CITRUS RESEARCH BOARD

Citrograph

MAGAZINE

FALL 2023

POST-HARVEST RESEARCH UPDATES


FALL 2023
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14

18

34

48

On the Cover: *Cal Poly, San Luis Obispo graduate student Kimiko Casuga pours agar media for surrogate tests. The surrogate has the potential to aid post-harvest operators in the validation of their food safety practices. Read more about this research in Validating Food Safety Practices in Citrus Packinghouses by Amanda Lathrop, Ph.D., Casuga and Steven Pao, Ph.D., on page 54 of this issue of Citrograph, which focuses on post-harvest and production efficiency research.*

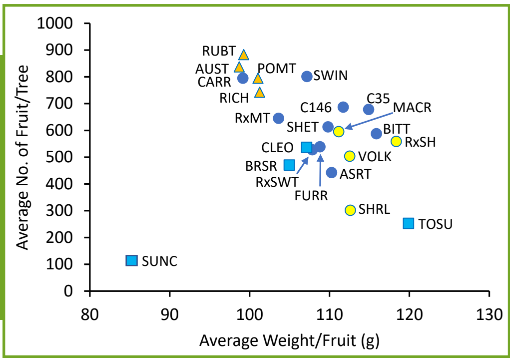
In This Issue

Fall 2023 | Volume 14 • Number 4 The Official Publication of The Citrus Research Board

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

Editor's Note: In the summer 2023 issue of *Citrograph*, there was a graphic error in the Roose/Federici article, "Rootstock Influences on 'Nules' Clementine Yield and Fruit Quality." Figure 1A inadvertently was a duplicate of Figure 1B. The corrected Figure 1A is shown at right, along with the appropriate part of the original caption shown below.

Figure 1. Plots of rootstock means for combinations of yield and fruit quality traits in November 2022. Trifoliate orange rootstocks are indicated by orange triangles, lemon-type rootstocks by yellow circles, other citrus rootstocks by teal squares and trifoliate hybrids by blue circles. See Table 1 for rootstock abbreviations. A. Average weight per fruit in grams (g) vs. average number (No.) of fruit per tree.



THE MISSION OF THE CITRUS RESEARCH BOARD

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

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UPCOMING EVENTS

2023

SEPTEMBER 19

CITRUS RESEARCH BOARD (CRB) ANNUAL MEETING

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

NOVEMBER 8

CITRUS PEST AND DISEASE PREVENTION COMMITTEE (CPDPC) MEETING

For more information, visit *www.cdfa.ca.gov/citruscommittee*

2024

MARCH 26-29, 2024

INTERNATIONAL RESEARCH CONFERENCE ON HUANGLONGBING VII (IRCHLB VII).

For more information, visit *www.irchlb.com*

From the PRESIDENT'S DESK

Marcy L. Martin

As the Citrus Research Board (CRB) enters the fall season, we begin preparing ourselves for next year's CRB activities, including hosting the seventh International Research Conference on Huanglongbing on March 26-29, 2024, in Riverside, California. Although we will not be hosting the California Citrus Conference this year, we hope you were able to join us at our Citrus Growers Educational Webinar Series held in June, or at the 41st Post-harvest Conference held earlier this month with the latest information for post-harvest and packinghouse professionals.

Beyond our outreach events, we also are preparing for the initiation of new research projects. Proposals for these projects were reviewed and recommended by their respective research committees, and they will be presented to the CRB Board of Directors later this month for approval at the CRB's Annual Board Meeting. You will hear more about these new research projects in the 2024 Summer issue of *Citrograph*.

Marcy L. Martin

Before diving into the research updates in this issue, I would like to take a moment to introduce our newest staff member, Ivan Milosavljević, Ph.D. He joined the CRB as an Integrated Pest Management Entomologist on July 3, 2023, and will be responsible for developing applied citrus pest research projects with industry input. He also will monitor the California Citrus Research and Field Trials (CA-CRaFT) project, which the CRB launched last year and is focused on strategies for mitigating Asian citrus psyllid.

This edition of *Citrograph* focuses on production and post-harvest research. It highlights the work of CRB-funded researchers to deliver timely and validated information on horticultural factors and pre- and post-harvest diseases to increase production efficiency. I want to highlight two projects in this area of research.

Jim Adaskaveg (Sweet Orange Scab Update)

James (Jim) Adaskaveg, Ph.D., at the University of California (UC), Riverside leads the Pre- and Post-harvest Citrus Disease Management Core Program to provide a state-of-the-art IPM program for diseases caused by fungi, fungal-like organisms and non-fastidious bacteria. The program actively studies several important citrus diseases, including sweet orange scab (SOS), which is caused by the fungus *Elsinoë australis. E. australis* is federally regulated and has been detected molecularly numerous times throughout southern California, resulting in 'regulated areas' impacting producers in the desert-growing regions. Although positive detections have been recorded, affected fruit in California present with atypical symptoms of SOS. To date, the core program has been unable to culture *E. australis* from fruit identified as molecularly positive for *E. australis*. Furthermore, molecular diagnostics performed by the core program suggest the molecular method currently being used to detect *E. australis* may not be specific and thus may be detecting other organisms. More information from this research project can be found on page 60.

Daniele Zaccaria (Citrus Evapotranspiration)

Daniele Zaccaria, Ph.D., at UC Davis is leading an extensive team of researchers to ground truth satellite remote sensing (SRS) methods to estimate citrus evapotranspiration (ET). The importance of water, particularly in California, cannot be emphasized enough, and the Board identified water-related research as one of its most important researchable areas. To address this critical research need, Zaccaria was sought out to perform research in this crucial area. Specifically, his research focuses on identifying the uncertainty level from SRS methods, providing recommendations to reduce this uncertainty and updating ET and water productivity information for citrus orchards in Tulare, Kern and Riverside counties. The outputs of this project will help improve water use efficiency within our industry. More information from this research can be found on page 66.

As the last issue of *Citrograph* for 2023, we hope the latest information shared has enabled you to have a broader view of the range of research projects supported by the CRB. The CRB remains committed to providing the most up-to-date information for growers through *Citrograph* and our grower-focused events like the Citrus Growers Educational Webinar Series and the Post-harvest Conference.

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

CRB HIRES IVAN MILOSAVLJEVIĆ AS IPM ENTOMOLOGIST

Caitlin Stanton

The Citrus Research Board (CRB) is proud to announce that Ivan Milosavljević, Ph.D., joined the organization as the integrated pest management (IPM) entomologist on July 3, 2023. He is responsible for developing applied citrus pest research projects with industry input. Milosavljević also monitors the California Citrus Research and Field Trials (CA-CRaFT) project, which CRB launched last year and is focused on strategies for mitigating Asian citrus psyllid (ACP).

Prior to accepting this position, he spent seven years as a researcher at the University of California, Riverside (UCR), investigating ACP and Argentine ants (AA), while developing applied recommendations for citrus growers. He earned his doctorate degree in Entomology from Washington State University.

Milosavljević's work on the ACP-biocontrol system focused on the impacts of two imported parasitoids, *Tamarixia radiata* and *Diaphorencyrtus aligarhensis*, on ACP in southern California's backyard citrus. This work has been run jointly by the UCR-California Department of Food and Agriculture-U.S. Department of Agriculture-CRB (UCR-CDFA-USDA-CRB) ACP biocontrol team and has demonstrated a significant reduction (equal to or greater than 70 percent) in ACP densities, contributing to lower rates of spread of ACP (and the citrus-killing pathogen it transmits) from infested urban areas into neighboring commercial citrus. One project Milosavljević is co-developing with other UCR scientists for AA, ACP and other sap-sucking pests (SSPs) (e.g., scales and mealybugs) that infest citrus, utilizes new and innovative approaches to achieve long-term sustainable management.

The IPM project being developed combines three tools:

- biodegradable hydrogel baits (HGBs) to control AA,
- infra-red sensors (IRS) to monitor AA and guide targeted applications of HGBs and
- flowering cover crops (FCCs) to enhance resident natural enemy populations, especially ACP parasitoids (*Tamarixia radiata*) and predators (syrphid flies) in commercial citrus.

This combination of tools – HGBs, IRS and FCCs – synergizes IPM of AA and biocontrol of SSPs infesting California grown citrus.

"Ivan Milosavljević is a great addition to the CRB and brings a wealth of knowledge to further the citrus industry's understanding of integrated pest management, as well as pursue mitigation strategies for ACP and other critical pests," stated CRB President Marcy L. Martin.

Milosavljević added, "I am very excited about my new role with the CRB and for the opportunity to continue to serve citrus growers in California."

He will be based in Riverside, California, and can be reached at *ivan@citrusresearch.org*.

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

INTERNATIONAL RESEARCH CONFERENCE ON HLB RETURNS IN 2024

Caitlin Stanton

The seventh International Research Conference on Huanglongbing (IRCHLB) will return on March 26-29, 2024, to the Riverside Convention Center in Riverside, California. The conference is sponsored and organized by the Citrus Research Board (CRB) and will bring together academia, government and the citrus industry from across the globe to continue the discussion of tackling the spread of Asian citrus psyllid (ACP) and huanglongbing (HLB). The sixth IRCHLB was held in Riverside in 2019 with more than 400 attendees from around the world.

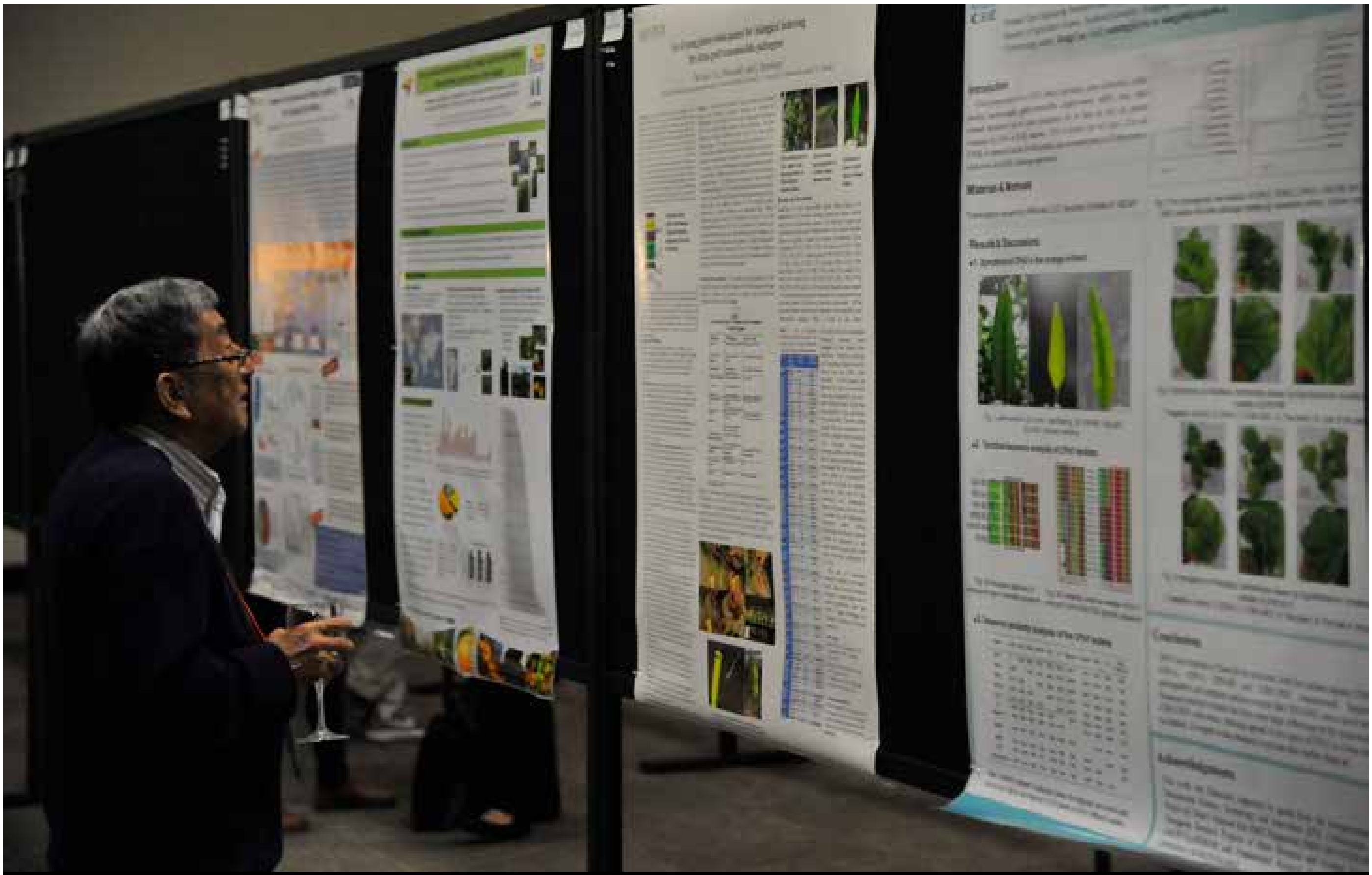
The theme of this coming year's conference is "transitioning research to field reality." Features will include keynote speakers who will provide research and technical updates regarding the global status of HLB, as well as technical and

IRCHLB Conference breaks present opportunities for attendees and researchers to network.

Attendees browsed research posters during the 2019 IRCHLB.

Jacqueline Fletcher, Ph.D., spoke during a session on the current status of HLB during the 2019 IRCHLB.

IRCHLB attendees have the opportunity to learn from the brightest minds leading the fight against HLB during keynote speaker sessions.



An attendee browsed research posters during the 2019 IRCHLB.

poster sessions presented by many of the leading researchers from around the world. The IRCHLB also will allow these scientists time to foster collaborations to advance their research and discuss notable and emerging ideas.

Conference registration is now open, and the cost per attendee is $550. Early bird or on-site registration rates may apply depending on the date of registration. Please visit *irchlb.com* for additional details and to secure your place at this important event. For more information on the IRCHLB, please contact Caitlin Stanton at *events@citrusresearch.org* or call +1 (559) 738-0246.

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

Hotel room blocks with special conference rates have been set aside near the convention center. All conference meetings and meals will be held at the Riverside Convention Center. Reservation links for each room block can be found on *irchlb.com*.

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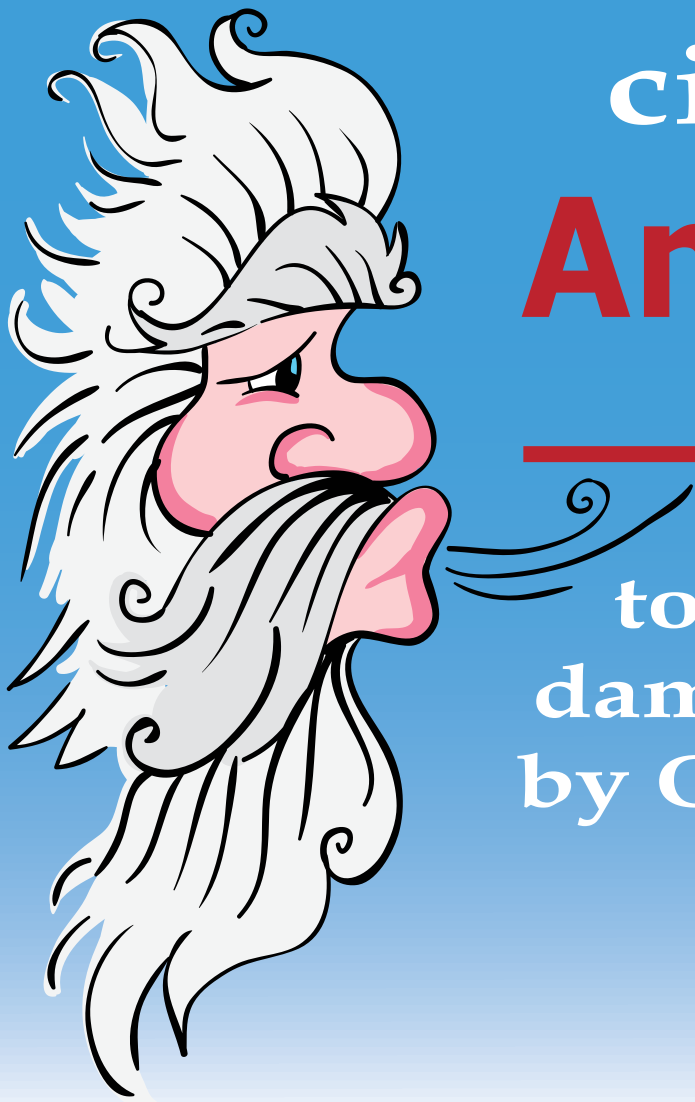

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Recap of the 2023 Citrus Growers Educational

WEBINAR SERIES

McCall Machado

The Citrus Research Board (CRB) held the fourth Citrus Growers Educational Webinar Series this past June, consisting of four one-hour webinars featuring industry experts and researchers. Each webinar explored valuable research and practical discussions for growers, covering topics such as crop management, post-harvest diseases and California crop water efficiencies.

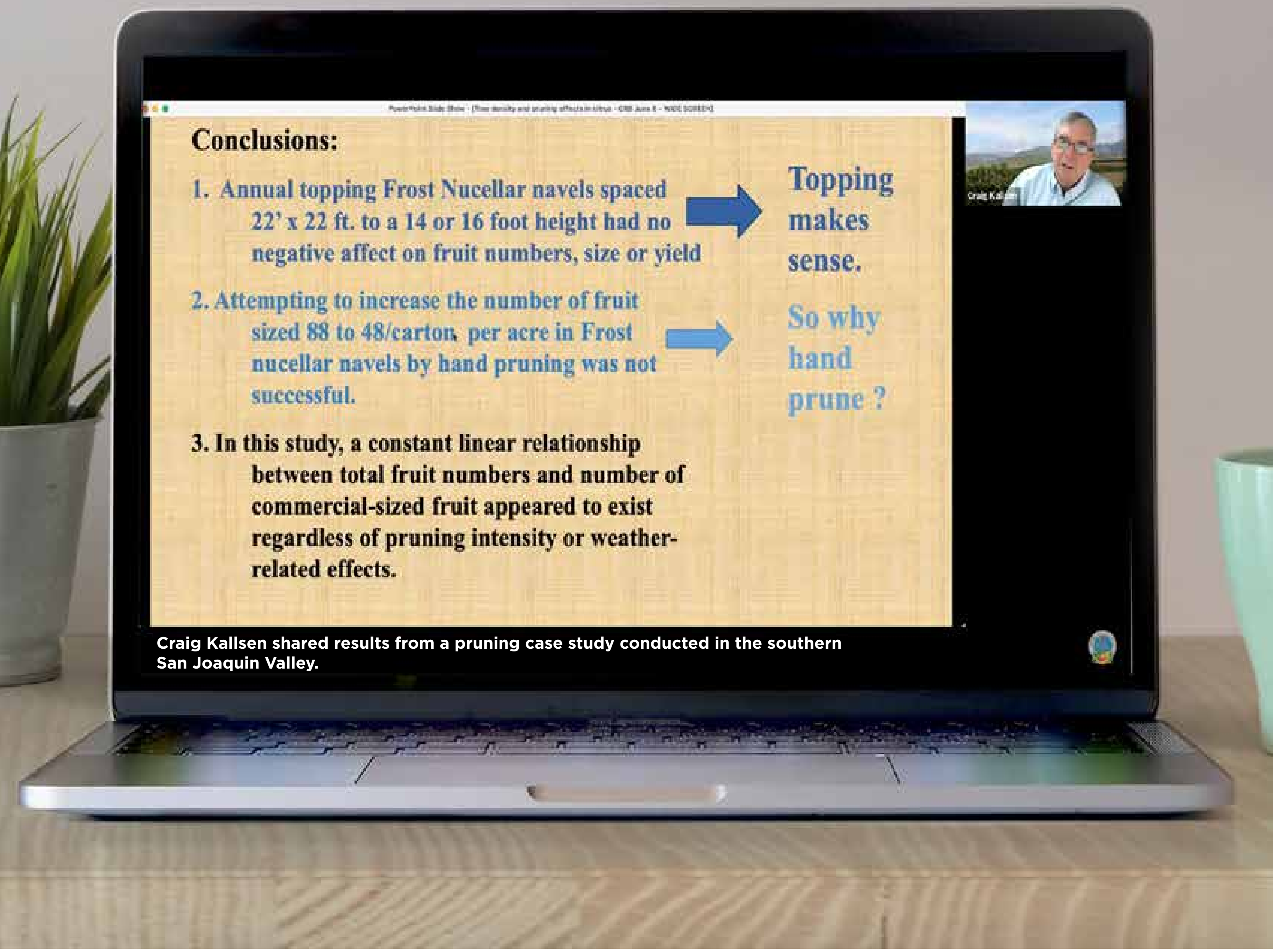
The series began on June 6 with a presentation by Citrus and Pistachio Farm Advisor Craig Kallsen from Kern County. His talk delved into the relationship between tree density and pruning as they affect yield and fruit quality parameters such as color development, fruit size, sugar acid ratio and yield in navel oranges. Results from the study showed planting trees further apart can result in an increased rate of fruit development. The presentation concluded with an overview of data collected from navel orange pruning trials conducted through the experimental packline at the University of California (UC) Lindcove Research and Extension Center (LREC). Growers gained valuable insight on how optimal tree density and pruning strategies depend on the citrus variety and each grower's specific goals for yield and fruit quality.

The second webinar featured University of California, Riverside (UCR) Professor and Plant Pathologist Jim Adaskaveg, Ph.D., who shared an in-depth update of his research on Sweet Orange Scab (SOS), as well as strategies for pre- and post-harvest disease management. In his SOS research update, Adaskaveg spoke on the need for additional surveys

and molecular diagnostics as current diagnostics may not be species-specific. Additionally, he discussed the impacts of these molecular detections and packinghouse procedures for fruit from quarantined areas. During the second half of his presentation, Adaskaveg provided information on the integration of pre- and post-harvest treatments for managing citrus diseases such as Phytophthora root rot and brown rot. The webinar concluded with information on new pre- and post-harvest fungicides and sanitizers that are being developed and registered to help fight against diseases including Septoria spot, Anthracnose, Sour rot and more.

In the third webinar, growers heard from Glenn Wright, Ph.D., who is an associate professor and extension specialist for tree fruit crops at the University of Arizona. The focus of his talk was on CRB-funded lemon variety, scion and rootstock research being conducted in three growing areas of California—Santa Paula, Exeter and Thermal. Wright provided an in-depth analysis of the annual data on yield, packout, tree size, tree health and exterior and interior quality that has been collected since 2015. The presentation concluded with a comparison of the scions and rootstocks performance in different locations throughout California. Wright shared promising results for several scions and rootstocks with good yields and fruit size.

The fourth and final webinar of the series featured Vice President of Design for Laurel Ag and Water Franklin Gaudi, Ph.D., who provided an overview of California's water availability and crop water efficiency strategies. Gaudi shared data on current and past years' snowpack, water supply and reservoir levels and spoke about the impact of California's water availability on agriculture. During the second half of the webinar, Gaudi discussed



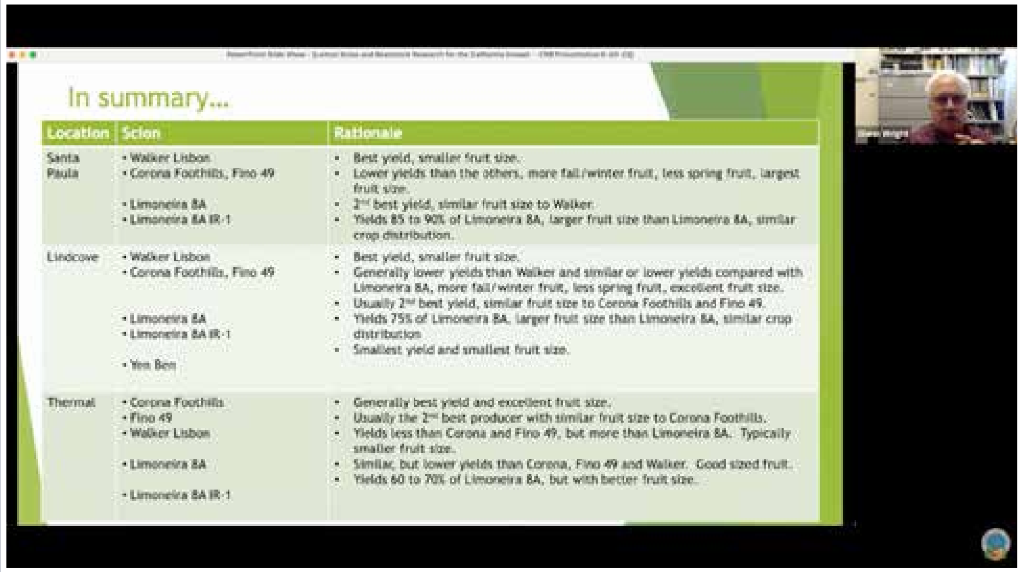
Craig Kallsen shared results from a pruning case study conducted in the southern San Joaquin Valley.

the importance of distribution uniformity in irrigation and how a good, well-maintained design can lead to better crop yield and reduce water usage. The webinar concluded with a discussion on the benefits of both irrigation efficiency and application efficiency, and how they can be calculated. His presentation shared valuable insights with growers on how irrigation systems can be designed and managed to maximize crop yields while minimizing water usage.

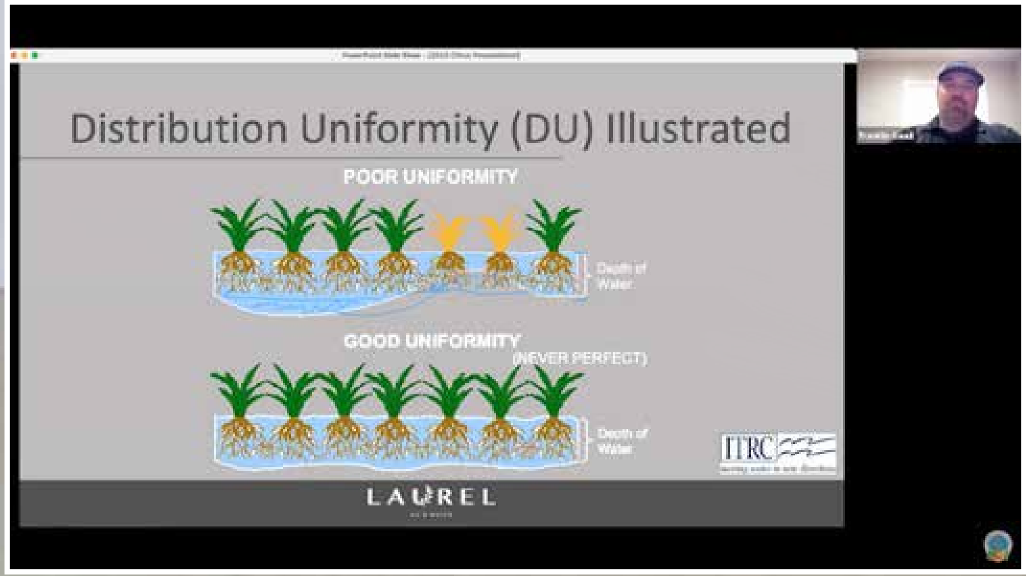
The CRB, which is dedicated to providing citrus growers with the most current information on research and developments in the industry through both in-person and online channels, would like to express its appreciation to the industry experts and researchers who contributed to the success of the 2023 Citrus Growers Educational Webinar Series. If you would like to view any of the webinars, please visit *www.citrusresearch.org* and click on the "News & Events" tab to view the recordings.

***McCall Machado is the communications and event coordinator for the Citrus Research Board. For more information, please contact* mccall@citrusresearch.org**

Jim Adaskaveg, Ph.D., guided attendees through best management practices of Sweet Orange Scab in citrus groves.



Glenn C. Wright, Ph.D., discussed the performance and results of several scions from various locations in California.



Franklin Gaudi, Ph.D., provided examples of distribution uniformity in irrigation.

UPDATE ON U.S. GRAPEFRUIT STANDARD

Casey D. Creamer

What Happened

The Florida Federal Marketing Order for Grapefruit, also known as Marketing Order 905.306, was established on April 30, 1948. It was put in place to regulate the marketing and handling of grapefruit in Florida, with the aim of maintaining quality standards and ensuring fair trade practices within the industry.

In the fall of 2021, after negotiations were completed on the United States-Mexico-Canada trade agreement (USMCA), the United States Department of Agriculture (USDA) officially revoked enforcement of the juice content standard on grapefruit imports by issuing an internal "Patch 65" notice. This notice caught the industry by surprise, as the USDA failed to communicate the change in policy to the marketing order committee where the rules were governed. The high volume of fruit that was now coming in uncontrolled by the quality standard drove down prices, resulting in millions of dollars lost for the domestic industry.

The three Citrus Mutuals in Florida, Texas and California sprung into action with high level meetings within the USDA, the United States Trade Representative (USTR) and with respective members of Congress. The USDA Agricultural Marketing Service (AMS) is the agency responsible for governing marketing orders, while the USTR enforces standards according to international law and trade agreements.

Current USDA leadership acknowledged the process failure that occurred under prior leadership and committed to working with industry. After extensive conversations, the USDA with support from the USTR, agreed to re-establish the juice content standard beginning October 1, 2022, through March 31, 2023, while it worked with the industry to review requirements. This was the right conclusion on the part of both agencies as it allowed some additional time to rectify the issue and begin a more collaborative process.

Effects on California Producers

While grapefruit acreage represents three percent of the total California citrus acreage, it represents 22 percent of District 3 production where 60 percent of the overall crop is grown. According to the 2022 California Department of Food and Agriculture (CDFA) Citrus Acreage Report, there are 7,970 bearing acres of grapefruit in California, of which 4,599 acres reside in District 3. District 1 encompasses 2,349 acres, followed by District 2 with 1,022 acres. Bearing acres have decreased by eight percent since 2014 statewide, but non-bearing acreage is starting to trend upward.

Florida's Federal Marketing Order doesn't govern California grapefruit, though California does have standards in place that are overseen by the CDFA and enforced by the local county agricultural commissioners. With the lapse in enforcement on imports, larger volumes of imports flooded the marketplace during peak seasons in Texas and Florida. The volume directly impacted pricing during their season to levels below profitability for U.S. producers, who endure significantly elevated costs maintaining higher labor, environmental and quality standards.

Additionally, California growers typically wait out the Texas season to enter the marketplace. The significant change in imports delayed the Texas season and lowered pricing well into the more typical California season. Once low prices are established, it becomes that much more difficult to push up pricing to profitable levels.

Research Being Conducted

A key component of reestablishing the standard was to work with industry to better understand how California grapefruit compared in relationship to the standards developed in Florida's marketing order. The Citrus Research Board (CRB) stepped up in support of the industry, funding critical research to evaluate juice content in fresh California grapefruit.

To test juice content, researchers started by following Florida standard protocols and obtaining samples from grapefruit shippers approximately every two weeks. Fruit was weighed, sized and juiced. Juice volume was then measured, and a sample was taken for Brix determination.

More research is needed, but initial results show that California could not rubberstamp the Florida grapefruit standard as it exists now. The climatic variation between the grapefruit growing regions necessitates a deeper dive into the characteristics that make domestic grapefruit highly sought after in the marketplace over imports that can be of lower quality. Research in this area must continue in California and across the United States, and the CRB has and will continue to lead that effort for California.

Looking Ahead

Texas, Florida and California have worked cooperatively on this issue as we have done to secure critical research dollars to address huanglongbing. This collaboration is vital to elevating the needs of citrus growers and must continue. While degrees of impact vary between the states, a unified front gives us a fighting chance.

Marketing Orders, like the Grapefruit Order, can be a useful tool to manage grades and quality of domestic production and can then require overseas competitors to meet those same standards to be allowed into the valuable U.S. marketplace. Coming to an agreement on what those standards should be across the varying growing regions will be the challenge internally. But we must work together to explore every technical, legal and political avenue to the maximum extent possible. While ultimately there may not be a silver bullet solution, every bit counts as we look to maintain the viability of our industry.

I want to thank the CRB for their work in funding and beginning the research process so quickly and the leadership and commitment they have shown to growers in the process. Without their willingness to put in the research work, it is unlikely that we would have been successful in getting the standard put back in place, despite its limited time duration. The continued collaboration between our organizations has and will continue to pay dividends to growers despite our challenges.

***Casey D. Creamer is the president and chief executive officer of California Citrus Mutual in Exeter, California. For additional information, contact* Casey@cacitrusmutual.com**

THREE UNIQUE CITRUS PACKING HOUSE OFFERINGS

+/-19.55 ACRES - GILLETTE CITRUS PACKING FACILITY - DINUBA, CA

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AMPLIFYING THIRD-PARTY VOICES TO CONNECT WITH RESIDENTS

Kevin Ball

The Citrus Pest and Disease Prevention Program (CPDPP) works side-by-side with a variety of different agriculture and citrus industry groups and organizations to advance our shared goal of preventing the spread of huanglongbing (HLB) and the Asian citrus psyllid (ACP) into our commercial citrus groves. While we are all working hard to ensure our groves remain free of HLB, the disease continues to spread throughout backyard citrus trees in southern California; and it's important that we continue our outreach efforts to connect with residents about the dangers this disease presents.

As the program's outreach team and staff members of the Citrus Pest and Disease Prevention Division (CPDPD) work to engage with residents in highly impacted areas about the threat that HLB and ACP pose to their backyard trees, using third-party partners to further connect with California residents helps amplify our message and increase cooperation. These messages include emphasizing the importance of caring for your backyard citrus trees, inspecting for signs and symptoms of the pest and disease, and cooperating with agriculture officials who may be working in their neighborhoods.

Building strong, collaborative relationships with third-party partners provides credibility and validates the impact of these messages that the CPDPP works to communicate daily with residents across the state. Through these strategic partnerships, we're able to reach a broader audience, equip our partners with the tools they need to identify solutions that will best serve California citrus growers and ensure residents are knowledgeable of the harm that HLB and ACP can cause. These efforts are key to slowing the spread of HLB and ACP – and this objective cannot be accomplished by one organization alone.

Master Gardeners

Earlier this year, the CPDPP outreach team – in coordination with Margaret O'Neill, Master Gardener program coordinator for the University of California (UC) Cooperative Extension in San Bernardino County – coordinated a Master Gardener Summit Webinar. Master Gardeners were given the opportunity to learn more about the current state of ACP and HLB, as well as participate in an interactive Q&A session with Victoria Hornbaker, director of the CPDPD. The CPDPP has had a longstanding partnership with the UC

Healthy residential citrus tree in southern California.

Master Gardener Program and continues to engage with the volunteer network in many areas across the state. The UC Master Gardener Program is a public service and outreach program under the UC Agriculture and Natural Resources, administered locally by participating UC Cooperative Extension county offices.

During the webinar, there was a lively and productive discussion around how Master Gardeners can best communicate with residents who may have questions about ACP or HLB in their own backyards. This included a presentation focused on how Master Gardeners can share best practices on protecting citrus trees with residents – including how to inspect their trees for ACP and symptoms of HLB, not moving citrus plant materials if they are located inside of an HLB quarantine zone and more. Master Gardeners are a trusted resource for providing research-based information on home gardening, pest management and more. The webinar was another tool among the variety of resources at their disposal that they could utilize to bolster their own knowledge, enabling them to further educate more residents and ultimately protect California's citrus.

Social Media Influencers

Through the past several years, there has been a seismic shift in how consumers prefer to receive information and what sources they trust for key resources. As digital platforms increase in relevance, social media influencers have proven to be a great tool for the CPDPP to connect with home garden hobbyists. According to a study conducted by Nielsen, 71 percent of consumers trust advertising, opinions and product placements from influencers. The CPDPP's outreach team has worked with a variety of influencers who live in California, and whose following has a strong focus on home gardening tips and tricks. A majority of the program's influencer partnerships have had a primary focus on sharing content featuring tips for growing citrus, proper harvesting and how to share homegrown citrus all while safely protecting their trees from ACP and HLB.

The program's outreach team recently facilitated an on-site visit to the Citrus Clonal Protection Program (CCPP) facility with a southern California gardening influencer. They captured content of the research facility and spoke with CCPP scientists about the work and history of the program, its importance in preserving the future of California citrus and how residents can utilize the CCPP to source clean budwood. With a shared goal of educating their followers on their social media platforms, our influencer partners continue to take the CPDPP's outreach efforts to the next level.

Social media influencer @CoastalHomestead (Chia-Ming Ro) visits with Georgios Vidalakis, Ph.D., professor and extension specialist in Plant Pathology and director of the Citrus Clonal Protection Program in the Department of Microbiology and Plant Pathology at the University of California, Riverside CCPP facility.

Industry partners and third-party voices are a key element to the CPDPP's outreach program. Keeping California's citrus healthy and thriving for years to come is integral to our livelihood as a citrus industry, and working with these partners is a key element to creating genuine connections with residents across the state and encouraging them to do their part. That said, as detections of the disease creep closer to major commercial citrus regions, we must recognize that we all need to work together to prevent the spread of the pest and disease. If you're interested in collaborating on future outreach opportunities in your area, please feel free to connect with myself or with the CPDPP via *CitrusInsider.org*.

Kevin Ball is the outreach subcommittee chair for the Citrus Pest and Disease Prevention Committee. For additional information, please contact **kevin.ball@aglandca.com**

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PRODUCTION AND POST-HARVEST PERSPECTIVES FROM AROUND THE INDUSTRY

Caitlin Stanton

From growers working in the field to marketers selling fruit, many stages are involved in getting citrus to the consumer. As this issue of Citrograph *is focused on production and post-harvest, we asked several industry members for different perspectives on minimizing post-harvest losses and diseases, food safety and current production challenges the industry faces.*

PRODUCTION PERSPECTIVE
MATTHEW WATKINS

Director of Farm Operations
Bee Sweet Citrus

With California's intense rainfall in early 2023, what practices have been implemented to reduce/minimize the weather's impacts?

We have applied some additional fungicides for the fruit on the tree; and during pre-bloom, we have done thrips sprays to help with tree health. We also have changed fertilizer applications so that they are more active with the lower soil temperatures. With the weather this year, trees definitely are acting differently than in an average year; but with today's weather, I don't know if there ever is a typical year anymore. The bloom was later, but the trees did flush out well, so tree health does not look like an issue. We do have some blocks that had some standing water for a while, which were a little weaker to get going, especially on the ends of rows. They probably will have a lighter fruit set because the roots were waterlogged for so long, so we are working on soil amendments and calcium applications to get some good aeration in the soil profile and ensure those roots can breathe. We didn't see any issues from rain in the desert, but things are still behind. On the Central Coast, we had quite a bit of rain in San Luis Obispo County, so we are using the same concept as the Central Valley and applying some soil amendments to get those roots a little more active because it has been so wet in the profile. We've had some tree mortality in low spots where things got wet and didn't drain. There are long-term drainage projects that we need to do—some blocks that have never had standing water before ended up with standing water, and we need to improve drainage so that water moves out and doesn't just sit there.

Are there any additional concerns that the rainfall will impact the lemon pitting situation occurring in the Central Valley?

I'm not sold on the exact cause of lemon pitting yet. Some people are more adamant in one direction if it is a tree stress issue, a pest issue or all of the above. I don't think the rain made the lemon pitting worse because the fruit on the trees was already there. It is probably a little too early to tell for this upcoming crop because the fruit on the lemons is slightly behind, and the same thing with the bloom and fruit set. Nothing is showing up yet, but the thought I have is that the trees look relatively healthy. If it is a stress issue, with the adequate water supply and good flush on these trees, there could be a lighter lemon pitting issue because I think we will have fewer trees in a stressful environment. So hopefully, we don't see that as much as we've seen it over the last few years when we've been in drought and high heat situations. Mites, which may or may not be a cause of lemon pitting, don't seem as prevalent this year. This could be because it has been a little wetter, and the mites have washed off, which would be positive if they are indeed a factor in lemon pitting. We still have a way to go, and it is warming up, so we will see. This year's biggest production issue is the late bloom with the fruit set and the warm weather we've seen lately. There is definitely quite a bit of fruit on the trees; it just matters how much sticks, but it is still too early to tell. Thrips pressure has been bad too, which doesn't help the utilization down the road. It could be a long season, but the goal is to get that fruit growing, keep it clean and have a great year.

PACKINGHOUSE PERSPECTIVE
MARTIN ALVARADO

Packinghouse Supervisor
Villa Park Orchards Association

PACKINGHOUSE PERSPECTIVE
FELIX MEZA

Strathmore Lemon Manager
Villa Park Orchards Association

What practices do you implement to minimize post-harvest loss? Does this involve changing how fruit is received? How do these practices look?

Alvarado: Over the years, we have learned how to minimize post-harvest loss by testing different procedures and seeing what works for our facility. We do several inspections throughout the facility to ensure that the fruit meets all standards. Two inspections are performed during our receiving process. The first is done when field trucks arrive, where we conduct a visual inspection to identify if they are full bins or half bins. After a final count is complete, bins are tagged and stored away from old fruit to prevent decay spores from spreading to new fruit. The second inspection is done to see if the fruit needs to be gassed because not gassing green fruit can result in losing several cartons to juice. By gassing fruit, we let it color to the desired level.

Meza: The most significant loss in a packinghouse is decay, which we battle the most at Villa Park Orchards Association. We follow a distinct set of procedures to prevent decay from happening. Our in-house sanitation is one of the biggest practices we prioritize, as it is crucial to us. Our night crew ensures we sanitize/clean everything from the beginning of our dump line to the end of our production line.

Most of our fruit is run within 24 hours or less of picking, which starts by applying the needed fungicides to help protect the rind from any type of injury. If picking on a Saturday for a Monday run, we will drench our fruit to apply the fungicides within 24 hours and not let the fruit sit over the weekend without any fungicide. If we pick too soon after rain, it creates problems such as excessive decay, navel end checks, rind breakdown, oleocellosis and water spotting.

Alvarado: Our wash system uses chemicals to prepare our fruit before waxing. The system is checked every 30 minutes to verify that our chemicals are at the correct levels; if they aren't at the correct levels, production is stopped, and chemicals are readjusted. After the wash system, the fruit goes through the MAF RODA sorting and grading machine, which allows us to remove greens, juice and rots before they get waxed and dry. Once the fruit passes through the dryer, it goes through the COMPAC machine and final hand grade, where the fruit is graded into Export, Domestic (SK/CH) and Standard. Our graders are trained to identify each graded piece of fruit and remove any decay/juice that made it past the system. The final process is placing the fruit into bins or packed. Packed and setback bins are monitored regularly to avoid decay during storage.

Meza: Maintaining cold storage temperatures with proper humidity control of inventory is also a significant factor when it comes to avoiding heavy loss in fruit. We watch in-house temperatures daily to make sure our temperatures are at the proper levels. We can't afford to open cooler doors or have cold fruit sit out. If the temperatures drop and the fruit starts to sweat, it also will start to blush/whiten, which can be harmful because of the moisture. Bacteria love wet surfaces and can lead to heavy decaying, so we try to limit opening cooler doors when pulling fruit out of the room. When we do fresh runs and bin out fruit straight from the field, we try to put it away into cold storage as soon as possible so we don't have it sitting out, especially during summer.

Inventory management is a big part of post-harvest loss. When it comes to using stored fruit, we always make sure to use the oldest first (first in, first out). Fruit rotation is essential and helps prevent aged fruit from decaying. We monitor fruit visually by going room by room to see how fruit is holding up. For example, if we have 30-day-old fruit with minimal signs of decay but 15-day-old fruit with a higher percentage of decay, we will run the 15-day-old fruit instead due to higher decay. Stored citrus with fewer storage days that display decay is run ahead of older citrus.

MARKETER PERSPECTIVE
DAVE ROOKE
SVP Sales
Wonderful Citrus

How is the citrus industry doing with food safety? Do retailers recognize that citrus is low risk because it has a peel?

The citrus industry is well-positioned to ensure all food safety protocols are met and has proactively met such requirements. Retailers recognize the low risk in citrus, but still require the same due diligence tied to other high-risk commodities.

How do you think the industry is handling issues that occur post-harvest? (such as post-harvest diseases, losses, etc.)

The industry works in a very collaborative way on post-harvest practices. Every season has new challenges, and all feedback and relevant data are shared accordingly. It is a challenging business environment and requires a team approach to survive long-term as an industry.

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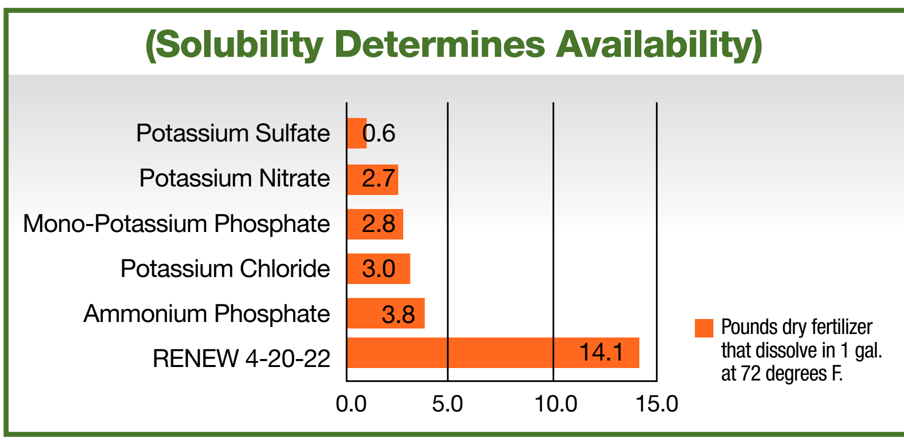

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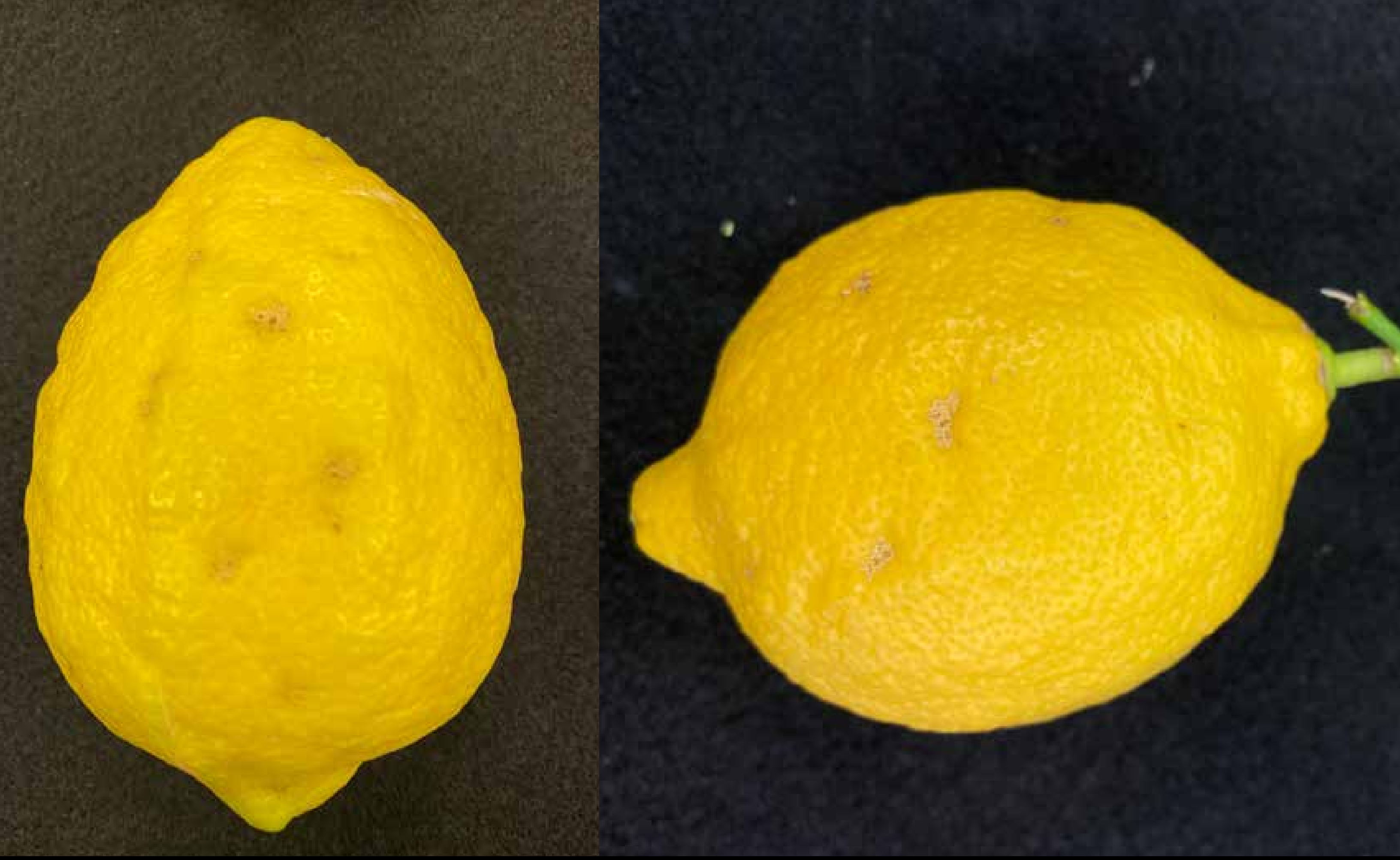

Figure 1. Fruit exhibiting web-scarred depressions characteristic of the lemon pitting observed in the San Joaquin Valley.
Photo credit: Ashraf El-Kereamy, Ph.D.

LEMON PITTING:

A Recurring Issue in the San Joaquin Valley

Joey S. Mayorquin and Melinda Klein

During the 2015-16 growing season, an unusual symptom on lemons was reported by several packinghouses in the San Joaquin Valley – affected lemons presented with webbed scarring and depressions across the fruit surface. Although these symptoms were only seen in a few blocks, a significant increase in this 'lemon pitting' has been shared with University of California (UC) researchers and advisors in the seasons following these initial reports. During the 2021-22 growing season and into the 2022-23 season, an increasing number of groves throughout the San Joaquin Valley were identified as having lemon pitting. The exact cause of the pitting remains unknown as earlier research conducted by UC researchers could not definitively identify the cause(s) of the pitting. At the beginning of 2023, the Citrus Research Board (CRB) initiated a research project, in conjunction with UC researchers, to investigate the cause of the lemon pitting seen throughout the Valley.

Introduction

Lemon pitting was first reported by packinghouses in the San Joaquin Valley during the 2015-16 growing season. Affected fruit presented with depressed areas over the entire surface, and pitted fruit only were identified from several blocks of harvested lemons. UC research entomologists conducted preliminary surveys of the blocks producing pitted lemons; and through these surveys, it was observed that pitted fruit were present throughout the entire tree canopy and block. Early symptoms of pitting included webbed scarring on fruit less than one inch in diameter that later developed into depressed areas on maturing fruit (**Figure 1**). Initially, the pitting was thought to be caused by insect damage; however, no definitive association between the pitting and any insect could be identified.

During the 2021-22 growing season, lemon pitting was reported from an increasing number of blocks, each with different management practices. On mature fruit, two different types of symptoms were observed: (1) depressed, scarred areas similar to the damage seen during the 2015-16 growing season and (2) non-depressed, reddish-brown patches. Affected fruit were observed throughout the tree canopy and were found throughout affected blocks. More specifically, pitting was observed most often in Lisbon lemon grafted on Carrizo plants ranging in age from four to 16 years old. Although mites initially were suspected, the observed pitting symptoms did not resemble mite feeding damage, and no signs of insect presence were uniformly observed in affected groves. Representative fruit samples also were tested for the presence of plant pathogens; however, no pathogen was isolated consistently from affected areas.

Given the persistent nature of this issue, the increasing acreage affected and the lack of a definitive cause, the CRB initiated a project in the spring of 2023 to address increasing concerns with lemon pitting in the San Joaquin Valley. A meeting was held with citrus producers in the San Joaquin Valley in March to devise an action plan to determine what factor(s) are causing this type of damage. Producers representing a range of locations and management styles were contacted to begin large-scale grove surveys during the 2023-24 growing season. Under the direction of the CRB, this project is being led by Lindcove Research and Extension Center Director Ashraf El-Kereamy, Ph.D. El-Kereamy will be supported by other UC personnel representing a range of expertise, including Mary Lu Arpaia, Ph.D., James (Jim) Adaskaveg, Ph.D., Sandipa Gautam, Ph.D., and Jay Rosenheim, Ph.D.

2023 Project Outline

This CRB-initiated project consists of seven main specific objectives that will aid in identifying the factor(s) causing lemon pitting in the San Joaquin Valley and offer management strategies for this issue:

1. compile and review grower records from lemon pitting-affected groves and nearby unaffected groves that are similarly managed (when available);
2. identify any common factors between affected groves;
3. identify the stages and morphology of damage;
4. conduct insect and pathogen surveys, and also perform histological studies;
5. collect 24-hour weather data (temperature, relative humidity and wind speed) for possible correlations to abiotic conditions;
6. assess leaf and fruit nutrient analysis and
7. assess field treatments that may aid in reducing the incidence of lemon pitting.

The current focus of the project is on compiling the large volume of records received from participating growers, including extensive grove attribute information (i.e., rootstock/scion varieties, soil type and drainage and adjacent crops), detailed symptomatology and history and detailed grove management information (i.e., spray records, irrigation activities and nutritional activities). The amount of information collected through this project is critical to researchers when assessing, and potentially correlating, numerous factors to the lemon pitting observed.

At the start of the 2024 season, field surveys will continue to identify the stages of damage associated with lemon pitting in addition to the pathogen and insect surveys in the event that damage is caused by biotic factors. Weather data, grove attribute and management information will continue to be collected throughout the duration of the study. It is expected this project will continue for at least three years to ensure adequate data collection; however, no definitive end date has been determined.

Looking Forward

Lemon pitting in the San Joaquin Valley is a chronic problem that requires oversight from the industry and the coordination of scientists from various disciplines. Together, these efforts will ensure the quickest resolve to this issue. As new information develops from this project, the CRB Research Department will provide updates to the industry through Citrograph and other venues.

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Figure 1. Exterior view of the five-acre CUPS structure at the Lindcove Research and Extension Center.

Prospects for Farming Citrus UNDER PROTECTIVE SCREEN

Philippe Rolshausen, Chandra Krintz, Rich Wolski, Mikeal Roose and Ashraf El-Kereamy

Project Summary

Indoor farming is getting increasing consideration globally because it offers many advantages, especially with respect to coping with climate change, invasive pests and diseases. It has been implemented for farming citrus in many citriculture areas for protection against sunburn, wind and hail damage. Growing "Citrus Under Protective Screen" (CUPS) is increasing in Florida as a way to manage the invasive Asian citrus psyllid (ACP) and huanglongbing (HLB) disease. The recent completion of a CUPS structure at the Lindcove Research and Extension Center (LREC) in California will enable future research into developing the best farming practices in CUPS with a cost-benefit analysis for adopting such practice.

Figure 2. Interior view of the five-acre CUPS structure at the Lindcove Research and Extension Center.

HLB is the most destructive citrus disease of all time (Bové 2006). The disease has become endemic to Florida where the citrus industry already has suffered a 74 percent decline in production with losses amounting to more than $1 billion annually (Li et al. 2020). HLB also has begun to affect the citrus industry in Texas, while the risks of its introduction and establishment in commercial groves in California are increasing. The California citrus industry cannot rely solely on insecticide treatments to manage the ACP vector long term. Unfortunately, commercially available HLB-resistant scion cultivars, another option for long-term disease control, are years away from being released. Using physical barriers such as Individual Protective Covers or CUPS are immediate solutions to HLB that seek science-based information to become adopted by a larger segment of the citrus grower community.

The CUPS footprint has been increasing in Florida during the past decade, with more than 550 planted acres in 2022 (Schuman et al. 2022). Research has shown that ACP-proof protective screen offers full and long-term protection of newly planted orchards against HLB. In addition, yield and fruit quality are greatly increased in CUPS under Florida conditions (Ferrarrezi et al. 2019). For example, based on recent data, grapefruit yields in CUPS totaled 5,929 boxes per acre which would yield $106,722 per acre at a price of $20 per box and a conservative pack-out rate of 90 percent (Citrus Industry Magazine 2022). In comparison, the U.S. Department of Agriculture (USDA) reported that Florida grapefruit yield for 2018–19 was 267 boxes per acre at a 50 percent pack-out rate and $20 per box for groves under HLB pressure.

However, building CUPS significantly increases the costs of citrus grove establishment. For this production system to be adopted by the industry, it must be profitable. This means that it must achieve the highest possible yield of premium-quality fresh fruit and a high market price so that the break-even point on investments is reached quickly. The challenge is that environmental conditions in CUPS are different than in the field. Thus, it is critical to understand how tree performance is affected under the CUPS environment and to select the rootstock and scion variety combinations best suited for those conditions. A partnership between the Citrus Research Board, University of California (UC) Agriculture and Natural Resources, and UC Riverside with support from the USDA-National Institute of Food and Agriculture Emergency Citrus Disease Research and Extension program, led to the construction of a five-acre CUPS at the LREC (**Figures 1** and **2**). This 18-foot-tall structure is covered with 50 mesh woven anti-psyllid screens that have been used in Florida to exclude ACP from citrus groves (Ebert et al. 2021). This investment will position California at the forefront of innovative citrus research and provide the industry with new options to manage HLB in the event of a disease epidemic scenario. In addition, it will enable growers to make informed business decisions with respect to CUPS investments.

Based on research data from South Africa, CUPS diffuses sunlight uniformly, increases relative humidity and protects against wind and sunburn, creating a conducive environment under which citrus trees thrive (Rolshausen et al. 2019). However, the anti-ACP screen used in the United States is a much tighter mesh than the sun and wind-proof net that is being used in South Africa, and likely provides different environmental conditions. The UC Santa Barbara research team has equipped the CUPS structure at Lindcove with several weather stations to measure the climate variations and dynamics both inside and outside the structure. Based on preliminary data from the weather stations at Lindcove,

Figure 3. Relative humidity inside the CUPS (green) and outside the CUPS (red) for 24-hour period ending May 25, 2023. The vertical grid shows five percent increments, and the horizontal grid is in two-hour time increments (leftmost is 9:00 AM May 24).

even prior to tree plantings, there are a number of significant meteorological differences. For example, **Figure 3** shows the relative humidity at five feet inside the structure (green traces) and outside the structure (red trace) for a 24-hour period. The humidity is higher inside the structure, and almost ten percent higher during the post-midnight hours. The team has instrumented the CUPS structure with real-time telemetry that allows users to visualize live weather data (updated every five minutes). The goal is also to use the live data streams as inputs to a Computational Fluid Dynamics model that will model airflow and heat transfer inside the structure in real time. **Figure 4** shows a snapshot from an early animated simulation of air velocity using this data. In the figure, the wind is blowing horizontally from the left. The dark regions are "wind shadows" where the airflow has stalled. From this image, it appears that there is a region of air flow stall near the top of the CUPS. This information will affect spraying activities inside the structure because areas where the aerosols will not be dispersed will need to be considered. Overall, our team plans to develop archival studies (e.g., an analysis of frost and near-frost events in the CUPS since its installation) and real-time modeling and decision support (based on real-time sensor data from the structure) so that it easily could be adopted by growers.

Another critical aspect of the research project is to measure how citrus tree performance is affected by those environmental changes. To address this, we will set up a

Figure 4. Snapshot Computational Fluid Dynamics model of CUPS (shown in outline) with horizontal wind from left. Dark areas show regions of "wind stall" where the air velocity is near stationary.

comparative study for citrus industry standard varieties (Cara Cara and Tango) both in CUPS and outdoor to collect a range of input (irrigation water needs, fertilizers and pesticides) and output data (flowering period, yield and fruit quality). This information will provide the basis for a cost benefit analysis on CUPS for the California fresh fruit market.

Should HLB become established in citrus breeding program plantings at UCR, one option is to conduct breeding and evaluation in CUPS structures. To test whether selections made in a CUPS environment also are likely to be desirable in an open field environment, we produced three trees from each of 96 progeny of Daisy x Kishu mandarins. One set has been planted in the field at Riverside, one set will be planted in the CUPS at Lindcove, and one set will be planted in an adjacent field at Lindcove. Tree characteristics and fruit samples from these trees will be evaluated by the UC Riverside citrus breeding program staff each year in the same way as other breeding populations. Comparison of observations between the populations will show whether varieties selected in a CUPS environment also will perform well in a field environment, including which traits are most affected. This population has been genotyped for about 56,000 single-nucleotide polymorphism[1] (SNP) markers, which should allow us to locate genes or genome regions that affect performance in a CUPS environment.

Deploying physical barriers for protection against environmental challenges is becoming mainstream in agricultural systems, especially to attain a premium quality for high dollar crops. CUPS structures have been designed to protect orchards against hail, wind and sun in several citriculture areas and in Florida for management of HLB. However, these structures also may become a suitable and economically viable system to grow premium quality fruit for niche market varieties, regardless of HLB. Amassing scientific information about this novel cultural approach is needed to prepare the citrus industry for the future of farming.

CRB Research Project #5400-154

Glossary

[1]**Single-nucleotide polymorphism:** A common type of genetic variation in all organisms where, at a particular position in DNA, some individuals have one nucleotide or base and other individuals have a different nucleotide. These differences may or may not affect the organism.

References

Bové, J. M. 2006. Huanglongbing: a destructive, newly-emerging, century-old disease of citrus. *Journal of Plant Pathology* 88(1):7–37.

Ebert T.A.; Schumann, A.W.; Waldo, L.; et al. 2021. A close-up look at screens for excluding Asian citrus psyllids. *UF/IFAS Extension SL489* DOI: 10.32473/edis-ss702-2021

Ferrarezi R.S.; Qureshi, J.A.; Wright, A.L.; et al. 2019. Citrus production under screen as a strategy to protect grapefruit trees from huanglongbing disease. *Frontiers in Plant Science* 10:1598. DOI: 10.3389/fpls.2019.01598

Li S.; Wu, F.; Duan, Y.; et al. 2020. Citrus greening: Management strategies and their economic impact. *HortScience* 55:604–612.

Rolshausen P.E.; Barry, G.; Schumann, A. 2019. Citrus Under Cover Production System (CUPS). *Citrograph* 10(1):40-43.

Schumann A.W.; Singerman, A.; Wright, A.L.; et al. 2022. 2022–2023 Florida Citrus Production Guide: Citrus Under Protective Screen (CUPS) Production Systems. *UF/IFAS Extension CMG19*. doi.org/10.32473/edis-hs1304-2022.

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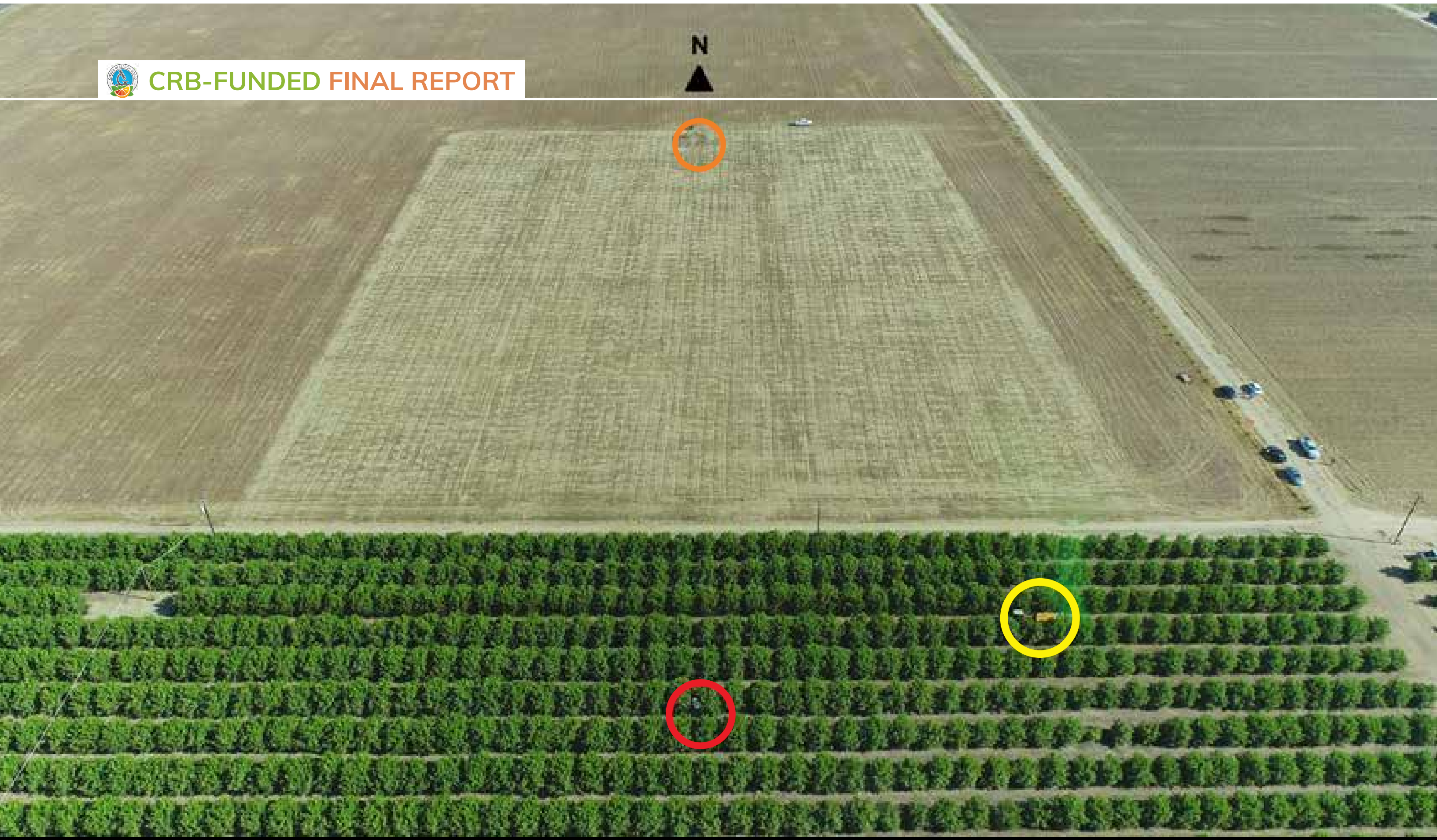

Figure 1. Oblique aerial view of the application area (orchard) and nearby sampling area (light colored area in open field). The sprayer (yellow circle) can be seen moving westward with drifting spray showing as a light green cloud at the rear. The locations of the weather stations are marked as red circle (Met 1) and orange circle (Met 2).

SPRAY DRIFT STUDY IN CITRUS TO SUPPORT AIRBLAST DRIFT MODELING EFFORT

Peter Larbi

Project Summary

This project focused on spray drift that potentially could occur when applying pesticides in citrus production using airblast sprayers[1]. The U.S. Environmental Protection Agency (EPA) assesses the human/environmental exposure to pesticides using the 20-year-old empirical model[2], AgDrift®, defaulting to the worst-case scenario of young and dormant apples for airblast spray applications on all crops. Notably, the dormant apple tree scenario is unlike foliated citrus canopies and likely will significantly overestimate drift that can occur in certain citrus applications.

Therefore, to promote more representative exposure estimates that account for actual field conditions, our single objective was to conduct airblast spray trials in citrus, almond and grapevines to generate spray drift data. This data will be used to validate a mechanistic drift risk assessment model being developed. To meet

Figure 2. Eye-level view of a section of the open field showing different structures used to hold drift collectors. The same distribution of drift collectors was replicated in four sampling lines from inside the orchard to (from edge of orchard) the open field. The sampling lines were centrally placed in the open field 60 feet apart, each having 11 flat cards, 10 artificial foliage samplers and 11 string samplers, totaling 2,688 samplers.

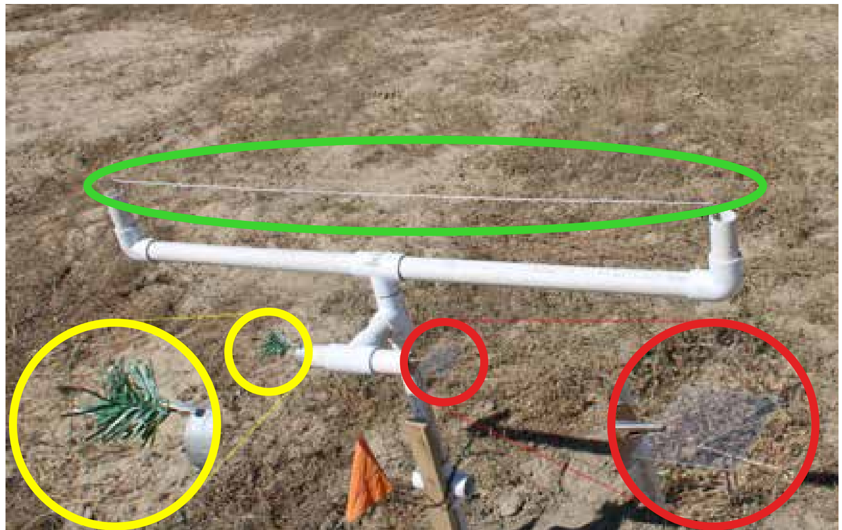

Figure 3. One of two types of structures that held a flat card (red circle), an artificial foliage (yellow circle), and a horizontal string collector (green oval) at the same time. This type was placed at 50, 100, 200, 400 and 600 feet in each sampling line. The other type which excludes the string collector was placed at 0, 10, 25, 75, 150 and 250 feet downwind, as well as within the orchard at -30 and -66 feet. A final type of structure was a 'tower' that held a vertical string collector that was placed at 25 and 75 feet downwind.

the objective, we applied spray with an airblast sprayer in a commercial citrus orchard and collected spray deposits. Comparing AgDrift simulation output with the new data revealed inconsistent estimation depending on distance. Comparing this test to similar tests done in grapes and almonds, we found that the drift amount at any distance depends greatly on the target canopy[3] diameter or width across row, and drift terminal distance depends on the canopy height or height attained by the spray after release from the sprayer. Work conducted in this project confirmed that drift initially is influenced more by wind direction, wind speed, air temperature and relative humidity. Through this study, we learned further downwind drift is influenced more by solar radiation and atmospheric pressure. All this learning provides new insights into the occurrence of drift that will aid in drift regulation, as well as to help improve upon best practice recommendations for pesticide users and registrants.

Introduction

The use of pesticides is an important aspect of citrus production in California. This is commonly done with airblast sprayers and other air-assisted sprayers[4], but particles of the applied pesticide potentially can drift to unintended areas. Because of the associated human health and environmental implications, the regulatory community (e.g., the U.S. EPA) assesses the human/environmental exposure to pesticides applied using airblast sprayers.

Using the 20-year-old empirical model, AgDrift, the EPA proposed in 2013 to adopt, as a default, the worst-case scenario of a sparse canopy (young and dormant 'apple') for airblast spray applications on all crops. Notably, the dormant apple tree scenario is unlike foliated citrus canopies and will likely significantly overestimate drift that can occur in certain citrus applications, potentially leading to overly restrictive regulations that affect or will affect the California citrus industry.

To promote more representative estimates, a mechanistic model[5] that considers the actual application parameters used in real citrus orchard situations is needed. Hence, this research project was conducted to generate spray drift data for validating a mechanistic orchard/vineyard airblast spray drift risk assessment model being developed to estimate exposure values.

Measuring Spray Drift

Guided by an EPA-approved protocol (Thistle et al. 2017), we performed airblast spray field trials in a commercial mandarin orchard in Del Rey, California. We placed artificial collectors in an open field nearby to catch drift deposits at different distances. The sprayer was a pull-behind engine-powered airblast sprayer with tank containing a mix of water and a water-soluble tracer dye[6], pyranine. To collect data on drift factors, we placed one weather station inside the orchard (Met 1) and another in the nearby open field (Met 2) to continuously measure the weather at four different heights. We also measured the physical properties of the tree canopies treated such as canopy diameter or width across row, height and foliage density.

Figure 1 is an aerial view of the orchard and nearby open field, while **Figure 2** is a closeup view of the sampling setup in the open field. **Figure 3** is an example of the sampling structures used, and **Figure 4** shows parts of Met 1. We

Figure 4. An auxiliary view showing parts of Met 1 weather station, including the uppermost two levels of weather instruments and a solar panel that was used to maintain electric power for the weather station.

accomplished 21 trials (replications) on April 5-16, 2021, retrieving the corresponding set of drift collectors after each trial, and analyzing in the lab (Larbi 2022a) to calculate dye deposit[7]. From this, we obtained airborne drift and drift deposit data and analyzed them along with the canopy and weather data to understand their influence on drift.

Previously, similar studies in dormant and foliated apples based on the same protocol were conducted by another research group in Washington state (Rathnayake et al. 2021). We also replicated this study in California table grapes and almonds, providing a basis for comparison to improve our understanding of drift across various commodities and tree architectures (Larbi et al. 2022).

Explaining Drift

An airblast spray application results in on-target gains (canopy deposition) and off-target losses (ground deposition and drift) (Salyani et al. 2007). This outcome is influenced by several variables, including:

- application parameters such as nozzle size and operating pressure,
- spray properties such as droplet size,
- orchard condition such as tree and row spacings,
- tree characteristics such as canopy size and foliage density and
- weather variables including wind speed and air temperature.

From our results, we confirmed that spray particles that do not deposit within the treated orchard (on tree canopies or ground) but remain aloft can move with the wind, causing drift (Larbi 2022b). We evaluated the drift terminal distance using artificial foliage collectors and string collectors. Comparing our data against corresponding AgDrift simulation output reveals a likelihood for AgDrift to both overestimate and underestimate drift downwind depending on the distance from the sprayer.

Comparing this study's results to similar studies done in grapes and almonds, we found that how much drift deposits at any distance depends greatly on the canopy diameter, and how far drift can occur before terminating depends on the canopy height or the height attained by the spray after release from the sprayer. We also learned that the occurrence of drift initially is influenced more by wind direction, wind speed, air temperature and relative humidity closer to the application site, but further downwind it is influenced more by solar radiation and atmospheric pressure. The practical extent of the influence of these variables on drift is case-specific depending ultimately on the overall amount of spray that misses the target canopy and is available to potentially drift.

Implications for California Citrus Growers

Airblast spray application of pesticides provides critical crop protection in citrus production. However, the potential for pesticide drift threatens (by regulation and pesticide resistance build-up in the pest) the sustained availability of crop protection products that growers rely on. An assurance of a sustained availability will require continued pesticide stewardship by citrus producers and regulations based on accurate drift estimation.

The learning from this study translates into additional spray application best practice recommendations for achieving effective pest control while upholding proper pesticide stewardship. Some of these recommendations already have been presented to California citrus growers through the University of California Agriculture and Natural Resources' Airblast Spray Application and Modeling Conference held in May 2022 and a citrus field day held in November 2022. Further extension publications highlighting these additional recommendations will be created and disseminated, and relevant training is being developed and provided via extension education to California citrus growers.

The learning from this study also is intended to aid the creation of a model that would be used for estimating pesticide exposure values. This new mechanistic model developed by the Larbi team, which will consider actual application parameters used in real citrus orchard situations, will provide accurate and reliable spray drift estimates. We anticipate adoption of this new model by regulators, such as the California Department of Pesticide Regulation. This is of significant relevance as the ability of regulators to evaluate drift exposure values more realistically likely will minimize the severity of regulations affecting growers. While this study was conducted in mandarins, confirming model validity across a range of citrus types is anticipated considering differences in plant architecture.

The use of the model will further increase our knowledge of best practices for minimizing drift. We expect information in this study will be incorporated in ongoing efforts promoting the continued use of safe, effective, sustainable pest management practices in California citrus production.

CRB Project #5400-161

Glossary

[1]**Airblast sprayers:** Type of sprayer that uses high-volume and high-speed air to aid in carrying spray droplets to a target. This is commonly used in applying pesticides on tree canopies where the air also helps to push the spray deeper into the canopy for the needed coverage.

[2]**Empirical model:** Model that predicts outcomes primarily based on an actual occurrence. It is limited by existing data from what has occurred.

[3]**Target canopy:** Tree canopy immediately adjacent to the sprayer outlet at any given instance on which spray is directly being applied.

[4]**Air-assisted sprayer:** Any type of sprayer that uses air in any form to aid spray application.

[5]**Mechanistic model:** Model that predicts outcomes based on theory.

[6]**Tracer dye:** Dye that when added to liquid will show the path liquid is traveling. In spray assessments, it can be used to show where and how much of the spray deposits.

[7]**Dye deposit:** Mass of dye captured on drift collector.

References

Larbi, P.A. 2022a. Configuration and assessment of a submersible fluorometer for evaluating fluorescent dye deposition. *Journal of Testing and Evaluation* 50(3):1286–1298. *https://doi.org/10.1520/JTE20210617*

Larbi, P.A. 2022b. From flight to rest – the journey of a droplet. Agricultural Application *Engineering Channel, UC ANR Agricultural Application Engineering Program*. Assessed November 29, 2022. Available online: *https://www.youtube.com/watch?v=ylOjgW8D00E*

Larbi, P.A.; Culumber, M.; Zhuang, G.; et al. 2022. Evaluation of downwind spray drift from airblast spray applications in almond, citrus and grape. *ASABE Paper* No. 2200871. St. Joseph, Michigan.: ASABE. *https://doi.org/10.13031/aim.202200871*

Rathnayake, A.P.; Khot, L.R.; Hoheisel, G.A.; et al. 2021. Downwind spray drift assessment for airblast sprayer applications in a modern apple orchard system. *Transactions of the ASABE* 64(2):601-613. *https://doi.org/10.13031/trans.14324*

Salyani, M.; Farooq, M.; Sweeb, R.D. 2007. Spray deposition and mass balance in citrus orchard applications. *Transactions of the ASABE* 50(6):1963-1969. *https://doi.org/10.13031/2013.24092*

Thistle, H.W.; Bonds, J.A.; Kees, G.J.; et al. 2017. Evaluation of spray drift from backpack and UTV spraying. *Transactions of the ASABE* 60 (1):41-50. *https://doi.org/10.13031/trans.11990*

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Figure 1. Map of sample locations in the Coachella Valley, Imperial Valley, Blythe and Borrego Springs.

WOOD ROTS FOUND IN CALIFORNIA DESERT CITRUS

RESULTS OF THE RECENT SURVEY

Glenn C. Wright, Joel Peña-Pacheco, Alissa Peña-Pacheco and Jiahuai (Alex) Hu

Project Summary

Wood rot fungal diseases have been a problem in desert citrus for more than 30 years. There are several fungi that cause wood rots in citrus, including Fomitopsis meliae, *which causes brown heartwood rot (BWR), and* Neoscytalidium dimidiatum, *which causes sooty canker (SC). A survey was initiated that found fungal canker and wood rots in citrus orchards near Westmorland, Calipatria, Niland, North Shore, Mecca, Oasis, Borrego Springs and Blythe, California. Fifty-one of the 201 samples had wood rot or wood canker disease. Of the 51,* F. meliae *was identified in 27,* Eutypella microtheca *or* E. citricola *in seven,* Coniophora eremophila *was found in six,* Dothiorella citricola *in four,* N. dimidiatum *in three and* Lasiodiplodia theobromae *in four. Neither* D. citricola *nor* L. theobromae *had been found previously in desert citrus to our knowledge. These results suggest that wood rot diseases are a threat to California desert citrus, and that cost-effective control methods should be developed to reduce yield losses.*

Wood Rots in the Sonora Desert

BWR has been known to cause serious problems in Arizona desert lemon trees since the 1960s. Still, it was not until 1992 that the responsible fungal species was initially identified morphologically as *Coniophora eremophila* (Matheron et al. 1992). This fungus is found in a number of native desert species, including saguaro and ironwood, but no fruiting bodies have ever been found (Gilbertson and Bigelow, 1998). By 1996, it was estimated that more than 30 percent of the trees in a typical lemon orchard in Arizona were infected with *C. eremophila* (Bigelow and Gilbertson 1996). A subsequent study in California found Coniophora decay in the Coachella Valley and in Borrego Springs, where more than 90 percent of the trees were infected in selected orchards (Mauk and Adaskaveg 2000).

Near the end of this research period concerning *C. eremophila*, a second fungal species, *Antrodia sinuosa*, was microscopically identified and found to cause BWR in living lemon trees in the Yuma area (Bigelow et al. 2008). Both fungi caused branch decay faster in warmer temperatures than in cooler temperatures, and *Antrodia* caused more branch decay in 'Lisbon' lemon than in 'Marsh' grapefruit or 'Valencia' orange (Matheron et al. 2006).

In Arizona orchards, and possibly California orchards, *A. sinuosa* appeared to be much more aggressive than *C. eremophila*. Growers began to report that the wood rot was infecting larger percentages of trees in an orchard, and the trees were becoming infected at an earlier age. In some cases, 70 to 100 percent of the trees were infected with *A. sinuosa*; and it was easy to find white mycelial[1] masses of *A. sinuosa* on infected wood and basidiocarp[2] fruiting bodies on decaying wood on the orchard floor. By 2010, reports of aggressive BWR in orchards in the California desert began to occur (*pers. observ.*). However, there have been no reports of *A. sinuosa* infecting citrus anywhere other than in the Sonora desert.

In 2019, we collected lemon branches showing symptoms of canker and BWR in orchards near Yuma and in California. *Fomitopsis meliae* was identified as the causal agent using morphological and molecular DNA sequences (Hu and Wright 2021). While this was the first instance of *F. meliae* found in lemon orchards, it is likely that the *A. sinuosa* reportedly found during previous studies was *F. meliae* since the two fungi are virtually indistinguishable when viewed microscopically. In a subsequent survey of more than 5,000 trees near Yuma, we found neither *A. sinuosa*, nor *C. eremophila*, but we did identify *F. meliae* in all ten lemon orchards studied (Hu and Wright 2022).

Wood Rot and Canker Distribution Symptoms and Control

BWR is usually found in trees more than seven years old (Hu and Wright 2022). These wood rot pathogens infect branches through various types of wounds, including fractures, bark cracks, wood split or complete breaks, due to heavy crop load, excessive wind or mechanical damage. Winds carry fungal spores and then deposit them in the wounds, where they germinate; and the resulting hyphae[3] infect and colonize the xylem of the wood by secreting fiber-degrading enzymes. Wood decay then develops. Once decay is advanced, much of the wood components that give it its strength have been consumed by the advancing infection. Thus, the wood weakens and can break (due to wind, heavy crop load or mechanical damage) and die. In severe cases when the trunk is decayed, a tree will split in half (Olsen et al. 2011). Even though several fungicides showed strong inhibitory activities against the growth of the fungus in the laboratory, there has been no effective control in the field, despite multiple attempts. Accordingly, it is almost impossible for currently labeled fungicides to come in contact with the fungus at a sufficient dose in diseased wood. The recommended control for brown wood rots is removal of affected branches.

Table 1. Location and number of citrus wood rots and stem canker diseases found in the California desert.

	FOMITOPSIS MELIAE	*CONIOPHORA EREMOPHILA*	*DOTHIORELLA CITRICOLA*	*NEOCYTALIDIUM DIMIDIATUM*	*EUTYPELLA MICROTHECA*	*LASIODIPLODIA THEOBROMAE*	TOTAL SAMPLES
Blythe	Collected	0	2	0	0	1	7
Borrego Springs	3	0	0	0	0	0	8
Westmoreland /Salton City	7	3	1	3	4	1	25
Niland/ Calipatria	7	0	0	0	2	2	33
Thermal/Oasis	3	3	0	0	1	0	45
Mecca/North Shore	5	0	1	0	0	0	83

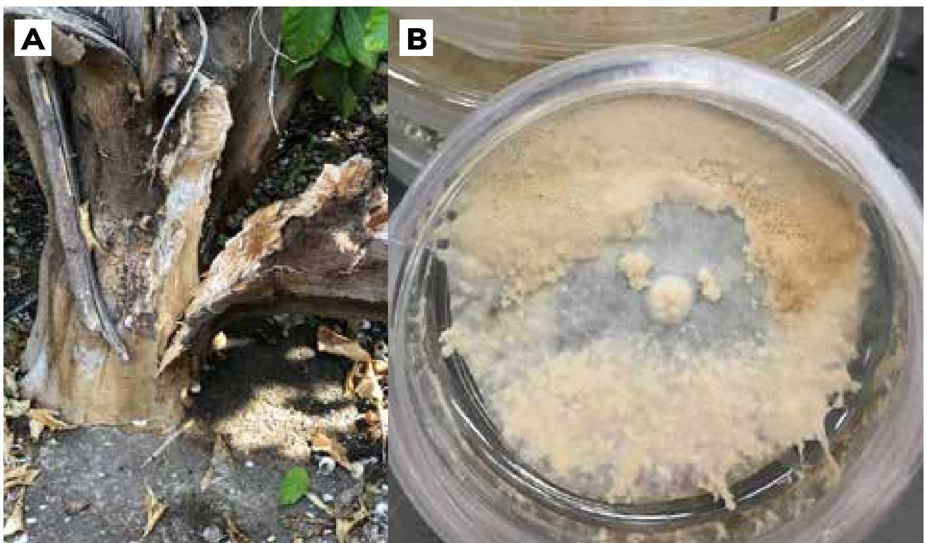

Figure 2. A) Brown wood rot caused by *Fomitopsis meliae*; note white mycelium. B) Four-week-old culture of *F. meliae*.

We have noted other canker and wood rot pathogens in orchards around Yuma, Arizona, including SC caused by *Neoscytalidium dimidiatum*, formerly *Hendersonula toruloidae* (Olsen et al. 2011). SC fungus infects branches through the bark that has been damaged by freeze, sunburn or mechanical injuries. As the cankered area on the affected branch grows, it often leads to girdling the entire branch and thus death. Sooty black fungal growth appears under the bark, killing the sapwood. Most SC-infected branches occur on the unshaded sides of the tree that face the sun. The best control of SC-infected branches is to remove them.

In October 2020, Wright and J. Peña-Pacheco conducted a visual assessment of more than 2,800 acres of citrus located in the deserts of Imperial, Riverside and San Diego counties. We did not take samples, just photographs. However, we noted many trees had what appeared to be symptoms of some of the fungal diseases noted above. In response, the Citrus Research Board asked for a more formal survey of California desert orchards to determine the extent of these diseases.

Survey and Disease Identification

Sample collection began in August 2022. We collected 201 samples, including 116 in Riverside County, 65 in Imperial County, 10 in Borrego Springs and 10 in Blythe, completing the work in February 2023. All except two were taken from commercial orchards. We attempted to spread sample collection evenly across the mature citrus orchards in the region. Sampling sites were older orchards where there was evidence of wood that appeared to be dying or dead. Each sample had a unique ID and GPS location, and many were photographed. Samples were brought back to the Wright lab in Yuma, then sent to the Hu lab in Tucson for identification by performing fungal isolation and identification using morphological features and DNA analysis.

Results

Fifty-one of the 201 samples had wood rot or wood canker disease, while the other 150 may have had fungal diseases other than wood rot or canker. Of the 51, *F. meliae* was identified in 27, *Eutypella microtheca* or *E. citricola* in seven, *C. eremophila* was found in six, *Dothiorella citricola* in four, *N. dimidiatum* in three and *Lasiodiplodia theobromae* in four.

On the map (**Figure 1**), locations of all the sample collection sites are marked with various colored "pins" based on the disease identified at each location. A summary of the sample collection sites with positive finds grouped by geographic area is found in **Table 1**.

F. meliae (**Figures 2A** and **B**) was found throughout the sampling area, near Borrego Springs, Blythe, both sides of the Imperial Valley and in the Coachella Valley near Mecca, North Shore, Thermal and Oasis. Most of these 2023 finds were near locations that we thought might have wood rot disease during our visual disease assessment in 2020. It is notable that we only encountered visual signs of wood rot on the east side of the Coachella Valley in 2020, but three years later, we have found it north of Oasis.

C. eremophila (**Figures 3A** and **B**) was identified in orchards near Westmoreland and between Oasis and the Coachella Valley Agricultural Research Station (CVARS). There were no finds of *Coniophora* on the east side of the Imperial or Coachella valleys. This is the first time we have identified this fungus in many years.

D. citricola (**Figures 4A** and **B**) was found near Thermal, Blythe and Westmoreland. *Dothiorella* causes branch cankers, dieback and gummosis (Eskalen and Adaskaveg 2019). It has not been reported in the desert.

N. dimidiatum (**Figures 5A** and **B**) was found west and northwest of Westmoreland. This fungus, originally named *H. toruloidae* in 1933, causes sooty canker disease (Machouart et al. 2013).

E. microtheca and *E. citricola*. (**Figures 6A**, **B** and **C**) were identified in orchards on the east and west side of the Imperial Valley and near Oasis in the Coachella Valley. These fungi cause branch canker and were first identified in California in 2011 in non-desert areas of Riverside and San Diego counties (Adesemoye and Eskalen 2011).

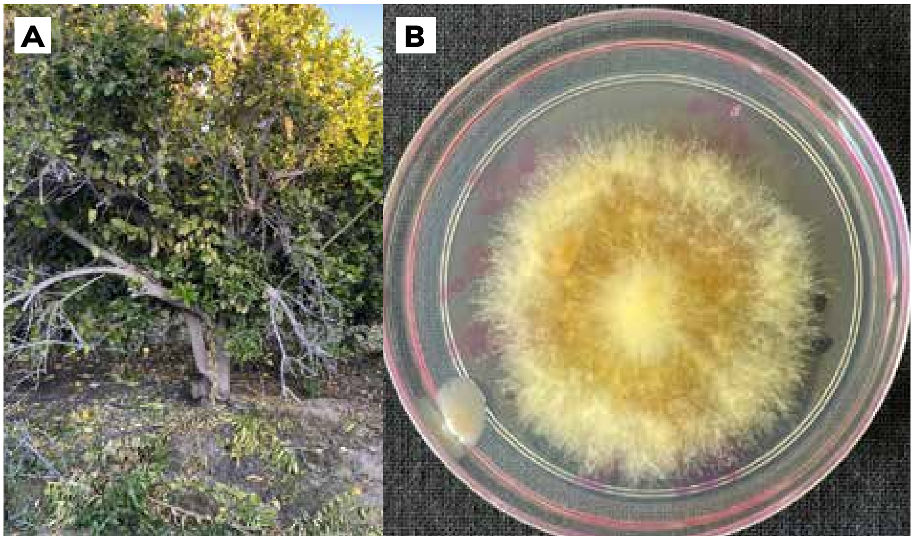

Figure 3. A) Brown wood rot caused by *Coniophora eremophila*. B) One-week-old culture of *C. eremophila*.

Figure 4. A) Branch wilt caused by *Dothiorella citricola*. B) Four-week-old culture of *D. citricola*.

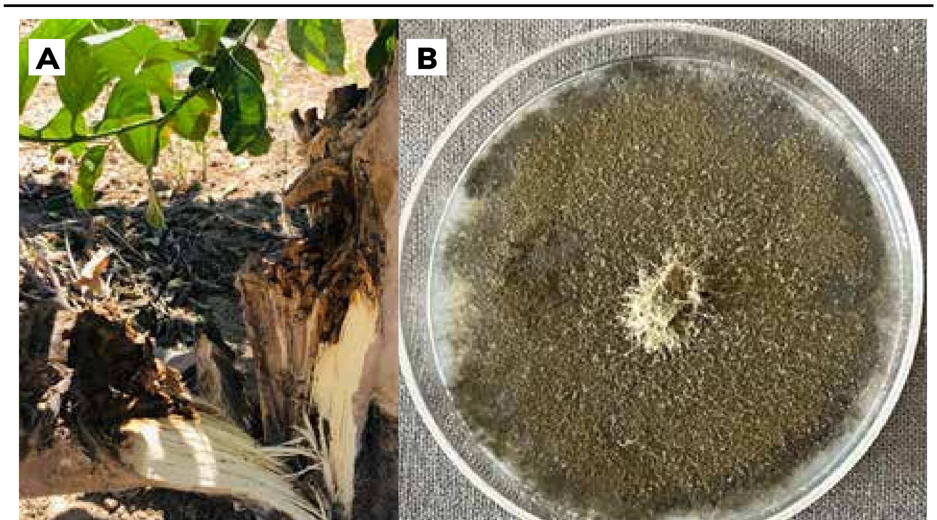

Figure 5. A) Sooty canker caused by *Neocytalidium dimidiatum*. B) Four-week-old culture of *N. dimidiatum*.

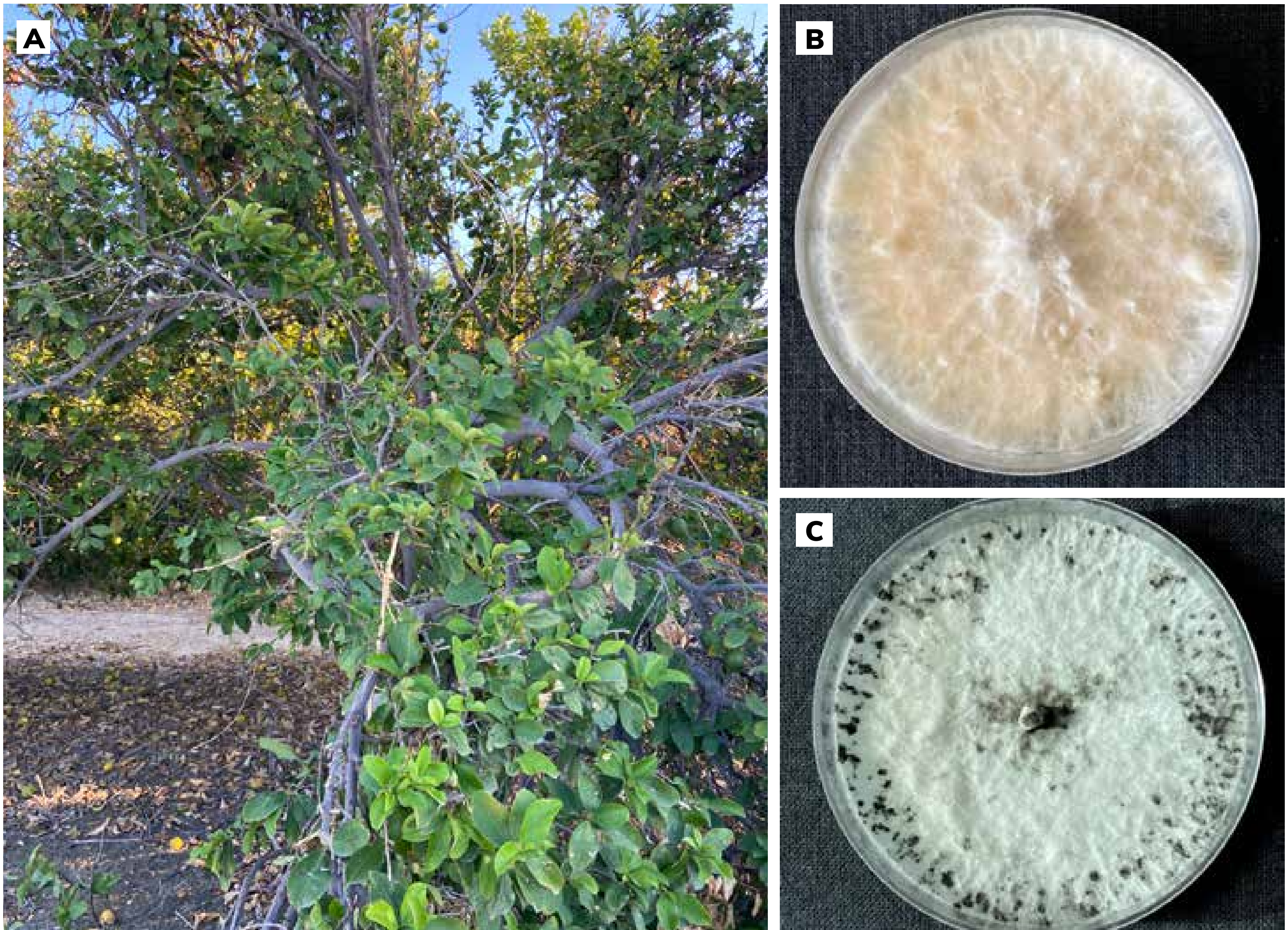

Figure 6.A) Branch canker and wilting caused by two species of *Eutypella*. B) Four-week-old culture of *E. microtheca*. C) Four-week-old culture of *E. citricola*.

Figure 7. A) Branch end rot caused by *Lasiodiplodia theobromae*. B) Four-week-old PDA culture of *L. theobromae*.

L. theobromae (**Figures 7A** and **B**) was found northwest of Westmoreland, near Niland and near Blythe. This disease is also known as Diplodia stem end rot on the fruit and is common in many citrus growing regions (Zheng et al., 2021).

Conclusions

These results suggest that wood rot and, to a lesser extent, stem canker diseases are present and may be increasing in the California desert. They are a threat to California citriculture, and control methods should be developed.

Currently, the recommended control is tree removal, pruning and field sanitation. This is costly because it requires hand labor; and if all the disease is not removed, it will continue to grow. Based on our laboratory experiments, the mycelial growth of *A. sinuosa* fungi was reduced following exposure to triazole fungicides, as well as mixtures of triazoles and azoxystrobins, such as triazole, tebuconazole, Folicur®, difenoconazole, Quadris Top®, Headline®, Flint®, Priaxor®, Xemium® and Pristine®. Success in the laboratory does not guarantee success in the field. Not all of these are registered on citrus, and there may be other fungicides, including biofungicides that may be effective. Identification of an efficacious fungicide in the orchard that has systemic properties and is cost-effective should be the next step.

CRB Research Project #5400-166

Glossary

[1]**Mycelial:** Of the mycelium. Mycelium is the vegetative part of a fungus that produces spores.

[2]**Basidiocarp:** A fruiting body of a group of fungi called Basidiomycetes. Sexual spores are produced within the basidiocarp.

[3]**Hyphae:** A long filament-like branch of a fungus.

Reference

Adesemoye A.O.; Eskalen, A. 2011. First report of *Eutypella* spp. associated with branch canker of citrus in California. *Plant Disease* 95(9):1187.

Bigelow, D.M.; Gilbertson, R.L.; Matheron, M.E. 1998. Cultural studies of fungi causing brown rot in heartwood of living lemon trees in Arizona. *Mycological Research* 102(3):257-262.

Bigelow, D.M.; Matheron, M.E.; Gilbertson, R.L. 1996. Biology and control of *Coniophora eremophila* on lemon trees in Arizona. *Plant Disease* 80(8):934-939.

Eskalen, A.; Adaskaveg, J.E. 2019. Bot Gummosis (Formerly Dothiorella Gummosis). Accessed May 29, 2023. *https://ipm.ucanr.edu/agriculture/citrus/dothiorella-gummosis/*

Gilbertson, R.L.; Bigelow, D.M. 1998. Annotated checklist of wood-rotting basidiomycetes of the sky islands in southeastern Arizona. *Journal of the Arizona-Nevada Academy of Science* 31(1):13-36.

Hu, J.; Wright, G. 2021. First report of *Fomitopsis meliae* causing brown wood rot on living lemon trees in Arizona and California. *Plant Disease* 105(9):2726.

Hu, J.; Wright, G. 2022. Canker and wood rot pathogens present in young lemon orchards in south-west Arizona. *Plant Pathology* 71(2):411-425.

Machouart, M.; Menir, P.; Helenon, R.; et al. 2013. Scytalidium and scytalidiosis: What's new in 2012? *Journal de Mycologie Médicale* 23(1):40-46.

Matheron, M.E.; Gilbertson, R.L.; Matejka, J.C. 1992. *Coniophora* sp. implicated in rapid development of wood rot on living branches of lemon trees in Arizona. *Phytopathology* 82:1083.

Matheron, M.E.; Porchas, M.; Bigelow, D.M. 2006. Factors affecting the development of wood rot on lemon trees infected with *Antrodia sinuosa*, *Coniophora eremophila* and a *Nodulisporium* sp. *Plant Disease* 90(5):554-558.

Mauk, P.A.; Adaskaveg, J.E. 2000. Coniophora decay associated with decline of lemons on Macrophylla rootstock in desert production areas of southern California and Arizona. P-26-28. In: Gumpf; D.; Polek, M. (eds). *Proceedings of Exotic Diseases of Citrus Workshop*. March 14-15, 2000, Visalia, California.

Olsen, M.; Matheron, M.; McClure, M.; et al. 2011. Diseases of Citrus in Arizona. *University of Arizona Cooperative Extension Publication* AZ1154. *https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1154.pdf*. Accessed May 26, 2023.

Zheng, Q.; Ozbudak, E.; Liu, G.; et al. 2021. Draft Genome Sequence Resource of the Citrus Stem-End Rot Fungal *Pathogen Lasiodiplodia theobromae* CITRA15. *Phytopathology* 111(4):761-764.

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VALIDATING FOOD SAFETY PRACTICES IN CITRUS PACKINGHOUSES

Amanda Lathrop, Kimiko Casuga
and Steven Pao

Kimiko Casuga, a Cal Poly graduate student pours agar media for surrogate tests. *Photo by Joe Johnston/Cal Poly*

Lemons are placed in containers for shedding and attachment studies during simulated washing. *Photo by Kimiko Casuga/Cal Poly*

Project Summary

Food safety regulations and auditing standards require post-harvest processing operations to demonstrate control of food safety practices such as the prevention of cross-contamination during washing. Control can be demonstrated through in-plant validation whereby the food safety practice is challenged with a surrogate[1]. This only can be done after laboratory studies evaluate the behavior of the pathogen of concern and the surrogate under specified test conditions. This research evaluated seven lactic acid bacterial strains to determine their suitability as a surrogate for Listeria monocytogenes (LM) *in citrus packinghouse operations. We identified a potential surrogate for in-plant validations of chlorine-based washing systems and for cross-contamination studies. This new tool has the potential to aid post-harvest operators in the validation of their food safety practices.*

Background

The Food and Drug Administration Produce Safety Rule (PSR) that went into effect in 2016 requires citrus growers and post-harvest operations to assess, manage and monitor food safety risks. Despite a lack of outbreaks associated with the consumption of fresh citrus, the need to meet regulatory requirements still exists. This process of becoming compliant with the PSR has identified the need for additional citrus food safety research.

One of these areas is understanding how foodborne pathogens behave in the post-harvest environment, particularly during washing steps. In preliminary research, we investigated the potential ability of foodborne pathogens to survive in some washing steps under laboratory conditions. However, translating and using these findings to support in-plant validations is challenging given the variability among packinghouse washing systems. Multiple parameters can impact sanitizer efficacy in these systems, making it impossible to mimic all conditions in the lab. Therefore, identifying a surrogate to support in-plant validation studies would provide the citrus industry with a practical validation tool.

This project aims to identify a citrus industry-specific surrogate that can be used for in-plant validation of food safety practices. This tool will help packinghouses demonstrate compliance with the PSR or identify opportunities for improvement. The project objectives are to screen and identify a surrogate for *LM* that:

1. can be detected on citrus fruit and in the packinghouse environment,
2. has similar behavior (survival, shedding and attachment) on citrus fruit and
3. has comparable sensitivity to chlorine.

LM was selected as the target because it is more resistant to sanitizers and survived the longest on lemons and oranges

Table 1. Bacterial strains selected for surrogate development and detection methods to identify bacteria on citrus fruit surfaces and in spent wash water.

ORGANISM (STRAIN)[1]	DETECTION METHOD
Lactobacillus plantarum (B-1846 and B-4306) *Pediococcus pentosaceus* (B-14009) *Pediococcus acidilactici* (B-639, B-1116 and B-2039)	De Man, Rogosa and Sharpe (MRS) agar supplemented with 25 mg/L of cycloheximide, incubation at 40°C for 48 hours
Enterococcus faecium (B-2354)	Tryptic soy agar (TSA) supplemented with 25 mg/L of cycloheximide and a bile esculin azide (BEA) agar overlay, incubation at 37°C for 48 hours

[1] *All surrogates were obtained from the USDA ARS (NRRL) culture collection.*

compared to Salmonella (Harris 2023). Chlorine was selected as the antimicrobial agent since it is commonly used in citrus packinghouses.

Surrogate Selection and Detection

Seven lactic acid bacterial strains were identified for screening, and detection methods were developed to distinguish the surrogates from microorganisms commonly found in the citrus packing environment. The developed detection methods are described in **Table 1**.

Survival on Citrus

Based on preliminary survival screening tests, *E. faecium* B-2354 (EF) and *P. pentosaceus* B-14009 (PP) were identified as the most likely strains to behave similarly to *LM* on citrus fruit surfaces and were, therefore, used in the final storage test. Briefly, waxed lemon, orange or mandarin fruit surfaces were spot inoculated (7 log colony forming units [CFU]/fruit) with either *EF*, *PP* or *LM* and air-dried for approximately 30 minutes. The fruit was then held at 5°C and 80 percent relative humidity for 27 days and tested for the presence of viable *EF*, *PP* or *LM* using the methods in **Table 1**. Viable *EF*, *PP* and *LM* declined during storage on all fruit, with *LM* exhibiting the largest reductions (**Figure 1**). Statistical analysis indicated that the difference in the decline of viability between *LM* and *EF* or *PP* was significant. Accordingly, both organisms were unsuitable surrogates for survival on citrus fruit surfaces studies. While this was not ideal, these findings provide further evidence that *LM* populations decline during citrus storage (Girbal et al. 2021).

Shedding and Attachment

EF and *PP* were evaluated for suitability as a surrogate for *LM* shedding and attachment on the surfaces of lemons, oranges and mandarins during washing. For shedding and attachment testing, the fruit (shedding) or the water (attachment) was inoculated with *EF*, *PP* or *LM* and a washing step was simulated. Washing was simulated by shaking individual fruit in a container with 400 ml of sterile water at 125 RPM for one minute on an orbital shaker. The wash water (shedding) or fruit (attachment) then was tested for the organism, and the percent of shed or attachment

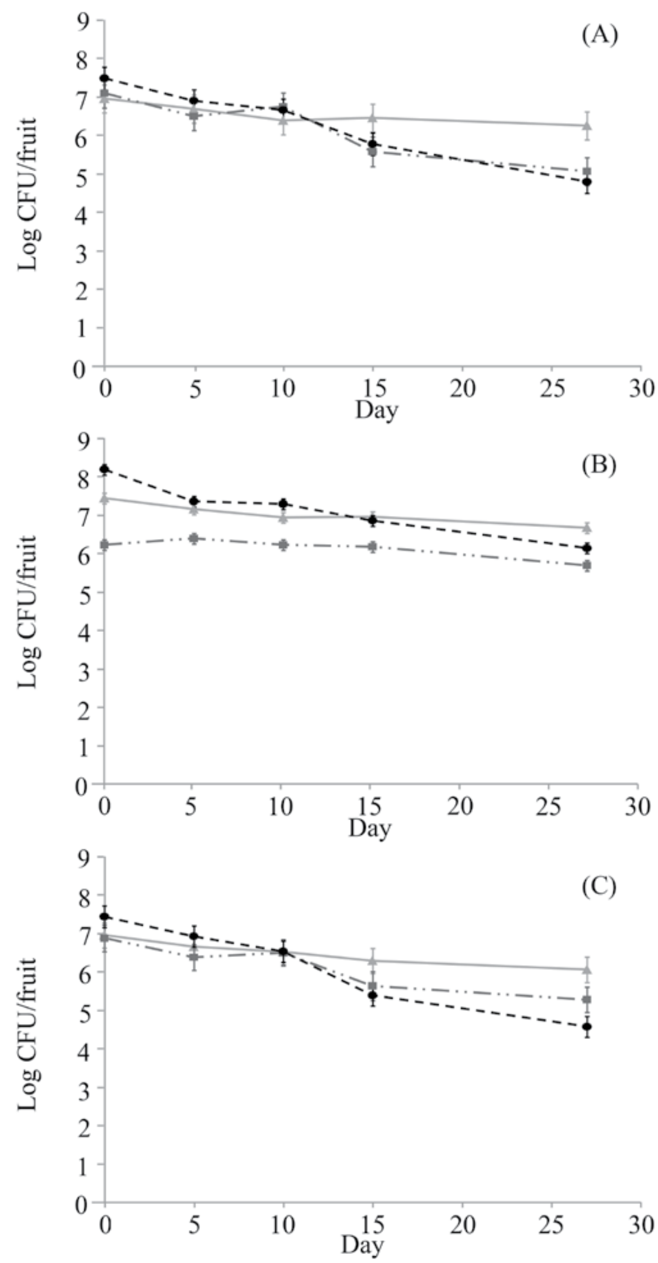

Figure 1. Populations (colony forming units [CFU] per fruit) of *Listeria monocytogenes* cocktail (–●–), *Enterococcus faecium* NRRL B-2354 (–▲–), and *Pediococcus pentosaceus* NRRL B-14009 (–■–) during storage at 5ºC, 80 percent relative humidity for 27 days on final wax (A) lemons, (B) mandarins and (C) oranges.

Table 2. Percent shed of *Listeria monocytogenes (LM), Enterococcus faecium (EF)* and *Pediococcus pentosaceus (PP)* during washing of lemons, mandarins and oranges[1].

FRUIT	AVERAGE PERCENTAGE SHED ±SE		
	L. MONOCYTOGENES (LM)	*E. FAECIUM (EF)*	*P. PENTOSACEUS (PP)*
LEMON	15.6 ±3.1	12.6 ±0.7	6.2 ±1.1
MANDARIN	12.4 ±1.7	10.0 ±0.6	16.6 ±1.5
ORANGE	16.3 ±3.2	11.0 ±0.9	17.3 ±3.6

[1] Fruit was inoculated in multiple concentrations ranging from 5-8 log CFU/fruit of LM, EF or PP.

Table 3. Percent attachment of *Listeria monocytogenes (LM), Enterococcus faecium (EF)* or *Pediococcus pentosaceus (PP)* during washing of lemons, mandarins and oranges[1].

FRUIT	AVERAGE PERCENT ATTACHMENT ±SE		
	L. MONOCYTOGENES (LM)	*E. FAECIUM (EF)*	*P. PENTOSACEUS (PP)*
LEMON	0.015 ±0.004	0.047 ±0.017	0.034 ±0.013
MANDARIN	0.036 ±0.010	0.023 ±0.006	0.014 ±0.005
ORANGE	0.039 ±0.011	0.063 ±0.016	0.069 ± 0.027

[1] The wash water contained 4 log colony forming units/milliliter of LM, EF or PP.

was calculated. Under most test conditions, *LM* was shed more and attached less than *EF* (**Tables 2** and **3**). Despite the difference in observed shed and attachment, *EF* could be used as a surrogate to estimate *LM* shedding and attachment using this study's percent shed/attachment data.

Chlorine Sensitivity

Minimum inhibitory concentration (MIC) testing was done to screen ten strains of *LM* and the seven potential surrogates. *EF* had the most comparable MIC value to the most resistant *LM* strain. These two organisms then were tested to determine if their resistance to chlorine was equivalent. *EF* and *LM* were exposed to free chlorine in the presence of organic matter (**Table 4**). Results showed complete agreement indicating *EF* is a suitable surrogate for *LM*.

Conclusions

Based on chlorine sensitivity testing, *EF* is a suitable surrogate for *LM* and can be used for in-plant chlorine validation studies. Shedding and attachment studies indicated that

Table 4. Inactivation of *Listeria monocytogenes (LM)* and *Enterococcus faecium (EF)* after exposure to three parts per million (ppm) free chlorine solution in the presence of organic matter.

ORGANIC LOAD (PPM TSB[1])	TIME EXPOSURE SECONDS	GROWTH (+) OR NO GROWTH (–)	
		LM	*EF*
20	30	–	–
	60	–	–
	90	–	–
	120	–	–
100	30	+	+
	60	+	+
	90	+	+
	120	+	+

[1] Tryptic Soy Broth

Mandarins, oranges and lemons that have been sampled for the detection of surrogates. ***Photo by Joe Johnston/Cal Poly***

while not equivalent, *EF* could be used as a surrogate for *LM* in citrus wash studies; however, some nuances would need to be considered when interpreting results. None of the tested organisms were an appropriate surrogate for citrus survival studies during storage. If needed, the impact of storage conditions on *LM* behavior should be done with *LM* in a controlled laboratory setting.

CRB research project #5400-168

Glossary

[1]**Surrogate:** A non-pathogenic microorganism that behaves like the pathogen of concern and can be used for in-plant testing.

References

Girbal, M.; Strawn, L.K.; Murphy, C.M.; et al. 2021. ComBase models are valid for predicting fate of *Listeria monocytogenes* on 10 whole intact raw fruits and vegetables. *Journal of Food Protection* 84(4):597-610.

Harris, L. 2019. Characterization and mitigation of bacteriological risks associated with packing fresh-market citrus. Center for Produce Safety Final Project Report. Accessed on June 2, 2023. *https://www.centerforproducesafety.org/researchproject/405/awards/Characterization_and_mitigation_of_bacteriological_risks_associated_with_packing_freshmarket_citrus.html*

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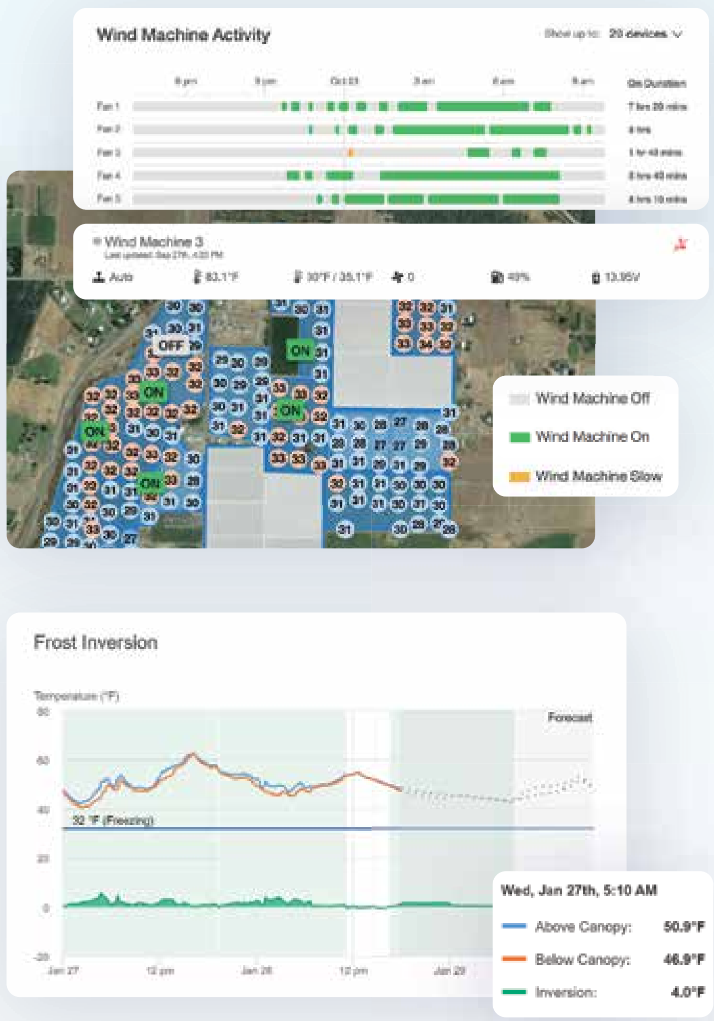

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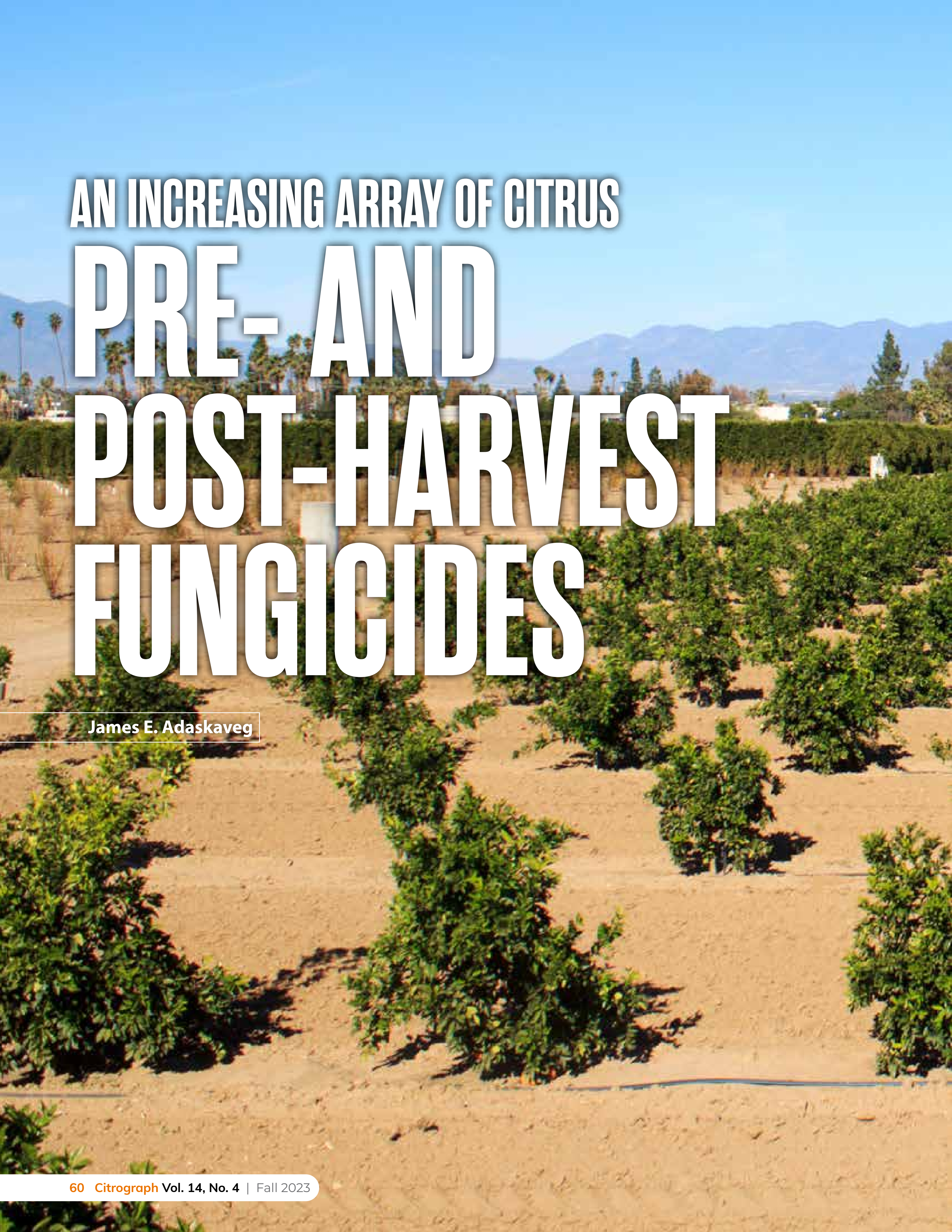
AN INCREASING ARRAY OF CITRUS

PRE- AND POST-HARVEST FUNGICIDES



James E. Adaskaveg

Project Summary

The California citrus industry faces numerous fungal disease problems in the field and post-harvest every growing season. These problems must be managed to produce a high-quality and profitable crop that is the foundation of a successful industry. Although cultural practices can mitigate the impact of some of these diseases, application of fungicides is considered the strategy with highest efficacy. Pre- and post-harvest treatments available for citrus disease management in California and the United States currently includes a wide range of compounds. Additionally decision-making in disease control options has become complex. Overall, fungicides have different modes of action and are grouped by FRAC (Fungicide Resistance Action Committee) Codes that facilitate the design of rotation and mixture programs to minimize resistance development. Several modes of action are available for most of the diseases occurring in California, providing the base for sustainable disease control. Proper application strategies include timing of treatments at critical host phenological stages and prior to favorable environments for infection and disease development. For post-harvest applications, suitable mixtures and sequential treatments with fruit coatings and sanitizers are critical for these treatments to be effective and to fully utilize these treatments.

New Fungicides for California Citrus Industry

The California citrus industry faces numerous fungal disease problems every growing season that must be managed to produce a high-quality, profitable crop. Several diseases, such as Septoria spot, Phytophthora brown rot and sweet orange scab (SOS), have caused quarantine restrictions and revenue loss in shipments of fruit to international markets. Post-harvest diseases such as brown rot, Penicillium decays (e.g., green, blue and whisker molds) and sour rot are chronic problems in long-term storage and shipment to distant markets. The quarantine diseases, as well as potential high levels of post-harvest decays, are considered trade barriers by the U.S. Department of Agriculture-Animal and Plant Health Inspection Service (USDA-APHIS). Although cultural practices can mitigate the impact of some of these diseases, pre- and post-harvest application of fungicides is considered the strategy with the highest efficacy.

Historically, few chemical compounds were available; and for some diseases, such as post-harvest sour rot and Penicillium decays caused by fungicide-resistant pathogen populations, effective treatments were lacking. During the last 20 years, numerous new active ingredients have been introduced through various research projects funded by the Citrus Research Board (CRB). Most of these new introductions are more environmentally friendly, safer to humans and more effective for disease control than previously registered treatments. Involved agrochemical industries have been very supportive of these endeavors; and importantly, they have been working with regulatory agencies in export countries to get residue limits established that will allow these fungicides to be used on fruit shipped to worldwide markets. Below is an overview of fungicide characteristics currently available compounds and a summary of their efficacy against targeted diseases.

Characteristics of Fungicides

Fungicides can be grouped in various ways. Currently, in the most widely used system, they are categorized according to their mode of action by FRAC (2022), an agrochemical industry work group focusing on fungicide resistance management. Each fungicide is assigned a FRAC Code, and the list of Codes is updated annually. Compounds with the same Code have the same molecular mode of action (the same target site in the fungal pathogen) and are at risk for cross-

Table 1. Fungicides registered for integrated management of pre- and post-harvest Phytophthora diseases of citrus[a]

FUNGICIDE CHEMICAL NAME	TRADE NAME	RESISTANCE RISK (FRAC CODE)[b]	FUNGICIDE EFFICACY RATINGS		
			PRE-HARVEST PHYTOPHTHORA DISEASES		POST-HARVEST BROWN ROT
			BROWN ROT	ROOT ROT	
Copper[c]	various	low (M1)	5	NL	NL
Ethaboxam[d]	Elumin	low to med. (22)	NL	4	NL
Fluopicolide	Presidio	high (43)	NL	5	NL
Mandipropamid	Revus	high (40)	5	5[e]	NL
Metalaxyl, mefenoxam	Ridomil, Ridomil Gold	high (4)	NL	3	NL
Oxathiapiprolin	Orondis	high (49)	5	5	NL
Phosphites	Various	medium (P07, 33)	4	4	4

[a] Rating: 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, and NL = not on label.
[b] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different code number are suitable to alternate or mix in a resistance management program.
[c] Multiple foliar applications may cause phytotoxicity.
[d] Registration pending in California.
[e] Nursery use only for containerized citrus trees.

Table 2. Fungicides registered for management of pre-harvest foliar and fruit diseases of citrus[a]

FUNGICIDE CHEMICAL NAME	TRADE NAME	RESISTANCE RISK (FRAC CODE)[b]	FUNGICIDE EFFICACY AGAINST SELECTED DISEASES				
			SEPTORIA SPOT	ANTHRAC-NOSE	ALTER-NARIA ROT	GREASY SPOT	SCAB DISEASES[c]
Azoxystrobin	Abound	high (11)	4	4	2	4	L, ND
Copper	various	low (M1)	4	3	1	3	L, ND
Cyprodinil/fludioxonil	Switch	medium (9/12)	5	5	2	4	NL
Difenoconazole/ azoxystrobin	Quadris Top	medium (3/11)	5	5	3	4	L, ND
Fluopyram/ trifloxystrobin	Luna Sensation	medium (7/11)	5	5	2	4	L, ND
Fluxapyroxad/ pyraclostrobin	Priaxor	medium (7/11)	5	5	2	4	L, ND
Mefentrifluconazole/ fluxapyroxadd	Mibelya	medium (3/7)	5	5	2	4	NL
Phosphites	Various	medium (P07, 33)	3	3	1	ND	NL
Polyoxin-D	Ph-D, Oso	high (19)	4	4	1	0	NL
Pydiflumetofen/ fludioxonild	Miravis Prime	medium (7/12)	5	5	2	4	NL
Pyraclostrobin	Headline	high (11)	4	4	2	4	L, ND
Fenbuconazole	Enable	high (3)	NL	NL	1	4	L, ND
Sulfur	various	low (M2)	0	0	0	3	ND
Trifloxystrobin	Flint Extra	high (11)	4	4	2	4	L, ND

[a] Rating: 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, L = labeled, NL = not labeled, and ND = no data for California.
[b] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different code number are suitable to alternate or mix in a resistance management program.
[c] Scab diseases on the label are for Elsinoe fawcettii and/or E. australis.
[d] Registration requested in California.

resistance. Example target sites within the pathogen include the cytoskeleton, respiration, synthesis of amino acids, proteins, the cell wall, lipids and nucleic acid metabolism. Code numbering is based on the temporal introduction of a new mode of action. Thus, the methyl benzimidazoles that were the first single-site mode of action fungicides introduced were assigned Code 1. Currently, more than 50 FRAC Codes have been described for single-site mode of action fungicides. For multi-site mode of action fungicides such as copper, the Code is preceded by the letter "M," copper being M 01, and there is currently a total of 12 FRAC Codes for multi-site compounds. Biological treatments are given Code BM 01 (plant extracts) or BM 02 (biocontrols). Codes for compounds that are considered to induce host plant defenses are preceded by the letter "P," whereas compounds with unknown modes of action have the letter "U."

A key aspect in fungicide resistance management is to avoid application of fungicides with the same FRAC Code repeatedly on the same crop lot without rotating or mixing with another FRAC Code. The FRAC Code of a fungicide is stated on the commercial container on the fungicide label, but also can be found on various online resources. Knowing the FRAC Code of a fungicide to be applied is the basis of designing fungicide programs that minimize resistance development, but also provide maximum disease management efficacy.

Single-site mode of action fungicides have a specific target site of activity in a physiological pathway of a fungus. Still, although the mode of action among fungicides of the same FRAC Code is the same, members of a Code may have different spectra of activities (i.e., toxicity against a specific range of fungi) or degree of toxicity (that is commonly measured as the effective concentration to inhibit growth of a fungus by 50 percent; i.e., the EC_{50} value). This is because active ingredients may have different affinities to certain fungal target sites. This is evident among succinate dehydrogenase inhibitors (FRAC Code 7) and especially among the demethylation inhibitors (DMIs; FRAC Code 3). For example, while the DMI propiconazole is highly effective against the sour rot pathogen *Geotrichum citri-aurantii*, imazalil has low efficacy, whereas other Code 3 fungicides (not registered on citrus) may be more efficacious.

FRAC Codes also vary in their potential to develop resistance in fungal target populations, and this risk determines how prudently they should be used in respect to the number of applications per season and proper timing. Spectra of activity and resistance risk of fungicides labeled on citrus in California are shown in **Tables 1**, **2** and **4**.

Uptake by plant tissues is another important characteristic of fungicides to be considered in their use. For example, in field applications after an infection event (e.g., rainfall) or in post-harvest applications where infections initiated some time before treatment need to be stopped, a fungicide with locally systemic action can reach the cell layers of the host that the pathogen has colonized at this timepoint. To reduce the risk of resistance development, but also to increase the spectrum of activity, some active ingredients are marketed only as pre-mixtures with another mode of action. Alternatively, single active ingredient fungicides may be mixed manually.

Managing Diseases Caused by *Phytophthora* spp.

Phytophthora spp. are not true fungi, rather, they belong to the kingdom: phylum of organisms, the Stramenopila: Oomycota. Accordingly, distinct modes of action are needed to manage diseases caused by these organisms. Until quite recently, only metalaxyl/mefenoxam and phosphite

Table 3. Timing of fungicide applications for optimal management of citrus diseases[a]

DISEASE	TIMING OF FUNGICIDE APPLICATION					
	SPRING ROOT FLUSH	FALL ROOT FLUSH	OCT./NOV.	JAN./FEB.	MARCH	5 TO 1 WK PHI
Phytophthora brown rot	0	0	3	3	2	1
Phytophthora root rot	3	3	0	0	0	0
Septoria spot	0	0	3	3	1	0
Anthracnoseb	0	0	0	0	0	3
Alternaria rotc	0	0	0	0	0	1/2
Greasy spot	0	0	0	0	0	3

[a] Rating: 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective.
[b] Anthracnose and greasy spot management is generally effective (i.e., +++) with pre-harvest applications before warm, wet weather.
[c] Alternaria fruit rot management with fungicides is generally low (+) with pre-harvest fungicide applications before wet weather (the current understanding of the epidemiology of the disease is limited).

fungicides were available as soil treatments for managing Phytophthora root rot, and phosphites and copper products were labeled as foliar applications to manage Phytophthora brown rot. There are two FRAC Code fungicides for the phosphites, P 07 and 33. Code 33 indicated direct toxicity to the organism; however, this classification was recently changed to P 07, suggesting that the mode of action of phosphites is induction of host plant defenses; i.e., it has an indirect effect on disease control. Activation of host defense systems has been demonstrated in some non-tree crops. However, for citrus diseases, the direct toxicity of phosphites against the pathogens is likely the primary mode of action (Hao et al. 2021).

Three additional fungicides for managing root rot with soil applications and brown rot with foliar applications were registered in recent years, including fluopicolide (for root rot), mandipropamid (for root rot in the nursery only and for field brown rot) and oxathiapiprolin (for root rot and brown rot) (**Table 1**). Additionally, ethaboxam is pending registration as a root rot treatment. Their high efficacy against root and brown rot diseases was demonstrated in multiple-year field studies in this program. The high efficacy of oxathiapiprolin and mandipropamid for managing root rot could be explained by root uptake, limited translocation into above-ground plant tissues and persistence for several weeks.

Managing Pre-harvest Fungal Diseases

Numerous fungicides, including several pre-mixtures, with high disease management efficacy are available for California citrus growers to manage Septoria spot, anthracnose and greasy spot (**Table 2**). Again, most of these fungicides were identified to be of value for citrus production in this program. Treatments for Septoria spot management were specifically requested by the citrus industry and USDA-APHIS to resolve the Korean quarantine on California oranges. These fungicides also are effective against *Colletotrichum, Mycosphaerella* and *Elsinoë* spp. DMI (FRAC Code 3), and QoI (FRAC Code 11) fungicides are federally labeled for scab diseases, but efficacy data in California are lacking. Highly effective fungicides are available to manage Alternaria rot, but because the pathogen is omnipresent and is very opportunistic in causing infections, performance ratings are lower (**Table 2**). In addition to wound infections from various kinds of rind damage, Alternaria rot often becomes

Table 4. Efficacy of fungicides registered for management of major post-harvest fruit diseases of citrus[a]

FUNGICIDE CHEMICAL NAME	TRADE NAME	RESISTANCE RISK (FRAC CODE)[b]	FUNGICIDE EFFICACY AGAINST THREE MAJOR POST-HARVEST DISEASES					
			GREEN MOLD		SOUR ROT		BROWN ROT	
			SENSITIVE[c]	RESISTANT	SENSITIVE	RESISTANT	SENSITIVE	RESISTANT
Azoxystrobin	Azoxy	high (11)	5	1	0, NL	no res.	0, NL	no res.
Azoxystrobin/ fludioxonil	Graduate A+	medium (11/12)	5	no res.	0, NL	no res.	0, NL	no res.
Imazalil	Imazalil, Deccozil, Fungaflor	high (3)	5	2	0, NL	no res.	0, NL	no res.
Imazalil/ pyrimethanil	Philabuster	high (3/9)	5	2	0, NL	no res.	0, NL	no res.
Fludioxonil	Graduate, FDL, Fludioxonil	medium (12)	5	5	0, NL	no res.	0, NL	no res.
Natamycin	BioSpectra, Cerafruta, Uniguard	low (48)	4	4	4	no res.	0, NL	no res.
Phosphites	various	medium (P07, 33)	1	1	0, NL	no res.	4	1
Propiconazole	Mentor, Propi	high (3)	5	2	5	3	0, NL	no res.
Pyrimethanil	Penbotec, Pyrimethanil	high (9)	5	0	0, NL	no res.	0, NL	no res.
Thiabendazole	Alumni, Decco Salt No. 19, TBZ	high (1)	5	1	0, NL	no res.	0, NL	no res.

[a] Rating: 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, and 0 = ineffective and NL = not on label
[b] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with different code numbers are suitable to alternate or mix in a resistance management program.
[c] Sensitive = pathogen is sensitive to the fungicide; resistant = pathogen sub-populations developed resistance. No res. = no resistance detected to date.

evident as a stem-end rot of lemons or a blossom-end rot of Navel oranges because water accumulates under the calyx, at fruit cracks and in the navel. Stem-end rots that may be caused by a range of pathogens other than *Alternaria* spp. in other citrus-growing areas are difficult to manage because the pathogens establish latent infections (no noticeable symptoms) on fruit peduncles and the button from where they slowly advance into fruit tissues. Effective treatment requires applying fungicides with good translaminar (i.e., locally systemic) properties and determining if fruit injuries have occurred at unusually high incidence.

Timing of Fungicide Application for Optimal Disease Management

Effective management using single-site mode of action fungicides requires the proper timing of applications, such as just prior to when conditions are favorable for infection and disease development because they are not as persistent as multi-site mode of action fungicides. Multi-site fungicides like Bordeaux or copper-adjuvant mixtures historically have been very persistent, but overuse led to phytotoxicity and soil and water contamination that limited their usage by regulations including environmental restrictions. Ideal timings for fungicide applications are presented in **Table 3**. For Phytophthora root rot, fungicide applications at spring and fall root flush, as well as at planting, provide optimal performance. For brown rot and Septoria spot, fungicide applications in October to November prior to winter rains and in January to February based on temperature and rainfall conditions provide effective control through the extended harvest season in most years. Returns are diminished when fungicides are applied after February. For the other diseases, five- to one-week pre-harvest intervals can be effective timing of fungicide applications (**Table 3**).

Managing Post-harvest Fungal Diseases

Currently registered fungicides for post-harvest use on citrus in packinghouses to manage green mold, sour rot and brown rot are shown in **Table 4**. Efficacy ratings are provided for fungicide-sensitive and -resistant populations of the pathogens. Most fungicides are ineffective against sour rot except propiconazole and natamycin, and ineffective against brown rot except for the phosphites. This inherent ineffectiveness of a fungicide against a pathogen cannot be considered resistance because the fungicide never had affinity to the target site, or the target site was missing altogether in the organism. Fungicides have been developed mainly for green mold management and have been used extensively. Thus, resistance to most fungicides has been selected for in *P. digitatum* populations, except to natamycin and fludioxonil. Shifts in EC_{95} values for fludioxonil in this pathogen have been observed in several packinghouse populations, while EC_{50} values remain the same as baseline values. This fungicide should only be used in mixtures or pre-mixtures similar to guidelines for other fungicides.

In general, aqueous, high-volume applications provide the highest level of control, but any re-cycling fungicide solution will need to be sanitized with sodium hypochlorite, peroxyacetic acid or another sanitizing agent. However, some fungicides like natamycin are incompatible with oxidizing sanitizers. Fungicides have reduced performance when applied in packing fruit coatings more than when using storage coatings. Therefore, they should be used at the higher labeled rates when mixed with fruit coatings. Timing of application is also critical. Fungicides should be applied as soon as possible and ideally within 12 to 16 hours of harvest.

CRB Research Project #5400-401

References

Adaskaveg, J.E.; Michailides, T.; Eskalen, A. 2022. Fungicides, bactericides, biocontrols, and natural products for deciduous tree fruit and nut, citrus, strawberry, and vine crops in California. Published online: *https://ipm.ucanr.edu/legacy_assets/pdf/pmg/fungicideefficacytiming.pdf*

Adaskaveg, J.E.; Förster, H.; Prusky, D.B. 2022. Post-harvest pathology of fruit and nut crops – principles, concepts, and management practices. APS Press, St. Paul, Minnesota, 606 pp.

Fungicide Resistance Action Committee (FRAC). 2022. FRAC Code List 2022: Fungal control agents sorted by cross resistance pattern and mode of action (including coding for FRAC Groups on product labels). *https://www.frac.info*

Hao, W.; Förster, H.; Adaskaveg, J.E. 2021. Resistance to potassium phosphite in phytophthora species causing citrus brown rot and integrated practices for management of resistant isolates. *Plant Disease* 105(4):972-977.

Hyun, J. W.; Peres, N.A.; Yi, S.-Y.; et al. 2007. Development of PCR assays for the identification of species and pathotypes of Elsinoë causing scab on citrus. *Plant Disease* 91(7):865-870.

Kunta, M.; Rascoe, J.; Sa, P.B.; et al. 2013. Sweet orange scab with a new scab disease "syndrome" of citrus in the USA associated with *Elsinoe australis*. *Tropical Plant Pathology* 38(3):203-212.

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Sweet orange scab (SOS) on orange (left) and lemon (center) fruit as observed in Brazil. The image to the right shows a lemon fruit that was determined to be SOS-positive by the California Department of Food and Agriculture using molecular methods. No spores or fruiting structures of *Elsinoé australis* were found on this and other fruit showing similar symptoms, and the pathogen was not isolated. Two fungicide applications should be applied from early bloom and again 3-4 weeks later to protect early developing fruit from infections during the 6- to 8-week period of susceptibility.

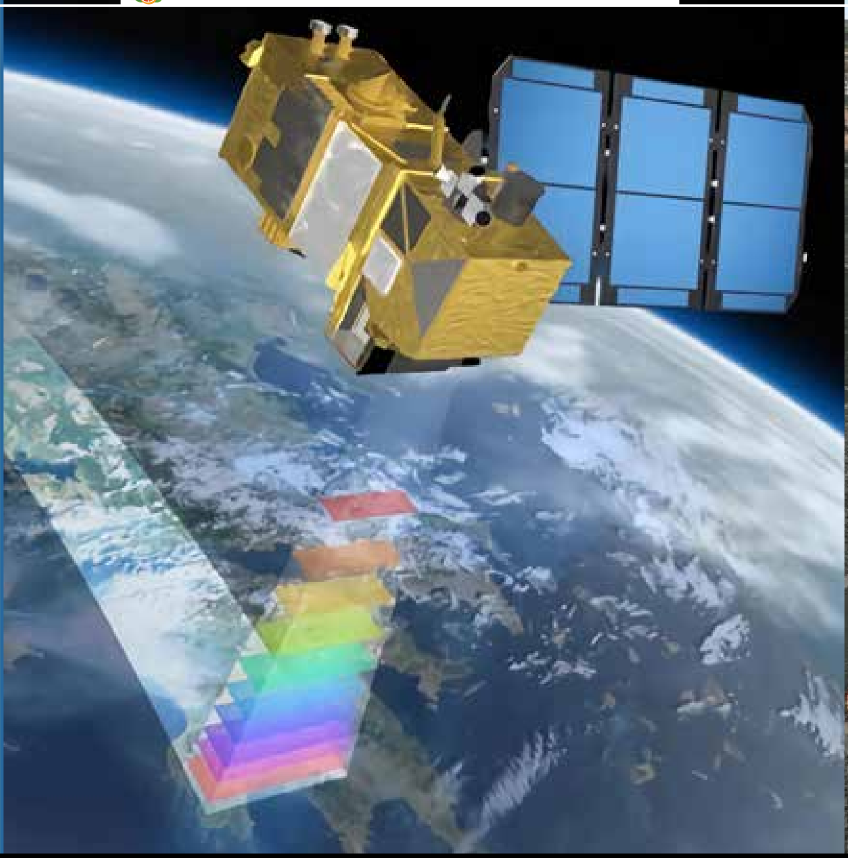
Sweet Orange Scab Update

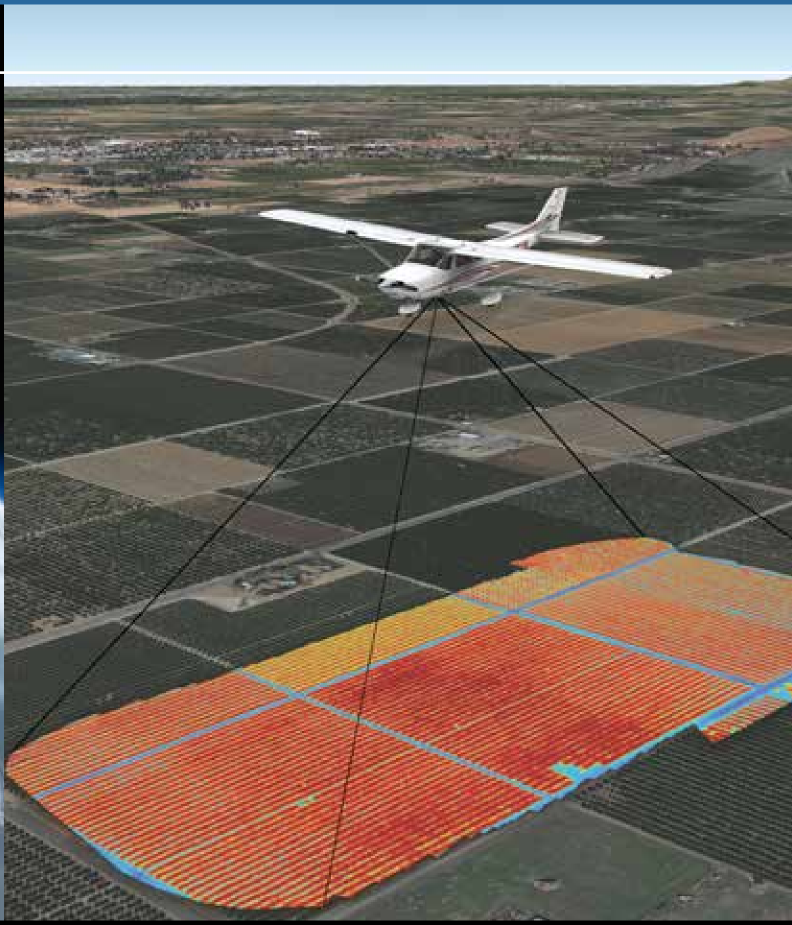
Sweet orange scab (SOS) is a fungal disease caused by *Elsinoë australis* that mainly affects citrus fruit and is rarely observed on leaves and stems. The disease was first identified in California in 2013. SOS also was detected in subsequent surveys in 2016, 2020 and 2021 by the California Department of Food and Agriculture (CDFA) on oranges, lemons and tangelos, as well as on unspecified citrus fruit in southern California, including Los Angeles, Orange, Riverside and Imperial counties where most detections occurred. Unlike most fungal diseases, all detections were based on molecular methods using published species-specific DNA primers (Hyun et al. 2007). The fungus is difficult to culture and grows very slowly. Thus, the molecular approach is justified. Symptoms in California appear similar to wind-scarring and are atypical of the disease. In humid, high-rainfall regions such as the southeastern United States, Central America and Brazil, citrus fruit scabs are raised and blister-like. In these raised scabs, the fungus produces sub-epidermal, asexual fruiting structures called acervuli where numerous asexual spores (conidia) are produced. Short-lived conidia are non-pigmented, either spindle-shaped or elliptical, and can reproduce by budding. The conidia can germinate and infect fruit in as little as three to four hours, but more typically in five to six hours at 21-27ºC. Infection of fruit has been reported from full bloom to six to eight weeks after bloom during early fruit development. The sexual stage of the SOS pathogen has been found only in Brazil.

The unusual aspect of not being able to culture or to see sporulation of the pathogen on positive-identified fruit has led to additional surveys of orchards that tested SOS-positive by the CDFA to look for scab symptoms, reproductive structures and conidia of the pathogen. We are evaluating the specificity of the "species-specific" primers being used for the detection of the pathogen. Epiphytic (growing on plant surfaces) fungal organisms such as *Meira* species that are common yeasts on fruit surfaces, have been found on fruit in these surveys, and these may not occur on fruit in humid regions. These yeast organisms produced DNA amplification products in polymerase chain reactions (PCR) with primers used to identify *E. australis*, and we recognize this as a false positive. To date, we have not been able to culture the pathogen from "wind-scarring" symptoms on fruit identified as positive by the CDFA using molecular methods, and we have not observed acervuli or conidia of the pathogen in wind-scar scabs on fruit from three citrus groves that tested positive. Our research will continue with additional surveys and with cultures of the pathogen sent to us from the University of Florida. We plan to conduct laboratory studies on detached fruit to observe symptoms and signs caused by this quarantine pathogen and to verify the molecular method of detection.

- James E. Adaskaveg, Ph.D.

CRB-FUNDED PROGRESS REPORT





Representation of satellite (left) and airborne (right) remote sensing imagery acquisition.

REMOTE SENSING ESTIMATES OF CITRUS EVAPOTRANSPIRATION

What error can the industry accept?

Daniele Zaccaria and Pasquale Steduto

Project Summary

Accurate quantifications of citrus water consumption, irrigation requirement and water productivity are crucial to:

- *ensure allocation of sufficient water supplies to citrus production areas,*
- *maintain or modify the existing citrus acreage and production targets,*
- *transfer water among hydrologic/groundwater basins and*
- *implement efficient irrigation management.*

These aspects are essential for citrus production when considering the recurring water shortages due to climate variability, occurrence of extreme weather events (drought and heat waves) and increasingly stringent environmental regulations.

Accordingly, several irrigation districts and groundwater sustainability agencies (GSAs) recently adopted satellite remote sensing (SRS) methods to estimate citrus evapotranspiration (ET) for assessments required by the Sustainable Groundwater Management Act (SGMA) and for water resource planning, allocation and delivery. However, solid ground-truthing and validation of the ET estimates against ground-based ET measurements were not sufficiently conducted for citrus.

This project aims to:

1. *develop updated water use and productivity information for citrus orchards grown in Tulare, Kern and Riverside counties;*

2. *provide information on acceptable, actual and potential accuracy of SRS-based ET estimates against ET measurements for micro-irrigated citrus orchards based on science-based findings; and*

3. *present recommendations to reduce uncertainties and errors in estimating citrus ET and irrigation demand with SRS methods.*

Since irrigation is key to sustaining citrus fruit yield and quality, the project's expected outcomes are updated information on citrus water use and accuracy of SRS-based ET estimates. These will be crucial for growers and water managers to improve water use efficiency and maintain the competitiveness of the California citrus production industry.

Introduction

In the last decade, California's major citrus production areas faced significant water shortages caused by droughts, groundwater depletion and increasingly stringent environmental regulations. The prospects of increasing climate variability and weather extremes (droughts, heat waves, floods) make accurate determination of citrus ET, irrigation requirements and water productivity crucial for:

1. ensuring sufficient water supplies to citrus growing areas,

2. maintaining or modifying the existing citrus acreage and production targets,

3. transferring water among hydrologic/groundwater basins and

4. implementing efficient irrigation management.

In California, ET and water productivity of micro-irrigated citrus orchards vary considerably with climatic conditions, tree density, row orientation and canopy vigor that regulate solar energy interception by trees, ET and fruit production. Currently, the accuracy of ET estimates considered acceptable by citrus production and water management stakeholders is unclear and uncertain. Several irrigation districts and GSAs recently adopted SRS methods to estimate ET for SGMA-related assessments and for surface/groundwater conjunctive use, but without conducting reliable validation of the SRS-based ET estimates for various crops (Jin et al. 2018), including citrus.

Research Overview and Expected Outcomes

This project aims to:

1. develop updated water use and productivity information for citrus orchards grown in Tulare, Kern and Riverside counties;

2. provide information on acceptable, actual and potential accuracy of SRS-based ET estimates against ET measurements for micro-irrigated citrus orchards based on science-based findings; and

3. present recommendations to reduce uncertainties and errors in estimating citrus ET and irrigation demand with SRS methods.

This information is critical for quantitative assessments of sustainable citrus acreage, groundwater extractions and surface water allocation necessary to maintain high-quality citrus production in areas with severely over-drafted aquifers and highly variable surface supplies. Recent advances in satellite technology and the ability to observe Earth's surface features and processes from space, along with the development of sophisticated computational procedures, provided an ample and diversified offer of SRS models to estimate ET over agricultural landscapes.

SRS models can monitor bio-physical processes over large areas, such as irrigation schemes, watersheds and hydrological basins. In California, SRS models currently are being used by water agencies and regulators to estimate crop ET at various scales, but they lack solid on the ground validation of the ET estimates, particularly in citrus production areas.

This research study focuses on well-managed, high-yielding citrus orchards in Tulare, Kern and Riverside counties for two purposes:

1. determine the acceptable accuracy of SRS-based citrus ET estimates by surveying the main citrus industry's stakeholders and water resource planners and managers; and

2. compare ground-based citrus ET measurements obtained with the eddy covariance[1] method against different SRS-based ET estimates, particularly those derived from OpenET, a shared web platform for ET data processing and model operation. Such a comparison allows quantifying the uncertainties and errors of SRS-based citrus ET values and relate them with acceptable accuracy thresholds derived through the stakeholder survey.

Preliminary comparisons of citrus ET estimates obtained from various SRS-based models and the OpenET model ensemble show substantial discrepancies (minus six percent to plus 75 percent) and large ET variations with respect to ground-based ET measurements (**Table 1**). These discrepancies and variations may result from inaccurate ET estimation algorithms or defective capture of bio-physical parameters that end up exposing the citrus industry to the risk of receiving unrealistic water supply allocations.

Evapotranspiration (ET) measurement station (eddy covariance tower) in a commercial citrus production orchard.

Table 1. Comparison of monthly ET values obtained from ground-based measurements (eddy covariance tower) versus satellite remote sensing (SRS)-based estimates, with indication of relative differences (%), for a micro-irrigated Navel orange orchard located in Lemon Cove, California, (Tulare County) during 2020.

MONTH	MONTHLY GROUND-MEASURED ET VALUES (IN.)	MONTHLY SRS-BASED ESTIMATED ET VALUES (IN.)	RELATIVE DIFFERENCE (%)
	EDDY COVARIANCE	OPENET	
1	1.04	1.03	-0.65
2	1.57	1.99	26.37
3	1.72	3.01	75.42
4	2.45	4.06	65.72
5	4.81	5.71	18.73
6	5.76	6.21	7.86
7	6.17	6.59	6.79
8	5.61	6.02	7.33
9	4.09	4.59	12.27
10	3.25	3.05	-6.31
11	1.44	1.64	13.94
12	1.01	1.23	20.96
Cumulative values	**38.91**	**45.11**	**15.95**

Growers and water agencies need reliable and accurate information on citrus ET, along with an enhanced capability to determine irrigation water demand for planning surface water diversions and groundwater extractions and transfer agricultural water supplies among production areas and groundwater basins.

Sharing knowledge about the magnitude of uncertainty and errors resulting from SRS-based ET determinations is essential for economic analysis, given the agronomic repercussions of inaccurate water allocations to citrus production. This research study also will provide recommendations on accuracy enhancements of SRS-based ET estimates through ground-truthing, calibration, validation and correction measures. Such information is necessary to improve allocation, delivery and management of highly variable and often-limited water supplies and to devise irrigation scheduling decisions for maintaining profitable citrus production.

Adoption of updated citrus ET information will help address water supply shortfalls imposed by environmental regulations, recurring droughts and increasing climate variability in water-limited citrus production areas.

CRB Research Project #5400-170

Glossary

[1]**Eddy covariance:** Micro-meteorological method to directly measure energy fluxes between ecosystems and the atmosphere.

References

Jin, Y.; He, R.; Marino, G.; et al., 2018. Spatially variable evapotranspiration over salt affected pistachio orchards analyzed with satellite remote sensing estimates. *Agricultural and Forest Meteorology*, 262, pp.178-191.

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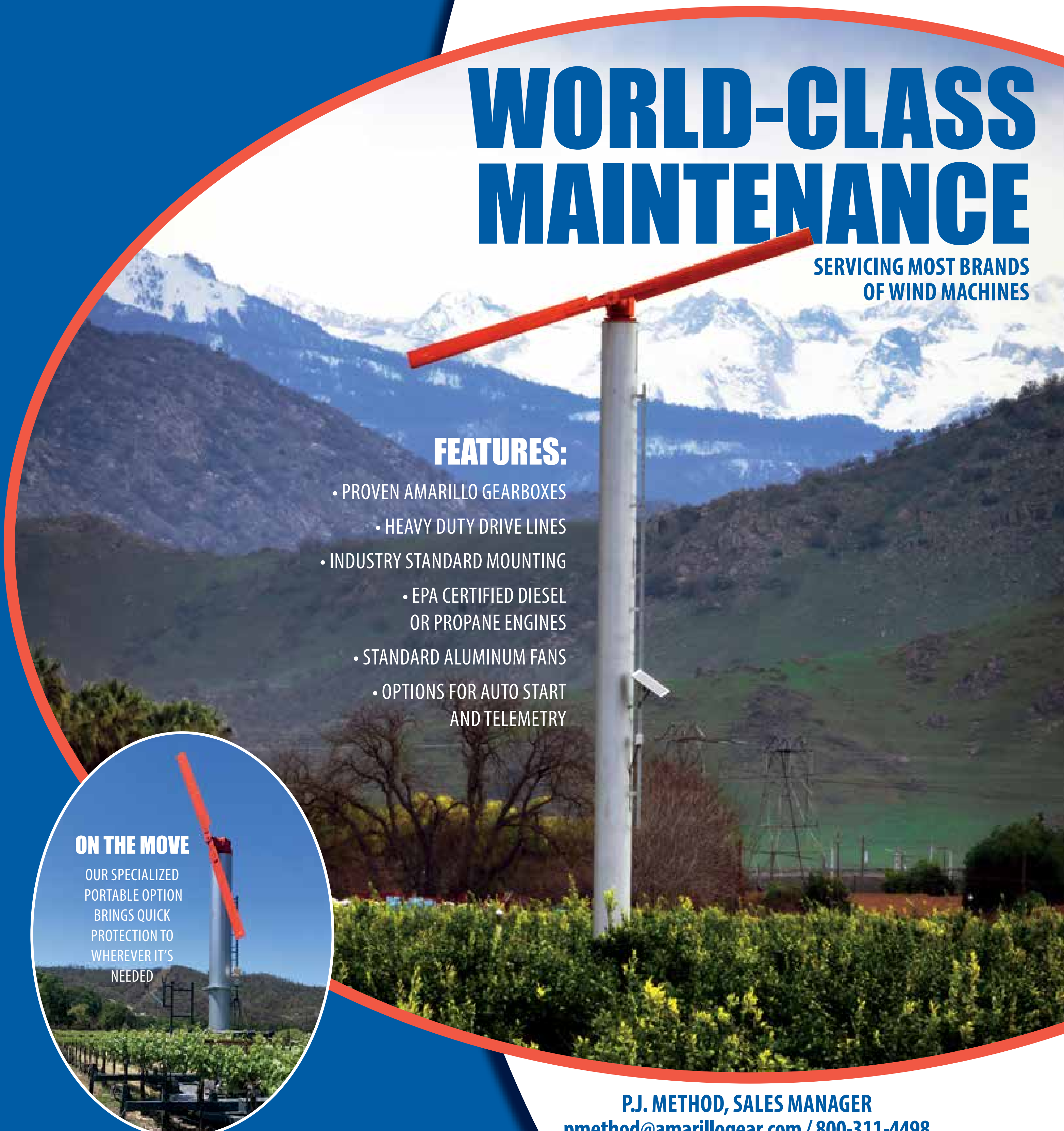
AMARILLO WIND MACHINE

PROVEN TECHNOLOGY



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