranch managers, 16% were PCAs, and 2% were PCOs. The rest (20%) self-identified as other, which could include packers, haulers, regulators, or university employees. Compared with the size distribution of orchards in the counties represented in the survey, small operations (<5 acres) were underrepresented, comprising 15% of the sample compared with 34% of orchards in those counties, and big operations (>500 acres) were overrepresented, comprising 38% of the sample compared with 18% of orchards in those counties (USDA-NASS 2019). Most participants (54%) were between 35 and 65 years of age, which is the most common (56%) age range for growers in California (USDA-NASS 2019). Participants younger than 35 were overrepresented in the survey (17 versus 6%), and participants older than 65 were slightly underrepresented (29 versus 38%) (USDA-NASS 2019). The majority of participants (71%) grew citrus conventionally, a few (4%) grew citrus organically, and some (25%) grew citrus under both management systems. This is representative of citrus production in California because it is estimated that approximately 8% of citrus operations and 3% of acreage in the state are certified organic (USDA-NASS 2017, 2019).

Approximately one-third (38%) of participants indicated that <25% of their income came from citrus, whereas another approximately one-third (35%) indicated that >75% of their income came from citrus. Participants had groves in the top 10 citrus-producing counties in California (from higher to lower acreage): Tulare (130,341 acres); Kern (66,720 acres); Fresno (56,326 acres); Ventura (18,447 acres); Riverside (17,333 acres); San Diego (11,701 acres); Imperial (10,328 acres); Madera (2,800 acres); San Bernardino (2,435 acres); and Santa Barbara (1,291 acres) (Fresno CAC 2019; Imperial CAC 2019; Kern CAC 2019; Madera CAC 2019; Riverside CAC 2019; San Bernardino CAC 2019; San Diego CAC 2019; Santa Barbara CAC 2019; Tulare CAC 2019; Ventura CAC 2019). Because participants were asked to indicate any counties in which they had groves (multiple response option), counties were grouped in three regions to simplify some of the analyses: Coast (38%), which included Ventura, Santa Barbara, combinations of Ventura and Santa Barbara, and Ventura and Tulare; Southern California or SoCal (22%), which included Imperial, Imperial and Riverside, Imperial and San Diego, Riverside, Riverside and Kern, Riverside and San Diego, Riverside and Ventura, San Bernardino, San Bernardino and Fresno, San Bernardino and San Diego, San Bernardino and Ventura, and San Diego and Santa Barbara; and the Central Valley or Valley (40%), which included Fresno, Fresno and Kern, Fresno and Madera, Fresno and Tulare, Kern, Kern and Tulare, Madera, Madera and Tulare, and Tulare.

TABLE 1. Socioeconomic characteristics of the survey respondents (n = 160)[a]

Survey item	Responses	Percentage of total
Role in citrus production		
Grove owner	68	43
Ranch manager	27	17
Pest control adviser	24	15
Pest control operator	3	2
Other	31	19
Farm size, acres		
<5	24	15
5–25	30	19
26–100	21	13
101–500	24	15
>500	61	38
Age, years		
<35	27	17
35–50	29	18
51–65	57	36
>65	47	29
Region		
Coast	61	38
SoCal	35	22
Valley	64	40
Management system		
Conventional	113	71
Organic	7	4
Both	39	24
Income from citrus, %		
<25	58	38
26–50	20	13
51–75	21	13
76–100	54	34

[a] Although the dataset that was used for the analyses included the responses from 160 participants, not all of them answered every socioeconomic question.

Statistical analysis. All statistical analyses were performed using the R programming environment version 3.5.3 (R Foundation for Statistical Computing 2019) with a Windows 10 Pro version 1909, 64-bit operating system (Microsoft, Redmond, WA, U.S.A.). Differences in the distribution of responses to a question based on the groups defined by responses to another question were tested using the Kruskal–Wallis test. Pairwise comparisons of the distribution of responses between two groups were tested using the nonparametric Wilcoxon–Mann–Whitney test. Plots were created using the R package "ggplot2" (Wickham 2016) with the complementary packages "likert" (Bryer and Speerschneider 2016), "lemon" (McKinnon Edwards et al. 2020), and "ggraph" (Pedersen 2020).

Grove owners, ranch managers, PCAs, PCOs, and other participants did not have significantly different distributions of responses to most questions; therefore, all categories were considered for analysis and may be referred to as "participants," "respondents," or "growers." In terms of correlations among socioeconomic factors, farm size was positively correlated with the percentage of income from citrus ($\rho = 0.56$; $P = 2.84 \times 10^{-14}$), and older participants tended to manage smaller groves ($\rho = -0.27$; $P = 7.04 \times 10^{-4}$). However, these two factors were not included at the same time in the selected model; therefore, these correlations did not interfere with the interpretation of our results.

Relating perceived vulnerability to HLB with an objective assessment of the likelihood of HLB detection. To assess whether the participants' perceived vulnerability to HLB (i.e., likelihood of HLB detection in their grove in the next year) was accurate, we compared it with an objective measure of the likelihood of HLB detection based on their geographical location. The location of the citrus groves in each county was taken from the commercial GIS citrus layer developed by the CRB (R. Dunn, *personal communication*). In the absence of individual-level coordinates for each participant's groves, the centroid of the citrus production area in the county where participants said they had groves was used as the point of origin, and we calculated the linear distance from each centroid to the closest confirmed HLB-positive tree anywhere in Southern California. For participants who indicated that they had groves in more than one county, we used the average distance from the centroid of the citrus production areas in the two counties indicated by the participant to the closest HLB detection. In addition, we calculated the average, minimum, and maximum distance from any grove registered in the CRB citrus layer in any of the counties indicated by the participants to the closest HLB-positive tree. Centroids and distances were calculated using ArcGIS Pro (Esri, Redlands, CA, U.S.A.). Then, distances were correlated with the perceived vulnerability indicated by the participants, on a numerical scale, using Spearman's rank correlation test. The coordinates of the HLB-positive trees were obtained from the database maintained by CDFA under terms of a data confidentiality memorandum of understanding among the CDFA, the UC, and CRB. Location-specific data for HLB-positive trees in California are confidential and cannot be shared in public documents.

Evaluating the impact of perceived vulnerability, information, communication, and socioeconomic factors on the propensity to adopt, and the interdependence between practices. To take a first look at relationships between pairs of practices and between practices and explanatory factors, we calculated Spearman's rank correlation coefficients (ρ) and their associated P

values using the R package "Hmisc" (Harrell and Dupont 2020). To perform these analyses, responses to questions that were expressed using an ordinal scale (i.e., questions 2 to 4, 6 to 11, and 13 to 20) were transformed to numeric (very unlikely = 1, unlikely = 2, maybe = 3, likely = 4, and very likely = 5).

Because some of the recommended practices may be interdependent, either as complements or as substitutes, using univariate ordinal regression models to predict the propensity to adopt each practice separately according to the selected explanatory factors may lead to inaccurate conclusions, since they ignore potential interdependencies between practices that are the basis of an IPM approach. To address this limitation, we investigated the use of a multivariate ordinal regression model (Hirk et al. 2019). To our knowledge, this is the first time that this type of model has been used in the context of practice adoption in plant disease management. The model is based on the idea that there is a latent variable that captures the utility of adopting practices (against HLB in this case), which was assessed through ordinal ratings. This latent variable is assumed to be a linear combination of observed explanatory factors and unobserved factors captured by a stochastic error term (Greene and Hensher 2010). Model parameters are estimated through composite likelihood methods. By using a cumulative logit link model, regression coefficients can be interpreted in terms of log odds ratios, and the error terms are assumed to jointly follow a multivariate logistic distribution (Hirk et al. 2019). By simultaneously considering the influence of explanatory factors on each of the different practices, while allowing the unobserved or unmeasured factors to be freely correlated, the model estimates a correlation matrix between practices whereby the coefficients indicate the polychoric correlations between the latent utilities of each pair of practices. Polychoric correlations are defined as the correlations between each pair of latent continuous variables that have been assessed through discrete ordinal ratings (Greene and Hensher 2010). If any correlation coefficient ρ_{ij} is significantly positive, it will indicate a complementary relationship between practices i and j. Conversely, if ρ_{ij} is significantly negative, it will indicate a substitute relationship between practices i and j (Cai et al. 2019; Hirk et al. 2019). Therefore, the model can estimate which practices within the recommended portfolio are likely to be adopted together once explanatory factors have been considered.

The multivariate ordinal regression model was fitted using the R package "mvord" (Hirk et al. 2020) to the eight practices recommended by the CPDPC, for which propensity to adopt was evaluated using a 5-point ordinal scale from very unlikely to very likely. Perceived vulnerability was included in the model as a numeric explanatory factor, the propensity to stay informed and communicate with the grower liaison or to communicate with neighbors were included as numeric explanatory factors, and socioeconomic factors were included as categorical or numeric explanatory factors. Categorical socioeconomic factors (role and management system) were transformed to binary so that being a grove owner would correspond to 1 and the rest of the options would correspond to 0. Similarly, growing citrus conventionally would correspond to 1 and growing citrus organically, or both conventionally and organically, would correspond to 0. Ordered socioeconomic factors (acreage, age, and income) were initially included as ordered factors to test their linear effect on adoption using orthogonal polynomial coding. Once the linear effect was verified, they were transformed to numeric so that the first response category would correspond to 1, the second would correspond to 2, and so on. Multicollinearity between explanatory factors was first examined through Spearman rank correlations and then checked through variance inflation factors (VIF) and condition indexes (CI), assuming that the ordinal ratings were numeric values (Daxini et al. 2018). VIFs and CIs did not indicate that there were severe multicollinearity problems in the dataset; therefore, all factors were considered for the regression analyses. To choose the most parsimonious model, models with different explanatory factors, thresholds, regression coefficients, and error structure specifications were compared using McFadden's pseudo R^2 (McFadden 1974), a Composite Likelihood Bayesian Information Criterion (CLBIC) (Hirk et al. 2019), and likelihood ratio tests (Greene and Hensher 2010), calculated with the R package "lmtest" (Zeileis and Hothorn 2002).

The probability of being likely or very likely to adopt each practice according to each explanatory factor was calculated using the formula of the selected multivariate ordinal regression model with the threshold parameter corresponding to the change between the categories maybe and likely and the estimated regression coefficients of the explanatory factors for each practice, fixing each factor except the one being evaluated at their mean value. With this formula, we calculated the log odds of answering maybe or less for each practice, which were transformed to an odds value, and then to a probability value corresponding to $P(Y \leq \text{maybe})$. The probability of answering likely or very likely was calculated as the complement of that value, so $P(Y > \text{maybe}) = 1 - P(Y \leq \text{maybe})$ (Greene and Hensher 2010).

RESULTS

The perceived vulnerability to HLB has declined over the course of the epidemic, but it is correlated with an objective assessment of the likelihood of HLB detection. The first goal of this study was to assess the California citrus industry's perceived vulnerability to HLB (i.e., likelihood of HLB detection in their grove in the coming year) to determine if it was related to their self-reported propensity to adopt the best management practices recommended by the CPDPC. We also wanted to test if the perceived vulnerability to HLB was accurate and to compare the answers to this question with a similar survey that was conducted in 2015 (Milne et al. 2018) to determine if there had been any changes in perceived vulnerability after 4 years of HLB spread in California.

Across the three main citrus-growing regions in California, the majority (71%) of respondents thought that it was unlikely or very unlikely that an HLB-positive tree would be detected in their grove in the next year (from July 2019 to June 2020). Only 7.5% thought that an HLB detection was likely or very likely. The likelihood of HLB detection varied with the region of origin ($P = 3.54 \times 10^{-7}$ for the Kruskal-Wallis test), and pairwise comparisons among regions showed that there was a significant difference between the Valley and the Coast ($P = 2.74 \times 10^{-7}$ for the Wilcoxon–Mann–Whitney test) and between the Valley and SoCal ($P = 4.71 \times 10^{-5}$). In the Valley, most participants (91%) believed that it was unlikely or very unlikely that there would be an HLB detection in their grove in the next year, whereas fewer people believed that in the Coast (54%) or in SoCal (63%), reflecting regional differences in perceived vulnerability.

To compare the respondents' perceived vulnerability to an objective assessment of the likelihood of detecting the disease, we calculated the distance from the centroid of the citrus production areas in the county that they indicated, or the average distance between the two counties indicated, to the closest HLB positive tree confirmed by CDFA (Fig. 1; Supplementary Table S1). Distances were then correlated with the likelihood of HLB detection indicated. As expected, the perception of the likelihood of an HLB detection in their grove in the coming year was negatively correlated with distance from an HLB-positive tree ($\rho = -0.32$; $P = 0.019$) Similar correlation coefficients were obtained when using the average distance ($\rho = -0.32$; $P = 0.017$) and maximum distance ($\rho = -0.30$; $P = 0.024$) from any grove in any of the counties indicated by the participants, but not when using the minimum distance ($\rho = -0.26$; $P = 0.054$) (Supplementary Fig. S1). Therefore, in general, participants who were further away from confirmed cases of HLB thought that the probability of finding HLB in their grove was lower, and participants who were closer to HLB-positive trees thought that the probability was higher. This pattern of responses seems to reflect a rational relationship between perceived vulnerability and actual probability of infection.

Because HLB is an invasive disease that is spreading in California, the participants' perception of the likelihood of an HLB detection in their grove was expected to influence their propensity to adopt some of the practices recommended by the CPDPC. Indeed, the likelihood of detecting HLB was positively correlated with scouting for ACP on flush ($\rho = 0.29$; $P = 0.0002$), surveying for HLB symptoms ($\rho = 0.16$; $P = 0.04$), and voluntarily testing trees and ACP ($\rho = 0.26$; $P = 0.001$). Therefore, participants who perceived a higher likelihood of detecting HLB seemed to be more willing to scout, survey, and test, which are three monitoring practices directly aimed at detecting HLB. Remarkably, the perceived likelihood of HLB detection was not correlated with the propensity to adopt any of the other practices.

In addition, we calculated the correlation between distance to confirmed HLB-positive trees and propensity to adopt the practices recommended by the CPDPC (Table 2). All correlation coefficients were negative, indicating that participants who were further away from HLB-positive trees were less likely, in general, to adopt any of the practices, and those who were closer were more likely to consider them. Distance from HLB was negatively and significantly correlated

TABLE 2. Spearman rank correlations between the propensity to adopt the recommended practices and the average distance from the centroid of the citrus acreage in each county or counties to the closest tree confirmed to be Huanglongbing (HLB)-positive by the California Department of Food and Agriculture (Fig. 1)

Question	Correlation coefficient	P
Perceived vulnerability	−0.40	1.12E-07
Stay informed and communicate with liaison	−0.22	0.005
Communicate with neighbors	−0.18	0.022
Protect new plantings	−0.09	0.286
Barriers	−0.19	0.018
Repellents applied to perimeter	−0.05	0.559
Scout for Asian citrus psyllid on flush	−0.39	4.40E-07
Survey for HLB symptoms	−0.28	3.04E-04
Test (quantitative polymerase chain reaction)	−0.16	0.044
Early detection technologies	−0.17	0.038
Bactericides	−0.10	0.215

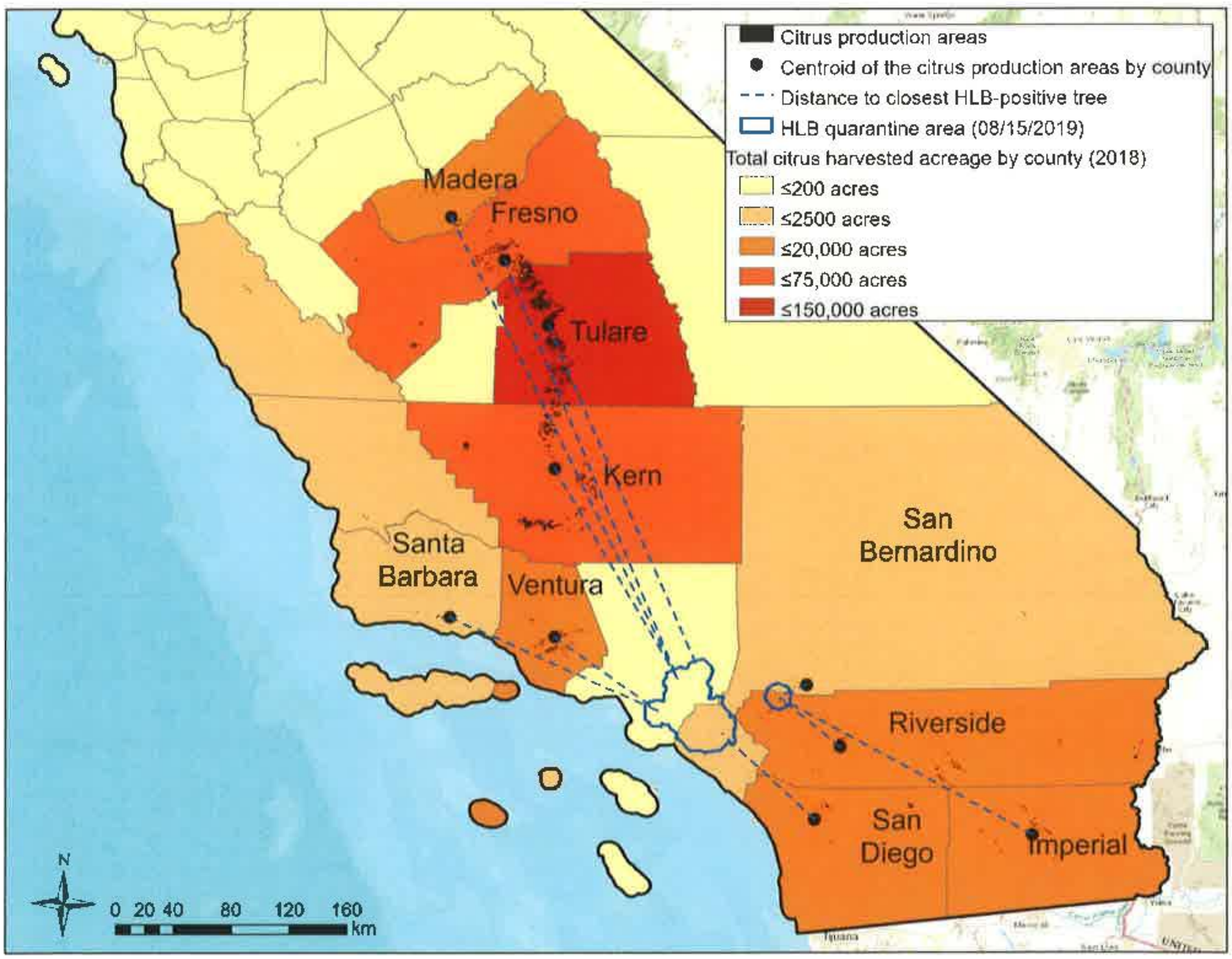

Fig. 1. Distance from the centroid of the citrus acreage in each county to the closest Huanglongbing (HLB)-positive tree detected by the California Department of Food and Agriculture (CDFA). The areas shaded in black represent the citrus production areas according to the Citrus Research Board (CRB) database (R. Dunn, *personal communication*). The black dots represent the coordinates of the centroid of those citrus production areas in each county. The blue dashed lines represent the distance from the centroids to the closest HLB-positive tree (actual distances are shown in Supplementary Table S1). The coordinates of the HLB-positive trees were obtained from the Citrus Pest and Disease Prevention Program (CPDPP) database maintained by the CDFA under terms of a data confidentiality memorandum of understanding between CDFA, the University of California, and CRB. The perimeter of the HLB quarantine zone at the time of the survey is shown in blue (R. Johnson, *personal communication*). The counties where survey participants had citrus groves have been labeled and colored in shades of orange according to the total citrus acreage harvested in each county during 2018 (Fresno CAC 2019; Imperial CAC 2019; Kern CAC 2019; Madera CAC 2019; Riverside CAC 2019; San Bernardino CAC 2019; San Diego CAC 2019; Santa Barbara CAC 2019; Tulare CAC 2019; Ventura CAC 2019).

with staying informed and communicating with the grower liaison, communicating with neighbors, protecting new plantings, applying repellents to the perimeter, surveying for HLB symptoms, and considering the use of EDTs. However, the propensity to install barriers, scout for ACP on flush, voluntarily test, or consider the use of bactericides did not significantly increase as participants got closer to HLB-positive trees.

Finally, we compared the answers obtained in 2019 with those of a similar survey that was distributed during analogous meetings in 2015 (Milne et al. 2018). At that time, participants were asked how likely they thought it was that their groves would be infected with HLB within 5 years, which corresponded to the year 2020. The respondent sample was similar between both surveys in terms of farm size, county of origin, and management system; therefore, we believe that differences in the perceived likelihood of HLB detection between the surveys might indicate changes in perception among citrus stakeholders in California. However, we note that both surveys consisted of a nonrandom sample of citrus stakeholders, and there may have been selection bias toward people who were engaged in HLB and ACP management.

In 2015, the perceived likelihood of HLB detection by 2020 was significantly associated with the location of groves. Participants with groves in San Bernardino, Riverside, San Diego, and Imperial counties (SoCal) thought they would almost certainly be infected by 2020; participants from the Coast thought it was possible or likely; and participants from the Central Valley thought it was unlikely or possible (Milne et al. 2018). Four years later, we noticed a shift toward thinking that HLB detection is unlikely or very unlikely. While in the 2015 survey, 26% of respondents statewide thought that it was *unlikely* or *very unlikely* that an HLB-positive tree would be detected in their grove by 2020 (Milne et al. 2018), in the 2019 survey, 71% of participants thought that an HLB detection in their grove was *unlikely* or *very unlikely* in the coming year (from July 2019 to June 2020). Therefore, our results appear to show that the majority of the citrus industry believes that the epidemic is not progressing as fast as they thought it would 4 years ago.

Propensity to adopt the best management practices for HLB. The second goal of the survey was to assess the propensity to adopt the best management practices recommended by the CPDPC as they were introduced to the California citrus industry for the first time. Because these practices were envisioned as a toolkit, the ultimate intention was not only to assess the participants' propensity to adopt these practices individually, but also to determine which practices were likely to be adopted together (H5), and assess the impact that perceived vulnerability (H1), propensity to stay informed and communicate (H2, H3), as well as individual socioeconomic factors (H4) might have on adoption. To achieve this, we first examined the responses through rank tests and correlation analyses; and then used a multivariate ordinal regression model to evaluate the propensity to adopt the eight recommended practices simultaneously.

At first glance, it was clear that not all of the practices had equal probability of being adopted (Fig. 2). Overall, the majority of participants were likely or very likely to survey for HLB symptoms (74%) and scout for ACP on flush (68%), but they were unlikely or very unlikely to install physical barriers along grove perimeters (71%), to voluntarily test trees and ACP (53%), and to use EDTs (54%). Remarkably, most participants said that they were likely or very likely to stay actively informed about HLB and communicate with their grower liaison (79%) and to communicate with neighbors (65%), suggesting engagement with both formal and informal information networks.

As mentioned, the eight practices were classified into three IPM categories: monitoring, prevention and suppression. Practices related to visual monitoring had a higher propensity to be adopted than preventive, suppressive, and more complex monitoring practices. Because an integrated approach to HLB would involve combinations of all these practices, we sought to investigate how they were being perceived in relation to the rest of the toolkit and what factors could impact adoption in subsequent analyses.

Determinants of the propensity to adopt best management practices for HLB. To test the impact that perceived vulnerability, disposition to stay informed and communicate with the grower liaisons, disposition to communicate with neighbors, and socioeconomic circumstances could have on the adoption of HLB management practices, these variables were included as explanatory factors in a multivariate ordinal logistic regression model. Among several model specifications, the most parsimonious one used a logit link function and assumed that the threshold parameters between propensity-to-adopt categories were the same for all practices and participants, that regression coefficients were specific to each practice, and that there was a general correlation structure between the error terms (Hirk et al. 2019). The participants' perceived vulnerability to HLB, their propensity to stay informed and communicate with the grower liaison, their propensity to communicate with neighbors, and farm size were included as numeric explanatory factors. We also included an interaction term between perceived vulnerability and propensity to stay informed and communicate to determine if providing information to growers fostered adoption under different vulnerability scenarios. Because differences in perceived vulnerability were associated with the region of origin, and because there was a strong correlation between perceived vulnerability and distance from HLB-positive trees, we decided to discard region and distance from HLB as explanatory factors and chose to focus on perceived vulnerability. The other explanatory factors were also discarded during model selection because they did not significantly improve model fit according to likelihood ratio tests (Supplementary Table S2). The most parsimonious model had a CLBIC of 26,506 and a McFadden's adjusted pseudo R^2 of 0.0291 (df = 583.8). All the explanatory factors had a significant impact on at least one practice. This model did not have significantly lower fit than the model with all explanatory factors, and it significantly improved fit compared with models with fewer explanatory factors ($P = 0.0032$) and the model with no predictors ($P < 2.2 \times 10^{-16}$), which had a CLBIC of 26,817 and an adjusted pseudo R^2 of −0.085 (df = 81.73).

In the most parsimonious model, there was a significant effect of perceived vulnerability, disposition to stay informed and communicate with both liaisons and neighbors, and farm size on one or more practices. There was also a significant interaction between perceived vulnerability and propensity to stay informed and communicate with the liaison (Fig. 3; Supplementary Table S3).

As hypothesized, the estimated likelihood of HLB detection in a citrus grove in the coming year (perceived vulnerability) had a positive impact on the participants' propensity to adopt most of the HLB management practices (H1). This indicates that participants who felt more vulnerable to HLB were more likely to protect their citrus groves, which is in line with the protection motivation theory. The exception was the use of EDTs, for which there was no apparent relationship with perceived vulnerability. The coefficients were positive and significant with 90% confidence for scouting for ACP, protecting replants, treating grove perimeters, and using bactericides (Fig. 3). Therefore, for a one unit increase in perceived vulnerability, the odds that someone would be more likely to protect new citrus plantings were 4.7 [exp(1.55)] times higher, 3.8 higher for scouting for ACP on flush, 2.7 times higher for treating the grove perimeter and 2.8 times higher for using bactericides. Interestingly, people who felt more vulnerable to HLB did not have significantly higher odds of testing their trees or surveying for HLB symptoms, suggesting that they were not willing to put more effort into detecting the disease.

As expected, the intention to stay informed and communicate with the grower liaison had a positive impact on the propensity to adopt all of the practices, and it was significant in most cases (H2). Participants who were more likely to seek information and be engaged with the regional coordinators of the HLB control program had significantly higher odds of adopting monitoring practices such as scouting for ACP and surveying for HLB symptoms, preventive practices such as protecting new plantings, installing barriers around citrus groves, and applying pesticides or repellents to the perimeter, as well as using bactericides. This confirms that the formal network that was created by the CPDPC might be effective for promoting the adoption of most practices. However, more engagement with the control program did not lead to a significantly higher odds of testing or using EDTs, indicating that alternative strategies might be required to foster the adoption of these two tools.

Moreover, we detected a significant interaction between the participants' intention to stay informed and communicate with the grower liaison and their perceived vulnerability to HLB on the adoption of two practices. This indicates that the benefits of promoting HLB management through the CPDPC outreach network might depend on how vulnerable citrus growers feel to HLB and, therefore, on the stage of the HLB epidemic. Positive regression coefficients of the interaction term would indicate a synergistic effect in which higher vulnerability and more information and communication act together to encourage further adoption than any of the two explanatory factors alone, whereas negative coefficients would indicate that the two factors may act against each other. Neither of the two positive interaction effects were significant, but two of the six negative ones were. This suggests that the odds of protecting replants or applying pesticides and repellents to the perimeter might only increase with information and interaction with the grower liaisons under low perceived vulnerability to HLB, and the trend may change under higher vulnerability scenarios.

The propensity to adopt some HLB management practices was also impacted by the intention to communicate with neighbors (H3), but the sign of this impact varied for each practice. For most practices it was positive, meaning that participants who were more likely to communicate with neighbors had higher odds of adoption, but it was only significant for two practices. A one-unit increase in the intention to communicate with neighbors led to 1.6-times and 1.33-times higher odds of surveying for HLB symptoms and using EDTs, respectively, indicating that informal networks might be a pathway to promote the adoption of these tools.

In terms of the impact that the participants' socioeconomic circumstances could have on their propensity to adopt HLB management practices, farm size was the only significant predictor of adoption, giving limited support to H4. Participants with larger citrus operations were significantly more likely to scout for

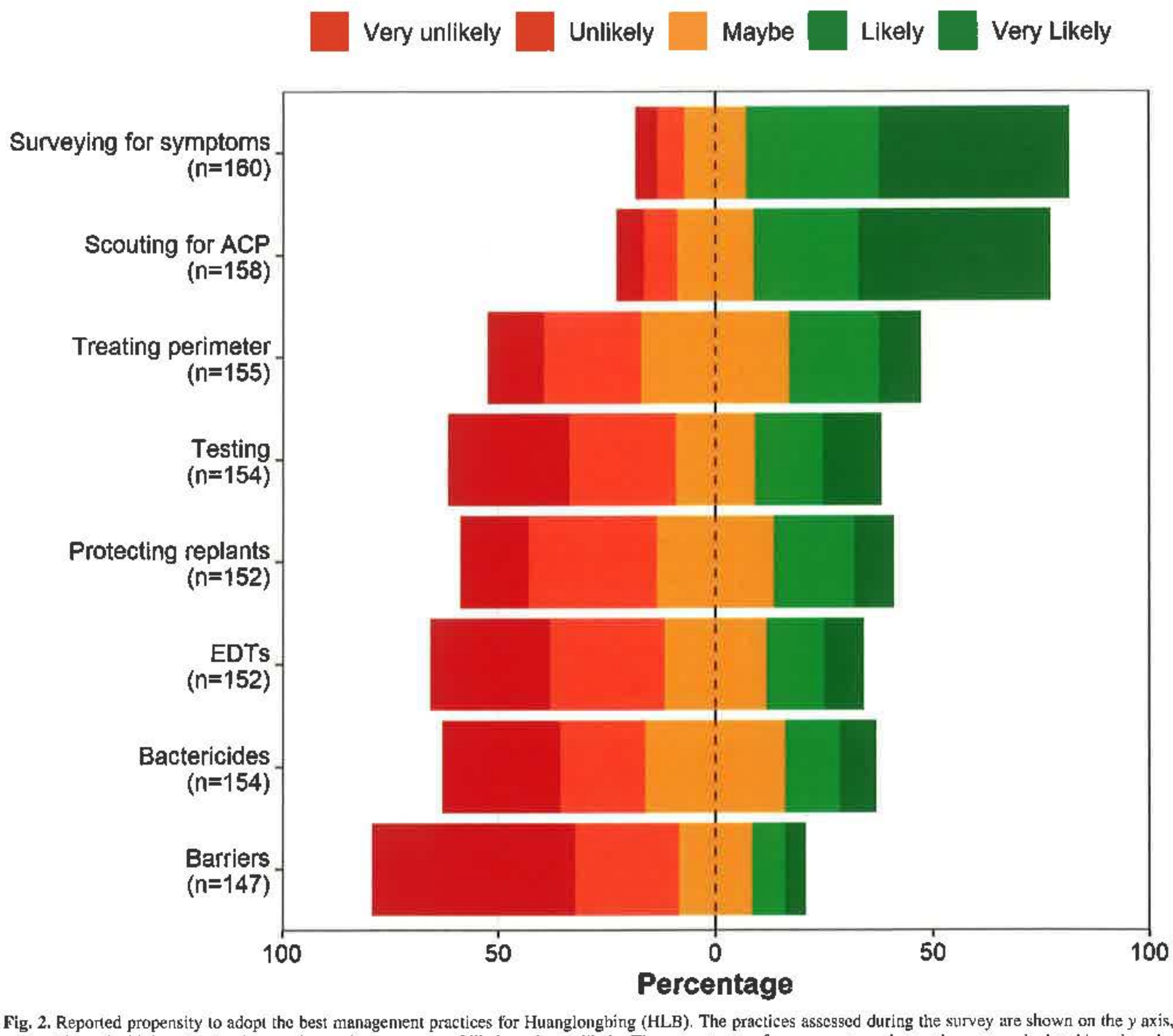

Fig. 2. Reported propensity to adopt the best management practices for Huanglongbing (HLB). The practices assessed during the survey are shown on the y axis, ordered from the highest (top) to lowest (bottom) percentages of likely and very likely. The percentages of responses to each question were calculated based on the total number of responses indicated between parentheses under each practice. The legend at the top shows the correspondence between the response chosen and the colors on the plot.

ACP and test, but they were less likely to perform extra measures to protect new plantings. In fact, for every 1-unit increase in the farm size category, participants had 0.75-times the odds of being more likely to protect replants. When perceived vulnerability to HLB and the intentions to stay informed and communicate were incorporated into the multivariate ordinal logistic regression model, the participants' role in citrus production, their age, their management system, and the percentage of their income from citrus were not significant predictors of their propensity to adopt any of the HLB management practices.

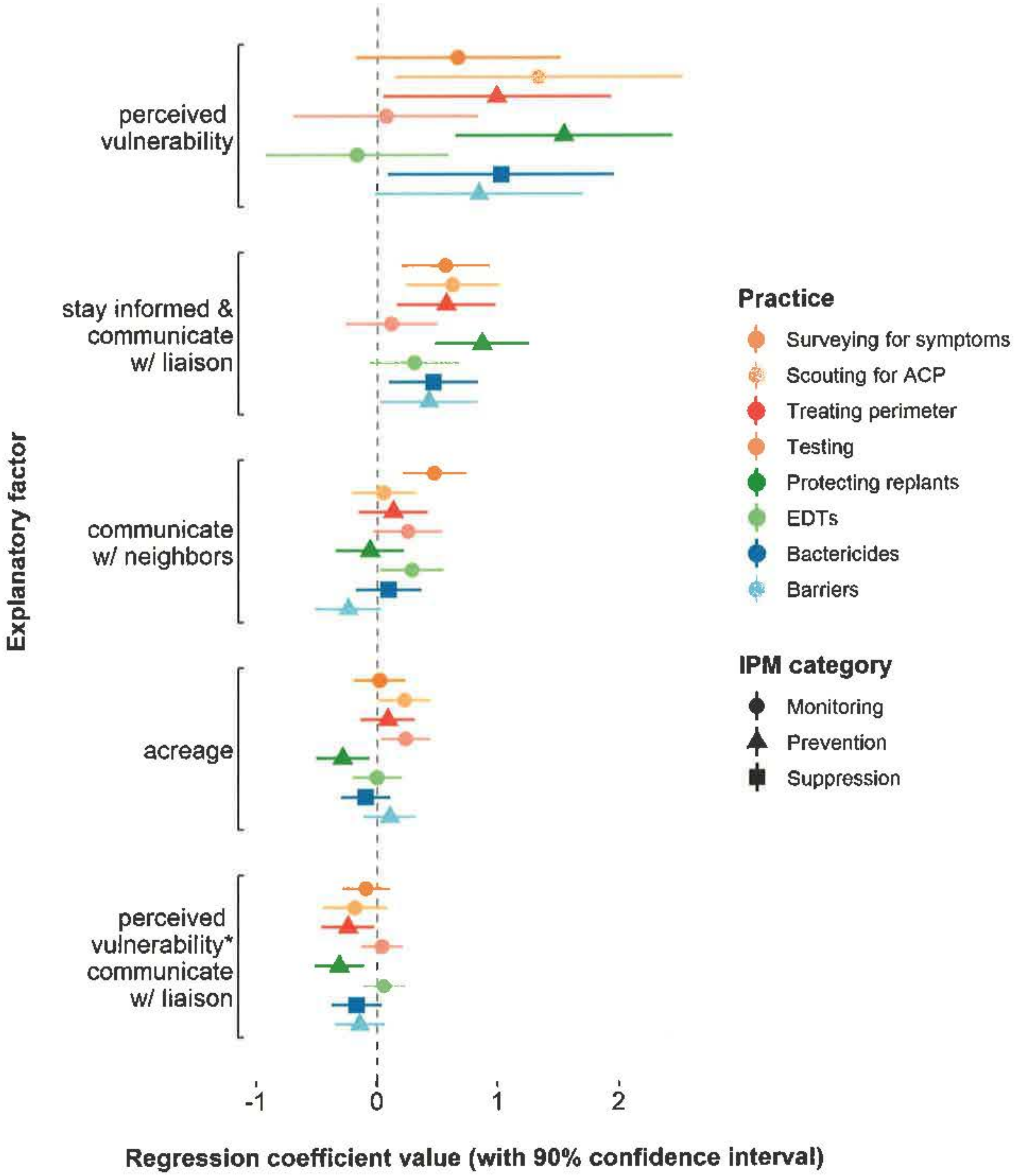

Fig. 3. Confidence intervals of the regression coefficients estimated by the multivariate ordinal regression model. The *x* axis represents the values of the regression coefficients. The *y* axis identifies the explanatory factor to which the coefficients correspond. The symbols indicate the value of the regression coefficients of the explanatory factors for each practice estimated by the multivariate ordinal regression model, and the whiskers represent the 90% confidence interval around the estimated value. The symbol shapes represent the integrated pest management (IPM) categories of the practices, and the colors represent the practices according to the legend on the right. Practices have been ordered from highest to lowest propensity to adopt (percentage of likely and very likely according to Fig. 2).

Estimating the probability of being likely or very likely to adopt the best management practices for HLB. The ultimate goal of using a regression model in this type of study is to be able to make predictions about the adoption of HLB management practices according to the variables that were identified from the existing literature and measured in the study. To facilitate the interpretation of the results, we calculated the predicted probabilities of being likely or very likely to adopt each of the practices in relation to each explanatory factor while keeping the rest of the factors at their mean value (Supplementary Fig. S2).

In particular, we were interested in examining the interaction between perceived vulnerability and the intention to stay informed and communicate with the grower liaison, because the significant regression coefficients of the interaction term suggested that the benefits of informing citrus stakeholders about the different practices might vary depending on the stage of the HLB epidemic. Indeed, as Figure 4 shows, the probability of being likely or very likely to adopt HLB management practices varies depending on the intention to stay informed and communicate with the grower liaison, as represented by the slopes of the different practices, and it also varies depending on the perceived vulnerability to HLB, as represented by the different panels. More importantly, the effects of information and communication on the adoption of some of these practices vary depending on the HLB scenario; this can be seen in the variation in the sign of the slopes of some practices across panels.

For example, when HLB detection is perceived to be unlikely or very unlikely, staying informed and communicating with the grower liaison tends to have a positive effect on the adoption of most practices (top left panels in Fig. 4). When HLB detection is perceived as very unlikely, the probability of surveying for symptoms increases from approximately 30% for people who are very unlikely to seek information and interact with the liaison to approximately 75% for people who are very likely to do so. However, when HLB detection is perceived to be likely or very likely, the effect of communication on adoption switches for several practices, and significantly for protecting replants and applying pesticides or repellents to the perimeter. Under high vulnerability to HLB, the adoption of these two practices decreases from 80 to 90% for people who are very unlikely to stay informed and communicate with the liaison to 20 to 30% for people who are very likely. Remarkably, the positive effects of communication on the adoption of

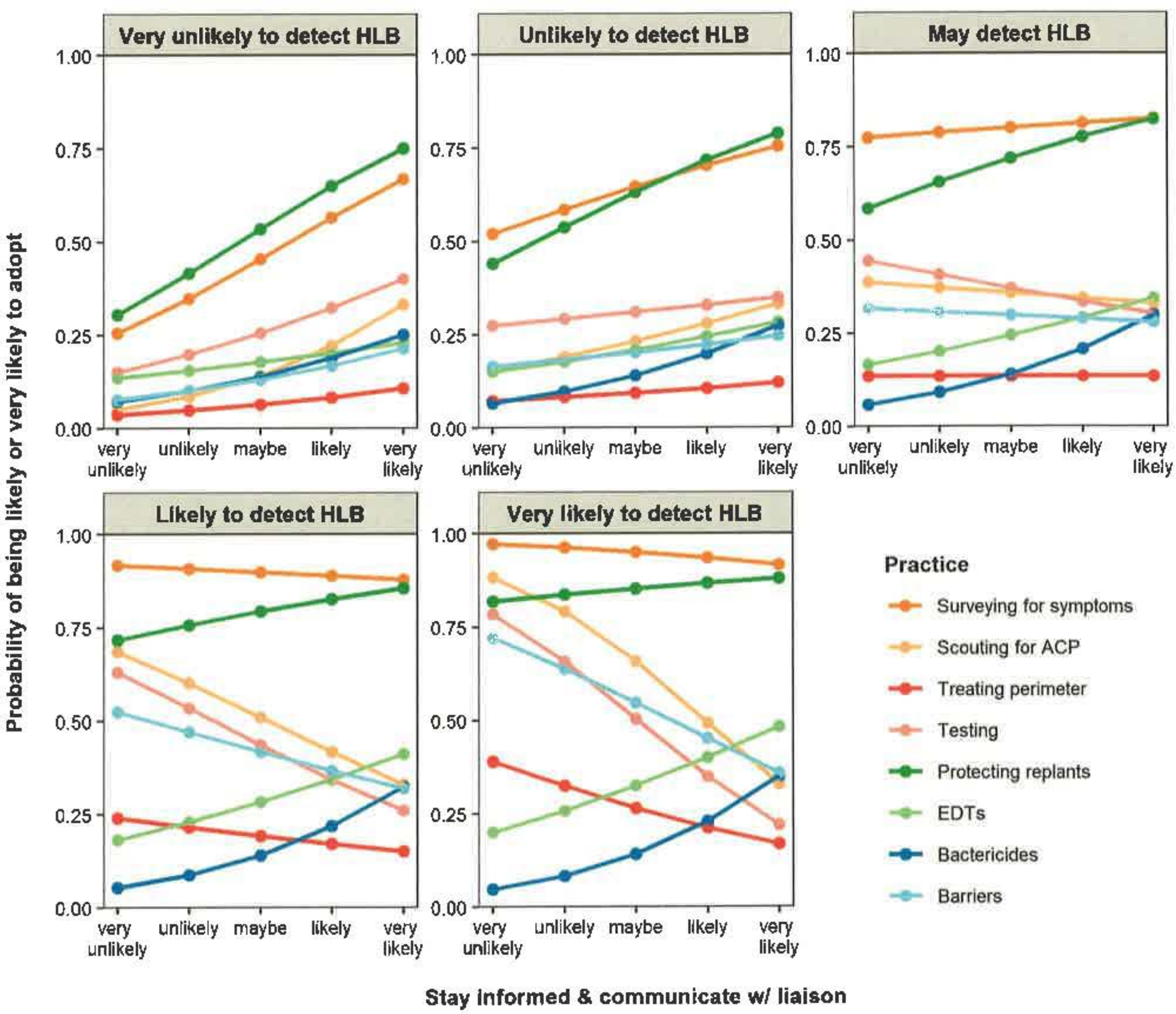

Fig. 4. Probability of being likely or very likely to adopt the best management practices for Huanglongbing (HLB) according to the perceived vulnerability to HLB and the propensity to stay informed and communicate with the grower liaison. The practices are colored according to the legend on the right.

surveys, testing, and EDTs tend to remain stable across the HLB scenarios, thus encouraging the CPDPC to continue promoting the adoption of these monitoring practices.

Interdependence in the propensity to adopt the best management practices for HLB. A preliminary calculation of rank correlations between practices suggested that several of them were likely to be adopted together, particularly those belonging to the same IPM category (Supplementary Table S4). However, rank correlations can only estimate the strength and direction of the monotonic relationship between two variables (i.e., if the propensity to adopt two variables increases or decreases in parallel). One of the strengths of using a multivariate ordinal regression model is that it allows the estimation of the polychoric correlations, which indicate the underlying propensity to adopt each pair of practices when explanatory factors have been considered (Greene and Hensher 2010).

The multivariate ordinal regression model indicated that there were several significant polychoric correlations between practices (Fig. 5; Supplementary Table S5), suggesting that the propensity to adopt different practices is interdependent, as hypothesized (H5). No significant negative correlations were found, indicating that most practices were perceived as complementary, thus supporting the idea of promoting these as a management toolkit. The two practices that had the highest acceptance (Fig. 2), visually inspecting for HLB symptoms and scouting for ACP, had a very high correlation and emerged at the core of the practice adoption network (Fig. 5). Considering that these two practices have been promoted for the longest period of time, are similar to other monitoring protocols that citrus stakeholders routinely follow, and they can be implemented simultaneously while inspecting citrus groves, it was reasonable that they would be highly accepted and highly correlated; however, we were surprised to find that they were not significantly correlated with any other practice, particularly the two other monitoring practices (testing and EDTs).

In contrast, practices that seemed to have low acceptance, such as using barriers, protecting replants, testing, and using EDTs, were highly correlated. These correlations show that practices in the same IPM category are perceived as complementary, and also that

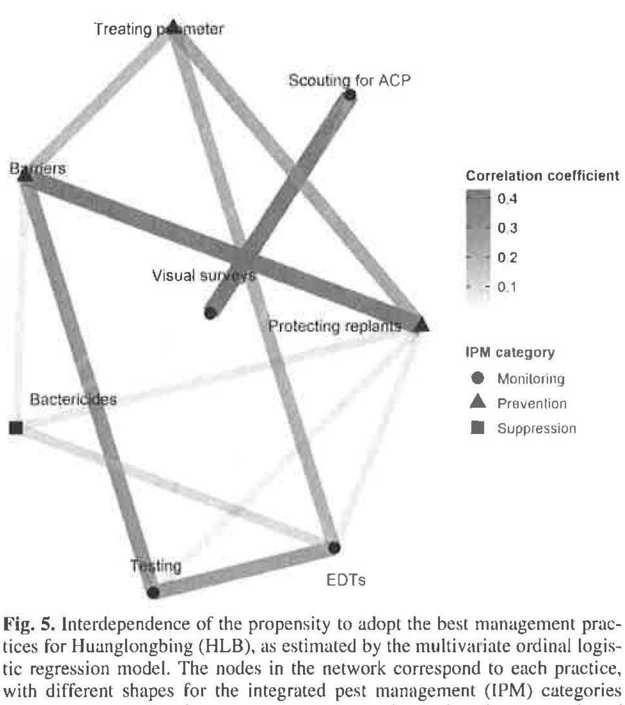

Fig. 5. Interdependence of the propensity to adopt the best management practices for Huanglongbing (HLB), as estimated by the multivariate ordinal logistic regression model. The nodes in the network correspond to each practice, with different shapes for the integrated pest management (IPM) categories of the practices according to the legend on the right. The width and color of the edges between nodes correspond to the correlation coefficients between practices estimated using the multivariate ordinal logistic regression model (Supplementary Table S5).

there is another dimension that relates them across categories that was not measured in our model. Additionally, the strong correlation between treating the grove perimeters and voluntarily testing suggests that these two practices may be perceived as two components of a strategy to prevent ACP from entering citrus groves and detect the presence of *C*Las as soon as possible, which was actually suggested during the presentation of the *Voluntary Grower Response Plan*. The use of bactericides, which was not officially recommended by the CPDPC, had very low acceptance and was only correlated with the use of EDTs and performing extra measures to protect new plantings. Therefore, it is unclear how California growers might integrate bactericides into HLB management.

DISCUSSION

The adoption of management practices for invasive plant diseases has been an understudied topic in plant pathology. Early surveys conducted by our group and collaborators in 2015 showed that risk perception and trust in control options were key factors in the decision to join the area-wide management program for HLB in California (Milne et al. 2018). At that time, suppressing the ACP population, removing HLB-positive trees, and using certified plant material were the main management practices recommended to the growers to prevent the spread of HLB (Gottwald 2010). Four years later, these measures seem to have been at least somewhat effective. HLB-positive trees are still confined to residential properties in the Los Angeles metropolitan area, but the number of trees detected increases weekly. As the portfolio of management practices expanded and the *Voluntary Grower Response Plan for Huanglongbing* was introduced to the citrus industry, it was deemed necessary to assess the propensity to adopt the recommended practices, in order to develop a targeted outreach program that could foster adoption.

In this study, participants were asked about their perception of the likelihood of an HLB detection in their grove in the coming year (July 2019 to June 2020), assuming that it could be one of the key factors prompting them to adopt management practices, in line with the human disease literature (Gaube et al. 2019; Sheeran et al. 2014). Despite some regional differences, the majority of participants believed that HLB detection was unlikely. This low perceived vulnerability was very surprising, especially considering that the ACP is widespread in Southern and Coastal California, and considering that *C*Las-positive trees and ACP had been detected close to commercial citrus groves in the counties of Riverside and San Bernardino. However, 1 year after the survey, by the end of June 2020, HLB-positive trees had not been detected in any commercial groves, proving that the participants' perception of the likelihood of HLB detection was not inaccurate. In fact, it was negatively correlated with distance from confirmed HLB-positive trees, providing evidence that they were aware of their proximity to infected trees.

Possible explanations for the widespread low perceived vulnerability to HLB could be a general belief that the control program has been effective at preventing HLB spread, for example, by covering citrus trucks with tarps to reduce ACP dispersal (McRoberts and Deniston-Sheets 2021); that the Mediterranean climate in California is not optimal for ACP and/or *C*Las and, thus, hinders spread (Narouei-Khandan et al. 2016); or that the 1-year horizon in the question about the likelihood of HLB detection was too short. We extended the time horizon in a follow-up survey in Ventura County in October 2019, in which we asked participants about the likelihood of HLB detection in their groves within 1 year and within 5 years (until October of 2024). Interestingly, although 60% of participants believed that it was unlikely or very unlikely that HLB would be detected in their grove within 1 year, only 16% of participants believed that within 5 years. The remaining 42% thought that it was likely or very likely, and 42% chose maybe, denoting considerable uncertainty about the future (*unpublished data*).

Immediately after the presentation of the *Voluntary Grower Response Plan for Huanglongbing*, our survey showed that not all of the HLB management practices are equally likely to be adopted. Although participants were in favor of surveying for HLB symptoms or scouting for ACP, they were reluctant to install barriers, test trees or ACP, or to consider the use of EDTs. Through the use of a multivariate ordinal regression model, we were able to gain insight into the heterogeneity in adoption, enhancing our understanding of the influence of perceived vulnerability, intentions to stay informed and communicate, and socioeconomic factors on adoption. We were also able to estimate which practices were likely to be adopted together.

This type of model, which was originally developed in a financial context to be freely implemented in R (Hirk et al. 2019), has great potential for practice adoption studies. First, it avoids the simplification of merging different practices into a single adoption score, which has been criticized previously (Puente et al. 2011). Second, it also avoids evaluating each practice in isolation, which may lead to biased and inefficient estimates (as explained by Kassie et al. 2013). Third, it can be used to analyze surveys with ordinal answers, which provide a finer scale to measure propensity to adopt than binary answers that would be analyzed with multivariate probit models (Cai et al. 2019).

In terms of the measured predictors of adoption, our results support the hypothesis that risk perception is a driver of management actions against invasive plant diseases, as proposed by the protection motivation theory in the context of human diseases (Rogers 1975) and by pioneering studies focused on plant pests (Heong and Escalada 1999). The multivariate ordinal logistic regression model indicated that perceived vulnerability to HLB had a positive effect on the probability of scouting for ACP on flush, protecting replants, treating grove perimeters, and using bactericides. However, the impact of perceived vulnerability was significant only for these four practices, and inconsistent relationships between risk perception and practice adoption have been observed in other studies of invasive plant diseases (Breukers et al. 2012; Mankad et al. 2019). Therefore, the evidence collected suggests that cross-sectional studies that predict the adoption of management practices with risk perception as the core predictor might be incomplete, and future longitudinal studies that consider risk perception and practice adoption at several time points (Raude et al. 2019) and include other explanatory factors might be more useful.

In fact, the intention to stay informed and communicate with the grower liaisons had a positive impact on the adoption of most practices, suggesting that the information network that was created by the CPDPC might be a relevant factor in promoting adoption. Remarkably, very few participants said that they did not know who their grower liaison was, and 79% were likely or very likely to communicate with them, proving their recognition by the community. Nevertheless, the interaction between perceived vulnerability and staying informed and communicating with the liaison suggests that the benefits of promoting HLB management through the CPDPC outreach network might depend on how vulnerable citrus growers feel to HLB, and therefore, on the stage of the HLB epidemic.

People who were more likely to communicate with neighbors had a higher propensity to adopt most practices, confirming the importance of informal communication networks on adoption, even though the effect was only significant for visual surveys and EDTs. Considering that EDTs were negatively impacted by the perceived vulnerability to HLB and not significantly impacted by staying informed and communicating with the grower liaison, neighbor-to-neighbor communication might be a way to promote the adoption of these innovative tools. Previous studies have shown that growers turn to other growers for information about disease management practices (Hillis et al. 2017; Maclean et al. 2019; Sherman et al. 2019), and participatory trials have successfully promoted the adoption of HLB management practices in Texas by letting the growers experience the benefits themselves and spread the word in their communities (Sétamou 2020).

Farm size was identified as the main socioeconomic factor that could impact the adoption of HLB management practices. As the size of the citrus operations increased, there was a positive effect on most practices, which is in line with previous literature about the adoption of other agricultural practices (Prokopy et al. 2019). This effect was significant for scouting for ACP and testing. However, larger citrus operations had a lower probability of taking extra measures to protect new plantings, probably because of the cost associated with these measures (Alferez et al. 2019).

Remarkably, the participants' role in citrus production, their age, their management system, and the percentage of their income from citrus did not have significant effects on the propensity to adopt HLB management practices. Initial rank tests only showed that PCAs were more in favor of using EDTs, that organic growers were less likely to apply extra pesticides or repellents to the perimeter of groves, and that participants who obtained 26 to 50% of their income from citrus were less likely to communicate with neighbors; while those who obtained 51 to 75% of their income from citrus were more likely to do so. Although these factors could not be used to predict adoption, the observations might still be useful for the outreach program. PCAs might be more inclined to use EDTs because they often manage multiple operations and need to make rapid, evidence-based decisions; therefore, they could be targeted by the outreach program and the companies providing EDT services to promote these tools among the citrus community. Because PCAs have an increasingly crucial role in advising growers (Eanes et al. 2019; Hillis et al. 2016), outreach activities and workshops aimed specifically at this group could be very beneficial. One of the reasons why organic growers might be less willing to treat grove perimeters is that there are only a few products approved for this use by organic certification programs. Finally, the peculiar effect of income on communication with neighbors is difficult to explain, but no other association was found between income dependency on citrus and propensity to adopt, contrary to previous studies of other invasive plant diseases (Mankad et al. 2019).

In terms of the interdependence between practices, the multivariate ordinal logistic regression model indicated that the propensity to adopt all of the practices was positively correlated, giving support to the idea of a management toolkit. The two monitoring practices that had been promoted from the beginning of the HLB epidemic, scouting for ACP and surveying for symptoms, were highly accepted and highly correlated, providing evidence of the citrus industry's commitment to monitor the vector and the disease. However, they were not correlated with the other two monitoring practices (tests and EDTs), showing a disconnect between visual inspections and more accurate and earlier diagnostic tests. In fact, tests and EDTs were the only two practices not significantly impacted by the intention to stay informed and communicate with the grower liaison, suggesting that they may be more difficult to promote through the CPDPC network. Voluntary testing in particular seemed to have low acceptance and did not seem to be correlated with many practices. This may be due to the uncertainty associated with the consequences of a positive test result and fear of quarantine restrictions, as a *C*Las-positive qPCR test on leaf material is considered a regulatory positive by the CDFA and it triggers mandatory action (i.e., tree removal and quarantine), while a *C*Las-positive ACP or a positive EDT test do not trigger mandatory action. One year after this study, the use of one type of EDT (Gottwald et al. 2020) has started in the Coast production area, and a comparable approach to detect ACP is being considered by the CPDPC. Therefore, clarifying the test options available, how they could be integrated in an HLB management plan, and clearly explaining the consequences of a positive result should be a priority for the outreach program to improve surveillance efforts.

Interestingly, some practices that seemed to have low acceptance, such as testing, using EDTs, installing barriers, and protecting replants were highly correlated. Two possible reasons for the low acceptance and correlations between these monitoring and preventive practices could be their novelty and cost, which were not measured in our survey. Previous studies have shown that growers tend to adopt practices if the benefits clearly outweigh the costs (Lubell et al. 2011), but adoption is limited for practices with benefits that are difficult to observe or extend over long periods of time (Rogers 2010). Although we did not ask any specific questions about perceived cost, installing barriers would be costly, particularly for groves with extensive perimeters, and EDTs were considered so new that the citrus industry decided not to include them in the *Voluntary Grower Response Plan*. Bactericides were not included, and they had very low acceptance and were only correlated with the use of EDTs and performing extra measures to protect new plantings, again suggesting that novelty might be a relevant factor for adoption. In addition, bactericides have provided mixed results in other citrus-growing areas (Blaustein et al. 2017), and they raise concerns among consumers about antibiotic residues potentially present on fruit (Jacobs 2017; Jacobs and Adno 2019); therefore, it is unclear how the use of bactericides will unfold as the HLB epidemic progresses in California.

Overall, we believe that future studies of the adoption of plant disease management practices would benefit from the explicit incorporation of behavioral models. One such model is the theory of planned behavior (Ajzen 1991), which has been widely used to explain practice adoption in agriculture (Borges et al. 2019; Daxini et al. 2018), with some pioneering applications in plant disease management (Breukers et al. 2012). The theory of planned behavior proposes that the *attitude* toward the behavior (the degree to which a person has a favorable or unfavorable evaluation of the behavior), *subjective norms* (perceived social pressure to perform the behavior), and *perceived behavioral control* (confidence in the ability to perform the behavior) collectively determine people's behavioral intentions and, ultimately, their behavior (Ajzen 1991). Therefore, asking stakeholders about these three factors in relation to any particular disease management practice might provide a better understanding of their ultimate intentions (Janssen et al. 2020). In fact, the finding that trust in control options had a higher impact on the success of a control campaign against an invasive plant pathogen than risk perception (Milne et al. 2020) is direct evidence of the importance of perceived behavioral control for practice adoption and, ultimately, successful control. Similarly, "values placed on social approval and peer comparisons" (i.e., perceived norms) were key motivating factors for adopting management actions during the first months after the detection of Panama TR4 in Australia (Mankad et al. 2019). In our case, it was hard to assess the citrus stakeholders' *attitudes, perceived norms* and *perceived behavioral control* about HLB management practices as they were hearing about some of them for the first time. However, once stakeholders become more familiar with these practices, we believe that future studies aimed at understanding adoption drivers may benefit from focusing more on these types of factors and a careful examination of the relationship between risk perception and protective behavior over time (Gaube et al. 2019), rather than on individual socioeconomic factors that should be used as controls but appear to yield only weak explanatory models of self-reported propensity to adopt management practices.

Conclusions. When an invasive plant disease is introduced in a new territory, management efforts have to be mobilized and coordinated at different scales to face the emerging threat, usually under conditions of high uncertainty and lack of previous experience. Individuals who could potentially be affected by the disease need to react quickly and adopt management practices in a coordinated manner to effectively prevent spread. Under these circumstances, it becomes crucial to understand what factors might drive or prevent the adoption of management practices, and how outreach efforts could be targeted to provide a more effective response to the invasive disease. This study contributes to this understanding by assessing the California citrus industry's propensity to adopt a toolkit of best management practices to prevent the spread of HLB when it was no longer possible to eradicate it, but before it had spread to commercial groves. Our results show that perceived vulnerability to HLB, intentions to stay informed and communicate with formal and informal networks, and farm size could be relevant factors for adoption, and that the adoption of different management practices is interdependent. Further studies that address the stakeholders' attitudes toward the practices, their perceived norms and their perceived behavioral control at different points in time will likely enhance our understanding of the drivers of protective action against invasive diseases, thereby contributing to ensuring the sustainability of crop production under HLB and other emergent plant diseases.

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Assessing the risk of containerized citrus contributing to Asian citrus psyllid (*Diaphorina citri*) spread in California: Residence times and insecticide residues at retail nursery outlets

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ABSTRACT

For phytophagous insects and plant pathogens, the unregulated movement of plant material can inadvertently promote long-distance spread, facilitating biological invasions. Such human-assisted spread has contributed to the invasion of the Asian citrus psyllid (*Diaphorina citri*), a vector of the pathogens associated with huanglongbing. Following the detection of *D. citri* in California, regulations were instituted to limit movement of *D. citri* host plants, by mandating insecticide treatments of citrus nursery stock, and limiting the amount of time host plants can reside at retail sites. We used a set of surveys and a field experiment to evaluate how well these steps mitigate the threat of containerized citrus playing a role in *D. citri* spread. A qualitative analysis of data collected by state regulators throughout Southern California found that containerized citrus may reside at retail sites for extended durations, in extreme cases upwards of 2 years post treatment. More detailed surveys at nearly 30 retail sites in Southern California showed that the majority of citrus plants were present past the 90 day regulatory limit, 33% had been treated more than 1 year prior, and 90% had imidacloprid residues below those known to be effective against *D. citri* nymphs. A field experiment confirmed that imidacloprid residues in trees grown in containers were affected by citrus species, watering level, soil mix, and time since treatment. Overall, plants had *D. citri*-effective residues for approximately 12 weeks, suggesting that imidacloprid treatments should protect the majority of containerized citrus against *D. citri* for approximately the duration of the 90 day regulatory limit. To further protect trees from infestation, nurseries should be encouraged to adopt practices that maximize the effectiveness of insecticide treatments, including ways to reduce residence times of host plants at retail sites.

1. Introduction

Invasive species impose enormous economic and environmental costs to agriculture, natural resources, and human health (CISR, 2016; Simberloff et al., 2013). The identification of pathways of introduction and spread that facilitate invasions of non-native species is critical to the successful implementation of management strategies that mitigate the threat of invasive species (Bayles et al., 2017). In the agricultural sector, the movement of plant material by individuals and through avenues of trade can be especially problematic because of the potential for the dissemination of species over a broad geographical range within a relatively short period of time, often before effective measures of containment and eradication are implemented (Halbert et al., 2010; Morse et al., 2016; Palumbo and Natwick, 2017).

The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Liviidae), was detected on citrus in southern California in 2008 at a residential property in San Diego County (Grafton-Cardwell, 2010), and has since become established throughout Southern California on both residential and commercial citrus (Bayles et al., 2017). Its principal form of damage is as a vector of the pathogens (*Candidatus* Liberibacter spp.) associated with huanglongbing (HLB or citrus greening) disease in citrus, for which there is currently no readily available cure (Grafton-Cardell et al., 2013). Symptoms of HLB include progressive mottling of leaves, deformed and off-flavor fruit (Dagulo et al., 2010), reductions in yield and eventual plant death (Bové, 2006). In 2012, the first HLB-positive tree in Southern California was detected in a residential

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neighborhood in Los Angeles County (Kumagai et al., 2013). Since that initial discovery, there have been further detections in Los Angeles, Orange, and Riverside counties with all of them in citrus trees grown in private residences.

The Florida citrus industry has been severely impacted by HLB, with estimated costs in excess of $4.5 billion for the five seasons between 2006/07 and 2010/11 (Hodges and Spreen, 2012). *D. citri* was first detected in Florida in 1998 and it spread quickly to all the major citrus-growing regions within the state in less than 3 years (Halbert et al., 2012). The unregulated movement of *D. citri*-infested nursery stock, both citrus and *Murraya paniculata*, is believed to have been the major contributing factor in the spread of both *D. citri* and HLB throughout Florida (Halbert et al., 2000, 2012) and in the interstate movement of *D. citri* from Florida to Texas (French et al., 2001). In 2009, over 10% of regulatory *D. citri* samples collected in Florida retail outlets tested positive for *Candidatus* Liberibacter asiaticus, and it took an average of 9 months after positive *D. citri* were detected for inspectors to find symptomatic plants that tested positive for the pathogen (Halbert et al., 2012). At many of the retail outlets where positive *D. citri*, no symptomatic plants were ever discovered, indicating that infected plants were already sold to homeowners.

Recognizing the importance of the passive dispersal of the vector on nursery stock, the detection of *D. citri* in California triggered a comprehensive effort on the part of state and federal regulators, scientists, and citrus industry stakeholders to implement measures that would limit its spread. The California Department of Food and Agriculture (CDFA) established quarantines that restricted the movement of *D. citri* host plants from areas known to be infested with *D. citri*. Production nurseries within quarantine areas are still required to treat all citrus nursery stock, and other *D. citri* host plants, with both an approved foliar insecticide and a systemic neonicotinoid insecticide in order to receive a 90-day certification, during which time plants may be shipped from the production facility to retail outlets. For shipments outside of the quarantine areas, including inter-state movement, nurseries must apply these treatments no more than 90 days, and no less than 30 days, prior to shipment (CDFA, 2017).

Currently, all existing *D. citri* quarantine control requirements apply only to production nurseries. There are no treatment requirements for retail outlets, a decision likely guided by the expectation that plants would reside at these nurseries for a short time. As a result, the residency time of citrus trees at retail nurseries may represent a critical window for *D. citri* infestation and spread, particularly if the 90-day certification period is exceeded. Furthermore, there is an increased likelihood that overwatering of trees at retail nurseries may contribute to lower neonicotinoid residues due to leaching of insecticide from pots (Cox et al., 1997; Liu et al., 2006).

In this study, we investigated the relationship between residency time at retail outlets and declining imidacloprid titers in containerized citrus trees, as well as the interaction between these parameters and the increased levels of *D. citri* infestation. To achieve this, we conducted an independent survey of citrus trees in retail outlets in Southern California and determined their imidacloprid concentrations and treatment histories from CDFA records.

To examine the effect of irrigation on insecticide titer, we conducted an outdoor trial in which potted trees treated systemically with imidacloprid were maintained under different watering schedules. We also incorporated citrus species and soil mix variables into our experimental plan. We were particularly interested in comparing citrus species with contrasting flushing patterns, and hypothesized that species with more frequent flushing habits would be limited in their capacities to maintain effective concentrations of imidacloprid due to the diluting effect of the new flush on available residues. Such trees would be at greater risk of infestation because the newer tissue is favored by *D. citri* for feeding and oviposition (Catling, 1970).

2. Materials and methods

2.1. CDFA nursery inspections

Following the establishment of the quarantine areas in California, the CDFA coordinated numerous inspections of production and retail nurseries to ensure compliance with regulations. When *D. citri* were detected at retail stores, a numerical tagging system that was implemented as part of quarantine regulations, permitted accurate traceability of infested trees to determine their origin and treatment histories. These data were documented by CDFA inspectors and represent an early record of the number of *D. citri*-infested nursery shipments as a function of the time since insecticide application. We were permitted access to this CDFA database to investigate a potential link between the incidence of *D. citri* infestations and extended residency times of trees at the retail outlets. Because no insecticide residue data were collected at the time of the inspections, the residency time would serve as a proxy for insecticide levels, with the expectation that titers would decline within the trees as the residency time lengthened.

Between May 2011 and June 2013, CDFA inspectors documented a total of 434 nursery shipments in Los Angeles (187), Orange (49), Riverside (118), San Bernardino (79), and San Diego (1) Counties, in which *D. citri* life stages were present on at least one plant in the shipment. Unfortunately, the number of *D. citri*-free nursery shipments was not recorded, so a formal analysis of the frequency of *D. citri* occurrence in nursery stock could not be determined. Nonetheless, the summary statistics for the dataset are presented as an indication of the scale of *D. citri* occurrence on nursery stock during this time period relative to the time elapsed since the trees were treated.

2.2. Detailed nursery inspections

To study the relationships among residence times, insecticide residues, and *D. citri* infestation on retail citrus trees, we conducted a set of detailed inspections at 29 randomly selected independent retail nurseries (14) and chain store garden centers (15) from Southern California. We compared these two types of retail sites because of our expectation that residence times of trees at independent nurseries might be longer due to a slower turnover of a more diverse citrus inventory, in contrast to the less specialized chain store garden centers that bulk buy more popular varieties that will provide them with a more rapid turnover of citrus stock. The inspections were conducted in Riverside, San Bernardino, and San Diego Counties between January and November 2013. Although each site was surveyed for all common *D. citri* host plants (CDFA, 2018), no non-citrus hosts were found during the surveys. At both types of retail sites, we inspected citrus nursery stock for the presence of *D. citri* with two-minute timed visual searches of each tree, noting separately the presence or absence of *D. citri* adults or any juvenile stages (i.e. eggs or nymphs). We visually inspected all citrus nursery stock at sites that had less than 50 citrus trees; at sites with 50 or greater citrus trees we randomly selected at least 20 trees for inspection. For each inspection, we recorded the predominant category of flush, the species, the trunk diameter at 5 cm above the graft union, and the shipment tag number. For flush characterization, we recorded the predominant stage of foliage present on each side of the tree, using four categories of classification ranging from new "feather flush" to mature "hardened-off" leaves: A) "feather flush": most fragile leaves, light green (petiole) with pink hue (apical buds/leaves), ranging from 0.1 to 1 cm in length; B) less fragile leaves, light green (pink/red hue more pronounced) on apical leaves, ranging from 1.5 to 3 cm; C) leaves with much greater integrity (more firm), darker green (loss of red tint), ranging from 3.5 to 5 cm; D) "hardened-off": largest of the leaves on the tree, full coloration (darkest green) on the entire tree (red tint absent), coarse, thick, and often brittle. Finally, for at least 20 of the trees inspected at each site, we collected a minimum of 4 leaf tissue samples that represented the youngest flush category available for imidacloprid residue analysis, and stored them at −80 °C until analysis. Although 3 systemic neonicotinoid insecticides (dinotefuran, imidacloprid, and thiamethoxam) are approved by the CDFA as quarantine treatments for intra-quarantine movement of host nursery stock (only dinotefuran and imidacloprid are approved for use in inter-state shipments), the tag information showed that imidacloprid was used almost exclusively by the production nurseries.

2.3. Field experiment of effects on insecticide residues and D. citri dynamics

2.3.1. Experimental design

In the summer of 2013, a field trial was conducted at the UC Citrus Research Center and Agriculture Experiment Station (CRC-AES) in Riverside, CA to estimate the uptake and residual efficacy of soil-applied imidacloprid over a range of simulated nursery conditions in two citrus species, Parent Washington navel oranges (*Citrus sinensis* L.) and Limoneira 8A lemons (*Citrus limon*). The trial consisted of a total of 260 potted citrus trees in a factorial combination of 2 insecticide treatments (imidacloprid or an untreated control), 2 citrus species (lemon or navel orange), 3 watering levels (120, 240, 480% of daily evapotranspiration), and 2 soil mixes (10% sand mix or 30% sand mix). There were 15 replicates of each species-water-soil mix combination for imidacloprid-treated trees (N = 180), and 6–10 replicates for each species-water-soil mix combination for control trees (N = 80).

2.3.2. Citrus tree production

The trees (n = 150 of each species) were budded in June 2012 on 'Carrizo' citrange rootstock growing in 12.7 cm diameter treepots (Stuewe & Sons; cat # CP512CH), and maintained in a protective structure free of any insecticide applications at the Lindcove Research and Extension Center (LREC) in Exeter, CA until they were approximately 1 yr old. Trees were transported to a lathe house at CRC-AES on June 13, 2013, and were repotted on June 24, 2013 into 18.9 L pots with one of two soil mixes. The soil mix consisted of two modified formulations of UC Soil Mix #1 (http://agops.ucr.edu/soil/) – a "30% sand mix" variant with 30% sand, 40% redwood bark, 15% moss, 15% coconut fiber, and a "10% sand mix" variant with 10% sand, 60% redwood bark, 15% moss, 15% coconut fiber. All other constituents were included at the standard level of UC Soil Mix #1. These two formulations were selected, after consultation with citrus nurserymen, to reflect soil mixes most likely to be used by production nurseries in California. All trees were top-dressed monthly with 150 g of a granular fertilizer (Nurserymans Citrus and Fruit Tree Fertilizer 8-4-2, Red Star Fertilizer Co., Corona, CA) over the course of the experiment. Two weeks after repotting (July 9), the trees were transferred from the lathe house to a field plot, where they were laid out in a grid pattern with 2 m spacing.

2.3.3. Irrigation

Each tree was provided with drip irrigation designed to deliver one of three watering levels. The different irrigation regimes were implemented using adjustable DIG® emitters, whose output was verified at the outset of the study.

The watering levels were established based on measures of daily evapotranspiration (ET) on a subset of 18 trees. This involved watering them to capacity, then weighing the entire potted tree within the next hour and again 24 h later to calculate the daily change in mass. ET measurements were repeated three times over successive days, and ranged from 0.947 to 1.067 L with a mean of 0.98 L per day. Based on this value we selected three irrigation rates that represented replacement watering, overwatering, and severe overwatering (approximately 1.2, 2.4, or 4.8 L per day to represent 120, 240, and 480% of ET, respectively).

2.3.4. Insecticide treatments

On July 11, 2013, all trees in the insecticide treatment received Admire Pro (imidacloprid; 0.55 kg AI per L suspension concentrate; Bayer CropScience, Research Triangle Park, NC) at a rate of 11.65 ml per cubic meter of soil mix (equivalent to 0.231 ml of product per pot based on 0.02 cu meter of soil mix per pot). Pots were pre-irrigated to ensure adequate wetting of the soil mix prior to insecticide application. The formulated insecticide was diluted in water, and then administered to each pot in a final volume of 250 mls using a measuring cylinder, followed by further watering from a watering can to ensure the insecticide had permeated below the soil mix surface into the root zone. Two days after imidacloprid applications were completed, we initiated the daily drip irrigation regime at each of the three water volume levels described above.

2.3.5. D. citri dynamics

Starting the same week as insecticide applications, we monitored trees regularly for *D. citri* presence, plant response, and imidacloprid residues. This included timed visual inspections of trees, following the same protocol used during nursery inspections, for the presence of adult or juvenile stages of *D. citri*, and notation of the earliest flush category present on the tree. In addition, we measured tree height from the soil surface to the top shoot, and the trunk diameter at 5 cm above the graft union.

2.4. Chemical quantification of imidacloprid

Imidacloprid residues in leaf tissue samples from the nursery surveys and the field trial were quantified by ELISA (Enzyme-Linked ImmunoSorbent Assay) at 2, 4, 8, 16 and 32 weeks post treatment using a commercially available ELISA kit (QuantiPlate Kit for Imidacloprid; Envirologix, Portland, ME, USA; cat # EP 006). The lower limit of quantitation (LOQ) of residues in citrus leaves for the ELISA was 75 ng imidacloprid per gram of leaf tissue, and was dependent on the inherent reactivity of the antibody with the insecticide after matrix effects had been accounted for by dilution (Byrne et al., 2005a,b).

Young leaf flush tissue (0.5 g) was placed in a vial, chopped into small pieces using scissors, and then extracted by the addition of 5 ml of 100% methanol. Extracts were shaken for 12 h at 25 °C. An aliquot of each extract was dried completely in a TurboVap LV evaporator (Caliper Life Sciences, Hopkinton, MA, USA) and then dissolved in a 0.05% aqueous solution of Triton X-100 prior to analysis by ELISA. An imidacloprid purification step was required to determine whether there was any contamination of extracts with imidacloprid metabolites (Nauen et al., 1998; Castle et al., 2005) that could potentially cross-react with the ELISA kit antibody (Byrne et al., 2005a,b). Observed residues were then corrected using a method that reliably relates ELISA values to more precisely resolved imidacloprid residues from thin layer chromatography (MPD, *unpublished data*). An aliquot of each imidacloprid extract was spotted directly on the concentrating zone of LK6DF silica gel 60 TLC plates (Whatman, Inc., Florham Park, NJ, USA) and then chromatographed in a mobile phase of methylene chloride + methanol + ammonium hydroxide (45 + 5+1 by volume). The position of imidacloprid was determined by co-chromatographing an imidacloprid standard (ChemServices, West Chester, PA, USA; cat # N-12206-500MG) with the citrus extracts. The imidacloprid bands were cut from the plate, washed from the silica with 100% methanol, and then quantified directly by ELISA. A subset of nearly 10% of the tissue samples were subjected to both ELISA and TLC. We then used a generalized additive model (GAM) to describe the relationship between the two readings (Crawley, 2009). Nearly 70% of the variation in the TLC reading was explained by a smoothed effect of the bulk ELISA reading, with modest additional explanatory power included via an effect of county and month of treatment. This fitted relationship was then used to correct the remaining 90% of sample ELISA values for further analysis.

2.5. Statistical analysis

All analyses of the detailed nursery inspections and the field experiment were conducted using the R programming language, version 3.0.2. For the detailed nursery inspections, a set of linear mixed-effects models was used to evaluate the effect of nursery type (i.e. independent nursery versus garden center) on time since treatment, with a random effect of the California county in which the nursery was located as a blocking effect, and a random effect of nursery identity to account for repeated measures of multiple trees made at an individual retail site. This included a linear mixed-effects model (Crawley, 2009) on the number of days since treatment, a generalized linear mixed-effects model (GLMM) with binomial error (Pinhero and Bates, 2009) on the fraction of trees that were more than 90 d post treatment and a similar GLMM on the fraction of trees that were more than 1 yr post treatment. For the residue data from the surveys, imidacloprid levels corrected for metabolites by TLC were $\log_{10}$ transformed for analysis with a linear mixed-effects model, with a fixed effect of time since treatment, a random effect of county in which the nursery was located, and a random effect of nursery identity to account for repeated measurements of multiple trees made at the same retail site. Initially, additional effects were included in the model (e.g., basal diameter, flush category, species, time of year), but these did not have strong enough effects to be retained in the analysis.

For the outdoor potted tree experiment, we compared imidacloprid residues in treated trees among the treatment combinations in two complementary ways. First, we analyzed imidacloprid concentration ($\log_{10}$[ppb+1]) with a linear mixed-effects model that included fixed effects of time (i.e. wk post application), watering level, citrus species, and soil mix, and a random effect of tree ID to account appropriately for autocorrelation stemming from repeated measurements of the same trees over time. In addition, we analyzed the fraction of trees above the target concentration of 220 ppb with a GLMM, with binomial error, fixed effects of time, watering level, species, and soil mix, and a random effect of tree ID. For both analyses, model simplification was used via step-wise deletion and lack-of-fit tests to arrive at the most parsimonious explanation of these data (Crawley, 2009).

In the field experiment we compared *D. citri* presence or absence on the containerized citrus with a pair of generalized linear mixed-effects models for *D. citri* adults and juvenile stages (i.e. eggs or nymphs), separately. Both models assumed bionomial error, fixed effects of insecticide treatment, citrus species, soil mix, irrigation (ET) level, and time since treatment, and a random effect of tree ID to account for repeated measurements. Model simplification was again used to arrive at the most parsimonious adequate model.

Finally, we analyzed tree status and condition over the course of the field experiment, that included comparisons of flush stage and two separate metrics of growth. For flush, the 4 relative age categories (A – D) were converted to integers (1–4), which were then averaged over the 13 censuses for each replicate tree to generate a mean relative flush category. For both tree height and trunk diameter, we subtracted the value at the first census from the value at the final census to generate two metrics of relative growth rate. These three metrics of tree status and condition were analyzed in a multivariate analysis of variance (Crawley, 2009), which included fixed effects of watering level, citrus species, and soil mix.

3. Results

3.1. CDFA nursery inspections

More than 83,000 trees in 434 nursery shipments were impacted as a result of *D. citri* detections by CDFA inspectors. For 233 of the detections, affecting more than 54,000 nursery plants, treatment history information was available, thereby enabling us to estimate the time elapsed between the inspection and treatment dates. The summary statistics for this dataset show the potential scale of *D. citri* occurrence on nursery stock during the 2-year survey period and the relative duration that nursery stock resided at retail sites.

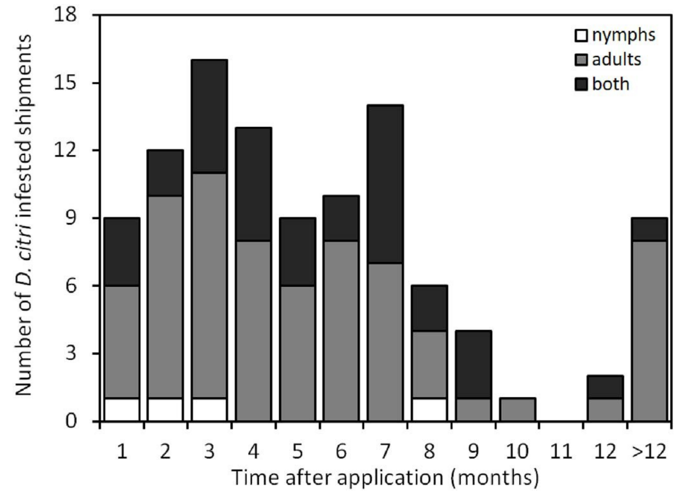

Fig. 1. Histogram showing the number of nursery shipments out of 105 total found during CDFA inspections between May 2011 and June 2013 to have *D. citri* adults, nymphs, or both stages present as a function of the time since insecticide application.

Based on the CDFA census data, 46% (105/233) of the shipments with complete treatment history information had *D. citri* detections at independent retail nurseries or chain store garden centers, affecting a total of 15,561 containerized citrus trees. For these shipments (Fig. 1), detections with only adult *D. citri* (64%) were found far more frequently than those with only nymphs (4%), while both stages were found in shipments approximately 32% of the time (34/105). For these trees, the time between the inspection (*D. citri* detection) and treatment dates ranged from as little as 2 weeks to more than 32 months. Only 35% of the shipments were within the 90-day certification period, while over 10% (11/105) of trees had exceeded the certification period by at least 365 days (Fig. 1).

3.2. Detailed nursery inspections

Of the trees inspected during our 9-month survey period in 2013, only four trees were infested with adult *D. citri*; juvenile stages were not detected on any trees. The time since treatment of the infested trees ranged between 113 and 369 days.

Using tag numbers collected at the 29 retail sites, we estimated the approximate residence times of more than 1,900 unique shipments of citrus nursery stock. Among those shipments, the time since insecticide treatment for *D. citri* ranged from approximately 2 weeks to more than 47 months. The linear mixed-effects model showed a non-significant effect of nursery type ($\chi^2 = 2.14$, df = 1, $P = 0.1435$), with a mean (± SE) residence time at chain store garden centers of 120.47 (± 162.54) days versus 301.54 (± 264.43) days for independent retail nurseries. The fraction residing longer than 90 days also did not vary between nursery types ($\chi^2 = 0.194$, df = 1, $P = 0.6599$) – approximately 45% (200/443) of garden center trees versus 58% (867/1489) of trees at independent nurseries. However, there was a significant difference in the fraction of trees with more than one year since treatment ($\chi^2 = 17.819$, df = 1, $P < 0.0001$), with just 5% (22/443) at garden centers versus 43% (640/1489) at independent nurseries (Fig. 2).

Imidacloprid residues were estimated for a total of 569 citrus trees, all from unique shipments. In particular, we investigated the extent to which plants at retail sites contained residues at minimum levels required to prevent the establishment of *D. citri* nymphs (i.e. 220 ppb, Setamou et al., 2010). There was a significant effect of time since treatment on imidacloprid residues ($\chi^2 = 6.406$, df = 1, $P = 0.0114$),

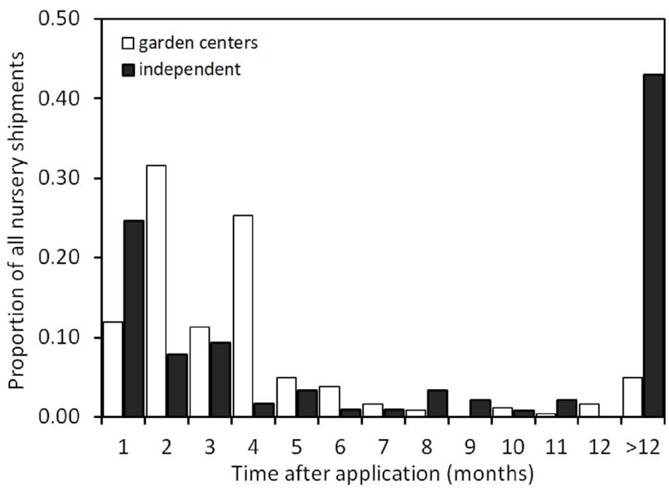

Fig. 2. Frequency histogram of the 443 total containerized citrus trees inspected at chain store garden centers and 1,489 at independent nurseries as a function of the time since insecticide application.

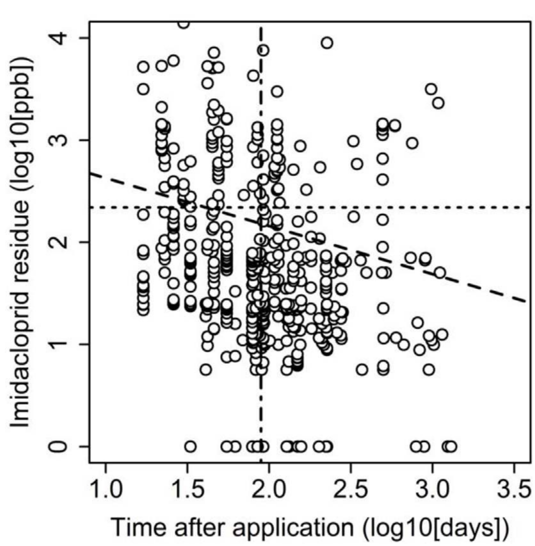

Fig. 3. Imidacloprid residues in containerized citrus trees at retail sites in Southern California. The dashed line denotes the fitted effect of time since treatment, the dotted line is the concentration target required to prevent the establishment of *D. citri* nymphs on trees, and the vertical dashed-dot line denotes the regulatory post-application time limit (i.e. 90 days on a log10 scale).

with a decline in residues over the gradient in time since treatment (Fig. 3). Overall, there were relatively low levels and substantial variability in imidacloprid residues in the nursery trees. For example, slightly less than 90% (279/312) of trees treated within the last 90 days had residues below 220 ppb (2.34 on a $\log_{10}$-scale) and more than 90% (232/257) of trees treated more than 90 days previously had residues below 220 ppb.

3.3. Field experiment of effects on insecticide residues and D. citri dynamics

The analysis of imidacloprid concentration showed significant effects of irrigation level, citrus species, and time since application, and all two-way interactions involving time (Table 1). All other interactions were non-significant and were dropped during model simplification. After peaking at 4 weeks, imidacloprid concentrations declined strongly (Fig. 4). By 16 weeks post application, no trees had detectable imidacloprid residues. At earlier timepoints, there were notable differences among the treatment combinations. In particular, residues in lemon trees were approximately half those in navel orange trees during the

Table 1
Test statistics for a linear mixed-effects model on imidacloprid concentration ($\log_{10}$[ppb +1]) and a generalized linear mixed-effects model on the fraction of samples with concentrations greater than 220 ppb between soil mix, citrus species, watering levels, and time since pesticide application.

Source	Concentration			Fraction > 220 ppb		
	χ^2	*df*	*P*	χ^2	*df*	*P*
Soil mix	0.048	1	0.8270	0.762	1	0.3826
Time	21616.5	7	< 0.0001	110.11	6	< 0.0001
Species	64.441	1	< 0.0001	26.936	1	< 0.0001
Water	16.601	2	0.0002	2.835	2	0.0922
Soil mix*Time	17.763	7	0.0131	–[a]	–	–
Species*Time	175.25	7	< 0.0001	11.154	4	0.0248
Water*Time	53.532	14	0.0001	–	–	–

[a] Term not included in the final model.

first month (Fig. 4a), residues in the severe overwatering treatment were lower for the first 2 months compared to replacement or overwatering treatments (Fig. 4b), and residues in the 30% sand mix treatment were slightly lower than in the 10% sand mix treatment for the first month, before converging after that (Fig. 4c). The fraction of trees with residues above the target threshold of 220 ppb showed similar results. The final model included significant effects of time since application, citrus species, a marginal effect of irrigation level, a non-significant effect of soil mix, and a significant interaction between citrus species and time since application (Table 1). By 12 weeks post treatment, less than 50% of trees, of which approximately 2/3 were orange trees, had concentrations above the 220 ppb threshold (Fig. 5). This fraction declined to zero by week16. Though not significant, when imidacloprid residues were averaged over the entire study, approximately 39% of samples from severely overwatered (480% ET) trees had concentrations above the threshold, compared to more than 43% for the replacement and overwatered treatments.

Overall, *D. citri* nymphs or eggs were detected on just 2% of trees censused, and were most prevalent at the beginning of the study (early-July), whereas adults were detected on 8% of trees, and were most prevalent during the later half of the census period (October and November; Fig. 6a). None of the trees were infested by *D. citri* for more than three successive censuses. Results were similar between the two analyses of *D. citri* presence. In the final model for *D. citri* juvenile stages, there were significant effects of citrus species, time since application, and a watering level by time interaction – all other effects were not significant (Table 2). In the final model for *D. citri* adults, there were significant effects of species, watering level, time since application, a marginally significant effect of insecticide treatment, and a non-significant effect of soil mix (Table 2).

Adults were 25% more likely to be present on control trees compared to insecticide-treated trees, whereas juvenile presence was more similar between the treatments (Table 3).

Juvenile stages were detected nearly 3 times more often on lemon compared to orange trees, and lemon trees were 40% more likely to have adults than were orange trees. Finally, higher watering levels increased the likelihood of adult presence, but had little effect on the presence of juvenile stages. An interaction between watering level and soil mix was also apparent in the analysis of adult *D. citri* presence, with replacement and overwatering treatments having similar prevalence between soil mixes, whereas the severe watering treatment had 3-fold greater presence in the 30% sand mix treatment compared to the 10% sand mix treatment (Fig. 6b).

Finally, the three metrics of tree status and condition (flush stage, tree height, and trunk diameter) showed significant effects of citrus species (Pillai's trace = 0.312, df = 1, $P < 0.0001$) and soil mix (Pillai's trace = 0.032, df = 1, $P = 0.0423$), but watering level was not significant (Pillai's trace = 0.012, df = 1, $P = 0.399$). All interactions between variables were dropped during model simplification. Overall,

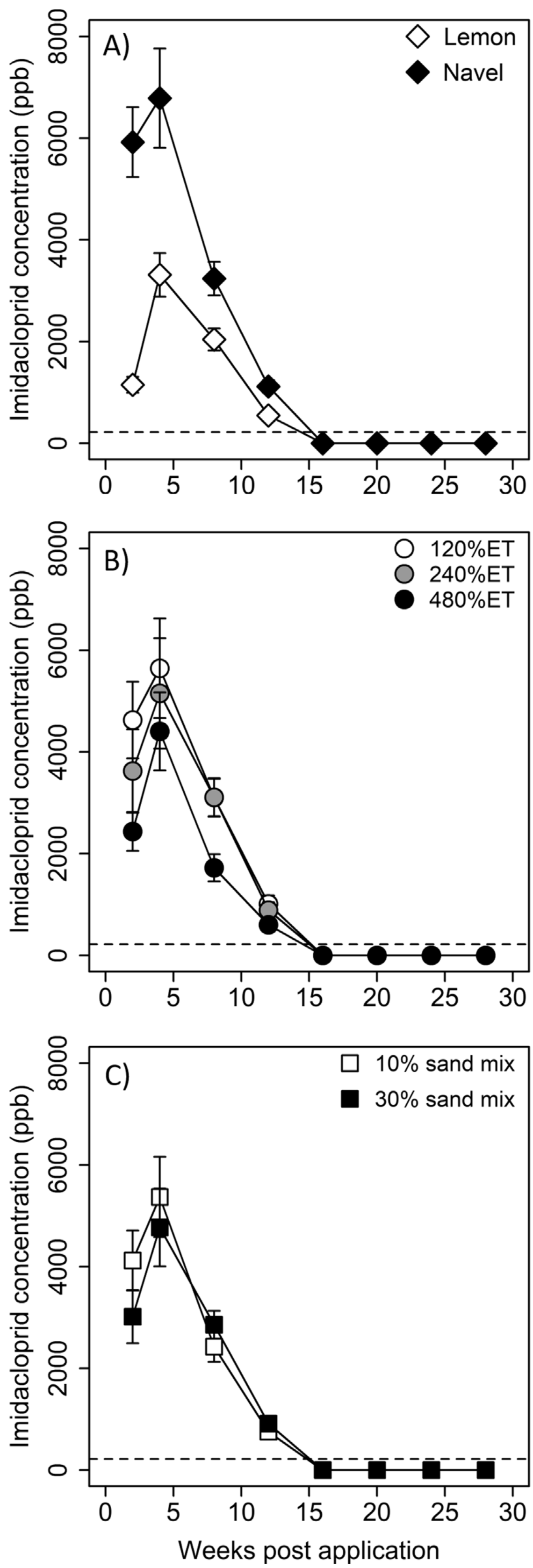

Fig. 4. Mean imidacloprid concentration (± SE; on an untransformed scale) over time since application between A) citrus species, B) watering levels, and C) soil mix. The dashed line is the concentration target required to prevent the establishment of *D. citri* nymphs on trees.

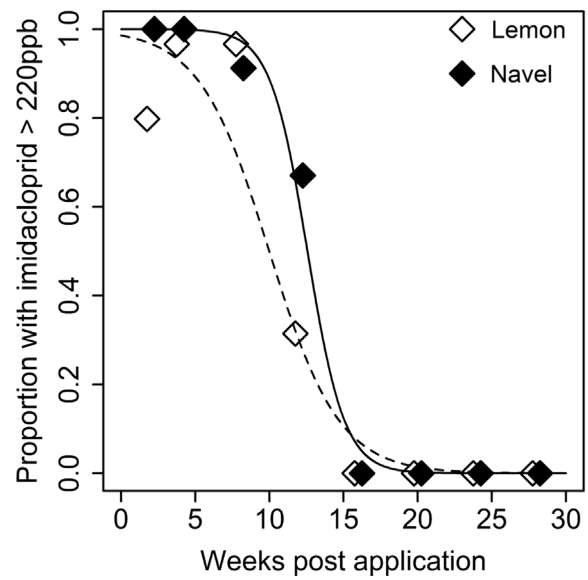

Fig. 5. Proportion of imidacloprid-treated lemon versus navel orange trees with concentrations above 220 ppb over time since application. Solid and dashed lines denote model fit to navel and lemon samples, respectively. Points are offset slightly for clarity.

lemon tree growth was more vigorous than that of the navel orange trees, and the lemon trees had younger mean flush categories (Table 4). In addition, the 10% sand mix encouraged more growth, particularly with respect to tree height.

4. Discussion

Diaphorina citri has proven difficult to suppress sufficiently to prevent disease spread in areas where it has become widespread (Belasque et al., 2010; Grafton-Cardell et al., 2013). Moreover, it has proven capable of efficiently dispersing substantial distances in association with the unregulated movement of its citrus host plants (French et al., 2001; Halbert et al., 2000). In California, regulations were put in place to limit the role that movement of nursery stock might play as a pathway for further *D. citri* invasion. We evaluated the effectiveness and implementation of those regulatory policies, specifically the duration of time containerized citrus was likely to reside at retail sites relative to the duration of time that mandated insecticide treatments adequately protect against *D. citri* establishment on plants, as well as several factors that could contribute to a more rapid decline in residues.

Data from the CDFA and our independent surveys at retail outlets in California showed that many trees were resident at nurseries well past the 90-day certification period, while others were infested with live *D. citri* when trees were still within the 90-day certification period. The purpose of mandated systemic insecticide treatments imposed on production nurseries shipping containerized citrus from within a quarantined area are to safeguard against the establishment of *D. citri* on trees awaiting sale at retail outlets. Our survey showed that imidacloprid was used almost exclusively by the nursery industry to satisfy the mandate. In this, and in an earlier study (Byrne et al., 2016), imidacloprid has been shown to be taken up quickly within containerized citrus, further supporting our recommendation (Byrne et al., 2016) that the minimum 30-day post-treatment shipping restriction from production facilities to retail outlets outside of quarantine be shortened to at least 14 days. Shortening the lag time between the treatment and shipping dates would maximize the protective effect of the treatments after the plants had shipped to retail outlets where additional treatments are not required.

Perhaps of most concern was the detection of live *D. citri* on trees still within the 90-day certification window. In our survey of imidacloprid titers within trees at retail outlets, we confirmed that during this

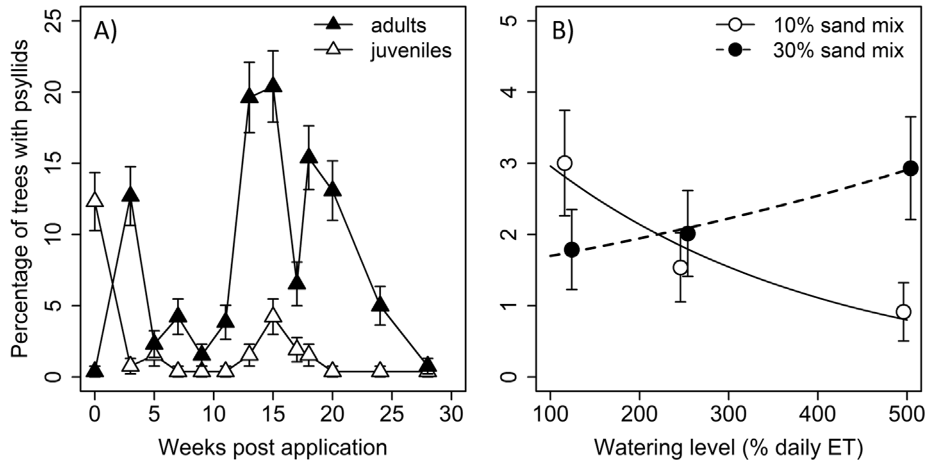

Fig. 6. Mean (±SE) percent of trees censused with A) *D. citri* adults versus juvenile stages present over time since insecticide application, and B) *D. citri* adult presence between 10% sand mix and 30% sand mix over a gradient in overwatering severity.

Table 2
Test statistics and significance values for separate generalized linear mixed-effects models of the effects of insecticide treatment, citrus species, watering level, soil mix, and time on the presence of *D. citri* nymphs and eggs or *D. citri* adults.

Source	Nymphs and eggs			Adults		
	x^2	*df*	*P*	x^2	*df*	*P*
Treatment	0.799	1	0.3715	3.318	1	0.0685
Species	15.545	1	< 0.0001	10.015	1	0.0016
Water	0.473	1	0.4916	4.026	1	0.0448
Soil mix	0.660	1	0.4165	2.374	1	0.1234
Time	95.850	12	< 0.0001	142.457	12	< 0.0001
Water*soil mix	8.056	1	0.0045	–[a]	–	–

[a] Term not included in final model.

Table 4
Mean (±SE) tree response (flush category, change in height, change in trunk diameter) between citrus species and soil mix. Response means followed by different consecutive letters denote significant differences between treatments.

Response	Species		Soil mix	
	Lemon	Orange	10% sand	30% sand
Flush category	2.771(0.028)[a]	2.974(0.038)[b]	2.840(0.034)[j]	2.908(0.034)[j]
Height (cm)	7.442(0.348)[d]	5.062(0.282)[e]	6.671(0.329)[l]	5.794(0.334)[m]
Diameter (cm)	0.141(0.005)[g]	0.076(0.004)[h]	0.103(0.005)[o]	0.113(0.006)[p]

time there was also a significant proportion of trees in which systemic imidacloprid residues required to preclude *D. citri* nymphal survival (Setamou et al., 2010) were below threshold. In fact, the survey showed that a proportion of trees with titers well below the 220 ppb minimum threshold were present as early as 20 days after treatment. Although poor application of insecticide could be a contributing factor, results from our outdoor potted tree study suggest that the problem of low residues in nursery trees, particularly at longer periods post treatment, is most likely due to conditions at the retail outlets that promote a more rapid than expected decline in residues. In our study, 90% of our experimental trees attained the desired levels within 2 weeks of treatment. Of the three experimental conditions evaluated as potential impediments to the uptake and retention of imidacloprid, significant effects of citrus species and watering levels were confirmed. The choice of soil mix was found to have minimal impact, with residues within trees in both categories evaluated (10% sand mix versus 30% sand mix) persisting for 12 weeks. However, the interaction between irrigation and soil mix on the infestation level of trees is an interesting finding, and suggests that physiological effects of severe overwatering on plants grown in the 30% sand mix could play a role in increasing the attractiveness of trees to *D. citri*. We did not detect any significant interaction between watering level and soil mix on the growth patterns of the trees, so the nature of the interaction as it relates to *D. citri* incidence warrants further investigation.

Citrus species had the most dramatic effect on the uptake and total amount of imidacloprid in trees. During the initial 12 weeks of the assessment period, the concentrations of imidacloprid were consistently higher in samples from navel orange trees, with the greatest difference occurring at 2 weeks when residues in orange trees were double those in lemons. The lower residues in lemon trees, especially during the first month following treatment, could be problematic for this species because they resulted in a significantly higher proportion of lemon trees with titers of imidacloprid below the 220 ppb minimum target threshold. However, despite the dramatic differences in titers between species, the levels of insecticide in both oranges and lemons were below the detection level of the ELISA after 12 weeks. The reason for the variability in insecticide titers between species is likely related to the disparate flushing patterns of orange and lemon trees. Although shoot growth occurs in most types of citrus in several well-defined flushes, typically 2 per year under Southern California climate conditions, new shoots emerge year-round in lemons (Spiegel-Roy and Goldschmidt,

Table 3
Mean (±SE) proportion of trees with either *D. citri* eggs or nymphs, or *D. citri* adults present between insecticide treatments, citrus species, or watering levels.

Response	Treatment		Species		Watering level[a]		
	Control	Imidacloprid	Lemon	Orange	120%	240%	480%
Egg or nymph	0.023 (0.005)	0.018 (0.003)	0.030 (0.004)	0.011 (0.003)	0.024 (0.004)	0.018 (0.004)	0.019 (0.004)
Adult	0.094 (0.009)	0.075 (0.005)	0.097 (0.007)	0.066 (0.006)	0.070 (0.008)	0.080 (0.008)	0.094 (0.009)

[a] As a percentage of average daily evapotranspiration.

1996). In avocados, imidacloprid concentrations are generally lower in young, newly developing flush (Byrne et al., 2012), due to the slower establishment of the insecticide in the rapidly expanding leaves, and the diluting effect that the extra tree growth has on measureable imidacloprid levels. We have observed a similar disparity in concentrations in citrus leaves of different ages (FJB, *unpublished data*). In this study, the lemon trees had a significantly younger mean flush rating and greater overall growth (both in terms of trunk diameter and tree height) than the orange trees. Young flush is also highly attractive to *D. citri* for oviposition and it is critical for nymphal development (Catling, 1970). In Southern California, *D. citri* population densities are driven by the seasonal flushing patterns of citrus trees. Thus, the constantly flushing pattern of lemon trees, combined with the lower imidacloprid titers, predispose this species to a higher risk for *D. citri* colonization, and this was borne out in the census data generated during the outdoor potted tree study. Although *D. citri* densities in the mature citrus surrounding the study site were low, due to both a predominance of navel and Valencia orange varieties which were not in flush (and therefore not supportive of high population densities), and *D. citri* control resulting from pesticide treatments, adult and immature *D. citri* stages were detected more often on the young lemon trees compared with the oranges. In addition, the imidacloprid treatments were more effective at preventing *D. citri* colonization of oranges, presumably because of the capacity of imidacloprid to establish at much higher titers in this species at a time when, according to our censuses, immature stages were more prevalent within the system.

Watering amount also had a significant impact on the concentrations of imidacloprid throughout the assessment period, with levels in trees that were severely overwatered (480% ET) consistently below those in trees that were under the replacement (120% ET) and overwatered (240% ET) regimens. This effect was accentuated in the lemon trees. But, as with the species effect, residues in all trees had declined below detectable levels after 12 weeks regardless of watering amount. This retention period is shorter than that recently determined for imidacloprid in containerized trees that were treated with a similar rate of insecticide and maintained under a replacement water regimen (Byrne et al., 2016). The results from both studies highlight the importance of eliminating unnecessary delays in shipment from production facilities once the trees have been treated. Moreover, the data suggest that day-to-day practices at retail sites, especially over-watering, can compromise the efficacy of *D. citri* treatments that were previously applied.

The expectation that prior treatments applied at production nurseries would suffice until plants were purchased by homeowners or landscapers needs to be reevaluated. There is no doubt that systemic treatments are a vital component in protecting containerized citrus awaiting sale at retail outlets. However, the limitations of these treatments to provide long-term protection against *D. citri* infestation must be emphasized. With the effects of the systemic treatments declining within 12 weeks, and the likelihood that not all trees will achieve the minimum threshold, the long residency times at the retail outlets increase the risk that trees could become infested with *D. citri*. Furthermore, the increasing number of HLB detections within Southern California has raised concerns that if trees within a retail outlet become infested with infectious *D. citri*, the trees and *D. citri* would then serve as a source of inoculum for the disease when planted in a residential area, a scenario not unlike that which occurred in Florida (Halbert and Manjunath, 2004; Halbert et al., 2012). For these reasons, the prolonged residency times at retail is a major issue that needs to be addressed if *D. citri* and HLB are to be dealt with effectively in California. One possible remedy to this problem would be to increase the application rate of the systemic insecticide in an effort to extend the efficacy of treatments beyond 90 days. However, given the almost complete reliance of production nurseries on imidacloprid as the systemic neonicotinoid treatment, a rate increase would require better harmonization of label rates on commercially available imidacloprid formulations to ensure that all citrus trees were treated in a uniform manner. With several generic formulations of imidacloprid currently listed on the treatment schedule for use by production nurseries, the label rate on the name brand product (Admire Pro®) is the only one on the current list that would permit application rates higher than those evaluated in this study. Using higher treatment rates would likely face strong opposition from environmental groups over concerns about pollinator safety. Furthermore, an increasing number of the larger retail companies in the U.S. now require suppliers to label plants that have been treated with neonicotinoids, over their concerns about the role that these insecticides may have in contributing to honeybee declines (Gillam, 2014). Regulators may be reluctant to support rate increases in the face of such strong opposition.

Retreating nursery stock at retail outlets that has surpassed the 90 day certification period is not an option that regulators could easily implement given the health and safety issues likely to ensue from using pesticides in public arenas, not to mention the logistical challenge of coordinating treatments at facilities where trees with different expiration dates were for sale. Most retail nurseries do not have the capacity to retreat the trees, and it is unlikely that they would accept the additional expense of retreating trees at their outlets. Thus, insecticide treatments at the production facilities will remain the sole means of protecting trees within retail. New systemic insecticides that have recently been introduced to the market may be potential additions to the quarantine treatment protocols, but they must be fully evaluated before they can replace or augment the current usage of the neonicotinoids. Another option to consider is that all citrus at retail outlets be confined within covered and enclosed areas such as a small shade house. Many retail outlets already place citrus trees together and this might be an easily implemented method to protect the trees, particularly at the larger facilities.

5. Conclusions

The California citrus nursery industry is facing major obstacles in its efforts to minimize the role of containerized citrus shipments in the spread of *D. citri*. Chief among these obstacles are delays in the timing of shipments from production facilities to retail outlets after mandated insecticide treatments have been completed, extended residency times of trees at retail outlets that exceed the current 90-day certification period conferred on treated trees, and biotic and abiotic factors that limit the longterm retention of systemic insecticides within trees while awaiting sale. To prevent the passive transport of *D. citri* on containerized citrus, unnecessary delays in shipping of trees after they have been treated should be avoided in order to extend the relative protective period of trees once they leave a production facility and await sale at the retail outlets. Trees treated systemically with imidacloprid could be shipped within 2 weeks of treatment, when peak residues have established within trees. To further prolong the efficacy of treatments, overwatering of trees at retail outlets should be avoided to maintain higher titers of imidacloprid, and to keep residues above critical thresholds required for *D. citri* control, particularly in citrus species that are prone to multiple flushing periods within a season. Finally, citrus stock should be protected at retail locations by placing in an enclosed shade house, and if trees have not been sold within 90 days, they should be destroyed, a measure that may require retailers to limit their inventory.

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Appendix 10. CA Risk-based Survey Model

CA Risk-based Survey Model

USDA

NC STATE UNIVERSITY

UC DAVIS UNIVERSITY OF CALIFORNIA

Weiqi Luo & Drew Posny

Neil McRoberts

Support: CRB #5300-199, 5300-212

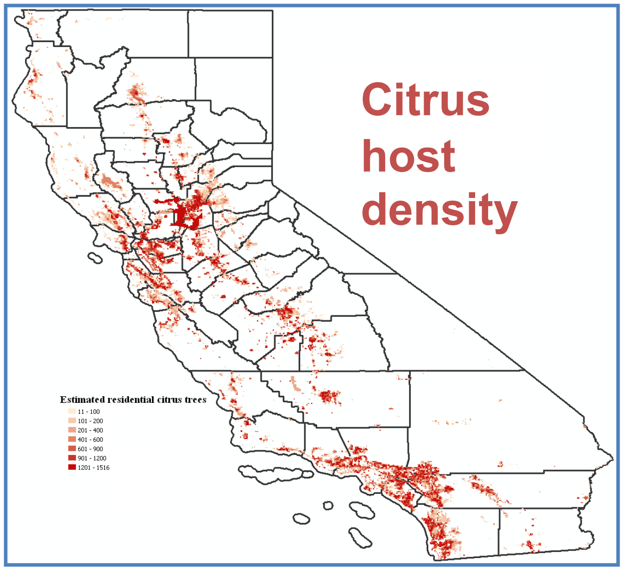
Revisit Risk-based survey (RBS) model framework (Residential & Commercial)

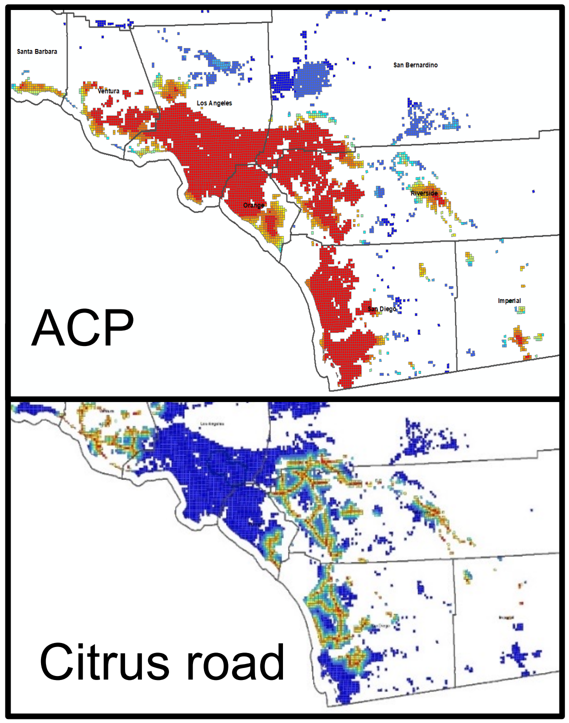
Maps are developed on 1-square mile grids (STRs)

Citrus Host Population Maps *F(Host)*

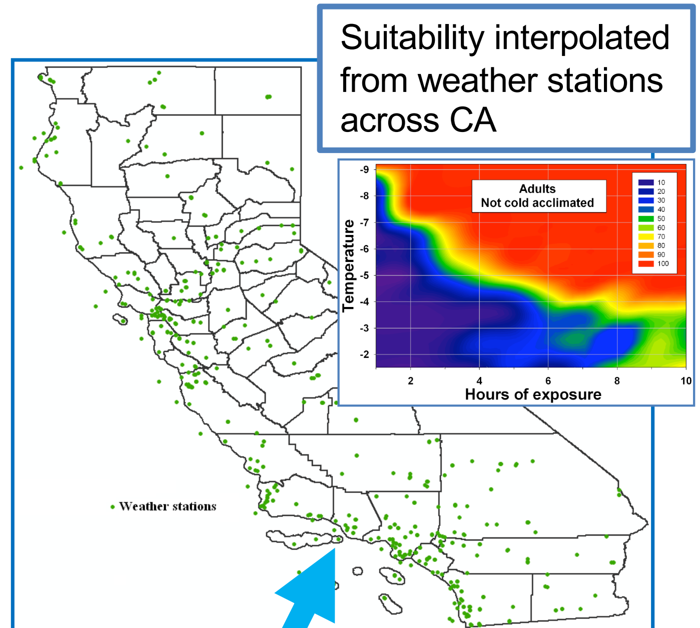
Dynamic *Spatial* Risk Models for each factor *(Risk$_i$)*

Climate Suitability *G(Suitability)*





Etc.….



$$Risk = F(Host) * \sum_i w_i Risk_i * G(Suitability)$$

Residential Citrus Host Map Development

$$Risk = \boxed{F(Host)} * \sum_i w_i Risk_i * G(Suitability)$$

GIS Data Filtering

Non-suitable landscape

Inaccessible areas for survey

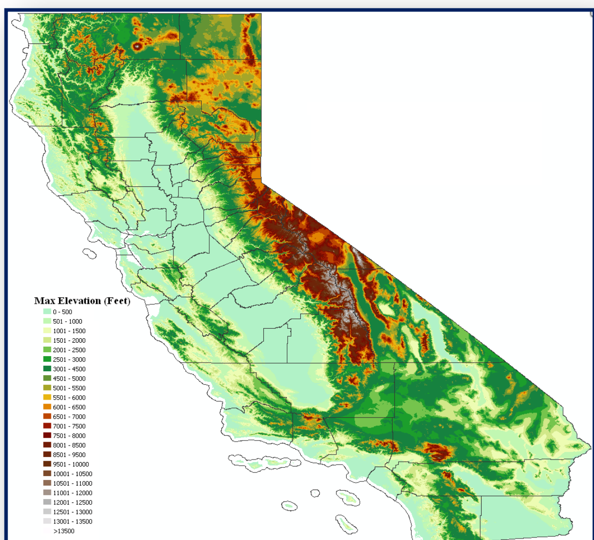
Land cover classification

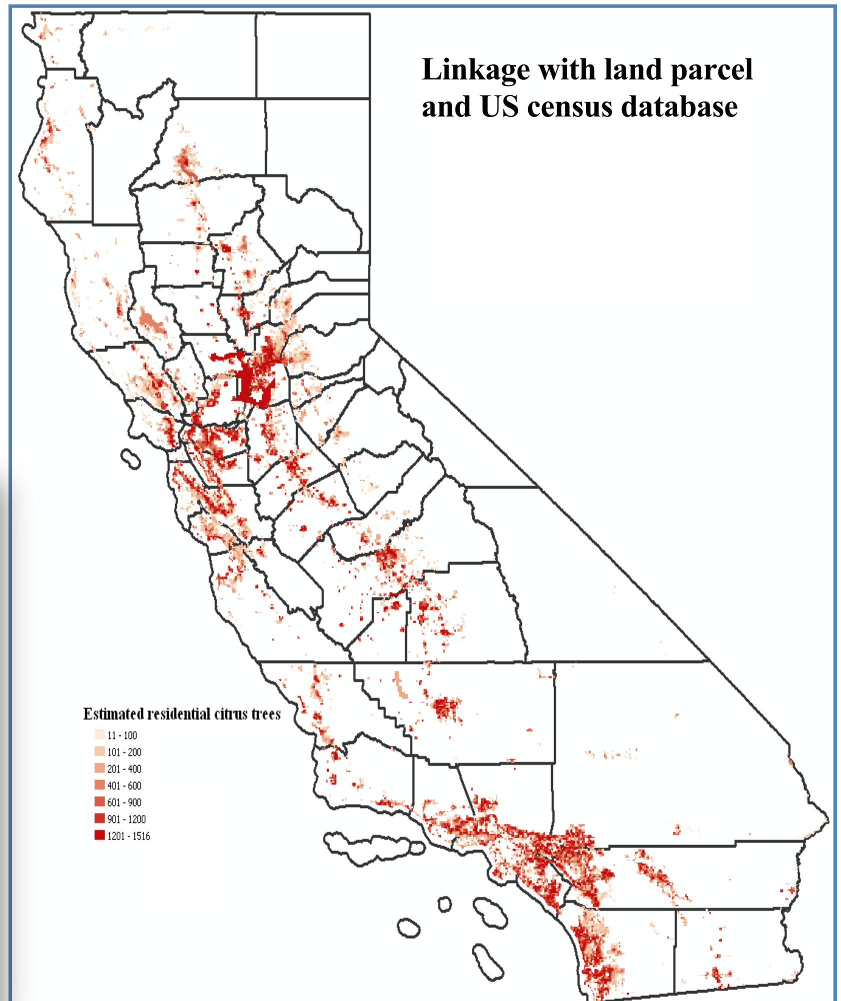
Geography/Topography

Human population relationship

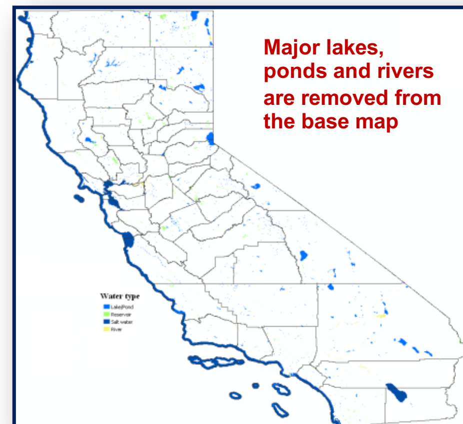
Conversion to Appropriate Grid

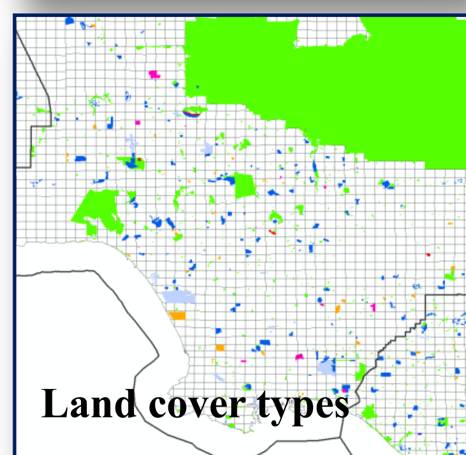
Consistency of data across regions





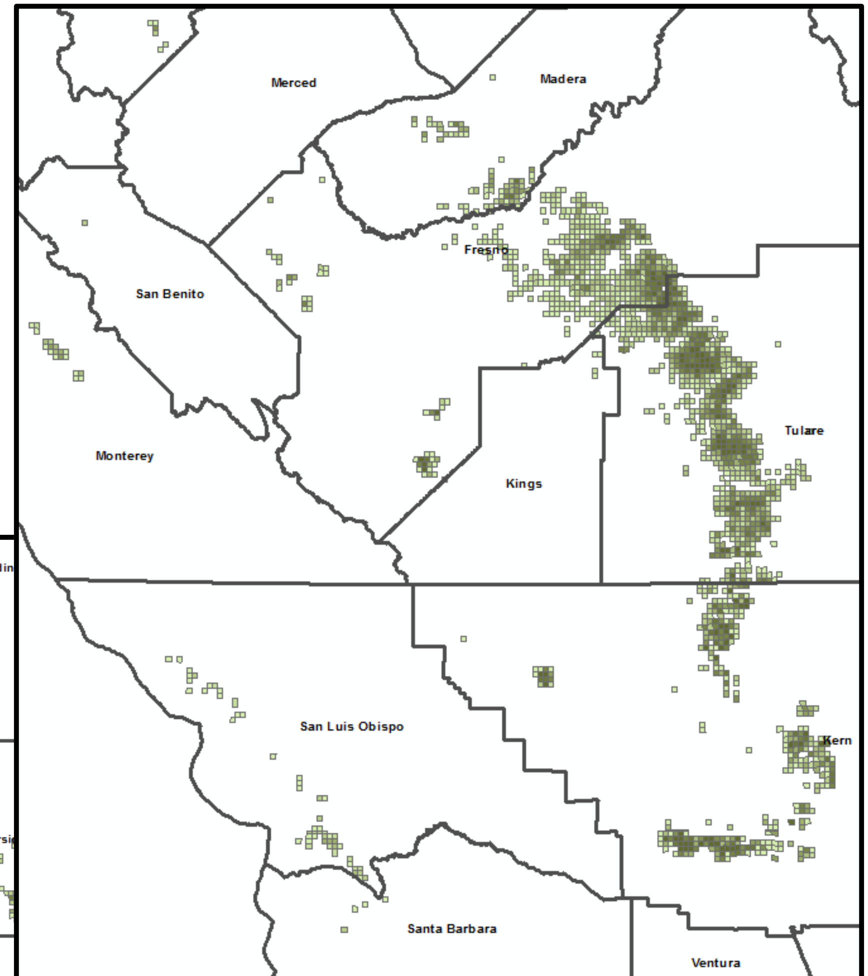
GIS Data Filtering

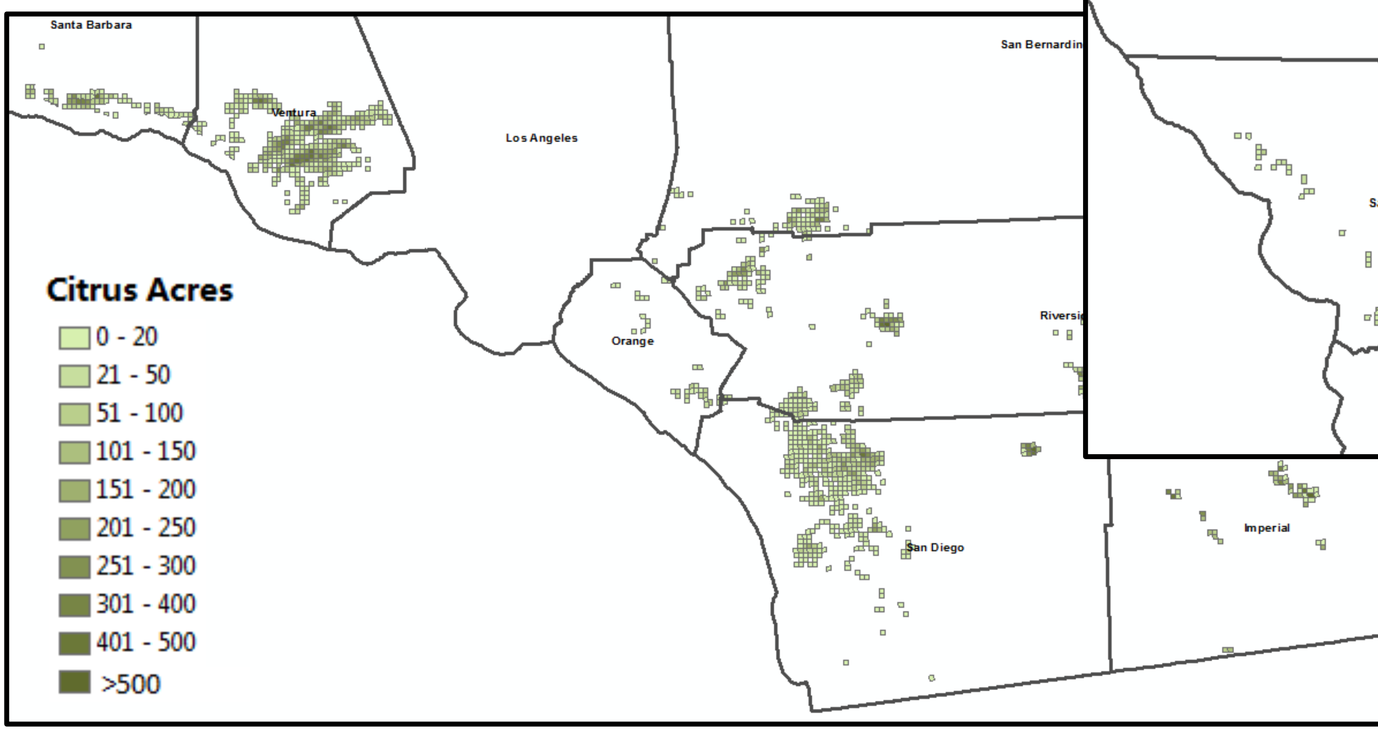




Commercial Citrus Host Map Development

- Summarize commercial citrus block acreage by species/type into STR grid
- Updates for new plantation or abandoned citrus (if any)





Dynamic Risk Models (Residential)

$$Risk = F(Host) * \sum_i w_i Risk_i * G(Suitability)$$

Dynamic Risk Factor Models

- **Census travel** — Introduction risk from HLB+ countries
- **ACP density** — ACP distribution
- **HLB Location** — CLas+ ACP/tree distribution
- **Citrus Road** — Citrus production related transport corridors
- **Plant Nurseries**, **Big box Store**, **Packing house** — Potential risk of ACP spread from nearby commercial nursery, juice processing facilities or packing house
- **Farm market** — Potential disease spread without strict regulation
- **Military installation, Native American Land & Organic citrus**

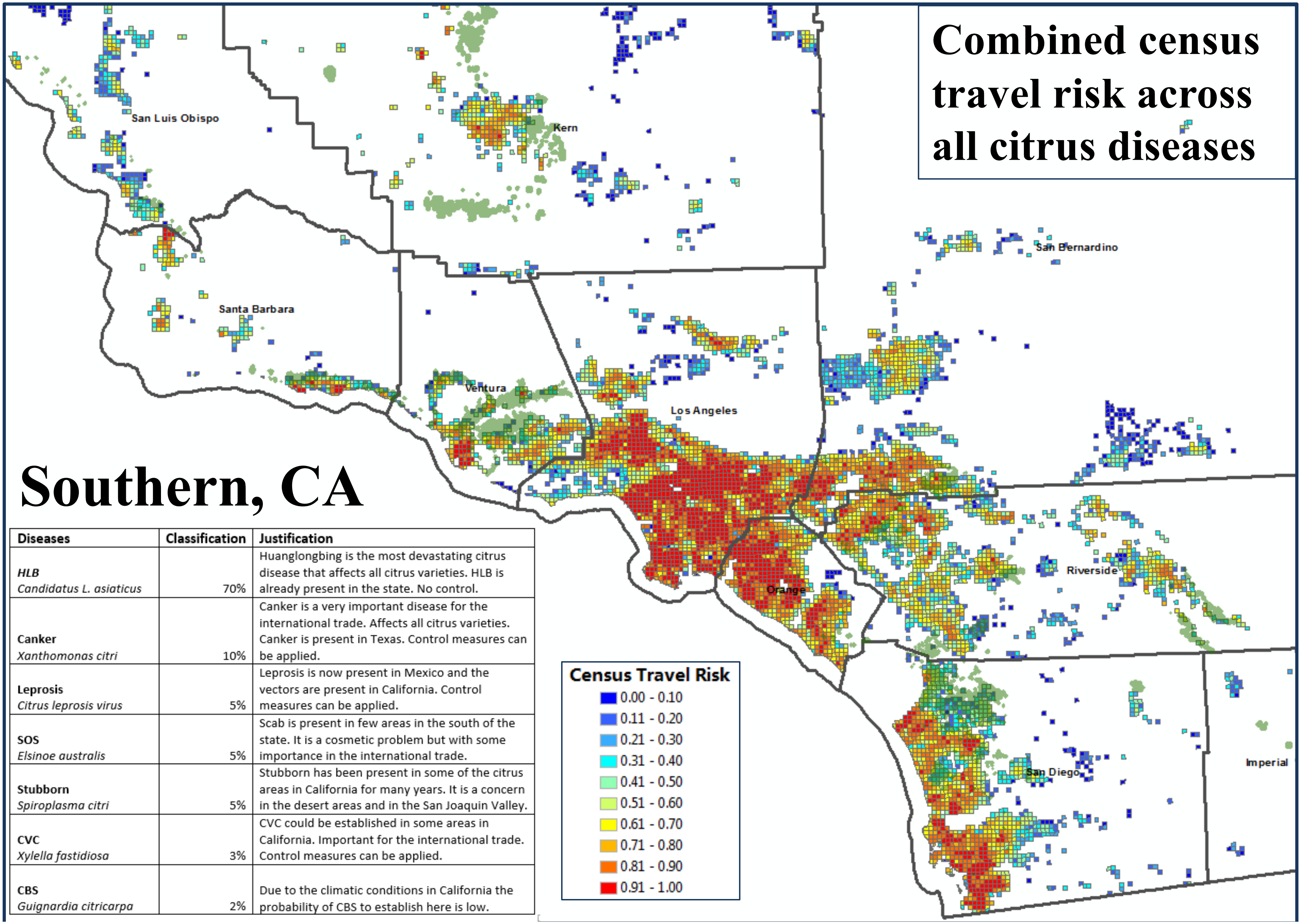
Dynamic Risk Models (Commercial)

$$Risk = F(Host) * \sum_i w_i Risk_i * G(Suitability)$$

Dynamic Risk Factor Models

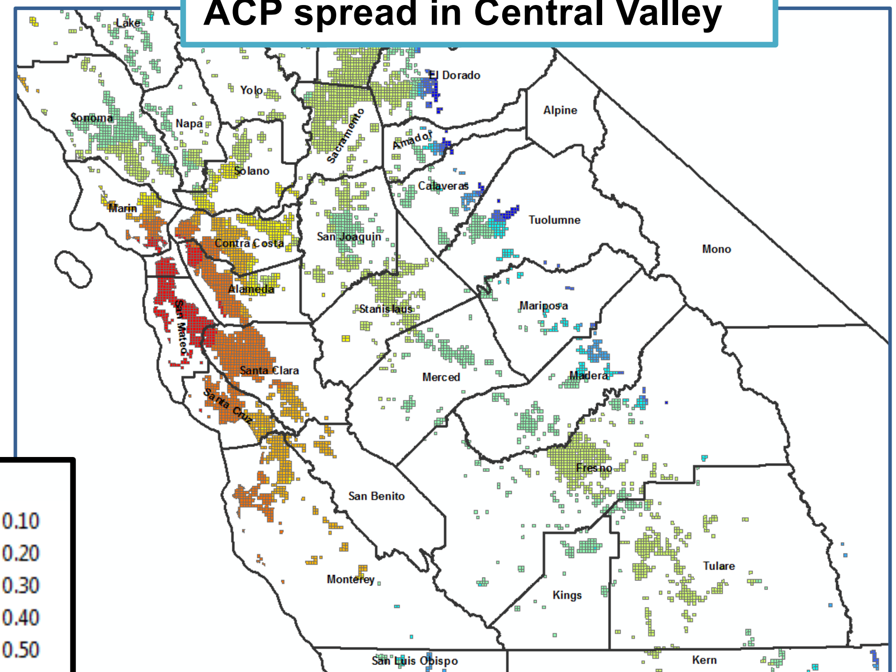
- **Census travel** — **Introduction risk across all citrus diseases**
  (HLB, Canker, Leprosis, SOS, Stubborn, CVC, CBS)
- **ACP density** — **ACP distribution**
- **HLB Location** — **CLas+ ACP/tree distribution**
- **Citrus Road** — **Citrus production related transport corridors**
- **Plant Nurseries**, **Big box Store**, **Packing house** — **Potential risk of ACP spread from nearby commercial nursery, juice processing facilities or packing house**
- **Residential exposure** — **Potential human-mediated spread**

Commercial RBS (Census travel as example)



Diseases	Classification	Justification
HLB *Candidatus L. asiaticus*	70%	Huanglongbing is the most devastating citrus disease that affects all citrus varieties. HLB is already present in the state. No control.
Canker *Xanthomonas citri*	10%	Canker is a very important disease for the international trade. Affects all citrus varieties. Canker is present in Texas. Control measures can be applied.
Leprosis *Citrus leprosis virus*	5%	Leprosis is now present in Mexico and the vectors are present in California. Control measures can be applied.
SOS *Elsinoe australis*	5%	Scab is present in few areas in the south of the state. It is a cosmetic problem but with some importance in the international trade.
Stubborn *Spiroplasma citri*	5%	Stubborn has been present in some of the citrus areas in California for many years. It is a concern in the desert areas and in the San Joaquin Valley.
CVC *Xylella fastidiosa*	3%	CVC could be established in some areas in California. Important for the international trade. Control measures can be applied.
CBS *Guignardia citricarpa*	2%	Due to the climatic conditions in California the probability of CBS to establish here is low.

Climate Suitability (Residential & Commercial)

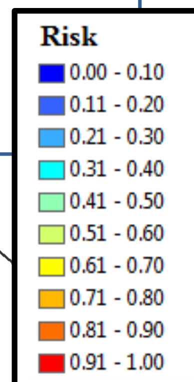


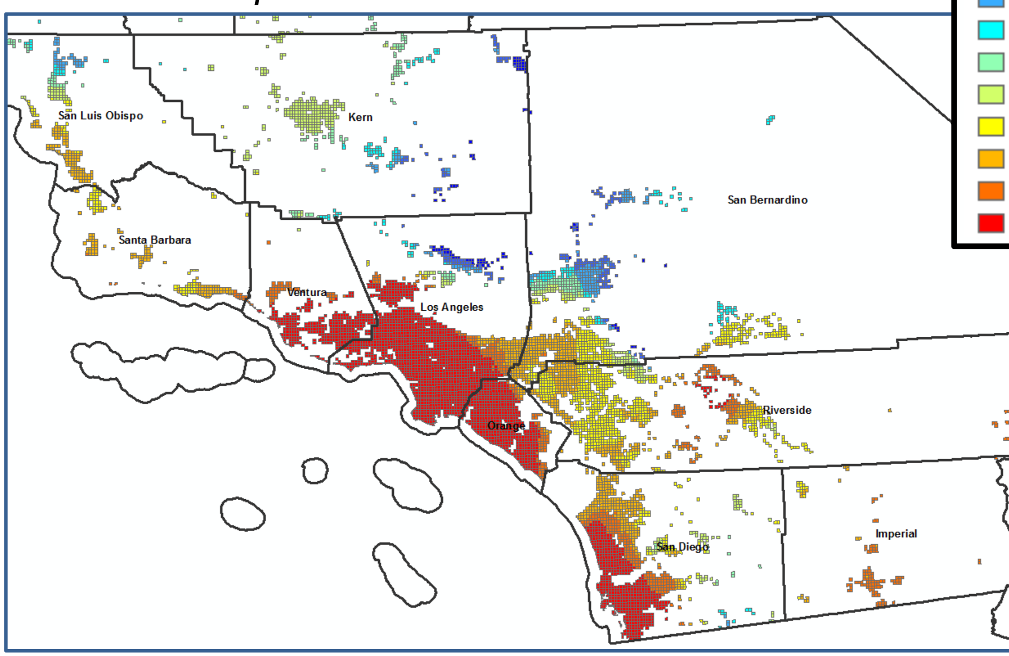
Cold weather slows down the ACP spread in Central Valley

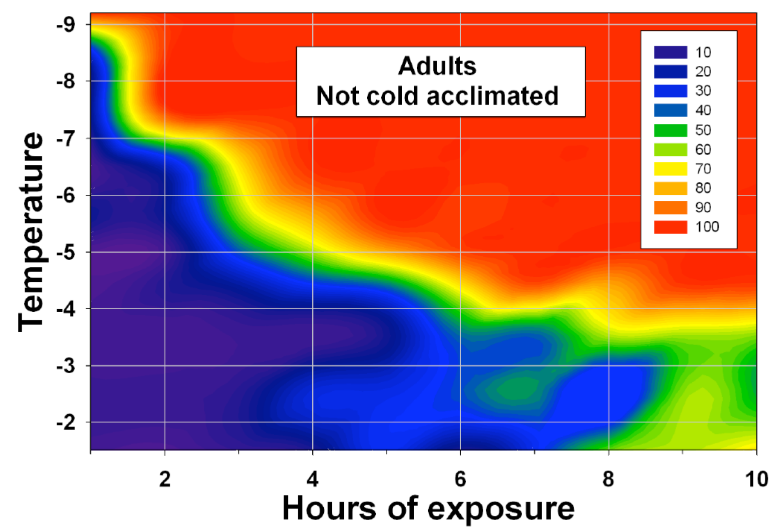
$$Risk = F(Host) * \sum_i w_i Risk_i * G(Suitability)$$

Estimate mitigating effects of weather on ACP survival/spread

Minimum Temperature







Historical weighting of risk model factors

The weighting of each risk factor will change/refine throughout HLB epidemic

Southern California

Risk factor	2013	2014	2015	2016	2017	2018	2019	2020	2021
Introduction risk (Census travel)	1	1	0.95	0.9	0.75	0.7	0.55	0.5	0.45
ACP density	1	1	0.6	0.85	0.9	0.8	0.85	0.8	0.9
LAS+ locations	1	1	0.85	0.95	0.9	0.95	0.95	1	1
Plant nursery & Big box store	0.5	0.5	0.6	0.6	0.75	0.75	0.55	0.6	0.6
Citrus Road	0.5	0.5	0.5	0.5	0.8	0.8	0.6	0.75	0.75
Packing house		0.25	0.25	0.25	0.9	0.9	0.25	0.4	0.5
Farm market		0.25	0.75	0.75	0.85	0.8	0.8	0.8	0.8
Military and Native American Lands	0.5	0.5	0.5	0.5	0.25	0.1	0.01	0.01	0.05
Organic citrus			0.1	0.1	0.1	0.1	0.1	0.1	0.1

First HLB detections in 2012, risk-based survey methodology design began in 2013.
The importance of each risk factor is estimated by their actual predictive power in detecting the new HLB locations

Thanks for your time and attention!

Special thanks to CDFA, DATOC & CRB for background data and support!