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“Fall in love with the process and the results will come!” - Eric Thomas
On the Cover: A member of the Gautam lab sprays miticide on a Brevipalpus mite as part of an integrated pest management (IPM) study to determine which miticides work better prior to testing in field trials. The circles on the fruit are to facilitate data collection. Circles keep track of the numbers of mites in each area. The areas beyond the circles are waxed with paraffin, and mites only feed on unwaxed surfaces. For more information about the work on mites currently being done in IPM, see “Stepping in as New UCCE Area Citrus IPM Advisor” by Sandipa Gautam, Ph.D. on page 24.
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Winter 2022 | Volume 13 • Number 1 The Official Publication of The Citrus Research Board

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### CITRUS RESEARCH BOARD MEMBER LIST

**By District 2021-2022**

(Terms Expire September 30)

#### District 1 – Northern California

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<tr>
<th>MEMBER</th>
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<tr>
<td>Andrew Brown</td>
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<td>Henk Griffin</td>
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<td>Ram Uckoo</td>
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<td>Justin Brown, Chairman</td>
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<td>Scott Carlisle</td>
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<td>Greg Galloway</td>
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<td>Justin Huffman</td>
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<td>John Konda, Vice Chairman</td>
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#### District 2 – Southern California – Coastal

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<td>Chris Boisseranc</td>
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<td>John Gless III</td>
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<td>Gabriel Olmos</td>
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#### District 3 – California Desert

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<td>Mark McBroom, Secretary/Treasurer</td>
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#### Public Member

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<td>Melissa Cregan</td>
<td>2022</td>
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NEW GENERATION K-PHITE 7LP
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PLANT FOOD SYSTEMS, INC.—ZELLWOOD, FL., the nation’s premier acidulator of potassium hydroxide introduces to California a unique chemistry in molecular form and efficacy, K-PHITE 7LP Systemic Fungicide Bactericide. Through the development of “Continuous Flow Reactor Manufacturing”, Plant Food Systems, Inc. brings to the citrus industry viable alternatives to disease control and plant health. A registered pesticide, KPHITE 7LP contains unique patented technology and is the product of groundbreaking molecular research regarding the manufacturing processes and development of co-polymeric phosphite molecules which display specific pathogenic activities not duplicated by other phosphites. University researched, field proven.

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♦ Anthracnose
♦ Botryosphaeria dothidea
♦ Fusarium
♦ Hyphoderma sambuci
♦ Phytophthora (soil borne and aerial phases including brown rot)
♦ Pseudomonas syringae
♦ Pythium
♦ Rhizoctonia
♦ Xanthomonas ssp. (including citri)

K-PHITE 7LP is a clear, pH neutral, linear polymer potassium phosphite exhibiting molecular stability and pathogenic activities that common materials do not display.

K-PHITE 7LP contains no sodium or chlorides for safe and compatible applications without rind stain. RE-NEW can be tank mixed with most pesticides, including fungicidal cop-per (maintain pH >6.2).

For more information including research results and scientific publications, contact;
Mark Brady, Western Marketing Manager, Plant Food Systems, Inc. (559) 731-1267
### JANUARY

**12**

**Citrus Pest and Disease Prevention Committee (CPDPC) Meeting.**

For more information, visit [www.cdfa.ca.gov/citruscommittee](http://www.cdfa.ca.gov/citruscommittee)

**26**

**Citrus Research Board (CRB) Meeting.**

For more information, contact the CRB at (559) 738-0246 or visit [www.citrusresearch.org](http://www.citrusresearch.org)

### MARCH

**3**

**California Citrus Mutual (CCM) Citrus Showcase.**

For more information, contact CCM at (559) 592-3790 or visit [www.cacitrusmutual.com](http://www.cacitrusmutual.com)

### APRIL

**13**

**Citrus Pest and Disease Prevention Committee (CPDPC) Meeting.**

For more information, visit [www.cdfa.ca.gov/citruscommittee](http://www.cdfa.ca.gov/citruscommittee)

### MAY

**10**

**Citrus Research Board (CRB) Meeting.**

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The Citrus Research Board (CRB) remains committed to supporting growers by investing in crucial research projects as the new year begins. Research has been our focus for more than 50 years and serves to support the industry in addressing challenges. The CRB’s mission focuses on ensuring a sustainable citrus industry by prioritizing, investing in and promoting sound science. Establishing priorities and recognizing the need for a research-guided sector was a tremendous move by those industry pioneers who came before us. Today, we keep these guiding principles close as we consider new research opportunities to benefit citrus growers and to ensure that California remains competitive within the domestic and global marketplace.

Marcy L. Martin
It is once again time for California citrus producers to cast their ballots for the CRB referendum vote. The California Department of Food and Agriculture (CDFA) will conduct the referendum, and we encourage every eligible California citrus producer to participate. The CDFA will release additional information in the coming months.

Over the past five years, the CRB has worked continuously to advance findings within our four research priorities: vectored diseases, pest management, production and post-harvest technologies, and new varieties.

One of our most significant focuses has been the mitigation of huanglongbing (HLB). An example of this work includes the Bayer Crop Science project, which focuses on discovering, developing and commercializing therapies for HLB. This project allows us to combine citrus industry support with the expertise of a leading agrochemical company that remains committed to developing new compounds for the citrus industry.

Within our pest management priority, we want to ensure that we supply the California citrus industry with scientifically validated tools for eradication and control while minimizing crop damage or economic losses. The U.S. Department of Agriculture (USDA) awarded the CRB $3.4 million to fund a newly-formed California Citrus Research and Field Trials (CRaFT) project that will cost-share with growers interested in implementing additional mitigations for psyllid control within commercial groves. An additional project centers on evaluating neonicotinoid risk, which found imidacloprid was not more toxic than other neonicotinoids and offered no significant risk to pollinators.

Non-vectored pathogens, pre- and post-harvest diseases and food safety have become vital aspects of our research portfolio as we study twig dieback, Septoria spot and packinghouse operations. In collaboration with university research programs, the USDA and the CDFA, these projects support research that will deliver valuable information to the industry. The CRB has two projects focused on the realm of food safety—a project developing surrogate options for Listeria monocytogenes and a separate project determining validation methods for controlling cross-contamination during washing. By addressing these vital food security issues, we can decide if current practices meet regulatory guidelines and where the industry can further advance in strategy.

California supplants other citrus production regions in fruit quality, and our research continues within breeding and varietal development. Through our newly-developed partnership with the USDA-Agricultural Research Service, we will be establishing a varietal evaluation program designed to assess high-quality citrus selections for California growers. These efforts will serve to expand public breeding efforts and bring USDA resources and expertise to California.

As research projects conclude, we want to ensure that this crucial information gets back into the growers’ groves. Our revamped website was launched in 2021 and features easy access to research articles with convenient access to research and assessment reports. Similar information also is dispersed quarterly through Citrograph magazine.

We welcomed the opportunity to gather in person again by hosting our first California Citrus Conference in three years. We had a fantastic group of growers in attendance as industry leaders shared essential updates, and several of our CRB-funded researchers provided updates on their projects. Moving forward, we are preparing to host our Grower Seminar Series this summer and the International Research Conference on Huanglongbing (IRCHLB) this fall. We make sure that our research partners’ work is accessible to the industry to utilize.

We hold fiscal responsibility as one of our primary directives when crafting and maintaining our budget. The CRB publishes its financial position for grower review in the summer issue of Citrograph. During FY2020/21, we funded 35 research projects for an investment of $6.5 million as more than 60 percent of our budget is allocated to research. In addition, our Board voted to maintain the reduced assessment rate of $0.03/carton for FY2021/22.

In closing, the CRB feels fortunate to have received the industry’s support for more than five decades and looks forward to continually improving upon the scientific underpinnings that allow the California citrus industry to thrive.

Marcy L. Martin is the president of the Citrus Research Board, based in Visalia, California. She also is the executive editor of Citrograph. For more information, please contact marcy@citrusresearch.org
Three new members joined the Citrus Research Board (CRB) following nomination meetings on September 16. Justin Huffmon of Bee Sweet Citrus, Inc. and Jason Reynolds of Booth Ranches LLC filled the open positions from District 1. Gabriel Olmos of Ventura Pacific Company joined the Board representing District 2. Current Board members re-elected for additional terms ending in 2024 include Justin Brown of D Bar J Orchards, Scott Carlisle of Villa Park Orchards Association, Greg Galloway of Sierra Crest Agriculture, John Konda of Konda Farms and Etienne Rabe of RF Citrus Ranches, LLC.

The Board unanimously voted to grant an additional term for the 2020-21 slate of officers. Brown will continue in his role as chairman. He has served the CRB since 2009 as chair or vice-chair of numerous committees. Konda will continue serving as vice-chairman. The Tulare County citrus grower has served on the Board since 2012, participating on nearly every CRB committee. A member of the Board since 2010, Mark McBroom will continue his term as Secretary/Treasurer into the next fiscal year.
"We are pleased to welcome a new group of members, as well as welcome back those reelected for an additional term," said CRB President Marcy L. Martin. "This group will bring a diverse set of experiences to address the complex needs of the California citrus industry."

Huffmon is serving his first term on the Board representing District 1. He has been working for Bee Sweet Citrus since 2007 after graduating from Fresno State University in 2006 with a Bachelor of Science degree in Plant Science. He began his career in grower relations and transitioned to pest control advisor (PCA). For the past several years, he has led the Pest Control Department as the PCA Manager. In addition, he serves on the Asian citrus psyllid/huanglongbing (HLB) San Joaquin Valley Task Force.

Huffmon comes from a long line of farmers in his family and is looking forward to contributing to future generations of farmers.

"I appreciate the opportunity to serve on the Citrus Research Board," Huffmon said. "I have been blessed to work with Bee Sweet Citrus for many years alongside a variety of growers who have allowed me to stay up-to-date on the latest issues facing the industry. I look forward to taking that knowledge and collaborating with other citrus industry leaders to find innovative and realistic solutions to some of our biggest challenges—ACP/HLB, mealybugs, red scale, thrips, water, export issues and more. New ideas in conjunction with scientific evidence are key to a thriving citrus industry, and I look forward to being part of a team that is dedicated to this work."

Reynolds joined the Board to fill the vacant seat in District 1. His term began on October 1, 2021, and will expire on September 30, 2022. Reynolds is the research agronomist at Booth Ranches, LLC. Driven to provide the best quality produce, he strives to find the best methods for farming citrus. Reynolds is a licensed PCA, qualified applicator and certified crop advisor specializing in nitrogen management. As a research agronomist, he is tasked with overseeing crop nutrition, cultural practices, in-field quality reporting, crop predictive analytics and all field trials. His goal is to increase production while developing sustainable practices that will allow Booth Ranches to grow high-quality citrus for generations to come.

"I am looking forward to bringing the viewpoint of the next generation of citrus farmers to the Board as we face new challenges in the industry," said Reynolds.

Olmos was born and raised in the Central Valley. He grew up surrounded by agriculture, learning early on the importance of this industry to the nation and the world. Olmos graduated from Fresno State University with a Bachelor of Science in Business Management and attained an MBA from USC Marshall School of Business. He spent 12 years with the Wonderful Companies, spanning various operations and general management roles. Olmos led global operations and North American/Latin American sales for Sinclair Systems International for five years. He currently serves as president of Ventura Pacific Company, a grower-owned, 75-year-old lemon packing and distribution cooperative based in Oxnard, California. Olmos was a member of the inaugural class of the Produce Marketing Association Emerging Leaders program.

Olmos added, "I want to help the California citrus industry thrive as it faces margin pressures, water scarcity and HLB."

Please join us in congratulating our executive leadership and welcoming the newly-elected Board members.

Caitlin Stanton is the communications coordinator with the Citrus Research Board and also serves as the editorial assistant on Citrograph. For more information, please contact caitlin@citrusresearch.org
The citrus industry gathered once again as the California Citrus Conference returned on October 6, 2021, in Visalia, California. Nearly 400 attendees descended upon the Wyndham Hotel to listen to notable industry updates and gain insight from a slate of Citrus Research Board (CRB)-funded researchers. The one-day conference provided a much-needed opportunity for essential citrus research to be shared through several talks and more than 30 scientific posters.

Casey Creamer of California Citrus Mutual (CCM) opened the conference with an encouraging outlook for the industry. As legislative, environmental and market challenges persist, CCM remains committed to investing in critical issues within the citrus industry. Pest and disease issues persist, labor availability is scarce and insufficient water allowances bring challenging obstacles that must be overcome. Creamer added that the
success of the California citrus industry relies on growers, packers, researchers and agencies collectively working toward achieving the desired results.

The Citrus Pest and Disease Prevention Division (CPDPD) is working tirelessly to treat Asian citrus psyllid (ACP) and prevent huanglongbing (HLB), while also attending to additional concerns. Victoria Hornbaker, director of the CPDPD, shared that the division remains focused on controlling the spread of HLB in California with preventive measures and quarantine enforcement. Hornbaker added the division is committed to improving data analysis and management and looks forward to continuing their partnership with the CRB, University of California researchers and the U.S. Department of Agriculture.

Attendees at the Conference were fortunate to receive insight from Rick Dantzler of Florida’s Citrus Research and Development Foundation (CRDF). “There is no rivalry [between California and Florida] when it comes to dealing with HLB,” said Dantzler. The CRB and the CRDF continue to work collaboratively on a long-term project with Bayer Crop Science to develop HLB mitigations. Dantzler continued with an overview of the CRDF’s research priorities including culturing ‘Candidatus Liberibacter asiaticus’ (CLas, the bacteria associated with HLB), citrus response to infection, disease epidemiology, citrus breeding for resistance and viral/bacterial-vector mediation of citrus resistance to disease.

“If there is anything that we can do from Florida that helps you not have to be burdened by [HLB], we will help you in any way we can,” added Dantzler.

New Assistant Cooperative Extension Area Citrus IPM Advisor Sandipa Gautam, Ph.D., spoke to attendees about citrus integrated pest management (IPM) in the San Joaquin Valley. Gautam provided an overview of key citrus pests in the San Joaquin Valley, highlighting best practices for monitoring and management. Growers in the region shared that most of their challenges stem from citrus thrips and California red scale, with some growers expressing concerns with citricola scale and mites. Citrus thrips populations are increasing due to dry winters, higher temperatures and insecticide resistance, added Gautam. As part of her extension programming, Gautam will host various field days at the Lindcove Research and Extension Center. Additional information can be found on www.lrec.ucanr.edu.

Danelle Seymour, Ph.D., provided insight on the work of the Core Breeding Program at the University of California, Riverside. As it can take more than 15 years to develop a new variety, the Core Program is establishing methods to reduce intervals between steps. The Program’s current efforts to streamline include confirming the parentage of hybrids and automating phenotype collection to facilitate trait discovery in scion and rootstock material.
The development of CRISPR-based methods to genetically modify ACP can lead to tools and systems for blockage of HLB transmission and population control, said Omar Akbari, Ph.D. The University of California, San Diego researcher has been establishing a transgenesis method that will allow researchers to develop a Cas9-mediated gene drive for ACP population suppression. This will allow further understanding of the biology of ACP and could be used to eradicate populations of the pest.

Jim Adaskaveg, Ph.D., covered several post-harvest diseases that have a direct impact on the California citrus industry. Diseases of concern include Septoria spot, Phytophthora brown rot and sweet orange scab. Adaskaveg also touched on the California Navel and Valencia Exports to Korea program, which has been updated to reduce the number of fungicide applications needed and maintain phytosanitary shipments to Korea. Pre-mixtures of post-harvest fungicides are becoming more common because of their benefits including improved fruit quality, reduced decay, extension of the shipping season, better management of fungicide resistance and greater flexibility for the packinghouse.

“This is what separates us from the rest of the citrus world market; we can provide the highest quality fruit to our export markets,” said Adaskaveg.

Between sessions, attendees had the opportunity to visit with researchers during scientific poster touring. Researchers from around the country shared applicable studies ranging from breeding strategies and trial results to real-time impact assessments of ACP and HLB management. More than 30 posters were on display, providing growers and researchers alike the opportunity to discuss some of the citrus industry’s most innovative research.

To begin the afternoon session, Sean Cutler, Ph.D., of the University of California, Riverside, spoke on accelerating citrus breeding through the use of genetic engineering and its influence on new variety development. Using a graft transmissible flowering signal (FT), the research team can chemically induce flowering on juvenile citrus, which expedites breeding. This technology should allow for a one-year “generation time,” which will result in increased introgression during the breeding process. The flowering technology currently is being used in several citrus breeding studies and will continue to be developed in the coming years.
As ACP control continues to be at the forefront of citrus industry concerns, Monique Rivera, Ph.D., outlined tips for scouting the troublesome pest, as well as strategies for organic management. Through several trials, Rivera's project found issues with generational overlap and a lack of control over eggs, which will be a focus in the future. Organic management of ACP is challenged by limited available materials and short-term residual activity, said Rivera. A possible solution is quick, repeated applications, making sure adequate water volumes are used for foliar sprays to ensure complete coverage. An additional aspect of Rivera's work includes a scouting project to determine the percentage of 'Candidatus Liberibacter asiaticus' (CLas)-positive ACP in commercial groves to better understand their presence over time. Of the thousands of psyllids tested, no CLas-positive detections have been recorded.

To conclude the research talks, Hailing Jin, Ph.D., of the University of California, Riverside, provided an overview of a dual function, stable antimicrobial peptide that inhibits CLas. Identified from HLB-tolerant finger lime varieties, Jin has isolated a stable antimicrobial peptide (SAMP) that can directly kill Liberibacter crescens, a bacteria similar to the HLB-causing CLas. SAMP is dual purpose and can act in a bactericidal function or to induce the plant immune system. This technology is safe and shedding new light on the fight against HLB.

CRB Chief Research Scientist Melinda Klein, Ph.D., concluded the conference with an overview of the upcoming California-focused Citrus Research and Field Trials (CA-CRaFT). The program will work with growers to test and demonstrate different ACP management strategies for California commercial citrus growers in those areas with endemic ACP populations. Applications are scheduled for release in late 2021 and will be monitored for several years.

For those who missed the conference, select talks are available to view on www.citrusresearch.org. While the International Research Conference on Huanglongbing (IRCHLB) will take the place of the California Citrus Conference in 2022, stay tuned for more upcoming events and opportunities to learn from “the best of the best” in citrus research.

Caitlin Stanton is the communications coordinator with the Citrus Research Board and also serves as the editorial assistant on Citrograph. For more information, please contact caitlin@citrusresearch.org
Members of the Citrus Research Board (CRB) gathered to discuss important industry topics and reaffirm support for vital research projects at the CRB Annual Meeting on September 21, 2021. A total of $3,416,210 in research funding was approved by the Board for FY21/22.

“We appreciated the ability to gather together as the citrus industry once again confirmed its support for the crucial research projects being funded within our priority areas,” said CRB President Marcy L. Martin. Board members and guests traveled from around the state to the Lindcove Research and Extension Center in Exeter, California, to attend the meeting. Joining the Board members were representatives from California Citrus Mutual, the California Citrus Quality Council (CCQC) and the California Department of Food and Agriculture (CDFA).
During the meeting, each committee chair provided an update on their group’s activities. They shared an impressive slate of research projects and informed attendees about current developments at the BSL-3P Laboratory, the Citrus Clonal Protection Program and the Data Analysis and Tactical Operations Center. Notably, the Board moved forward with the establishment of an additional Core Program focused on developing an innovative pre- and post-harvest disease management program for diseases caused by fungi and non-fastidious bacteria. This program will be led by Jim Adaskaveg, Ph.D., at the University of California, Riverside. The new projects approved during this meeting are listed below. Additional information on these projects will be highlighted in the Summer 2022 issue of Citrograph.

The Finance Committee provided an update on the CRB’s financial position. The CRB remains committed to ensuring that fiscal responsibility is one of the organization’s key principles.

In addition, Jim Cranney of the CCQC spoke to the group, who agreed to continue the CRB and the CCQC’s commitment to food safety research by funding a sponsorship of the Center for Produce Safety.

The Board voted to maintain the current assessment rate of $0.03/carton, with a total estimate of $6,000,000. More than 66 percent of this funding will be spent on research, and the bulk of that funding will focus on Asian citrus psyllids and huanglongbing. This rate has been sent to the CDFA Secretary for approval.

Retiring Board members Keith Watkins and Alan Washburn were recognized for their service as they concluded their tenure with the CRB. Keith Watkins of Bee Sweet Citrus served on the Board for six years from 2015-21 and chaired several committees including the Communications Committee and the BSL-3P Science Screening/Review Committee. Alan Washburn of Washburn and Sons, Inc. dedicated 19 years to the CRB as a member of the Board from 2002-21. He was a member of numerous research committees, including vice chair of both the Joint Agency Biological Control Task Force and Non-Vectored Diseases Research Committee (now known as the Production and Post-harvest Technology Research Committee). We wish to thank these retiring Board members for their many years of dedicated service to California citrus growers.

Executing vital research projects, maintaining an appropriate budget and communicating these activities to the growers remain the primary focus as the CRB mission is carried out.

CRB staff members are looking forward to working with the Board and its various committees to continue the mission of the organization as we strive to maintain a sustainable citrus industry established on sound science.

Caitlin Stanton is the communications coordinator with the Citrus Research Board and also serves as the editorial assistant on Citrograph. For more information, please contact caitlin@citrusresearch.org

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<tr>
<th>PROJECT NUMBER</th>
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<td>5300-214</td>
<td>Field evaluation of a novel virus-like RNA as an expression vector for HLB &amp; Tristeza management</td>
<td>Kiran Gadhave</td>
<td>University of California, Riverside</td>
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<td>5400-165</td>
<td>Disease development, epidemiology, and management of Colletotrichum dieback and Alternaria rot</td>
<td>Themis Michailides</td>
<td>University of California, Davis</td>
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<td>5400-166</td>
<td>A survey of wood rots in California desert citrus</td>
<td>Glenn Wright</td>
<td>University of Arizona</td>
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<td>Pre- and post-harvest citrus disease management – Core Project</td>
<td>Jim Adaskaveg</td>
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<td>Developing molecular markers to identify citrus rootstocks in the field</td>
<td>Greg Douhan</td>
<td>University of California, Cooperative Extension</td>
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<td>5400-168</td>
<td>Identification of a surrogate for use in citrus specific validation studies</td>
<td>Amanda Lathrop</td>
<td>Cal Poly, San Luis Obispo</td>
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<td>Developing and testing an IPM approach for managing root rats in citrus</td>
<td>Roger Baldwin</td>
<td>University of California, Davis</td>
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<td>5500-226*</td>
<td>California adapted <em>Tamarixia radiata</em> to support ACP biological control</td>
<td>Raju Pandey</td>
<td>Citrus Research Board</td>
<td>$129,100</td>
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*Funded by Citrus Pest and Disease Prevention Program
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The California citrus industry, with state and federal support, has spent significant time, effort and resources protecting commercial citrus production from huanglongbing (HLB) since 2008 when the first Asian citrus psyllid (ACP) was found in San Diego. By following established pest management guidelines – a shift to screenhouse production of nursery stock and mandatory removal of infected trees, the state has been able to slow disease spread in southern California and limit ACP establishment to areas south of the San Joaquin Valley.

Current efforts to limit the spread and presence of ACP in California are focused on an extensive statewide monitoring program, biocontrol agent releases in residential areas and the use of coordinated insecticide treatments (CPDPP 2019). Unfortunately, southern California has a range of environmental and societal conditions that result in continued ACP persistence. Review of trap finds from commercial groves across various southern California counties (Figure 1) demonstrates that psyllid control remains an ongoing need in commercial production settings.

With the increasing number of HLB-positive trees detected in residential areas, especially those near commercial production, additional mitigations may be needed to help slow the spread of ACP (and potentially HLB) into commercial groves. To address this threat, a statewide program called California Focused Citrus Research and Field Trials (CA-CRaFT) is being initiated to evaluate and demonstrate the effectiveness of various preventive and threshold-based ACP treatments in commercial citrus orchards across differing geographic regions in the state.

Through a grant from the United States Department of Agriculture–Animal and Plant Health Inspection Service Huanglongbing Multi-agency Coordination (HLB MAC) Group, funds will be made available to offset partial costs incurred for the additional ACP treatments adopted by those growers accepted into the program. Program participants will allow access for psyllid monitoring in groves. Results from this project will be shared at the regional, state and national levels to help inform citrus producers how to better manage ACP populations.

ACP mitigations that are being considered at the program start include the use of more permanent barriers (trap crops, windbreaks and fencing), as well as more temporary border treatments (psyllid repellents, ant control measures and biocontrol releases).

Growers will be able to submit multiple applications. Grove selection will be based on factors including the type of psyllid control treatments of interest.
to the grower, grove type, grove size and age, the level of psyllid pressure found in the grove, geographic region, historic psyllid density in the grove and proximity to psyllid risk factors (such as residential areas and transportation corridors). Both organic and conventional groves will be included in this project. Growers will be asked if they are willing to host regional field days. This project is not expected to replace adherence to current UC IPM guidelines or regional spray guidelines.

Growers and industry members interested in learning more about the program should look for updates in Citrus Research Board (CRB) eNewsletters and on the CRB website. Growers interested in obtaining more information should e-mail the CRB directly at CRAFT@citrusresearch.org for more details.

References

Melinda Klein, Ph.D., is the chief research scientist at the Citrus Research Board in Visalia, California, where she also serves as scientific editor of Citrograph. For additional information, contact melinda@citrusresearch.org

Figure 1. Percent of traps containing at least one Asian citrus psyllid within the county identified between 2015 and March 2021. Data provided by Data Analysis and Tactical Operations Center (DATOC).
STEPPING IN AS NEW UCCE AREA CITRUS IPM ADVISOR

Sandipa Gautam
This past July, I joined the University of California (UC) Agriculture and Natural Resources as an Assistant UC Cooperative Extension (UCCE) Area Citrus Integrated Pest Management (IPM) Advisor. This position is located at the Lindcove Research and Extension Center (LREC) in Exeter, California. My responsibilities include conducting research, extension and education programs for integrated pest management of insects and mites important to citrus growers in the San Joaquin Valley (SJV).

The overarching goal for this position is to build a state-of-the-art research, extension and education program for integrated management of citrus pests, thereby contributing to improving the economic viability of citrus production in the SJV.

Biggest Challenges and Opportunities

A good pest management program evolves to respond to factors that influence pest pressure – such as changes in weather conditions, introduction of invasive pests, new varieties and resistance to insecticides – and to best utilize the tools and options available for management. The initial biggest challenge for me is understanding the needs of growers and identifying the research gaps. Our understanding of pest damage, sampling, monitoring and recommendations is often based on oranges, which may differ for citrus varieties like mandarins. In terms of priority pests, SJV growers have different needs than growers in other regions of California. While Asian citrus psyllid (ACP) and huanglongbing are a priority for growers in southern California, ACP remains under an area-wide eradication program in the SJV. Citrus thrips and California red scale continue to be the two key pest challenges for growers in the SJV. In 2021, many growers sprayed more than three times to control citrus thrips. Hot and dry weather conditions and insecticide resistance seem to be the main reasons for the citrus thrips problem. My approach is to spend time with growers and Pest Control Advisors (PCAs), identify, understand and prioritize their needs and conduct experiments to fill in those gaps.

Projects

Since 2018, the Citrus Research Board has supported my research through the Core IPM Program. I anticipate continuing this work to profile mite damage, resistance management for citrus thrips and extension and outreach for pests of export significance; however, priorities are based on industry input and may change going forward.

One identified need is management of Delegate® resistance in citrus thrips, which have become increasingly resistant to Delegate in the SJV. Coupled with hot and dry weather
conditions, citrus thrips ranked as the number one pest for SJV growers and PCAs in the Valley. In the coming year, my team is planning to test thrips materials against resistant populations.

Other projects I am working on are using a hydrogel-baiting system for fire ant control in SJV orchards and evaluating the post-harvest systems approach on pests of export significance. Besides these, I am interested in determining what research is needed into non-chemical/biological methods to manage problems that are important to organic growers. For future directions of the research program, I plan to spend time with growers/PCAs to identify research gaps for conventional and organic growers and then design projects to fill in those gaps.

As for extension and outreach, growers/PCAs find interactive field days the most effective means of communication. Given the need for field events on specific pests, my team has successfully organized field events on citrus thrips, citricola scale, and a full-day workshop on California red scale in the first four months I have held this position. We will continue to do field events in the coming years.

Research activities involve the development and integration of sampling and monitoring methods, as well as laboratory and field studies testing biological and chemical compounds as they relate to pest management. Extension activities include reaching out to citrus industry stakeholders to communicate research findings and educating pest control advisors/growers on specific pest issues.

My Background

I conducted my undergraduate studies at the Tribhuvan University, Nepal, and received a Bachelor of Science in Agriculture in 2007. Two big concepts – agricultural food security and integrated pest management – and my passion for solving problems landed me at the Oklahoma State University (OSU) to pursue a Master of Science in Entomology. I remained at OSU for my Ph.D. in Entomology and two years of post-doctoral research training working on various projects focused on improving pest management practices for stored product pests in post-harvest systems. When I first visited California in September 2010 to meet with Spencer Walse’s team, I was awed by the high-value agriculture in California. Little did I know that I would move to California a few years later and contribute to IPM in citrus.

In February 2016, I joined the research group of Beth Grafton-Cardwell, Ph.D., as an assistant research entomologist at the Kearney Agricultural Research and Extension Center. In this position, I led a post-harvest research and extension program that primarily focused on (a) understanding the pest ecology, behavior and damage potential of export concern pests and (b) developing post-harvest treatment strategies that provide quarantine level control for species of export significance. California red scale and Fuller rose beetle (eggs) are a phytosanitary concern for Korea, and bean thrips and mites (Brevipalpus spp., Lorryia formosa, Taronemus bakeri), are of phytosanitary concern to Australia and New Zealand. Our field and laboratory studies on two key mites of export concern, L. formosa and T. bakeri, showed these mites feed on honeydew and sooty molds but not directly on citrus, and, therefore, are a low-risk species. Similarly, bean thrips and Fuller rose beetle do not cause damage to citrus. The regulatory phase-out of methyl bromide has left a burden on California growers to effectively eliminate insects or mites from fruit destined for export. Field treatments do not eliminate these pests from fruit because of the nature of where they are found – overwintering bean thrips in navel oranges, Fuller rose beetle eggs and mites under the sepal – ultimately requiring a post-harvest treatment.

Since 2016, my team at Kearney worked with Walse at the U.S. Department of Agriculture-Agricultural Research Service in Parlier, California, to develop post-harvest treatments for citrus pests of export significance. Phosphine fumigation schedules for bean thrips also reduce mites on citrus. In collaboration with Walse’s team, my group developed fogging with pyrethrins and a post-harvest fumigation protocol for ethyl formate (Vapormate™) for controlling ACP in bulk citrus, which also helps control other export concern species. My team continues to work with fumigants and on combined events in the post-harvest system (ethyl formate, phosphine and storage at the transit temperature), searching for a silver bullet that controls all export concern pests.

In addition to research and extension, I worked with Jim Cranney, president of the California Citrus Quality Council, to provide feedback on pest risk analysis documents for import or market access to countries like Vietnam and Thailand.

I am dedicated to being of service to the California citrus growers. Please reach out to me at (559) 592-2408 ext. 1156, email me at sangautam@ucanr.edu or drop by for an office visit at the LREC with any research problems you would like to see addressed and/or pest problems that would benefit from outreach education programs. Send me an email to be included in the listerv for LREC events, and follow @sandipa_gautam (UCANR Citrus IPM) on twitter.

Together, we can learn from experiences and push forward toward a better future.

Sandipa Gautam, Ph.D., is an assistant UCCE IPM advisor at Lindcove Research and Extension Center. For additional information, please contact sangautam@ucanr.edu
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Until recently, huanglongbing (HLB) only had been detected in residential trees in Los Angeles, Orange, Riverside and San Bernardino counties. However, in early August, the California Department of Food and Agriculture (CDFA) confirmed two HLB-positive citrus trees on a residential property in Oceanside. These findings marked the first detection of the disease in San Diego County.
communications plan to guide message consistency, clarity and timeliness during such situations. Since the newly expanded quarantine in San Diego County applies to both residents and commercial operations, awareness and action among all audiences is critical to stopping the spread of HLB.

Educating San Diego Homeowners

Following the initial San Diego County HLB detections, there have been several subsequent finds in the Oceanside area. Thus, it was critical to inform and educate local homeowners about the threat that the Asian citrus psyllid (ACP) – the pest that can carry the disease – and HLB impose on their community’s citrus and how they can help prevent it.

In collaboration with the San Diego County Agricultural Commissioner’s (CAC) office, the CPDPP outreach team also secured a combination of earned media and opinion-editorial pieces in key San Diego County publications and broadcast outlets, including Times of San Diego, The San Diego Union-Tribune, KPBS, NBC 7 San Diego and others, resulting in 48 stories and more than 1.6 million estimated impressions. Each piece of coverage illustrated the importance of homeowners doing their part to protect California citrus by:

- reporting HLB signs or symptoms to the free CDFA pest hotline at 800-491-1899;
- not moving citrus plants, foliage or fruit in or out of the area;
- cooperating with agricultural officials; and
- ensuring proper care of their citrus trees or removing unwanted trees.

To reach residents through their preferred languages, the CPDPP outreach team worked with the San Diego CAC office to identify homeowner-focused informational materials for translation into Arabic and Tagalog to complement existing materials available in English, Chinese, Spanish and Vietnamese.

CDFA staff removed the HLB-positive trees in Oceanside to prevent the fatal citrus tree disease from spreading to neighboring citrus.

This concerning milestone triggered a 68-square-mile HLB quarantine expansion, resulting in operational and regulatory changes for the area. As with any new development in the fight against HLB, a clear and concise plan of action is pertinent to ensure that homeowners, the citrus industry and stakeholders are informed and prepared for the challenge. The Citrus Pest and Disease Prevention Program (CPDPP) moved swiftly to implement its issues management and crisis management plans to guide message consistency, clarity and timeliness during such situations. Since the newly expanded quarantine in San Diego County applies to both residents and commercial operations, awareness and action among all audiences is critical to stopping the spread of HLB.

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Engaging Elected Officials

To ensure elected officials in the newly expanded HLB quarantine area (covering portions of Oceanside, Carlsbad and Vista) were aware of the presence of the disease and the activities taking place, the outreach team established regular communication with key officials. Through one-on-one conversations and virtual deskside briefings with city councilmembers and staff, the program ensured that local leaders were aware and supportive of the program’s on-the-ground activities.

Beyond the cities within the HLB quarantine zone, digital communications were shared with all county and city officials within San Diego County to notify them of the recent detections and encourage them to communicate with their constituents about what they can do in the fight against ACP and HLB. Establishing relationships and the CPDPP’s role as the ACP/HLB resource among elected officials throughout San Diego County is a conduit to creating more engaged and informed homeowners.

Keeping the Citrus Industry Informed

In response to the first detection of HLB in San Diego County, the CPDPP’s outreach partner, Nuffer, Smith, Tucker, assisted local Grower Liaison Sandra Zwaal in coordinating a county-wide grower meeting to address HLB regulatory requirements and quarantines, treatment updates and the latest ACP research. The San Diego citrus grower meeting was the program’s first hybrid event – with more than 20 in-person attendees and more than 50 participating virtually.
San Diego HLB Expansion Has Statewide Impacts
More than 2,500 trees have been detected with HLB in California. Whether you live in southern California or the San Joaquin Valley, the recent HLB expansion into San Diego County has statewide impacts for California residents and the citrus industry alike. Now is the time to increase vigilance and follow best practices to protect citrus trees from ACP to prevent further spread of HLB. California’s citrus and the livelihoods that depend on it are at stake.

To ensure that homeowners and industry members are informed with timely and accurate updates on the latest citrus pest and disease developments, the CPDPP outreach team stands ready to execute comprehensive outreach campaigns at a moment’s notice.

Mark McBroom is the vice chair for the Citrus Pest and Disease Prevention Program and outreach subcommittee chairman. For additional information, contact Mark at desertcitrus@aol.com

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The California Citrus Pest and Disease Prevention Program (CPDPP), established nearly a decade ago in response to the threat of huanglongbing (HLB) to California citrus, is composed of a Grower Committee appointed by the California Department of Food and Agriculture (CDFA) Secretary, as well as a dedicated division within the CDFA of 168 people to handle program responsibilities.

The over-arching goal of the CPDPP is to “keep HLB out of commercial citrus groves as long as possible.” This is the guiding principle.

The CPDPP Committee is served via a host of Subcommittees to digest information and make recommendations to the full Committee. This includes the Executive Committee, as well as Operations, Outreach, Finance and Science Subcommittees. The Subcommittees review information and data generated by the program and make recommendations to the full Committee for decisions.

The Science Subcommittee plays an integral role in the functioning of the program. Since all the actions and protocols followed by the program are underpinned by science, a number of important decisions are made at this level for consideration by the full Committee.

The program now administers an annual budget of more than $40 million, about 50 percent of which is paid via grower assessments and the remainder via Federal and State funding. As such, it is crucial that the work being done can be justified both scientifically and economically – getting the best bang for the buck and not just embarking on an exercise based on assumptions or emotions, understanding that resources may become increasingly tight.

Some examples of the important decisions on which the program is now based where the Science Subcommittee had a major role in vetting the information and recommending action by the Committee include the following.

1. **Delimitation boundaries.** The initial boundary around an HLB find was set at 800 meters. In subsequent years, based on more research knowledge, this has been sequentially reduced to 400 meters and now 250 meters. As the area surveyed exponentially reduced from 800 meters down to the current 250 meters, it allows for savings in labor and better allocation of resources without jeopardizing the intent of the program.

2. **Area-wide border treatment.** These are residential treatments around commercial citrus. The area also has been reduced to 250 meters from the original 400 meters. Again, this is a major savings in time and effort without reducing program efficacy.

3. **Risk-based survey.** The ongoing survey evaluates residential regions on various factors and assigns a certain HLB-related risk or weight. Based on this statistical model, specific areas are surveyed to a higher or lesser intensity. There is continual debate at the Science Subcommittee and input regarding this effort and how it can be rendered more efficacious and less laborious.

4. **Ethyl formate registration for treatment of loads emanating from HLB quarantine regions.** Commercial citrus groves that fall within a five-mile radius HLB quarantine must comply with strict regulatory requirements to move the fruit to packinghouses outside of the quarantine. There currently are limited and not very desirable options available to accomplish these regulatory requirements. The California Citrus Quality Council is working with regulators to get ethyl formate registered for post-harvest bulk fruit fumigation of truckloads.

During its history, the CPDPP has been served by a Science Advisory Panel (SAP), comprising some of the leading scientists in the HLB field. This independent group periodically
analyzed the latest science as it relates to program execution. Unfortunately, we did not have this practice continue during recent years. In the meantime, the Science Subcommittee began an in-depth evaluation of CPDPP actions as they relate to southern California residential areas by analyzing effort and effect and how it adds to safeguarding the commercial citrus industry from the HLB threat.

CDFA Secretary Karen Ross has agreed to initiate a new SAP to be convened in the foreseeable future to evaluate all current program activities against the latest science. The SAP will make recommendations to her and the Committee on whether to stay the course or to adjust activities. The work started by the Science Subcommittee on the southern California effort served as a starting point to delve into a full program SAP review.

**Important questions to answer include the following.**

- Using the best science available, evaluate whether the program’s existing strategies/activities are still the most effective for meeting program goals. Evaluate the efficacy of the strategies by region:
  - Southern California
  - Central Coast
  - Central Valley
  - Northern California
- Are the identified strategies in each region the most efficient use of resources?
- How might the strategies be improved in each region to increase efficiency while still being as effective as possible?

The CPDPP, its subcommittees and CDFA staff are dedicated to the goals stated above by working diligently to limit HLB spread to commercial groves.

*Etienne Rabe, Ph.D., is the vice president of horticulture for Wonderful Citrus and serves as a CRB Board Member and the chair of the CPDPP Science and Technology Subcommittee. For more information, contact etienne.rabe@wonderful.com*
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MATING DISRUPTION EASES CALIFORNIA RED SCALE PROBLEMS

Joel Leonard, Beth Grafton-Cardwell, Matt Daugherty and David Headrick
Project Summary

CheckMate® CRS mating disruption¹ was evaluated in 12 commercial citrus orchards in 2016-19. Mating disruption of California red scale (CRS) significantly reduced the number of males that were attracted to trap cards, scale infestation of wood and the percentage of fruit with large numbers of scale. It worked best in large plots when applied before the first male flight and when initial scale populations were not high. Mating disruption will help San Joaquin Valley growers reduce, if not eliminate, insecticide treatments for CRS.

Background Information

There is a long history of integrated pest management for CRS, including parasitoid releases and selective insecticides (Grafton-Cardwell and Stewart 2012). Despite these efforts, the pest status of CRS has increased in the central San Joaquin Valley of California in recent years (Grafton-Cardwell and Douhan 2017). Factors that have contributed to scale problems include:

1. hotter summers and warmer winters increasing the number of CRS generations per season,
2. reduced populations of natural enemies because of increased pesticide use for invasive pests such as Asian citrus psyllid and pests of export importance such as Fuller Rose beetle and
3. loss of efficacy of the insecticide Esteem® because of resistance in CRS after more than 20 years of use.

Mating disruption with synthetic pheromones² is commonly used for lepidopteran pest management but not for other types of insects such as scale pests. In Spain, slow-release mating disruption was effective in reducing CRS for three to four flights a year and reduced the amount of scale-infested fruit (Vacas et al. 2010). In California, there are four to five flights of CRS males per year depending on location and accumulation of heat units. There was uncertainty that a synthetic pheromone could be released in sufficient quantities and over enough generations to fully control CRS. The objective of this study was to evaluate the efficacy of mating disruption for CRS in central California commercial navel and Valencia citrus orchards using the Suterra CheckMate® CRS mesoporous dispenser³ (Photo 1).

What We Did

In all field trials, CheckMate CRS dispensers were deployed in trees at a rate of 180 per acre. In the first two trials, one conducted in 2016 and one in 2017, the plot sizes were 2.5-4 acres. Treated and untreated areas were replicated four times. Half received CheckMate CRS dispensers in May after the first male flight, and half received nothing. Ten additional trials were conducted, five in 2018 and five in 2019. In these trials, half of each 20- or 40-acre citrus orchard received CheckMate CRS dispensers in February or March before the first CRS male flight, and the other half received nothing. Nine of the ten 2018-19 sites were treated with Movento® in May in both the control and mating disruption treatment areas. Efficacy was determined in all locations by evaluating CRS male flight trap cards using Suterra CRS lures (Photo 2), counting CRS on leaf and twig samples and estimating the percentage of fruit that was infested with CRS in the central trees of each plot. In one navel orchard during one flight in 2018, virgin female CRS-infested lemons were hung in pheromone-treated and untreated areas, and the rate of successful scale mating was evaluated.

Photo 1. CheckMate CRS slow-release dispenser clipped on a branch inside the canopy of the citrus tree. (Photographer: B. Grafton-Cardwell)
What We Found

Figure 1 shows that mating disruption provided good suppression of male CRS (Photo 4) throughout the season. However, in 2016-17 (Figure 1A), the population of males in the pheromone-treated area increased toward the end of the season, suggesting a loss of control. The 2018-19 sites (Figure 1B), with lower initial scale populations and larger plot sizes, showed excellent, season-long control of CRS.

When lemons infested with virgin female CRS were hung for two weeks in the treated and untreated areas of one block in 2018, the CheckMate CRS dispensers prevented mating of 95 percent of these CRS females. This has two benefits: (1) it reduces the number of crawlers the females can produce and (2) it holds CRS in the stage that is most preferred and most vulnerable to Aphytis parasitism, enhancing biological control (Vacas et al. 2012).

There was an average 93 percent reduction of CRS on twigs and leaves in the mating disruption areas. The percentage of heavily infested fruit (Photo 3, more than ten CRS per fruit) was significantly reduced by mating disruption both in 2016-17 and 2018-19 (Figure 3). The percentage reduction was greater in the 2018-19 sites where the treatment areas were larger and the initial CRS populations were generally lower. Figure 4 further shows the relationship between male CRS trap card suppression and heavily infested fruit. When males were reduced by more than 95 percent, very few fruit had dense patches of scales. The five sites that did not show as much efficacy tended to be the sites with higher early season densities of CRS and/or the two sites where mating disruption was applied after the first male flight. The result was that in seven of the 12 sites there was less than 0.5 percent heavily infested fruit at the end of the season – a dramatic result considering this was just a single year of treatment with mating disruption.

In contrast, there was an average of 5.6 percent (range 1-13 percent) heavily CRS-infested fruit in untreated areas.

Strategies to Maximize CheckMate CRS Mating Disruption Efficacy

Our study demonstrated that CheckMate CRS can be very effective in disrupting CRS mating by reducing scale populations on twigs, leaves and
fruit. Based on this research, important strategies for how best to use the mating disruption to control CRS can be implemented. First, deploying the dispensers before the first flight helps to keep the spring population from developing, which is a more effective strategy than waiting until after the first flight. Second, the larger the area in which CheckMate CRS dispensers are deployed, the better. Third, heavy CRS populations are going to be harder to control because the males and females develop next to each other, and it will be harder for the synthetic pheromone to compete with the natural pheromone emitted by nearby CRS females. It is critical to reduce heavy populations of CRS with insecticides ahead of or in addition to the mating disruption to reduce the need for pesticides in subsequent years. Finally, pest control advisors experienced with the product say that it can take up to three years of use for mating disruption to work on its own, especially if the initial population is high. This study monitored only one year of mating disruption treatment in

![Photo 3. Fruit with more than ten California red scales, such as this navel orange, are considered heavily infested. (Photographer: B. Grafton-Cardwell)](image)

![Figure 2. Lemons infested with virgin female California red scale (CRS) were hung in the treated and untreated areas of the orchard for two weeks. Less than three percent of female CRS were mated and became gravid in the mating disruption treated areas during that time period. For each pair of bars, the different letters indicate statistically significant differences.](image)

![Figure 3. Mating disruption successfully reduced the percentage of fruit with a few California red scale (CRS) (1-10) and many CRS (greater than 10) in (A) two sites in 2016-17 and (B) 10 sites in 2018-19. In 2018-19, the percentage of heavy CRS was reduced below one percent. For each pair of bars, the different letters indicate statistically significant differences.](image)
combination with a Movento treatment. Yet, CRS in seven of 12 sites was very successfully managed. Based on these results, mating disruption has great potential to reduce, if not eliminate, the need for pesticides for CRS populations in the San Joaquin Valley.

References


Acknowledgements
We thank Booth Ranches, LLC for use of their orchards for the study and Suterra® USA for supplying products. We thank Stephanie Doria, Ping Gu and Josh Reger for technical assistance.

CRB Research Project #5500-501

Glossary

¹*Mating disruption:* A pest management technique involving the release of a synthetic pheromone to confuse males so that they cannot find females and mate with them.

²Pheromones: Chemicals produced by female insects to attract males for mating.

³Mesoporous dispenser: A packet holding liquid pheromone with a very fine porous membrane opening (pore diameter between 2-50 nanometers) to allow for the slow release of the pheromone over many months.

*Joel Leonard, M.S., is director of operations at Sun Pacific. Beth Grafton-Cardwell, Ph.D., is an emeritus entomology specialist and Matt Daugherty, Ph.D., is an entomology specialist, both at the University of California, Riverside. Dave Headrick, Ph.D., is a professor of entomology in the Horticulture and Crop Science Department at California Polytechnic State University, San Luis Obispo. For additional information, contact eegraftoncardwell@ucanr.edu*
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Photo 1. Citrus leafminer moth. (J.K. Clark photographer.)

Project Summary

A three-year study was conducted at the Lindcove Research and Extension Center (LREC) to determine the impact of citrus leafminer larvae per leaf on newly planted Tango mandarins. Tender leaves, suitable for egg-laying by citrus leafminer, were available in spring, summer and fall; however, populations of citrus leafminer were not significant until summer and fall. Reductions in citrus leafminer densities were achieved with systemic imidacloprid and 2-5 foliar insecticide treatments. Yield was higher in the second and third year of treatments when the foliar insecticides were applied in addition to systemic imidacloprid. Individual insecticide applications generally provided only two to three weeks of leafminer suppression. The amount of tender leaf flush¹ and larval densities declined over the three years of the study. These data support the use of insecticides to control citrus leafminer on young Tango mandarins, and demonstrate that applications are needed at frequent intervals in the early years to limit damage.
Background Information

The citrus leafminer, *Phyllocnistis citrella*, is a tiny moth (*Photo 1*) that invaded the United States in 1990, arrived in California in 2000 and spread into the Central Valley in 2006 (Heppner 1993; Grafton-Cardwell et al. 2008). Eggs are laid in developing leaves, and the larval stage tunnels under the outer layer of leaf tissue (*Photo 2*), reducing photosynthetic capability and causing leaves to curl and look unsightly (*Photo 3*). California was one of the last citrus-growing regions to experience this pest; and by then, it was well-known that while leaf damage looks bad, mature trees can tolerate the damage without any effect on yield or tree growth. However, there were indications in limes and oranges that growth and yield of young citrus plantings were significantly affected by citrus leafminer damage (Peña et al. 2000; Powell et al. 2009). During the first three to four years after planting, trees are particularly susceptible to citrus leafminer damage because they produce new leaf flush more frequently than mature trees.

In California, citrus growers apply systemic and foliar insecticides multiple times per year, for up to four years, to reduce citrus leafminer damage of new flush during summer and fall (Grafton-Cardwell et al. 2020). Many insecticides, such as neonicotinoids, pyrethroids, diamides (Exirel® and Altacor®), abamectin, spinetoram (Delegate®), diflubenzuron (Micromite®) and others, are effective against citrus leafminer (Grafton-Cardwell et al. 2016; 2017; 2020); however, the effect generally lasts one generation (a few weeks) at most. Insecticides taken up by plants (either translaminar or systemic compounds) have a somewhat longer residual effect because young leaf flush cannot outgrow treatments as easily.

California mandarin acreage has increased dramatically from four percent of planted acreage in 2002 to 24 percent in 2020 (CDFA 2002; 2020). The W. Murcott Afourer mandarin and its irradiated selection, Tango, comprise approximately 42 percent of the mandarin acreage. Fruit of mandarins and their hybrids in the *Citrus reticulata* group are resistant to early season pest damage by forktailed bush katydid and citrus thrips (Mueller et al. 2019; Cass et al. 2020). It was not known if pesticide treatments for citrus leafminer applied during the first four years after planting were needed for these mandarin types.
What We Did

In 2011-13, we evaluated three insecticide treatment regimens to reduce citrus leafminer densities compared to untreated trees to determine if growth and development of Tango mandarin trees were affected during the first four years after planting. On May 25, 2010, 912 Tango mandarin trees on Carrizo rootstock were planted in a 9 x 18-foot spacing at the LREC in Exeter, California. The orchard was divided into 12 groups of three-row plots each, and treatments were applied in each of the three subsequent years (2011-13):

Table 1. Insecticides applied to Tango mandarins one to three years after planting May 2010.

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>Insecticide</th>
<th>Rate formulated /acre</th>
<th>% 415 oil</th>
<th>Date of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>1 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>1 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Altacor WG</td>
<td>4 oz</td>
<td>0.25%</td>
<td>27 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Delegate WG</td>
<td>6 oz</td>
<td>0.5%</td>
<td>15 August</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Agri-Mek SC</td>
<td>2.125 fl oz</td>
<td>0.5%</td>
<td>30 September</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>1 June</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Altacor WG</td>
<td>4 oz</td>
<td>0.25%</td>
<td>27 June</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Actara WG</td>
<td>5.5 oz</td>
<td>0.25%</td>
<td>19 July</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Delegate WG</td>
<td>6 oz</td>
<td>0.5%</td>
<td>15 August</td>
</tr>
<tr>
<td></td>
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<td>Agri-Mek SC</td>
<td>2.125 fl oz</td>
<td>0.5%</td>
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</tr>
<tr>
<td></td>
<td>4</td>
<td>Micromite WGS</td>
<td>6.25 oz</td>
<td>0.5%</td>
<td>28 October</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>6 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>6 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Delegate WG</td>
<td>6 oz</td>
<td>0.25%</td>
<td>13 August</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Agri-Mek SC</td>
<td>2.125 fl oz</td>
<td>0.25%</td>
<td>25 September</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>6 June</td>
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<tr>
<td></td>
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<td>Altacor WG</td>
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<td>0.25%</td>
<td>13 July</td>
</tr>
<tr>
<td></td>
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<td>Delegate WG</td>
<td>6 oz</td>
<td>0.25%</td>
<td>13 August</td>
</tr>
<tr>
<td></td>
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<td>5.5 oz</td>
<td>0.25%</td>
<td>11 September</td>
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<tr>
<td></td>
<td>4</td>
<td>Micromite WGS</td>
<td>6.25 oz</td>
<td>0.5%</td>
<td>25 October</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>24 May</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>24 May</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Delegate WG</td>
<td>6 oz</td>
<td>0.25%</td>
<td>6 June</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Actara WG</td>
<td>5.5 oz</td>
<td>0.25%</td>
<td>3 September</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Admire Pro</td>
<td>7 fl oz</td>
<td></td>
<td>24 May</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Delegate WG</td>
<td>6 oz</td>
<td>0.25%</td>
<td>6 June</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Altacor WG</td>
<td>4 oz</td>
<td>0.25%</td>
<td>18 June</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Actara WG</td>
<td>5.5 oz</td>
<td>0.25%</td>
<td>3 September</td>
</tr>
</tbody>
</table>
1. untreated,
2. systemic imidacloprid applied through the irrigation system,
3. systemic imidacloprid plus two to three applications of foliar insecticides timed for major increases in citrus leafminer activity and
4. systemic imidacloprid plus three to five applications of foliar insecticides applied three to five times to more continuously suppress citrus leafminer activity compared to treatment 3 (Table 1). Citrus leafminer larvae densities were evaluated on two shoots per tree on a weekly basis.

At the end of the year, trees were individually harvested to measure fruit yield, weight and size using the LREC fruit grading system.

What We Found

The number of leaves that were suitable for oviposition by citrus leafminer fluctuated during each year, with the lowest numbers occurring during the summer heat. However, suitable leaves were available on all sample dates in all three years (Figure 1A). Suitable leaf availability (soft flush for egg laying) per sampled shoot declined as the trees aged during the three years of the experiment (Figure 1A). Individual insecticide applications reduced leafminer density for two to three weeks, including the systemic Admire Pro® applied at seven fluid ounces per acre; but all the insecticide treatment programs, especially those that included foliar applications, significantly reduced leafminer density compared to untreated control trees through much of the season. The maximum larvae per leaf in untreated control trees was 1.1 in 2011 (Figure 1B), 0.70 in 2012 (Figure 1C) and 0.4 in 2013 (Figure 1D), indicating a decline in citrus leafminer infestation over the three years of the experiment.
Tree trunk circumference doubled during the course of the study and tended to be larger for insecticide-treated trees than untreated control trees; however, this was not statistically significant between treatments. Tree canopy volume was measured in April 2013 (Photo 4) after two seasons of treatments and was highest in the imidacloprid plus three to five foliar insecticide sprays treatment (Figure 2). Most importantly, the reduction in leafminer densities by the imidacloprid plus two to three foliar insecticide treatments and the imidacloprid plus three to five foliar insecticide treatments increased yield two- to three-fold at 32 months (2013 harvest) and 1.2-1.8-fold at 45 months (2014 harvest) after planting, respectively (Figure 3A). Mean fruit weights were similar among the treatment groups in 2013, whereas the imidacloprid plus three to five foliar treatments showed slightly to significantly lower fruit weight the following year (Figure 3B). This trade-off between yield and fruit size is well-known for citrus and is regulated by growers via pruning, fertilization and irrigation. Small, medium and undersize fruit were the most common size classes during the 2014 harvest; and in each of these classes, there were more total fruit when trees were treated with insecticides (Figure 4).
Conclusions

Similar to other regions of the world, citrus leafminer densities were low in the spring, presumably due to overwintering mortality, and gradually increased through the summer and fall (June through October), highlighting the time of year when protection against citrus leafminer is needed. Both the amount of tender leaf flush per shoot and the citrus leafminer populations per leaf declined during the three years of the study, reducing the number of applications of insecticides needed as trees matured. Systemic imidacloprid combined with multiple foliar insecticides significantly improved the yield of trees in years three and four when they first came into bearing. This is the first demonstration of tree growth and yield impacts on young Tango mandarins due to uncontrolled citrus leafminer. This research demonstrates that protection of young Tango trees during the first three to four years after planting is warranted. However, monitoring for larval mining activity should be conducted to determine the timing and frequency of treatments because activity of citrus leafminer varies during the season and tends to decline with tree age.

Glossary

°Tender leaf flush: New leaf flush that is tender enough for the newly hatched citrus leafminer larvae to mine.

References


Acknowledgements
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CRB Research Project #5500-501

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The Asian citrus psyllid (ACP) detector canines worked in Kern County from January - March 2021 with the Citrus Pest Detection Program (CPDP). The goal of this three-month project was to develop best practices for implementation of this new technology in areas where ACP are not established. Two new practices were developed. The first is a system of deployment that enables the canines to work in regions not generally infested with ACP by utilizing a rotation of teams mid-week between counties where they can work with live ACP and those where they must use an ACP pseudo-scent¹. The second is an improved search pattern that increases the number of trees that can be inspected in a day by 26 percent. This will reduce the per tree cost to growers or government agencies when utilizing this technology. A systematic method for visual scouting was developed, and field inspection equipment was evaluated. A document of best practices for utilizing ACP detector canines was written to assist the citrus industry when implementing this new technology.
The Problem

Huanglongbing is transmitted by ACP, and monitoring for this elusive pest in regions that are not generally infested is difficult. The current methods for detecting low-density ACP populations are yellow sticky traps, visual inspection, tapping and sweep net. The currently used yellow sticky traps are only marginally effective (Czokajlo et al. 2015) since these traps are not as attractive as new leaves. When new flush is available, psyllids are more attracted to the flush than the yellow cards (Poudel et al. 2016) because citrus leaves have chemical attractants in addition to their color. Visual scouting a subset of flushes for psyllid life stages may miss a psyllid infestation. The citrus industry would benefit from new, additional scouting methods to use in areas that are not generally infested.

Canine-assisted ACP scouting can increase the number of trees per day that can be effectively screened for ACP, which can assist with local eradication efforts. The primary goal of this project was to develop best practices to effectively utilize ACP detection canines in regions not generally infested.
Training aids have an important role to play in the science of detector canines. They are used to keep the canines focused on a trained odor (e.g., explosives, narcotics, bedbugs, ACP) and to evaluate the canines’ ongoing proficiency while working. They also are utilized to maintain the canines’ motivation to hunt for their target odor. In our work, when a canine locates live ACP or pseudo-scent, a reward is given – a toy and playtime with their handler. Detection canines cannot be regularly used in locations with very few opportunities to experience their target odor (live ACP) without training aids. Their accuracy and motivation to work will be affected. However, current United States Department of Agriculture and California Department of Food and Agriculture ACP zoning regulations do not allow for the use of live ACP training aids in areas not already generally infested with ACP. A live ACP training aid is a vented vial that contains live ACP on citrus seedlings but prevents the release of live ACP into the environment. This is a significant barrier to using ACP detection canines in the San Joaquin Valley that needed a solution.

Additional problems the project sought to address are the high cost of ACP detection canine services and the difficulty of visually locating low levels of ACP after canine alerts. Data were collected on search patterns to determine the most effective and efficient system of inspecting perimeter trees and to develop additional methods for visual scouting of trees after canine alerts. This is critically important because the canines do not receive their reward after alerting unless live ACP can be visually confirmed.

![System of Inspecting Perimeter Trees](image)

Figure 1. System of Inspecting Perimeter Trees
The brown arrows are the first pass, and the purple arrows are the second pass. This pattern allows the canine nose to cover all sides of the tree in the most efficient manner. It also increases the odds the canine nose will be on the right side of the wind to catch the insect’s odor.
How the Study was Conducted

Canine teams worked side by side with field inspectors from the CPDP in commercial groves in Kern County to test possible solutions to utilizing the dogs without live ACP training aids and to maximize their efficiency and efficacy. The CPDP, which is managed by the Central California Tristeza Eradication Agency (CCTEA), selected citrus blocks to be surveyed during the project. In addition to the high risk-based survey model, the CPDP utilizes information from grower liaisons’ newsletters to select blocks for ACP surveys.

This project assessed a new deployment system that utilized two handler/canine teams. A team consisted of one handler with two dogs and a van. Team 1 worked in Kern County for the first half of the week utilizing an ACP pseudo-scent training aid, then went to Riverside County for the second half of the week where live ACP training aids could be used. Team 2 worked the first part of the week in Riverside County with live ACP training aids, then worked in Kern County the second half of the week utilizing ACP pseudo-scent training aids. This deployment system allowed a single canine team to work Monday through Friday in Kern County.

Results

An efficient system of searching perimeter trees was developed through trial and error (Figure 1). The initial search pattern tested was moving all the way around the perimeter, reversing and searching the other side of the trees back to the starting point. This resulted in 778 trees surveyed per day with one handler, an assistant and two dogs. The Central machinery aspirator (left) and shop vac aspirator (above).
next search pattern broke the perimeter into sections of 40 trees. Teams searched 40 trees up and back, then moved the car forward to start the next section of 40. This resulted in 1,050 trees surveyed per day, a 26 percent increase in productivity.

Field-testing the use of an ACP pseudo-scent was conducted to optimize the use of canines in areas where live ACP training aids are not allowed. Sensitivity data on the use of live training aids in commercial orchards during HLB Multi-agency Coordination (HLB-MAC) Group-funded research in 2020 utilizing the same six canines is used here for comparative purposes (unpublished data), as live ACP training aids were not used in Kern County. The sensitivity² (accuracy) with pseudo-scent was three percent lower than with live training aids in commercial orchards.

During this study, the relationship between the set time³ of pseudo training aids, number of drops of pseudo, height of placement and alerts and misses was examined. The optimal set time for the training aid was determined to be 15 minutes. Other variables such as tree type (i.e., oranges, lemons), flush level, tree height and planting density were studied as well and showed no statistically significant effect on the probability of an alert occurring.

The performance of the six canines was assessed individually and as a group over time. Performance of each canine was consistent during the trials as there was no evidence of systematic change in probability of alerts over the course of time. There were no statistical differences between individual canine performance or that of any canine/handler team combinations. Of the 6,624 trees inspected in Kern County during the project, canines alerted on 42 trees (0.63 percent alert rate). However, live ACP could not be located to confirm the alerts.

Seven different pieces of field-scouting equipment were evaluated. Tools that were the most helpful were the 14x Bosch & Lomb Hastings Magnifier, a tall step stool and a "Cut 'n' Hold" pruner device (see photos on page 53). Based on the above findings, a "Best-practices for Implementation of ACP Detector Canines" document and a "Systematic Visual Scouting Worksheet" were developed to assist growers when utilizing the ACP detection canines.

Discussion

There were three valuable insights gained from the project. The first was the discovery of a search pattern that increased the efficiency of the canine/handler team by 26 percent. This will reduce the per tree cost of utilizing this technology for growers or government agencies. The second is the possibility of a system for deploying detector canine/teams in regions where live ACP training aids are not permitted. The data indicate that canines are not as accurate with pseudo-scent as with live ACP. The regular use of a pseudo-scent in regions not generally infested may be negatively affecting the canine’s ability to locate ACP populations. The third is the determination that the optimal set time for ACP pseudo-scent is 15 minutes. This will assist ACP canine teams in the future.

Conclusion

This new technology, ACP detection canines, can be utilized in regions not generally infested by utilizing ACP pseudo-scent and the rotation of canine/handler teams. To receive the highest potential benefit from the canines, live ACP training aids should be used instead of ACP pseudo-scent when possible. 📚

CRB Research Project #5300-213

Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Pseudo-scent</td>
<td>A proprietary mix of compounds that provide a surrogate scent for maintaining a detection canine’s motivation while deployed in areas where the actual target odor cannot be use as a training aid.</td>
</tr>
<tr>
<td>Sensitivity²</td>
<td>A measure of how well a canine identifies ACP or ACP pseudo-scent.</td>
</tr>
<tr>
<td>Set Time³</td>
<td>The duration of time from when a training aid is placed to when the canine arrives at its location.</td>
</tr>
</tbody>
</table>

References


Acknowledgment

We would like to thank Neil McRoberts, Ph.D., from the Quantitative Biology & Epidemiology Research Group, Plant Pathology Department, University of California, Davis for statistical analysis of the data.

Lisa Finke, M.S. in Psychology, is the owner of Canine Detection Services Corporation. Subhas Hajeri, Ph.D., is a plant pathologist and program director at the Citrus Pest Detection Program. For additional information, contact lisa@canine-detection.com

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Managing Asian citrus psyllid (ACP) in Organic Citrus

For the past two years, our research has focused on understanding how organic treatments for ACP can be used. We worked with the San Joaquin Valley (SJV) Organic Citrus Committee to best understand what treatments were of interest to organic growers and determine the most promising treatments. Organic treatments for ACP are known to have very little residual activity and low efficacy when compared to conventional insecticide treatments. To address these issues, we have focused on the efficacy of new treatments coming to the market and the ability of adjuvants to extend ACP control.

Our first field trial was conducted in 2019. However, the field was so overly infested with ACP that the data were hard to interpret due to the number of overlapping ACP generations in the field. There was also inconsistent ACP pressure across the field, which further made the treatments difficult to evaluate. Given this outcome, we needed to deduce the variables that were causing the challenges to data interpretation. We ran a greenhouse trial using field rates with select combinations of compounds and adjuvants that showed the most promise (Figure 1) and continued the study in the field in early 2021 (Figure 2). We found that assessing organic treatments in the field was a continuing challenge due to the movement of the insects throughout the field. As we were using a high-density planting, we hypothesized that a higher volume of water per acre would be helpful. Despite the challenges and poor results, we currently are finalizing our third field trial and have gleaned some important suggestions for using organic products to effectively manage ACP.

Ultimately, there are many important factors for improving the use of organic materials for ACP management. From our work with organic treatments, we have identified some points to consider:

1. **Infestation level matters.** If infestation levels are high (multiple generations of nymphs/adults counts anywhere in the grove over 50 nymphs/flush), treatments must be applied consistently every four to six weeks or possibly combined with another treatment, such as before application of PyGanic® EC 5.0. If infestation is low (with an average below 10 nymphs per flush), couple the treatments with yellow sticky cards and scouting to determine when best to apply the next treatment.

2. **Water volume is a make-or-break element of application.** 200-300 gallons per acre is ideal. Low volume treatment applications, especially for high ACP infestations, risk low coverage and reduced efficacy.

3. **Scouting is essential to understanding populations.** Scouting is key to understanding the infestation and where ACP population hotspots are in the grove. Scouting drives proper treatment application timing. Organic blocks will have higher levels of infestation, but it is important to consider timing applications. Earlier flush (“feather flush” and initial emergence stages of flush) is best, but not if there are many eggs present. Treatments are likely to be less effective since we have not seen any treatment efficacy against eggs.
Delegate® Resistance in Citrus Thrips is Concerning to Growers

Citrus thrips have become challenging to control in California in recent years. Although weather factors such as heat and dry winter may have contributed to high pupal survival that led to increased population pressure, insecticide resistance in citrus thrips cannot be ignored. Citrus thrips reproduce fast and have a known history of rapidly developing resistance to chemicals used frequently and repeatedly for their control (Morse and Schweizer 1996). Thrips populations in the SJV developed resistance to insecticides like Carzol® and Dimethoate in the 1980s and resistance to Beta-cyfluthrin® in the 1990s. Success®/Entrust® (Spinosyn), which belong to the same class of insecticide, have been used since 1998. Since Delegate (Spinetoram) was registered in 2008, it has been heavily used and relied upon to control citrus thrips. Consequently, the combined use of these two insecticides has exposed
citrus thrips to the spinosyn chemical class for more than 20 years. It is not surprising that research by Joseph Morse, Ph.D., and Elizabeth Grafton-Cardwell, Ph.D., showed that Delegate resistance appeared in the Valley during the 2010s.

We used a Munger cell laboratory bioassay (Morse and Brawner 1986) for monitoring Delegate resistance in 13 field populations collected from different citrus orchards in the SJV using a discriminating dose of one part per million (ppm) and 10 ppm (10-fold discriminating dose). Of the 13 populations tested, none showed full susceptibility to one ppm Delegate (100 percent mortality). The percent of populations surviving the discriminating dose in all 13 populations ranged from 31.4 to 76.6 percent (less than 23.4 percent mortality) (Figure 3). This means that one out of every four thrips survived the discriminating dose, indicating significant resistance levels. More importantly, compared with results from 2017-19 (Doria et al. 2018), the number of populations surviving 10 ppm is increasing through the years (Figure 4). In 2021, none of the populations were controlled by 10ppm. Four populations showed less than 80 percent mortality at 10 ppm and are likely to survive the field rates. Two main ways to manage resistance are rotating insecticide groups and minimizing the frequency of spray applications. Similarly, monitoring the orchard population to target applications for maximum efficacy is important and minimizes resistance development within the population. Registered insecticides with a different mode of action for citrus thrips are Exirel® (group 28), Abamectin® (group 6) and Veratan® (botanical). When thrips pressure is low, Movento® (group 23) and Sivanto® (group 4D) also can be used as rotational products.

We will continue to monitor citrus thrips resistance and initiate insecticide trials to determine effective rates to control Delegate-resistant citrus thrips in spring 2022.

**Glossary**

1. **Adjuvants**: Chemicals, compounds or substances that enhance the activity of, in this case, ACP insecticides.

2. **Discriminating dose**: A dose of insecticide used to identify the proportions of susceptible and resistant individuals in an insect population.
Figure 4. Percentage of citrus thrips surviving discriminating doses of one and ten ppm of Delegate. Field rate of Delegate is 4-6 oz/acre in 250 gallons per acre (i.e., 30-45 parts per million [ppm]).

References


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NEONICOTINOID INDEPENDENT ANALYSIS
A REVIEW OF THE DEPARTMENT OF PESTICIDE REGULATION’S NEONICOTINOID RISK ASSESSMENT

Joey S. Mayorquin and Casey D. Creamer
Introduction

Neonicotinoids (neonics) represent a class of insecticides, chemically similar to nicotine, which affect the nerves and muscles of insects. In citrus, neonicotinoids are used to control Citricola scale, Fuller rose beetle and the Asian citrus psyllid. The latter can vector the bacterium ‘Candidatus Liberibacter asiaticus,’ believed to cause huanglongbing (HLB). The importance of these insecticides to the citrus industry cannot be understated, especially when considering the threat that HLB poses to California citrus production. Although neonicotinoids were developed as alternatives to organophosphate and carbamate insecticides, which have greater potential to affect human health, the effects of neonicotinoids on pollinators have been called into question (CDPR 2018).

In 2008, the CDPR was notified of pollinator health concerns in response to a study of neonicotinoid use in ornamental plants. The department initiated a re-evaluation in 2009 of four neonicotinoid active ingredients: imidacloprid, thiamethoxam, clothianidin and dinotefuran. Of these, only imidacloprid and thiamethoxam are used by growers on commercial citrus in California. The CDPR, along with other agencies, developed methods to assess the risk of exposure to pollinators foraging on nectar and pollen in crops treated with neonicotinoids (CDPR 2018).

CDPR’s Review and Conclusions

The CDPR used several studies in which bee colonies were exposed to the four neonicotinoids to determine pollen and nectar residues that produced no observed effect concentrations (NOECs). These NOECs were then compared to residue levels obtained from field data of agricultural commodities to establish risk levels between crop groups and neonicotinoid application methods (foliar and soil). Any field residue levels above the NOEC were classified as a risk, whereas any field residues below the NOEC were classified as a low risk. In its study, the department noted its findings were based on the maximum annual application rates for each neonicotinoid for each crop group in California; and thus, these findings represented “worst-case” scenario. Actual application rates could present less risk (CDPR 2018).

Based on the findings of the re-evaluation from two studies (one using two foliar applications of imidacloprid and one using a soil application), imidacloprid residues in citrus pollen (3257.9 micrograms [μg]/kilogram [kg]) exceeded the NOEC of 97.5μg/kg for pollen. Similarly, imidacloprid residues in citrus nectar (267.1μg/kg [foliar application] and 25μg/kg [soil application]) from these studies exceeded the NOEC of 23μg/kg for nectar. Thus, imidacloprid was identified as a risk for all crops in the citrus fruit group at maximum application rates (CDPR 2018). It is important to note the vast majority of imidacloprid applications in California citrus are systemically applied through irrigation and are not foliar applied.

Exponent’s Review and Conclusions on Systemic Imidacloprid

Based on the CDPR’s risk determination for imidacloprid and the limited use of foliar imidacloprid applications in citrus in California, Exponent focused its review on systemic imidacloprid use. Exponent determined the department’s
assessment protocol to be consistent with standard risk assessments utilizing laboratory toxicity data, estimates of exposure for individual bees and residue studies with bee colonies.

In a colony feeding study exposing honeybees to nectar spiked with imidacloprid, the overall lowest observed effects concentration³ (LOEC) and NOEC were determined to be 50μg/kg and 25μg/kg respectively. However, the CDPR selected the concentration of 23μg/kg for the NOEC. From a study measuring imidacloprid residues in nectar from soil applications, the CDPR calculated residue concentrations under the assumption that pollinators obtained 100 percent of their nectar from citrus and that imidacloprid was applied at maximum label rates. However, not all data from this study were included in the department’s analysis; only data from maximum application rates were used. Furthermore, this study included a site with sandy loam soil. This soil type may not reflect the major California citrus production areas. Upon removing the site with sandy loam soil and including all relevant nectar samples, E’ponent determined the expected concentration (22.6μg/kg) to be less than the concentration (23.0μg/kg) selected by the department, thus indicating no risk to honeybees from nectar using the recalculated number (E’ponent 2020).

In a study looking at chronic effects of pollen spiked with imidacloprid (foliar application), no effects on foraging activity or colony performance were observed during or directly after exposure to imidacloprid. In its review, the CDPR selected the average exposure concentration from the highest concentration applied in this study (97.5μg/kg) as the NOEC for pollen exposure without any information characterizing the LOEC. Due to a lack of extensive data on imidacloprid pollen residue concentrations, the CDPR proposed using pollen residue data from thiamethoxam (NOEC of 372μg/kg) to infer residue concentrations of imidacloprid in pollen, leading them to propose an application rate limit of 0.086 pounds per acre per season. This decision however does not take into consideration the different intrinsic activities of thiamethoxam and imidacloprid (E’ponent 2020).

Considering the tendency for thiamethoxam, unlike imidacloprid, to accumulate in nectar and pollen over time from consecutive year soil applications, E’ponent used a ratio of pollen concentrations to nectar concentrations of thiamethoxam residues to estimate imidacloprid residues. Assuming similar distribution patterns to nectar and pollen for both neonicotinoids within citrus trees, this ratio gave an expected NOEC of 85.9μg/kg for imidacloprid, a greater than four-fold lower concentration than that proposed by the department (372μg/kg), and significantly below the LOEC (E’ponent 2020).
Conclusions

Overall, Exponent recommended applying the NOEC for clothianidin to imidacloprid as was done for thiamethoxam and dinotefuran. Additionally, any data from unrepresentative conditions should not be considered when establishing expected concentrations and the contribution of pollen to honeybee diets should be considered when determining the significance of risk through this route. If known, reliable data of imidacloprid residue studies should be used whenever possible.

As the CDPR continues to evaluate and consider mitigation strategies for neonicotinoid usage, CCM will work closely with its industry partners to ensure that the California citrus industry has continued access to its most critically needed pesticides. This new information highlights that current uses of imidacloprid in California citrus do not present a significant risk to honeybees. CCM is hopeful that the CDPR will view these conclusions favorably.

CRB Research Project #5500-223

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Glossary

¹No Observed Effect Concentration: The level of a substance where there is no significant increase in negative effects observed on an organism.

²Systemic: Absorbed and distributed throughout a plant.

³Lowest Observed Effect Concentration: The lowest level of a substance where a negative effect is observed on an organism.
Project Summary

During an eight-year period, about 2.3 million genetically variable Tamarixia wasps were produced to optimize the biological control of the Asian citrus psyllid (ACP) in California. Part of the 2.3 million wasps were used by the California Department of Food and Agriculture (CDFA) insectary to produce a total of about 23 million Tamarixia that have been released statewide, while the remainder was directly released by the CDFA.
Biological control can be a highly successful and inexpensive method of insect pest control. The citrus industry has benefited greatly from this method. For instance, the control program for cottony cushion scale saved the industry from disaster in 1888. The cottony cushion scale was killing citrus trees in California. After much inquiry, this pest insect was found in Australia where it did not appear to be causing much harm. Subsequently, a United States Department of Agriculture entomologist was sent over to find natural enemies for the pest, and a lady beetle, the vedalia beetle, was found that specifically fed on cottony cushion scale. The vedalia beetle was shipped to California and reared on cottony cushion scale-infested trees. The subsequent distribution of these lady beetles throughout the state led to the successful control of cottony cushion scale on citrus to this day. Yet not all insect biological control projects are that successful – only 30-40 percent of introductions lead to some level of control.

Purebreds vs Mutts, or Pitfall #1:
Introducing Genetic Diversity

Why are we not capable of reaching a higher success level? One factor is the quality of the natural enemies that we release. Often only a few specimens of a natural enemy species are collected in the native area of the pest we are looking to control. These few individuals then form the colonies that are reared for many generations before being released for biological control. The problem is that only a few individuals end up creating an entire population of natural enemies. The result is that inbreeding takes place and less fit individuals are released in the environment to find and kill pests. This lack of genetic variation in the breeding stock can limit the effectiveness of insect biocontrol programs. A good example of problems associated with a limited breeding stock are purebred dogs. Such beautiful dogs have a much higher incidence of all sorts of genetic diseases than mutts. A solution to this insect biocontrol problem is not to import just a few individuals that form the basis of the colonies, but to import many individuals. With a large number of individuals, there would be an increase in genetic variation of the breeding stock, resulting in increased effectiveness of natural enemies that are released for biocontrol of an insect pest.

Indian Runner Ducks vs Mutts, or Pitfall #2:
Maintaining Genetic Diversity

However, as is often the case with simple solutions (bringing in a large number of individuals), other problems arise. For natural enemies used for biological control, the process from being collected in the native area to being released in the invaded area is a long one. After the collection, they first must go into quarantine to ensure that they are indeed suitable natural enemies that can be used to control the intended pest. Next, to satisfy safety concerns, many experiments must be done to ensure they will only attack the pest we are trying to control. Once that has been shown and permission is obtained, only then can the natural enemy be released into the field. This whole process takes years. For natural enemies with a generation time of about two weeks, after three years of rearing, that adds up to about 75 generations under artificial conditions in quarantine. As stated above, increased genetic variation is needed to avoid the inbreeding associated with few individuals starting the population used for mass rearing. However, there also are issues associated with prolonged mass rearing after starting with many individuals.

In rearing natural enemies, we try to offer them the pest that they reproduce on in large quantities because we want to produce as many natural enemy offspring as possible. In the case of Tamarixia radiata, we place plants with many third and fourth instar ACP nymphs on them in cages and release Tamarixia wasps into these cages. The wasps do not need to search for a long time to find an ACP; nor do they have to fly to a place where they might find an ACP; nor do they have to find nectar on which to feed. We create the best possible circumstances for them – plenty of food, plenty of hosts and even the wasps that don’t search very well will stumble into an ACP. The only thing they have to do is lay eggs. The wasps that lay the most eggs will leave the most descendants. Let us say wasps that do not fly much, but spend all their time laying eggs as fast as possible, will be selected under these conditions. Since producing eggs is costly, some other trait of the wasps must be sacrificed to lay more eggs. Genetic forms that produce fewer flight muscles can use the energy not spent on those muscles to produce more eggs. After 75 generations, a large fraction of the mass-reared wasps will produce many eggs (which is good – kills many ACP) but will not be able to fly very far. That is not a problem for mass rearing itself. We will be producing large numbers of wasps; however, when we ask these wasps to go out in the real world and kill ACP, they will not be very good at doing that. Before they can lay an egg in an ACP in a tree, they must find the ACP, which involves flying. They also need to find nectar on which to feed; but during the mass rearing, that never was a limiting factor. These prolonged periods of insectary rearing will produce wasps that may not perform very well in the field; and, of course, we want them to do well in the field and establish a self-perpetuating population there.

An example of this is that through generations in Indonesia, folks have selected mallards to produce lots of eggs. This has resulted in the Indian Runner...
Duck breed, which can produce up to 300 eggs per female per year – a very successful breeding effort. However, if one wanted to establish a wild population of mallards to clean out water plants from many ponds over a wide area, Indian Runner ducks would be worthless. While they can produce a lot of offspring, they have been bred to mainly feed on land; they are no longer capable of flying, and predators will easily catch them.

Avoiding the Mutt to Indian Runner Duck Transition

Now we have two problems. If we start with few individuals, we create purebred dogs with all their associated genetic issues; if we start with many individuals, we are starting with mallards and ending with Indian Runner ducks. How can we solve this problem? Strangely enough, it involves first creating purebred lines and subsequently interbreeding these lines to create mutts. These mutts are then bred for only a few generations in mass rearing before being released into the wild to avoid the Indian Runner duck effect. For mass-rearing of Tamarixia in California a similar approach has been used. Material was collected from Pakistan by Mark Hoddle, Ph.D., and used to initiate many small populations of wasps that were not allowed to interbreed with other lines. Next, wasps from the purebred lines were placed in cages where they were allowed to interbreed and produce genetically variable offspring (mutts). Around 2.3 million offspring were produced by the University of California, Riverside during an eight-year period and were provided to David Morgan, Ph.D., at the CDFA mass-rearing facility where some of these wasps were multiplied for only one or two more generations before their 23 million offspring were released in the field. The remainder of the wasps, not used for further multiplication, also was released in the field by the CDFA. This was all done to ensure we were releasing T. radiata comparable to mutts, not purebreds, nor Indian Runner ducks.

Future of Genetically Diverse Tamarixia in California

The next phase (which started in October 2021) of the release of Tamarixia involves the same process executed in the Citrus Research Board laboratory with Raju Pandey, Ph.D., at the CDFA Mount Rubidoux Field Station in Riverside, California. In addition to maintaining the lines from Pakistan, Pandey’s team will create new lines of T. radiata collected from citrus at sites where it was previously released in California. The assumption is that Tamarixia that have survived many generations in the field in California will be better adapted to the California circumstances (Mallards that are adapted to the dry conditions in California) and rearing these lines under the same set-up (avoid making them into Indian Runner ducks) will allow us to introduce Tamarixia better adapted to killing ACP in California citrus.

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These images from the Citrus Roots Collection show some of the fumigation technology used in the orange and lemon groves of California in the early 20th century. Note the enormous tents workers would place over each tree, which gives some sense of the scale of fumigation as the primary means for controlling pests.

For more information, contact bjenkins@laverne.edu

-- Courtesy of Benjamin Jenkins, Ph.D.
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