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Citrograph
MAGAZINE
WINTER 2026

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On the Cover: *Welcome to the winter 2026 issue of* Citrograph*, which highlights advancements in integrated pest management (IPM). This issue's cover features a close-up photo of Argentine ants (AA) feeding on biodegradable alginate hydrogel beads infused with a sugary liquid dyed with blue food color—just one of the new baiting methods being evaluated for AA control. To learn more about this research, visit page 32 for "Updates on Hydrogel Baits for Argentine Ant Control in Citrus," written by Ivan Milosavljević, Ph.D, et al. (photo credit: Mike Lewis). We hope you enjoy this issue.*

In This Issue

Winter 2026 | Volume 17 • Number 1 The Official Publication of The Citrus Research Board

Citrograph's **mission is to inform citrus producers and other industry members of research progress and results that will help ensure the sustainability of California citrus.**

THE MISSION OF THE CITRUS RESEARCH BOARD

Ensure a sustainable California citrus industry for the benefit of growers by prioritizing, investing in and promoting sound science.

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2026 UPCOMING EVENTS

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For more information, contact the CRB at (559) 738-0246 or visit *www.citrusresearch.org*

MARCH 10
CITRUS PEST AND DISEASE PREVENTION COMMITTEE (CPDPC) MEETING
For more information, visit *www.cdfa.ca.gov/citruscommittee*

MARCH 11
CALIFORNIA CITRUS MUTUAL (CCM) CITRUS SHOWCASE
For more information, contact CCM at (559) 592-3790 or visit *www.cacitrusmutual.com*

MAY 5
CITRUS RESEARCH BOARD (CRB) BOARD MEETING
For more information, contact the CRB at (559) 738-0246 or visit *www.citrusresearch.org*

JUNE 10
CITRUS PEST AND DISEASE PREVENTION COMMITTEE (CPDPC) MEETING
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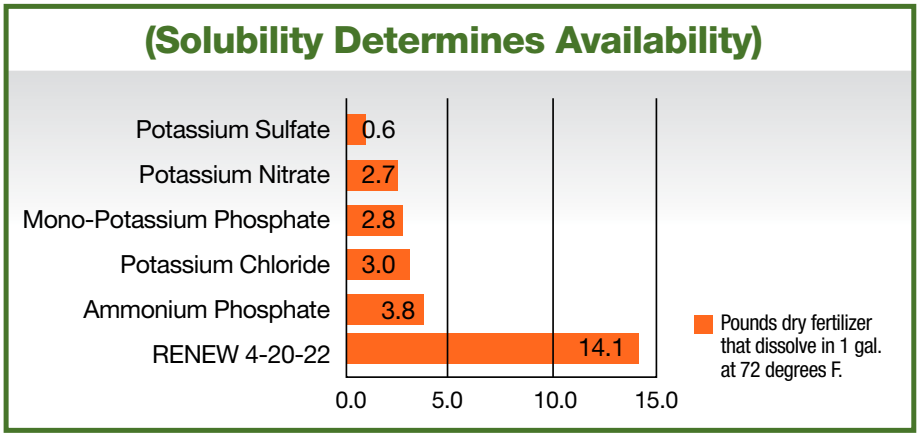


For more information including research results and scientific publications, contact;

Mark Brady, Western Marketing Manager, Plant Food Systems, Inc. (559) 731-1267

Plant Food systems

From the PRESIDENT'S DESK

Marcy L. Martin

The Citrus Research Board (CRB) takes every opportunity to learn from those around us who are in the field each day and have a deep understanding of the complexities of growing citrus. Each interaction with a grower or pest control advisor (PCA) provides us with a wealth of information about the issues we aim to solve through the research we support. This issue of *Citrograph* highlights many of CRB's integrated pest management (IPM) projects, which are developed in response to industry needs and identified through our connections with California's citrus growers. We invite you to explore the research contained within this issue, highlighting important work on Argentine ants, citrus thrips, mealybugs, California red scale, Asian citrus psyllids, and more.

Marcy L. Martin

CRB staff members continually interface with growers and their PCAs, so we remain knowledgeable about current pest concerns. Discussions include issues with control, material availability, and efficacy, and how each of these concerns affects citrus production. The CRB's Research Department communicates regularly with growers and researchers to share the latest information from both sides, ensuring advancements are made for the industry's benefit. It also promptly addresses any new concerns that arise throughout the season. Our Pest Management Research Committee meets several times throughout the year to review projects and direct research toward areas of concern for further consideration. Much of the information contained in *Citrograph* comes from CRB-supported research projects that were developed based on industry needs.

Through our California-focused Citrus Research and Field Trials program (CA-CRaFT), CRB regularly visits commercial orchards to observe and participate in our Asian citrus psyllid (ACP) tracking program. This program, funded by the United States Department of Agriculture (USDA), enabled the CRB to form partnerships with commercial citrus growers to mitigate the impacts of huanglongbing (HLB) through ACP mitigation strategies. These strategies include permanent barriers, such as mesh fencing and living windbreaks, as well as threshold-based mitigations, which involve pesticide applications or psyllid repellent sprays. An update on the program can be found on page 26 and includes the results of these mitigations after several years. The CA-CRaFT program staff conduct extensive outreach activities while maintaining strong communication with participating growers to ensure that data is collected and analyzed to inform the future direction of the program. Frequent visits to field sites and biannual surveys not only yield valuable information, but also face-to-face connections with California growers as we work together to maintain low pest levels.

Argentine ants are another area of IPM research that we are invested in, as CRB IPM entomologist Ivan Milosavljević, Ph.D., has spent several years scrutinizing alternative control methods for these disruptive pests. Along with researchers David Haviland and Mark Hoddle, Ph.D., the team explored the use of hydrogel baits to replace prohibited materials, which has shown promise in controlling ant populations and slowing mealybug accumulation, as it allows natural enemies to prey on mealybugs. Registration of these ant control products depends on a complex regulatory pathway. Researchers are discussing the regulatory procedure with the California Department of Pesticide Regulation (CDPR) and the U.S. Environmental Protection Agency (EPA) to register these products, making them available for growers' use in the future. Additional information about this work can be found on page 32.

CRB staff continues to interface with growers, researchers, and regulatory staff to ensure that the best interests of the California citrus industry are represented and addressed. As we enter the new year, we will continue to drive crucial research in each of our priority areas and partner with researchers to deliver results to our growers.

***Marcy L. Martin serves as the president of the Citrus Research Board, based in Visalia, California. She is also the executive editor of* Citrograph. *For more information, contact* marcy@citrusresearch.org**

2025-26 CRB RESEARCH AGENDA APPROVED AT ANNUAL BOARD MEETING

Caitlin Stanton

The Citrus Research Board (CRB) convened on September 23, 2025, to approve the annual budget and confirm the research agenda for the 2025-26 period. Board members and guests from around the state traveled to Visalia, California, to attend the meeting. Joining the Board members were representatives from the California Citrus Mutual (CCM), California Citrus Quality Council (CCQC), EcoData Technology, and the California Department of Food and Agriculture (CDFA).

"Each year, the Board convenes to review and support valuable research projects that will have tangible impacts on California's citrus growers," said CRB President, Marcy L. Martin. "We value this time to gather for productive discussion on the industry's needs and to highlight the work we have accomplished over the year."

The meeting included updates from each committee chair, reporting on their group's activities and sharing research projects for consideration. CRB-funded research projects are subject to rigorous reviews by internal and external experts before committee discussion and before being ultimately approved by the Board each September. Both new and continuing projects were approved in the following committees: New Varieties Research, Pest Management Research, and Production & Post-Harvest Technology Research. A new project was also approved by the Vectored Diseases Research Committee. CRB will publish a complete

list of FY2025-26 research projects in the upcoming summer issue of *Citrograph*. Committee chairs also informed attendees about current developments at the BSL-3P Laboratory, updates on the Nanovel mechanical harvester project, as well as ongoing work at the Citrus Clonal Protection Program.

CRB integrated pest management entomologist, Ivan Milosavljević, Ph.D., shared an update on his ongoing research into Asian citrus psyllid and Argentine ant, as well as the California-focused Citrus Research and Field Trials (CRaFT) Program. The meeting also included updates from Jim Cranney of CCQC, who shared his ongoing work trade issues in various export markets, and Casey Creamer of CCM, who provided an overview of the legislative landscape and discussed current quarantines in Southern California. Additionally, Robert Clark, Ph.D., of EcoData Technology, reported on his project of using machine learning to detect huanglongbing in California.

The Finance Committee provided an update on the CRB's financial position. Fiscal responsibility remains one of the organization's key principles, and an overview of the CRB's financial position will also be shared in the summer issue of the magazine.

The Board approved an assessment rate of $0.035/carton, with an estimated total of $7,000,000 in fiscal year funding. More than 66 percent of this funding will be directed to core research programs with field-level applications that benefit growers. This rate has been approved by the CDFA Secretary.

Additionally, members of the Board held elections to determine the slate of officers for the 2025-26 term. Mark McBroom of Bloom to Box Crop Care, Inc. in District 3 was re-elected for an additional term as chairman. Scott Carlisle of Villa Park Orchards Association in District 1 will continue the role of vice chairman, while John C. Gless of Bagdasarian Farms in District 2 will continue to serve as the secretary/treasurer.

Retiring Board members, Andrew Brown and Gabriel Olmos, were recognized for their service as they concluded their time on the Board. Brown of A&A Ag Services served on the Board for nine years and participated in many committees, including the Vectored Diseases Research Committee, Pest Management Research Committee, Research Priority Screening Committee, and Finance Committee. Olmos of Ventura Pacific Company served on the Board from 2021 to 2025 and participated on the Production & Post-Harvest Technology Research Committee, Research Priority Screening Committee, Finance Committee, and Nominating Committee. We want to thank both individuals for their unwavering dedication to the CRB and the California citrus industry.

The CRB remains committed to administering crucial research projects, maintaining an appropriate budget, and communicating these activities to the growers. The CRB staff looks forward to working with the Board and its various committees to continue the organization's mission, striving to maintain a sustainable citrus industry established on sound science.

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

CRB Welcomes Three New Board Members

Caitlin Stanton

The Citrus Research Board (CRB) recently welcomed three new members to the Board to represent the industry. At the CRB nomination meeting held on September 10, 2025, Aaron Henderson of Red Wolf Farms, LLC, and David Mabs of Patterson Enterprises were elected to represent District One. Four current Board members were re-elected to serve additional three-year terms – Justin Golding of Sun Pacific; Zac Green of WN Citrus; Jason Reynolds of Booth Ranches; and Mark McBroom of Bloom to Box Crop Care, Inc. At the CRB's Annual Board Meeting on September 23, 2025, Tony Atchley of Ventura Pacific Company was nominated to complete a remaining term in District Two.

"We are pleased to welcome Aaron Henderson, David Mabs, and Tony Atchley to the Citrus Research Board," said CRB President, Marcy L. Martin. "They bring distinctive experiences from multiple parts of the industry, and we look forward to collaborating with each of them."

Henderson is a native of California's Central Valley and currently serves as part of the AgriCare management team, where he helps to oversee over 3,000 acres of citrus across multiple areas. He has deep family roots in California agriculture, and much of his time is spent navigating the complex challenges of California's water and regulatory environment, coordinating with groundwater sustainability agencies, irrigation districts, and growers to support long-term sustainability.

"I'm honored to serve on the Citrus Research Board and to help strengthen the sustainability and profitability of California's citrus industry," Henderson said. "My goal is to support research that delivers real, practical results for growers—especially in areas of production and postharvest technology, pest management, and water efficiency."

Being raised on a citrus farm in Ducor, California, Mabs was introduced to farming at an early age. He earned a bachelor's degree in landscape architecture from Cal Poly, Pomona, before returning to the Central Valley and beginning his career at TreeSource Citrus Nursery. He currently manages his family farm, Patterson Enterprises, where he has been busy developing their wholesale citrus nursery, GKP Nursery. Additionally, he oversees the production and redevelopment of 400 acres of orchards, half of which is Dekopon citrus. Outside of farming, Mabs is an active member of Porterville Church of the Nazarene and enjoys fly fishing as well as spending time with his wife and three children.

Mabs shared, "While on the Citrus Research Board, I look forward to keeping citrus farming profitable for the average farmer. Citrus in California has always been a good crop for small-scale farms, and I believe we can maintain its viability with innovation and specialized varieties. Each week on our ranches, I spend time at our trellis and high-density plantings, and I'm constantly testing new ideas at the nursery. I hope to bring that creativity and innovative spirit to the CRB."

Atchley is the director of engineering and food safety at Ventura Pacific Company in Oxnard, California. He oversees capital projects, equipment reliability, food safety, quality, and continuous improvement. Atchley comes from a fourth-generation farming family in Ventura County, where they grow lemons and avocados. He is a graduate of Cal Poly, San Luis Obispo, earning his bachelor's degree in bio-resources and agricultural engineering. With his combined deep agricultural roots and advanced engineering expertise, Atchley has spent much of his career advancing efficiency, reliability, and food safety in fresh produce operations. Most notably, Atchley designed and built a state-of-the-art lemon processing facility in 2020.

"While serving on the Citrus Research Board, I look forward to contributing my engineering and operational perspective to support research that directly benefits growers, packers, and the broader citrus industry," Atchley said. "Most importantly, I want to contribute to the Board's mission of safeguarding and strengthening the citrus industry for future generations, while honoring the legacy of growers and packers who have built its foundation."

Please join the CRB in welcoming our newly elected Board members and congratulating those who were re-appointed. We look forward to working with the 2025-26 Board to continue our mission of ensuring a sustainable California citrus industry.

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

CRB STAFF UPDATES

Caitlin Stanton and Graci Bell

Meagan Iott

Graci Bell

Ana Cabello

The Citrus Research Board (CRB) is excited to welcome several new staff to our team, adding to our research, communications, and accounting departments.

Meagan Iott, a dedicated scientist passionate about finding sustainable and economical solutions for growers, joined the CRB as the associate research scientist and brings expertise in a variety of cropping systems and pathogens. In this position, Iott is responsible for organizing CRB's research portfolio by conducting regular communication with researchers, reviewing reports and proposals, and sharing projects with committee members. She will also participate on the *Citrograph* editorial team, conducting professional outreach and planning committee meetings.

Iott has over nine years of experience with Bayer, where she worked in biologics, providing product support and

serving as the project coordinator for their citrus greening project. Most recently, she worked for Ginkgo Bioworks, a biotech company, where she managed the plant pathology lab and met project goals for multiple clients. She holds a master's degree in plant pathology from North Carolina State University and a bachelor's degree in agroecology from Montana State University. Iott is married with two wonderful children and enjoys spending time outdoors and quilting.

Central Valley native Graci Bell joins the CRB as the communications and administrative assistant. Her core responsibilities include assisting in day-to-day administrative tasks, helping with in-house meetings, aiding in event management, and supporting functions of internal programs. Bell recently graduated with a degree in agricultural communications from Cal Poly, San Luis Obispo.

Ana Cabello was recently hired by the CRB as an associate accountant. Cabello has a proven background in financial strategy, compliance, and audit readiness, having previously served as an accounting specialist at Harris Ranch Beef. Cabello provides support across accounts receivable, accounts payable, banking, reporting, and other finance-related functions as needed.

Please join us in welcoming our newest team members. We look forward to their contributions to the CRB as we work together to ensure a sustainable citrus industry for California's citrus growers through our investments in research.

Caitlin Stanton is the director of communications and Graci Bell is the communications and administrative assistant, both at the Citrus Research Board. For additional information, contact **caitlin@citrusresearch.org**

California Citrus: A Legacy Protected Through Integrated Pest Management

Dahmoon Maeesomy

California citrus is more than a commercial industry that fuels our great state — it's a tradition, a livelihood and part of everyday life. But invasive pests and diseases, such as the Asian citrus psyllid (ACP) and huanglongbing (HLB), continue to threaten this legacy. Protecting citrus requires more than just reactive responses — it demands a proactive, sustainable approach rooted in integrated pest management (IPM) principles. This science-based strategy combines biological, physical, and chemical tools to manage pests in the most environmentally and economically sound way possible.

An IPM approach to invasive pests and diseases calls for involvement from not only growers and scientists, but also requires everyday citizens to take action.

From the choices we make in our own backyards, to the steps we take while traveling, everyone has a role to play. That's why the Citrus Pest and Disease Prevention Division's (CPDPD) outreach program recently launched new efforts designed to put residents at the center of the solution and at the heart of IPM.

Backyard Battlegrounds: Residents as IPM Partners

Since ACP first appeared in California in 2008, the main battleground in the fight against the pest and HLB has been fought among backyard citrus trees in California neighborhoods, and the actions of residents can significantly impact and influence IPM strategies. Understanding the importance of their cooperation, the CPDPD has focused on empowering residents with the tools, resources and knowledge to make informed, sustainable decisions that align with IPM principles. One of the newest ways this commitment is coming to life is through the refreshed resident-focused website.

A Fresh Resource: A New Resident-Focused Website

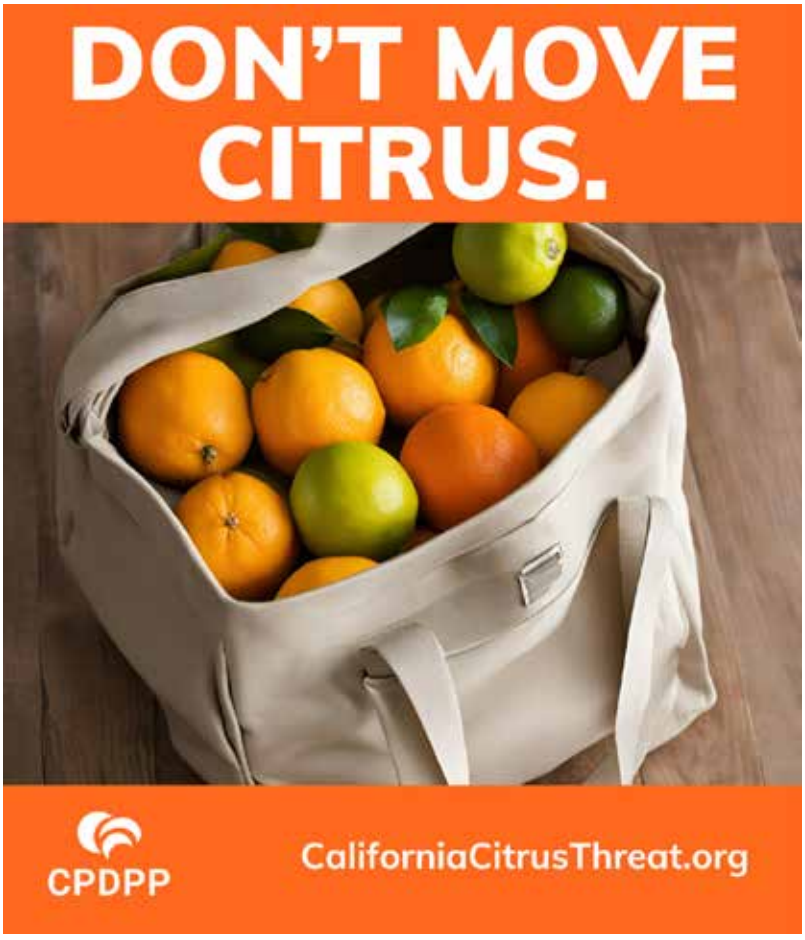
The website, *CaliforniaCitrusThreat.org*, serves as a hub for nearly all residential ACP and HLB outreach tactics. From social media ads and community events to brochures and videos, each outreach element guides residents to learn more about ACP and HLB by visiting the website. In 2025, the outreach team refreshed the website with engaging, relevant content that would incite action and further explain how to apply IPM-based practices. With a new look and feel, the website is equipped with explainer videos, details on emerging invasive threats, and updated FAQs, designed to answer the questions residents ask most: What's happening in my area? How do I spot symptoms? What should I do if I suspect a problem? By simplifying complex information and presenting it in easy-to-use formats, the website serves as a credible starting point for all California residents. It emphasizes early detection, proper sanitation and the use of biological controls — all core components of IPM. Digital resources are only part of the equation. Many residents turn to trusted experts in their own communities when they need answers, especially master gardeners.

Training Trusted Messengers: Master Gardeners as IPM Resources

University of California Master Gardeners are a go-to resource for Californians seeking guidance on backyard citrus trees and plant health. Recognizing their influence and the dynamic nature of the threat ACP and HLB present, the CPDPD outreach team recently conducted a statewide training session to ensure these trusted messengers are equipped with the most accurate, up-to-date information and IPM-based resources. Hosting over 170 attendees, the virtual session focused on the state of ACP and HLB, their symptoms and signs, regulatory best practices for residents, IPM strategies including monitoring, control methods, and responsible pesticide use, and tips for master gardeners on how to best communicate with residents about the pest and disease. With their expanded knowledge, master gardeners can now pass along science-based solutions and prevention practices to numerous residents, thereby multiplying the impact of their outreach efforts and reinforcing IPM principles at the community level. While master gardeners help answer questions close to home, another challenge arises when residents hit the road.

On the Move: Labor Day Travel Campaign

Holidays like Labor Day are peak times for travel, and with travel comes the temptation to share fruit, clippings or potted plants with friends and family. Unfortunately, these well-intentioned gestures can also artificially spread pests and diseases, such as ACP and HLB. To mitigate this risk, the CPDPD outreach team launched an integrated campaign reminding Californians: *Don't Move Citrus* — a simple yet powerful IPM message focused on prevention. Through a bilingual press release distributed to media



outlets statewide and via the California newswire, an audio news release in English and Spanish broadcast to stations statewide, and English and Spanish social media ads targeted to major California markets, the campaign resulted in an estimated 25.5 million touch points. The simple IPM-focused message, urging caution among travelers on-the-go, was a small reminder that leaving citrus at home can make a big difference.

Empowering Residents Through IPM: Education, Engagement, Action

Together, these three initiatives demonstrate a clear pattern: empowering residents through education, engagement and action — all grounded in IPM. Each effort meets Californians where they are — online, in their communities, or on the move while reinforcing the same message that residents have the power to safeguard citrus. By layering strategies, the CPDPD ensures outreach is comprehensive, credible and impactful.

From backyards to road trips, residents play a central role in protecting citrus. With the right tools and knowledge, Californians can help stop the spread of invasive pests and ensure citrus thrives for generations to come. Visit the new website, seek guidance from local master gardeners, and remember to keep citrus at home when you travel. If we work together and apply IPM principles where feasible, we can preserve not only an industry but also a cherished part of California's identity.

Dahmoon Maeesomy is the outreach coordinator for the Citrus Pest and Disease Prevention Program of the California Department of Food and Agriculture.
For additional information, please contact
dahmoon.maeesomy@cdfa.ca.gov

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INDUSTRY VIEWS

Caitlin Stanton

California's citrus growers face many challenges with the variety of pests found in growing areas. For this IPM-focused issue of Citrograph, we spoke with two industry professionals about the problems they are seeing in the field and how the industry can best respond to pest challenges.

DAVID MABS
Patterson Enterprises
Tulare County, California

What pests are you most concerned about this season? How important is it to develop the threshold range and particular timing of activities and management decisions?

By far the most concerning pest for me recently has been the two-spotted spider mite in our citrus nursery. It's not a new pest by any means, but it seems to be making a comeback. It isn't easy to pin down a threshold because of its short life cycle during peak summer temperatures. Humidity is also a significant factor. When conditions are right, populations can explode, and the webbing they create prevents good spray coverage. Scouting often to detect early "hot spots" is key for us. Keeping the population under control ultimately pays off with fewer sprays and "softer" chemicals, but regaining normalcy from a population explosion can be frustrating and expensive. We need ongoing access to effective pesticides we can include in our IPM program.

Are there any new or emerging pests for which integrated pest management programs should be considered?

In recent years, insect populations have been more aggressive in my area. An unknown combination of factors is triggering rapid growth, but it's challenging to predict precisely when this will occur. I'd like to see more research into the environmental factors triggering these explosions and what we can do about them.

JEFF SLOVER
Helena Agri
Fresno, Tulare, and Kings Counties, California

What pests are you most concerned about this season? How important is it to develop the threshold range and particular timing of activities and management decisions?

I am most concerned about citrus thrips and mealybug. Now that we have specific chemicals to treat specific pests, it is more important than ever to understand the timing of their development, so we can time the application of materials to maximize the knockdown of the pest. To accomplish this, more specific information about a pest's development should be provided to the pest control advisors, such as the number of generations and the most susceptible timing for spraying, etc.

Are there any new or emerging pests for which integrated pest management programs should be considered?

I believe the mealybug is an emerging pest that exhibits unique growth patterns, making it challenging to control with pesticides. We released some mealybug destroyers this year with some good results. We also allowed other predators to develop, which helped hold down the population. It would be beneficial to have a pheromone to distribute in the field that would reduce reproduction and consequently, the total population.

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

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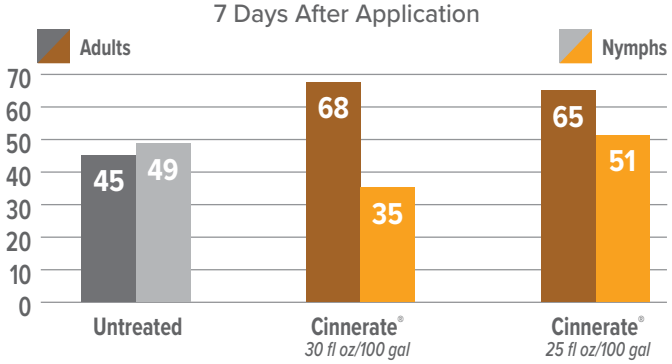
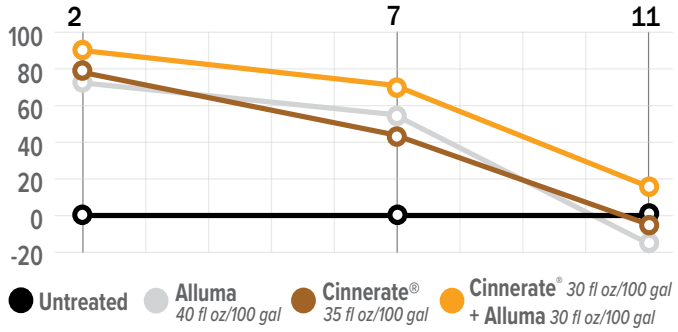


Citrus Mandarin | *Var. Gold Nugget* | Elderwood, CA

Citrus Thrip Control (% of Untreated)
Days After Application



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On the Ground with CA-CRaFT

Ivan Milosavljević

Adult Asian citrus psyllids feeding on tender foliage *(photo by Mike Lewis, UC Riverside).*

Summary

In two operational years, from mid-2023 through September 2025, California's Citrus Research and Field Trials (CA-CRaFT) program has expanded from 1,500 acres to nearly 6,500 acres, keeping Asian citrus psyllid (ACP) numbers extremely low across participating groves. Data collected through CA-CRaFT show that in mature groves, initial infestations begin along grove edges, where psyllids first land, while interior rows often remain pest-free. Coordinated monitoring under the CA-CRaFT program using traps, taps, and canine surveys has made early detection faster and more accurate. Detection dogs have found ACP in about 20 percent of blocks missed by visual scouting, proving their value as a reliable, field-ready tool. Together, these efforts help growers act early, contain infestations, and protect California's citrus industry—representing the first program and dataset of its kind to integrate and assess multiple monitoring tactics across extensive acreage and document ACP colonization patterns in commercial citrus groves.

What Has Been Achieved

Growers have helped the CA-CRaFT program expand rapidly—from about 1,500 acres at its launch in mid-2023 to nearly 6,500 acres by 2024—with most participating groves located in the Imperial and Coachella Valleys (Gehrig 2023; Milosavljević & Gehrig 2025). This growth reflects strong grower confidence and commitment to coordinated, area-wide management of ACP.

Field data collected through the program so far show that CA-CRaFT has successfully kept ACP populations at very low levels across all participating groves from its launch through September 2025 (**Figure 1**). Success has come from a combination of efficient monitoring, regular coordination with growers, and rapid grower response to detections, ensuring that infestations are addressed before they can spread.

In addition to maintaining low ACP levels, CA-CRaFT has delivered the first large-scale, on-farm comparison of multiple detection methods—trap, tap, visual, and canine inspections—under commercial California conditions. Each monitored block was divided into four cardinal directions—north, south, east, and west—to ensure consistent coverage. A yellow sticky trap was placed along the border of each side to capture adult psyllids. Ten randomly selected trees

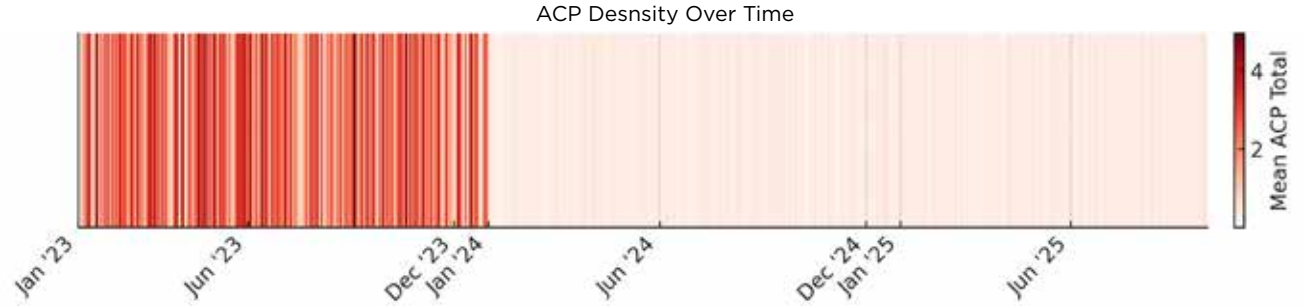

Figure 1: Asian citrus psyllid (ACP) adults and eggs (upper left) and nymphs (upper right) on citrus flush. Close-up views show early-stage infestations used in training canine detection teams and validating field monitoring tools (*photos by Mike Lewis, UC Riverside*). The heat map shows consistently low ACP infestations across participating CA-CRaFT groves from June 2023 through September 2025. "Mean ACP Total" represents the average number of both adults and nymphs per grove on each sampling date, based on visual and tap sampling results, regardless of grove size.

per side, along with ten trees from the grove center, were sampled for both tap and visual flush inspections. Two tap samples were taken per tree by striking branches over a collection tray to record adults resting in the canopy, while visual inspections of two new flush shoots documented nymphs on young growth. Canine inspections involved trained detection dogs walking the full perimeter of each monitored block, checking every tree along the border rows for ACP scent. Handlers recorded each alert by block side, providing a sensitive, scent-based confirmation tool that complements trap, tap, and visual scouting.

Program data shows that adult counts from tap samples have remained near zero, and nymph detections on flush have stayed below 0.1 percent, with no measurable spread into grove interiors. Trap counts and canine detections mirrored these findings, showing consistently low adult numbers across all four cardinal directions.

Where Do ACP Infestations First Occur in Groves?

CA-CRaFT program surveys show a clear and consistent pattern across all monitored groves. ACP activity begins along the outer edges of citrus blocks rather than in the center. These border rows are the first landing and breeding points for psyllids arriving from outside the grove. By combining trap counts for adults, tap samples of canopy adults, visual inspections of nymphs on flush, and canine surveys for all life stages, CA-CRaFT has been able to identify and address these edge infestations before they spread inward. This edge-driven pattern has been reported for ACP in smaller trials in Florida (Boina et al. 2009) and Texas (Sétamou & Bartels 2015), and in California using traps placed near urban interfaces (Bayles et al. 2022). HLB infection patterns in Florida and Brazil (Gottwald 2010) have been shown to follow the same perimeter-based trend. CA-CRaFT is the first to meticulously and systematically document this pattern for ACP at a regional scale using multiple detection tools under commercial citrus-growing conditions in California.

Program results to date show that about 99.5 percent of all ACP detections—both adults from tap samples and nymphs from flush inspections—came from border trees, while only about 0.5 percent were found in grove interiors. When detections were separated by cardinal direction, the pattern was the same; edges consistently showed activity, and interior rows remained nearly pest-free. Cardinal-direction averages did not significantly differ from one another, with adult detections of 30.8 percent in the East, 28.9 percent in the South, 27.3 percent in the North, and 26.4 percent in the West, and corresponding nymph detections of 27.2, 25.4, 23.6, and 23.1 percent, respectively.

Figure 2: Integrated detection methods in CA-CRaFT groves include yellow sticky traps to capture adults on perimeter trees (top photo), while trained detection dogs locate infested trees with high precision (bottom; *photo by Lisa Finke, Canine Detection Services Corporation*).

Program trap data placed along grove borders (**Figure 2**) also aligned closely with tap and visual inspection results, showing strong agreement across all cardinal directions —81.5 percent in the East, 82.8 percent in the South, 79.2 percent in the North, and 81.3 percent in the West.

Figure 3: Kaolin applications and protective netting are used in CA-CRaFT groves. Physical barriers and reflective coatings help deter psyllid landing and oviposition on young citrus shoots.

Collectively, these CA-CRaFT results point to the same conclusion; ACP pressure builds first along the edges, where psyllids encounter the outer canopy before moving inward. Prioritizing monitoring and treatments along these perimeter rows (**Figure 3**) allows infestations to be detected and managed early, saving time, reducing costs, and preventing spread into the grove interiors.

How Effective Are ACP Detection Dogs?

CA-CRaFT results have also identified the use of scouting dogs as one of the most effective new tools for detecting ACP early (Finke & Hajeri 2022). These dogs are specially conditioned to recognize the scent of ACP adults, nymphs, and egg clusters—often long before they can be seen during routine visual scouting (**Figure 2**). Their ability to locate insects at very low densities makes them a powerful addition to traditional trapping and tapping, especially during the earliest stages of infestation or in regions with lower ACP pressure, where early detection is most beneficial.

Seasonal canine surveys within the CA-CRaFT program covered 300 to 500 acres each year, focusing on groves where trap or tap samples collected one week earlier indicated ACP activity, along with "control" groves where field technicians had reported zero psyllids during the same period. Handlers and dogs walked the full perimeter of each block—regardless of grove size—following the same rows sampled earlier by scouts. Every tree along those border rows were checked, including the ten trees previously inspected on each side. Canine results were recorded for each block and cardinal direction and then compared with the tap, trap, and visual findings collected the week before from those same areas, allowing the program to evaluate overall agreement across methods (Milosavljević & Gehrig 2025).

Dog detections matched 85–92 percent of positive or zero tap or visual findings, confirming their accuracy and reliability in commercial field conditions. Agreement was highest in the East (92.2 percent), followed by the South (89.2 percent), North (88.7 percent), and West (84.5 percent). Tap and visual results followed the same pattern, indicating that all detection methods were identifying ACP activity in the same areas at the same times.

One of the most noteworthy outcomes came from the control orchards—blocks that had been inspected by field technicians and recorded zero psyllids through tap and visual sampling. In about 20 percent of these orchards, the dogs detected ACP that had gone unnoticed by human scouts. Follow-up inspections by dog handlers confirmed these detections, demonstrating that dogs can identify psyllids at extremely low population levels. Overall, the results show that canine detection adds a highly sensitive, field-ready

layer to CA-CRaFT. Future efforts will look at how to use dogs where they help growers most—identifying the spots that should be revisited by scouting crews and determining the ACP levels where canine inspections add the greatest value.

Outcomes and Next Steps

After two years of operation, the program has shown, and continues to demonstrate, that consistent edge-focused monitoring and rapid follow-up are key to preventing psyllid establishment and maintaining pest-free groves. The next phase will focus on expanding into Ventura County and other high-risk regions, with management strategies tailored to the specific needs of each area.

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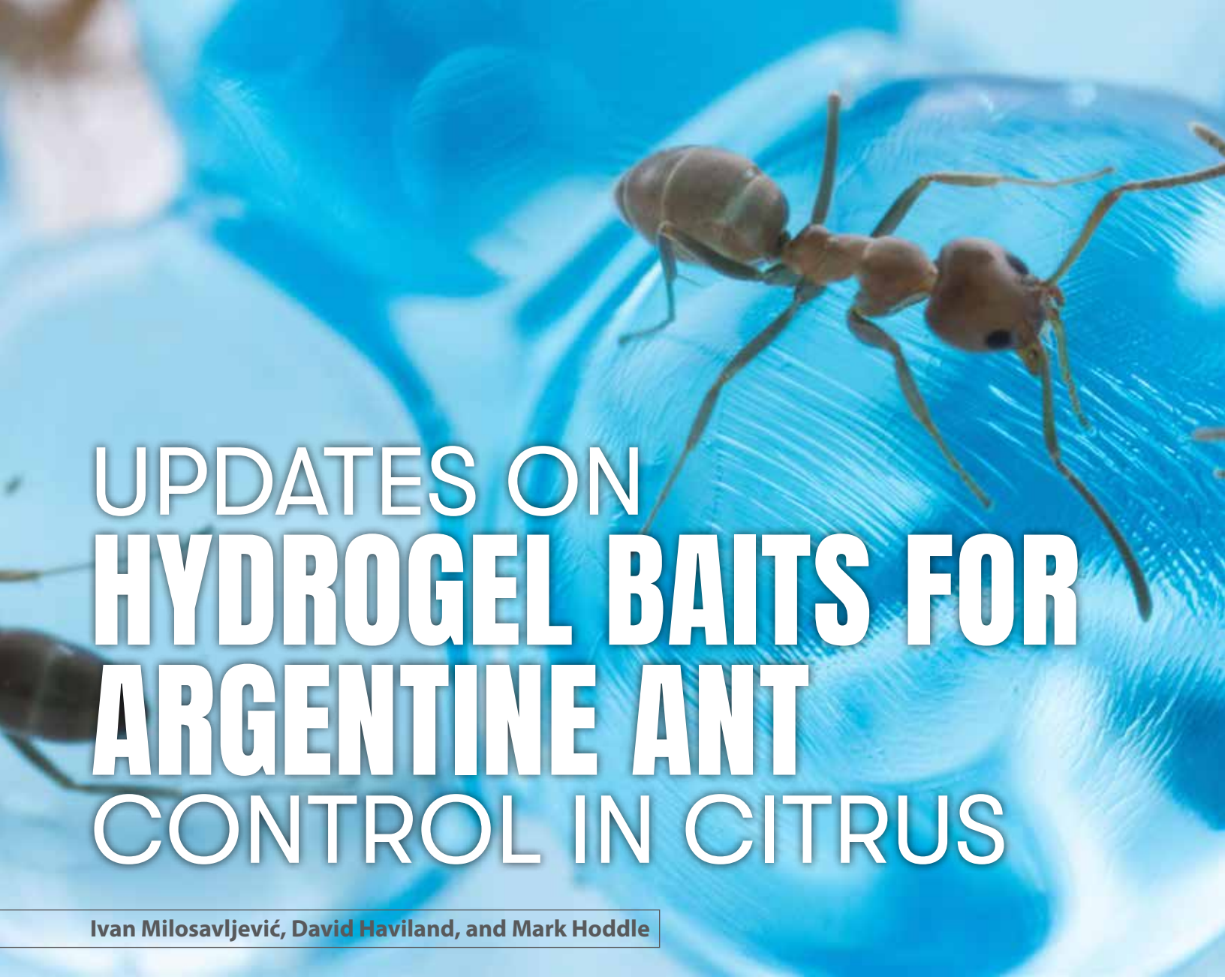

UPDATES ON HYDROGEL BAITS FOR ARGENTINE ANT CONTROL IN CITRUS

Ivan Milosavljević, David Haviland, and Mark Hoddle

Summary

Argentine ants continue to disrupt pest management in California citrus by protecting ACP, mealybugs, and other sap-feeding pests. Their activity undermines biological control, raises the risk of HLB spread, and causes costly packinghouse losses. For decades, chlorpyrifos was the only cost-effective management tool available, but this broad-spectrum insecticide disrupted biological control and failed to eliminate subterranean ant colonies. When chlorpyrifos was banned in 2021, alternative management tools did not exist. Soon after, hydrogel baits were developed as a replacement for chlorpyrifos. Hydrogels infused with sugar water laced with very small doses of insecticide provide toxic food that ants drink and carry back to their nests, where they repeatedly feed queens and brood. As the insecticide load accumulates in the nest, it reaches a lethal concentration causing colonies to die. Field trials with hydrogels consistently show strong levels of ant suppression, improved natural enemy activity, lower pest densities, and no harm to non-target organisms. Ongoing efforts now focus on completing the regulatory process to bring this promising new ant management tool to growers.

Close-up of Argentine ants feeding on biodegradable alginate hydrogel beads infused with sugary liquid dyed with blue food color *(photo by Mike Lewis, UC Riverside)*.

Figure 1. Argentine ants tending to citrus mealybugs and the result of heavy fruit mealybug infestations in one of the experimental plots.

Why Hydrogels?

Argentine ants (AA) and other sugar-feeding ants have long been a stubborn and costly problem for California citrus growers. By tending sap-sucking pests like Asian citrus psyllid (ACP), mealybugs, and soft scales, ants gain access to honeydew, a rich food source. In exchange, they aggressively defend these pests from their natural enemies (**Figure 1**), allowing both ant and sapsucker populations to increase (McCalla et al. 2023). Higher ACP densities heighten the risk of CLas transmission and the spread of huanglongbing (HLB), a lethal citrus disease. Likewise, heavy mealybug infestations cause fruit downgrades or rejections at packinghouses, reducing fruit quality and financial returns (**Figure 1**).

For decades, chlorpyrifos—a broad-spectrum organophosphate insecticide—was the only cost-effective tool available for AA control in citrus. Chlorpyrifos trunk and soil sprays applied along ant trails provided temporary knockdown of foraging workers but rarely reached queens in underground nests, allowing colonies to rebound quickly. Because of its broad-spectrum nature, chlorpyrifos was not IPM-friendly, and it disrupted biological control by killing beneficial insects. Despite these drawbacks, growers did not have other ant control options available to them.

When chlorpyrifos was banned in California in 2021, alternative products did not exist, and the lack of effective IPM-compatible ant control tools became painfully clear. This was the driver for the development of hydrogel baits; a novel low-toxicity approach targeted towards ants, which are highly compatible with natural enemies. Hydrogel baits have the potential to offer growers a practical, sustainable solution for managing AA and other sugar-feeding pest ants in citrus orchards.

Figure 2. Argentine ants drinking a sugary solution laced with thiamethoxam insecticide from biodegradable alginate hydrogel beads during field trials (*photos by Mike Lewis, UC Riverside*).

How Do Hydrogels Work and Which Types Are Being Tested?

Hydrogels are water-absorbing polymers that form a gelatinous matrix capable of holding and slowly releasing liquid. In ant control, they act as miniature bait stations infused with sugar-water containing a very low concentration of an efficacious insecticide. The toxic solution is held within the gel matrix, and its porous surface allows ants to drink directly from it. When hydrogels are applied on the orchard floor beneath citrus trees, foraging ants quickly locate and consume the sweet bait (**Figure 2**). Worker ants then carry the ingested liquid in their foregut[1] back to the nest and share it with nestmates—other workers, broods, and queens —through trophallaxis, a food-sharing behavior that ensures the toxic sugar water reaches the reproductive members of the colony. Once they die, no new ants are produced, and the colony collapses.

Two types of hydrogels are currently being tested in citrus for ant control (**Figures 2** & **3**). Biodegradable alginate hydrogel beads can be made by growers using food-grade sodium alginate and calcium chloride. After soaking overnight in sugar-water with insecticide, the beads are ready for use the next morning. Their simple preparation and non-toxic composition make them a highly promising insecticide delivery tool with high potential for use in organic orchards.

Polyacrylamide crystals are the second type of hydrogel. Sold as dry crystals in bulk, they absorb sugar-water and toxicant to form hydrated gels that are easy to prepare in large volumes and apply directly to the orchard floor. They are inexpensive, quick to use, and ideal for large-scale applications in conventional citrus operations. However, because of their petroleum-based polymer structure, they are not suitable for use in organic systems. Encouragingly, both hydrogel types have worked well in field trials against different sugar-feeding ants, including AA.

How Effective Are Hydrogels for Controlling Ants?

Our previous work showed that thiamethoxam, a neonicotinoid insecticide, applied at 0.001% in hydrogels, was the most effective treatment for controlling AA in conventional citrus. In organic systems, spinosad at 0.01% performed equally well when delivered in biodegradable alginate hydrogel beads. At these concentrations, both active ingredients reduced ant numbers by about 80% compared to untreated control plots (Milosavljević et al. 2024). Similar results were observed in table grape trials targeting the native grey ant, a common species tending mealybugs in Central Valley citrus (Haviland, *unpublished data*).

Building on these results, our 2024 field trials in citrus groves in San Diego and Fresno counties showed that applying 5–10 gallons of polyacrylamide hydrogel per acre, combined with 25% sugar solution and 0.001% thiamethoxam, was highly effective against AA (Milosavljević & Haviland, *unpublished data*). In treated plots, AA activity dropped below the action threshold of 60 ants per minute—the level at which predators and parasitoids can function effectively. Ant tending of mealybugs fell below 20%, while predator attacks on mealybugs increased by 35%, indicating a strong resurgence of natural enemy activity when AA densities were reduced (Milosavljević & Haviland, *unpublished data*).

Figure 3. Automated large-scale application of polyacrylamide hydrogels in experimental plots in San Diego County using an ATV equipped with a seeder (left) and buckets with prepared polyacrylamide gels (right).

Timing of hydrogel applications is key to maximizing their impact. Field trials in citrus showed the greatest efficacy when baits were applied early—during April through May in the Central Valley and May through June on the Central Coast—when both ant and pest populations were low and hydrogels served as the primary sugar source in orchards. (Milosavljević & Haviland, *unpublished data*). These results suggest that early-season ant control helps slow mealybug buildup on fruit later in the year by allowing natural enemies greater access to their prey.

Do Hydrogels Harm the Environment?

One of the main advantages of hydrogels is their use of extremely low insecticide concentrations—10 to 100 times lower than standard citrus-approved foliar sprays with the same active ingredients (Haviland et al. 2023). Because gels are applied directly to the ground where worker ants forage, treatments are highly targeted and leave no residue on leaves or fruit.

Our recently completed field studies in California citrus orchards, supported by studies from other habitats such as grasslands, urban gardens, and apiaries, found no evidence of harm to non-target organisms such as bees or larger animals (Buczkowski 2020). Videography of hydrogels placed in commercial citrus orchards during the 2024–2025 field trials (Kwon 2025) further support these findings, with preliminary analysis indicating negligible risks to non-target organisms.

Next Steps: Where Do We Stand with Hydrogel Registration?

Getting hydrogels into growers' hands depends on clearing a complicated regulatory pathway. Due to the novel use of hydrogels in distributing pesticides for AA control, there are currently ongoing discussions between the California Department of Pesticide Regulation (CDPR) and the U.S. Environmental Protection Agency (EPA) to decide the best regulatory path forward. Follow-up meetings are taking place between the agencies and additional scientists to continue their discussions on this topic. We continue to work closely with all regulatory stakeholders to move both hydrogel types forward for use by growers.

As the regulatory process advances, the next phase of work will focus on broadening the IPM toolbox—identifying new or additional insecticides that can be used in hydrogels for ant control, exploring the use of combining multiple insecticides with different modes of action in hydrogels to reduce the risk of insecticide resistance, and fine-tuning application timings, rates, and frequencies. We will also

target additional ant species, such as grey field ant, work to reduce application costs for growers, and work to get full support from CDPR so that commercial adoption can be realized. Once these milestones are achieved, hydrogel baits are expected to become a cornerstone of sustainable pest management in California citrus.

Glossary

[1]Foregut (crop): A storage part of an ant's digestive system where liquid food is held before digestion.

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RECAP OF THE CITRUS POST-HARVEST CONFERENCE

Caitlin Stanton and Joey S. Mayorquin

The Citrus Post-Harvest Pest Control Conference is a long-standing meeting for the California citrus industry to share the latest information in post-harvest technologies. This meeting originally was organized as an extension course in 1978 through the University of California, Riverside (UCR) and was overseen by Joseph Eckert, Ph.D., a renowned citrus post-harvest pathologist. In 1993, UCR cooperative extension specialist of subtropical horticulture, Mary Lu Arpaia, Ph.D., assumed responsibility for producing the conference. While the Citrus Research Board (CRB) became the official co-organizer of the conference in 2017, the CRB began providing input into the program in 2009. Since its inception, the conference remains committed to its original objective of providing technical information to packinghouse personnel and service providers in the areas of post-harvest pest management, quarantine requirements, trade issues and, more recently, food safety issues.

Conference Recap

On September 4, 2025, the 42nd Citrus Post-Harvest Conference was held in Visalia, California. The conference was well-attended by more than 100 participants from both academia and industry. A diverse group of speakers representing academia, government and private industry provided conference attendees with the most up-to-date information on critical post-harvest disease control and food safety areas and included a special discussion about current and future trends in citrus retail buying. As the conference is geared toward industry personnel, service company representatives, and packinghouse professionals, the conference also provided attendees with the opportunity to network with their peers.

Eight speakers were invited to share their expertise with conference attendees in one of four main areas: food safety, disease management, post-harvest technologies, and trade issues. This year's speakers represented George Nikolich Consulting, the University of California (Riverside and Davis), Walmart, the United States Department of Agriculture-Agricultural Research Service, Syngenta, and the California Citrus Quality Council (CCQC).

Food Safety Session

Food safety presentations were provided by George Nikolich and Luxin Wang, Ph.D. Nikolich opened the conference with a look into establishing a clean break—a defined production break that involves documented cleaning and sanitation of surfaces that come into contact with food products. Nikolich stressed the need to develop sanitary standard operating procedures (SSOPs), continued training, and vigilant record keeping to maintain a food safe facility. Wang's presentation shared information on waxing roller brush materials, patterns, and how enhanced cleaning and sanitation could reduce microbial counts on these brushes. Following the two presentations, Nikolich and Wang were joined by Ahmed El-Moghazy, Ph.D., for a food safety panel to discuss food safety monitoring and outbreak responses, as well as answer questions from the audience.

Disease Management Session

James (Jim) Adaskaveg, Ph.D., provided two presentations on post-harvest fungicide use. The first presentation focused on management of Septoria spot, Phytophthora diseases, Penicillium decays, and sour rot. Septoria spot sporulation has been found to be best controlled by an application of Azoxystrobin/Fludioxonil and/or thiabendazole prior to fruit coating and/or in a fruit coating or wax. Management of Phytophthora diseases needs to be completed in an integrated system using a combination of cultural practices, preplant fumigations and fungicides. There are a variety of fungicides available for pre-harvest use with several newly registered, such as Orondis® and Revus®, as well as registration ongoing for Elumin®. For post-harvest use, potassium phosphite was highly effective when applied after soda ash and a water rinse. Cyproconazole is being studied for post-harvest treatment of Penicillium decays and sour rot and is on track to be available for use in the next several years. Cyproconazole was also found to be compatible with chlorine, sodium bicarbonate and peroxyacetic acid. Adaskaveg's second presentation discussed propiconazole resistance in sour rot, noting *Geotrichum citri-aurantii* is the primary sour rot pathogen in healthy, non-senescent citrus fruit, whereas *G. candidum* is only a weak pathogen on senescent fruit with weakened defenses. For resistance monitoring, moderate and high resistance phenotypes were identified in a *G. citri-aurantii* and a single gene was determined to confer this resistance. General management strategies include avoiding fruit injuries, applying post-harvest treatments within 14-18 hours of harvest, and using different mixture rotations in pre- and post-harvest treatments.

Retailer Discussion

New this year, the Post-Harvest Conference featured a retailer discussion with a representative from Walmart's citrus buyer, Nicholas Robbins. Robbins discussed buying trends he is seeing in the industry and how Walmart approaches food safety requirements. Throughout the discussion, Robbins answered questions from industry members and provided thoughtful insight on the future of California's industry. We look forward to including more retailer-driven discussions at future conferences.

Post-Harvest Technologies Session

Predictive modeling is an important tool to provide insight. Wenlin Chen, Ph.D., discussed how he is using predictive modeling to forecast crop residues to develop new postharvest products at Syngenta. While these models aren't designed to replace traditional product studies, they do help support more efficient product development.

Trade Issues Session

Spencer Walse, Ph.D., discussed managing quarantine pests. He highlighted tephritid fruit fly outbreaks which, through a post-harvest fumigation 'systems approach,' involves several treatments in tandem that provide enhanced/acceptable pest mortality rates. Dr. Walse also highlighted several trials his lab is working on, using ethyl formate, phosphine and cold treatments as part of this 'system's approach.' To conclude the conference, Jim Cranney of the CCQC shared an update on trade issues, including imports, tariffs, market access, and maximum residue levels.

Looking Forward

The Citrus Post-Harvest Pest Control Conference continues to provide the California citrus industry with a forum where valuable technical information can be exchanged. The industry is committed to staying at the forefront of post-harvest issues, and the research needed to address these issues. The CRB looks forward to continuing its role as a co-organizer of the conference.

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Brown garden snails feeding on a green citrus fruit on the orchard floor.

When Brown GARDEN SNAILS Take Over the Grove

Ivan Milosavljević, and Xavier Martini

Summary

Brown garden snails (BGS) are becoming a serious problem in California citrus. With mild winters, irrigated orchards, and weedy vegetation, it creates a perfect environment for these pests to thrive. Their long life span, reproductive capacity, and tendency to cluster also make them persistent and hard to control. Growers rely on baits, decollate snails, trunk barriers, and rescue sprays for management, but these are more individual efforts than coordinated IPM programs. New Citrus Research Board (CRB)–funded work is evaluating traps and refining baiting strategies as the first step toward a true integrated program that improves timing, combines tactics, and reduces reliance on broad-spectrum chemicals.

Why Are Brown Garden Snails Such a Problem in Citrus?

Brown garden snails (*Cornu aspersum*; [BGS]) are becoming a serious and persistent problem in California citrus orchards (**Figure 1**). Originally brought from France in the mid-1800s as a delicacy, this Mediterranean species escaped into the landscape through nursery trade and ornamental plant movement. California's mild winters, irrigated groves, and shaded canopies provided ideal conditions for it to thrive, and so over time, this slow-moving but remarkably well-adapted invader spread across citrus-growing regions in California. Their biology makes them particularly tough to manage. BGS are simultaneous hermaphrodites, meaning each snail has both male and female reproductive organs. After mating, both individuals can lay eggs. In simple terms, every adult can produce the next generation. This gives the species a lot of reproductive flexibility and helps them establish quickly in new areas by making it easier to find a mate even at low densities.

BGS live for several years and rely on moisture to stay active. They return to the same hiding spots night after night, follow each other's slime trails, and gather in sheltered places like weeds, skirts, braces, irrigation lines, or debris at the base of trees. They lay multiple batches of eggs in protected soil crevices, and it can take up to two years for young snails to mature. This slow buildup, followed by sudden surges after wet winters, make populations especially hard to keep in check.

When hot and dry weather arrives, snails seal themselves inside their shells and wait for the next rain or irrigation to reemerge. Citrus orchards offer everything they need year-round. Regular irrigation keeps the soil moist; the canopy provides shade, and the orchard floor gives them plenty of hiding spots. After wet winters, it is not unusual to find thousands of snails clustered on a single tree. Using their rasping tongue, called a *radula*, they scrape away the fruit's colored rind, exposing the white albedo underneath and leaving scars that are easily flagged at the packinghouse (**Figure 1**). Even light feeding can open the door for pathogens to enter and increase the risk of decay, while heavy damage usually means the fruit is automatically culled. On young trees, nighttime feeding can defoliate shoots, strip bark, and even kill trunks outright, setting orchard establishment back by years. All of this makes BGS a stubborn and costly pest to deal with.

What Are Growers Doing Now?

Most growers use a mix of individual tactics rather than one coordinated program to manage BGS. Each method can help, but timing and how these methods are combined often make the difference between control and frustration.

Figure 1. Pruned tree branches, fallen fruit, and orchard debris act as reservoir spots for brown garden snails, providing shelter and breeding sites.

Figure 2. Copper-painted tree trunks help prevent brown garden snails from climbing into canopy and damaging fruit (left). However, removing rootstock suckers is crucial, as these shoots can form a bridge over the paint barrier, enabling snails to climb from the ground onto the tree (right).

Baits are the primary tool used by growers (Morse et al. 1985). Pellets containing metaldehyde or iron phosphate work best after rainfall, heavy dew, or irrigation when snails are actively foraging. Placement matters just as much as timing. Bait bands at the drip line or between rows can pull snails away from trunks, and smaller pellets are usually more attractive. When baits go out at the wrong time, they are often wasted because snails are inactive in refuges. Additionally, once snails climb into trees, baits are of little use. Some growers have also reported baits seeming less effective than in the past, although molluscicide resistance in snails has not been well studied. This makes timing and strategy all the more critical. Metaldehyde baits can also be very toxic to pets and wildlife, so they need to be handled with extra care.

Cultural practices are also essential. Lifting canopy skirts about two to three feet off the ground removes the bridge snails use to climb into fruiting wood. Cleaning up weeds, leaf litter, and dropped fruit eliminates refuges and moisture pockets where snails hide. Weed management is particularly important because tall vegetation allows snails to bypass trunk barriers. Good irrigation discipline, such as avoiding prolonged surface wetting and fixing leaks, helps dry out the areas snails rely on.

Exclusion methods add another layer of defense. Copper-based trunk sprays or copper bands can create strong barriers that snails avoid crossing (**Figure 2**). Plastic trunk collars can also help by forming a smooth surface, making it difficult for snails to climb.

In the past, some growers turned to broad-spectrum sprays as a rescue measure when snail populations exploded in canopies, and other methods fell short. There are currently no sprays registered for snail control in California citrus, and even when they were available, they were not ideal. These products were non-selective, posed risks to beneficial insects, and could trigger secondary pest flare-ups. With chemical rescue options now off the table, effective control depends on smart use and coordination of other measures. These methods work especially well in young orchards, where canopies sit lower and snails can reach fruiting wood more easily. They can also be effective in older trees, as long as skirts are lifted, and there are not weeds, braces, or irrigation lines touching the trunk that snails could use as bridges to bypass the barriers. Regular cleaning or reapplication is essential to keep them working, though this can be time-consuming and costly.

Figure 3. Adult decollate snails (left and top right) with elongated shells, and comparison with brown garden snails (bottom right) showing the difference in shell shape and size *(photos by Mike Lewis, UC Riverside).*

Can Biological Control Help?

Growers have experimented with biological control in citrus for decades, and some of the most memorable stories come from coastal Ventura County (Bosch 1992). Along the coast, some organic growers once used ducks to clear out snails. Ducks are voracious snail eaters, and in some groves, they dramatically reduced or even eliminated infestations. However, modern food safety and health regulations no longer allow poultry in commercial citrus, so this once-effective strategy is no longer permitted.

Decollate snails (Sakovich et al. 1984) have also been used as a biological control tool (**Figure 3**).These snails feed on eggs and small juveniles of BGS. Some growers have collected them from areas where they are abundant and moved them into infested blocks to help suppress populations. Results, however, have been mixed. Decollates are facultative predators, not specialized snail hunters, so they don't always establish well. Their use is also limited to the counties in California where they are already present because of concerns about their impacts on native snails and slugs. Another key limitation is that decollates do not climb trees, so once BGS move up into the canopy, decollates provide no control. Where they do persist, they can help keep populations down over time, but they are not a quick or complete solution (Fisher et al. 1980).

Predatory beetles offer another potential avenue. One intriguing possibility is exploring specialized snail-eating ground beetles known as *Scaphinotus*. There are at least 15 species of these beetles in California, all adapted to hunting snails. Their long, narrow heads allow them to reach inside snail shells, making them highly effective predators in their native habitats. Investigating their potential use in citrus would require long-term research and regulatory approvals, and there is no guarantee it would work, but it remains a potential future option.

For now, biological control plays more of a supporting role than a primary solution. Knowing how it fits in with other IPM tools helps growers use it more effectively and get better overall results.

What Could a Real IPM Program for Snails Look Like?

BGS management in citrus has mostly relied on individual tactics used at different times, with little coordination. While each tool can help on its own, this piecemeal approach has never added up to consistent, lasting control. One of the biggest hurdles is timing. BGS activity changes with orchard conditions and the season, and if treatments are not timed when snails are most active and exposed, even good tools can end up wasted.

Not much structured research on BGS has been done in California citrus since the 1990s, so this is very much a fresh start. A new CRB–funded project with the University of Florida is tackling this gap by primarily focusing on trapping. We are adapting practical trap designs developed in Florida for ghost snails (*Bulimulus bonariensis*) to see how well they work against BGS in citrus orchards here. The trap structure and the bait inside will both be critical to success, and effective designs need to attract snails while avoiding non-target impacts.

If these traps work as expected, they'll give us a way to pinpoint when and where BGS activity peaks across the season. That information will help identify hotspots within orchards, so control efforts can be focused where they are needed most rather than spread thin everywhere. Better timing and more strategic placement should make baiting and sanitation efforts more effective and economical over time.

This is just the first step toward building a true, coordinated IPM program for snails. In the long run, trapping and improved baiting will need to be combined with cultural practices like sanitation, canopy skirting, and physical exclusion to manage populations before they surge into canopies. Other strategies, like disrupting snail trails to limit their movement and reproduction, could also play a role as the program develops. The goal is a practical, grower-focused approach that uses multiple compatible tactics in a smart, coordinated way—not a patchwork of one-off measures.

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Targeted ACP Biological Control WITH CALIFORNIA ADAPTED *TAMARIXIA RADIATA*

Raju Pandey

Closeup of *Tamarixia radiata* adult (*photo by Mike Lewis, UC Riverside*).

Summary

Parasitic wasp Tamarixia radiata *imported from Pakistan has successfully established in California environments, playing a key role in suppressing invasive Asian citrus psyllid (ACP), primarily in urban residential areas. Efforts to collect* T. radiata *from coastal to desert-like environments has successfully led to establishing various isolines that are being used for supplying source material to the California Department of Food and Agriculture's (CDFA) mass production programs. Incorporating fresh blood from the fields will help keep the mass-produced wasps in good health and fitness, which can provide more effective pest control in a targeted manner.*

Asian citrus psyllid (*Diaphorina citri*; ACP) is the vector of the phloem-limited bacterium *Candidatus* Liberibacter asiaticus (CLas), the causal agent of the citrus greening disease, huanglongbing (HLB). ACP was first detected in California in San Diego and Los Angeles counties in 2008 (Grafton-Cardwell et al. 2011) and has widely established in several citrus growing counties throughout the state. The first HLB positive tree in California was discovered in 2013 in Los Angeles County (Kumagai et al. 2013). Since then, over 10,000 residential citrus trees in Southern California have tested positive for HLB, and the ACP-HLB complex continues to be the greatest threat to the California citrus industry.

Tamarixia radiata, a natural enemy of ACP, is widely distributed throughout Asia. This tiny wasp was identified as a potential biocontrol agent to limit ACP spread in California. After rigorous quarantine evaluation, *T. radiata* release in California started in 2011. Over 33 million wasps have been released, mostly in residential areas in Southern California. Subsequent surveys have shown that *T. radiata* has successfully established itself in the state. Parasitism by *T. radiata* exceeded a rate of 60% during periods of peak activity and was determined to be a significant factor in ACP population control. Additionally, field surveys have shown that densities of all ACP life stages have decreased by more than 75%, and it is believed that *T. radiata* has played a significant role in slowing the spread of ACP and CLas in California (Milosavljević et al. 2021).

Tamarixia wasps originally brought from Pakistan were maintained at the University of California, Riverside (UCR). To support a robust production program, parental lines were

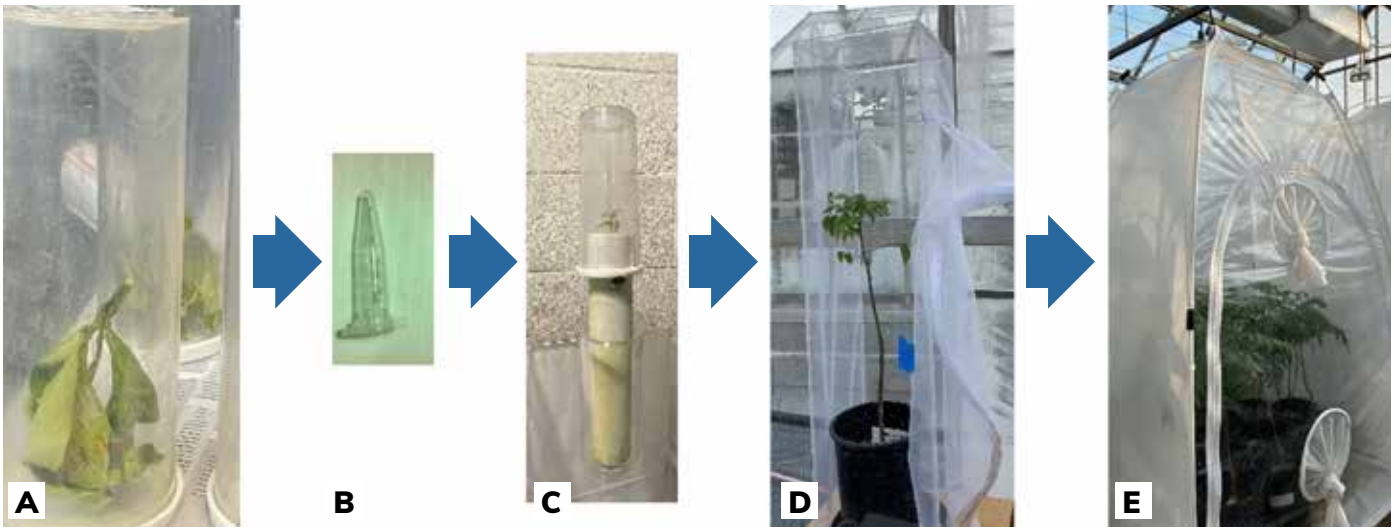

Figure 1. Schematic representation of steps (not to scale) involved in production of *Tamarixia radiata* isolines: a. Field collected material in a vial; b. Emerged *T. radiata* collected in a small tube; c. *T. radiata* pair provided with late instar ACP nymphs in a nursery; d. *T. radiata* progenies from nursery transferred to an acrylic cage for isoline production and maintenance; and e. Mass sting cage where individuals from various isolines are mixed to produce source material for mass production cages.

developed and maintained to maximize genetic diversity. These lines were used as source material for mass production of *T. radiata* for field releases across California and handed over to the Citrus Research Board in 2021.

After continuous rearing of insects in captivity for prolonged periods, lab-maintained populations tend to lose their desired fitness characteristics (such as host searching ability, field survival etc.). The introduction of field-adapted materials as parental lines is a common practice to rejuvenate the vigor of insects used for mass production.

Attempts to collect parasitoids adapted to California climate, from the mild coast to the hot and dry desert were successful. The process started by attempting to locate and establish *T. radiata* collected from various California environments including coast, inland and desert areas. Information about sites with active ACP and T. radiata populations was received through the CDFA, local pest control advisors, and county staff. Multiple field visits were made to previous T. radiata release sites (when more than one year had passed since wasps were released), or sites that were at least a mile away from a recent release. ACP nymphs and mummies were collected and transported to the laboratory for further observation and incubation (**Figure 1A**). Twenty late instar ACP nymphs were provided every day for five consecutive days (one hundred total nymphs) to a single female and male from the same field site (**Figure 1C**). Wasps emerging from this 'nursery' were transferred to acrylic cages with single curry leaf plants with suitable stages of ACP nymphs (**Figure 1D**). The acrylic cages with isolines were placed within another BugDorm® to avoid accidental contamination between lines. Progenies from the isolines were mixed and multiplied in larger BugDorms ® commonly known as 'mass-sting' cages (**Figure 1E**). Wasps collected from these mass-sting cages were then used as source materials for CDFA's mass production program.

So far, *T. radiata* has emerged from 52 field-collected parasitized ACP nymphs/mummies, of which the highest occurrence was from the inland region (26), followed by coastal (19) and desert (6) regions. Success of *T. radiata* collection from the field appears to be primarily affected by seasonal fluctuations in ACP population. The parasitoid recovery was higher from ACP nymphs collected from fall flush (November-December) than in the summer flush (June-July) (**Figure 2**). The winter flush harbored little ACP, probably due to unfavorable cooler temperatures.

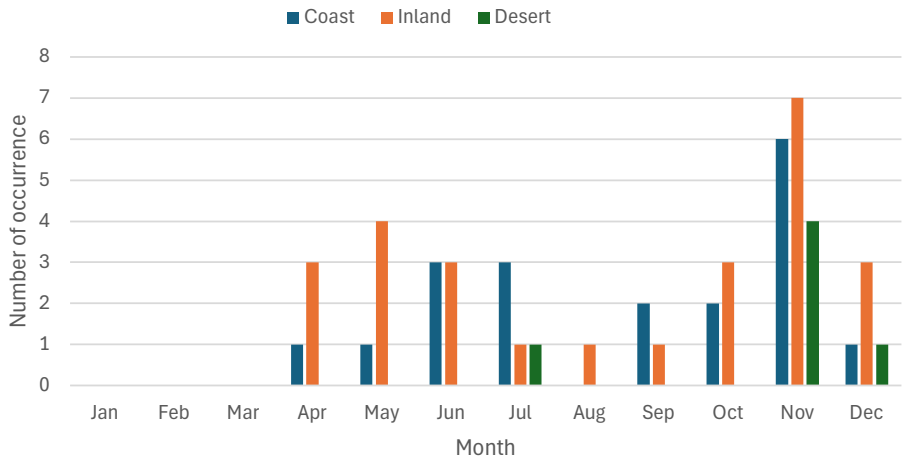

Figure 2. Emergence of *Tamarixia radiata* from field collected Asian citrus psyllid nymph and mummies during various months.

The analysis of mitochondrial DNA sequence can provide a quick assessment of genetic variation among *T. radiata* isolines collected from the field. Samples were tested at Rugman-Jones lab at UCR. So far, H2 Haplotype has been found most often followed by H4 and H16 (**Figure 3**). Other haplotypes recovered from the field included H2e, H3, H17, H18, H20 and H31. All these materials represent the materials collected from Pakistan.

The original Pakistan lines have been completely replaced by California-adapted lines from desert, coastal and inland environments. We anticipate a more effective and efficient use of resources if releases are made to the regions with *T. radiata* produced by using source materials that are adapted to the target environment. At present, we have three desert lines, four coastal lines, and nine inland lines. Our efforts to collect more California-adapted lines will continue. Our plan is to collect and maintain at least fifteen lines, five lines from each environment. The isoline material production in the greenhouses stabilized in 2025 (**Figure 4**).

Once we have enough lines, we plan to produce two mixes: a desert and inland mix for desert and inland areas and a

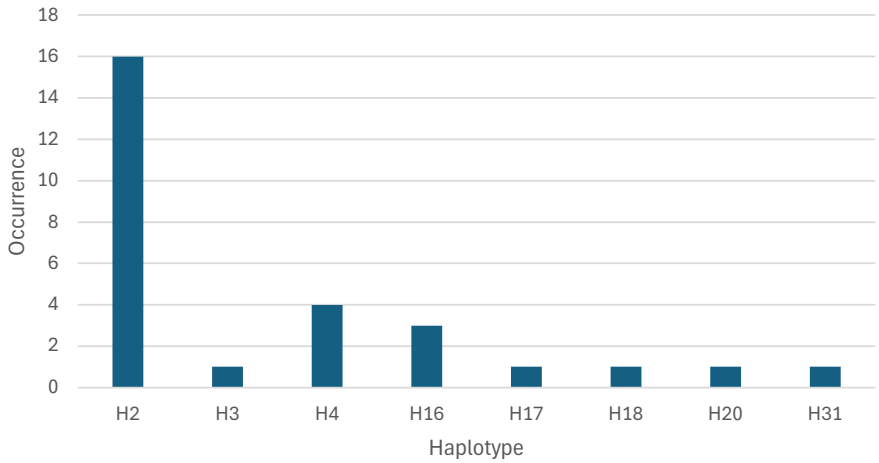

Figure 3. Genetic analysis of California-adapted *Tamarixia radiata*.

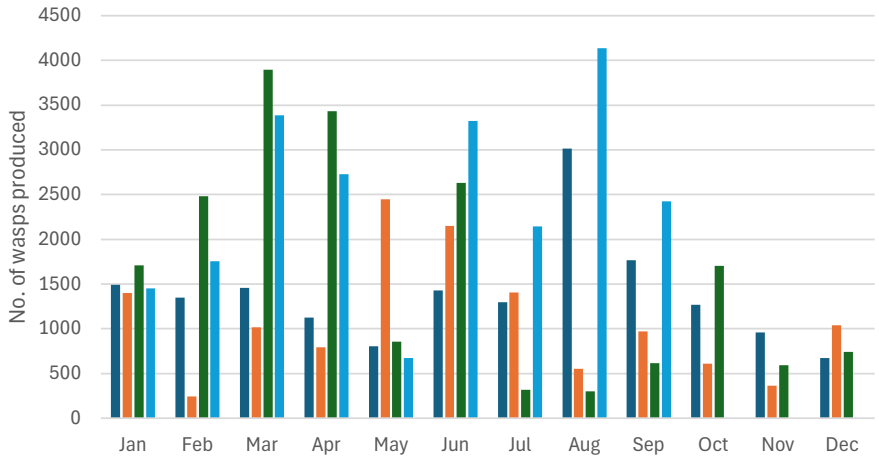

Figure 4. Summary of *Tamarixia radiata* isoline materials produced.

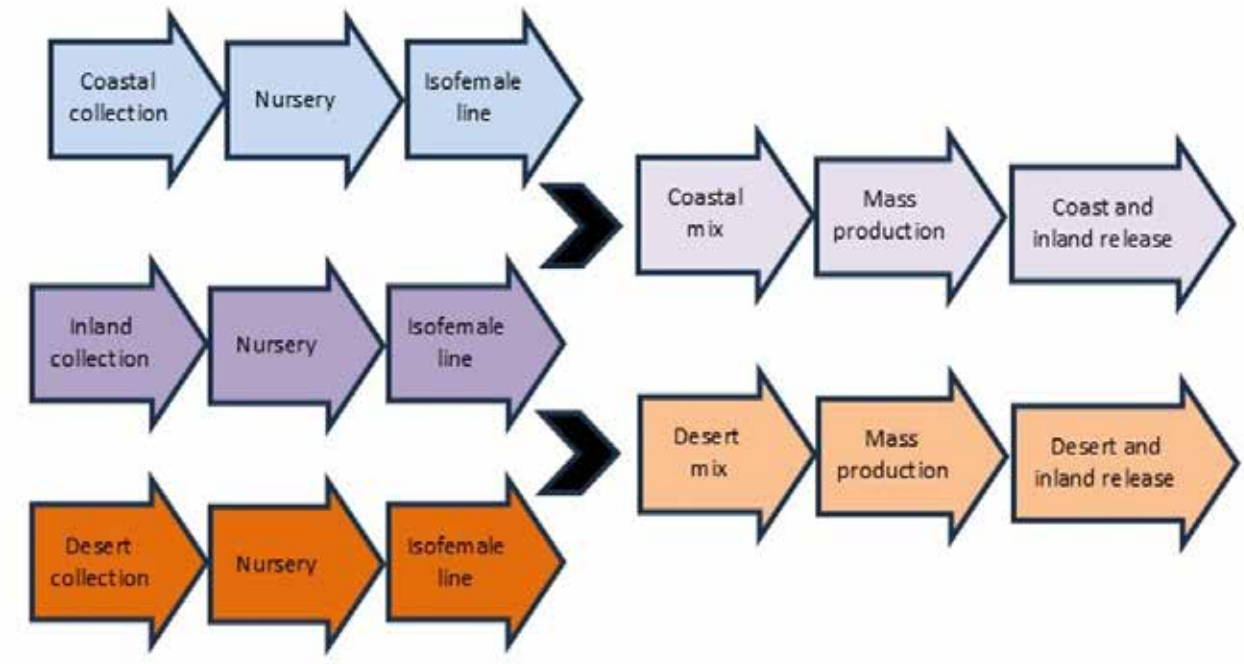

Figure 5. *Tamarixia radiata* isoline proposed usage plan within California citrus growing regions.

coast and inland mix for inland and coastal areas (**Figure 5**). We expect this scheme will optimize *Tamarixia* activity by matching adapted isolines to their environment and will avoid releasing desert adapted materials along the coast or vice versa.

So far, ACP has not been established in the Central Valley, however, should it get established there, our plan is to release *T. radiata* from all available lines. Once *Tamarixia* is established, efforts will be made to collect isolines from the Central Valley for further multiplication.

CRB Research Project #5500-226

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DEVELOPING SELF-DISPERSING TAMARIXIA CAGES

for Biocontrol of Asian Citrus Psyllid in Commercial Orchards

Raju Pandey and Ivan Milosavljević

Summary

Self-dispersing Tamarixia cages represent a promising step toward sustainable Asian citrus psyllid (ACP) control in commercial citrus. By turning part of the orchard into a living insectary, growers can produce and release beneficial wasps where they are most needed. By using curry leaf as a host plant, careful pruning, and timed ACP and Tamarixia radiata *inoculations, cages can sustain wasp production for several months. While practical challenges like gophers, ants, and weeds must be addressed, the system shows strong potential to reduce ACP populations and strengthen biological control. Continued work is focused on refining management protocols and integrating cages into broader integrated pest management programs.*

The Problem at Hand

The Asian citrus psyllid (ACP), *Diaphorina citri*, remains one of the most serious threats to California citrus because it transmits *Candidatus* Liberibacter asiaticus (CLas), the bacterium associated with huanglongbing (HLB) (Bové 2006). By the time ACP was detected in California in 2008, the devastating impact of the ACP-HLB complex on Florida's citrus industry was already clear, spreading rapidly and reshaping their citrus industry. In response, the California citrus industry worked closely with state and federal agencies to take swift action to avoid a similar fate. A key strategy was to identify, import, and release natural enemies of ACP to help suppress populations, especially in urban areas where insecticide applications are not practical.

Two ACP parasitoids[1], *Tamarixia radiata* and *Diaphorencyrtus aligarhensis*, were imported and evaluated under quarantine at the University of California, Riverside (UCR). Both species were cleared for release by the United States Department of

Figure 1. Building a field cage.

Agriculture (USDA) and introduced into urban areas as part of the classical biological control program. *T. radiata* adapted successfully and has become a key biological control agent, while *D. aligarhensis* did not (Milosavljević et al. 2021, 2022). Following its establishment, *T. radiata* production was scaled up at UCR, the California Department of Food and Agriculture (CDFA), and a private insectary under controlled conditions. The Citrus Research Board (CRB), with USDA support, also developed a field cage insectary system using mature citrus and curry leaf trees to produce *T. radiata* more quickly and cost-effectively. To date, more than 33 million wasps have been released across California, primarily in urban neighborhoods where controlling ACP populations with insecticides is unrealistic.

Despite this success, commercial citrus growers in California have had limited direct access to *T. radiata*. The only private insectary that produced these wasps at scale discontinued operations, noting high costs associated with maintaining host plants, psyllid colonies, and labor-intensive collection and distribution. This gap raised a key question: Could we create a system that produces and disperses *T. radiata* directly within commercial groves, in a way that is practical, affordable, and sustainable?

Field Cages as a Solution

To answer this question, we are adapting the experiences we learned from the field cage insectary approach into a self-dispersing Tamarixia cage system, designed to function directly in the orchard. These cages are intended to act as in-field insectaries, producing a continuous supply of wasps that disperse naturally into surrounding citrus trees to provide ongoing biological control of ACP.

The cages being used for these trials measure 5 × 5 × 6 feet and are built with UV-stabilized 52 × 52 mesh fabric. They are supported by a metal pipe frame and secured with 18-inch stakes for stability. A double-door entry system allows access to the parasitoid while minimizing ACP escapes (**Figure 1**), and the roof is fitted with an alternate mesh that allows the smaller *T. radiata* to leave the cages while retaining the ACP inside. The base of each cage is buried in the soil to seal the perimeter. This simple, yet durable structure enables the establishment of a self-contained ACP–*Tamarixia* colony that generates a steady supply of beneficial wasps where they are most needed.

How the System Worked

Inside each cage, curry leaf plants (*Murraya koenigii*) were grown as host plants for ACP. Curry leaf is immune to CLas (Beloti et al 2018), making it ideal for ACP rearing in disease-free areas. It grows rapidly, responds well to pruning, and produces frequent flush—perfect conditions for ACP production and development.

Two curry leaf trees were planted per cage. One was pruned while the other retained actively growing tips. One hundred greenhouse-reared ACP adults were introduced into the cage, and they quickly colonized the unpruned tree, laying eggs on the tender flush. With proper timing, there is the potential for hundreds of nymphs to develop on each leaf.

Figure 2. Pruning curry leaf plants encourages production of multiple new shoots (left) which can eventually lead to a bushy structure with multiple branches (right).

As the pruned tree resprouts, adults move to its new flush, creating a sequential wave of colonization.

One hundred *T. radiata* adults were released into the cage two weeks after ACP introduction, when nymphs began to reach the fourth stage (the optimal development stage for parasitism by *T. radiata*). This timing is critical since *T. radiata* only parasitizes later stage nymphs, so releases must coincide with this developmental stage. Adding *T. radiata* too early may lead to *T. radiata* not finding a suitable host to parasitize and adding too late may lead to greater proportions of nymphs escaping parasitization and producing ACP adults. The sequential flush production on two trees prolongs the availability of suitable nymphs, extending the wasps' reproductive window.

Although two trees were used in the first year, we wanted to evaluate whether a single well-managed tree would be sufficient if trained and pruned correctly. When curry leaf stems are pruned, two to three new shoots emerge from each branch within two weeks (**Figure 2**). After roughly three months of growth, the tree can be pruned again to generate additional flush. Through repeated pruning, a shrub-like structure can develop within a year (**Figure 2**), allowing branches to be pruned on a rotating, bi-weekly schedule to maintain a steady supply of new flush. This would provide a continuous source of ACP nymphs for *T. radiata* reproduction, supporting long-term parasitoid production inside the cage.

Practical Challenges in the Field

Developing and maintaining self-dispersing cages in commercial orchards comes with practical challenges that must be addressed for the system to succeed. Gopher damage was one of the first concerns raised by growers. Protecting curry leaf roots with gopher baskets has proven essential in many locations. Ant activity is another major issue. Argentine ants are strongly attracted to ACP honeydew and can disrupt parasitism by defending nymphs. We have found that applying Tanglefoot around the main stem provides an effective physical barrier. To make this work, the lower 12 inches of the trunk should be kept clear of lateral branches so that the barrier can be neatly maintained. Over time, dust, debris, or dead ants can reduce the barrier's effectiveness, so periodic reapplication is necessary.

Weed growth around the curry tree inside the cages can also interfere with operations and act as "bridges" for ants to bypass the Tanglefoot barrier. Using weed fabric around the base of the cage has been effective at suppressing weeds

Figure 3. During summer months, Asian citrus psyllid populations can increase fast, with a lot of nymphs on leaves and stems (left). The high density of nymphs can produce a lot of honeydew which falls on lower leaves (middle), eventually supporting the growth of black sooty mold (right).

and conserving soil moisture. If curry leaf branches grow large enough to touch the cage walls, ants may use those contact points to enter. Regular pruning helps prevent this.

Heavy ACP infestations can lead to honeydew accumulation on lower leaves, fostering sooty mold (**Figure 3**). Affected leaves may need to be pruned periodically to maintain healthy host plants and optimal rearing conditions inside the cage.

Looking Ahead

We have found that inoculating each cage with 100 ACP adults is sufficient to establish a stable colony. The timing of *T. radiata* introduction is important, and these wasps should be released when ACP nymphs begin to reach the fourth stage. With sequential pruning and careful management, cages can remain productive for four to six months. We continuously strive to refine the self-dispersing cage system to make *T. radiata* field production practical and to effectively synchronize *T. radiata* production in these cages with ACP population peaks in citrus groves. Our team is fine-tuning installation methods, inoculation timing, and maintenance practices to develop clear, grower-friendly guidelines to help develop sustainable ACP management programs that delay HLB spread.

CRB Research Project #5500-229

Glossary

[1]Parasitoid: An organism that develops within a host, killing it. Parasitoids are generally specialized and have species-specific hosts.

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Core Citrus IPM Project Activities

on Three Major Pests Impacting San Joaquin Valley Growers

Sandipa Gautam

Summary

Damage due to insect pests poses a constant challenge for the profitable production of fresh citrus in California. Managing pests effectively means staying ahead and developing pest-specific integrated management strategies, while also combining rigorous science with practical, grower-focused solutions. The Core Citrus Integrated Pest Management (IPM) project targets three of the crop's most persistent pests: citrus thrips, citrus mealybug, and California red scale. Although application of insecticides is considered the main strategy with the highest efficacy, proper application strategies, including timing of treatments at a critical pest phenological stage before crop damage, integrating biological control, and resistance management are important for sustainable IPM. As such, Core Citrus IPM project work crosses the continuum from lab bioassays on pests and natural enemies, seasonal phenology and pest monitoring, field efficacy trials, and grower outreach. The result is a pragmatic approach designed to provide growers with contemporary solutions to reduce chemical dependence, delay resistance, and sustain orchard productivity.

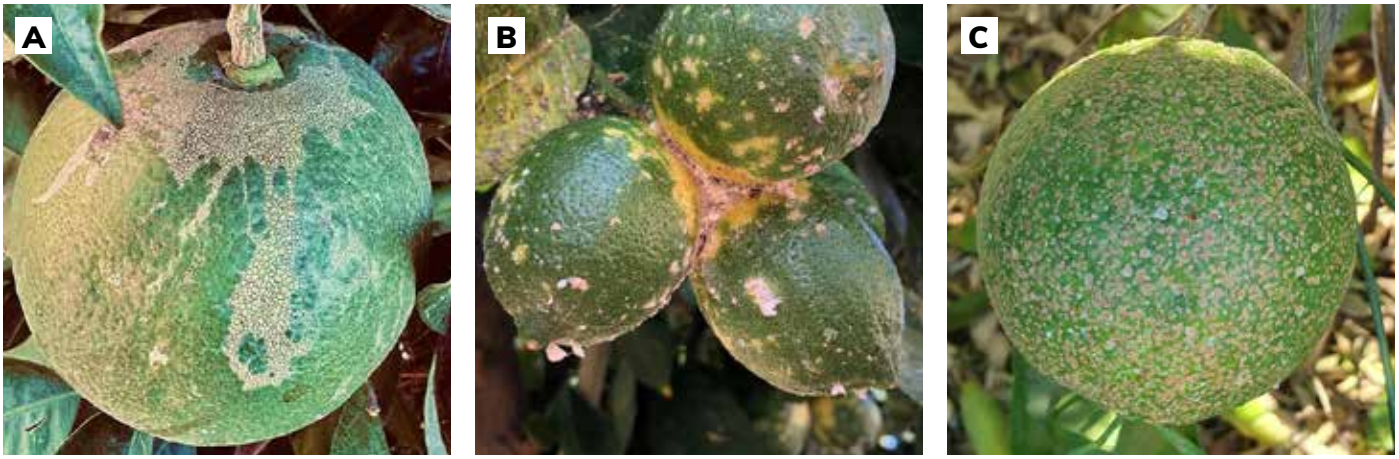

Figure 1. Fruit specimens showing damage caused by citrus thrips (A), citrus mealybug on fruit and feeding damage (B), California red scale infestation on fruit (C).

Citrus Thrips Remains Top Concern for Growers

Citrus thrips remains the most economically important pest for San Joaquin Valley citrus growers. Feeding by both immature and adult thrips on the soft leaf and fruit tissue causes scarring, resulting in scarred tissue that reduces fruit marketability (**Figure 1A**). Thrips populations are favored by new flush and fruit set. Managing them up to eight weeks after petal fall when the fruit is tender and attractive to thrips is crucial to reducing damage.

Monitoring thrips and making insecticide applications when immature thrips are present is important to get the highest efficacy from insecticide applications. That's because eggs are embedded within leaf and fruit tissue, and most insecticides do not affect eggs. For monitoring, it's best to check 100 pieces of fruit in each orchard, about 25 fruits (1-2 fruit per tree) from each corner of the orchard. Growers can look for immature thrips under the fruit calyces and record the percentage of fruit infestation. Thrips can be more damaging to certain cultivars, and because fruit is more susceptible during early growth stages, treatment thresholds can vary. Although a common practice is to treat when ~5% of fruit is infested with immature thrips, field experiences from past years have shown that adult presence on fruit cannot be ignored, especially early in the season.

During the 2025 season, we compared efficacy of a new active ingredient, isocycloseram (Plinazolin®), alone or with other active ingredients against two grower standard treatments to reduce thrips scarring in Washington navels at LREC (**Table 1**). Applications were made at and two weeks post petal fall. Among the treatments tested, Plinazolin® was most effective in decreasing scarring,

Table 1. Citrus thrips treatments with application timing, rates, and additives applied. First application took place on May 1, 2025. The second application (when applied) was on May 15, 2025. All treatments were applied at 125 gallons per acre.

	TREATMENT	APPLICATION RATE	ADDITIVE
Untreated Control	Untreated Control	N/A	N/A
Treatments with Plinazolin®	Plinazolin®, petal fall application	1.54 oz	1% 415 oil
	Plinazolin®, two applications	1.54 oz	1% 415 oil
	Plinazolin® > Minecto® Pro	1.54 oz; 12 oz	1% 415 oil
Grower standards used in trial	Exirel®> AgriMek®	20.5 oz; 4.25 oz	1% 415 oil
	Beleaf® > Minecto® Pro	4.28 oz; 12 oz	1% 415 oil
Organic treatments*	Gargoil®	2%	Xena® - 4 fl oz/100gal, pH adjusted to 4.5 with citric acid
	Gargoil®	1%	Xena® - 4 fl oz/100gal, pH adjusted to 4.5 with citric acid
	Lime Sulfur TKI	2 gal	Manni-Plex K®, to adjust to pH 9.5
	Lime Sulfur Ultra	1.50%	Manni-Plex K®, to adjust to pH 9.6
	Grandevo®	2 lb	1% 415 oil
	Venerate®	2 qt	1% 415 oil

**all organic treatments applied twice*

reducing severely scarred fruit to less than 1% even after a single application (**Figure 2**). Among the grower standard treatments, Beleaf® followed by Minecto® Pro had the lowest percentage of severe scarred fruit (2.8%), compared to Exirel® followed by AgriMek® treatment (6.1%), and the untreated control (33.8%).

We also compared the efficacy of different organic products to reduce thrips scarring in Washington navel orange (**Table 1** & **Figure 3**). Results show that two applications of 1% Gargoil®, Grandevo®, Venerate®, and Lime Sulfur Ultra significantly reduced severe scarring compared to the untreated control. However, in all organic treatments tested, scarring was significantly higher than the conventional treatment of Beleaf®, followed by Minecto® Pro (**Figure 3**).

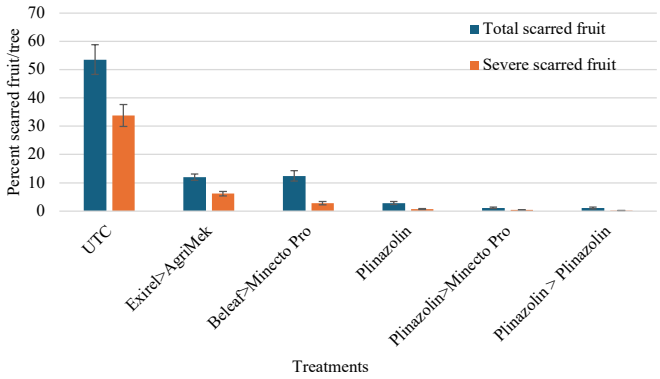

Figure 2. Percent total and severe scarred fruit in August after insecticide applications in May targeting citrus thrips.

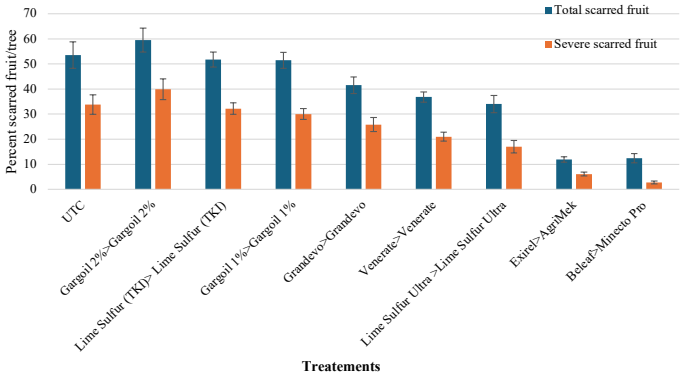

Figure 3. Percent total and severe scarred fruit in August after insecticide applications in May targeting citrus thrips.

Citrus Mealybug Management

Citrus mealybug (CMB) has become an increasingly important pest for San Joaquin Valley citrus growers since 2021. Mealybugs are soft, oval, distinctly segmented insects that feed on fruits, twigs, and leaves. They extract plant sap, which as a result, reduces tree vigor. Early infestations can cause fruit drop, and mid-season infestations can cause fruit discoloration and lumps, which reduce marketability (**Figure 1B**). If not removed, mealybugs can continue to breed on fruit after harvest, causing loss during transit and storage. As mealybug populations can increase tremendously in summer and fall and become difficult to control, early season management is recommended.

Immature CMB are the most susceptible life stage to kill with insecticides. It is crucial to monitor when the immature population is active to get the highest efficacy from insecticide applications, especially as CMB eggs are protected within egg sacs. Early in the season, from January to March, mealybugs overwinter as eggs and adults in cracks and crevices and between fruit clusters, making low populations hard to detect. If an orchard has a history of CMB infestation, it is best to monitor hot spots and treat early in the season. CMB also prefers inside the canopy, so spray coverage is critical. Another option growers can use to monitor for CMB is by using pheromone lure trap cards to trap males to determine if a block has an infestation. Currently, no formal economic threshold or action threshold has been established in California citrus. Mealybugs can develop rapidly, especially if ant activity is high due to them protecting mealybugs from natural enemies. Natural enemies can contribute to CMB control, especially in the late summer and fall. During this time, monitoring should focus on the presence of natural enemies and be taken into account when deciding management options.

In 2025, we evaluated the efficacy of five different treatment combinations to reduce citrus mealybug infestation in Star Ruby grapefruit (**Table 2**). Treatments were applied by the grower on June 14, 2025. Assessments were done weekly for five weeks by counting 30 fruits for the presence or absence of CMB from the inside canopy to determine the percentage of infested fruit.

On the fifth week, 30 fruits from each treatment were picked and brought to the lab where they were observed under the stereo microscope. The number of live CMB were rated using a scale of 0, 1-10, 11-30, and more than 30. Parasitized CMB were also counted using the stereoscope. Five weeks after treatment, Assail® + Centaur® provided the most consistent control of citrus mealybug, with infestation remaining lowest across all post-treatment weeks while increasing more slowly than other treatments. Sefina® + Centaur® and Fujimite® + Centaur® showed early reductions but rose sharply by five weeks after treatment. Untreated plots had the highest infestations throughout the trial (**Figure 4**). Although the infestation data looked similar across treatments, lab assessment showed that the treatments had significantly lower healthy CMB populations on week 5. While all treatments reduced infestation compared to the untreated plot, Sefina® + Centaur® and Fujimite® + Centaur® showed the greatest reduction (<5%); Assail® + Centaur® and AzaPro + Cinnerate® treatments provided moderate control. Based on signs of parasitism observed in 3rd instar and adults, parasitism was highest in the untreated control (44%), followed by AzaPro + Cinnerate® (37%), Senstar® (33%),

Table 2. Citrus mealybug treatments with insecticide rates, and spray volumes (gallons per acre, GPA). 0.5% 415 spray oil was used as adjuvant for all treatments, excluding untreated control.

TREATMENTS	RATES/ACRE	SURFACTANT AND RATE/ACRE	GPA
Untreated control			
Sefina® + Centaur®	**Sefina® – 14 oz Centaur® – 46 oz**	Exit – 3 pt	750
Fujimite® + Centaur®	**Fujimite® – 3 pts Centaur® – 46 oz**	Exit – 3 pt	750
Assail® + Centaur®	**Assail® – 5.7 oz Centaur® – 46 oz**	Exit – 3 pt	750
Aza Pro + Cinnerate®	**Aza Pro – 2 pint Cinnerate® – 50 oz/100 gallon (375 oz total)**	Nufilm – 8 oz	750
Senstar™	**Senstar™ – 20 oz**	Exit – 12 pt	750

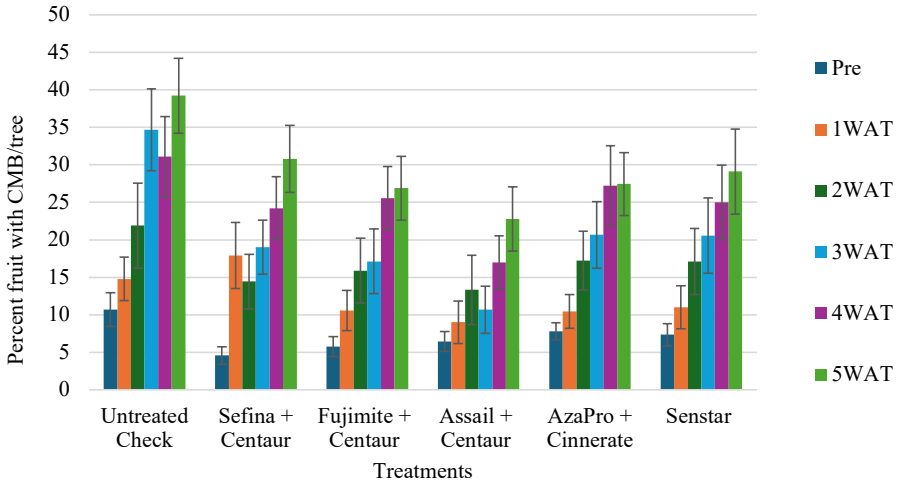

Figure 4. Percent fruit infestation with citrus mealybug over time following insecticide treatments in a field trial after a single application. Weeks after treatment noted as WAT.

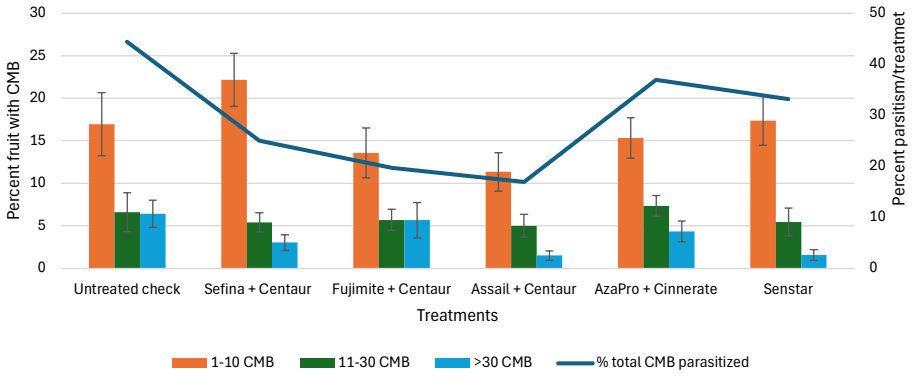

Figure 5. Percent fruit infested with citrus mealybug (CMB), total number of CMB per fruit (all life stages), percentage parasitism across insecticide treatments at five weeks after treatment. Bars represent infestation severity classes (1–10, 11–30, and >30 CMB per fruit), and line shows percent of parasitized mealybugs (3rd instar and adult females).

Sefina® + Centaur® (25%), and Fujimite® + Centaur® (20%). Parasitism was lowest in Assail® + Centaur® (17%), suggesting some insecticide programs may reduce natural enemy activity **(Figure 5)**.

Strong Monitoring and Smart Decision-Making Keeps California Red Scale in Check

California red scale (CRS) is another key perennial pest of California citrus, infesting leaves, twigs, and fruit, reducing tree vigor and marketability. Effective management depends on accurate monitoring before treatment. UC Pest Management Guidelines for monitoring recommends using pheromone traps to track male flights and degree day[1] models to predict crawler emergence which are tailored for field orchards to optimize spray timing or *Aphytis* releases. Our team emphasizes a combination of degree-day modeling with visual inspections to target the most vulnerable immature stages, reducing unnecessary applications and improving efficacy. The team educates growers on translating degree-day data into timely and effective field management decisions.

For testing efficacy of insecticides, the Core Citrus IPM program examines a spectrum of chemistries and timing for managing CRS. In an ongoing trial, we

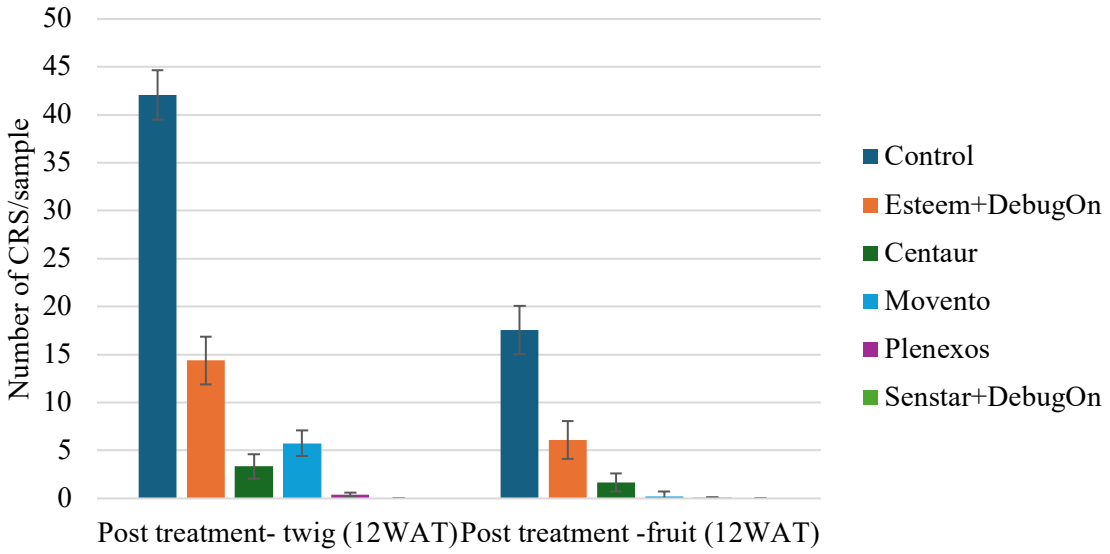

Figure 6. Number of California red scale across insecticide treatments 12 weeks after the application (12WAT).

are evaluating the effects of Centaur®, Movento®, Plenexos®, Senstar® + Debug® On, Esteem® + Debug® On to reduce CRS population on Tango mandarin. Preliminary results show that 12 weeks post application, all treatments significantly reduced CRS population compared to untreated on both twigs and fruit. Among the treatments, Movento®, Plenexos®, and Senstar® + Debug® On had the least CRS on fruit. Final evaluations will be done at harvest (**Figure 6**).

Industry Resources Through Core IPM

The Core Citrus IPM program team continues to play a vital role in supporting the California industry through timely,

science-based pest management communication, with a strong emphasis on extension and outreach. The team has developed a strong extension pipeline that delivers relevant, actionable information directly to growers, pest control advisors (PCAs), and industry leaders. A key component of this effort includes the development of pest-specific memos addressing urgent management needs for citrus thrips, California red scale, and citrus mealybug. These memos, circulated through Citrus Research Board newsletters and grower email networks, provide seasonal guidelines, degree-day timing insights, and resistance management strategies to improve field decision-making.

Hands-on education also remains central to the program. In 2025, the team organized a series of pest-focused field days and workshops, delivering current research directly to growers and pest control advisors. On April 24, a Citrus Thrips Field Day was held, followed by a Citrus Mealybug Field Day on May 7, where attendees observed scouting methods, monitoring tools, and natural enemy interactions firsthand. On October 1, the team also hosted a California Red Scale and Natural Enemies Workshop, featuring demonstrations on parasitoid activity, biocontrol conservation, and selective pesticide use. Responding to industry concerns over escalating citrus mealybug pressure and management failures, the team also organized a citrus mealybug PCA roundtable on September 3, which facilitated knowledge-sharing among PCAs and fostered collaborative problem-solving. Through these efforts, Dr. Gautam's team continues to strengthen IPM adoption, promote sustainable pest solutions, and support grower-driven innovation in California citrus.

CRB Research Project Number #5500-501

Glossary

[1]**Degree day:** a cumulative measure of heat units that drives insect development.

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INTEGRATED TACTICS FOR THREE KEY PESTS

The Core Citrus IPM program continues to focus on addressing these three key pests with strategies based on biology, monitoring, efficacy testing, and outreach. The Core IPM team suggests the following strategies for each target pest:

Citrus thrips

- **Timing is everything:** Citrus thrips cause cosmetic damage to young, developing fruit. Monitoring prior to and at petal fall and early fruit development is recommended to narrow treatment windows and reduce repeat sprays.
- **Selective materials and biopesticides:** Especially early in the season, the program recommends selective products for biologicals which have fewer toxic effects on natural enemies such as *Euseius tularensis* and *Aphytis melinus*. Rapid knockdown materials should be reserved for high-pressure outbreaks.

Citrus mealybug

- **Early detection and spot treatments:** As mealybugs form patches and hide under cracks and in pruning wounds inside the canopy, the team emphasizes regular inspections and spot treatments early in the season to target overwintering hatches before populations become widespread.
- **Natural enemy conservation and ant control:** Parasitoid wasps and generalist predators have been observed to be active in the San Joaquin Valley region and can contribute to CMB management, especially when sugar-feeding ants are controlled. Parasitoid activity is evident from mid-July through fall and needs to be considered when managing CMB. Softer chemistries help in natural enemy conservation, while broad-spectrum products should be reserved for high pest pressure situations.
- **Products and spray coverage:** Spray application should target immature populations. CMB is often present inside the canopy on the tree trunk and inner branches between the fruit clusters (if fruit is present). When insect growth regulators, slow-acting systemic products and rapid knockdown materials are combined, growers can expect the best results. Coverage is essential, as most products have low residual activity.

California red scale

- **Monitoring and targeting crawlers:** Control of CRS relies on hitting the most vulnerable crawler stage. Management should pair degree-day predictions with field monitoring to identify crawler emergence windows and precisely time insecticides.
- **Mating disruption and biological control reinforcement:** Adoption of mating disruption and augmentative releases of *Aphytis melinus* promotes conservation of scale parasitoids as a long-term suppression strategy.

ADVANCES IN THE DEVELOPMENT OF FUTURE MANAGEMENT TOOLS FOR CITRUS GREENING DISEASE

Lukasz Stelinski

Summary

Citrus greening disease, also known as huanglongbing (HLB), has devastated citrus production in Florida and around the world. The disease is spread by the Asian citrus psyllid (ACP), a tiny sap-sucking insect that feeds on citrus trees. When psyllids feed, they can carry and transmit the bacterium Candidatus Liberibacter asiaticus (CLas), the causal agent of HLB. Shortly after the first detection of greening in Florida in 2005, growers began to rely heavily on insecticides to control psyllid populations. While insecticides can reduce psyllid numbers, this strategy alone has proven costly, inconsistent, and has led to pesticide resistance in some psyllid populations.

For these reasons, we are working on new technologies that could provide longer-term, more sustainable solutions. Several areas of research are showing promise, including the use of pesticidal proteins from bacteria, gene-silencing RNAs, transgenic citrus, and even gut-binding peptides that block the bacterium inside the psyllid. While many of these approaches are still experimental, they could eventually give growers new tools for reducing psyllid populations and slowing the spread of HLB.

Pesticidal Proteins from Nature

One focus of research, led by Dr. Bryony Bonning's laboratory in the entomology and nematology department at the University of Florida (UF), is on pesticidal proteins produced by the soil bacterium *Bacillus thuringiensis* (Bt). Bt has long been used safely in agriculture to control insect pests, and its proteins are highly specific to certain insects, while remaining harmless to humans, pollinators, and other beneficial organisms.

Researchers at UF have screened a wide range of Bt proteins to identify which are toxic to ACP (Fernandez-Luna et al. 2019, Mishra et al. 2022, Tavares and Bonning 2022). Some proteins have shown promise, but the challenge is delivering them into the phloem—the plant tissue where psyllids feed. Two strategies have been tested:

1. **Virus Delivery:** Harmless strains of citrus tristeza virus (CTV), which naturally live in citrus phloem, can be modified to produce Bt proteins inside citrus trees. Once infected with these modified viruses, the tree continuously produces the proteins where psyllids feed. This could serve as a substitute for frequent insecticide sprays.

2. **Transgenic Plants:** Citrus plants can be engineered to produce Bt proteins in their phloem. For example, transgenic curry leaf plants have been produced that are lethal to psyllids and also highly attractive to them (Ravanfar et al. 2022). This suggests the possibility of "trap crops" that draw psyllids away from groves while killing them.

Because of the possibility of resistance development to Bt alone, the UF team has also explored combining Bt with gene-silencing RNAs to create a "two-pronged" approach to reducing psyllid populations (**Figure 1**). Gene-silencing RNAs are tiny molecules that can turn off specific genes, like flipping a switch to stop a cell from making a certain protein. Scientists use them to block harmful genes in pests like ACP (Kishk et al. 2024). Bt proteins damage the psyllid's gut (Orbovic et al. 2023), which then allows the RNA molecules to enter gut cells and shut down vital survival genes. This

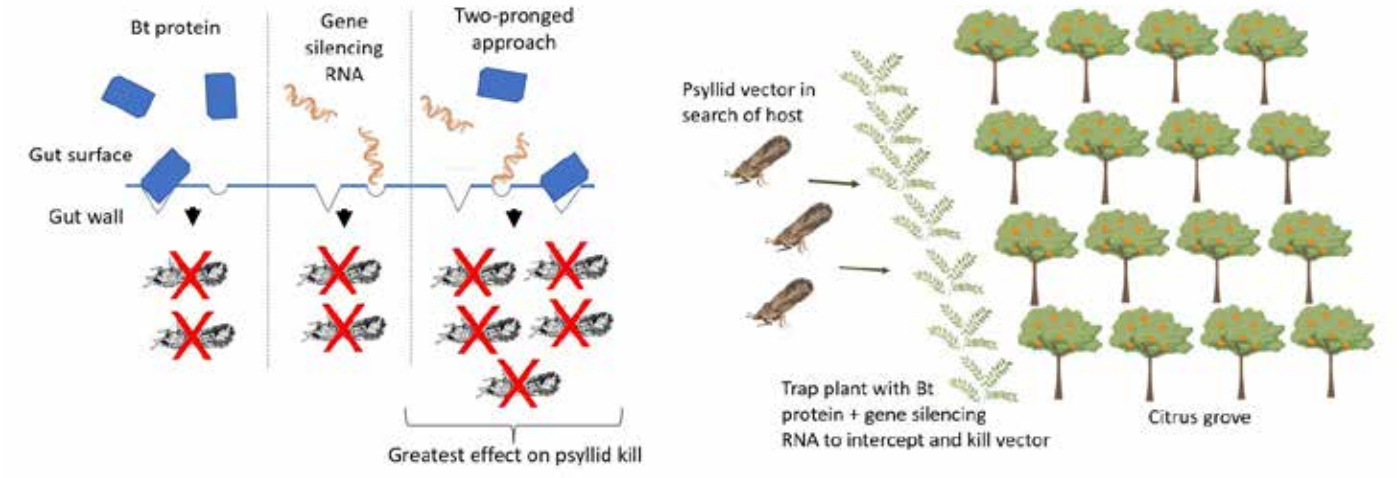

Figure 1. *Bacillus thuringiensis* proteins and gene silencing RNAs are individually effective tools that kill Asian citrus psyllid. However, combining the two increases effectiveness better than either approach alone.

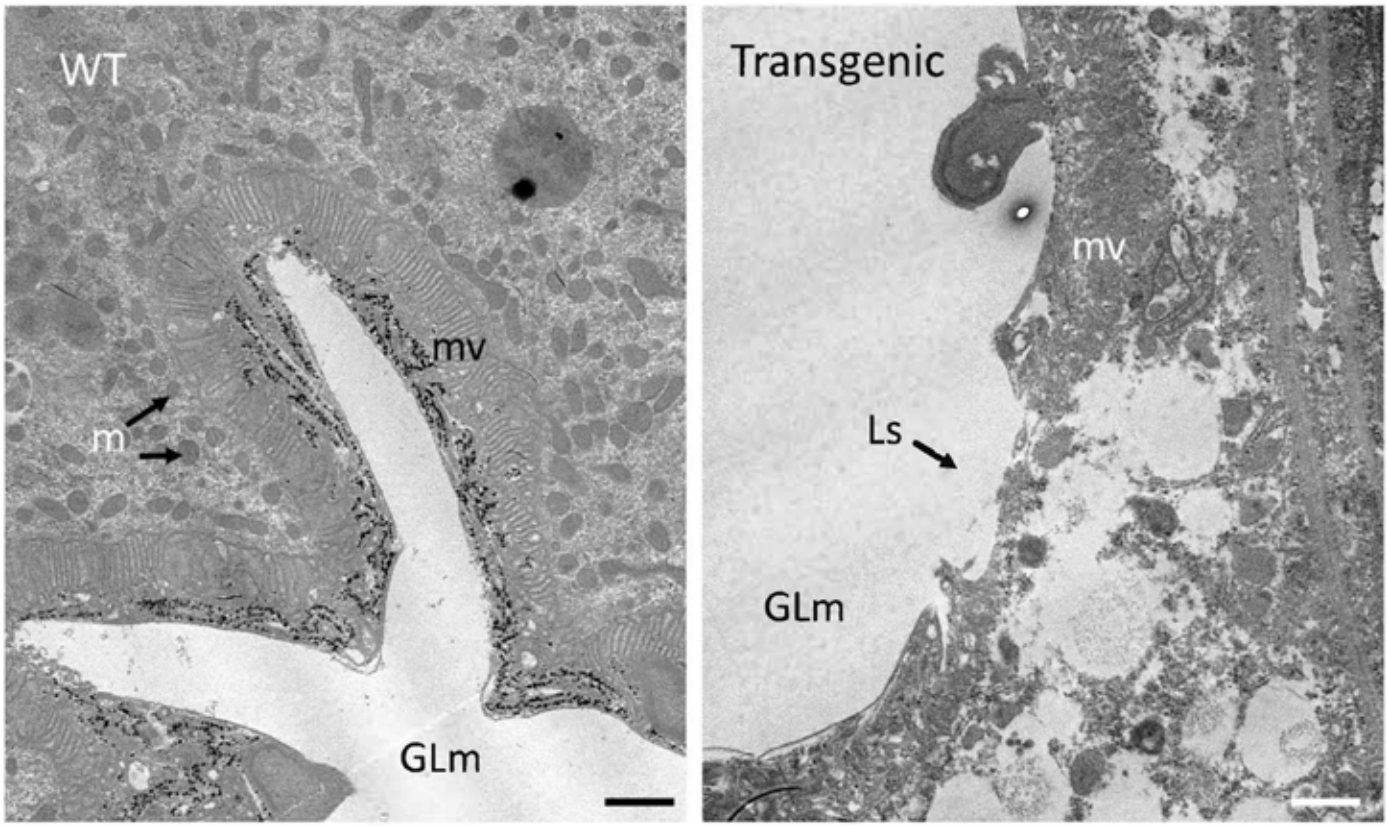

Figure 2. This illustrates damage to the gut lining of the Asian citrus psyllid caused by the Mpp51Aa1 protein. These microscope images show the gut cells of psyllids that fed on either normal (WT, left) or genetically modified (Transgenic, right) curry leaf plants. In psyllids that fed on normal plants, the gut surface appears healthy with a dense layer of finger-like projections called microvilli. In contrast, psyllids that fed on plants producing the Mpp51Aa1 protein show clear damage—microvilli are fewer, disrupted, and contain multiple lesions. These images demonstrate that the transgenic plants successfully produced the Mpp51Aa1 protein, which harmed the insect's gut cells. Labels: GLm = gut lumen; mv = microvilli; m = mitochondria; Ls = lesion in microvilli. Scale bar = 1 µm.

combined strategy has worked well against other crop pests like the western corn rootworm and could have potential against psyllids as well.

Transgenic Citrus Plants with Stronger Psyllid Resistance

Building on this work, we focused on specific Bt proteins known to be effective against ACP. One promising protein, called Mpp51Aa1, was engineered into different citrus varieties including 'Valencia' sweet orange, grapefruit, and Carrizo citrange (Mishra et al. 2023).

In greenhouse tests, psyllids feeding on these plants showed major gut damage (**Figure 2**), higher death rates, and a drastic reduction in the survival of their offspring. In fact, psyllid reproduction dropped by up to 100% on some transgenic citrus lines (Mishra et al. 2023). These results point to the potential for citrus varieties that can defend themselves from psyllid attack, much like Bt cotton and Bt corn have successfully protected those industries from insect pests.

Blocking the Bacterium Inside the Psyllid

While reducing psyllid numbers is one strategy, another is to prevent psyllids from spreading the HLB bacterium in the first place. Researchers in Dr. Kirsten Stelinski's lab at the Citrus Research and Education Center in Lake Alfred, Florida, in collaboration with Dr. Bonning's lab, are targeting the interaction between *Candidatus Liberibacter asiaticus* (CLas) and the psyllid's gut.

One method uses RNA interference (RNAi) to silence psyllid genes that produce proteins on the surface of the gut. Although the results are still pending publication, the completed study showed that when psyllids were fed double-stranded RNA targeting these gut proteins, their feeding activity declined, survival decreased, and, most importantly, they became less capable of acquiring the bacterium from infected trees. By reducing the efficiency of CLas acquisition, this strategy could slow reinfection of healthy trees even if psyllids are present.

Another method relies on gut-binding peptides (GBPs)—tiny molecules that can attach to the psyllid's gut lining. Certain peptides discovered through advanced screening techniques appear to block CLas from entering gut cells. When psyllids were fed these peptides, their ability to acquire and transmit the bacterium was reduced.

Together, these gut-targeting approaches represent a new way of thinking about greening management. Rather than focusing only on killing psyllids, we might also make them less effective carriers of the disease.

Looking Ahead

These technologies are still under development, and more research, field testing, and regulatory review will be needed before they can be deployed in commercial groves. Each approach has strengths and challenges:

- **Bt proteins and transgenic plants** could provide long-term protection against psyllids, much like Bt cotton and corn. However, consumer acceptance of transgenic crops has been slow.
- **RNAi and gut-binding peptides** may not eliminate psyllids, but could dramatically reduce disease spread.
- **Combinations of these strategies**—such as pairing pesticidal proteins with RNAi—seem especially powerful.

No single tool will solve HLB on its own. However, these innovations are designed to work alongside other practices—such as improved tree health management, biological control, and cultural practices—to form a more integrated and sustainable approach to greening management.

The ultimate goal is to reduce reliance on chemical insecticides, preserve beneficial insects, and provide growers with practical, cost-effective tools to keep groves productive. While these advances will take time to reach the field, the research pipeline is active and promising, with input from both scientists and industry advisors.

While citrus greening remains the most serious challenge facing the citrus industry, leveraging natural pesticidal proteins, genetic engineering, RNA-based technologies, and peptide blockers, may create new tools that can integrate seamlessly into existing management programs—whether those programs are still centered on quarantine and eradication, as in California, or on long-term survival and coping with an endemic disease, as in Florida.

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SYSTEMIC FUNGICIDE BACTERICIDE

NEW GENERATION *K-PHITE 7LP* BRINGS SUPERIOR EFFICACIES TO DISEASE CONTROL FOR CALIFORNIA CITRUS GROWERS

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.

THE MOST EXTENSIVE EPA, CA. DPR LABELED POTASSIUM PHOSPHITE IN THE INDUSTRY: While the trade is afloat with numerous nutrient labels illegally alleging increases in plant health, ***K-PHITE 7LP*** affords citrus growers and PCAs a legal, safe, low cost solution to address multiple citrus diseases. ***K-PHITE 7LP*** shows efficacy and is registered for control of the following diseases:

- ***Alternaria alternata***
- ***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;
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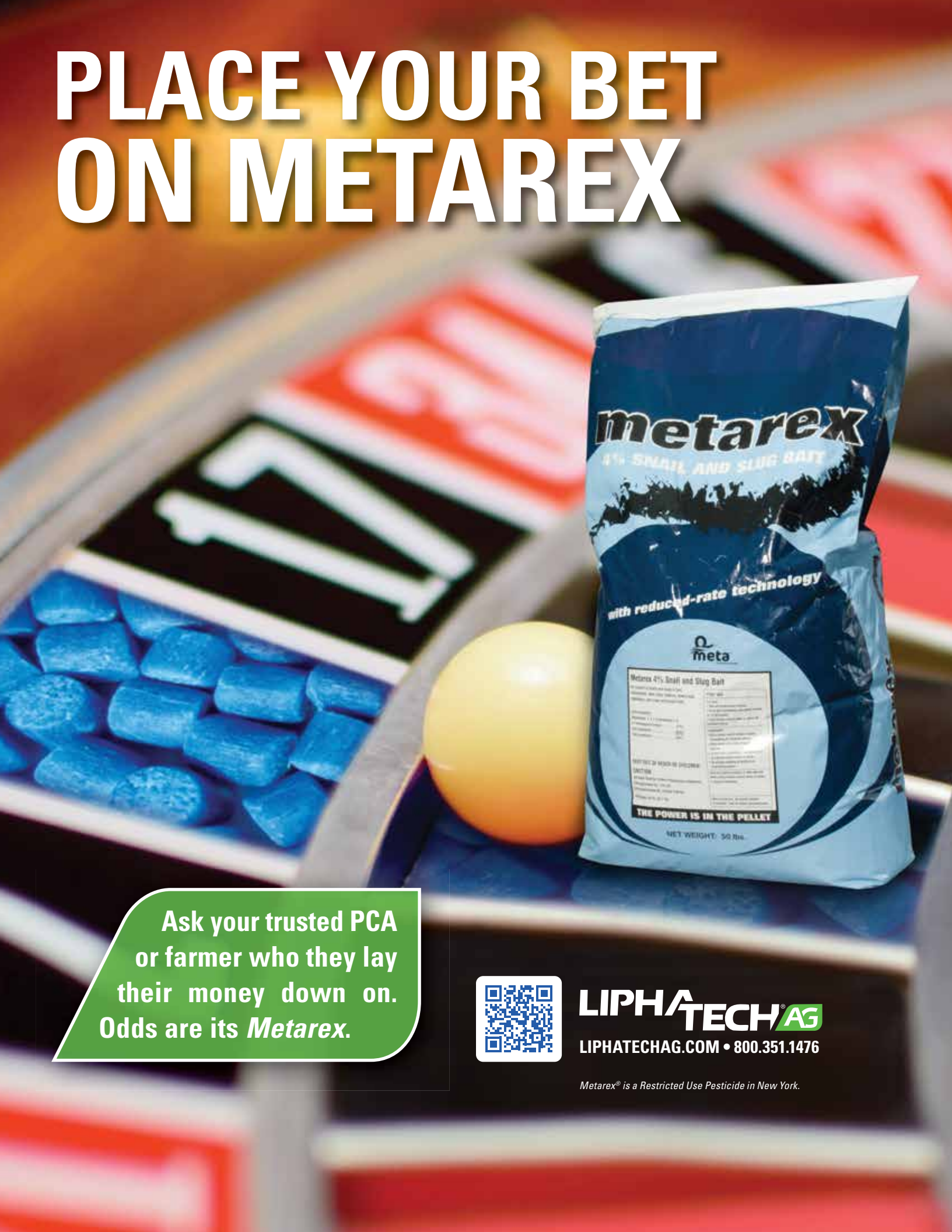
Plant Food systems

PLACE YOUR BET ON METAREX



Ask your trusted PCA or farmer who they lay their money down on. Odds are its *Metarex*.

LIPHATECH AG

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Metarex® is a Restricted Use Pesticide in New York.