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“Fall in love with the process and the results will come!” - Eric Thomas
On the Cover: In this fall’s edition of Citrograph, we are focusing on production and post-harvest technology research. On page 14, you’ll find an article by Citrus Research Board (CRB) Member Joe Stewart, who heads up the CRB’s Production and Post-harvest Technology Research Committee, that discusses the work that the growers are funding in these areas to help them make more informed decisions. Several research articles in the magazine also take an in-depth look at the research being done in post-harvest technology and production. We hope you find this issue interesting and informative.
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Fall 2021 | Volume 12 • Number 4 | The Official Publication of The Citrus Research Board

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# 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.

## Citrus Research Board Member List

By District 2020-2021 (Terms Expire September 30)

### District 1 - Northern California

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<tr>
<th>Member</th>
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<td>Justin Brown, Chairman</td>
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<td>Scott Carlisle</td>
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<td>Greg Galloway</td>
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<td>John Konda, Vice Chairman</td>
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<td>Etienne Rabe</td>
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<td>Andrew Brown</td>
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<td>Chris Boisseranc</td>
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<td>John Gless III</td>
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<td>Craig Armstrong</td>
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### Public Member

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<td>Melissa Cregan</td>
<td>2021</td>
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NEW GENERATION K-PHITE 7LP
BRINGS SUPERIOR EFFICACIES TO
DISEASE CONTROL FOR CALIFORNIA CITRUS GROWERS

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

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

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

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For more information including research results and scientific publications, contact;
Mark Brady, Western Marketing Manager, Plant Food Systems, Inc.  (559) 731-1267
2021-22 CALENDAR OF EVENTS

SEPTEMBER
21

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

OCTOBER
6

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

NOVEMBER
10

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

JANUARY
??

Citrus Research Board (CRB) Meeting. For more information, contact the CRB at (559) 738-0246 or visit www.citrusresearch.org
When one cold night can ruin an entire year’s hard work...

It’s best to play it safe.

Since 1967, we have hand-crafted our wind machines with precision technology. We take pride in the details, which is why citrus growers from around the world trust Orchard-Rite® wind machines to protect their mature stock and new plantings from the dangers of frost. We are dedicated to serving you and your crops by providing the tools, knowledge and service to stave off those frosty nights, protecting your harvest and your future.
As food continued to reach consumers during the past year, many realized the value of farmers and the entire agricultural industry. Shortages of fruit and vegetables never really materialized, and consumers continued to see stocked produce aisles at the grocery store. The dedication of growers, packers and shippers who worked diligently every day to grow, harvest and distribute our crops came into greater focus.

The last year and a half has shown the importance of joining together to explore different avenues and think creatively to find solutions. While COVID-19 uncertainties will continue, we believe we can take the same solutions-based spirit and move forward. At the Citrus Research Board (CRB), we’ve never lost sight of our mission statement. We have continued to promote a sustainable California citrus industry to benefit growers by prioritizing, investing in and promoting the research programs with which we are involved.

Marcy L. Martin
Continuing to Connect

We have continued to connect and collaborate, albeit virtually, which has allowed the CRB to take on additional projects. Our quarterly Board Meetings have continued with high attendance rates and with more frequent committee meetings to further our collective priorities. This year could not have been accomplished without our devoted staff and accommodating Board Members. In addition, our researchers persevered as restrictions were often burdensome, but we are proud to have funded more than $3.1 million in research throughout the past year.

During a year of virtual presence, we still were able to make significant strides in research advancements. Following a majority vote of support from our Board of Directors, we applied for and were awarded $3.4 million through the Huanglongbing Multi-Agency Coordination Group (HLB MAC). This award will enable us to implement a Citrus Research and Field Trial (CRaFT) program in California to advance Asian citrus psyllid (ACP) controls. The overarching goal of the CRaFT project is to demonstrate additional mitigations to improve psyllid control within commercial citrus groves across the various citrus-growing regions in California. This information will inform areawide control efforts and demonstrate the benefits of control measures currently available to growers for regional, state and national benefit.

The project aims to demonstrate reduced psyllid levels (through trap, tap and visual monitoring) within treated groves as a year-by-year measurement relative to regional psyllid levels.

Our Citrus Webinar Series returned in June 2021 with nearly 600 attendees during the four-part series. Topics included pesticide laws and regulations, integrated pest management, crucial California water updates and information on new rootstock and scion cultivars. Four regional crop advisors provided information on the different growing regions—including Tulare, Riverside, Ventura and Placer counties. We are grateful that these experts took time out of their schedules to speak with our growers. Many thanks to the team at UC Integrated Pest Management for their assistance in organizing and facilitating the webinar series.

We are looking forward to the Annual Meeting in September where the FY2021-22 research projects will be confirmed and approved. Following this will be the California Citrus Conference on October 6, 2021, with speakers highlighting the vast number of areas we invest in research; pest management, California’s Citrus Division, molecular mechanisms of plant immunity and more. We are excited for the return of this in-person conference as we showcase the best of the best in citrus research. For more information on this free conference, please see the overview on page 12.

Moving Forward

While we are preparing to resume in-person meetings, we can continue learning from and growing in our virtual capacities. We have enjoyed the increased level of engagement from many of our stakeholders and have been able to undertake a deepened collaboration with our colleagues across the country.

We are looking forward to support from the industry during our upcoming referendum year, and we are confident in serving another five years with the best interest of our growers at the forefront. If you have any questions regarding the referendum or our ongoing efforts in citrus research, please do not hesitate to reach out.

In the next year, we are looking forward to more face-to-face conversations with our growers as we return to in-person gatherings. The CRaFT project will be established over the coming months as we work toward improved ACP control with this critical program. In addition, the International Research Conference on Huanglongbing will return to the Riverside Convention Center in October 2022, once again highlighting relevant international research in combatting HLB.

With a full calendar heading into 2022, we will continue our service to the citrus industry and strengthen our connection with our growers.

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
THE CALIFORNIA CITRUS CONFERENCE IS BACK

Tamara Tollison, Caitlin Stanton and Ivy Leventhal
The Citrus Research Board (CRB) is pleased to announce the return of the California Citrus Conference on October 6, 2021, in Visalia, California. This event will showcase the best of the best in citrus research, highlighting various topics such as the fight against Asian citrus psyllid (ACP) and huanglongbing (HLB). After a year of virtual events, the entire citrus industry is invited to participate in this free, in-person conference.

“We are delighted to welcome the citrus industry back to the California Citrus Conference where we will showcase the best of CRB-funded research,” said CRB Chairman Justin Brown. “It is important for all of us to gather together so that we can network and learn about the critical research developments that have taken place over the last few years.”
SCHEDULED SPEAKERS INCLUDE:

- Casey Creamer, California Citrus Mutual
- Victoria Hornbaker, Citrus Pest and Disease Prevention Division
- Sandipa Gautam, University of California Agriculture and Natural Resources
- Danelle Seymour, University of California, Riverside
- Omar Akbari, University of California, San Diego
- Jim Adaskaveg, University of California, Riverside
- Sean Cutler, University of California, Riverside
- Monique Rivera, University of California, Riverside
- Rick Dantzler, Citrus Research and Development Foundation
- Hailing Jin, University of California, Riverside

In addition to the scheduled speakers, research posters will be displayed, with researchers available to answer questions. Continuing education units have been applied for and will be available to conference attendees, pending approval by the California Department of Pesticide Regulation (CDPR).

Registration for the conference is now open and highly recommended. Although this is a free event, attendance has increased each year and space is limited. To register or learn more about the conference, please visit www.citrusresearch.org. Registered attendees will receive conference materials and admission to all sessions, along with a complimentary hot breakfast, lunch and break refreshments.

The Wyndham Visalia is located at 9000 W. Airport Drive in Visalia and has served as the site for previous California Citrus Conferences. Please contact the CRB Communications Department at events@citrusresearch.org if you are in need of a room reservation for the event.

Once again, we are thrilled to have this event in-person and look forward to seeing you all in October.

Tamara Tollison is the communications specialist with the Citrus Research Board and also serves as the communications assistant on Citrograph. Caitlin Stanton is the communications coordinator with the Citrus Research Board and also serves as a communications assistant on Citrograph. Ivy Leventhal is the managing editor of Citrograph. For more information, please contact events@citrusresearch.org

Stay tuned to www.irchlb.org for more conference details.
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Eliminate labor costs while increasing control over your production.
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Price includes 5 years of cellular data costs.
MEET THE PRODUCTION AND POST-HARVEST TECHNOLOGY RESEARCH COMMITTEE

Joe Stewart

PRODUCTION AND POST-HARVEST TECHNOLOGY RESEARCH COMMITTEE

CRB BOARD MEMBERS ARE LISTED IN BOLD TYPE.

• Joe Stewart (Committee Chair)
• Mark McBroom (Committee Vice Chair)
• Scott Carlisle
• Megan Morreale
• Jason Oriopp
• Etienne Rabe, Ph.D.
• Keith Watkins
• Henk Du Plessis
• Arno Erasmus, Ph.D.
• Kris Tomlinson
With 10 members, Production and Post-harvest Technology Research is one of the larger Citrus Research Board (CRB) committees. The purpose of this committee is to support research that will deliver timely and validated information to address concerns and improve industry practices around horticultural activities, food safety concerns and non-vectored pathogens (both in the field and the packinghouse) with a larger goal of improving pre- and post-harvest production efforts in the grove and in the packinghouse. We also focus on keeping California growers and processors competitive in domestic and international markets.

Funded Research

Eight research projects were overseen by our committee in the 2020-21 fiscal year for a total of $596,906.

Continuing projects included:

- evaluating the effects of citrus dwarfing viroid in common California citrus varieties to see how dwarfed varieties might meet the increasing challenges of citrus production (e.g., labor costs, water shortages, land reduction),
- evaluating new treatments to reduce Phytophthora diseases,
- forecasting and managing Septoria spot of citrus [see page 46 for more information] and
- estimating the impacts of the Sustainable Groundwater Management Act (SGMA) on citrus acreage and production throughout the state [see page 32 for more information].

New projects focused on:

- generating citrus-specific spray drift data in California to validate pesticide risk assessment models,
- assessing and mitigating the impact of anthracnose and Alternaria Rot on production,
- developing new sanitation treatments for post-harvest decays and
- validating existing packinghouse sanitation processes to meet audit and/or regulatory requirements.

Key Projects

One of the key continuing research projects supported by this committee that is of particular value to packinghouses and to grower returns is managed by James Adaskaveg, Ph.D. He has been monitoring fungal resistance and evaluating new post-harvest fungicide treatments for the benefit of both domestic and international markets, with this committee’s support for the past 15 years.

Another key goal is our search for mechanized/robotic harvesting technologies to address the specific needs of our industry. Last fiscal year, we worked with senior engineering students from California Polytechnic, San Luis Obispo on developing a prototype labor aid. For more information on this project, see "Cal Poly Engineering Students Create Citrus Harvest Aid" on page 44. Even though we do not have a currently funded robotic project, we continue to offer mechanized harvesting as a researchable priority every year. There have been advancements recently in other commodities, so hopefully citrus will not be far behind; however, the clipping required for citrus is a hurdle at this point.

Still one more important research effort looks at the impact of the state-mandated SGMA water pumping regulation on California citrus. The project has taken a two-part approach – first looking at crop demand before compiling data to see the impact of SGMA on citrus in the eight over drafted sub-basins where citrus is grown in California.

The Production and Post-harvest Technology Committee works cooperatively and in concert with university research programs, the U.S. Department of Agriculture, the California Department of Food and Agriculture, other California citrus organizations and scientists from around the world to maximize funding, information sharing, brain power and results to seek research solutions that will help maintain the sustainability of the California citrus industry. For more information on the projects described above and other CRB-supported work, please visit our website, https://citrusresearch.org/research-projects to view the CRB’s active and archived research project reports.

Joe Stewart is the chair of the Citrus Research Board’s Production and Post-harvest Technology Research Committee. The Exeter, California, resident also works for Eastside Packing and has his own farming company. For more information, contact joestewartfarm@gmail.com
Memorial Day weekend historically has marked the unofficial start to the summer travel season. As travel rebounded due to easing COVID-19 restrictions, more than 37 million Americans — a 60 percent increase compared to 2020 — were expected to travel out of town over the three-day weekend this year. The Citrus Pest & Disease Prevention Program (CPDPP) saw the perfect opportunity to launch a “Don’t Move Citrus” campaign, emphasizing to California residents the importance of what not to bring along on their summer travels: homegrown citrus fruit and plant material.

Mark McBroom
Why You Should Leave Citrus at Home

Within the past year, we have seen sporadic ACP detections popping up in areas of California where populations typically are not established, often believed to be caused by unauthorized transportation. These recent ACP detections are a reminder that we must remain vigilant against this elusive pest and the dangerous disease it spreads. For residents across the state, leaving citrus fruit and plant material at home is crucial for the well-being of California citrus. The most effective way to prevent the spread of HLB is to keep psyllids out of our orchards and backyards.

Moving homegrown citrus from southern California – where the deadly tree disease has been found in nearly 2,400 residential trees – into the San Joaquin Valley is a particular concern, as hitchhiking ACP could introduce the deadly disease to many of the state’s commercial groves.

Through the “Don’t Move Citrus” campaign, California Department of Food and Agriculture (CDFA) officials urged Californians to obey plant quarantine restrictions that prohibit the movement of citrus fruit or plant material into or out of quarantine boundaries. Residents were advised to take extra precaution when gifting citrus fruit from their own backyard trees as summer travel rebounds. If citrus must be moved, residents were reminded that fruit must be thoroughly washed and clear of any leaves or stems as transporting citrus fruit with leaves still attached can inadvertently spread the pest to new areas of the state.

Leveraging Paid and Earned Strategies

Securing more than 127 million estimated touchpoints throughout the state, the “Don’t Move Citrus” campaign leveraged paid, earned and social media strategies to educate residents why they should keep their beloved citrus at home when traveling.

Earned Media
To kick off the campaign, the CPDPP outreach team contacted media outlets across the state to highlight the dangers HLB presents to residential and commercial citrus trees, and the importance of leaving fruit and plant material behind as residents travel this summer. Through tailored pitches and
Los Angeles Daily News

Southern California travelers warned not to transport backyard citrus fruit

A tiny pest, the Asian citrus psyllid, has infected residential trees with a deadly tree disease.

The California citrus industry has a message for road trippers traveling this Memorial Day weekend: Don't give grandma (or anyone else for that matter) your homegrown fruit.

The transport of backyard oranges, lemons, grapefruits and kumquats is illegal in most of Southern California, which is under a citrus fruit and plant quarantine. That's because movement of fruit, citrus trees and even seeds can unknowingly spread a pest that can infect healthy citrus trees with a deadly plant disease that has no cure.

Because homegrown citrus is a place the Asian citrus psyllid, or ACP, likes to hang out, transporting this hitchhiking pest can allow it to infect other trees with a plant disease it can carry, called Huanglongbing, also known as HLB or citrus greening disease.

Their advice is pack the kids, the shorts, the swim goggles and suntan lotion but not the homegrown fruit.

Paid Media

To support the successful earned media placements, the CPDPP outreach team developed a comprehensive paid media plan to ensure that repetition of these important messages blanketed California prior to the holiday weekend. Paid media tactics included traditional radio and Facebook advertising – in both English and Spanish – targeted toward key areas of the state where ACP and HLB are present. In addition, billboards were secured along major transportation corridors in key citrus growing regions, including Ventura, San Bernardino and Riverside counties, which provided more than 3.6 million estimated views by motorists and community residents.

As media consumption habits continue to shift, the CPDPP outreach team introduced Pandora streaming ads, a new tactic for the program, to broaden reach beyond traditional radio. Paid media tactics resulted in nearly 4.8 million estimated touchpoints throughout the state.

A Word of Caution

The "Don't Move Citrus" campaign reached millions of Californians with an important message at a relevant and critical time. But the urgency to leave citrus fruit and plant material at home continues year-round, not only as travel picked up during the warm summer months. Californians must continue to leave behind their beloved citrus year-round as they travel throughout the state to help keep ACP populations at bay, which can spread HLB.

The state's $7 billion in economic revenue and the livelihoods of more than 22,000 individuals who work in the citrus industry are at stake. The widespread effort to preserve backyard and commercial citrus in California...
has reached a critical point. As the CPDPP continues to conduct outreach and increase education and awareness about the pest and disease, residents and the industry alike must work together to ensure we can continue to enjoy California citrus for generations to come.

Mark McBroom is the vice chair for the Citrus Pest & Disease Prevention Committee and outreach subcommittee chairman. He also serves as secretary-treasurer of the Citrus Research Board. For more information, contact desertcitrus@aol.com

Billboards placed in Ventura, San Bernardino and Riverside counties earned more than 3.6 million impressions.
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Pace InSite™ is a cloud-based data management software that allows you to access reports and export packing line data. It conveniently analyzes trends to help you make informed decisions about day-to-day operations.

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Pace International offers a complete line of sustainable postharvest solutions, services, and application equipment to protect and enhance the quality of produce and increase packer/shipper profitability.
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The most powerful MRL-exempt slug and snail baits—period.

Increase control of snails and simplify compliance with FerroxxAQ and Sluggo Maxx baits from Neudorff. Broadcast applications, crop contact and irrigation are unrestricted with iron baits. Aerial and aquatic applications are allowed, there is no retreatment interval or annual maximum, and the MRL exemption broadens your market by simplifying exports.

Iron baits from Neudorff offer both conventional and organic growers a powerful tool for year-long control because iron baits remain effective under cool and wet conditions. These baits are highly palatable to pests and can be used around pets and wildlife. Plus, they provide a maximum number of baiting points.

Ferroxx AQ or Sluggo Maxx.

Make your choice. Then, Bait Back!

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Over time, many of the regulatory issues facing the California citrus industry have remained constant. Regulators continue to assess pesticide safety, and plant protection officials still require risk reduction protocols in many export markets. However, while many of these issues have remained the same, the regulatory environment surrounding those issues is becoming increasingly complex.

If you are a Facebook user, you are one of the platform's 2.8 billion global users, which represents 36 percent of the world’s population. It is also highly likely that you view YouTube, since 81 percent of U.S. adults said they used it in 2021. Information is circulating more easily and frequently than in any period in history. For better or worse, people are formulating opinions and attitudes based on a combination of reliable information and misinformation, and those attitudes are seeping into all aspects of society, including the regulatory environment. Many of those attitudes conflict with science-based regulatory policy. Consumer attitudes inform the marketplace and government institutions, locally and globally, and affect the regulatory environment that affects citrus producers.
The European Union (EU) has initiated a process to revolutionize the European continent by achieving a carbon neutral economy by 2050. The proposals affect a broad scope of EU economic sectors, including agricultural production, as the plan calls for a 50 percent reduction in pesticide use and risk by 2030, a 20 percent reduction in fertilizer use and transforming organic production from eight percent of agricultural acreage to 25 percent by 2030. The EU aspires to be the global standard for sustainability and proposes to use international venues such as Codex, the United Nations and the Food and Agriculture Organization to promote a global transition to food production systems mirroring the EU approach. The EU is planning to use its international influence to persuade other countries around the world to adopt its sustainability goals. Since the EU is a large market for exporters, it is likely to require imported products to meet the same standards as European growers. Climate change and sustainability policies will also be a potential avenue for protectionist policies that could impose sustainability measures on imports or tariffs that would account for higher production costs of domestic producers who operate with fewer inputs or tools to maintain yields.

In addition to its climate change and sustainability initiatives, the EU is in the process of reviewing all pesticides used in agricultural production in its member countries. Relying on a precautionary approach to risk assessment, the EU is expected to cancel registrations for the majority of crop protection tools and their associated maximum residue limits (MRLs) during the next ten years.

The EU’s politically driven proposals provide a familiar backdrop to other actions by global regulators subjected to political and social pressure. For example, Mexican authorities have proposed phasing out glyphosate without conducting a scientific review, while Thailand is phasing out glyphosate, chlorpyrifos and paraquat, also without scientific reviews.

On the phytosanitary front, global plant protection officials (PPO) are under greater social and legal scrutiny related to biosecurity. This has led to more demands to control bean thrips in citrus exports to Australia and New Zealand and Spotted Wing Drosophila in New Zealand, which, in turn, have led to requirements to fumigate orange exports to Australia and New Zealand with phosphine.

In this environment, the California Citrus Quality Council (CCQC) has been working on a broad scope of regulatory issues including the following:

Environmental Protection Agency (EPA) Registration Review

The EPA is required to conduct a safety review of each registered pesticide every 15 years, and the agency has been reviewing scores of pesticides during the past two years, some of which are critically important for California citrus production. The CCQC has provided comments to the EPA on thiamethoxam, imidacloprid, pyrethroids, chlorpyrifos, mandipropamid, pyrimethanil, phosphine, propiconazole, imazalil and sodium ortho-phenyl phenol (SOPP). These comments provide the EPA with information on the importance of crop protection tools for the California citrus industry and help the EPA conduct their risk assessments.

The EPA’s imazalil review proposed restrictions on use that would have made it difficult for packinghouses to use the industry’s most important post-harvest fungicide. The CCQC worked with the University of California (UC), Riverside's...
Jim Adaskaveg, Ph.D., Decco and JBT to conduct a survey of mixer-loaders that provided data to the EPA on imazalil exposures. The federal agency used the data to refine its analysis and eventually removed the proposed mitigation measures. The loss of imazalil would have increased packinghouse costs, increased shipping losses from decay and lowered grower returns.

The CCQC also is working with the Draslovka Group on the registration of ethyl formate, which will be an important fumigant that can be used post-harvest to kill Asian citrus psyllids and is a potential new tool to support export protocols for Australia and New Zealand.

Endangered Species Act Implementation

The federal government is required to ensure that when pesticides are registered, they are not harmful to endangered species. Policymakers have been arguing for more than a decade over the methodology that should be used to conduct the evaluation, and the process has been fraught with legal challenges. The EPA has begun its Endangered Species Act (ESA) reviews, which may impact some important pesticides for citrus growers.

The CCQC has commented on the EPA’s glyphosate and simazine biological evaluations and urged the EPA to use actual application rates instead of maximum label rates to conduct evaluations. Overly conservative ESA evaluations pose a significant threat to the availability of pesticides for growers or restrictions on their use. The Citrus Research Board (CRB) supported CCQC to identify ESA interface areas with citrus and is partnering with other specialty crop organizations through the Minor Crop Farmer Alliance (MCFA) to provide alternative review methodologies that would generate more accurate assessments.

CDPR Neonicotinoid Review

Closer to home, the California Department of Pesticide Regulation (CDPR) has proposed significant restrictions on the use of neonicotinoid pesticides to protect honeybees using a conservative risk assessment that the CCQC and California Citrus Mutual (CCM) have contested. The CDPR has convened a panel of stakeholders to evaluate the CDPR’s proposal for reducing the use of pesticides in California production and relying more on integrated pest management (IPM). While pesticides are a common element in IPM programs, the CDPR proposal would minimize the role of pesticides in these programs.

The CDPR is conducting a review of thiamethoxam and imidacloprid and has proposed significant restrictions on the use of these important pesticides. The Department used a conservative methodology to conduct its preliminary review, which determined that honeybees are harmed by some uses of thiamethoxam and imidacloprid. The CCQC and CCM, with research support from the CRB, have challenged the CDPR’s approach and submitted significant comments to the CDPR about the proposal. The Department is evaluating the comments and plans to issue a final proposal later this year.

Label Improvements and 24(c) Registrations

The CCQC has been working with AMVAC®️ on a multi-year project to improve the label for 2,4-D. The changes clarify that two applications of 2,4-D are permissible and that it can be used on trees younger than six years old. Mandarins were added to the label. While no rates were changed, the greatest benefit was clarifying that two applications are permitted for fruit size and pre-harvest fruit drop.

The CCQC, Wonderful Citrus and Valent are working together to evaluate potential rate changes for the ProGibb®️ label that would improve fruit color for lemons and also improve fruit set. Wonderful Citrus is conducting the efficacy trials that will be used to develop a 24(c) registration application. A 24(c) is a special local need registration that allows states to register new uses for pesticides that already have an approved tolerance. The application is reviewed by the state and approved by EPA. Once the trials are evaluated, the 24(c) application will be submitted to the CDPR for approval. If it is approved, it will help growers delay color development on lemons, which would increase the marketing window and maintain higher prices.

The CCQC also has been working with Adaskaveg and Syngenta to submit a 24(c) application that would increase
the rates of propiconazole for sour rot control on lemons. Once approved, the higher rates will help packinghouses store lemons for a longer period, which will help marketing. Lemon growers have been severely affected by reduced food service demand due to restaurant COVID restrictions. The application could be approved this fall.

International and Market Access Issues

The CCQC continues to monitor global issues that can impact the California citrus industry and is working to maintain and expand market access for the industry.

The CCQC collaborated with the U.S. Department of Agriculture-Animal and Plant Health Inspection Service (USDA-APHIS) to find an option to address New Zealand’s requirement for Spotted Wing Drosophila (SWD) mitigation for exports to New Zealand. The CCQC plans to continue working with APHIS, along with Sunkist, to minimize the impact of New Zealand’s requirements.

Sunkist and the CCQC also have been working with APHIS to expand market access for citrus to Vietnam. Vietnam’s Ministry of Agriculture and Rural Development (MARD) has provided market access for oranges, and we currently are waiting for a response from MARD on grapefruit, lemons and mandarins.

As part of its international activities, the CCQC provides information to the USDA and registrants to establish MRLs in major export markets. The CCQC has been working on a multi-year effort with registrants to establish MRLs for important crop protection tools for the Korean market and has helped establish more than 170 MRLs for Korea, which is the industry’s largest orange export market. The EU also is conducting a complete review of registered pesticides, which has led to frequent cancellations and the loss of more MRLs. We expect this process to continue on the same trajectory as the EU cancels more pesticide uses and transitions to biologically-based pest management systems and organic agriculture under its Farm to Fork policy.

Several months ago, Thailand announced a pesticide residue monitoring program that would be troublesome for citrus exporters. The regulation allowed importers the option to require exporters to certify with residue sampling that imports met the new regulation. This would potentially add additional costs to exports to Thailand. The CCQC sent letters to Thailand’s Food and Drug Administration (TFDA) to request an alternative approach and collaborated with the USDA’s Foreign Agricultural Service to request changes in the proposal. TFDA recently moved citrus from the high-risk category to the low-risk classification, so no testing will be required. The new policy aligns with recommendations from CCQC.

Earlier this year, APHIS announced a proposal to expand the acreage in Australia that would qualify for export to the United States. The CCQC worked with Sandipa Gautam, Ph.D., and Beth Grafton-Cardwell, Ph.D., to develop comments to oppose the proposal. APHIS is evaluating comments but has not released any additional information about the proposal.

The CCQC also has been working within the industry to coordinate a transition in the number of fungicides that should be declared on domestic and export shipping cartons. This change will allow packers greater flexibility in controlling storage pathogens that cause decay and result in lower fruit quality for consumers and unwanted claims for packers. When there are a limited number of fungicides listed on the carton, it is difficult for packers to transition to other fungicides that would be more effective in controlling resistance that develops later in the season. Packers now will have the flexibility to use any of the fungicides as the need dictates.

Food safety is a national priority for China. For the last several years, regulators have been developing food safety regulations that will take effect on January 1, 2022, and will require registration of packing and processing facilities, food safety certification and possible food safety audits. The CCQC will continue to monitor the issue and assist the industry with compliance.

Issues on the Horizon

Substantive climate change policies, regulations and laws are likely to be implemented within the next two to three years. Greater awareness of the threat of climate change and urgency for action is driving global legislative bodies, regulatory agencies and international bodies to develop concrete action for change.

The EU is developing laws and regulations that will revolutionize agricultural production under its Green Deal and Farm to Fork policy, and Japan recently announced its Green Food System plan which urges importers to buy from suppliers that produce food sustainably. This activity also is driving demands for change in agricultural production such as reduced pesticide use, greater biodiversity, more organic agriculture and pollinator protection. We expect major global initiatives to reduce the use of plastics, and more initiatives to increase recycling and demands on suppliers to transition to more sustainable packaging. The CCQC will continue to monitor all of these issues and work to minimize the negative impact on the California citrus industry.

James R. Cranney, Jr. is president of the California Citrus Quality Council. For more information, please contact jcranney@ccqc.org
Information overload is a signature dilemma of our age. For example, Google Scholar displays 35,000 results for “citrus” from the past year. How can anyone keep up? To the rescue comes The Genus Citrus, a hefty tome edited by Manuel Talon, Marco Caruso and Fred G. Gmitter Jr., and written by an international dream team of contributors, offering an up-to-date overview of 24 topics from genomics to economics.

Chapter 1, “The citrus genome,” describes the rapid progress made in the past two decades in sequencing ten types of citrus, how this allows scientists to distinguish pure from admixed species and a brief but intriguing account of the evolution and domestication of mandarins. It’s largely comprehensible to general readers, although many may not be familiar with every word (“pseudomolecules,” “panmictic”).
Chapter 2 integrates recent scientific articles into a readable account of citrus origins – how citrus originated on the border of China, India and Myanmar; how, when and where the various citrus types evolved and spread; and how they’re related to each other. Anyone with the slightest interest in citrus should find this fascinating.

Recent genomic discoveries have sowed taxonomic confusion by confirming that many important citrus types actually are admixtures of species. Chapter 4 proposes a new trinomial nomenclature that adheres to the genetic evidence, but also incorporates familiar usage. For example, orange, Citrus sinensis in the standard Swingle system, becomes Citrus × aurantium var. sinensis L. It makes sense and is easy to use, but the official rules of taxonomic nomenclature require strict adherence to precedent, and it remains to be seen whether this, or the new U.S. Department of Agriculture taxonomy or another system will gain traction.

Among the following chapters are authoritative accounts of scion and rootstock varieties, traditional and genomic breeding, biotechnology, fruit growth and development, pests and diseases, post-harvest, flavor chemistry and health effects. Most include plentiful literature citations.

The book generally is well written but could have used a good copy editor to correct occasional typos and refine the writing of authors whose first language is not English. Overall, because of its scope and expertise, this is one of the most important citrus publications since The Citrus Industry (5 vols., 1967-1980). The Genus Citrus is available in both print and online editions, the latter free to those who have access to the University of California library system at <https://www.sciencedirect.com/book/9780128121634/the-genus-citrus>.
For a vision of citriculture 300 years ago, search out the elephant folio–size book, weighing 9.6 lbs., reproducing the color illustrations from Johann Christoph Volkamer’s *Nürnbergische Hesperides*. Born to a family of merchants and scholars in Nuremberg, Bavaria, Volkamer (1644-1720) devoted himself to his extensive home garden, particularly to growing citrus, and published two lavishly illustrated volumes in 1708 and 1714.

The upper portions of most images depict a citrus variety, whole and cut open, along with leaves and flowers; the lower parts show the gardens, structures and landscapes in which they grew in Germany and Italy. The combination of fruit and landscaping is appealingly surreal, which partly explains why many original copies of Volkamer’s book have been cut up and sold as individual plates.

Particularly significant for citrus historians are the illustrations for the never-published third volume, which are shown here, in the original black and white, for the first time. The excellent introduction by Iris Lauterbach, a Swiss-based art historian, places Volkamer in his historical context in an era when affluent aficionados spent fortunes on extravagant orangeries.

Neither of these giant books is beach reading, but both will provide knowledge and pleasure to citrus lovers.

*David Karp is an assistant specialist in the Department of Botany and Plant Sciences, University of California, Riverside. His Modern Citrus Cultivars Descriptive Database recently appeared at https://citrusvariety.ucr.edu/MCCDD.html. For more information, contact dkarp@ucr.edu*
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WILL CITRUS SURVIVE SGMA?
UNDERSTANDING CALIFORNIA GROWER CROP CHOICE

Bruce Babcock, Mehdi Nemati and Dat Tran

Project Summary
Our research objective is to provide insight into how water supply reductions under California’s Sustainable Groundwater Management Act (SGMA) will impact competition between citrus and other crops for water, labor and land. To meet this objective requires constructing a spatial crop choice model for groundwater sub-basins with significant citrus acreage. Year one was devoted to data collection and estimation of key demand and supply model coefficients that will determine modeling outcomes. These coefficients include measures of grower response to demand changes and market price response to acreage changes. In this progress report, we discuss how changes to California’s cropping pattern over the last 20 years were used to estimate demand-side coefficients.
California’s SGMA objective is to balance groundwater usage with replenishment. Water use reductions are expected in groundwater basins where current use exceeds replenishment. (Escriva-Bou et al. 2021; Hanak et al. 2019; Moran and Wendell 2015). Water reductions in California translate directly to reduced crop acreage and downstream supply chain activities. Our research objective is to determine how SGMA will impact California’s citrus industry.

The Citrus Research Board’s (CRB) 2019 acreage survey indicates that 83 percent of California’s 330,000 acres of citrus are in SGMA-impacted sub-basins. Based on submitted sustainability plans, reductions in total water use in these citrus regions could range up to 19 percent (Figure 1). Citrus production will compete with other crops for a share of smaller water supplies once SGMA is implemented. The acreage planted to major crops in the citrus growing sub-basins that will compete for available resources is shown in Table 1.

Our first step was to determine which factors will affect the outcome of this competition. Growers will want to plant crops that are the most profitable. Holding all else constant, lower costs lead to higher profits, which suggests that less water and labor-intensive crops will have the advantage. But lower costs do not automatically translate into higher profits. Planting crops in high demand that fetch higher prices can more than make up for higher labor and water costs.

Water scarcity is not a new issue facing California growers. A better understanding of how the current mix of crops evolved will provide insight into the attributes of crops that will dominate the future. Changes in California crop acreage during the last 20 years have been considerable with an explosion in tree crop acreage, particularly almonds, mandarins, pistachios and walnuts and sharp contractions in field crop acreage and some tree crops, such as Valencia oranges (Figure 2).

Understanding what drove these acreage changes will help us model which crops will be best positioned to compete for future irrigated acres.

Table 1. Major crops planted in citrus-producing sub-basins from Figure 1.

<table>
<thead>
<tr>
<th>CROP</th>
<th>ACREAGE</th>
<th>SHARE (PERCENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almonds</td>
<td>664,725</td>
<td>23.67</td>
</tr>
<tr>
<td>Grapes</td>
<td>415,435</td>
<td>14.79</td>
</tr>
<tr>
<td>Pistachios</td>
<td>344,700</td>
<td>12.28</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>289,572</td>
<td>10.31</td>
</tr>
<tr>
<td>Citrus</td>
<td>277,168</td>
<td>9.87</td>
</tr>
<tr>
<td>Corn</td>
<td>277,124</td>
<td>9.87</td>
</tr>
<tr>
<td>Walnuts</td>
<td>168,908</td>
<td>6.02</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>135,528</td>
<td>4.83</td>
</tr>
</tbody>
</table>

Source: Citrus crop acreage for 2019 was provided by the Citrus Research Board. California Department of Water Resources GIS data for 2019 were used for non-citrus crops.
Both supply-side and demand-side factors can drive acreage changes. Supply-side technologies, along with the prices and availability of key factors of production such as water, land and labor, can change relative production costs enough to entice growers to switch crops. Demand-side developments reflecting changes in consumer food preferences can lead growers to plant the types of crops that consumers demand. If demand growth is the primary acreage driver, then consumers will dictate planted acreage. If technology and resource availability are determinant, then crop-specific investments that increase productivity will dictate future acreage. Our initial analysis of the data shows a high correspondence between demand growth for crops and acreage changes, which leads us to conclude that demand has been the primary driver of California planting decisions and will likely continue to be so in the future.

**Figure 2. Percentage changes in California acreage of selected crops since 2000.**  

**Demand Growth and Responsiveness to Price**

It would seem straightforward to estimate which crops have had the greatest demand growth: just look at which crops have expanded acreage. But it is not so simple. Technological change enables growers to increase profitability by lowering per-unit costs, allowing them to expand production profitably, even at a lower market price. Indeed, during the last 70 years, technology has increased crop supplies faster than crop demand, explaining why inflation-adjusted crop prices have fallen even while U.S. crop acreage has remained constant. Thus, we need to estimate both demand growth, which measures how much can be sold at a given price over time, and demand responsiveness, which measures how much can be sold at different prices at a point in time.
The method that we chose to use to estimate demand growth and responsiveness was to take advantage of the fact that there is a unique amount of demand growth in a given year for any given level of responsiveness. For example, if we have 20 years of prices and quantities, a given level of responsiveness provides 19 estimates of demand changes. We used market information about demand shifts, such as the loss of an export market, to reveal which level of price responsiveness generates demand shifts that are most consistent with observed prices and quantities (Babcock et al. 2021). Economists measure demand responsiveness by the ratio of the percentage change in quantity sold divided by the percentage change in price. This ratio is called demand elasticity. If demand responsiveness to price is low, then demand is said to be inelastic, and the demand elasticity will be between 0 and -1. Conversely, if price responsiveness is low, then demand is elastic, and the demand elasticity is less than -1.

### Demand Growth for California Citrus and Tree Nuts

Our estimated range of demand elasticities for citrus crops and tree nuts is presented in Table 2. Notably, demand for all these crops is inelastic. This means that if California growers increase production by 10 percent, price will decline by greater than 10 percent, and revenue will fall. Conversely, if SGMA leads to a 10 percent drop in production of any of these crops, their price will increase by more than 10 percent, thereby increasing revenue.

#### Table 2. Estimated elasticities of demand for citrus and tree nut crops.

<table>
<thead>
<tr>
<th>CROP</th>
<th>LIKELY RANGE</th>
<th>MOST LIKELY ELASTICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almonds</td>
<td>[-0.15, -0.45]</td>
<td>-0.40</td>
</tr>
<tr>
<td>Lemons</td>
<td>[-0.20, -0.60]</td>
<td>-0.40</td>
</tr>
<tr>
<td>Mandarins</td>
<td>[-0.30, -0.70]</td>
<td>-0.50</td>
</tr>
<tr>
<td>Fresh Navel Oranges</td>
<td>[-0.30, -0.70]</td>
<td>-0.50</td>
</tr>
<tr>
<td>Pistachios</td>
<td>[-0.30, -0.70]</td>
<td>-0.50</td>
</tr>
<tr>
<td>Walnuts</td>
<td>[-0.10, -0.30]</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

Source: Calculated by authors.

One conclusion from Table 2 is that demand elasticity cannot explain why growers have increased tree nut and mandarin acreage relative to navel oranges and lemons over this period. Instead, we must look to demand growth for this explanation. Figure 3 shows indices (index = 100 in the year 2000) of demand facing U.S. growers over time using most-likely elasticities. Crops with high demand growth rates are the crops that expanded acreage during the last 20 years. Regarding citrus crops, our demand growth estimates imply that growers could sell four times as many mandarins in 2019 as were sold in 2000 while receiving the same inflation-adjusted market price. The rapid growth in mandarin demand seems to have begun with the widespread availability of the seedless Tango variety. In contrast, demand for navel oranges has not changed much at all. Lemon demand has increased modestly during the last 20 years, particularly the last 10 years. Regarding major competing crops, annual demand for almonds, pistachios and walnuts during the last 20 years grew by 7.3, 9.1 and 5.8 percent respectively.

### California Grower Response to Demand Changes

In response to demand growth, California growers increased acreage of mandarins, almonds, pistachios and walnuts. Since 2000, acreage for these four crops has grown at average annual rates of 10.6 percent, 4.4 percent, 7.5 percent and 3.2 percent respectively. California mandarin acreage growth has exceeded demand growth because acreage in other producing states has declined. Navel orange acreage has declined because yield growth has been more than adequate to meet scant demand growth. California
lemon acreage has not really changed since 2000, though California's share of U.S. acreage has increased.

Figure 4 presents average annual U.S. supply and demand growth rates since 2000. Supply growth includes both acreage and yield growth. Demand growth has been larger than supply growth for almonds, mandarins, walnuts and pistachios. This excess demand has resulted in strong prices for these crops. Lemon prices have not been strong in recent years because much of the excess demand growth shown in Figure 4 has been met by imported lemons. Supply growth has exceeded demand growth for navels which explains why navel prices have been weak.

Concluding Remarks

The large changes in California crop acreage during the last 20 years offer an opportunity to identify the key factors that drive grower planting decisions. This knowledge is needed in our CRB research project to enable us to model how California growers will respond to future reductions in water supplies under SGMA. The data are consistent with California growers planting crops in high demand and shunning those crops with stagnant demand or crops that can best be grown in other states or countries.

California agriculture will prosper in the future by being flexible in responding to demand, but not so flexible that the resulting increase in supply outstrips demand growth. Based on the available data for all but one of the important crops examined here, supply growth has not kept up with demand growth, which has resulted in higher inflation-adjusted prices. This is the recipe for a profitable agricultural sector. The one exception is navel oranges, with almost no demand growth during the last 20 years. Without a reversal of demand for navel oranges, the recent profit squeeze for the navel orange is likely to continue.

One crucial question to growers is the extent to which they can influence future demand growth by pooling their resources to fund marketing efforts. Did consumers simply realize that their lives would be better by eating more nuts and mandarins? Or did marketing efforts by grower associations and large companies nudge domestic
and overseas consumers toward their choices? Should growers fund development of demand-side technologies to create new consumer products, such as almond milk, seedless mandarins and frozen pistachio desserts to drive future demands, or should that be left to non-grower entrepreneurs? Although the answers to these questions are beyond our current research project scope, it is clear from the data that California growers have decided that their prosperity hinges on growing the crops that consumers want to buy.

CRB Research Project #5400-158

References


Bruce Babcock, Ph.D., is an agricultural economist and professor, Mehdi Nemati, Ph.D., is an assistant professor of cooperative extension and Dat Tran, Ph.D., is a post-doctoral scholar, all in the School of Public Policy at the University of California, Riverside. For additional information, contact bruce.babcock@ucr.edu
Air Temperature and Stress May Lead to Pre-Harvest Lemon Fruit Drop

Glenn Wright, Carol Lovatt and Akif Eskalen

Project Summary
Pre-harvest lemon fruit drop (LFD) occurs when full-sized fruit fall from apparently healthy trees. Significant economic loss can occur. We identified potential factors that might lead to LFD, including presence of fungi on the fruit and in the soil, leaf mineral deficiencies and climactic conditions. In 2018 and 2019, we collected soil, fruit and leaf samples in California and Arizona orchards and applied plant growth regulators (PGRs), fungicides and mineral nutrients to attempt drop reduction. In both years, neither leaf mineral nutrient concentrations nor soil and fruit pathogen sampling results correlated to LFD. Fungicide and PGR treatments applied did not affect LFD counts or orchard yields. Data suggest that temperature may be the primary cause of LFD, especially for early bloom fruit. Harvesting earlier appeared to reduce LFD, which occurred shortly after daily maximum temperatures dropped due to the reduction of the Southwestern Monsoon. With this new insight, research to determine the proper time for PGR application is needed.
Background and Significance to California Growers

Pre-harvest lemon fruit drop occurs in orchards in the Southwestern desert during the late summer and early fall when full-sized fruit fall from apparently healthy trees (Figure 1). Fallen lemons are usually light green or yellow, with a thin rind and hollow central core (Figure 2) and are more mature than similarly sized green fruit that remain on the tree. Depending on the tree size, up to 100 fruit can drop, constituting a significant economic loss. LFD occurs on Eureka and Lisbon lemons on most common rootstocks used in the area, but does not occur in every orchard.

Due to the recent appearance of this problem and the lack of research, there are many opinions among lemon producers about the cause of LFD. Based on March 2018 pre-experiment grower interviews, some potential causes include fungal pathogens that infest the stem of the fruit or soil pathogens that reduce root growth leading to tree stress. Other suggested causes include high temperature at harvest and reduced irrigation before harvest, sometimes to reduce oil spot.

Objectives

Based on the interviews, we proposed the following two objectives for the experiment:

1. Field sampling of LFD to determine if pathogens are causing it and/or if nutritional/climactic factors are associated with it.
2. Chemical treatment of orchards to alleviate LFD.

This work was conducted on four experimental sites in 2018 and 2019. In 2018, the sites were located near Thermal, Mecca (Mecca B) and Niland, California, and in Yuma, Arizona. The Thermal and Yuma sites had minimal LFD in 2018 and were replaced in 2019 by another in Mecca (Mecca A) and North Shore, California.

Soil and Fruit Pathogen Tests

We looked at common suspect soil pathogens, such as *Phytophthora parasitica*, and *P. citrophthora*, and identified *Globisporangium ultimum* as a new pathogen, but there was not a common soil pathogen found across all sites tested. A similar test for fruit pathogens was conducted, but no pathogen found matched the common suspect fruit pathogens, such as *Colletotrichum acutatum*, the cause of post-bloom fruit drop in Florida (Peres and Dewdney, 2020), nor was any common pathogen found across all affected fruit samples.

Leaf Nutrient Analysis

We collected leaves for nutrient analysis at the sites in August 2018 and 2019. There was no consistent nutrient excess or deficiency that we could correlate with LFD in 2018, and in 2019, none of the trees were deficient or excessive in any nutrient (Lovatt 2014).

Climate

Data from various weather stations were collected near the experimental sites in 2018 and 2019. There were no indications that excessive wind of more than 28 miles per hour (mph) led to LFD. We tested for relationships between temperatures occurring during the seven to 14 days prior to the initiation of LFD. Daily maximum air temperature dropped and remained below 100°F between September 29 and October 1 in 2018 and during the week of September 24 in 2019. Daily minimum air temperature dropped and remained below 60°F between October 8-16 in 2018 and the week of October 1 in 2019. These dates are shown by...
the red and blue arrows, respectively, in Figures 3 and 4. Temperature reductions during this time are typical and indicative of the end of the Southwestern Monsoon.

**Fungicide and PGR Treatments**

We applied fungicide and PGR treatments at recommended rates in 2018 and 2019 to determine if LFD could be reduced. Treatments included Fungi-phite®️ (a fast-acting phosphite fungicide), the fruit senescence inhibitors ProGibb®️ LV Plus (GA3), Primacy Alpha®️ (a cytokinin) and Citrus-Fix®️ (an auxin) applied in Yuma only, and liquid foliar fertilizers Megafol®️ or Brexil®️.

**Fruit Drop**

Weekly LFD counts were collected in 2018 (Figure 3). Fruit drop increased at all sites, but those increases were minimal at Yuma and Thermal. Therefore, these sites were replaced in 2019. LFD for Mecca B and Niland increased from about five fruit per tree to as many as 40 per tree starting on September 28. LFD fell to levels below 20 fruit per tree in early October, then increased to rates of 30 to 40 fruit per tree in late October, before falling again. LFD was variable from tree to tree, and there was no significant effect of the treatments.

In early October 2018, LFD at the Niland site had a small peak, where drop increased above 10 fruit per tree. Later, there was an October and November peak of 30 to 40 fruit per tree. There was no apparent effect of the treatments. Drop may have been greater due to persistent issues with salinity at the site.

Figure 4 shows LFD for 2019. At Mecca A, drop increased from zero in August to 20-30 fruit per tree by early November. There were no significant effects of the treatments due to the high variability among the trees.

LFD at Mecca B increased from zero in August to almost 20 fruit per tree in early November, 30-40 fruit per tree in mid-November and then continued at 15-30 fruit per tree until the final measurement in mid-January. This site was harvested late, which accounts for the continued drop after mid-November. There was no significant effect of the treatments.
Figure 4. Weekly fruit drop counts at four orchards in California in 2019. For each orchard, the red arrow indicates when maximum air temperature dropped and remained below 100°F, and the blue arrow indicates when minimum air temperature dropped and remained below 60°F.

LFD at Niland increased from zero in mid-August to 40-50 fruit per tree in mid-October, then falling to 20-30 fruit per tree in late November and increasing to 50-65 fruit per tree in mid-December. This site has issues with saline irrigation water. Both the first and second harvests were rather late, which may have allowed LFD to peak. Again, there were no significant effects of the treatments due to the high variability among the trees.

LFD at North Shore was low compared to the other sites, ranging from zero in August to seven to ten fruit per tree in late October. Since this site was completely harvested by early November, subsequent LFD was eliminated.

Yields
We collected yield data at all four sites in 2018 and 2019. There was no effect of the treatments upon yield. Orchards that were harvested early had less LFD, while those harvested late had more LFD.

Return Bloom
We estimated return bloom in spring 2020 on the control trees and trees treated with ProGibb LV Plus and Primacy Alpha in 2019 (Table 2).

At Mecca B, return bloom was significantly reduced by treatments 2 and 3. Both contained GA3 as ProGibb LV Plus, which, depending on application time, can reduce flowering. This could reduce the

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>NILAND</th>
<th>NORTH SHORE</th>
<th>MECCA B</th>
<th>MECCA A</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.63 a</td>
<td>6.25 a</td>
<td>4.25 b</td>
<td>6.25 a</td>
</tr>
<tr>
<td>3</td>
<td>4.25 a</td>
<td>6.88 a</td>
<td>3.63 b</td>
<td>5.00 a</td>
</tr>
<tr>
<td>5</td>
<td>4.25 a</td>
<td>6.88 a</td>
<td>6.88 a</td>
<td>4.00 a</td>
</tr>
<tr>
<td>P-value</td>
<td>0.5874</td>
<td>0.8418</td>
<td>0.0100</td>
<td>0.2202</td>
</tr>
</tbody>
</table>
potential usefulness of the ProGibb as a tool to limit LFD. Further research is required to determine how late in the season GA3 can be applied without reducing return bloom. This is important not only for the future use of GA3 to reduce LFD, but also for the use of GA3 to maintain the highly desirable light yellow to yellow green color of the fruit peel.

Relationship Between Temperature and LFD

The initiation of LFD was closely related to when the maximum air temperature dropped and remained below 100°F and when the minimum air temperature dropped below 60°F in the area around the Niland and Thermal orchards in 2018 (Figure 3) and the Mecca A, Mecca B, Niland and North Shore orchards in 2019 (Figure 4). At the beginning of LFD, the greater the drop in minimum air temperature from September 22 to October 1, the greater the number of fruit that dropped during that period in both 2018 and 2019. Thus, changes in minimum air temperature explained 63 percent and 99 percent of the variation in the number of lemons that dropped between September 22 and October 1 in 2018 and 2019, respectively. Ninety-five percent of the variation of fruit drop in 2019 was explained by the decrease in maximum and minimum air temperatures that occurred from October 1 to October 15.

Furthermore in 2018, the drop in maximum air temperature to less than 100°F from November 1 to 15 explained 76 percent of the variation in the LFD; the greater the decrease in maximum air temperature, the greater the number of lemon fruit that dropped. Although of lesser importance, the decrease in minimum air temperature over this same period explained more than 50 percent of the variation in the number of lemon fruit that dropped. These relationships require further research across more orchards and years, but might prove useful in predicting LFD and for properly timing PGR treatments to reduce LFD.

Conclusions

Based on factors that were tested but had no effect on LFD, through the process of elimination, one can speculate about the cause of LFD as follows:

1. Soil- and fruit-borne fungi do not appear to affect LFD. Applications of fungicide did not reduce LFD. Leaf nutrient deficiency or excess do not cause LFD, nor did the application of foliar nutrients reduce LFD.
2. Applications of ProGibb LV Plus and Primacy Alpha, had no effect on LFD. However, it is likely that our treatment applications in early to mid-September were too late to be effective. The use of GA3 to prolong fruit retention should be re-evaluated in the context of earlier applications, but the use of Primacy Alpha alone might be warranted.

Once these factors are eliminated from consideration, the issues of fruit maturity and temperature remain. Lemons often have some early-season (November through February) bloom that leads to fruit that matures in mid-summer during the humid Southwestern Monsoon. These fruit can be difficult to pick when mature because of oil spot and because there is often not enough volume of fruit on a tree to justify picking. Therefore, the early-maturing fruit show signs of senescence when it hangs on the tree for several weeks until picking commences.

This suggests that LFD is a problem of fruit maturity and possibly stress. Fruit that are early bloom, fruit from salinity-stressed trees and fruit that are affected by the reduction in temperature as the Southwestern Monsoon fades away may be those found on the ground in October. Our analysis of the relationship between the drop in maximum and minimum air temperatures below 100°F and 60°F respectively and continued decreases in air temperature and LFD are consistent with and support this interpretation.

The solution may be as simple as picking earlier. If most of the crop is removed in September, as occurred in North Shore, drop might be reduced. Of course, harvest at this time brings challenges, since the market may not need fruit that early, and desert packinghouses might not be open. Also, oil spot will be a problem, and pickers will be inefficient if they are ring-picking, leading to higher harvest costs. Continued research into proper application rates and timings of PGRs may ultimately lead to another solution.

CRB Research Project #5400-153

References


Glenn Wright, Ph.D., is an associate extension specialist and professor of horticulture at the University of Arizona in Yuma. Carol Lovatt, Ph.D., is a professor of plant physiology at the University of California, Riverside. Akif Eskalen, Ph.D., is a plant pathologist and cooperative extension specialist at the University of California, Davis. For more information, contact gwright@ag.arizona.edu
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Project Summary

Due to rising labor costs and falling labor availability, traditional methods of citrus harvesting practiced widely throughout California are becoming less profitable. The citrus industry needs new tools to improve worker productivity and to reduce the overall cost of harvesting.

The BioResource and Agricultural Engineering (BRAE) and Agricultural Systems Management (ASM) senior design experience is a sequence of five classes completed by students in their final year at California Polytechnic State University, San Luis Obispo (Cal Poly). Teams composed of five to seven students from these two majors work together to design, fabricate, test and document a system that solves a real-world engineering challenge presented by an industry sponsor.

During the 2019-20 year, a team of five Cal Poly students developed a new tool to improve citrus harvest operations. This project resulted in a prototype device that may inspire new, commercially available machines. Moreover, this project prepared several young engineers to enter work in the citrus industry.
In fall 2019, the team conducted extensive research into current California citrus harvesting practices by performing site visits and interviewing citrus growers. The team identified several opportunities for improvement and selected one to pursue for the remainder of the academic year – a new machine to (1) convey harvest workers through the field and elevate them to the level of the fruit, replacing ladders and (2) collect the harvested fruit, replacing baskets.

The students performed an extensive literature review, formally defined the problem to be solved, generated solution concepts via ideation exercises, analyzed alternative solutions and ultimately selected the device concept illustrated in Figure 1: a machine with elevated platforms that positions workers at the desired height, rotates to position workers at the desired distance from the tree and chutes that convey the fruit from the workers to collection bins.

By studying the duration of conventional harvesting techniques, the students projected that the new device could reduce harvest labor costs by approximately 28 percent. The device also would reduce physical demands on harvest workers. Students completed a detailed design and fabricated one of the rotating platforms, as shown in Figure 2, demonstrating the ability of the machine to be produced economically. In June 2020, the students delivered an oral presentation, a short film summarizing the project experience, computer aided design (CAD) models, a written report and an Operation, Maintenance and Safety Manual (per course requirements) to a working group of the Citrus Research Board.

Due to restrictions imposed in the spring of 2020 by the COVID-19 pandemic, the performance of the device could not be evaluated in the field before the students graduated, so its immediate impact on citrus harvest practice is unknown. Nonetheless, by completing this work, the students demonstrated their readiness to tackle the unique engineering challenges of California agriculture.

CRB Research Project #5400-160

Trevor Martin, Will Kirk, Connor Morris, Tyler Sarner and John Reggiardo were senior undergraduate students during the 2019-20 school year. Their work was supervised by Lecturer Garrett Forbes, Assistant Professor G.W. Bates, Ph.D., and Assistant Professor Matt Haberland, Ph.D., in the Cal Poly BioResource and Agricultural Engineering Department. For additional information, please contact mhaberla@calpoly.edu
THE REVISED NAVEK CERTIFICATION PROGRAM

Addressing industry concerns and providing new options

James E. Adaskaveg

Project Summary

The Navel and Valencia Exports to Korea (NAVEK) program has successfully forecasted Septoria spot caused by the fungus Septoria citri, provided guidelines for timing of fungicide applications to manage the disease and officially certified grower fruit lots for the U.S. Department of Agriculture-Animal and Plant Health Inspection Service (USDA-APHIS) trade agreement with Korea for 17 years. The NAVEK program was initiated at a time when disease incidence in Central Valley growing areas of California was high. It was designed to reduce disease levels following a management program based on preventive fungicide applications at the beginning of the harvest season and additional treatments following favorable environmental conditions for disease development. The NAVEK program relies on a disease risk model that is based on the accumulation of environmental factors during the growing season. The program has evolved over time, and changes have been made to adapt from mandatory requirements to voluntary guidelines based on Good Agricultural Practices (GAP) that are annually revised and posted on industry websites such as that of the California Citrus Quality Council (CCQC) at https://ccqc.org/programs/korea-septoria. To help growers and packers, the program continues to be updated and provides options for the citrus industry to export fruit to Korea.
The current disease management program is summarized as follows: the first application of a copper-zinc-lime treatment is applied by November 30 to protect fruit prior to winter rainfall, and the second and third applications of a fungicide (e.g., copper, a QoI¹, or DMI²-QoI or SDHI³-QoI pre-mixtures⁴) are based on accumulated hours of temperatures at or below -1°C (30.2°F) and total precipitation after the first application. Cold temperatures may cause fruit surface injuries (i.e., ice marks), and wet conditions allow sporulation, dissemination and spore germination of the pathogen. Additional fungicide applications help to prevent fungal colonization of injuries to fruit if orchards experience these environmental conditions. To minimize the number of statewide applications, disease risk forecasts are developed for each citrus-producing county exporting fruit to Korea and are distributed through industry advisories.

The disease has not been eradicated in California, but has been reduced to low levels in most orange groves. Septoria spot has been managed successfully with no detection in Korea since 2010. Still, the citrus industry is concerned about possible excess fungicide applications. Additionally, with the registration of several new fungicides that prevent sporulation, growers, packers and shippers have inquired about integrating them into the NAVEK program to allow more fruit to be eligible for export. Specifically, for the NAVEK program, the issues are:

1. a forecasted fungicide application based on environmental conditions indicates that all grower lots destined for export to Korea must be treated (regardless of the program submission reports on the positive or negative detection of the pathogen); and samples that tested positive in the NAVEK certification process were ineligible for export to Korea for the remaining season.

Starting in the 2018-19 season, a pilot program with revised NAVEK certification requirements was initiated and continued through the 2020-21 season to address industry concerns. A flow chart of the revised program compared to the original disease forecasting program for applying additional fungicides is shown in **Figure 1**. A fruit sample submitted to NAVEK has two outcomes: it is either negative or positive for Septoria spot.

**Figure 1. The Navel and Valencia Exports to Korea (NAVEK) program showing the original disease-risk forecasting (left side) and the revised certification program (right side) for submitted samples to determine the eligibility of exporting fruit to Korea.**
If a sample is positive for Septoria spot, the original program had called for removal of the lot for export to Korea for the rest of the season. In the revised program, the lot still is eligible for export provided that:

1. an anti-sporulation fungicide (e.g., QoI, DMI-QoI, SDHI-QoI) is used for additional applications based on county disease-risk forecasts; and
2. a second fruit sample is submitted prior to harvest and export.

On the submission form (i.e., displayed as a check box), it must be indicated that the sample is a “resubmission after a previous positive.” NAVEK personnel will examine the sample for sporulation of the pathogen. If the lot is negative for sporulation, it can be prepared for export to Korea; whereas if it is positive, the fruit lot is ineligible for export for the remainder of the season.

For both types of fruit lots (described above) that are exempt from the second application, fruit still should be treated with the anti-sporulation post-harvest fungicides⁵ (e.g., azoxystrobin and fludioxonil) to minimize any possibility of sporulation of S. citri in transit. Fortunately, these fungicides have international export tolerances or maximum residue limits (MRLs) and are approved for export on all citrus fruit, including oranges to Japan starting in the 2021-22 season and other markets.

Positive outcomes of the revised NAVEK program include:

- Increased scouting and orchard evaluations;
- Increased NAVEK participation with more submitted samples as opposed to automatic fungicide applications by growers;
- Does not remove potential orchards from export unless sporulation is observed on second submission to lab;
- Integrated use of copper in citrus disease control;
- Allows the use of non-copper fungicide alternatives;
- Potentially decreased total number of fungicide applications and the associated costs; and
- Integrated pre-harvest and post-harvest decay and sporulation control.

The revised NAVEK program will continue as described herein for the 2021-22 season and will be the standard program henceforth, but will continue to be updated as needed. Proper documentation will be required for each fruit lot submitted to the County Agricultural Commissioner’s office and to USDA-APHIS officials. Documentation includes the negative NAVEK report for samples submitted to the lab after January 1 to be exempt from the second fungicide application, and for re-submission of samples after a positive detection, a negative NAVEK report indicating no sporulation and use reports for anti-sporulation fungicides. The revised NAVEK program allows more options to export fruit while still preventing dissemination of the pathogen to trade partners and maintains the quarantine and trade agreement with Korea.

### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>QoI</td>
<td>A type of fungicide that belongs to the Fungicide Resistance Action Committee (FRAC) Code 11 with a unique mode of action affecting fungal respiration.</td>
</tr>
<tr>
<td>DMI</td>
<td>A type of fungicide with a unique mode of action preventing fungal energy production that belongs to the Fungicide Resistance Action Committee (FRAC) Code 7.</td>
</tr>
<tr>
<td>SDHI</td>
<td>A type of fungicide with a unique mode of action preventing fungal sterol production that belongs to the Fungicide Resistance Action Committee (FRAC) Code 3.</td>
</tr>
<tr>
<td>Pre-mixture</td>
<td>A pesticide product containing two or more pesticides (i.e., fungicide) with different modes of action.</td>
</tr>
<tr>
<td>Anti-sporulation</td>
<td>A property of a fungicide that inhibits the production of spores or propagules of the organism.</td>
</tr>
<tr>
<td>Post-harvest fungicides</td>
<td>Fungicides applied to harvested fruit in a packinghouse to preserve fruit quality and reduce decay during storage, transit and marketing.</td>
</tr>
</tbody>
</table>

### References


James E. Adaskaveg, Ph.D., is a professor of plant pathology at the University of California, Riverside, and director of the NAVEK Certification Program since its inception for the California citrus industry. For more information, contact jim.adaskaveg@ucr.edu
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POST-HARVEST OPTIONS TO CONTROL BREVIPALPUS CALIFORNICUS FLAT MITE

Sandipa Gautam, Elizabeth Grafton-Cardwell and Spencer Walse
Flat mite, *Brevipalpus* spp., is a minor pest of California citrus. Growers occasionally spray sulfur or acaricides to control mite infestations in citrus orchards (Grafton-Cardwell et al. 2017). However, these treatments do not fully eliminate *Brevipalpus* mites, especially those residing under the calyces, allowing mites to be present on citrus at the time of harvest, which is an export issue requiring mitigation measures for growers exporting fruit to Australia and New Zealand.

The current method of disinfestation of *Brevipalpus* mites from citrus fruit arriving in Australia or New Zealand is methyl bromide (MeBr) fumigation. However, Australia and New Zealand are poised to remove this treatment option likely due to global regulatory pressures and treatment logistics. Consequently, an alternative treatment, either in the form of a stand-alone treatment or an approach combining different treatments is needed to mitigate the phytosanitary risks associated with export concern pests such as flat mites and bean thrips. Phosphine fumigation at 260-1,000 parts per million (ppm) for 12 hours at 41°F or greater is an approved treatment schedule to control bean thrips. However, a much longer time interval (4.9 days) is needed to cause more than 99 percent mortality of flat mites (*Table 1*). Therefore, there is a need to find an alternative treatment or combination of treatments that are effective in controlling these mites.

To determine the efficacy of post-harvest treatments, we investigated the effects of exposure to the fumigants; phosphine, methyl bromide and propylene oxide; and the effects of low temperatures on *Brevipalpus* survival. Citrus fruit were infested with mites at the Kearney Research and Extension Center lab and then taken to the U.S. Department of Agriculture-Agricultural Research Service fumigation facility at the San Joaquin Valley Agricultural Sciences Center in Parlier, California, for fumigation (*Figure 1*). Evaluations were made by counting dead and live mites following treatments.

**Table 1. Post-harvest treatments evaluated, lethal doses (LD) to kill 50 (LD$_{50}$) and 99 (LD$_{99}$) percent of *Brevipalpus californicus* mites, numbers treated and treatment registration status in California.**

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>LD$_{50}$</th>
<th>LD$_{99}$</th>
<th>NUMBER OF MITES TREATED</th>
<th>CALIFORNIA REGISTRATION STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-harvest fumigants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphine 1,000 ppm, 41°F</td>
<td>2.3 days</td>
<td>4.9 days</td>
<td>7,726</td>
<td>Registered for post-harvest use in citrus</td>
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<tr>
<td>Methyl bromide two hours, 60°F</td>
<td>17 mg/L*</td>
<td>89 mg/L</td>
<td>2,726</td>
<td>Quarantine and pre-shipment treatments only</td>
</tr>
<tr>
<td>Propylene oxide two hours, 60°F</td>
<td>11.4 mg/L</td>
<td>67 mg/L</td>
<td>2,632</td>
<td>Not registered</td>
</tr>
<tr>
<td>Cold treatment (days)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31°F</td>
<td>5.4 days</td>
<td>9.9 days</td>
<td>5,550</td>
<td>Non-chemical option</td>
</tr>
<tr>
<td>37°F**</td>
<td>10.9 days</td>
<td>22.4 days</td>
<td>1,054</td>
<td>Non-chemical option</td>
</tr>
</tbody>
</table>

*Milligram/Liter (mg/L)  
** Temperature during transit to Australia and New Zealand ranges from 34-42°F. Approximately 99 percent mortality was confirmed over repeated experiments testing 30,000 flat mites.
Among the post-harvest fumigants, phosphine required 4.9 days exposure at 41°F using 1,000 parts per million (ppm), whereas propylene oxide and methyl bromide were effective in killing 99 percent of the mites during a two-hour exposure at 60°F (Table 1). Exposure to a low-temperature equivalent to storage temperature during transit (37°F for 22 days) controlled 99 percent of the flat mites. When the temperature was lowered to 31°F, the time required to control 99 percent of the mites was less than ten days. While mites exposed to low temperatures often looked healthy when observed under the stereoscope, they did not respond to prodding and were counted as dead. We further confirmed approximately 99 percent mortality of mites exposed to three weeks at 37°F in repeated trials with more than 30,000 mites. Our results show that this significant mite mortality, because of exposure to cold temperature storage, already occurs during transit to Australia and New Zealand.

A major outcome in evaluating post-harvest treatments against flat mites was the understanding that they are relatively tolerant to fumigants compared to bean thrips, which also are a major export concern pest for Australia and New Zealand. Phosphine fumigation takes about five days to control flat mites when used alone, whereas propylene oxide is effective with a two-hour exposure. We have demonstrated that flat mites are susceptible to cold and that about a three-week transit time has adverse effects on flat mite survival. This led to the development of a concept to combine post-harvest fumigants and cold treatment for increased efficacy. Combined treatments of 12- or 48- hours of phosphine followed by cold have shown promising results to cause more than 99 percent mortality of flat mites (Figure 2). We will continue to evaluate post-harvest fumigants and combination treatments to provide the industry with a set of treatments for controlling flat mites.

CRB Research Project #5500-501

References

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PRE-HARVEST MANDARIN RIND DISORDER IN CALIFORNIA

Ashraf El-kereamy, Mary Lu Arpaia, Greg Douhan and David Obenland
Project Summary

Every year, the citrus industry loses a significant amount of mandarin fruit either before or shortly after harvesting due to rind disorder. The damage is initiated in the fall, especially following rain. It begins with irregular water-soaked areas that develop into dark-brown necrotic lesions covering large portions of the fruit’s surface (Figure 1). The damage is evident in citrus types such as Satsuma Owari mandarins and other cultivars. Fruit located in the outer part of the canopy suffer more than fruit in the interior canopy. In the 2019-20 season, the susceptibility to this kind of damage differed among varieties with the most susceptible being Kishu (ranked at 4.5 when using a scale from 1-5), followed by Satsuma Owari (3.4) and Gold Nugget (2.9), while Page (1.2), Tango (1) and W. Murcott (1) showed significant tolerance to this disorder. We were able to reduce this damage in Satsuma Owari mandarins by applying 2,4-dichlorophenoxyacetic acid (2,4-D) at 16 milligrams/Liter (mg/L), gibberellic acid (GA) at 20 mg/L or VaporGard® at 0.5 percent (v/v) at the color break stage. However, GA caused a delay in color development by approximately four weeks. The delay in coloration in response to GA treatment differed among varieties. Tango’s response was more significant, Page was less responsive, and Satsuma Owari and W. Murcott each had an intermediate response. Based on post-harvest data, GA treatment at the color break stage reduces the damage of the fruit stored at 35°F for four weeks. In laboratory screening, some new materials showed potential as treatments for field testing. These included salicylic acid (SA), jasmonic acid (JA) and abscisic acid (ABA) inhibitors.

Figure 1. Appearance of the pre-harvest rind disorder of Satsuma Owari mandarin following rain during December 2019. The disorder appears as dark-brown, necrotic lesions on the fruit surface.

Project Goals

The goal was to identify the physiological factors involved in the induction of the rind disorder following rain and provide the industry with an effective treatment to reduce them. We also evaluated the relative susceptibility of several mandarin varieties.
Procedures

To understand the physiological reasons behind the mandarin rind disorder, samples from major mandarin varieties were collected from different orchards. During the 2019 season, we evaluated different varieties including, Satsuma Owari, Page, W. Murcott, Kishu, Gold Nugget and Tango. The orchards were monitored biweekly from color break stage until harvest. The number of fruit that were affected by the rind disorder was recorded through the ripening season. Rind samples from healthy and damaged fruit were collected and frozen immediately using liquid nitrogen to determine the levels of plant-produced hormones and metabolites. The hormone and metabolite analyses were performed at the University of California, Riverside metabolomics core facility. In the laboratory, the rind disorder was induced as described by Adaskaveg et al. (2010), and fruit were evaluated for the incidence of rind lesions. The same procedures were repeated following treatment with different materials, including 2,4-D, gibberellic acid (GA), abscisic acid (ABA), cytokinin (CK), ethephon, the ethylene action inhibitor aminoethoxyvinylglycine (AVG), calcium chloride, VaporGard and salicylic acid (SA). These materials were selected based on their use in previous published reports to mitigate similar rind disorders.

A field trial was designed to test the effectiveness of different materials on reducing the incidence of the damage in several varieties. Treatments included untreated control, 2,4-D at 16 mg/L, GA at 20 mg/L and VaporGard at 0.5 percent (v/v). These treatments were applied at the color break stage, which occurred in 2019 between August-October. At harvest, fruit quality was determined (fruit firmness, peel color, soluble solids content, titratable acidity), and fruit were stored at the University of California (UC) Kearney Agricultural Research and Extension Center F.G. Mitchell Post-harvest Laboratory in Parlier at two different temperatures, 33ºF and 45ºF, for four weeks before being re-evaluated.

Progress Summary

Laboratory induction of rind disorder damage initially appears as a transparent soaked area in the rind. Over time, the damaged areas turn into brown lesions when held under ambient conditions (68ºF; Figure 2).

Monitoring Satsuma Owari trees during the season and following field treatments showed that this kind of disorder happens following rain when fruit are close to harvest, and its percentage is higher in fruit in the outer canopy compared to interior fruit (Figure 3). The percentage of fruit that suffer this damage in the field is approximately 12 percent in Satsuma (cv. Owari), but was undetectable in the other varieties evaluated (Page, W. Murcott and Tango).

Field treatments with VaporGard, GA and 2,4-D reduced this damage significantly. GA at 20 parts per million (ppm) was the most effective treatment; however, a delay in the rind coloration was observed (Figure 4). GA-treated fruit changed their color completely four weeks after the control, and the rind damage was at a very low percentage. Delaying rind
senescence could be a good strategy to reduce the damage in mandarin orchards.

Based on comparative evaluation of relative rind disorder severity, the most susceptible variety was Kishu, followed by Satsuma Owari and Gold Nugget, while Page, Tango and W. Murcott showed significant tolerance to this kind of disorder (Figure 5).

No significant difference was observed between healthy and damaged rinds in ABA content; however, the content was slightly lower in the damaged fruit. There was a significant difference in ABA content among varieties. ABA content was significantly higher in Satsuma Owari, Kishu and Page compared to Gold Nugget, Tango and W. Murcott. ABA may be more correlated with early ripeness rather than rind disorder. Based on hormonal analyses in this study, there was a higher level of jasmonate compounds (variations of the plant hormone jasmonic acid) in the affected area of the fruit. These compounds include the jasmonate precursor 12-oxophytodienoic acid (OPDA), jasmonic acid (JA) and the isoleucine (Ile) conjugate of jasmonic acid (JA-Ile).

Of the compounds examined, it seems that JA content is correlated with the susceptibility of the varieties to the rind disorder (Figure 6). An inhibitor of JA production could be tested for preventing this disorder in mandarins.

Metabolic analysis showed that healthy rind is rich in amino acids compared to damaged rind. Laboratory screening for the efficacy of different materials to control the pre-harvest rind disorder showed that SA and ethephon have the potential to reduce rind disorder significantly in the susceptible varieties. However, this laboratory data needs to be confirmed in the field. In addition, ABA treatment increased the incidence of this disorder under laboratory conditions, so it may be that an ABA inhibitor also could be a potential treatment to test in the field.

Fruit from the four field treatments were washed and prepared by the packing line at Lindcove Research and Extension Center and stored at two different temperatures, 33°F and 45°F, for four weeks at the UC Kearney.
Agricultural Research and Extension Center. Pre-harvest treatments had no significant effect on fruit brix, acidity or total soluble solids/Acid ratio. Data obtained from storing the fruit from the four-color break treatments showed that GA was the most effective in improving fruit storability by reducing fruit rind disorder in all four varieties (Satsuma Owari, Page, Tango and W. Murcott) followed by VaporGard and then 2,4-D when fruit were stored at the two different temperatures.

Conclusions

Pre-harvest mandarin rind disorder happens following rain. The fruit located on the outer canopy are more susceptible than fruit in the interior tree canopy. The cause of this rind disorder was previously thought to be physiological (Adaskaveg et al. 2010). We showed significant differences in hormonal content following rind disorder damage and among varieties. The pre-harvest rind disorder varies among varieties, with the most susceptible being Kishu, followed by Satsuma Owari and Gold Nugget, while Page, Tango and W. Murcott showed significant tolerance. We were able to reduce the damage in Satsuma Owari mandarins to some extent by a pre-harvest color break spray of 2,4-D and VaporGard, while a 20 ppm GA treatment reduced the damage to a very low level. However, GA caused a delay in the color development, which differed among varieties. The delay in coloration in response to GA treatment varies among varieties (Figure 4); Tango’s response was more significant, and Page was less responsive, while Satsuma Owari and W. Murcott were intermediate. Post-harvest GA treatment at color break reduces the damage of the fruit stored at 35°F for four weeks. Laboratory screening of new materials identified some potential treatments including SA, JA and ABA inhibitors for field testing. These are the findings for one season (2019-20).

CRB Research Project #5400-159

References


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GRAY MOLD
FUNGICIDE RESISTANCE IN THE PATHOGEN BOTRYTIS CINEREA AND ITS IMPACT ON CONTROL

Seiya Saito and Chang-Lin Xiao

Project Summary
Gray mold caused by the fungus Botrytis cinerea has recently become a major post-harvest fruit rot disease of California mandarins after extended storage. B. cinerea historically has not been among the target pathogens in post-harvest disease control programs for citrus. To develop post-harvest disease control programs for gray mold, information is needed about whether isolates of B. cinerea from mandarins are resistant to the currently registered post-harvest fungicides that are known to be effective against this fungus such as azoxystrobin, pyrimethanil, fludioxonil and thiabendazole. We found that B. cinerea resistance to azoxystrobin, pyrimethanil and thiabendazole is widespread, but no resistance to fludioxonil was detected. B. cinerea isolates from mandarin demonstrated five different fungicide-resistance phenotypes¹ including the most prevalent one that is triple resistant to azoxystrobin, pyrimethanil and thiabendazole. In efficacy tests, azoxystrobin, pyrimethanil and thiabendazole failed to control gray mold on mandarin fruit inoculated with the respective fungicide resistant isolate. However, fludioxonil remained effective as no fludioxonil resistance was detected in the current populations. Efficacy of natamycin, a newly registered biofungicide, also was evaluated for gray mold control. Natamycin effectively controlled gray mold on mandarin fruit, regardless of B. cinerea fungicide resistance phenotypes. Natamycin appears to be a promising tool for fungicide resistance management and post-harvest disease control programs.

Figure 1. Gray mold on mandarin fruit demonstrating decay symptoms and sporulation.
Introduction

In recent years, storing mandarin fruit to extend the marketing window has become a common practice in the California citrus industry. However, extended storage can increase the risk of fruit rot caused by fungal pathogens. Previously, we conducted a survey in citrus packinghouses to determine the major post-harvest diseases affecting stored mandarins in California and found that gray mold, caused by the fungal pathogen *Botrytis cinerea*, was a major fruit rot disease (Figure 1) (Saito and Xiao 2017).

*B. cinerea* is a widespread fungal pathogen that can infect many economically important crops. *B. cinerea* infection of mandarins occurs near or at harvest and during post-harvest handling, leading to gray mold in storage. Historically, *B. cinerea* has not been a target of post-harvest citrus disease control programs because it only recently has become a post-harvest problem on stored mandarins. The use of post-harvest fungicides has been effective in controlling post-harvest gray mold in other fresh fruit such as apples and pears. However, *B. cinerea* is a high-risk fungal pathogen as it readily develops fungicide resistance, and fungicide resistance in *B. cinerea* populations often can result in the failure of chemical control (Leroux 2004). In the Central Valley of California, citrus groves are often adjacent to table grape vineyards, blueberry fields, stone fruit or pistachio orchards where fungicides are used to control various fungal pathogens including *B. cinerea*. Resistance to multiple fungicides commonly is present in populations of *B. cinerea* in blueberries and table grapes in the region (Saito et al. 2016, 2019).

In California, foliar fungal diseases generally are not major concerns during the citrus fruit growing season. Thus, fungicides are not commonly used in citrus groves. However, the inoculum of fungicide-resistant *B. cinerea* can come from fields of other *Botrytis*-susceptible crops grown in the vicinity of the mandarin groves because *B. cinerea* spores are airborne and can be spread by wind. Post-harvest use of fungicides may not be effective for control of citrus gray mold caused by fungicide-resistant *B. cinerea* strains.

In this study, we examined the fungicide resistance of *B. cinerea* isolates collected from decayed mandarin fruit to four citrus post-harvest fungicides (azoxystrobin, fludioxonil, pyrimethanil and thiabendazole) that are known to be effective against *B. cinerea*. We evaluated the efficacy of these as post-harvest fungicides to control *B. cinerea* exhibiting different fungicide resistant phenotypes.

Natamycin is a newly registered biofungicide for post-harvest use on certain fresh fruit, including citrus. Its mode of action differs from those of other citrus post-harvest fungicides. Natamycin is effective in controlling various citrus post-harvest diseases, such as green mold, blue mold and sour rot (Yigiter et al. 2014). As an additional tool for post-harvest citrus disease control, we tested the efficacy of natamycin to control gray mold on mandarin fruit caused by *B. cinerea* isolates that are resistant to other citrus post-harvest fungicides.

![Figure 2. Efficacy of four post-harvest fungicides for the control of gray mold on mandarin fruit inoculated with five different fungicide-resistant phenotypes of *Botrytis cinerea*. Azo, azoxystrobin; Pym, pyrimethanil; Flu, fludioxonil; Tbz, thiabendazole; *, sensitive; *, resistant.](image-url)
In total, 200 *B. cinerea* isolates were obtained from decayed mandarins and tested for resistance to citrus post-harvest fungicides following the methods described previously (Saito et al. 2018). Resistance to azoxystrobin, pyrimethanil or thiabendazole was common among these *B. cinerea* isolates; however, none were resistant to fludioxonil (Table 1). The most frequently occurring resistance phenotype seen was triple resistance to azoxystrobin, pyrimethanil and thiabendazole (Table 1). Of these 200 *B. cinerea* isolates, five percent, 23.5 percent and 62 percent were resistant to one, two or three fungicides, respectively, indicating that multiple resistance (i.e., resistance to two or more fungicides) is dominant in the *B. cinerea* populations from mandarin fruit grown in the Central Valley (Table 1).

To test whether the fungicides are effective for post-harvest control of gray mold on mandarin fruit, mandarins were inoculated with five *B. cinerea* isolates with different fungicide resistant phenotypes. One hour after inoculation, fruit were treated by dipping them into the fungicide solutions for 30 seconds. Azoxystrobin (573 parts per million [ppm]), pyrimethanil (464 ppm), fludioxonil (255 ppm) or thiabendazole (529 ppm) at the recommended label rates were used for this test, and water was used as a control. Treated fruit were stored at 41°F for two weeks. After storage, disease incidence (percent) was recorded. In these tests, azoxystrobin was not effective against any isolate, and pyrimethanil and thiabendazole failed to control gray mold on mandarin fruit inoculated with *B. cinerea* isolates that are resistant to the respective fungicide. Fludioxonil remained effective as no fludioxonil resistance was detected in *B. cinerea* from mandarins (Figure 2).

Decay control efficacy tests with natamycin were conducted on mandarin fruit inoculated with *B. cinerea* isolates exhibiting five different fungicide-resistant phenotypes. The lowest (460 ppm) and the highest (920 ppm) label rates of natamycin were used in this study, and these are hereafter referred to as “low” and “high,” respectively. Natamycin applied at both low and high rates significantly reduced disease incidence regardless of the *B. cinerea* fungicide resistance pattern, suggesting natamycin is a promising tool for control of gray mold (Figure 3).

### Results

In total, 200 *B. cinerea* isolates were obtained from decayed mandarins and tested for resistance to citrus post-harvest fungicides following the methods described previously (Saito et al. 2018). Resistance to azoxystrobin, pyrimethanil or thiabendazole was common among these *B. cinerea* isolates; however, none were resistant to fludioxonil (Table 1). The most frequently occurring resistance phenotype seen was triple resistance to azoxystrobin, pyrimethanil and thiabendazole (Table 1). Of these 200 *B. cinerea* isolates, five percent, 23.5 percent and 62 percent were resistant to one, two or three fungicides, respectively, indicating that multiple resistance (i.e., resistance to two or more fungicides) is dominant in the *B. cinerea* populations from mandarin fruit grown in the Central Valley (Table 1).

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### Table 1. Frequency of five fungicide-resistant phenotypes in 200 *Botrytis cinerea* isolates collected from decayed mandarin fruit in 2015 and 2016.

<table>
<thead>
<tr>
<th>PHENOTYPES</th>
<th>FREQUENCY (%)</th>
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<td>2015</td>
<td>2016</td>
<td>AVERAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azo⁰Pym⁰Flu⁰Tbz⁰</td>
<td>17</td>
<td>2</td>
<td>9.5</td>
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<tr>
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<td>8</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Azo⁰Pym⁰Flu⁰Tbz⁰</td>
<td>12</td>
<td>28</td>
<td>20</td>
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<tr>
<td>Azo⁰Pym⁰Flu⁰Tbz⁰</td>
<td>4</td>
<td>3</td>
<td>3.5</td>
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<td></td>
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<tr>
<td>Azo⁰Pym⁰Flu⁰Tbz⁰</td>
<td>59</td>
<td>65</td>
<td>62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Azo: azoxystrobin; Pym: pyrimethanil; Flu: fludioxonil; Tbz: thiabendazole; ⁰: sensitive; ⁰: resistant.

### Figure 3. Efficacy of natamycin at two label rates for the control of gray mold incidence on mandarin fruit inoculated with five different fungicide resistant phenotypes of *Botrytis cinerea*. Azo, azoxystrobin; Pym, pyrimethanil; Flu, fludioxonil; Tbz, thiabendazole; ⁰, sensitive; ⁰, resistant; low, low rate of natamycin (460 ppm); high, high rate of natamycin (920 ppm).

### Figure 4. Effect of time between inoculation and treatment on gray mold incidence. Two label rates of natamycin (low and high recommended rates) were used for mandarin fruit inoculated with an isolate of *Botrytis cinerea*. Fruit were treated one, six, 12 or 24 hours after inoculation. Low, low rate of natamycin (460 ppm); high, high rate of natamycin (920 ppm); water was used as control.
We also evaluated whether a delay of natamycin treatment post inoculation compromises its efficacy in controlling gray mold. A B. cinerea isolate that is sensitive to all fungicides was used for this test. Fruit were treated with natamycin one, six, 12 or 24 hours after inoculation. Both low and high rates of natamycin significantly reduced disease incidence at all post-inoculation treatment times; however, the later the fruit were treated, the less effective natamycin controlled gray mold (Figure 4).

In summary, resistance to multiple, commonly used fungicides for gray mold control was dominant in the B. cinerea populations collected from mandarin fruit, and this fungicide resistance resulted in the failure of several fungicides in managing gray mold except fludioxonil, which remained effective. The new biofungicide natamycin appears to be a promising tool for fungicide resistance management and post-harvest disease control programs. To maximize the efficacy of natamycin, fruit should be treated soon after harvest.

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Acknowledgements
We thank F. Wang and K. Fjeld for technical assistance and the personnel of the citrus packinghouses for providing us with mandarin fruit.

Glossary

¹Phenotype: Observable features of an organism.

References


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Eradication of trees with citrus tristeza virus (CTV) that react with MCA13 continues in three of five pest control districts in central California, despite prevalent use of CTV-tolerant or -resistant rootstocks in California’s citrus industry. This study was conducted to examine the genetic diversity, virulence and spread of local MCA13-reactive CTV strains. MCA13 reacted to four genotypes (T36, RB, S1 and VT) of CTV collected from central California. These strains were graft inoculated to six commercial cultivars on Carrizo rootstock and grown for four years in a screenhouse and examined for virulence. Based on metabolic changes and smaller trunk diameters, VT strains were considered more virulent, whereas non-VT strains were asymptomatic and considered mild. Virus titer of VT strains remained consistently high, while titer of non-VT strains fluctuated seasonally and, in many cases, became non-detectable during hot summer weather. The annual spread of CTV was 0.9 percent in orchards with mandatory aphid vector control and eradication of trees infected with MCA13-reactive strains, whereas the spread rate was 1.4 percent in non-eradication plots in the Navel and Valencia Export to Korea (NAVEK) program. This small 0.5 percent difference of spread rate suggested that pest control in the NAVEK program may be slowing CTV spread by reducing aphid vector populations. Spatial and temporal spread of MCA13 CTV in non-eradication plots showed spread was not occurring from outside of the orchard, but from MCA13-positive trees within the field. These studies highlight the differences between mild and severe strains that react to MCA13 and eradication efforts that are limiting MCA13 CTV spread to adjacent non-eradication orchards.
Introduction
CTV is a regulated pathogen in California (CDFA 2011). The California Citrus Tristeza Eradication Agency surveys citrus in the Central Valley, Southern Tulare and Kern County Citrus Pest Control Districts and eradicates trees infected with MCA13-reactive CTV strains. In contrast, no CTV surveys or eradication are conducted in the West Fresno County Red Scale Protective District or Tulare County Pest Control Districts (Barnier et al. 2010). Although certain CTV strains cause Quick Decline of citrus grown on sour orange rootstock (Figure 1) which results in rapid tree death, Quick Decline is controlled by growing citrus on CTV-tolerant or -resistant rootstock. However, there are severe strains of CTV that induce stem pitting along with chlorotic and stunted flush growth (seedling yellows), regardless of rootstock (Garnsey et al. 2005).

This study was conducted to examine the genetic diversity, virulence and spread of local MCA13-reactive CTV strains relative to the current impact of CTV on local citrus production. The specific objectives were:

1. determine the genomic sequences of local CTV isolates and compare with several CTV strains from Peru where severe sweet orange stem pitting CTV is common and mild strain cross-protection⁵ is used to maintain citrus production;
2. evaluate the severity of California CTV genotypes in commercial citrus cultivars on Carrizo rootstock in a screenhouse to simulate field conditions; and contrast CTV spread patterns over time and distance in orchards with eradicative and non-eradicative activities with focus on MCA13-reactive CTV.

Comparative Whole Genome Sequences

Whole genome sequences of four California MCA13-reactive CTV strains were determined and results indicated they comprise a diverse group of strains representing four distinct genotypes: T36, RB, S1 and VT (Chen et al. 2018; Yokomi et al. 2016, 2018). Sequences of RB genotypes (Selvaraj et al. 2016) found in California were similar to a Peruvian RB cross-protective strain suggesting a potential to cross-protect against exotic stem pitting CTV like those in Peru.

Screenhouse Evaluation of CTV Genotypes
Virulence of the four genotype strains that reacted to MCA13 was examined in a screenhouse along with a virulent (SY568⁶), mild (T30), and healthy control in a quarantine screenhouse in commercial citrus cultivars on Carrizo rootstock to simulate field conditions. After four years, some differences
were seen in metabolites and sugars among citrus cultivars infected with VT genotypes. Trunk diameters of citrus infected with VT genotypes were smaller, indicating growth reduction, but statistical differences were found only in Lisbon Lemon (Figure 2). Virus titer of VT genotypes was significantly higher than the other genotypes (P < 0.05) (Figure 3) in all cultivars tested. In comparison, MCA13-reactive, non-VT strains had significantly less titer and were at the same level as the MCA13-negative T30 control. Seasonal seedling yellows-like symptoms were observed in trees infected with VT genotypes in spring, and some stem pitting was detected in Valencia, Navel and Minneola. High diurnal summer temperatures greater than 110°F were common in the screenhouse, which had no fans for air circulation. These high temperatures resulted in reduction of the virus titer to marginal or non-detectable levels by reverse transcription (RT)-qPCR except for VT strains which maintained detectable titer levels. Consequently, some plants were reinoculated to ensure CTV infection for the duration of the experiment. Oroblanco was included in this study because it is sensitive to stem pitting by virulent strains like SY568 (Figure 4A) in the greenhouse. However, stem pitting was completely absent in Oroblanco (Figure 4B) infected by SY568 in the screenhouse. This is notable since it suggests attenuation of symptoms can

Table 1. Comparison of citrus tristeza virus (CTV) incidence in plots in the Lindcove Research and Extension Center (LREC) CTV protective zone versus non-eradication plots.

<table>
<thead>
<tr>
<th>Number of orchards</th>
<th>CTV incidence in protective zone</th>
<th>CTV incidence in non-eradication plots&lt;sup&gt;z&lt;/sup&gt;</th>
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<tbody>
<tr>
<td></td>
<td>2007</td>
<td>2020</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
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<tr>
<td>5</td>
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</tr>
<tr>
<td>5</td>
<td>&gt; 10</td>
<td>28.3</td>
</tr>
<tr>
<td>Avg.</td>
<td>0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

<sup>z</sup> Plots outside of the LREC Protective Zone, but in the Navel and Valencia Export to Korea (NAVEK) program.
occur under field conditions like hot summer temperatures. SY568, which was eradicated in the 1970s, was used as a reference strain under permit to show severe symptoms in this study. No severe stem pitting was observed in Oroblanco or other cultivars in the screenhouse.

Cultivars in the screenhouse experiment differed in relative CTV titer for the duration of the study as measured by RT-qPCR (P < 0.05). To compare varietal susceptibility to CTV, virus titer amongst strains were combined by cultivar. Valencia and Navel supported the highest level of virus replication (Cycle threshold⁷ [Ct] 21.3 to 22.0); followed by Minneola and Lisbon Lemon (Ct 24.0 to 24.8); W. Murcott (Ct 26.6) and Oroblanco (Ct 27.6). Currently, fruit harvest and quality measurements have begun; however, preliminary data does not show any significant differences between CTV genotypes to date.

Tree Removal and Aphid Control Impact

Evaluation of CTV spread was conducted in the one-mile CTV protective zone surrounding the Lindcove Research and Extension Center (LREC) (Yokomi et al. 2020) where CTV incidence was estimated by a statistical sampling method (Hughes and Gottwald 2000). Trees infected with MCA13-reactive CTV were removed, but MCA13-negative CTV trees were left in place. Citrus in the protective zone also was sprayed biannually for aphid control. Orchards in this eradication zone were partitioned into four categories of CTV incidence (zero, less than five percent, five to ten percent and greater than ten percent) in 2007, and CTV incidence was compared between these groups in 2020 (Table 1). CTV incidence per year increased from 0.9 percent in 2007 to 1.4 percent in 2020. No exponential increase was observed in spread, regardless of initial incidence in 2007, suggesting that aphid control was limiting CTV spread. CTV testing was performed on all trees in non-eradication plots to determine the number and proximity of trees infected with MCA13-reactive CTV. Results showed that spread was occurring from source trees within the orchard rather than from trees outside the orchard. This supports the notion that eradication in the protective zone around the LREC was limiting MCA13-CTV spread to adjacent non-eradication orchards. MCA13-reactive strains from the field plots were examined by strain discriminating primers and probes by RT-qPCR and were found to be VT or mixtures of VT and T30 strains. However, these trees were asymptomatic and appeared to have normal production yields (Yokomi et al. 2020).

Conclusions

Biological and epidemiological studies on CTV were conducted in this study. Sequencing showed MCA13-reactive CTV strains in California included genotypes T36, RB, S1 and VT. Virus titer of VT genotypes in the screenhouse tests was generally about 100 times greater than those of non-VT genotypes and was more tolerant to high summer temperatures. Severe stem pitting observed in a greenhouse in Oroblanco infected by SY568 was not observed in the screenhouse, presumably attenuated by high temperature. Preliminary fruit yields between strains showed no differences, but plans are in place to collect more fruit data next year. The field study showed that spread of MCA13-reactive CTV strains to adjacent orchards was virtually eliminated by roguing of MCA13-infected trees and aphid control in the one-mile protective zone around the LREC. In addition, NAVEK-related pest control practices in non-eradication plots also reduced CTV spread.

References


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Since the nineteenth century, the cultivation of citrus fruit in California has motivated the development of related industries. From fumigators to mechanical packing supplies, citrus growers in the Golden State have experimented with a variety of industrial technologies to effectively plant, grow, pick, pack and ship oranges and lemons.

Among the most important activities linked to early citrus production was industrial icing. This was a major challenge in the nineteenth and early twentieth centuries, when orange and lemon growers had to rely on railroads to ship their fruit. Depending on the destination, it could take up to a week to bring the goods to markets across the country.

Keeping fruit cool in railroad cars as they rolled east required inventive thinking. Early citrus growers used primitive methods to preserve their crops in transit. In 1877, when grower Joseph Wolfskill shipped the first carload of oranges via the Southern Pacific Railroad, his fruit had to be cooled 11 times during the journey.

Within a decade, the railroads that served the orange groves and packinghouses of California had improved their icing efforts. The Santa Fe and Southern Pacific railroads developed ventilated and refrigerated cars to keep cool air circulating and better preserve ice in transit. Large chunks of ice were loaded into refrigerator cars to maintain a cool temperature for oranges and lemons.

These historical images from the Citrus Roots Collection at the University of La Verne offer a glimpse into icing in the orange empire. The large structure pictured here is an icing plant in Colton, California. That city also was home to an enormous railyard used by the Southern Pacific Company, one of the most important transportation networks in California. Without critical services such as icing offered by the railroads, the citrus industry would not have developed into one of the most profitable economic sectors in the Golden State by the turn of the twentieth century.

For more information, contact bjenkins@laverne.edu

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ENHANCED BLOOM SET, LESS FRUIT DROP AND MORE RESPONSIVE EARLY FRUIT DEVELOPMENT: Phosphorus is a key element to cell division, the meiosis and mitosis functions necessary for both bud initiation and development, as well as flower fertilization and post fertilization early fruit growth. Phosphorus is also a determinate factor in peduncle strength and the reduction in fruit drop. Additionally phosphorus results in early fruit development and sizing. Adequate tissue phosphorus levels are often misdiagnosed due to older research using low solubility soil applied phosphorus. Our recommendation is that leaf tissues for high quality producing citrus groves in California should have a value of 0.20-0.22 % Phosphorus. To get to those ranges apply 2-4 gallons of RENEW per acre pre-bloom and 2-4 gallons of RENEW 6 weeks later. RENEW’s solubility advantage allows nutrients to be absorbed through the stomata as well hydrophilic channels in the leaf surface, movement other products can’t come close to equaling. Research has scientifically measured leaf analysis increase of P in trees at the 35 - 50 % range, far superior to low solubility monopotassium phosphate materials.

RENEW is a clear, pH balanced nutritional containing low biuret urea to foster enhanced leaf absorption. RENEW contains no sodium or chlorides for safe compatible applications without rind stain. RENEW can be tank mixed with most pesticides, including fungicidal copper (maintain pH >6.2).

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<th>(Solubility Determines Availability)</th>
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<td>Potassium Chloride</td>
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<td>Ammonium Phosphate</td>
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</tbody>
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