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On the Cover: Beginning with this issue, Citrograph will focus on a specific topic each season. Inside this edition, you’ll find news articles, features and research reports that take a closer look at integrated pest management (IPM)-related issues, although there are some general articles, as well. This spring, our next issue will center on vectored diseases.
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Winter 2021 | Volume 12 • Number 1  The Official Publication of The Citrus Research Board

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<td><strong>MEMBER</strong></td>
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FEBRUARY

17

Citrus Pest and Disease Prevention Committee (CPDPC) Meeting. For more information, visit www.cdfa.ca.gov/citruscommittee

JANUARY

28

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

FEBRUARY

4

California Citrus Quality Council (CCQC) Annual Membership and Board Meeting. For more information, visit http://ccqc.org

MAY

12

Citrus Pest and Disease Prevention Committee (CPDPC) Meeting. For more information, visit www.cdfa.ca.gov/citruscommittee

MAY

11

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

AUGUST

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Four new and four returning Board members were selected to serve on the Citrus Research Board (CRB) for the 2020-23 fiscal year term. The representatives were selected during CRB Nomination Meetings held this past September 17-18 by the California Department of Food and Agriculture (CDFA). Approval to seat the Board members subsequently was granted by CDFA Secretary Karen Ross.

“We are delighted to welcome some familiar faces back to the boardroom,” said CRB President Marcy L. Martin, “and we very much look forward to working with the new appointees. The research that is conducted by the Board and its committees has critical, long-reaching consequences for the continuation, evolution, sustainability and success of the California citrus industry, so these appointments carry a great deal of weight.

“We also would like to extend our most sincere gratitude to those who have rotated off the Board, but who served the industry so ably and with such dedication for so many years – Jim Gorden, Kevin Olsen, Jeff Steen and Mike Perricone,” Martin added. “We can’t thank them enough and wish them all the very best.”

Please meet the new faces in the class of 2020-23 who will be serving the complex needs of the industry in the coming years and learn about what they are looking forward to contributing.
Armstrong is a third-generation grower in the southern California desert and first generation citrus grove owner who grew up in the industry. He previously had served on the Board from 2000-16 and is happy and proud to be back. Armstrong operates Thermiculture, a commercial farm management company specializing in citrus and dates in the desert. He also farms 2,100 acres of both commodities in the Coachella and Imperial Valleys and San Diego County. Additionally, Armstrong serves on the Citrus Pest and Disease Prevention Committee and is the secretary of the Coachella Valley Pest Control District.

The primary areas of Armstrong’s citrus research interest are new varietals, pest management and nutrition/plant vitality. “I have a complete industry perspective from my experience/involvement in farming, packing, sales and marketing of citrus during the past 20 years,” he shared. “I hope to bring the perspective of small and mid-sized citrus growers all the way to large commercial industry needs.” Armstrong said that he is farming about half of his acreage organically, “bringing simple traditional and practical agronomy and pest management practices to the forefront of research.” He added that his long-term goals are practical application and timely execution of results that growers easily can implement.

Griffin has been involved in citrus farming and ranch management throughout Fresno, Kern, Madera, Tulare and Ventura counties. In recent years, he has been farming citrus, pistachios and almonds on the old S&J Ranch in Madera County. He offered the following thoughts:

“I’d first like to note that it is an honor to be appointed as a member of the Citrus Research Board. As the world is getting smaller, trade, especially fresh produce trade, is becoming more competitive. As an industry, we have well-defined areas where we know that gaining and maintaining a competitive advantage is crucial to keep our industry profitable. Producing a crop that is preferred by the consumer, be it based on flavor, quality, consistency or availability, and figuring out how to produce that crop consistently, economically and in large quantities, are essential to the success of everyone within this industry.

“The first step in successful research is figuring out what is worth pursuing, and that should be followed by a real-world estimation of the feasibility of implementation to achieve the desired results consistently. Easier said than done because we do not know what we do not know. We are fortunate to have an abundance of first-class scientists and state-of-the-art facilities and equipment right here in our backyard. Unfortunately, our industry also faces significant threats. ACP/HLB, limited water, increased regulatory and public pressure on crop protection products and their use are just a few major concerns deserving the attention of our research community. The CRB plays a crucial role in ensuring that industry-funded resources are dispensed in areas and in ways that hold the biggest potential for the improved success of our industry as a whole.

“As someone who works on the farming side, realizing how little we really know about the crop we grow is a regular occurrence, often served with a slice of humble-pie. I am looking forward to being more involved on the research side with folks who have superior knowledge and experience compared to mine, and to playing a role in translating successful research results into applicable and efficient on-farm practices.”

Morreale has served as vice president of PennyMac since 2013, where she is involved in succession management, performance management and leadership development. Prior to PennyMac, Morreale was with Microsoft. During her 22 years of employment, she was responsible for technical recruiting, human resources for the Office business unit and enterprise-wide executive assessment and development.
RAM UCKOO, PH.D.
Agronomy Department
Wonderful Citrus, LLC

Uckoo has conducted citrus research for 15 years and received his Ph.D. in Horticultural Science from Texas A&M University. Since 2014, he has worked for Wonderful Citrus. He also served on the CRB Vectored Diseases Committee during that time. He is a member of the Science and Technology Committee for the Produce Marketing Association and the Science Subcommittee for the Citrus Pest and Disease Prevention Committee. “My primary research interests include (but are not limited to) new varieties, agronomy, disease management and mechanization,” Uckoo said.

He added that he understood “it is a true privilege to be nominated to the Citrus Research Board. I am very excited and look forward to joining the energetic discussions on priority setting for future research on crop production. I also am keen on strategizing a vision statement for the Board to address the ever-changing dynamics of the citrus industry impacting not only the producers, but also the consumers who ultimately drive it.”

Additionally, here is a brief recap of the four Board members who have been re-appointed for an additional term. They, too, shared their thoughts about what they are looking forward to during the next three years.

CHRIS BOISSERANC
Pest Control Advisor
Owner, Southwest Ag Consulting, Inc.

Returning Board member Boisseranc is in his fifth year with the CRB. He previously had represented District 3, but moving ahead, he will be serving District 2. “I am looking forward to another term of exciting new projects that could lead to breakthrough research and innovations to keep our California citrus industry competitive globally,” Boisseranc shared. “I hope we can get back to business as usual in this next term with fewer complications from COVID, more handshakes and fewer Zoom meetings!”

(To learn more about Boisseranc’s role as chairman of the Pest Management Research Committee, see “Meet the Pest Management Research Committee” on page 22.)

JOHN GLESS III
Southern California Farm Manager
Gless Ranch, Inc.

Another returning Board member, Gless has served on the Board since the 2012-13 fiscal year and is a representative for Coastal District 2. Gless grew up in the citrus industry.

“In this next term on the Board, I am looking forward to seeing progression in Asian citrus psyllid (ACP) and huanglongbing (HLB) research,” he said. “Additionally, I’m looking forward to finding new ways we can combat this bug and the disease and move forward to all being profitable citrus growers.”

JASON ORLOPP
President/Manager
Foothill Ag Services, Inc.

Returning for another three-year term, Orlopp has served on the Board for five years as a District 1 representative. “I am looking forward to helping the industry navigate through these unprecedented events and diseases,” he said.

JOE STEWART
Field Operations Manager
Eastside Packing, Inc.

Stewart also is embarking on another three years of serving the industry. He has served as a Board member from District 1 for more than a decade and has been in the citrus industry since 1985.

“I am looking forward to continuing the research for the betterment of the growers, including HLB detections/cure, helping growers be profitable with research on new pesticides, farming techniques and new varieties,” Stewart shared.

Tamara Tollison is a communications specialist at the Citrus Research Board and also serves as an editorial assistant on Citrograph. Ivy Leventhal is the managing editor of Citrograph. For more information, contact tamara@citrusresearch.org
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The California citrus industry was pleased to welcome Adalberto (Beto) Perez de Leon, Ph.D., when he was appointed this past July as the new director of the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) San Joaquin Valley Agricultural Sciences Center (SJVASC) in Parlier.

“We at the Citrus Research Board (CRB) are enthusiastic about teaming with Beto Perez de Leon to work for the sustainability and betterment of California citrus,” said Marcy L. Martin.

Citrograph spoke with Perez de Leon to learn more about the work done at the SJVASC, his new responsibilities, and the expertise he brings to the industry.

**Citrograph:** What is the mission of the SJVASC?

**Perez de Leon (PDL):** The overall mission of the 135 individuals who work at the Center is to conduct innovative research to increase productivity, quality and marketability of crops by solving agricultural problems in an environmentally sustainable manner.

**Citrograph:** Who are the stakeholder commodity groups, and how do you interact with them?

**PDL:** Our research focuses on solving agricultural problems for California producers and processors of horticultural commodities including citrus, table grapes, almonds, walnuts and stone fruit. We have research aimed at developing new and improved management strategies for insect pests and plant pathogens impacting numerous horticultural commodities. We also advance efforts of stakeholders who must meet domestic and foreign export market requirements for fresh and stored commodities. Our agricultural research aims to develop new and environmentally sustainable crop management strategies, increase water use efficiency and reduce the impact of agro-chemicals on soil and water quality. The SJVASC also hosts the National Arid Land Plant Genetics Resource Unit.

As federal employees, SJVASC scientists engage with stakeholders in research collaboration, scientific consulting, transferring technology and public-private partnerships.

**Citrograph:** What are the key strengths of the SJVASC research programs?

**PDL:** The SJVASC is uniquely positioned to fulfill its mission. Our diverse team of scientists conducts trans-disciplinary research across three research units applying state-of-the-art technologies.
that allow us to take a systems approach to solving agricultural problems. The Center in Parlier is located in the heart of the San Joaquin Valley, which provides the nexus for strong interactions with our stakeholders. We have a collaboration that spans decades with scientists at the University of California (UC) Kearney Agricultural Research and Extension Center, which is across the street from the SJVASC, the UC Lindcove Research and Extension Center in Exeter that includes the Citrus Clonal Protection Program facilities and the UC Division of Agriculture and Natural Resources Cooperative Extension in Fresno, Tulare and Bakersfield. We also collaborate with colleges and universities throughout California and abroad, including China and Italy.

**Citrograph:** How do you envision the SJVASC interacting with the CRB and the California citrus growers?

**PDL:** I learned by reading a recent Citrograph issue that citrus production in California is not for the faint of heart. The ARS has a lot to offer for the continuity of a resilient production system yielding flavorful, nutritious, vigorous, healthy and profitable citrus crops. We continue to conduct CRB-funded research and also collaborate with the CRB in research that supports USDA-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (APHIS-PPQ) programs to improve citrus disease diagnostics and surveillance. The ARS has exciting research initiatives like Partnerships for Data Innovations and Ag100Pest that align with the USDA vision to “Do Right and Feed Everyone.” We were in discussion with ARS leadership at the Pacific West Area Office in Albany, California, and the Office of National Programs in Beltsville, Maryland, to engage in those initiatives to augment the impact of research efforts at the SJVASC on the horticultural commodities industry, including California citrus production. I am excited about the opportunity to enhance the SJVASC-CRB research partnership.

**Citrograph:** What aspect of your work do you enjoy the most?

**PDL:** I am passionate about fulfilling the ARS mission and elated to be part of the stellar ARS team in Parlier. I enjoy developing mutually productive research partnerships and collaborating with stakeholders. We have an outstanding team of talented and dedicated scientists at the SJVASC. I look forward to synergizing the partnership with the CRB for the sustainability of California citrus production.

**Citrograph:** What expertise and background do you bring to your new position?

**PDL:** I have 33 years of experience, including research and development of technologies for integrated pest management and invasive insect species and vector-borne diseases. I worked in the private sector for ten years before joining the USDA-ARS in 2009. My experience in the industry ranged from discovery research to product development working in the agrochemical, pharmaceutical and biotechnology sectors. Of relevance are my interactions with diverse stakeholder groups. In my previous job with the ARS, I led research supporting eradication programs for insect pests of high consequence to agriculture should they re-invade the U.S. Mutually productive interactions with stakeholders provided insights that helped our research program stay on target to solve their agricultural problems, which ultimately contributed to the prosperity of our society. My graduate degrees in entomology include a Master of Science from the University of Georgia and a Ph.D. from the University of Wyoming. I pursued these graduate studies after getting a degree as a Doctor of Veterinary Medicine and Animal Husbandry at the Universidad Veracruzana.

To learn more about the research conducted at the SJVASC, visit their website at www.ars.usda.gov/pacific-west-area/parlier/sjvasc/.

**Ed Civerolo, Ph.D., serves as a research and editorial consultant to the Citrus Research Board. Ivy Leventhal is the managing editor of Citrograph. For more information, contact ivy@citrographmag.com**
In Memoriam:

MIKE MATHERON

Glenn C. Wright

On August 14, 2020, family, friends and colleagues bid farewell to Michael (Mike) Matheron, Ph.D., after his long battle with cancer. Mike was the consummate extension specialist, research scientist and professor, deeply aware of the challenges facing citrus and vegetable growers, homeowners and students in the Desert Southwest and willing to go to great lengths to meet their needs for information and research. Mike was a humble, gentle person, a man who was devoted to his family and to his faith.

Mike was born in Pittsburg, California, and grew up in nearby Concord, and it was there that he gained his love of sports and the outdoors. He earned a degree in biology at the University of California, Davis (UC Davis) but turned his focus to plants at Oregon State University, where he earned a Master’s degree in plant physiology, followed by a Ph.D. from UC Davis. Mike joined the University of Arizona as an extension plant pathologist in 1984. He worked at the Yuma Agriculture Center where he stayed for the rest of his career, devoting his time and efforts to the desert agriculture industry.

Throughout the course of his career, Mike wrote dozens of peer-reviewed journal articles, extension publications and newspaper columns, and also conducted many interviews. Mike was just as comfortable speaking in front of large crowds as to an individual grower or with a small group at a field day. He taught an upper-division plant pathology course at the University of Arizona-Yuma, and he fielded many questions from homeowners.

Additionally, Mike conducted a dynamic, problem-solving research program that was focused on developing new innovative methods and increasing the efficiency of present plant disease management strategies. He also operated the Arizona plant diagnostic laboratory, which provided valuable information to growers and homeowners alike.

In citrus, he was best known for his research on Phytophthora root rot and gummosis and on brown wood rot (Fomitopsis meliae). Through his ability to disseminate contemporary information pertaining to disease initiation, development and management, Mike provided Arizona citrus growers with much of their basic knowledge of Phytophthora and Fomitopsis.

Not limiting himself to citrus, Mike’s work was instrumental in understanding and combatting several important vegetable diseases, including Phytophthora stem and root rot of chile pepper, downy mildew of broccoli and lettuce, powdery mildew of lettuce and melons, Fusarium wilt of lettuce and Sclerotinia leaf drop of lettuce. Research on Fusarium is still ongoing, building on Mike’s foundational work. In his 35 years at the University of Arizona, Mike’s proudest achievement was helping vegetable growers find the solution for Sclerotinia.

Mike was always available to talk. He was humble, generous, caring and always spoke well of everyone. Undoubtedly, these characteristics were attractive to his future wife, Diane, then an oceanography student at Oregon State. Together, they raised two boys who now have families of their own.

Outside of work, Mike loved to travel and to help others. Both he and Diane actively volunteered in their faith, both in the U.S. and overseas.

Mike is survived by his wife, Diane Matheron; sons, David (Marlita) and Daniel (Emily) Matheron; brother, Jim (Lonnie) Matheron; uncle, John (Kristin) Bomben; nieces, Jaime Matheron and Kelsey (Adam) Gilbert in addition to many extended families. All these, along with many friends and colleagues, will greatly miss him.

Glenn C. Wright, Ph.D., is an associate professor and extension tree fruit specialist at the University of Arizona-Yuma Agriculture Center. For more information, contact gwright@email.arizona.edu
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Robert F. Luck, Professor of Entomology, Emeritus at the University of California, Riverside (UCR), internationally known for his research on biological control of citrus pests and the basic science underpinning biological control, passed away on September 6, 2020, in Santa Rosa, California. His leadership and pioneering research in citrus pest management were based on an in-depth understanding of the ecology and behavior of pest insects and their natural enemies. He stressed the importance of observing insects in the field and often disappeared from campus exclaiming, “Somebody has to do the field work!” The results of his research enabled him to make informed decisions about optimizing pest management strategies. Professor Luck had the valuable ability to operate as both a fundamental and practical scientist, delving into the causes as well as consequences of pest outbreaks.

Bob Luck was born in 1941 in Vancouver, Canada, and his family moved to Salinas in 1946. During his youth, his love of nature was enhanced by his years in the Boy Scouts, where he became an Eagle Scout. He attended the University of California, Berkeley (UCB), earning a B.S. degree in Forestry in 1964 and a Master’s degree in Entomology in 1966. Because he had enrolled in the ROTC to finance his studies, he served in the U.S. Navy following his M.S. degree. Upon leaving the Navy as a lieutenant, Bob obtained his Ph.D. at UCB, working on scale insects in pines. Shortly after completing his Ph.D. in April 1973, he accepted a position in the Department of Entomology at UCR. There he continued his work on forest pests until the 1980s, when he initiated studies on insect pests of citrus.

During the next decade, he conducted detailed laboratory and field studies on various natural enemies that attacked scale insects in citrus. He became an expert in designing experiments to determine optimal parasitoid release rates and to monitor the impacts of natural enemies. He applied this fundamental knowledge to develop integrated biological control systems for citrus production in California’s Central Valley. His novel management methods were used to control a suite of citrus pests with natural enemies.

In 1992, Bob hosted Professor Joop van Lenteren from Wageningen University in the Netherlands for a sabbatical. Joop remembers how Bob explained to growers in clear and straightforward terms how biocontrol works. He initially received a rather lukewarm response, with comments like “biocontrol was kind of a religion and did not really work.” At one meeting, a rather forceful grower strongly advocated the need for pesticides, but surprisingly allowed Bob to conduct a biocontrol experiment in his groves. The experiment was successful, converting the grower into an enthusiastic user and promoter of integrated pest management practices. Later, Joop and Bob visited the grower, and the convert immediately started telling this supposedly naïve guest from Holland how important Bob’s work was for the growers in California and worldwide.

In appreciation of his contributions, the California Citrus Quality Council presented Bob with the Albert G. Salter Memorial Award for his significant discoveries benefiting California citrus growers.

Professor Luck was an exceptionally engaged and approachable research program leader, well known as an enthusiastic educator and mentor of graduate students. During his career, several staff research associates provided technical support and were true partners in his research. These included Glenn Scriven in the 1970s and 1980s and Lisa Forster from the 1980s onward until he retired from UCR in 2011.

Bob and his wife Nancy enjoyed living in northern California and never expected to remain in Riverside throughout his entire career. After his retirement, they returned north, settling in Santa Rosa in the Sonoma Valley. He is survived by Nancy, his wife of 55 years; their two daughters, Stephanie and Andrea; his son-in-law, Philippe and two grandchildren, Antoine and Sylvie.

Richard Stouthamer, Ph.D., is a professor of entomology at the University of California, Riverside. For additional information, please contact richard.stouthamer@ucr.edu
Here in California, it often feels like the hits keep on coming. After the cancelation of non-granular chlorpyrifos, the California Department of Pesticide Regulation (DPR) released a "discussion draft" as a preliminary proposal on the future regulation of four classes of neonicotinoids. As currently proposed, the draft would restrict the use of imidacloprid for citrus to half the label rate and limit the use of any and all neonicotinoid classes to one application per year. This is the first step in a lengthy process. I assure you the citrus industry is working collaboratively to ensure the final regulation does not restrict neonicotinoids out of use for citrus.

The discussion draft’s release follows the Federal Environmental Protection Agency’s review of neonicotinoids, which maintains the current allowable uses in citrus and many other commodities. It also follows a risk determination conducted by the DPR itself in which soil-applied imidacloprid was just barely over the agency’s own established "No Observed Effect Concentration (NOEC)" level.
After careful review of the proposed restrictions, it is evident that there is no reasonable connection between the risk evaluation and the subsequent proposed mitigations in the discussion draft.

In partnership with the Citrus Research Board, California Citrus Mutual (CCM) has hired a team of scientific consultants with experience in pesticide risk evaluations and regulatory processes to advise us as we engage with DPR scientists. Citrus is one of the few commodities that has been extensively studied concerning neonicotinoids’ effects on bees. The DPR’s review of these studies is the rationale for the re-evaluation and basis for the proposed mitigations. Our team is regularly meeting with the DPR to do a deep dive into the existing research and determine where the evidence does not support such stringent restrictions of neonicotinoids. Our team’s own scientific review of the same studies suggest there is evidence that current application rates in citrus are already below the NOEC level.

CCM continues to engage early and often with policymakers who can shape public policy to the benefit or the detriment of the industry. Most of us realize by now that the current California administration has a vastly different and unrealistic view of pesticide use and believes many of the threats we face can be addressed through organics or biologicals. Some believe that restricting synthetic pesticides will preserve the environment and lower the risks for human health. As an organization, we know that misunderstandings and fear-mongering lead to over-reactions and over-regulation. We also are not naïve to the fact that some are informed, but have an agenda that is the opposite of ours. At this stage of the neonicotinoid regulation, we are doing our best to close the information gap that we know is present.

Our efforts have been focused on educating DPR leadership of the threat of the Asian citrus psyllid (ACP) and huanglongbing (HLB) to our industry. DPR Director Val Dolcini visited citrus groves and toured the Biosafety Level-3 lab in Riverside. He and his leadership continue to reach out and show a genuine interest in the industry’s efforts to stop ACP and HLB and the status of our research in finding a cure. I am confident they understand the importance of citrus health to California and want to get the science and the regulation right. It is our job as an industry to help them get there.

As I write this today, our team and the broader citrus industry are drafting comments in response to the discussion draft. The DPR has indicated that they will
be reviewing all comments and are expecting to release a revised draft early this year. I am confident that we have approached the issue correctly up to this point and will make significant progress with the DPR. I also am quite confident that there will be more work to do when the updated regulation is released. The CCM Board, Resources Committee and staff will work on this issue through every avenue available. We understand the importance of maintaining this vital chemistry to the future of the California citrus industry. Please continue to stay engaged and look out for important updates as we continue throughout the year. And importantly, never hesitate to contact us with any questions or concerns.

California Citrus Mutual is a voluntary non-profit trade association that advocates for commercial citrus growers on matters that affect their economic livelihood.

Casey Creamer is the president and CEO of California Citrus Mutual. For more information, contact casey@citrusmutual.com
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Committee Introduction

The goal of the Pest Management (5500) Research Committee is to ensure that its research provides California citrus growers with timely and scientifically valid information on eradication, control strategies and tool identification to manage pests to minimize crop damage and economic losses while maintaining foreign and domestic market accessibility. The committee’s diverse experience helps identify and facilitate strategic research projects that respond to the different needs within the industry.
Core IPM Review

One of the Pest Management Committee’s 2020 accomplishments, despite COVID-19 delays, was the Core Integrated Pest Management (IPM) Program external review, which initiated a method to set standard procedures and processes to better identify industry needs. Identifying, consolidating and bringing forward the most prevalent needs in pest management are imperative to the industry. The committee looks forward to frequent engagement with the newly fortified Core IPM team as we move into the 2021 growing season.

Lindcove Research and Extension Center

The Pest Management Committee would like to see University of California, Riverside Assistant Extension Specialist and Research Entomologist Monique Rivera, Ph.D., and Kearney Agricultural Research and Extension Center Assistant Research Entomologist Sandipa Gautam, Ph.D., study the logistics of the San Joaquin Valley Core IPM Program and other projects to get fieldwork ready and outreach implemented for 2021 onward. The committee hopes to have the Lindcove Research and Extension Center utilized at full capacity and maintain all previous successes, online resources and current ongoing programs, including any which may have lapsed with the departure of Beth Grafton-Cardwell, Ph.D. (see “Pushing Forward: The New Core IPM Program” on page 44).

Core IPM Program

The Citrus Research Board (CRB) Core IPM program is led by Rivera and Gautam. Several projects currently are underway with fieldwork wrapping up for the 2019-2020 season. Due to the cancellation of Lorsban® in December 2020, the Pest Management Committee felt it was imperative to look for ant material alternatives. Rivera rapidly incorporated this need into the Core IPM program, which highlights the flexibility to address industry needs by the CRB and UC partnerships. We are encouraged by early reporting on the ant management project, which is producing good data to recommend effective material options for the industry. The Pest Management Committee and UC researchers would like to meet early this spring to discuss relevant projects and facility needs for the upcoming year to help generate more industry valued projects.

Pest Management Committee Moving Forward

The committee is looking forward to a meeting this month to discuss currently funded projects, review our RFP for proposals for the next funding cycle and attend to other committee-related business. On a personal note, I would like to thank all of the Pest Management Committee members, both past and present, for their unwavering devotion to ensuring the most critical pest management needs of the California citrus industry are being met.

Chris Boisseranc is chairman of the Pest Management Research Committee and a CRB Board member. To learn more about Boisseranc, see “Board Member Introductions” on page 10. For more information about the Pest Management Research Committee, contact cboisser@gmail.com
This past summer, California’s commercial citrus industry experienced a shot across the bow in its ongoing battle against huanglongbing (HLB) with the state’s first commercial detection of a ‘Candidatus Liberibacter asiaticus’ (CLas)-positive Asian citrus psyllid (ACP). As with all major developments in the fight against HLB, swift and accurate communication is paramount to ensuring the industry is informed and protected – and in this instance, the outreach subcommittee was prepared for the challenge.

Mark McBroom
The ACP sample was confirmed positive for CLas, the bacterium that causes HLB, by the Citrus Research Board’s Jerry Dimitman Laboratory after it was collected from a commercial citrus grove in the Woodcrest area of Riverside County. This single adult psyllid was the first CLas-positive ACP found in a commercial citrus grove in California’s history. As of press time, all plant samples taken from that tree and the surrounding area have tested negative for HLB, but that doesn’t mean we can let our guard down.

In anticipation of a situation like this, the Citrus Pest & Disease Prevention Committee (CPDPC) outreach subcommittee revised a proactive issues management and crisis communications plan that would efficiently guide the committee, the Citrus Pest & Disease Prevention Division (CPDPD) and its partners through the critical first steps once an HLB-positive tree or CLas-positive psyllid/nymph was detected in a California commercial citrus grove. At these crucial times, it is imperative that the CPDPC acts quickly to ensure the messages being communicated are accurate and consistent so that assumptions or misinformation don’t create confusion. Additionally, arming the industry’s network of trusted voices is key to ensuring that we’re collaborating and maximizing the use of communication resources to keep the citrus industry informed.

Within hours of the positive psyllid confirmation, the CPDPC outreach subcommittee set this plan into motion with a meeting of the crisis communications management team – comprising a variety of stakeholders – to assess the situation and identify roles and responsibilities. Once the messaging was confirmed and outreach tactics were agreed upon, the team went to work notifying the industry. Our messaging strategy was centered on the notion that although CLas itself was not found in a commercial grove, there is still a great need for industry vigilance in protecting our crops. While the consequences of this detection are not the same as they would be for a positive CLas detection, we were able to utilize the issues management and crisis plan framework to act swiftly and communicate the situation. In collaboration with the Riverside County Agricultural Commissioner’s office, the CPDPD and the outreach subcommittee, all impacted growers, partners and elected officials in the area were notified and prepared to support our efforts. Also, thanks to the work conducted by Monique Rivera, Ph.D., at the University of California, Riverside and also the CPDPD staff, a treatment solution was identified for the detection property to limit further spread of the pest or disease.

The Asian citrus psyllid is only about 1/8th of an inch long, but can carry HLB from tree to tree as it feeds.
As a result of the CLas-positive ACP detection in Riverside, Nuffer, Smith, Tucker (the CPDPP’s outreach partner), the Riverside County Agricultural Commissioner’s office and the CPDPD staff coordinated a virtual grower meeting to inform key industry members of the implications of the detection, review regulatory requirements associated with the existing HLB quarantine area and provide a regulatory response overview should HLB be detected in a commercial grove in the future. More than 50 growers, industry members, CPDPD staff, CPDPP partners and others attended the meeting, providing the opportunity for dialogue and clarification on these important developments. In addition, information on the detection was distributed via Citrus Insider’s email newsletter, and coverage was secured in 11 industry publications, including The Packer, Agri-Pulse and Western Farm Press.

As we continue in the fight against HLB and ACP in our commercial citrus groves, the outreach subcommittee is refining its issues and crisis response plan and is ready to spring into action to ensure the industry is kept advised of the latest developments. Furthermore, it is important for industry members to stay informed about any potential detections in their area by getting to know their regional grower liaison, attending grower meetings, talking with neighbors and visiting informational websites, including www.CitrusInsider.org.

While we can’t predict what the future will hold, we can plan ahead for potential scenarios. At the CPDPC, we are doing all that we can to help fight off this imminent threat, and we want you to be the first to know about it. Sign up for your regional newsletter by reaching out to your local grower liaison or visiting www.CitrusInsider.org.

Mark McBroom is the vice chair for the Citrus Pest & Disease Prevention Committee and outreach subcommittee chairman. He also serves as secretary-treasurer of the Citrus Research Board. For more information, contact desertcitrus@aol.com.
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UPDATE ON BIOSAFETY LEVEL-3 LAB FOR HLB AND ACP RESEARCH

Figure 1. Citrus plants growing in a BSL-3 growth room. (Photo credit: Le’Kneitah Smith.)
Since the official ribbon cutting ceremony and opening of the Biosafety Level-3 (BSL-3) Laboratory in Riverside held in September 2019, researchers have been moving in, setting up workspaces and equipment and ramping up to conduct needed in-state work for the California citrus industry. The lab, built through the generous support of industry donors, was designed for researchers to conduct work with regulated plant pathogens, like the presumed causal agent of huanglongbing (HLB) ‘Candidatus Liberibacter asiaticus’ (CLas), that previously could not be done in southern California.

Research projects currently moving forward within the facility are focused on several areas of needed HLB studies for California. HLB-tolerant/resistant rootstocks and scion varieties valuable to the California industry will be developed through both traditional and non-traditional (i.e., CRISPR) breeding efforts and tested in state. Citrus Research Board (CRB)-funded researcher Chandrika Ramadugu, Ph.D., from the University of California, Riverside (UCR), is leading efforts to evaluate novel hybrids for HLB resistance/tolerance. This project is designed to identify HLB-resistance genes from these novel hybrids, which could be used in later conventional breeding efforts to introduce HLB-resistance traits into commercial citrus varieties.
CRB-funded researcher Mikeal Roose, Ph.D., from UCR, is leading California efforts in coordination with Florida to standardize greenhouse methods for the evaluation of HLB tolerance and resistance of scions and rootstocks. Roose will focus on evaluating California commercial varieties like Washington navel and Tango.

This multi-state project is designed to establish standard methods to determine and assess relative HLB tolerance/resistance of rootstocks and scions. This, in turn, will inform the industry of the varieties available and how best these materials can be utilized.

Finally, UCR’s Caroline Roper, Ph.D., is leading efforts to identify compounds that could be used either before or after CLas infection to suppress or kill the bacterium. This project is expected to identify the most promising antimicrobial compounds and application methods for future development into effective CLas/HLB mitigation therapies.

Riverside BSL-3 Research Updates

Two CLas strains, one from Florida (Psy62 strain) and one from California (Hacienda Heights strain), were introduced into the BSL-3 Laboratory during the summer, marking a significant milestone for the facility, as the introduction of the pathogen allows critically needed HLB/ACP research in California to begin in earnest. Before CLas was accepted into the efforts focused on preparing facility laboratory space, growth chambers and growth rooms. Work to establish citrus plants for the eventual introduction of CLas was also initiated. As the facility now contains CLas, HLB research is expected to ramp up in the coming year once CLas-infected source citrus plants needed for future experiments are well established.

Construction of an on-site greenhouse attached to the BSL-3 facility is anticipated in the coming year. Currently, without the BSL-3 facility greenhouse, researchers need to grow plants off site, then transfer plants to the facility’s growing room. Expansion of the facility to include an attached greenhouse should facilitate increased productivity of ongoing research activities as it makes available additional space for researchers to grow and maintain plant material on site.

The CRB is eagerly anticipating the research results from these and other projects as they conduct and complete their work within the facility and will work to keep the industry abreast on BSL-3 Lab progress through periodic updates in Citrograph.

Joey S. Mayorquin, Ph.D., is a research associate with the Citrus Research Board in Visalia, California, and serves as associate science editor of Citrograph. Melinda Klein, Ph.D., is the chief research scientist for the Citrus Research Board in Visalia, California, and the science editor for Citrograph. For more information, contact research@citrusresearch.org
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CITRUS TARPING REQUIREMENTS
REDUCE ACP MOVEMENT
The Citrus Pest and Disease Prevention Committee (CPDPC) strives to make decisions that balance safeguarding the citrus industry from huanglongbing (HLB) with the resulting additional costs and work incurred by HLB mitigation efforts. One difficult decision came in 2017 when the CPDPC voted to impose tarping requirements on trucks moving bulk citrus. To determine if tarping has influenced Asian citrus psyllid (ACP) movement, the Data Analysis and Tactical Operations Center (DATOC) was asked to review ACP detections close to highways. The results strongly support tarping.
The San Joaquin Valley (SJV) contains more than 70 percent of California’s packinghouses, and coastal and southern California counties ship more than 63 million pounds of bulk citrus into the SJV annually for processing, according to data provided by the California Department of Food and Agriculture (Figure 1). This equates to 1,400 – 1,750 trucks, each one delivering 40-50 900-pound bins. An unfortunate consequence of this movement is “hitchhikers” – ACP that travel on harvested fruit to new areas. Because ACP can spread ‘Candidatus Liberibacter asiaticus,’ the bacterium associated with HLB, the CPDPC implemented policies to address this issue, including a new requirement in 2017 that bulk citrus must be completely enclosed during transportation. It was important to determine the policy’s effectiveness after implementation, since using tarps to enclose shipments is costly and potentially risky for workers.

**Figure 1.** Left: The volume of citrus fruit (as 900 lb. field bins) moved into the San Joaquin Valley from other Asian citrus psyllid (ACP) quarantine zones during the 2018-19 growing season. Data provided by the California Department of Food and Agriculture. Right: Typical truckload of 48 bins, with compliant tarping - tight and down to truck bed. (Photo credit: Chris Sayer, Petty Ranch, Ventura County, California)

**Figure 2.** The daily increase of Asian citrus psyllid (ACP) detections (black line) on yellow sticky traps within five miles of transportation corridors, pre- and post-tarping regulations. Red and blue dashed lines indicate the average increase in cumulative ACP detections from a linear model using time and the period (pre- or post-tarping) as predictors. The cumulative numbers showed exponential growth, so the daily average increase was found by fitting a linear regression to the natural log (log_e) of the data.
DATOC examined ACP monitoring data collected by the Citrus Pest and Disease Prevention Division’s trapping program. The data examined were limited to traps within five miles of major transportation routes as previous analyses from Florida indicated areas of high risk were on either side of transport routes (Gottwald 2013). Roads that connect packinghouses to major thoroughfares also were included. There was a clear, statistically significant reduction in the rate of ACP detection in the SJV that started when tarping regulations were enacted (Figure 2). This implies that tarping is accomplishing its intended goal of reducing ACP movement out of southern California (Figure 3).

CRB Research Project #5300-182

References

Neil McRoberts, Ph.D., is a plant pathology professor at the University of California, Davis, and the western region director/deputy executive director for the National Plant Diagnostic Network. Holly Deniston-Sheets is the DATOC coordinator. For additional information, contact holly@citrusresearch.org
MINING VALUE FROM ACP PREVALENCE DATA

Neil McRoberts, Rick Dunn and Holly Deniston-Sheets

Project Summary

The Asian citrus psyllid (ACP) has spread throughout southern California since 2008, when it was first detected in the state. While it is now established in many southern counties, these areas have varying levels of ACP infestations. To gain a better understanding of annual population dynamics, possible environmental differences between counties in southern California and possible reasons for those patterns, we examined five years of ACP population data in California from 2015 through 2019. Our conclusions will be used to evaluate the effectiveness of employed control strategies, as well as guide proactive protective measures in the future. Since the California citrus industry is
undertaking some of the most ambitious and costly efforts to suppress huanglongbing (HLB) in the world, it is important to evaluate the effectiveness of these efforts and put data collected by the Citrus Pest and Disease Prevention Division (CPDPD) trapping program to good use. We report here on early results from an on-going Data Analysis and Tactical Operations Center (DATOC) project to support the CPDPD in its efforts to suppress the spread of HLB in California.

The incidence of HLB appears to be increasing more slowly in California than it has in other citrus-growing regions, but it is unclear how much of that difference can be attributed to control efforts and how much to other factors, such as climate effects on ACP populations. California’s citrus is grown in a variety of climatic conditions in 23 counties; Riverside County alone, for example, contains six different climatic groups (according to the Köppen climate classification). This variation is much greater than in other areas of the world where ACP has spread and HLB incidence has increased. The entire state of Florida, by comparison, contains only four climatic zones (Prism 2020). In addition to questions about climate variability, California’s overall climate is more Mediterranean than most places ACP have invaded previously, so it remains unclear how well ACP are suited to the conditions encountered here. Determining the extent of these effects on ACP population dynamics will help us quantify the success of the regulatory control program, as well as determine how we can reallocate program resources for optimal success.

A key component in the analysis was CPDPD commercial grove trapping data for four counties – Imperial, Riverside, San Bernardino and Ventura – from 2015-19, and for San Diego from 2016-19. Much of the CPDPD’s activity and data collection are focused in residential areas. The trapping data from commercial citrus rarely have been included in the analysis for program support. Our work is, therefore, expanding the value provided to the CPDPD from this piece of the program. Although trapping data can be difficult to interpret, previous research has shown that psyllids are moderately attracted to yellow panel traps, and trap catches fluctuate in sync with ACP populations that are observed by tap sampling (Hall et al. 2007).

The CPDPD trapping program was restructured in 2016, and the number of traps in southern California was reduced. Every month since then, about 50 traps have been checked in San Diego, 60 in Imperial, 70 in San Bernardino, 80 in Riverside and 200 in Ventura. In total, the analyses presented here used data from nearly 75,000 trap reports. These grove traps are currently placed at one per square mile, but not all commercial citrus acreage is covered (Figure 1).

Figure 1. An example of trap locations used in this analysis (to a one square mile resolution): locations from traps collected in 2019 in the southern California counties examined in this analysis. Trap locations between 2015-18 were similar to those depicted in 2019.

Weather data were compiled from the California Irrigation
Management Information System (CIMIS) and the National Oceanic and Atmospheric Administration National Climatic Data Center for the same timeframes and locations as the trapping data. Citrus flush patterns from residential grapefruit, lemon, lime, orange, tangelo and tangerine trees were extracted from data provided by David Morgan, Ph.D., of the California Department of Food and Agriculture (CDFA) Biological Control Program (Figure 2). These data were collected in the same counties as the ACP data and in approximately the same time frame. Weather and ACP data from Riverside were split into two categories (designated as “west” and “east”) based on a distinct climatic difference.

The time series data for the traps confirm that there are stable differences in ACP populations between southern California counties (Figure 3). ACP prevalence is highest in San Diego, where more than 50 percent of traps routinely catch ACP year-round, and lowest in Imperial and eastern Riverside, where populations are mainly detected in March and April, but many traps catch no ACP at all. In western Riverside, San Bernardino and Ventura, prevalence is variable, but spring and fall peaks generally can be seen in April and November with year-to-year variation.

To determine relative importance of the environmental conditions, we must boil down the complexity of all the weather and flush data to a few key factors that allow us to summarize the major patterns. This was done by using a statistical reduction of all the variables into just two dimensions, which captured 67 percent of the environmental variation. Contributions to this over-all synthesis were:

- humidity (maximum and minimum), 36 percent;
- temperature (maximum and minimum), 32 percent;
- number of days/month within (ACP)-suitable temperature range, 14 percent;
- monthly rainfall, 11 percent;
- and suitable flush available, eight percent.

**Figure 2.** Average monthly climatic conditions from 2015-19 and flush patterns for the southern California counties examined in this project.
This type of work is an important preliminary step to be able to ascribe relative importance to the environment and the program activities in determining ACP population prevalence, which in turn will help determine how growers and the industry can respond to those expected levels of prevalence. As this project progresses, we will continue to use statistical analyses to match the patterns of ACP prevalence to weather data. The next steps are to include the effects of historic levels of grower coordination in area-wide insecticide applications on county-wide ACP populations and to correlate trap data with nymph and tap-sampling data collected by a Huanglongbing Multi-agency Coordination Group project. As this project draws to a close, its conclusions will be used to project expected patterns of ACP prevalence in different areas of southern California and the San Joaquin Valley if ACP were to become established there. These projections will help guide proactive protective measures for California citrus.

**Figure 3.** Monthly prevalence of Asian citrus psyllid from traps in five counties of southern California between 2015-19 (data only available in San Diego since 2016). Each row is a year and each column is a month within that year. The fill color indicates the percent of deployed traps that caught ACP that month. Data courtesy of the Citrus Pest and Disease Prevention Division.

**CRB Research Project #5300-182**

**References**


*Neil McRoberts, Ph.D., is a professor of plant pathology at the University of California, Davis, and the western region director/deputy executive director for the National Plant Diagnostic Network. Rick Dunn is the director of data and information management at the Citrus Research Board. Holly Deniston-Sheets is the DATOC coordinator. For additional information, contact holly@citrusresearch.org*
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Pushing Forward: The New Core IPM Program

Monique J. Rivera and Sandipa Gautam
Project Summary

The Core Integrated Pest Management (IPM) program provides the California citrus industry with real-time information to optimize and refine citrus IPM practices. The program has been in place for more than a decade. Following the retirement of Joe Morse, Ph.D. (2016) and Beth Grafton-Cardwell, Ph.D. (2020), the program has new leadership through Assistant Cooperative Extension Specialist Monique Rivera, Ph.D., with additional oversight from Assistant Research Entomologist Sandipa Gautam, Ph.D. The over-all goal in 2020-21 is to address the changing dynamics of established and new threats to California citrus through research on chemical control, pesticide resistance and post-harvest controls, as well as through educational programs that bring solutions directly to growers.

Introduction to 2020-21 Goals

Each region of California citrus has unique insect pest dynamics and priorities. With the looming threat of huanglongbing (HLB) and uneven distribution of its vector, the Asian citrus psyllid (ACP), across the state, it is critical to take into consideration how each region is handling pest issues in order to align IPM programs with the collective goal of preventing the spread of HLB. Controlling ACP populations and regulatory removal of pesticide options have disrupted long-standing citrus IPM programs in many regions. Thus, new pest issues are arising, and it is the purpose of the Core IPM program to address these issues in real-time.

In citrus-growing regions where ACP has not become established, for example, in the San Joaquin Valley, prolonged periods of heat and drought have exacerbated conditions for existing pests such as California red scale, citrus thrips or mites. When pest pressure increases, pesticide use increases. The development of pesticide resistance is a critical concern moving forward. The Core IPM program group will address the changing dynamics of the existing IPM programs through research, extension and education.

Pre-harvest Goals

Pre-harvest pest management has been a central focus of the Core IPM program, which did not change in 2020. In the 2020-21 Core IPM program, ACP is now included as part of pre-harvest pest control initiatives. Historically, this work has occurred outside of the Core IPM program. A critical issue with ACP is the optimization of available, but limited, organic-certified tools. This cycle, the team will work to optimize the effectiveness of organic pesticides with adjuvant and oil mixes to assist in prolonging the amount of time the compounds remain effective (residuality).

New chemical compounds, such as Sefina® and Sivanto® recently have been made available to the California citrus industry, and old compounds have been removed. The team will test compounds for control of ants, mealybugs, citrus thrips and California red scale. With the reduction of chlorpyrifos products (Lorsban®) from the chemical
control toolbox, ants have become a major disruptor of pest management programs in many growing regions. Investigation of the field efficacy of commercially available chemicals to control ants will be conducted. Similarly, mealybug outbreaks have been occurring in places where they have not been seen for years. In response to this, efforts will be initiated to confirm mealybug species identifications and evaluate the efficacy of new and available chemicals for management of this pest.

Pesticide resistance in citrus thrips to spinetoram (Delegate®) may be increasing in the San Joaquin Valley. To address this issue and monitor for development of resistance to spinetoram in citrus thrips, field populations will be screened. The team also will continue to monitor for pyriproxyfen (Esteem®) resistance in California red scale populations.

Similarly, mites and their associated damage increasingly are becoming a concern, especially for lemon growers in the San Joaquin Valley. This year, we will initiate studies to understand the cause of the damage, develop sampling and monitoring plans and to evaluate efficacies of registered miticides.

**Post-harvest/Regulatory Goals**

In the last five years, the post-harvest part of the Core IPM program has focused on identifying solutions for pests of export concern and researching post-harvest methods to control ACP in bulk citrus. Insects including Fuller rose beetle and bean thrips, as well as mites, have become an important issue for growers exporting citrus. Phosphine is a promising effective post-harvest fumigant; and this year, the team will...
continue work to optimize fumigation treatments through evaluating different time and temperature combinations for propylene oxide and will finalize studies to evaluate propylene oxide residues after treatment.

Moreover, new species interceptions will require understanding pest ecologies in citrus orchards, identifying conditions leading to interception and evaluating the effectiveness of existing tools to mitigate the risks. The goals of the 2020-21 Core IPM post-harvest and regulatory research will be to continue to evaluate chemical and non-chemical options and their combined effects to control existing pests of export concern for the Korean and Australian markets.

Extension Goals
The goals of the extension portion of the 2020-21 Core IPM program are to gather and analyze stakeholder feedback on issues within each citrus growing region and to provide IPM educational programming on a statewide basis. With varying conditions throughout California, it is critical to understand region-specific challenges for citrus production, particularly those that interact with HLB control efforts. During the 2020-21 IPM program, the team will continue to hold CRB-funded regional workshops to address the varying needs by region. In addition, the program will provide continuity for long-standing training sessions held at the Lindcove Research and Extension Center (LREC).

Conclusion
It is an honor to serve the citrus industry through the Core IPM program. We aim to provide needed data to the industry and to receive feedback on the program. Through the collaboration and expertise of the Core IPM team along with the incoming UCANR Farm Advisor, we plan to holistically address IPM needs, as well as drive innovation in today’s California citrus industry.

Monique J. Rivera, Ph.D., is an assistant extension specialist and research entomologist based at the University of California, Riverside in Riverside, California. Sandipa Gautam, Ph.D., is an assistant research entomologist based at the Kearney Agricultural Research and Extension Center in Parlier, California. For additional information or to provide feedback, please contact monique.rivera@ucr.edu
Project Summary

Fork-tailed bush katydids are a serious fruit-feeding pest of sweet oranges, chewing deep holes in the young fruit after petal fall. Their feeding damage leaves round, scabby scars that persist to harvest. In contrast, fork-tailed bush katydids are not considered economic pests in ‘Tango’ and ‘W. Murcott’ mandarins because they do not readily feed on the fruit. We determined the status of fork-tailed bush katydids in clementine mandarins, using a combination of traditional field experiments and analyses of grower and pest control advisor (PCA) data collected from 201 commercial groves in the San Joaquin Valley. Like sweet oranges, katydid nymphs are present in commercial groves and feed readily on the young fruit of the four common clementine cultivars we tested. However, the feeding damage develops into jagged, irregular and sometimes webbed scars on mature clementines, more similar in appearance to caterpillar damage in oranges, but not the characteristic round katydid scars seen in oranges. The katydid-scarred clementine fruit also frequently split and abscise¹ late in the season, creating additional economic losses. We are updating the UC IPM Pest Management Guidelines for Citrus to include specific guidelines for mandarins that reflect this new information – that fork-tailed bush katydids are clearly a fruit-eating pest in clementines, causing scarring with a previously unrecognized appearance.
Do Katydids Damage Clementines?
Citrus fruit with visible imperfections in the rind are consistently rejected by consumers, meaning that scarred fruit are downgraded to ‘choice’ or ‘juice’ at the packing house for a net loss of value. Insect pests that directly feed on young citrus fruit are, therefore, among the most concerning for citrus growers in California’s fresh market industry. Fork-tailed bush katydids (*Scudderia furcata*) are one of these serious early-season pests of sweet oranges (*Citrus sinensis*), with the voracious nymphs feeding directly on young fruit after petal fall, creating characteristic round, scabby scars that persist to harvest. In contrast to sweet oranges, the most commonly grown cultivars of “true” mandarins (*C. reticulata*), ‘Tango’ and ‘W. Murcott Afourer,’ are resistant to fruit damage by fork-tailed bush katydids. The nymphs may be present in the groves of these mandarins, but reject opportunities to feed on the young fruit, at most causing very minor, shallow indentations in the fruit surface that are imperceptible at harvest compared to other minor mechanical damage incurred throughout the season. Clementines represent a third citrus species, *C. clementina*, that recently has increased in popularity to rank as the third most common citrus group grown in the Central Valley (CDFA & CASS 2018). The goal of this research was to determine the status of fork-tailed bush katydids in clementines.

Analyses with “Big Data” and Field Experiments
As part of our broader project to develop ecoinformatics methods for pest management in California citrus, we have constructed a large “Citrusformatics” database of pest management records contributed from growers and PCAs in Tulare and Fresno counties. We analyzed a subset of this database covering 201 commercial groves each sampled for one to ten years for katydid densities and damage in sweet oranges and clementines, controlling for effects of other variables such as crop year and grove size. The field scouting reports indicated that the incidence of katydid nymphs in the weeks after petal fall is similar in commercial sweet orange and clementine groves. However, the scarring attributed to katydids in surveys of fruit in harvest bins was relatively low in clementines. Scarring attributed to cutworms, by contrast, was higher than expected in clementines, as cutworm densities were generally very low.

These database analyses demonstrate that katydid nymphs are present in clementine groves, but there were several possible explanations for the low reported scarring, which we needed to test experimentally. We conducted two...
complementary experiments during the 2018-19 season in a mixed block of clementines at the Lindcove Research and Extension Center, using cultivars ‘Clemenules,’ ‘Corsica 1,’ ‘Fina’ and ‘Fina Sodea.’ In the first experiment, katydid nymphs were caged onto terminal branches bearing young fruit for seven days, after which they were removed and the feeding damage on each fruit was assessed. In the second experiment, artificial rind damage was mechanically applied to young fruit to mimic katydid feeding, but in a standardized way. Each fruit was tagged and monitored until it abscised or matured to harvest.

Together, these experiments tested four hypotheses to explain the lower than expected katydid scarring in commercial clementines:

1. feeding aversion: katydids are present in the groves but not feeding on young clementines;
2. scar healing: damaged clementines recover during development;
3. preferential shedding: clementines damaged by katydid feeding preferentially abscise; and
4. scar misclassification: katydid scars on clementines have a novel, undocumented appearance, different from that observed on sweet oranges that could cause misclassification of scarring in harvest bin surveys (Figure 1).

In the case of the third hypothesis, the timing of preferential abscission also is important. If the damaged fruit are shed during the “June drop” as part of the overall proportion of fruit already set to shed, the tree is essentially taking care of the damage, whereas fruit shed later in the season already have taken resources from the tree to mature thereby reducing yield.

We found strong support for hypotheses 3 and 4. We did not find support for hypotheses 1 or 2. The katydids fed heavily on many of the young clementine fruit of all four cultivars tested (Figure 2A). The feeding damage ranged from small, shallow cuts (Figure 2B) to multiple overlapping bites creating contiguous areas of superficial damage (Figure 1).
Figure 2. Katydids fed heavily on many of the young fruit of all four common clementine cultivars tested. The bar graph (A) indicates the mean percentage of fruit per cage with each damage type upon removal of the katydids. The feeding damage ranged from small, shallow cuts (B); to areas of superficial damage (C); to deep holes (D) or fruit chewed off at the base (E). The low levels of damage in the control cages were likely mechanical damage from wind or minor preexisting feeding damage from before the cages were applied.

Figure 3. The feeding damage developed into irregular scars (A) and the near-mature fruit sometimes split along the scar lines (B). At harvest, the fruit retained from katydid treatment cages had highly variable scars, including large, deep, scabby, and irregular or webbed scars (C-E), smaller (F) and thinner (G) scars. An example of a circular scar typical of katydid damage in sweet oranges is provided for comparison (H).
Maturing fruit did not recover from the damage. They developed substantial scarring where the katydids had fed, in many cases leaving long, irregular, or jagged scars (Figure 3A). Fruit damaged by katydids were more likely overall to abscise than undamaged fruit, with abscission of heavily damaged fruit occurring throughout the season, but especially late in the season from August onward. At the monitoring timepoint in October, we noticed that several of these nearly mature fruit had split along the katydid scars (Figure 3B), which likely contributed to the late abscission. At harvest, the retained fruit from katydid treatment cages had a range of scar morphologies. In some cases, the scars were large, deep, scabby and irregular or webbed in shape (Figure 3C-E). Other scars were smaller (Figure 3F) or thinner (Figure 3G). An example of a circular scar typical of katydid damage in sweet oranges is included for comparison (Figure 3H). Fruit that were mechanically damaged with a standardized, circular hole developed round scars and were not more likely to abscise than undamaged controls, indicating that the katydid feeding interacting with the fruit growth caused the unexpected scar appearance and increased fruit abscission.

2C) to deep holes (Figure 2D). In some cases, the fruit were chewed off at the base or completely consumed down to the floral disc (Figure 2E).

Fork-tailed bush katydid.

Building a Profile of Katydid in California Citrus

These results provide a two-fold explanation for the lower-than-expected katydid scarring of clementines in commercial harvest bins:

1. katydid-damaged clementine fruit often are shed from the tree late in the season, meaning fewer scarred fruit make it into harvest bins, and

2. katydid scarring in clementines looks more like caterpillar damage in oranges than katydid damage in oranges, leading to an underestimation of katydid scarring and an over-estimation of caterpillar scarring in commercial clementine harvests.

The effect of the increase of pre-harvest fruit drop is somewhat difficult to assess. This abscission does save the cost of harvesting fruit destined for downgrading, but reduces yield, as the tree already has invested resources maturing the damaged fruit.

For growers, this means there is a need to monitor and control katydids on clementines. Growers also need to update the interpretation of damage found at harvest in bin
samples for clementines to a search image of jagged and irregular scars of a range of shapes, rather than just round scars. Control methods for caterpillars and katydids are quite different, making it important to distinguish between these two early-season insect pests. We tested only four of the most commonly grown cultivars of clementines (‘Clemenules,’ ‘Corsica 1,’ ‘Fina,’ and ‘Fina Sodea’), but the results may extend to other cultivars in the species C. clementina.

Combining these findings with our earlier studies reveals three very different pest profiles of katydids in the three common citrus species considered. Fork-tailed bush katydids are notorious pests in sweet oranges, where their feeding generates deep, round scars. This project has demonstrated that these katydids also are clearly fruit-feeding pests in clementines, where they cause irregular scars and fruit drop. In contrast, katydids are not pests in ‘Tango’ and ‘W. Murcott Afourer’ mandarins, where they rarely feed on the fruit.

**Establishing IPM Guidelines for Mandarins**

This project has been part of a larger effort to revise the citrus IPM guidelines to include information specific to California mandarins. We chose to focus this report on these recent findings concerning katydids in clementines due to their immediate implications for katydid management and to refer the reader to previous reports about the Citrusformatics database (Cass et al. 2018, Cass et al. 2019, Cass et al. 2020), katydids in ‘true’ mandarins (Cass et al. 2019a,b) and citrus thrips in multiple mandarin species (Mueller et al. 2019). We now are in the process of updating the UC IPM Guidelines for Citrus to include specific sections on katydids and citrus thrips in mandarins and clementines (Grafton-Cardwell et al. 2020), updating the UCANR katydid online course (https://campus.extension.org/course/index.php?categoryid=142) and producing a Photographic Guide to Early Season Fruit Scarring in Sweet Orange and Mandarins to complement UCANR Publication 8090 (Grafton-Cardwell et al. 2003). We thank all the growers and PCAs who have supported this research and contributed data to the “Citrusformatics” database. While the current projects conclude, the database continues to grow, serving as a resource to address future challenges in citrus. Our experimental research continues with a focus on determining the status of European earwigs as fruit-feeding pests in oranges and mandarins, supported by CRB Research Project #5500-220.

**Glossary**

1. **Abscission:** The shedding or dropping of leaves, fruit, flowers or seeds in the case of plants.

2. **Ecoinformatics:** A research data mining method to collect and analyze a large volume of data pooled from multiple sources, often covering a larger scale and timeframe relative to traditional field experiments.

**CRB Research Project #5500-214**

**References**


**Bodil Cass, Ph.D., is a post-doctoral scholar of entomology at the University of California, Davis. Elizabeth Grafton-Cardwell, Ph.D., is the retired director of the Lindcove Research and Extension Center and research entomologist at the University of California, Riverside. Jay Rosenheim, Ph.D., is a distinguished professor of entomology at the University of California, Davis. For additional information, contact bncass@ucdavis.edu**
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(Solubility Determines Availability)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium Sulfate</td>
<td>0.6</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>2.7</td>
</tr>
<tr>
<td>Mono-Potassium Phosphate</td>
<td>2.8</td>
</tr>
<tr>
<td>Potassium Chloride</td>
<td>3.0</td>
</tr>
<tr>
<td>Ammonium Phosphate</td>
<td>3.8</td>
</tr>
<tr>
<td>RENEW 4-20-22</td>
<td>14.1</td>
</tr>
</tbody>
</table>

Pounds dry fertilizer that dissolve in 1 gal. at 72 degrees F.

For more information including research results and scientific publications, contact;
Mark Brady, Western Marketing Manager, Plant Food Systems, Inc. (559) 731-1267
Fungicide Management of Alternaria Rot in San Joaquin Valley Mandarins

Paulo S. F. Lichtemberg, Ryan Puckett, Miriam Marzall-Pereira, João Brosin, David Rodriguez and Themis J. Michailides
Project Summary

In the 2018-19 and 2019-20 growing seasons, we evaluated the efficacy and best timing of several registered fungicides to control Alternaria rot (AR) in mandarins. In this study, latent infections¹ of Alternaria alternata, the causal agent of AR, were not affected by pre-harvest fungicide applications since disease incidences were not reduced below 60 percent. However, the spray effect on fruit drop was significant, revealing different efficacies among commercial fungicides already registered for this crop. This study will indicate the candidate fungicides for pre-harvest use if growers decide to manage AR in the field.

Alternaria alternata, which causes AR, is important as a pathogen of fruit in long-term storage, but also can cause pre-harvest losses in groves when high levels of inoculum are present and weather conditions are conducive to disease development (Lichtemberg et al. 2020). In the last few years, growers have expressed concerns about increasing fruit drop, particularly for mandarins, due to this disease. Difficulties in identifying early symptoms that may indicate a problem can result in excessive fruit drop in cases when infections occur at the fruit stem end. Early and late AR colonization on fruit collected from the tree and the orchard ground, respectively, can be seen in Figure 1.

The current recommendations for AR are to maintain a well-managed and healthy grove to reduce tree stress and fruit damage and prevent the inclusion of infected fruit in the harvested crop (Adaskaveg et al. 2016). The same authors state that pre-harvest fungicide treatments usually

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Table 1. Chemicals and application rates used in three efficacy trials against Alternaria rot in Tulare County, California. ‘X’ denotes a chemical used in a trial and ‘NI’ denotes a chemical not included in a trial.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Active ingredient</th>
<th>Registrant</th>
<th>Application Rate</th>
<th>Sumo (Season 1)</th>
<th>Sumo (Season 2)</th>
<th>Satsuma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actinovate AG</td>
<td>Streptomyces lydicus WYE 108</td>
<td>Novozymes BioAG Inc</td>
<td>12 ounces/A (A)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Kocide 3000</td>
<td>Copper Hydroxide</td>
<td>DuPont</td>
<td>3.5 pounds/A</td>
<td>NI</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>K-Phite 7LP</td>
<td>salts of phosphorous acid</td>
<td>Plant Food Systems Inc</td>
<td>2 quarts/A</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Luna Experience</td>
<td>Flupyrad+ Tebuconazole</td>
<td>Bayer CropScience LP</td>
<td>7.6 fluid ounces/A</td>
<td>X</td>
<td>X</td>
<td>NI</td>
</tr>
<tr>
<td>Luna Sensation</td>
<td>Flupyrad+ Trifloxystrobin</td>
<td>Bayer CropScience LP</td>
<td>7.6 fluid ounces/A</td>
<td>NI</td>
<td>NI</td>
<td>X</td>
</tr>
<tr>
<td>Parka</td>
<td>phospholipids</td>
<td>Cultiva LLC</td>
<td>1 gallon/A</td>
<td>X</td>
<td>NI</td>
<td>NI</td>
</tr>
<tr>
<td>Ph-D</td>
<td>Polyoxin D zinc salt</td>
<td>Arysta LifeScience</td>
<td>6.2 ounces/A</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pristine</td>
<td>Pyraclostrobin + Bosalid</td>
<td>BASF Corporation</td>
<td>18.5 ounces/A</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pristine/Vapor Gard/Pristine</td>
<td></td>
<td></td>
<td>18.5 ounces/A</td>
<td>NI</td>
<td>X</td>
<td>NI</td>
</tr>
<tr>
<td>Quadris Top</td>
<td>Azoxystrobin + Difenoconazole</td>
<td>Syngenta Crop Protection LLC</td>
<td>15.4 fluid ounces/A</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Quadris Top + Sanitation</td>
<td>Azoxystrobin + Difenoconazole</td>
<td>Syngenta Crop Protection LLC</td>
<td>15.4 fluid ounces/A</td>
<td>NI</td>
<td>X</td>
<td>NI</td>
</tr>
<tr>
<td>Vapor Gard</td>
<td>di-1-p-Menthene</td>
<td>Miler Chemical &amp; Fertilizer</td>
<td>1 gallon/A</td>
<td>X</td>
<td>X</td>
<td>NI</td>
</tr>
</tbody>
</table>

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¹ Latent infections refer to infections that are present but not yet visible or symptomatic.
are ineffective and suggest that delaying harvest until the infected fruit has fallen can reduce post-harvest losses. However, excessive fruit drop can have a considerable economic impact, especially for high value cultivars such as 'Sumo Citrus®' mandarins. For this reason, our trial aimed to determine the effects of fungicide sprays on *A. alternata* latent infections and fruit drop. Additionally, we report results of a one-year study on the best timing to apply fungicides if a single application is desired.

### Fungicide Efficacy

Fungicide trials were conducted in Tulare County commercial groves of 'Sumo' on trifoliate rootstock and satsuma on C-34 rootstock during the successive seasons of 2018-19 and 2019-20 ('Sumo' trial) and 2019-20 (satsuma trial) using various registered products (Table 1). For the 'Sumo' trial, each treatment consisted of five clustered trees per row with evaluations made on the three central trees. Fungicides were applied at the label rate in 100 gallons per acre on November 15 and December 13, 2018 for season 1; and November 5 and December 15, 2019 and January 15, 2020 for season 2. For the satsuma trial, each treatment consisted of five individual trees randomized within each row and fungicides were applied on September 3, October 1 and November 1, 2019.

#### Table 2. Fungicide efficacy trial against Alternaria rot in 'Sumo' mandarins during the 2018-19 season.

<table>
<thead>
<tr>
<th>Product</th>
<th>Latent Infection (%) (std)</th>
<th>Mean fruit Drop (%) (std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-Phite</td>
<td>63.2 (0.11) a</td>
<td>12.4 (8.92) bc</td>
</tr>
<tr>
<td>Quadris Top</td>
<td>69.6 (0.24) ab</td>
<td>4.8 (5.59) a</td>
</tr>
<tr>
<td>Vapor Gard</td>
<td>82.0 (0.10) bc</td>
<td>25.3 (11.77) ef</td>
</tr>
<tr>
<td>Luna Experience</td>
<td>83.9 (0.20) bc</td>
<td>10 (3.87) bc</td>
</tr>
<tr>
<td>Pristine</td>
<td>86.7 (0.09) bc</td>
<td>7.6 (4.42) ab</td>
</tr>
<tr>
<td>Ph-D</td>
<td>90.0 (0.07) c</td>
<td>16.3 (10.26) cd</td>
</tr>
<tr>
<td>Untreated</td>
<td>91.4 (0.10) c</td>
<td>21.8 (12.15) def</td>
</tr>
<tr>
<td>Actinovate AG</td>
<td>92.2 (0.05) c</td>
<td>27.2 (11.52) f</td>
</tr>
<tr>
<td>Parka</td>
<td>93.8 (0.11) c</td>
<td>16.3 (7.37) cde</td>
</tr>
</tbody>
</table>

**Notes:**
- *Spreader 90 at 16 fluid ounces per acre was added to all treatments.
- Number of fruit examined for latent infection (n=180), number of trees inspected for fruit drop (n=9).
- Standard deviation (std) of mean and column numbers followed by the same letter are not significantly different.

#### Table 3. Fungicide efficacy trial against Alternaria rot in 'Sumo' mandarins during the 2019-20 season.

<table>
<thead>
<tr>
<th>Product</th>
<th>Latent Infection (%) (std)</th>
<th>Mean fruit Drop (%) (std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-Phite 7LP</td>
<td>79.4 (0.17) a</td>
<td>1.6 (11) bcd</td>
</tr>
<tr>
<td>Ph-D</td>
<td>82.4 (0.08) a</td>
<td>1.2 (1.0) abc</td>
</tr>
<tr>
<td>Quadris Top (sanitation)</td>
<td>84.4 (0.11) a</td>
<td>0.6 (0.6) a</td>
</tr>
<tr>
<td>Luna Experience</td>
<td>86.5 (0.03) a</td>
<td>1.1 (1.1) ab</td>
</tr>
<tr>
<td>Kocide 3000</td>
<td>87.6 (0.03) a</td>
<td>1.3 (1.5) abc</td>
</tr>
<tr>
<td>Quadris Top</td>
<td>87.6 (0.11) a</td>
<td>1.0 (0.8) ab</td>
</tr>
<tr>
<td>Pristine/VaporGard /Pristine</td>
<td>87.7 (0.08) a</td>
<td>1.9 (1.4) cd</td>
</tr>
<tr>
<td>Untreated</td>
<td>87.7 (0.08) a</td>
<td>2.2 (1.6) d</td>
</tr>
<tr>
<td>Actinovate AG</td>
<td>88.3 (0.06) a</td>
<td>1.4 (1.1) abcd</td>
</tr>
<tr>
<td>Pristine</td>
<td>90.0 (0.08) a</td>
<td>1.2 (1.1) abc</td>
</tr>
<tr>
<td>Vapor Gard</td>
<td>90.5 (0.05) a</td>
<td>1.3 (0.9) abc</td>
</tr>
</tbody>
</table>

**Notes:**
- *Spreader 90 at 16 fluid ounces per acre was added to all treatments.
- Number of fruit examined for latent infection (n=180), number of trees inspected for fruit drop (n=15).
- Standard deviation (std) of mean and column numbers followed by the same letter are not significantly different.
Table 4. Fungicide efficacy trial against Alternaria rot in satsuma mandarins during the 2019-2020 season.

<table>
<thead>
<tr>
<th>Product</th>
<th>Latent Infectiona % (stdb)</th>
<th>Mean fruit Dropc (stdc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luna Sensation</td>
<td>64.6 (0.17) a</td>
<td>0.6 (0.55) ab</td>
</tr>
<tr>
<td>Ph-D</td>
<td>69.1 (0.09) ab</td>
<td>1.6 (1.52) b</td>
</tr>
<tr>
<td>Quadris Top</td>
<td>72.9 (0.10) abc</td>
<td>0 (0) a</td>
</tr>
<tr>
<td>K-Phite</td>
<td>77.1 (0.11) bcd</td>
<td>0.4 (0.89) ab</td>
</tr>
<tr>
<td>Actinovate AG</td>
<td>76.2 (0.13) bcd</td>
<td>0.8 (1.1) ab</td>
</tr>
<tr>
<td>Kocide 3000</td>
<td>80.6 (0.10) cd</td>
<td>1.2 (0.84) ab</td>
</tr>
<tr>
<td>Pristine</td>
<td>80.6 (0.13) cd</td>
<td>1.6 (1.34) b</td>
</tr>
<tr>
<td>Untreated</td>
<td>83.6 (0.09) d</td>
<td>3.2 (1.1) c</td>
</tr>
</tbody>
</table>

a Spreader 90 at 16 fluid ounces per acre was added to all treatments.  
b Number of fruit examined for latent infection (n=200), number of trees inspected for fruit drop (n=5).  
c Standard deviation (std) of mean and column numbers followed by the same letter are not significantly different.

for the ‘Sumo’ trial, and 100 fruit per treatment were sampled two weeks after each spray application for the satsuma trial. AR symptomatic fruit that had fallen onto the ground were counted at the time of harvest – January for the ‘Sumo’ trial and mid-November for the satsuma trial.

Fungicide Timing

Three rows of a commercial ‘Gold Nugget’ grove in Tulare County were used to determine optimum spray timing to achieve the best AR control with a single spray per season. At two-week intervals, 15 individual trees clustered in groups of five and randomized within each row were sprayed with Pristine® (BASF Corporation) at 18.5 ounces per acre. A single Pristine spray was applied on January 6, January 20, February 3, February 17 or March 2, 2020 as described above. Fifteen trees served as untreated controls. At the time of harvest (March 21, 2020), the dropped fruit with AR symptoms were counted.

Storage Evaluation

To evaluate whether field sprays can offer protection of fruit from AR while in storage, we harvested and stored satsuma

![Figure 2. Effect of a single Pristine spray application on fruit drop of ‘Gold Nugget’ evaluated on March 21, 2020. Bars connected by the same letter are not significantly different.](image-url)
(120 fruit per treatment or 24 per tree) and 'Sumo' (90 fruit per treatment or 30 per row in season 1, and 75 fruit per treatment or 25 per row in season 2) mandarins for six weeks. The cold-room regimen was three days at 40ºF, seven days at 50ºF, then five weeks at 43ºF. The number of fruit showing AR symptoms was counted weekly.

**Fungicide Efficacy**

In the 2018-19 'Sumo' trial, K-Phite® and Quadris Top® reduced the incidence of latent infections by 28.2 percent and 21.8 percent, respectively, compared to the untreated control. However, the reductions by Quadris Top did not differ from the

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**Figure 3.** Alternaria rot decay of 'Sumo' mandarin stored for 28 days after harvest during the 2018-19 season. Lines connected by the same letter are not significantly different.

**Figure 4.** Alternaria rot decay of 'Sumo' mandarin stored for 42 days at 40 to 50°F after harvest during the 2019-20 season. Lines connected by the same letter are not significantly different.
Vapor Gard®, Luna® Experience or Pristine treatments (Table 2). Trees treated with Quadris Top and Pristine had the lowest number of dropped fruit counted at harvest time with 4.8 and 7.6 fruit, respectively. Dropped fruit from trees treated with Luna Experience and K-Phite averaged 10 and 12.4 fruit per tree respectively, which are statistically similar to that from Pristine-treated trees (Table 2). Despite the low number of fruit drop observed in the 2019-20 trial, treatment with Quadris Top, combined with sanitation practices (careful removal of dead twigs and ground litter) provided better fruit protection than K-Phite, the spray rotation program including Pristine and Vapor Gard, and the untreated control (Table 3).

The satsuma fruit treated with Luna Sensation resulted in the lowest incidence of latent infections (64.6 percent), corresponding to a reduction of 1.3 times the incidence in the control (Table 4). There was a low amount of dropped fruit at harvest time, and few products demonstrated statistical advantage (Table 4).

There were high incidences of latent infections in all three efficacy trials (above 60 percent) even after applying fungicides. These rates correspond to the winter incidence (Lichtemberg et al. 2020) on mandarins from Tulare County. With such levels, the risk of AR to cause excessive fruit loss at pre-harvest is potentially increased if weather conditions are conducive for the disease. For instance, in the 2019-20 season, the ‘Sumo’ untreated control had 90 percent fewer dropped fruit than in the previous season, which could be attributed to the differences in rainfall during the two seasons for this cultivar. The California Irrigation Management Information System for the Lindcove weather station in Tulare County (the one closest to our trial site) reported total rainfall three to ten times higher for January and February 2019, respectively, compared to the same period in 2020 (CIMIS 2020).

**Timing Trial**

The last two seasonal sprays applied on February 17 and March 2 resulted in lower fruit drop counts that differed statistically from those counted under the untreated trees (Figure 2). These two best times for spraying correspond to 34 and 20 days before harvest of ‘Gold Nugget’ mandarins.

**Storage Evaluation**

In 2018-19, AR caused an overall fruit decay of 13 percent after 28 days in storage (data not shown). Extended AR control was observed with Ph-D field-treated fruit, with an average of 5.6 percent incidence of symptomatic fruit. Treatment with K-Phite, Quadris Top and Luna Sensation resulted in an AR decay ranging from 10-13 percent, which was not statistically different from the other treatments, including the untreated control (18 percent decay; Figure 3). In 2019-20, AR storage decay was lower than
in the previous year with an overall average of four percent at the end of the sixth week (data not shown). In general, field-treated fruit showed no differences among chemical products evaluated, but differed from the untreated control where ten percent of the fruit developed AR (Figure 4). No AR decay developed in satsuma mandarins (data not shown).

Conclusion
Field sprays in these trials were ineffective in preventing latent infection by *A. alternata*. However, preventive spray applications resulted in decreased numbers of dropped fruit at harvest time. In these three efficacy trials, Quadris Top reduced latent infections of *A. alternata* and fruit drop. For this reason, alternating Quadris Top with other high-performance products is recommended when decisions to spray for AR are made. Sanitation practices appear to decrease losses caused by AR and always should be implemented when economically feasible.

We suggest that field treatment against AR is only recommended for groves when AR is a concern due to a history of losses caused by this disease or when the orchard is located in an area that is under high disease pressure (Lichtemberg et al. 2020). Above normal precipitation forecasts prior to harvest should trigger a spray to provide protection of fruit from AR. If a single seasonal spray is chosen, our first-year trial indicates better results with a spray within two months prior to fruit harvesting, considering the pre-harvest interval specified on the product’s label. Some of the trials presented here will be repeated during the 2020-21 season for better understanding of AR epidemiology.

CRB Research Project #5400-157

Glossary

¹Latent infection: A close, parasitic relationship between pathogen and plant that develops symptoms after an initial symptom-free period.

References


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TAKING A SECOND LOOK AT EXPORT ISSUE MITES

Lorryia formosa and Tarsonemus bakeri Mites are Non-damaging to Citrus

Sandipa Gautam and Elizabeth Grafton-Cardwell

Figure 1. Mite specimens were identified using a microscope. (Photo: Yuling Ouyang, Staff Research Associate, Citrus Entomology Laboratory.)
Project Summary

Lorryia formosa Cooreman and Tarsonemus bakeri Ewing are two non-damaging mites often associated with citrus that are an export concern for Australia and New Zealand. Based on field surveys of 78 citrus orchards, L. formosa and T. bakeri are always associated with sooty mold. These mites were found year-round on leaves and fruit in two orchards that were sampled monthly, although overall numbers fluctuated seasonally. In laboratory tests of leaf versus plastic substrate and different food types and their combinations, both species require food with sugary substances or molds to survive. No feeding damage of leaves or fruit due to mite infestation was observed in the field or under laboratory conditions. These studies confirm that L. formosa and T. bakeri are associated with sooty mold in citrus orchards, cannot sustain populations on leaf tissue alone and do not damage citrus fruit in California.

Introduction

Lorryia formosa Cooreman (Brachytyedus formosa) and Tarsonemus bakeri Ewing are two species of mites often associated with citrus in many countries, including the United States. Early reports suggested they were citrus pests because of their widespread occurrence (Smirnoff 1957; McGregor 1942). However, several studies, including field surveys, reported no plant or fruit damage. Instead, a complex feeding behavior of L. formosa and fungal feeding behavior of T. bakeri were described (McGregor 1956; Mendel and Gerson 1982; Aguilar-Piedra 2001). California pest control advisers acknowledge that these mites are commonly seen feeding on sooty mold, a dark colored fungus that grows on honeydew excreted by sap-sucking insects, especially under humid conditions.

These mite species may be a part of the natural fauna in California and never have been reported as a concern by California citrus growers (Gautam et al. 2018). Although importing countries have a right to reject fruit with mites that they do not have, reports suggesting a phytophagous1 nature by McGregor (1942) and Smirnoff (1957) provided grounds to categorize them as risk species. Both L. formosa and T. bakeri are quarantine pests in Australia and New Zealand and require mitigation measures when intercepted. Between 2013-17, L. formosa and T. bakeri were intercepted 94 and 104 times, respectively, in New Zealand. The current method of disinfesting citrus arriving in Australia or New Zealand upon quarantine pest interception is fumigation using methyl bromide. This project aimed to understand the seasonal abundance of mites in California citrus orchards, their feeding habits and potential for damage.

Approach

Field Surveys

In 2018, we conducted field surveys of 17 citrus orchards in Ventura (July), 16 orchards in the city of Riverside (August) and 45 orchards in the Coachella and Imperial Valleys (November/December). Each site was surveyed once. The citrus orchards were selected as representatives of management methods (conventional/organic) and varieties in the area and are a part of an ongoing Asian citrus psyllid (Diaphorina citri Kuwayama) monitoring project. The percentage of sooty mold infestation in each orchard was determined by sampling trees along the north, south, east, west and center of the field. Fifty sooty mold-infested leaves were randomly collected and microscopically evaluated for mites. Any mites found were preserved in a glass vial with 75 percent alcohol for later identification (Figure 1).

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1. Phytophagous: feeding on plants.
Figure 3. Percentage infestation by fungal feeding mites of citrus orchards. A total of 78 orchards were surveyed - 17 in Ventura, 16 in Riverside and 45 in Coachella and Imperial valleys.

In addition to the field surveys, two orchards were surveyed on a monthly basis to understand the seasonal distribution and population structure (life stages, sex ratio) of mites in citrus orchards. The orchards were selected after confirming the presence of Lorryia or Tarsonemus mites. For L. formosa, samples were collected from a “Gold Nugget” mandarin orchard in Ventura County from January 2015 to December 2016. For T. bakeri, samples were collected from a “Washington” navel orange orchard in Fresno County from June 2018 to May 2019. Five leaves and one fruit per tree were randomly sampled from 30 trees every month and brought back to the laboratory, where the mites were counted under the microscope to determine the seasonal population structure.

**Food Suitability and Feeding Damage**

We tested the ability of L. formosa and T. bakeri to survive and multiply on different food sources in the laboratory.

Figure 4. *Lorryia formosa* mite aggregated around a cottony cushion scale (left) and around sooty mold (right).
**Figure 5.** (A) Mean number of *Lorryia formosa* and (B) *Tarsonemus* spp. per leaf or fruit on samples collected during the field survey. *Tarsonemus* mites were sampled from June 2018 to May 2019.

**Figure 6.** Percentage survival of *Lorryia formosa* adults on different food sources over a period of four weeks. L – excised leaf, HD – honeydew, SW – sugar water, CCS – cottony cushion scale, SM – sooty mold.
Fifteen adult mites were transferred to the underside of a fully expanded mandarin leaf (Figure 2). *Lorryia* were provided either:
1. a citrus leaf,
2. a leaf + honeydew produced by cottony cushion scale (CCS),
3. a leaf + sugar water,
4. a leaf + honeydew producing CCS,
5. a leaf + sooty mold or
6. a leaf + a combination of these food items.

*Tarsonemus* were provided either:
1. plastic substrate or citrus leaf,
2. plastic substrate or leaf + *Alternaria* fungus,
3. plastic substrate or leaf + molasses + honeydew or
4. plastic substrate or leaf + a combination of these food items.

Each treatment was replicated four times. Numbers of live and dead mites were counted twice every week for four weeks to determine the effects of the food source on survival.

Figure 7. Mean number of *Tarsonemus bakeri* on different food sources over a period of four weeks. L – excised leaf, Alt – *Alternaria* spp., HD – honeydew, M – molasses, P – plastic substrate.

Figure 8. *Tarsonemus bakeri* feeding on *Alternaria* spp. growing on an excised orange leaf. This nine-month old population has been thriving on this decaying leaf since April 2019.
Lorryia and Tarsonemus mites. One hundred percent of citrus trees surveyed in Ventura county orchards had sooty mold-infested leaves ranging from low to very high levels (less than 20 percent of trees and 100 percent of trees with sooty mold, respectively), and 65 percent of these sites had infestations of Lorryia and/or Tarsonemus mites (Figure 3). In contrast, citrus trees in the Coachella Valley and Imperial Valley did not have sooty mold or mites. Twenty-five percent of the sites in the city of Riverside had very low levels of sooty mold, and the Tarsonemus mites were found only in orchards that had sooty mold (Figure 3). Irrespective of the citrus variety or management style, the presence of Lorryia and Tarsonemus mites were always associated with sooty mold. Furthermore, leaves without sooty mold did not have any mites, suggesting mites require sooty mold. When present, mites preferred to aggregate around a honeydew-producing insect or sooty mold along the midrib on the underside of the leaf or under the calyx² of fruit (Figure 4).

In the two field population studies, mites were present during every sampling period – January 2015 through December 2016 for L. formosa (Figure 5A) and June 2018 through May 2019 for Tarsonemus bakeri (Figure 5B). For both species, population size fluctuated across the sampling period. In general, fruit had higher number of mites suggesting that was where these mites preferred to reside. Both species preferred the shaded side of the tree, inside the canopy, and they were always associated with sooty mold on leaves or fruit.

Food suitability and feeding damage. In food suitability studies, both species required food in the form of sugary substances or mold (fungus) to survive (Figures 6 and 7). All L. formosa adults and immature stages died within 14 days on excised leaves without supplementary food and caused no visible feeding damage when observed with a microscope. In contrast, they survived for four weeks when given any kind of sugary substance. The exception was the treatment that included all food types because the leaves degraded.

T. bakeri survived and reproduced on both excised leaves and the plastic substrate when given additional food sources but did not survive when additional food was not available. Population growth was best supported on a leaf substrate with Alternaria, honeydew and molasses (Figure 7). T. bakeri continued to survive and multiply on the decaying leaf. We have noted Tarsonemus spp. mites on decaying leaves in the field. These observations support that Tarsonemus mites feed on fungus growing on decomposing leaves (Figure 8). Mendel and Gerson (1982) noted that fungal feeding mites may be considered beneficial, providing sanitation of leaves and fruit by removing mold.

Conclusion

Lorryia formosa and Tarsonemus bakeri are associated with sooty mold in citrus orchards. Mites reside on sooty mold infested leaves year-round and move to new fruit when sooty mold is present on fruit.

Acknowledgements

We would like to acknowledge Joel Leonard, California Polytechnic State University, San Luis Obispo and Kevin Gonzalez, University of California, Riverside for assistance with the field surveys. The Kearney Agricultural Research and Extension Center team, Yuling Ouyang, Ping Gu and Monty Lo, conducted field population and food suitability studies.

References


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It has been 30 years since a major frost hit the groves in the Central Valley, but the threat is still there. One or more could occur in any given winter. In the early twentieth century, California orange growers had to find effective ways to contend with the menace of frost damage to their groves, as major frosts occurred in 1913 and 1937, taking a significant financial toll on the citrus industry. To combat low temperatures, orange growers developed orchard heaters, colloquially referred to as “smudge pots” because of the smoke they emitted. These devices, pictured here in a bulletin from the California Extension Service in 1939, highlight the important role that orchard heaters played in preventing groves from freezing.

Smudge pots are no longer legal in California. Growers now use special methods of running water and wind machines to help control the temperature in the groves during frost or freezing conditions.

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