CITRUS RESEARCH BOARD

Citrograph

MAGAZINE

SUMMER 2023

NEW CITRUS VARIETIES

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On the Cover: *Welcome to the summer 2023 issue of* Citrograph, *which features some of the Citrus Research Board-funded studies being conducted on new citrus varieties. The cover photo is from one of these studies and shows a Shiranui fruit quality evaluation that was conducted in the Givaudan Citrus Variety Collection fruit quality laboratory. The Shiranui and Tieu mandarins are two of the varieties catalogued on the Citrus Clonal Protection Program's "Early Release" list. Read more about this important research project on page 60, "New Mandarin Cultivars Have Potential to Diversify Market" by Toni Siebert Wooldridge, Karene Trunelle, Toan Khuong and Tracy Kahn, Ph.D.* Photo courtesy of Toni Siebert Wooldridge and Karene Trunnelle.

In This Issue

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

Editor's Note: In the *'Evaluations of Antimicrobial Peptides for HLB Control'* article in the winter 2023 issue of *Citrograph*, one of the author's affiliations was listed incorrectly. Marco Gebiola is with the Department of Entomology at the University of California, Riverside.

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 2022-2023 (Terms Expire September 30)

DISTRICT 1 – NORTHERN CALIFORNIA

MEMBER	EXPIRES
Henk Griffin	2023
Megan Morreale	2023
Jason Orlopp	2023
Joe Stewart	2023
Ram Uckoo	2023
Justin Brown, Chairman	2024
Scott Carlisle	2024
Greg Galloway	2024
Justin Huffmon	2024
John Konda	2024
Etienne Rabe	2024
Andrew Brown	2025
Justin Golding	2025
Zac Green	2025
Jason Reynolds	2025

DISTRICT 2 – SOUTHERN CALIFORNIA – COASTAL

MEMBER	EXPIRES
Chris Boisseranc	2023
John Gless III, Secretary/Treasurer	2023
Gabriel Olmos	2024

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MEMBER	EXPIRES
Craig Armstrong	2023
Mark McBroom, Vice Chairman	2025

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MEMBER	EXPIRES
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2023

CALENDAR OF EVENTS

JUNE 6, 13, 20 AND 27
2023 CITRUS RESEARCH BOARD WEBINAR SERIES
Series dates, see page 22.

AUGUST 8
CITRUS RESEARCH BOARD (CRB) MEETING
For more information, contact the CRB at (559) 738-0246 or visit *www.citrusresearch.org*

AUGUST 9
CITRUS PEST AND DISEASE PREVENTION COMMITTEE (CPDPC) MEETING
For more information, visit *www.cdfa.ca.gov/citruscommittee*

SEPTEMBER 6
POST-HARVEST CONFERENCE
For more information, contact the CRB at (559) 738-0246 or visit *www.citrusresearch.org*

SEPTEMBER 19
CITRUS RESEARCH BOARD (CRB) ANNUAL MEETING
For more information, contact the CRB at (559) 738-0246 or visit *www.citrusresearch.org*

NOVEMBER 8
CITRUS PEST AND DISEASE PREVENTION COMMITTEE (CPDPC) MEETING
For more information, visit *www.cdfa.ca.gov/citruscommittee*

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From the PRESIDENT'S DESK

Marcy L. Martin

Marcy L. Martin

Welcome to the summer edition of *Citrograph*, which focuses on new variety development. The Citrus Research Board (CRB) remains steadfast in our commitment to promoting research that advances the California citrus industry. I would like to recognize critical work being done within the CRB, as well as ongoing new varieties research being completed by our university partners.

The Asian Citrus Psyllid (ACP) Biological Control Team has been recognized by the Entomology Society of America for the Pacific Branch Entomology Team Work Award. This award recognizes a collaborative team of entomologists for their successful efforts to achieve outstanding accomplishments in research and education. The ACP Biological Control Team is led by Raju Pandey, Ph.D., at the CRB in collaboration with the University of California, Riverside (UCR), the U.S. Department of Agriculture and the California Department of Food and Agriculture. A significant part of the ACP Biological Control

Team is classical and augmentative biological control of ACP in urban areas to reduce *'Candidatus* Liberibacter asiaticus' (CLas) pressure on neighboring commercial citrus production areas. Two major outcomes from their work have been a documented decrease of more than 70 percent in ACP densities in urban areas since the inception of the classical biological control program, as well as the development of innovative and highly effective control and monitoring technologies for the Argentine ant. We congratulate the team on their achievement and look forward to seeing future accomplishments with ACP control.

In this issue of *Citrograph*, the CRB's Integrated Citrus Breeding and Evaluation Core Program shares several updates on research projects currently underway. Led by Co-Principal Investigators Tracy Kahn, Ph.D., Mikeal Roose, Ph.D., and Danelle Seymour, Ph.D., of UCR, the research performed under this program is multi-faceted and designed to address the needs of the California citrus industry in providing access to new and improved varieties for meeting market demands, improving production and, to a degree, identifying disease tolerance/resistance. On page 60, Dr. Kahn provides an overview of two mandarin varieties currently under "early release" from the Citrus Clonal Protection Program. On page 54, Dr. Roose shares the results of the effects of various rootstocks on yield and fruit quality of 'Nules' clementines. Finally, on page 48, Dr. Seymour presents how genetic information can be incorporated into the existing framework of the program to assist in selecting varieties with desirable traits.

The CRB strives to provide a range of grower education throughout the year. This summer, we are pleased to host our informative webinar series, as well as welcome the return of our Post-harvest Pest Control Conference. The Citrus Growers' Educational Webinar Series will highlight four citrus researchers covering a range of topics each Tuesday in June. Additional information can be found on page 22. On September 6, we are thrilled to host the 41st Post-harvest Pest Control Conference at the Visalia Convention Center. This conference will provide the latest information for post-harvest and packinghouse professionals, and further information can be found on page 24. We look forward to seeing you at these events.

As a grower-funded organization, one of our most important mandates is to be diligent stewards of our budget and provide transparency on the use of funds. We invite you to review the CRB's annual financial report on page 12, which includes a comprehensive overview of the previous year's expenses, as well as a summary of FY2021/22 research projects. We would like to highlight that the grower assessment rate continues to sit at a historically low rate. In addition, an overview of CRB-funded research projects for FY2022/23 on page 16 provides a look at new and continuing projects in each research area.

In partnership with our industry stakeholders and research colleagues, we continue to move ahead in the development of new varieties as we adapt to the future of the citrus industry. We look forward to seeing you at one of our educational events this summer, and we hope you enjoy this issue of *Citrograph*.

***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**

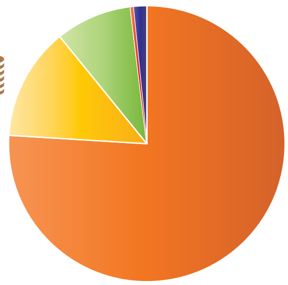
BY THE NUMBERS: **FINANCIAL REPORT**

FINANCIAL POSITION

2019/20

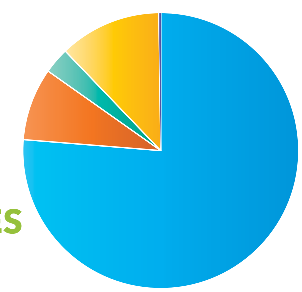
ASSETS $13,878,336
LIABILITIES $2,234,489
NET ASSETS $11,643,847

ASSESSMENT RATE: $0.048



2020 INCOME
$12,967,269

- **76 %** **ASSESSMENT INCOME:** $10,246,146
- **13.2 %** **CPDPP GRANT INCOME:** $1,664,233
- **8.9 %** **FEDERAL GRANT INCOME:** $853,960
- **0.3 %** **INVESTMENT INCOME:** $53,836
- **1.6 %** **OTHER INCOME:** $149,094



2020 EXPENSES
$11,137,939

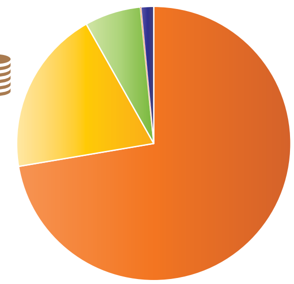
- **76.3 %** **RESEARCH EXPENSES:** $8,078,766
- **8.5 %** **OPERATIONS EXPENSES:** $1,083,693
- **3 %** **COMMUNICATIONS EXPENSES:** $306,691
- **12 %** **ADMINISTRATIVE EXPENSES:** $1,667,223
- **0.2 %** **OTHER EXPENSES:** $1,566

2020 **INCREASE (DECREASE) IN NET ASSETS**
$1,829,330 ⬆

2020/21

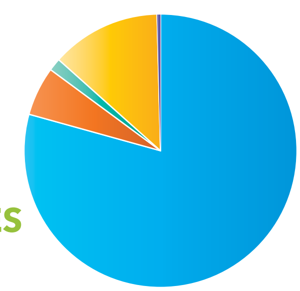
ASSETS $10,869,050
LIABILITIES $791,005
NET ASSETS $10,078,046

ASSESSMENT RATE: $0.030



2021 INCOME
$8,304,895

- **72 %** **ASSESSMENT INCOME:** $5,966,371
- **19.4 %** **CPDPP GRANT INCOME:** $1,613,602
- **6.6 %** **FEDERAL GRANT INCOME:** $551,712
- **0.5 %** **INVESTMENT INCOME:** $43,996
- **1.5 %** **OTHER INCOME:** $129,214



2021 EXPENSES
$9,864,849

- **79.3 %** **RESEARCH EXPENSES:** $7,818,818
- **5.8 %** **OPERATIONS EXPENSES:** $574,153
- **1.5 %** **COMMUNICATIONS EXPENSES:** $145,739
- **13 %** **ADMINISTRATIVE EXPENSES:** $1,284,744
- **0.4 %** **OTHER EXPENSES:** $41,395

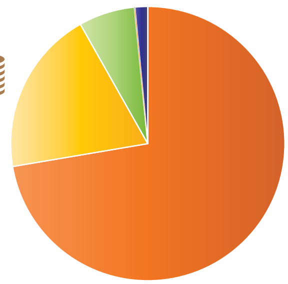
2021 **INCREASE (DECREASE) IN NET ASSETS**
$1,559,955 ⬇

These data represent the financial statement of the Citrus Research Board for the years ended September 30, 2020, 2021 and 2022. You are welcome to visit us at any time to discuss any elements of the program and explore our portfolio of work. This program is paid through your grower assessment dollars, and the board welcomes your feedback.
-Marcy L. Martin, CRB President

2021/22

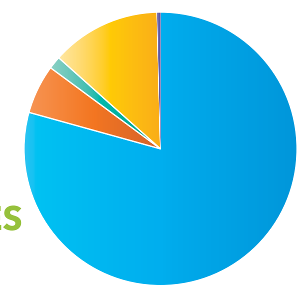
ASSETS $9,807,132
LIABILITIES $1,085,887
NET ASSETS $8,721,245

ASSESSMENT RATE: $0.032



2022 INCOME
$7,762,854

- **65.2%** **ASSESSMENT INCOME:** $5,059,644
- **20.9%** **CPDPP GRANT INCOME:** $1,620,272
- **11%** **FEDERAL GRANT INCOME:** $852,967
- **0.5 %** **INVESTMENT INCOME:** $38,865
- **2.4%** **OTHER INCOME:** $191,104



2022 EXPENSES
$8,727,657

- **74.6%** **RESEARCH EXPENSES:** $6,506,660
- **7.4%** **OPERATIONS EXPENSES:** $650,683
- **3.4%** **COMMUNICATIONS EXPENSES:** $293,859
- **13.3%** **ADMINISTRATIVE EXPENSES:** $1,156,726
- **1.3%** **OTHER EXPENSES:** $117,075

2022 **INCREASE (DECREASE) IN NET ASSETS**
$964,803

FY 2021/22
RESEARCH PROJECTS FUNDED
25

FY 2021/22
RESEARCH INVESTMENT
$5.6 MILLION

FY 2021/22
RESEARCH INSTITUTIONS FUNDED
12

CITRUS RESEARCH BOARD NOMINATION MEETINGS

PLEASE NOTE: Information about how the 2023 CRB Board nominations and elections will be conducted will be sent to you via U.S. mail. You also may check the CRB website at* citrusresearch.org *for updates. We appreciate your understanding.

California citrus producers in District 1 (Northern California), District 2 (Southern California Coastal) and District 3 (California Desert) should make plans to attend the appropriate Citrus Research Board (CRB) nomination meetings. Four positions in District 1 and one position in District 3 expire on September 30, 2023. The public nomination meetings will be conducted by officials of the California Department of Food and Agriculture (CDFA) and the CRB.

In addition to the elected positions mentioned above, the Board will have the opportunity to consider the extended appointment of the public member at its annual meeting on September 19, 2023.

The detailed list of seats expiring this September may be found on page 6, where the current Board member roster appears by name, district and year of term expiration. Member terms are for three years.

Board Member Responsibilities

The bulk of the Board's time is spent considering a broad portfolio of citrus research proposals and projects estimated at $10 million. Members are involved in:

- developing research priorities and requests for proposals,
- prioritizing responses and awarding funds,
- devising successful implementation strategies,
- assessing progress and
- providing critiques of project results.

The 21-member CRB is served by 13 staff with headquarters in Visalia and two laboratories in Riverside. There is a relatively high time commitment compared to many other volunteer commodity boards, but those involved with the CRB are integral in directing the response to critical citrus research needs in California. Members are expected to attend Board meetings and to serve on research and/or administrative committees. A typical fiscal year has five Board meetings in various geographic locations, occasional committee meetings and the opportunity to attend a number of citrus-related conferences and events.

Voter Qualifications

(as provided by the CDFA Marketing Branch)

- Any owner, officer or employee of an entity in California in the business of producing, or causing to be produced for market, 750 or more standard field boxes (or the equivalent) of any variety of citrus (except limes) is qualified to participate in the nomination proceedings.
- If you wish to nominate a person at a nomination meeting to serve on the Board, you should determine the candidate's eligibility and willingness to serve prior to the nomination meeting.
- An individual person is entitled to represent only one legal entity at a nomination meeting.
- In the case of a partnership, only one of the partners may vote.
- In the case of a corporation, a person affiliated with the corporation, preferably an officer, may represent the corporation.
- A married couple operating a production entity is entitled to just one vote, unless each spouse owns and operates separate and distinct entities.
- To participate in a district's nomination meeting, a business entity must have citrus production within that district. Any entity with production in more than one district must choose a single district in which to participate to vote. If a separate production entity can be proven as the operating entity in another district, the person qualified to act as the representative of that entity may vote in that district, even if he/she has voted as a representative of another entity in another district. Essentially, each separate citrus-producing business entity is entitled to one vote in the district in which it operates.
- Voting by proxy is not permitted.

For more information, the California Citrus Research Program Marketing Order may be viewed on-line at: *http://www.cdfa.ca.gov/mkt/mkt/pdf/Laws/CitrusResearchMarketingOrder.pdf.* Questions may be directed to CDFA Marketing Branch Economist Steven Donaldson at (916) 900-5018 or CRB President Marcy L. Martin at (559) 738-0246.

***Caitlin Stanton is the director of communications for the Citrus Research Board and also serves as the editorial assistant on* Citrograph. *For more information, please contact* caitlin@citrusresearch.org**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CRB-FUNDED RESEARCH PROJECTS FOR FY22-23

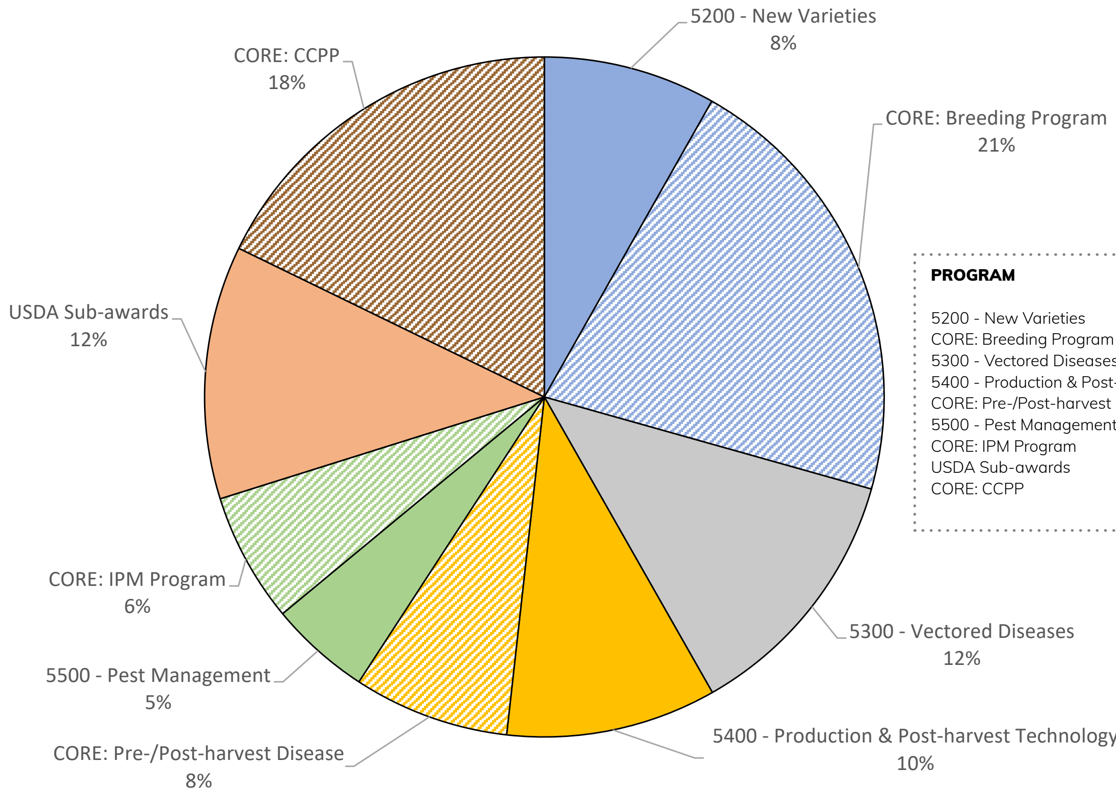
Joey S. Mayorquin and Melinda Klein

On September 20, 2022, the Citrus Research Board (CRB) approved the funding of all new and continuing research projects for the 2022-2023 fiscal year at their annual meeting. This year, five new projects, nine continuing projects, four core programs and one United States Department of Agriculture (USDA) sub-award were approved for funding by the Board for a total of $4,073,887 (**Tables 1** and **2**).

Huanglongbing (HLB)-related projects are one focus of the CRB research portfolio, with projects underway to create and evaluate improved citrus varieties and projects furthering potential disease control efforts. Work exploring and refining potential tools for effective bacterial and vector management to manage both the HLB-associated bacterium *'Candidatus* Liberibacter asiaticus' (CLas) and the Asian citrus psyllid (ACP) - the vectoring pest – continue, as well.

Research efforts outside of the HLB-related projects approved this year were selected to address the broad range of needs across the California citrus industry including current production issues in water use, sustainability, pest management, disease management and export market access.

Table 1: Listing of CRB-funded research projects for the 2022-23 fiscal year by category



PROGRAM	APPROVED BUDGET
5200 - New Varieties	$334,193
CORE: Breeding Program	$862,117
5300 - Vectored Diseases	$505,175
5400 - Production & Post-harvest Technology	$407,669
CORE: Pre-/Post-harvest Disease	$302,190
5500 - Pest Management	$195,886
CORE: IPM Program	$251,012
USDA Sub-awards	$490,645
CORE: CCPP	$725,000
TOTAL	**$4,073,887**

CRB-funded research projects are overseen by one of four CRB Research Committees – New Varieties, Vectored Diseases, Production and Post-harvest Technology, and Pest Management. The Citrus Clonal Protection Program (CCPP), a core program, is overseen by its own CRB committee.

New Varieties Research (5200) Committee

Research projects within this committee focus on improving the development and evaluation steps needed for the creation of new varieties, as well as the production of new citrus varieties to meet market demands. Three continuing research projects, including the Integrated Citrus Breeding and Evaluation core program, and two new projects received support this year with a budget of $1,196,310 (**Tables 1** and **2**). Continuing projects include Florida field evaluations of rootstocks for HLB mitigation, development and evaluation of HLB-tolerant and -resistant citrus hybrids by conventional breeding methods and the creation of new citrus varieties via genetic engineering for HLB resistance and tolerance. The two new projects approved this year will focus on evaluating gene-edited Carrizo rootstock lines for HLB resistance and testing a protocol to improve the genetic transformation rates of commercial citrus varieties. Activities within the Integrated Citrus Breeding and Evaluation core program, led by Tracy Kahn, Ph.D., and Mikeal Roose, Ph.D., at the University of California, Riverside (UCR), continue to focus on the development and evaluation of new scion and rootstock cultivars for the California citrus industry.

Vectored Diseases Research (5300) Committee

Research projects within this committee focus on detection, eradication, control and management strategies and tools for insect-vectored pathogens to minimize crop damage and economic losses. Four continuing projects are receiving support this year in the amount of $505,175 (**Tables 1** and **2**). The first project is testing high-throughput sequencing protocols for official approval and implementation to speed up and reduce the costs of citrus pathogen detection in regulatory laboratories. The second project is evaluating the potential of a citrus virus modified to introduce therapies for HLB and other pathogens into commercial citrus cultivars.

With the support of the Citrus Pest and Disease Prevention Program (CPDPP), the CRB continues to oversee the remaining two projects: a risk-based model used to identify likely areas of HLB infection for ongoing state-wide surveys

Table 2: Listing of all CRB-funded research projects for the 2022-23 fiscal year

Project Number	Project Title	Principal Investigator	Affiliation	Approved Budget
5200 - New Varieties				
Continuing Projects				
5200-169	Field testing to identify elite rootstocks that can mitigate or prevent HLB in scions commercially I	Jude Grosser	University of Florida	$36,080
5200-173	Breeding for generating HLB-resistant citrus, and field evaluation of selected HLB-tolerant hybrids	Chandrika Ramadugu	UC Riverside	$135,000
5200-201	CORE: Integrated citrus breeding and evaluation for California	Tracy Kahn and Mikeal Roose	UC Riverside	$862,117
New Projects				
5200-177	Evaluating novel gene-edited Carrizo mutants for resistance to huanglongbing (HLB) and protection of citrus scion cultivars	Zhanao Deng	University of Florida	$64,221
5200-178	Development of an *in planta* approach to improve citrus transformation	Vivian Irish	Yale University	$98,892
5300 - Vectored Diseases				
Continuing Projects				
5300-199[a]	Risk-based survey for decision making in the management of huanglongbing: Phase II	Weiqi Luo	North Carolina State University	$242,283
5300-205	Phase 2 of high-throughput sequencing as a CCPP routine diagnostic tool for variety introduction	Georgios Vidalakis	UC Riverside	$83,894
5300-212[a]	Predicting the likelihood of ACP/HLB dispersal into California commercial citrus groves via scenario	Weiqi Luo	North Carolina State University	$99,998
5300-214	Field evaluation of a novel virus-like RNA as an expression vector for HLB and Tristeza management	Georgios Vidalakis	UC Riverside	$79,000

Table 2: Listing of all CRB-funded research projects for the 2022-23 fiscal year

Project Number	Project Title	Principal Investigator	Affiliation	Approved Budget
5400 - Production & Post-harvest Technologies				
Continuing Projects				
5100-154	Citrus dwarfing of commercial varieties using TsnRNAs	Georgios Vidalakis	UC Riverside	$80,650
5400-168	Identification of a surrogate for use in citrus specific validation studies	Amanda Lathrop	California Polytechnic State University San Luis Obispo	$85,270
5400-401	CORE: Pre- and Post-harvest Citrus Disease Management	James Adaskaveg	UC Riverside	$302,190
New Projects				
5400-170	Appraising uncertainties and errors of citrus ET estimated with satellite remote sensing methods	Daniele Zaccaria	UC Davis	$166,777
5400-171	A comprehensive, process-based and geospatially specific life cycle analysis of California citrus production	Alissa Kendall	UC Davis	$74,972
5500 - Pest Management				
Continuing Projects				
5500-226[a]	California adapted *Tamarixia radiata* to support ACP biological control	Raju Pandey	CRB	$151,976
5500-501	CORE: Citrus IPM Program	Sandipa Gautam	UC Agriculture and Natural Resources	$251,012
New Projects				
5500-227	Developing a sampling method and an economic injury threshold for the European earwig	Jay Rosenheim	UC Davis	$43,910
USDA Sub-awards				
5050-010[b]	Breaking critical pest-related trade barriers for California citrus exports	Spencer Walse	USDA-ARS	$490,645
Other Programs				
6100	Citrus Clonal Protection Program (CCPP)	Georgios Vidalakis	UC Riverside	$725,000
			Total:	**$4,073,887**

[a]Funding provided by the CDFA California Pest & Disease Protection Program (CPDPP)
[b]Funding provided by the USDA Technical Assistance for Specialty Crops (TASC)

and a predictive model for ACP and HLB movement between residential and commercial areas.

Production and Post-harvest Technology Research (5400) Committee

Research projects in this committee focus on horticultural factors and production methods both in the grove and in the packinghouse that impact fruit quality for the California citrus industry. Maximizing food safety and minimizing trade barriers to maintain foreign and domestic market accessibility are committee priorities, as well.

Two new projects and three continuing projects, including the Pre- and Post-harvest Citrus Disease Management core program, are receiving $709,859 in support this year (**Tables 1** and **2**). The first continuing project is a field evaluation of a citrus dwarfing viroid introduced to common California citrus varieties in an effort to reduce citrus production costs (e.g., labor, water and land) while minimizing negative yield impacts. The second continuing project is working to identify non-pathogenic bacteria to serve as surrogate species for food safety studies in packinghouse research. New projects approved under this committee include one comparing remote satellite-based citrus evapotranspiration (ET) estimates with ground-based ET measurements and one developing a California-specific life cycle assessment model to address sustainability questions in citrus orchard production.

This research committee also oversees the Pre- and Post-harvest Citrus Disease Management core program, led by James (Jim) Adaskaveg, Ph.D., at UCR, which focuses on management of pre- and post-harvest diseases of citrus caused by fungi, fungal-like organisms and non-fastidious bacteria.

Pest Management Research (5500) Committee

Pest Management research projects focus on eradication, control or management strategies and tools against insect pests to minimize crop damage and to maintain foreign and domestic market accessibility. One continuing project, one new project and the Integrated Pest Management (IPM) core program were funded for the 2022-23 fiscal year at $446,898 (**Tables 1** and **2**). The continuing project includes infrastructure support for ACP colonies at a Riverside production facility for research projects and biocontrol programs (with CPDPP assistance). The new project will develop a sampling method and economic injury thresholds for European earwig damage.

The Citrus IPM core program currently is led by Cooperative Extension Area Citrus IPM Advisor Sandipa Gautam, Ph.D., at the Lindcove Research and Extension Center. This core program conducts long-term research applying IPM strategies to manage major citrus pests in California, with citrus mealybug, thrips and California red scale being the key pests of study for the current year.

The CRB also continues to oversee a cost-sharing grant with the USDA Technical Assistance for Specialty Crops (TASC) Program providing additional research funds to researchers to develop systems-based control measures for pests of export concern (i.e., bean thrips, Fuller rose beetle, California red scale, ACP, flat mites, *Phytophthora*) in Korea, China, Australia and New Zealand.

Citrus Clonal Protection Program (CCPP)

The CCPP, led by Georgios Vidalakis, Ph.D., at UCR, continues its work providing a safe mechanism for the introduction and distribution of clean citrus varieties to the California citrus industry and residents. The 2022-23 budget disbursement to CCPP is $725,000 (**Tables 1** and **2**).

Summary

The CRB remains committed to prioritizing, investing in and promoting research that improves the sustainability and profitability of the California citrus industry. At this time, HLB is a significant area of focus with eight of these new and continuing CRB research projects actively engaged in HLB and ACP or related research projects. Other CRB-funded projects support the ongoing core programs and address current production and export needs of the California industry. The CRB also continues to identify, develop and join collaborations with other funding agencies to maximize California citrus grower investments in research. The projects underway support a sustainable California citrus industry by taking a proactive stance on identifying and implementing short-, medium- and long-term solutions to the threats and concerns of the California citrus environments and markets.

***Joey S. Mayorquin, Ph.D., is a research associate with the Citrus Research Board in Visalia, California, and additionally serves as associate science editor of* Citrograph. *Melinda Klein, Ph.D., is Chief Research Scientist at the Citrus Research Board in Visalia, California, where she also serves as scientific editor of* Citrograph. *For more information, contact* melinda@citrusresearch.org**

CRB Educational WEBINAR SERIES Streaming Each Tuesday in June

Caitlin Stanton

The Citrus Research Board (CRB) is looking forward to hosting the 2023 Citrus Growers Educational Webinar Series this month. The four one-hour webinars are scheduled for June 6, June 13, June 20 and June 27. Each webinar will highlight a specific CRB-funded research area and provide technical insight for growers. This year marks the fourth year the Citrus Growers Educational Webinar Series has been held virtually, and each year has featured an impressive line-up of extension professionals, industry experts and researchers. Past topics included an update on pesticide laws and regulations, insight into citrus IPM, a report on California's water situation and a preview of new cultivars being developed through the CRB's Core Breeding Program.

Continuing education units will be available through the California Department of Pesticide Regulation and Certified Crop Advisers, pending approval.

It's not too late to participate. For up-to-date information—including speakers, topics and CEU information—please visit *www.citrusresearch.org*.

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

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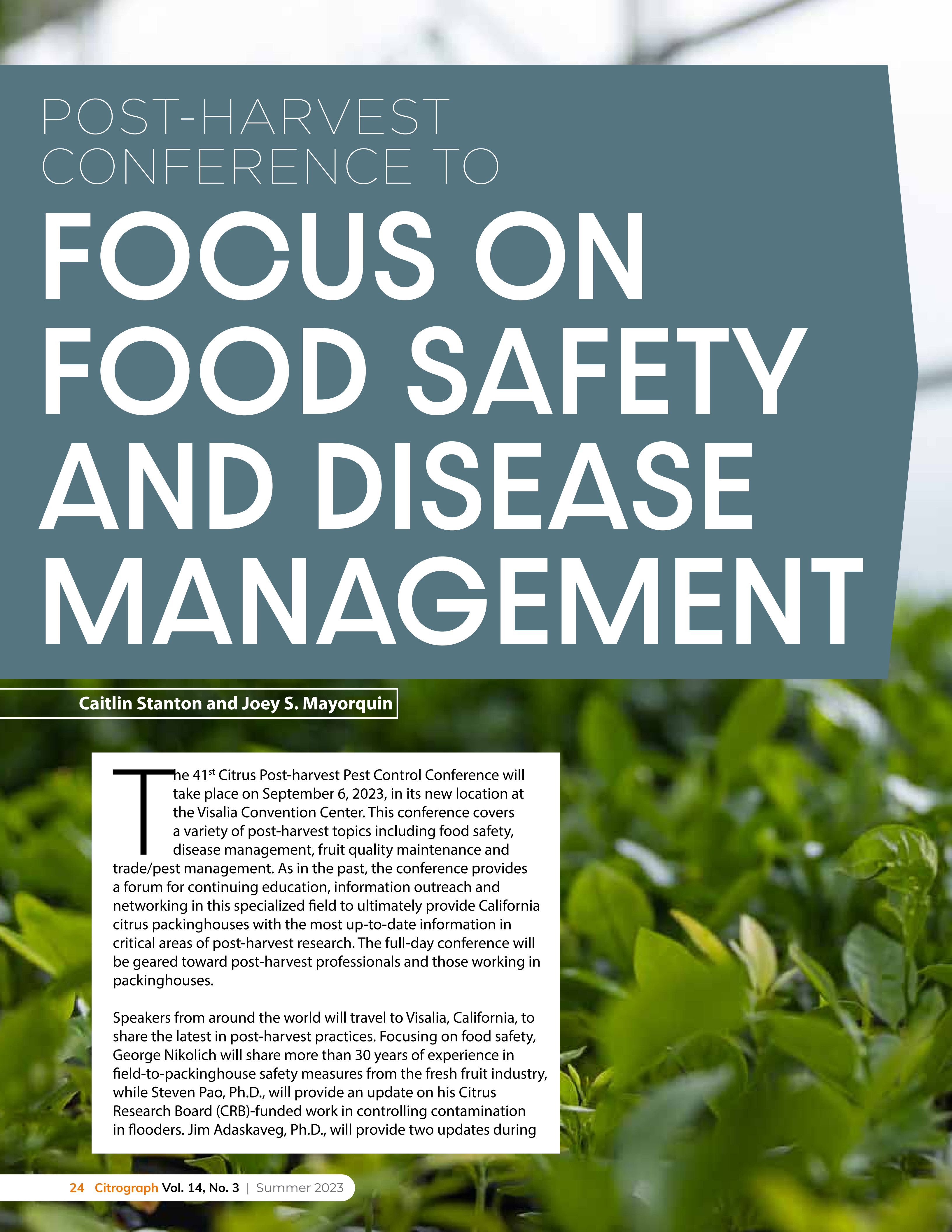


POST-HARVEST CONFERENCE TO FOCUS ON FOOD SAFETY AND DISEASE MANAGEMENT

Caitlin Stanton and Joey S. Mayorquin

The 41st Citrus Post-harvest Pest Control Conference will take place on September 6, 2023, in its new location at the Visalia Convention Center. This conference covers a variety of post-harvest topics including food safety, disease management, fruit quality maintenance and trade/pest management. As in the past, the conference provides a forum for continuing education, information outreach and networking in this specialized field to ultimately provide California citrus packinghouses with the most up-to-date information in critical areas of post-harvest research. The full-day conference will be geared toward post-harvest professionals and those working in packinghouses.

Speakers from around the world will travel to Visalia, California, to share the latest in post-harvest practices. Focusing on food safety, George Nikolich will share more than 30 years of experience in field-to-packinghouse safety measures from the fresh fruit industry, while Steven Pao, Ph.D., will provide an update on his Citrus Research Board (CRB)-funded work in controlling contamination in flooders. Jim Adaskaveg, Ph.D., will provide two updates during

Elizabeth Baldwin, Ph.D., spoke to a room full of industry members during the 2019 Post-harvest Pest Control Conference.

Industry members listened intently as speakers shared the latest post-harvest information during the 2019 Post-harvest Pest Control Conference.

Charlene Jewell, Jim Adaskaveg, Ph.D., and Jim Cranney visited during the 2019 Post-harvest Pest Control Conference. All three of the speakers will return to the 2023 conference.

the conference—one will cover a general overview of post-harvest pathogen management, while the second talk will focus on biology and management of brown rot. To round out the disease management portion of the conference, Themis Michailides, Ph.D., will share his research on post-harvest management of Alternaria rot and anthracnose; and Geert de Wever, Ph.D., will provide an update on the use of imazilil and other treatments.

Within the area of fruit quality maintenance, Mary Lu Arpaia, Ph.D., will share an update on her research regarding field practices to improve quality. Irwin Donis-Gonzalez, Ph.D., will share principles of packing and shipping for quality, while Charlene Jewell will provide an update on principles of fruit coatings. The final area of focus, trade and pest management, will feature four speakers. Spencer Walse, Ph.D., will provide an overview of export and domestic issues of ethyl formate for Asian citrus psyllid (ACP) management, while Heidi Irrig will speak on maximum residue limits. To round out the schedule, Pauline Voorbraak will speak about world trade issues, and Jim Cranney will provide a general update on trade.

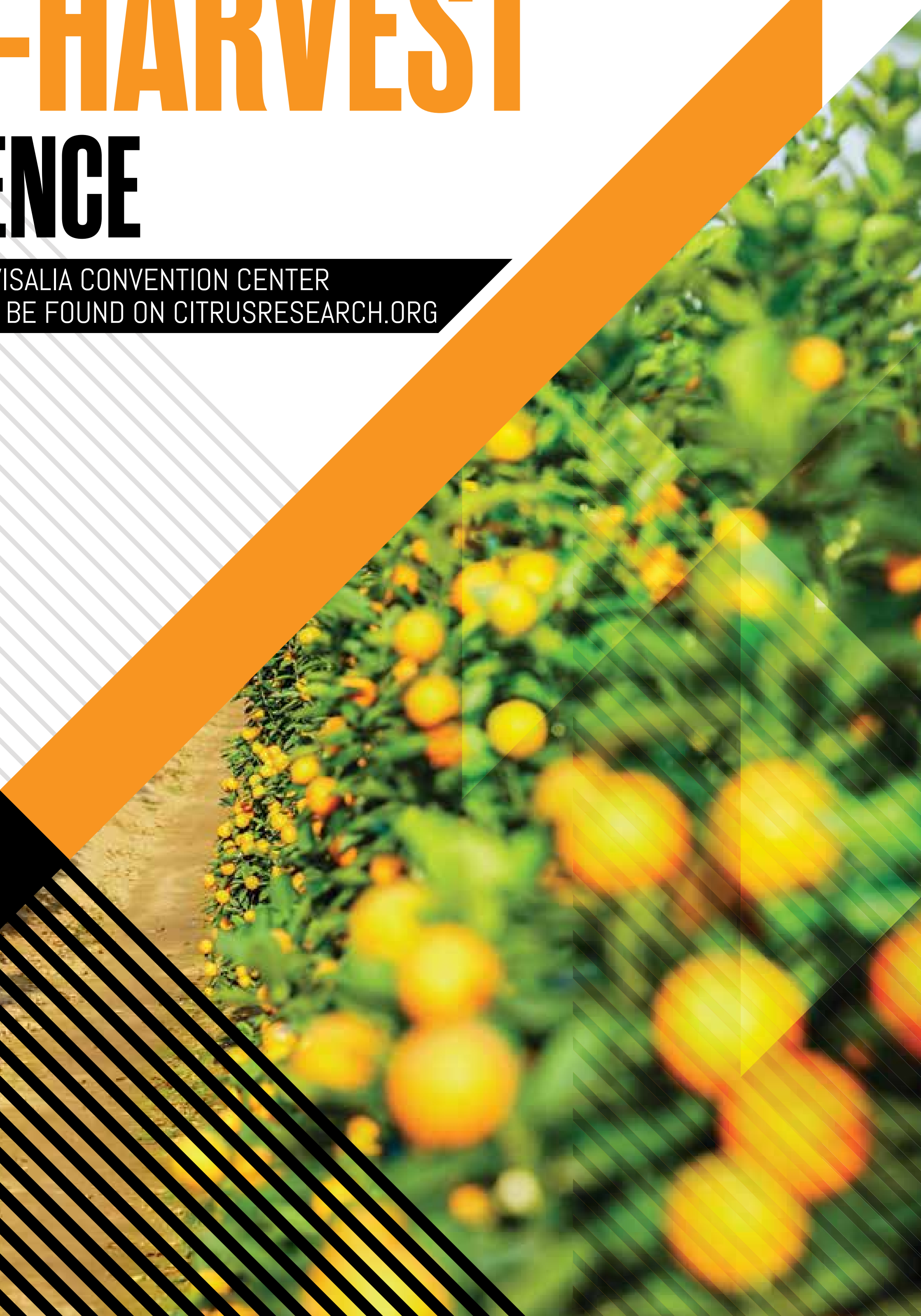
Continuing education units will be available pending approval from the California Department of Pesticide Regulations (DPR) and Certified Crop Advisers (CCA). Registration for the conference opens this summer. The registration fee is $75 per person, and hotel rooms are available at the Visalia Marriott. For more information about the Post-harvest Conference and to register, please visit *www.citrusresearch.org*.

***Caitlin Stanton is the director of communications for the Citrus Research Board and also serves as the editorial assistant on* Citrograph. *Joey S. Mayorquin, Ph.D., is a research associate with the Citrus Research Board in Visalia, California, and additionally serves as associate science editor of* Citrograph. *For more information, please contact* caitlin@citrusresearch.org**

Industry members visited with speaker Mary Lu Arpaia, Ph.D.

Industry members listened intently as speakers shared the latest post-harvest information during the 2019 Post-harvest Pest Control Conference.

GENERAL TOPIC	SPEAKER	AFFILIATION
Food Safety	George Nikolich	George Nikolich Consulting
	Steven Pao, Ph.D.	California State University, Fresno
Disease Management	Jim Adaskaveg, Ph.D.	University of California, Riverside
	Themis Michailides, Ph.D.	University of California Agriculture and Natural Resources
	Geert de Wever, Ph.D.	Janssen
Fruit Quality Maintenance	Mary Lu Arpaia Ph.D.	University of California Agriculture and Natural Resources
	Irwin Donis-Gonzalez, Ph.D.	University of California, Davis
	Charlene Jewell	JBT Corporation
Trade/Pest Management	Spencer Walse, Ph.D.	USDA-ARS
	Heidi Irrig	Syngenta
	Pauline Voorbraak	Janssen
	Jim Cranney	California Citrus Quality Council



INDUSTRY VIEWS: NEW VARIETIES

McCall Machado

This edition of Citrograph *is focused on new varieties. We recently asked citrus industry members working in nursery operations for their insight on new varieties of current interest to California growers and what they hope to see in coming years.*

STACEY JOHNSTON

WN Citrus
Owner
Bakersfield, California

What new varieties are your buyers or clients currently working with the most? What new traits do they have that will benefit the industry (or seem to be key drivers of interest by the industry)?

Hot varieties right now are mid-season Navels. Who doesn't enjoy a Parent Washington in late December through February when it is at the peak of flavor! Varieties with a pink or red flesh are popular because they taste great and are something different. The interest in Mandarins is still very high, and we continue to see strong interest in the easy-peel varieties since kids love Mandarins.

What varieties or traits are not of interest to growers (customers) these days?

The Gold Nugget is the one variety that comes to mind. It is a late season Mandarin and great-tasting piece of fruit; but that does not matter if you do not have buyers to purchase it from the packinghouses. In many areas, Tangos are still available; but I'm not sure if that is the problem, or if the lack of sales has to do with its oily skin and bumpy appearance, or if it just didn't have a big marketing push behind it. The Dekopons are bumpy and ugly but fly out of the store. I do know it was overplanted, and farmers learned how to grow it and produce more fruit. The bottom line is you can only sell so many boxes each season.

What traits do you want to see in new varieties in the next few years? Why?

I would like to see varieties and rootstocks that are huanglongbing (HLB)-resistant. As a nursery owner and citrus grower, I am always concerned about HLB and other diseases that could devastate our industry.

HEIDI CERVANTES

TreeSource Citrus Nursery
Sales Manager
Woodlake, California

What new varieties are your buyers or clients currently working with the most? What new traits do they have that will benefit the industry (or seem to be key drivers of interest by the industry)?

The newest varieties we have been working with are coming out of Biogold. They have quite the selection of early Navels to late Mandarins to choose from that will fill gaps in production or offer different fruit attributes. They have 50-plus varieties they are developing, with around 15 of those varieties at some stage of commercialization currently in California. We also are working with a new variety, Rosy Red Valencia. It is exclusive to TreeSource, and we are really excited about it. It is a deep-colored Valencia that not only offers the fruit color, but juice color, as well. It has unique foliage and is just being released to growers in 2023. From the nursery side, we do not see a big demand for color. The retail side is always looking for something new, but it is not always applicable to commercial growers. We are also starting to see a swing back to the tried-and-true varieties of the past. The Parent Washington navels seem to be making a big comeback right now for growers looking to get a steady return.

What varieties or traits are not of interest to growers (customers) these days?

Anything with seeds. W. Murcotts are still a big hit, but Tango is holding its spot ahead of it because there is no need to net the trees. Most packinghouses will tell you seedless and easy-to-peel is the way to go. Any variety that does not meet those criteria seems to get less traction.

What traits do you want to see in new varieties in the next few years? Why?

In my opinion, the main thing that needs to stay front and center is resistance/tolerance to HLB. Colored fruit is pretty and fun, but to keep the industry healthy and viable, we need to make sure we have varieties that can survive this devastating disease. New rootstocks or varieties that will fit the bill will be vital to our industry.

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

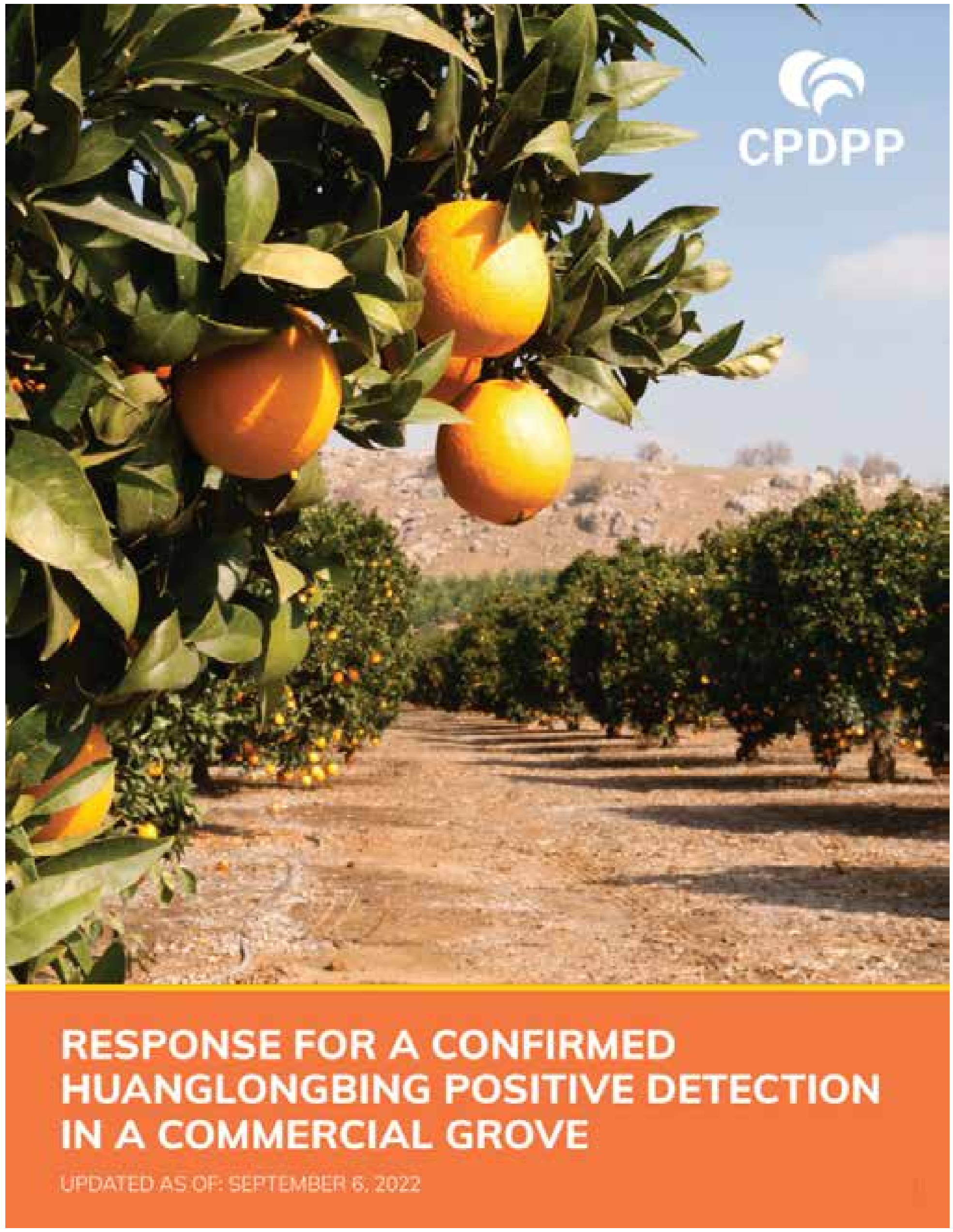
STAY PREPARED

NEWLY DEVELOPED COMMERCIAL HLB DETECTION RESPONSE GUIDE

Kevin Ball

Beginning well before the first Asian citrus psyllid (ACP) or huanglongbing (HLB) detection occurred in California, citrus industry leaders wisely took a proactive approach to best protect their groves against these formidable foes. Leaders recognized the importance of getting ahead of the pest and disease to minimize the devastating impact HLB could cause to their livelihoods, and the Citrus Pest and Disease Prevention Program (CPDPP) and California Department of Food and Agriculture (CDFA) continue this approach today. Through a deep commitment to keeping an eye on the horizon, the committee and our partners at the state level are continually developing proactive strategies that can be activated to help preserve the California citrus industry's vibrancy, but it's also imperative that industry members understand their role in these plans before unwelcomed milestones are reached.

To ensure California citrus growers are well prepared in the event of a potential commercial grove detection of HLB, the CPDPP has developed a response guide for growers to utilize and to educate themselves on the CDFA action plan (see right). *The Response Guide for a Confirmed HLB Positive Detection in a Commercial Grove* details the mandatory response to be taken by the CDFA and the actions required of the property or grove owner should a confirmed citrus plant sample test positive for the HLB-associated *'Candidatus* Liberibacter asiaticus' (CLas). The actions in the response guide represent the most effective tools known to the citrus industry at this time and are meant to protect California's citrus groves and support the CDFA's current required regulatory response.



While the response guide goes into great detail regarding the mandatory actions that would be taken in the event of an HLB-positive plant sample in a commercial grove, the following is a high-level overview as to what grove owners or managers can expect if a plant sample should test positive for CLas via the polymerase chain reaction (PCR) method:

- The Citrus Pest and Disease Prevention Division (CPDPD) will notify the grower upon confirmation.
- The grower will be required to treat the tree with a foliar insecticide from the University of California (UC) recommended list of insecticides for bulk citrus treatment within 72 hours of notification.
- After the infected tree has been treated, the grower must remove and destroy the diseased citrus tree, including tree stump and roots, per the abatement procedures. Removal may include cutting the tree down and removing the stump or pushing the infected tree completely out of the ground and allowing it to dry completely. Growers should monitor for suckers or resprouts, which are very attractive to the ACP. If suckers or resprouts are found, the grower is directed to remove them.
- The CPDPD initiates a survey of all citrus trees on the perimeter (all end rows/trees in all directions) of the affected grove and all groves within 250 meters. In addition, all host plants within 250 meters of the detection must be treated. Grower Liaisons will communicate with growers who are in the 250-meter treatment area, and the CPDPD will notify any residential property owners who fall within the treatment area.
- If the grower does not show proof of treatment, the CDFA or the County Agricultural Commissioner will treat the property. The grower will be billed for the treatment, and a hold order will be issued on the property. Growers should consult the UC's recommended list of ACP-effective insecticides when choosing treatment.
- A new compliance agreement will need to be signed that outlines HLB quarantine requirements and options for meeting the pest risk mitigation performance standard when moving fruit.
- Mitigation measures to meet the performance standard vary on the destination of the fruit, but can include a pre-harvest treatment, machine/grate field cleaning and a wet wash. See **Table 1** for additional details.

Table 1. Movement of citrus grown in an HLB quarantine area.

Orgin	Destination	
	Within the same contiguous HLB quarantine area	**Outside of HLB quarantine area OR different HLB quarantine area**
HLB quarantine area	Field cleaned by machine **OR** grate cleaned* **OR** spray & harvest **AND** transport completely tarped or in a fully enclosed vehicle **AND** complete HLB pest risk mitigation form	Wet wash **OR** field cleaned by machine/grate cleaned* and spray & harvest **AND** transport completely tarped or in a fully enclosed vehicle **AND** complete HLB pest risk mitigation form

This table and others may be found online at cdfa.ca.gov/citrus

The response guide mentioned above does not include actions taken if a CLas-positive ACP is found in a commercial citrus grove, as many of the actions are not mandatory. The recommendations in response to a CLas-positive ACP in a commercial grove – in addition to a list of voluntary actions and recommendations based on a grower's proximity to an HLB detection – can be found at *CitrusInsider.org*.

While our state's citrus industry has shown a remarkable ability to limit the spread of this deadly disease, we must continue to work together with increased diligence to prepare for the next battle in the war against HLB. In addition to the requirements outlined in the guide, growers are encouraged to use as many methods as feasible for their operation to limit the spread of ACP and HLB. To read or download the response guide, please visit *CitrusInsider.org*.

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

CLAS TESTING

of Scions and Rootstocks Under Greenhouse Conditions

Rayane B. Bisi, Ute Albrecht and Kim D. Bowman

Washington Navel and Tango trees being tested for tolerance to huanglongbing (HLB) in the greenhouse at the U.S. Department of Agriculture, Ft. Pierce, Florida.

Project Summary

*Choosing a '*Candidatus *Liberibacter asiaticus' (CLas)-tolerant scion and/or rootstock at planting is important for reducing costs in a huanglongbing (HLB)-endemic environment and maximizing financial returns. To better understand scion and rootstock response to CLas infection, four experiments were carried out under controlled CLas inoculation and greenhouse environmental conditions. In these experiments, we studied the scion and rootstock response to CLas infection among specific clones, related species and hybrids. Our goal was to help guide choices by California growers about which cultivars to use for new plantings and to support future citrus breeding efforts to develop varieties demonstrating HLB resistance[1] or tolerance[2]. Responses to CLas infection differed greatly among the germplasm evaluated.*

In an HLB-endemic environment, several different strategies are being used to minimize the impact of CLas infection and reduce the losses in fruit production in citrus orchards. These include the suppression of the disease vector using insecticides, improved nutrient management, and the use of hormones and antibiotics. Generally, the cost of implementing these chemical strategies is high, as frequent applications are needed, and there is a significant risk of the vector and the bacteria developing resistance to the control materials. Consequently, there is major interest in identifying and using suitable HLB-tolerant and/or resistant cultivars for commercial citrus production.

With a goal of identifying relative tolerance or sensitivity[3] among a range of different scion and rootstock cultivars and citrus breeding materials, we planned a series of tests in Florida and California to evaluate the tolerance of 26 citrus varieties (**Table 1**) to CLas. Testing in Florida used a CLas isolate common in Florida, and testing in California used a CLas isolate from California. The experiments were conducted under controlled greenhouse conditions, avoiding the erratic spread of CLas typical under field conditions and impact from other stresses that would affect field tree performance. All four experiments were completed in Florida, and the results presented here are focused on those tests. Testing under the project in California is still in progress.

In each experiment, about 400 potted plants were graft-inoculated with buds from CLas-infected citrus source plants or mock-inoculated with buds from healthy plants. Plants were monitored through 18 or 21 months after inoculation for shoot and other growth metrics, HLB and nutritional

Table 1. Citrus varieties used in the four experiments.

CULTIVAR	PARENTAGE	VALENCIA	SEEDLING	TANGO	W. NAVEL
Assad citron	*Citrus medica*		X		
C-146 citrandarin	*C. reticulata* 'Sunki' × *Poncirus trifoliata* 'Swingle'				X
C-22 'Bitters' citrandarin	*C. reticulata* 'Sunki' × *P. trifoliata* 'Swingle'			X	X
C-57 'Furr' citrandarin	*C. reticulata* 'Sunki' × *P. trifoliata* 'Swingle'			X	X
Carrizo citrange	*C. sinensis* 'Washington' × *P. trifoliata*	X		X	X
Cleopatra mandarin	*C. reticulata*	X	X	X	X
Duncan grapefruit	*C. paradisi*		X		
Flying Dragon trifoliate orange	*P. trifoliata*			X	
Kinnow mandarin	*C. nobilis* 'King' × *C. deliciosa* 'Willow Leaf'		X		
Microcitrus Inodora	*Microcitrus inodora*		X		
Olinda Valencia orange	*C. sinensis*		X		
Rich 16-6 trifoliate orange	*P. trifoliata*		X		X
Ridge Pineapple sweet orange	*C. sinensis*	X			
Sour orange	*C. aurantium*	X			
Sunburst mandarin	Robinson [*C. reticulata* x (*C. paradisi* × *C. reticulata*)] × Osceola [*C. reticulata* x (*C. paradisi* × *C. reticulata*)]		X		
Swingle citrumelo	*C. paradisi* × *P. trifoliata*	X		X	X
Triumph hybrid	*C. sinensis* × *C. paradisi*		X		
US-1283 citrandarin	*C. reticulata* 'Ninkat' × *P. trifoliata* 'Gotha Road'			X	X
US-1284 citrandarin	*C. reticulata* 'Ninkat' × *P. trifoliata* 'Gotha Road'			X	X
US-1516 hybrid	*C. maxima* 'African' × *P. trifoliata* 'Flying Dragon'	X		X	
US-802 hybrid	*C. maxima* 'Siamese' × *P. trifoliata* 'Gotha Road'	X			
US-812 citrandarin	*C. reticulata* 'Sunki' × *P. trifoliata* 'Benecke'	X		X	X
US-897 citrandarin	*C. reticulata* 'Cleopatra' × *P. trifoliata* 'Flying Dragon'	X	X	X	X
US-942 citrandarin	*C. reticulata* 'Sunki' × *P. trifoliata* 'Flying Dragon'	X		X	X
Valencia 1-14-19 orange	*C. sinensis*		X	X	X
W. Murcott mandarin	*C. reticulata*		X		

symptoms and CLas titers using real-time polymerase chain reaction (PCR) analysis. The four experiments conducted were:

1. **Valencia grafted tree experiment:** 10 commercially important rootstocks grafted with Valencia 1-14-19 sweet orange scion.
2. **Seedling experiment:** seedlings from 12 commercially important scions and rootstocks.
3. **Tango grafted tree experiment:** 13 commercially important rootstocks grafted with Tango scion.
4. **Washington Navel grafted tree experiment:** 13 commercially important rootstocks grafted with Washington Navel scion.

Results from Valencia grafted trees showed that most trees on rootstocks with trifoliate orange ancestry were less affected by CLas infection when compared with other rootstocks. The canopy volume of Valencia trees was reduced by more than 60 percent in infected plants grafted on Cleopatra mandarin and Ridge orange rootstocks (**Figure 1**) (Bodaghi et al. 2022). These results were similar to a previous comparison of Valencia rootstocks in a greenhouse study (Bowman and Albrecht 2020) but failed to reconfirm significant performance improvements from the rootstocks US-942 and US-812 that had been observed in field studies affected by CLas (Bowman and Joubert 2020). There are observations that improved nutrition can contribute to better field performance of trees infected with CLas, so perhaps the optimized nutrition in greenhouse growth conditions could explain the somewhat different relative effects of CLas infection on various cultivars.

Varieties reported before as susceptible to HLB in field conditions also were highly affected by CLas infection in the seedling experiment using controlled CLas infection and greenhouse conditions. In this experiment, CLas infection significantly reduced the trunk growth of Cleopatra, Duncan, Olinda Valencia, Sunburst mandarin and Valencia 1-14-19.

Each plant was assessed on a five-point standard scale for blotchy mottle:

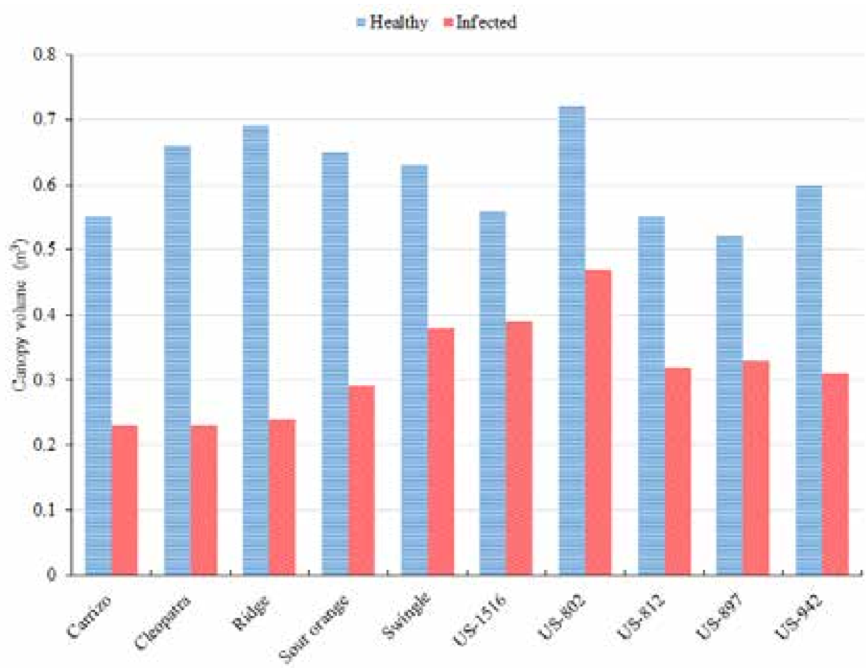


Figure 1. Canopy volume (m³) of healthy and infected 'Valencia' trees grafted on different rootstocks 21 months after inoculation.

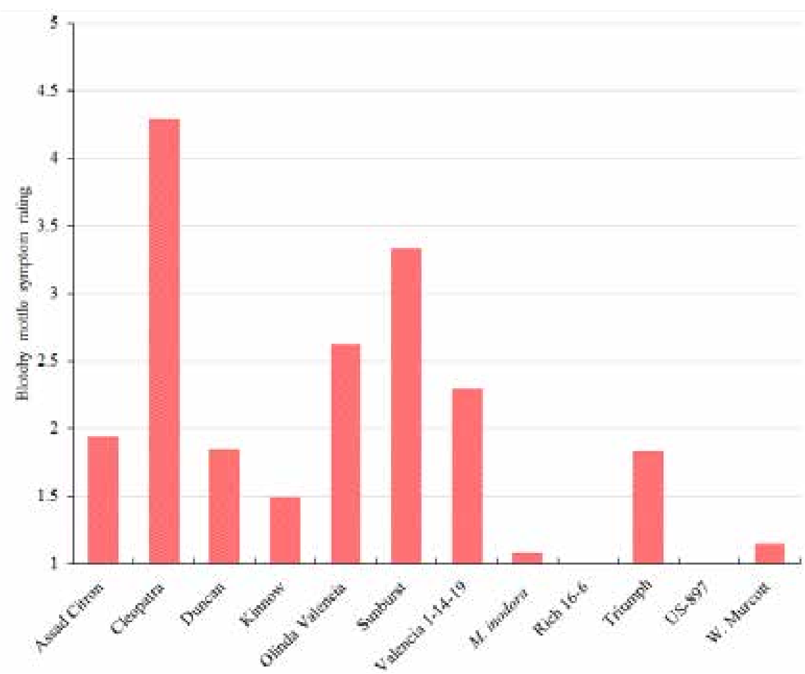


Figure 2. Average blotchy mottle symptom ratings of *'Candidatus* Liberibacter asiaticus'-infected seedlings 18 months after inoculation. Ratings were conducted on a scale of 1 (no blotchy mottle) to 5 (more than 75 percent of leaves with blotchy mottle).

- 1 = no foliar symptoms;
- 2 = foliar symptoms on less than 25 percent of leaves;
- 3 = 25-50 percent of leaves with symptoms;
- 4 = 50-75 percent of leaves with symptoms;
- 5 = more than 75 percent of leaves with symptoms.

In the seedling experiment, infected plants of sensitive cultivars started to show significant blotchy mottle symptoms at about 12 to18 months after inoculation (**Figure 2**). Also, CLas infection reduced plant biomass substantially for Cleopatra and Sunburst mandarins and Olinda Valencia sweet oranges (**Figures 3** and **4**).

The results from our studies showed tolerance to CLas infection in *Microcitrus inodora*, P. *trifoliata* and some *P. trifoliata* hybrids commonly used as rootstocks. Among these cultivars, only a few plants showed light blotchy mottle symptoms, with less than 25 percent of the leaves affected, and plant growth was not reduced by CLas infection. Other greenhouse and field studies also have shown tolerance to HLB symptoms in these species (Albrecht and Bowman 2011; Boava et al. 2015; Curtolo et al. 2020; Alves et al. 2021).

With Tango and Washington Navel scion, the percentage of plants that became CLas-positive following graft inoculation generally were low, with an average of 26 percent of the plants infected from Tango and 16 percent of the plants infected from W. Navel at 15 months after inoculation. These low numbers may be attributed to the difficulty to transmit CLas bacteria by grafting, or it may suggest some tolerance in these scion varieties. Further studies with Washington Navel and Tango are needed to clearly define the response of these varieties to CLas infection. Most of the Tango and W. Navel plants did not show any HLB symptoms. Overall, only a few plants showed very mild HLB symptoms, even when grafted on very susceptible rootstocks as Cleopatra and Valencia.

The results from these experiments conducted under controlled CLas inoculation and environmental conditions showed that Valencia sweet oranges and some mandarins are highly susceptible to CLas infection and show strong HLB symptoms, while *P. trifoliata*, some of its hybrids and *Microcitrus inodora* exhibit only minor effects from infection. Even under optimum growing conditions in the greenhouse, HLB symptoms and plant growth reductions generally were severe in infected plants for the most

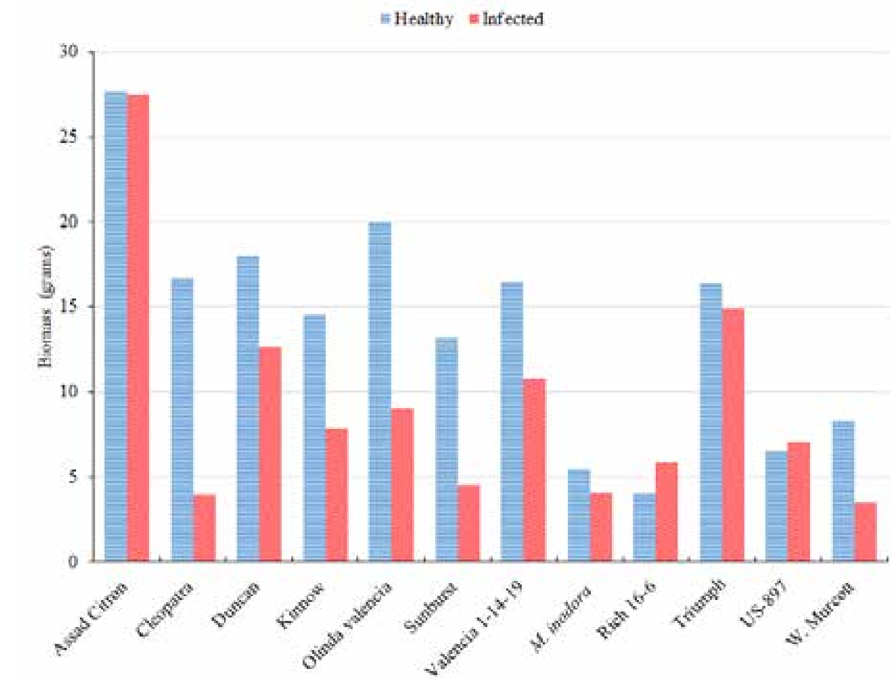


Figure 3. Dry biomass of healthy and *'Candidatus* Liberibacter asiaticus'-infected seedlings of each cultivar 18 months after inoculation.

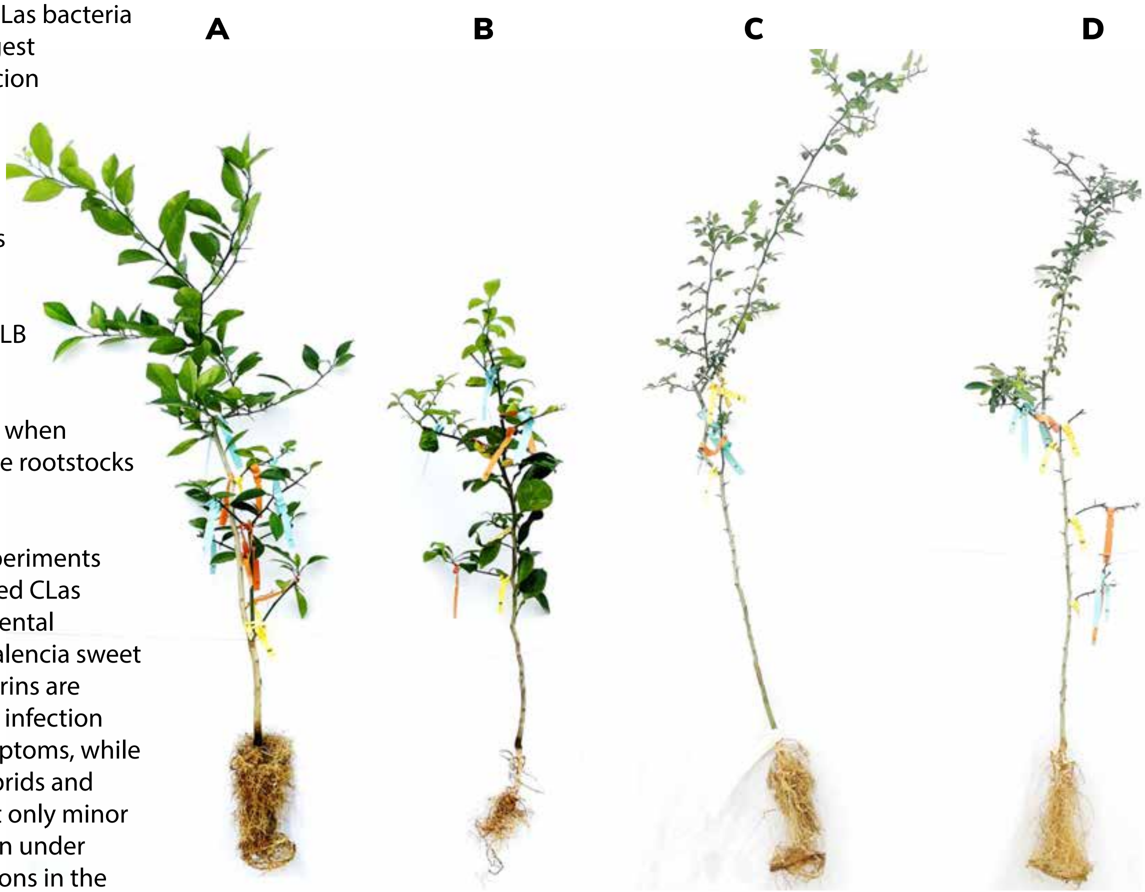


Figure 4. Comparison of healthy (A) and infected (B) Olinda Valencia, and healthy (C) and infected (D) Rich 16-6 seedlings 18 months after inoculation.

susceptible cultivars. In the field, other factors besides the CLas infection often exacerbate tree stress and consequent tree decline and HLB symptom expression.

The results from this project provide new knowledge on HLB tolerance of existing cultivars of commercial importance and assist in the development of new cultivars with improved HLB tolerance or resistance. This information aids California citrus growers in making informed choices on scion and rootstock varieties and contributes to the success of citrus production in a changing environment.

CRB Research Project # 5200-168

Glossary

[1]**Resistance:** The ability of a species or cultivar to exclude or reduce *'Candidatus* Liberibacter asiaticus' (CLas) titer, as compared with other cultivars.

[2]**Tolerance:** The ability of a species or cultivar to grow well and be productive even when infected with *'Candidatus* Liberibacter asiaticus.'

[3]**Sensitivy:** The relative degree of damage to health, growth or fruit production of a species or cultivar following *'Candidatus* Liberibacter asiaticus' (CLas) infection.

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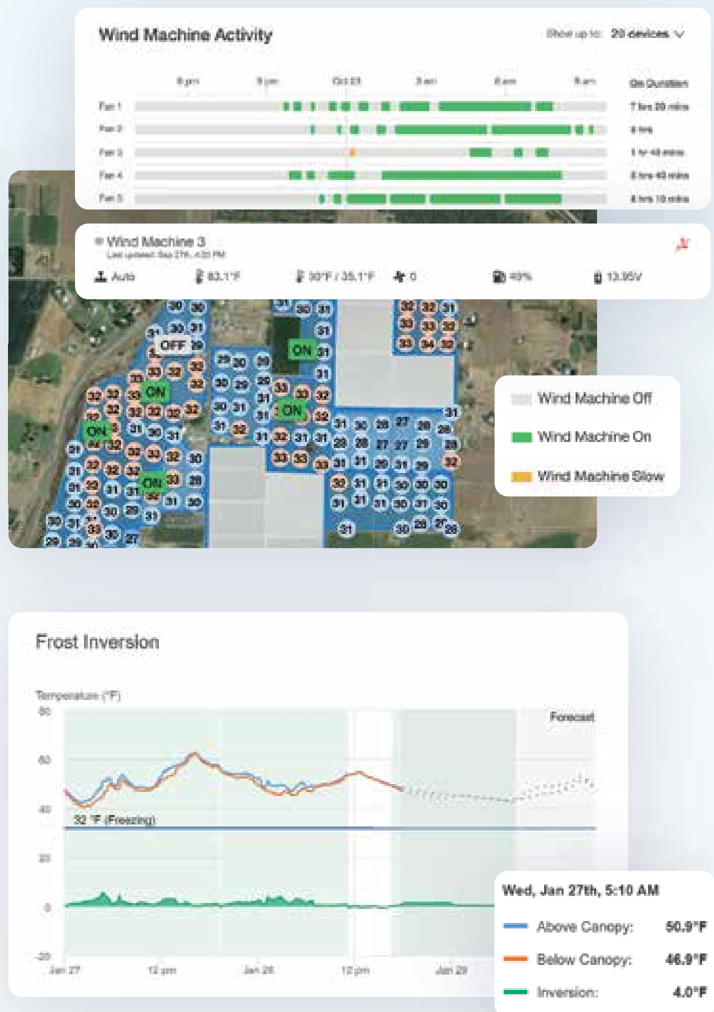

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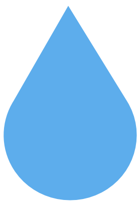

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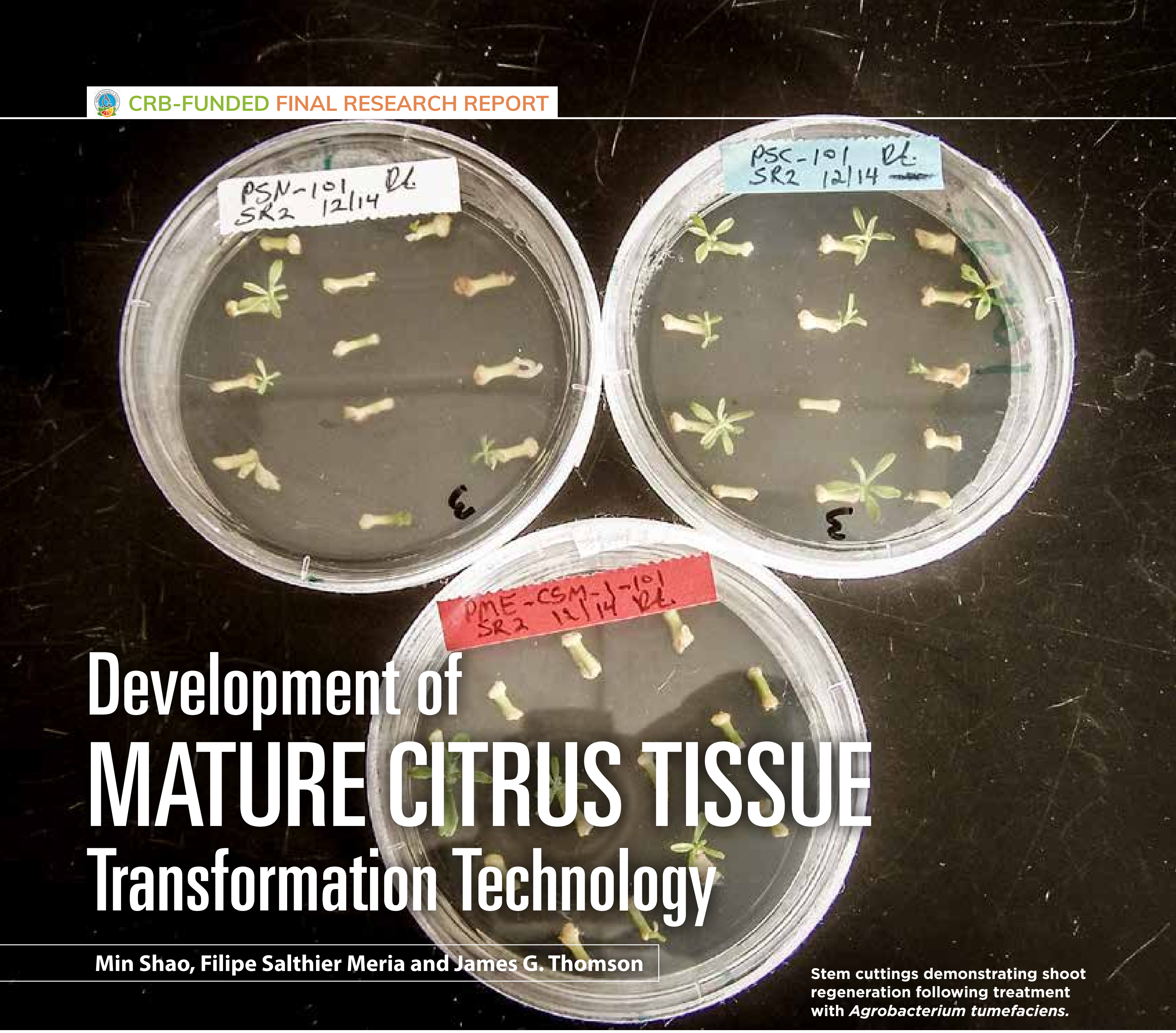

Development of MATURE CITRUS TISSUE Transformation Technology

Min Shao, Filipe Salthier Meria and James G. Thomson

Stem cuttings demonstrating shoot regeneration following treatment with *Agrobacterium tumefaciens*.

Tissue transformation is a process that allows DNA modification of the plant genome. The modification can be used for a host of improvements such as, but not limited to, fruit color change and increased disease resistance. With the threat of huanglongbing (HLB) to commercial citrus production in California, improved disease resistance is the main driver for this project. Transformation technology in citrus is difficult, time consuming and limited to a few non-commercially relevant cultivars. Without improvements to the citrus transformation process, if a cure for HLB is discovered that requires genome modification, a majority of the existing citrus cultivars will lose commercial viability due to low transformation rates.

Previously, through a Citrus Research Board (CRB)-funded project (#5200-165), it was discovered that the use of surfactants (soaps), novel basal medias and genes that induce tissue growth could be used to enhance mature tissue transformation. A novel wild *Agrobacterium* (strain 1416) also was discovered that appeared effective for mature citrus transformation. This project developed the novel wild *Agrobacterium* specifically for mature citrus transformation and converted it into an effective and stable system for stacking single or multiple genes within *Agrobacterium* for plant genome modification. The project also expanded on the development of unique media (including surfactants and genes to induce tissue growth) to enhance tissue regeneration in multiple citrus cultivars, with specific interest in the Washington Navel.

The most straightforward method for improving citrus transformation is simply to find a basal media recipe that allows tissue to regenerate more effectively and with greater health while in culture. Basal medias are essentially the salts, sugar, vitamins and hormones that allow plant tissue to grow suspended in agar. We previously showed (De Oliveira et al. 2016) that using the medium Murashige and Skoog (Murashige and Skoog 1962) instead of Driver and Kuniyuk (DKW; [Driver and Kuniyuk 1984]) increased the frequency of shoot regeneration and increased shoot size of Washington Navel plantlets.

To further investigate improved tissue regeneration methods, 20 basal media were evaluated for several citrus cultivars, but we focused more on Washington Navel due to it being non-seeded and of high value to the California market. Small young plant stems or explants were cleaned, cut into 16 two-centimeter-long segments and placed on the surface of the various basal media with similar hormone levels to stimulate regeneration. The plant tissue was grown at 27ºC with a 16-hour day/eight-hour night cycle for three months. After initial evaluation of the 20 basal media, it was evident that only ten were worth pursuing. Thus, the ten best media were used to regenerate tissue from 21 cultivars (**Table 1**) in three experiments over two years. It was noticed early in the experiment that evaluations conducted in the spring (March-May) and fall (September-early November), when citrus normally flush, yielded the highest efficiency. Inconsistent results were obtained during other times of the year. As expected, each cultivar had its own favorite media; however, by pooling the information gathered, it was determined that Rugini Olive Medium (Rugini 1984) was the media that performed the best across the tested cultivars and worked especially well for mature Washington Navel regeneration.

The next enhancement for citrus transformation was the development of a novel *Agrobacterium* strain specifically for mature citrus tissue. *Agrobacterium* normally infect specific plant hosts. To date, there never has been a study conducted to discover a strain with preference for citrus.

Previous research discovered that the novel *Agrobacterium* strain 1416 worked well for mature tissue citrus transformation. To expand the usefulness of 1416, it was modified to accept Gene Assembly in *Agrobacterium* by Nucleic acid Transfer using Recombinase technology (GAANTRY) technology (Collier et al. 2018) – an effective and stable system for stacking multiple genes within the *Agrobacterium* for plant transformation. The system appears to have an effective transfer capacity of 40-50kb (effectively 20-25 genes; Collier et al. 2018). That is, entire metabolic or disease-resistant pathways could be moved into citrus as needed. *Agrobacterium* strain 1416 was made competent for both traditional transformation and for the GAANTRY system. Both technologies were evaluated for citrus tissue transformation efficiency against the traditionally used *Agrobacterium* strain EHA105. *Agrobacterium* strain 1416 was found to be superior to strain EHA105 on transformation of mature citrus tissue (*Thomson unpublished*).

An early enhancement of plant tissue transformation technology was the use of surfactants. Surfactants are adjuvants that facilitate and enhance the spreading, wetting, emulsifying, dispersing or other surface modifying properties of liquids. Although widely used, the effects of surfactants on plant tissue range from inhibitory, phytotoxic effects at higher concentrations to stimulatory effects at lower concentrations and, therefore, should be used judicially. The surfactant Silwet® L-77 aids *Agrobacterium* infiltration into the intercellular spaces within plant tissue by helping to break water surface tension. This allows

Table 1. Summary table of citrus cultivars and tissue type used for novel media analysis.

CULTIVAR	TISSUE TYPE
Changsha Mandarin	Juvenile
Sunki Mandarin	Juvenile
Fina Sodea Mandarin	Juvenile
W Murcott Mandarin	Juvenile
Grapefruit 343	Juvenile
Lisbon Lemon	Juvenile
Valencia Orange	Juvenile
Pineapple Orange	Juvenile
Washington Navel Orange	Mature
Lane Late Navel Orange	Mature
Tango Mandarin	Mature
Gold Nugget Mandarin	Mature
Pixie Mandarin	Mature
Owaisi Mandarin	Mature
Valencia Orange	Mature
Bearss Lime	Mature
Mexican Lime	Mature
Nagami Kumquat	Mature
Carrizo	Mature
Cocktail Grapefruit	Mature

more of the bacteria to penetrate the waxy cuticle, thereby increasing transformation efficiency. Silwet L-77 often is used in biotechnology for plant transformation due to its ability to reduce surface tension comparatively more than most surfactants and at doses with low phytotoxicity, thereby enhancing entry of *Agrobacterium* into relatively inaccessible plant tissues, but with low tissue stress.

Using the model plant species *Arabidopsis*, we tested seven novel surfactants (BREAK THRU® products OE 446, S 200, S 233, S 240, S 279, S 301 and SP 133) to assess how they influence transformation efficiency rates compared to Silwet L-77 (Huynh et al. 2022). Surfactants S 200, S 240 and S 279 demonstrated the greatest enhancement in transformation. All seedlings appeared healthy; in fact, S 200, S 233 and S 240 appeared to produce larger and more robust plants than the remaining surfactants, including the control transformation with Silwet L-77.

With knowledge gained to date, mature tissue transformation of the Washington Navel with medium Rugini Olive Medium, surfactant S 200 using *Agrobacterium* strain 1416 with pCTAGV-KCN3 vector was tested in two transformation studies. The first in March 2022 yielded a transformation efficiency of 63 percent (transgenic regenerated shoots/total number of explants). The second study was conducted in September 2022 and generated a transformation efficiency rate of 50 percent. The average rate of transformation during the spring and fall flush was 56 percent. Interestingly, this same protocol when conducted in the summer months produced a seven percent efficiency, while the winter months were effectively zero. Numbers are based on duplicate trials, and transgenesis of shoots was determined by DSRed expression from the developed plantlet. The DSRed gene is a nontoxic protein that will glow red under certain wavelengths of light. This allows fast scoring for plants that actually are transgenic avoiding plants that have "escaped" the selection process and are not transformed.

Other progress has been made in the design of a genetic system that provides extra genes to help boost rates of transformation. Some genes (BI-1, DAD1 and BAG4 from Arabidopsis; **Table 2**) help reduce cell death under tissue culture conditions, providing longer life under artificial conditions. Other genes help the tissue produce new shoots. Genes for enhancing transformation also were evaluated (Table 2). These genes normally are turned on during early embryogenesis and plant development. The genes are being used in the transformation process to induce more tissue growth from mature tissue. Of the genes tested, Lec2 and Knotted were the most effective in enhancing regeneration from mature Washington Navel tissue with transformation rates of 86 percent and 71 percent observed, respectively. While productive, these genes still lack the molecular control required for foolproof utilization and, therefore, are still under investigation to improve the technology.

Table 2. Summary table of gene names, gene abbreviations, gene origin and purpose for inclusion (cell death repression or improved tissue regeneration).

NAME	ABBREVIATION	ORIGIN	EVALUATED FOR
Bax inhibitor 1	BI-1	Arabidopsis	Reducing cell death
Defective Anther Dehiscence 1	DAD1	Arabidopsis	Reducing cell death
Bcl-2-associated athanogene 4	BAG4	Arabidopsis	Reducing cell death
Early 35 kDa protein	P35	baculovirus	Reducing cell death
Baby Boom	BBM	Citrus	Improving tissue regeneration
Fusca 3	FUS3	Arabidopsis	Improving tissue regeneration
Growth factor regulator 4	GFR4	Citrus	Improving tissue regeneration
Growth factor regulator 5	GFR5	Citrus	Improving tissue regeneration
Knotted	KNT	Maize	Improving tissue regeneration
Leafy Cotlyedon 1	LEC1	Arabidopsis	Improving tissue regeneration
Leafy Cotlyedon 2	LECS2	Arabidopsis	Improving tissue regeneration
Sulfonamide resistance gene	SUL1	*Escherichia coli*	Improving tissue regeneration
Translationally Controlled Tumor Protein 2	TCTP2	Arabidopsis	Improving tissue regeneration
Wuschel-related homeobox gene 2	WOX2	Citrus	Improving tissue regeneration
Wuschel-related homeobox gene 4	WOX4	Citrus	Improving tissue regeneration
Wuschel-related homeobox gene 5	WOX5	Citrus	Improving tissue regeneration
Wuschel	WUS	Citrus	Improving tissue regeneration

Conclusion

Improvement to citrus transformation technology is being investigated for use on a broad array of citrus cultivars, with special emphasis on the Washington Navel, and using mature stem tissue. To date, a number of improvements have been made such as the identification of media more conducive to citrus regeneration. With few exceptions, both cultivars and tissue types (mature vs. juvenile) preferred Rugini Olive Medium over the DKW, and surfactant S 200 was determined to be more effective than Silwet L 77. The *Agrobacterium* strain 1416 was found competent for mature citrus transformation and modified to work with both traditional and GAANTRY techniques. Transformation efficiency of mature citrus tissue using *Agrobacterium* strain 1416 was higher than when *Agrobacterium* strain EHA105 was used for Carrizo, Washington Navel and Valencia. Combining these technologies and selecting tissue for transformation at the correct time of the year led to the most efficient rates (56 percent) of mature citrus tissue transformation this lab has seen to date.

For citrus growers, this means that improvements to existing transformation technology are available for companies and labs to use in the fight against HLB or enhancements of other horticultural citrus traits. All techniques, constructs and *Agrobacterium* strains will be made available to the citrus community at presentations, scientific conferences, publications in peer-reviewed journals and will be disseminated upon request. As this project involves *Agrobacterium*, biotechnology and genetic engineering, federal regulatory review and approval will be needed prior to commercialization of citrus cultivars exhibiting desired traits.

CRB Research Project #5200-170

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USING DIVERSE GERMPLASM TO REVEAL GENETIC CONTROL OF FRUIT QUALITY

Claire Federici, Ryan Piscatella, Toni Siebert Wooldridge, Zachary Thomas, Karene Trunnelle, Mikeal Roose, Tracy Kahn and Danelle Seymour

A sample of fruit diversity from the Givaudan Citrus Variety Collection. Fruit display by Toni Siebert Wooldridge and Karene Trunnelle.
Photo by Danelle Seymour.

Project Summary

The University of California, Riverside (UCR) Core Citrus Breeding Program evaluates new scion hybrids each year to identify individuals with potential commercial value. Selection criteria currently are based on horticultural characteristics and fruit quality, including traits related to internal and external fruit quality. The integration of genetic information into selection criteria has proven to increase the probability of identifying hybrids with an optimal combination of beneficial characteristics. Here, we establish a framework for integrating genetic information into the selection of scion hybrids. In the long-term, this framework will facilitate culling of undesirable individuals at the seedling stage, ensuring evaluation efforts are focused on the most promising new germplasm.

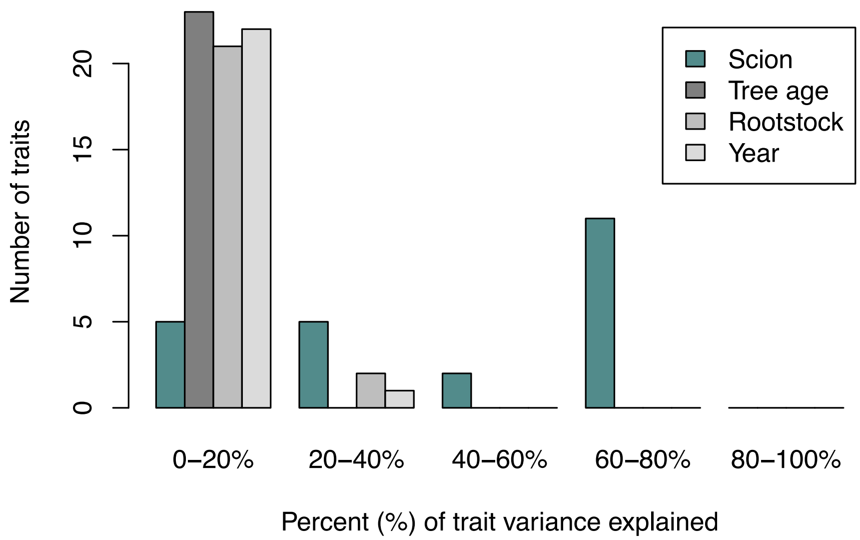

Figure 1. A summary of the relative influence or "variance explained" by environmental (tree age and harvest year) and genetic (scion and rootstock genotype) factors on 23 external fruit quality traits assayed by the commercial packline at Lindcove Research and Extension Center. For most traits, the influence of scion genotype exceeded that of all other factors (rootstock, tree age, harvest year).

Every year, the UCR Core Citrus Breeding Program produces around 600 new scion hybrids, each with the potential to mix and match beneficial horticultural and fruit quality characteristics. To identify scion hybrids with potential commercial value, each individual is evaluated for multiple characteristics, or traits[1], including those related to both internal and external fruit quality. Once the top performing hybrids are selected, they advance to evaluation in replicated field trials, where their productivity is monitored in relevant citrus growing regions across California. Ultimately, the selection of promising scion hybrids and subsequent evaluation in these locations leads to the release of new scion cultivars specifically tailored to the needs of the California citrus industry.

The probability of generating a hybrid with the optimal combination of characteristics depends on the total number of individuals that can be evaluated in a given year. In theory, increasing the number of hybrids tested annually would increase the likelihood that an individual selection will lead to a commercial cultivar. A major challenge to breeding new cultivars in perennial tree crop systems is the field space needed to grow a tree to fruiting.

Integrating genetic information into the breeding process to inform selection criteria has proven to increase the probability of identifying top performing hybrids (Hasan et al. 2021). With such an approach, the genetic profile of seedlings can be assayed; and those with inferior genetic combinations can be culled, reducing the number of low-performing hybrids to be evaluated in the field. Without increasing field space, the application of genetic information can increase the likelihood that commercially relevant selections are identified during each breeding cycle.

The research presented here is a case study within the Core Breeding Program in the application of genetic information to facilitate the selection of top-performing scion hybrids. This is a multi-step process that begins with addressing two important questions. First, is there genetic control of characteristics that are relevant to market preferences? If the goal is to increase fruit size, we design an experiment to determine factors that may contribute to variation in fruit size, including environmental factors like tree age or harvest year and genetic factors like the genetic background of scion cultivars and their current rootstock. If scion genotype is a statistically important factor in determining fruit size, we move on to the second question. What is the genetic basis

Table 1. List of 23 fruit characteristics examined in this study.

SIZE TRAITS	TEXTURE TRAITS	COLOR TRAITS	OTHER TRAITS	SHAPE TRAITS
Weight	Texture	Red	Stem angle	Overall roundness
Major diameter	Light scar	Red orange	Calyx size	Flatness
Minor diameter	Dark scar	Dark orange	Stem size	
Volume	Rough skin	Orange		
	Smoothness	Orange yellow		
		Yellow green		
		Green		
		Dark green		
		Yellow		

Members of the CORE breeding program wash fruit with soap and water to ensure material is psyllid-free before transporting to Lindcove Research and Extension Center.

of traits relevant to market preferences? To address this question, we use genetic mapping[2] approaches to pinpoint sections of the genome that are statistically linked to specific traits – in this case, fruit size. This information then can be used to design specific assays, or markers[3], to track relevant genomic regions[4] in populations of new hybrids. With marker-assisted breeding[5], hybrids with genotypic combinations associated with small fruit size then can be culled, even before the tree sets its first fruit.

Beginning in 2020, the Core Citrus Breeding Program started profiling fruit characteristics for 600 accessions maintained in the Givaudan Citrus Variety Collection (GCVC) at UCR. This germplasm collection curates more than 1,000 accessions representing citrus relatives, as well as cultivated accessions, including important breeding parents. Importantly, the GCVC houses immense diversity in both internal and external fruit quality characteristics. In total, more than 100,000 fruit from 557 accessions were evaluated over two years. From each accession, approximately 50 fruit were harvested during an optimal interval for fruit quality and transported to the Lindcove Research and Extension Center for evaluation on the commercial packline. With this large-scale data set, we can evaluate the potential for marker-assisted breeding for scion fruit quality.

We began by addressing our first question. Is there genetic control of fruit quality traits? Because the GCVC is designed as a germplasm repository, trees can vary in both their age and associated rootstock. The relative impact of a factor on a trait is expressed as the "variance explained" by said factor. We estimated the relative impact of scion genotype, rootstock genotype, tree age and harvest year. We found that a majority of the variation in fruit characteristics is due to the effect of the scion (**Figure 1**). The variance explained by the scion genotype ranged from 14-73 percent in this panel of accessions for the 23 assayed packline traits (**Table 1**). The effect of tree age was limited, explaining less than

An example of data collection on the commercial packline at Lindcove Research and Extension Center.

five percent of trait variance across all measured traits. On average, rootstock also explained very little trait variance (less than five percent). However, several traits, including those associated with fruit texture, were substantially influenced by the rootstock. A similar trend was observed for harvest year, which explained very little trait variation, with fruit texture being the trait most influenced by year. Overall, there is a strong influence of scion genotype on external fruit quality traits estimated by the packline, with limited influence of other environmental factors.

With this new knowledge in hand, we moved on to our second question. What is the genetic basis of fruit quality traits? Traditional genetic mapping approaches were used to pinpoint regions of the genome statistically associated with each trait. This work relied on high-density genetic information previously developed for each accession by Mikeal Roose, Ph.D. For 90 percent of measured traits, we were able to pinpoint candidate regions of the genome associated with the fruit quality trait of interest. In summary, we established that there is indeed genetic control of fruit quality traits assayed by the packline; and in most cases, candidate genomic regions associated with each trait were identified.

This research is a first step toward the implementation of marker-assisted selection for fruit quality-related traits. Our future work will focus on integrating marker assays to track some of these regions in breeding populations, with the ultimate goal of ensuring that new hybrids with desirable combinations of fruit quality traits are preferentially evaluated in the field each year.

CRB Research Project #5200-201

Glossary

[1]**Trait:** A quality or characteristic of an organism.

[2]**Genetic mapping:** A method used to reveal the relative locations of genes, or regions, linked to traits of interest.

[3]**Markers:** DNA sequence with known physical location on a chromosome.

[4]**Genomic regions:** A stretch of DNA sequence at a specific location on a chromosome.

[5]**Marker-assisted breeding:** The use of genetic markers as indirect selection criteria in plant breeding.

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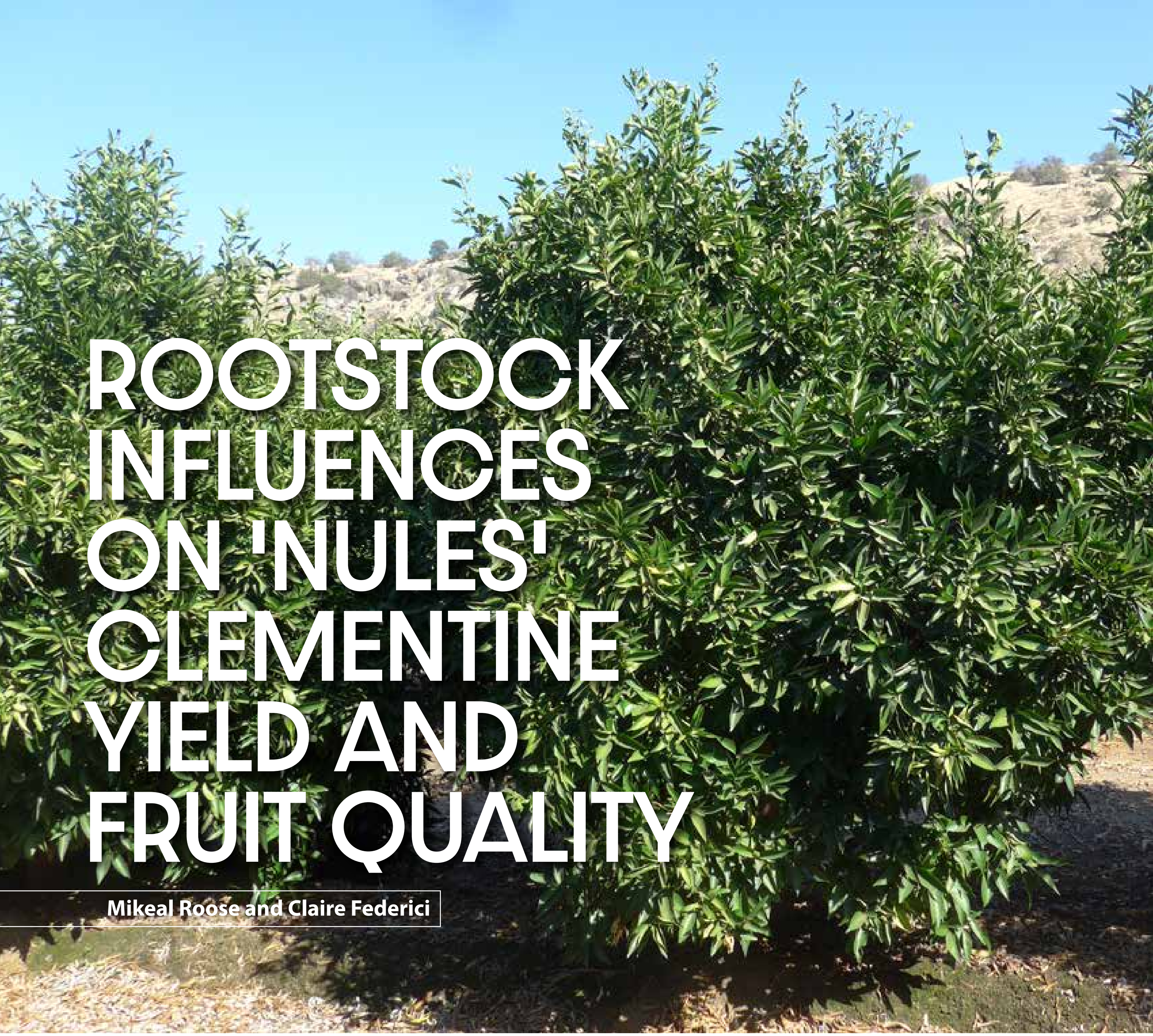


ROOTSTOCK INFLUENCES ON 'NULES' CLEMENTINE YIELD AND FRUIT QUALITY

Mikeal Roose and Claire Federici

Project Summary

Selecting a rootstock is an important decision for citrus growers and is likely to affect the productivity, life and profitability of the planting. There have been few trials in California to evaluate the performance of Clementines on many of the rootstocks now available. This report summarizes results of a San Joaquin Valley trial to evaluate 'Nules' Clementine on 22 released or experimental rootstocks. The largest cumulative yields were from trees on 'C35,' 'Bitters,' 'Rubidoux' trifoliate, 'Australian' trifoliate, 'Swingle' and 'Carrizo,' a group that includes several rootstocks producing smaller-sized trees. Rootstocks also differed in effects on fruit size and internal and external fruit quality. The choice of rootstock requires balancing the many advantages and disadvantages of the various rootstocks available.

Introduction

Clementines are a relatively new crop to California but are the most important early season mandarins in the state. Although Federici et al. (2020) reported on the performance of 10- to 11-year-old 'Tango' mandarins on 21 rootstocks at three locations, there have been few trials to evaluate Clementine performance on different rootstocks. This trial, part of the Citrus Research Board (CRB)-funded Core Breeding and Evaluation project, was planted in 2012 at the University of California-Agriculture and Natural Resources (UC-ANR) Lindcove Research and Extension Center (LREC) in Exeter, California. The site is on a west-facing, gently sloping hillside, with a deep sandy loam soil of neutral pH. Rootstocks (**Table 1**) were selected based on promising results in trait evaluation studies and good performance in trials with other scions. The trees were grown in a nursery at the LREC using budwood from the Citrus Clonal Protection Program budded onto seedling rootstocks. They were planted on berms in September 2012 with 12 replicates, each containing one tree on each rootstock. Trees were pruned annually after 2015 to permit application of nets to exclude bees and prevent seediness.

Tree size, health and bud union data collected in July 2022 are reported here. Canopy volume was calculated as tree height x tree width down row x tree width across row/4. Tree health ratings were 0 (dead) to 5 (excellent) and reflect mainly canopy density. Dead trees were treated as missing.

Table 1. Rootstocks included in the 'Nules' Clementine trial, abbreviations used in the text and status of whether they are publicly released or still experimental.

ROOTSTOCK	ABBREV.	ROOTSTOCK TYPE	STATUS
African Shaddock x 'Rubidoux' trifoliate	ASRT	Trifoliate hybrid	Released
'Australian trifoliate #22'	AUST	Trifoliate orange	Experimental
'Bitters' (C22) (Sunki x Swingle trifoliate)	BITT	Trifoliate hybrid	Released
'Brazilian' Sour Orange	BRSR	Other citrus	Released
'C146' (Sunki x Swingle trifoliate)	C146	Trifoliate hybrid	Released
'C35' citrange	C35	Trifoliate hybrid	Released
'Carrizo' citrange	CARR	Trifoliate hybrid	Released
'Cleopatra' mandarin	CLEO	Other citrus	Released
'Furr' (C57) (Sunki x Swingle trifoliate)	FURR	Trifoliate hybrid	Released
Macrophylla	MACR	Lemon	Released
'Pomeroy' trifoliate	POMT	Trifoliate orange	Released
'Rich 16-6' trifoliate	RICH	Trifoliate orange	Released
'Rubidoux' trifoliate	RUBT	Trifoliate orange	Released
Rangpur x 'Marks' trifoliate	RxMT	Trifoliate hybrid	Experimental
Rangpur x Shekwasha	RxSH	Lemon	Experimental
Rangpur x Swingle trifoliate	RxSW	Trifoliate hybrid	Experimental
Shekwasha x 'English' trifoliate	SHET	Trifoliate hybrid	Experimental
'Schaub' rough lemon	SHRL	Lemon	Released
'Sun Chu Sha Kat' mandarin	SUNC	Other citrus	Released
'Swingle' citrumelo	SWIN	Trifoliate hybrid	Released
'Tosu' sour orange hybrid	TOSU	Other citrus	Released
'Volkameriana'	VOLK	Lemon	Released

Tree Size and Yield

Tree survival was high (97 percent) with only seven trees dying from rodent damage or other accidents relatively soon after planting. Rootstocks with the highest cumulative yield were 'C35,' 'Bitters,' 'Rubidoux' trifoliate, 'Australian' trifoliate, 'Swingle' and 'Carrizo,' and those with the lowest yields were 'Sun Chu Sha Kat,' 'Tosu,' 'Cleopatra,' 'Schaub' rough lemon and 'Brazilian' sour (**Table 2**). Trees on 'Sun Chu Sha Kat' produced such low yields that they were outliers and were excluded from some statistical analyses. Yields in 2021 and 2022 showed mostly similar patterns to the cumulative yield. In earlier years, it had appeared that trees on trifoliate orange rootstocks had less alternate bearing than others, but this pattern did not continue.

Trees on ASRT, 'Furr,' 'Brazilian' sour, 'C146' and 'Pomeroy' trifoliate produced the largest canopies with 'Sun Chu Sha Kat' and 'Swingle' similar to 'Pomeroy;' but of these, only 'Swingle' was in the high-yielding group. The smallest tree canopies in 2022 were those on 'Rich 16-6' trifoliate, Macrophylla, Shekwasha x 'English' trifoliate, Rangpur x Shekwasha, and 'Australian' trifoliate, rootstocks with both fairly high and low yields. The highest cumulative yield relative to canopy volume was for trees on 'C35,' 'Rich 16-6,' 'Australian' trifoliate, 'Bitters' and Macrophylla. Considering only yields in 2021 and 2022, the rootstocks with high yields for their size were 'C35,' 'Carrizo,' Macrophylla and Rangpur x 'Marks' trifoliate.

Table 2. Average cumulative yields for 2014-22; combined yield for 2021 and 2022; 2022 canopy volume; cumulative yield to canopy volume ratio; 2022 tree health rating from 0 (dead) to 5 (excellent); and bud union rating which is a visual estimate of the ratio of scion/rootstock width at four centimeters above and below the union, with rating 1=ratio of 0.5, 2=0.62, 3= 0.75, 4= 0.87, 5=1.0, and 6= 1.13. The five largest and five smallest values are colored orange and blue, respectively. Rootstock trait values within one percent of the five largest ranked stocks are shown in dark orange. All traits had statistically significant differences across the rootstocks tested.

ROOTSTOCK	Cum. Yield (lb/tree)	2021 + 2022	CANOPY VOLUME (CU FT)	YIELD/ CANOPY (LB/CU FT)	TREE HEALTH RATING (0-5)	UNION RATING (1-6)
'ASRT'	841	209	368	2.37	4.79	2.96
'Australian trif. #22'	1016	263	281	3.70	4.17	2.42
'Bitters' (C22)	1025	258	285	3.65	4.38	3.79
'Brazilian' Sour	769	205	324	2.37	4.25	4.67
'C146'	928	297	318	2.95	4.25	2.50
'C35'	1217	355	299	4.09	4.04	3.25
'Carrizo'	1008	331	289	3.53	4.08	2.92
'Cleopatra'	716	206	306	2.36	4.21	4.25
'Furr' (C57)	906	260	330	2.82	4.50	2.88
Macrophylla	930	279	262	3.63	4.25	4.71
'Pomeroy' trifoliate	952	268	315	3.13	4.21	1.83
'Rich 16-6' trifoliate	911	263	258	3.71	4.08	3.00
'Rubidoux' trifoliate	1023	278	310	3.38	4.29	2.96
Rangpur x 'Marks' trifoliate	970	299	290	3.35	4.08	2.88
Rangpur x Shekwasha	808	227	274	3.03	4.32	4.14
Rangpur x Swingle trifoliate	798	213	307	2.57	4.33	3.21
Shekwasha x Eng. trifoliate	822	256	271	3.14	4.50	3.42
'Schaub' rough lemon	720	181	294	2.47	4.33	4.00
'Sun Chu Sha Kat'	258	73	314	0.79	3.46	4.42
'Swingle' citrumelo	1013	299	314	3.27	4.29	1.83
'Tosu'	581	174	303	1.95	3.43	3.67
'Volkameriana'	907	246	297	3.14	4.32	4.14
LSD (0.05)	126	52.1	41.1	0.42	0.39	0.36

Figure 1. Plots of rootstock means for combinations of yield and fruit quality traits in November 2022. Trifoliate orange rootstocks are indicated by orange triangles, lemon-type rootstocks by yellow circles, other citrus rootstocks by teal squares and trifoliate hybrids by blue circles. See Table 1 for rootstock abbreviations. A. Average weight per fruit in grams (g) vs. average number (No.) of fruit per tree. B. Total number of fruit per tree vs. number of large (over 2.25-inch diameter) to mammoth (up to three-inch diameter) size fruit per tree. C. Percent (%) of rind graded as yellow-green in early (November 3) vs. late (November 28) harvests. D. Brix values measured by packline in early vs. late November.

FIGURE 1A

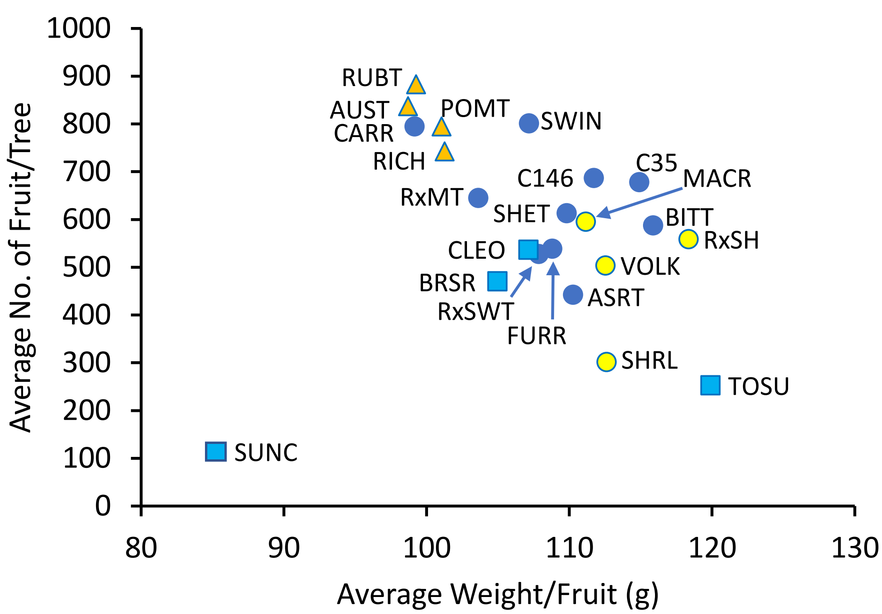
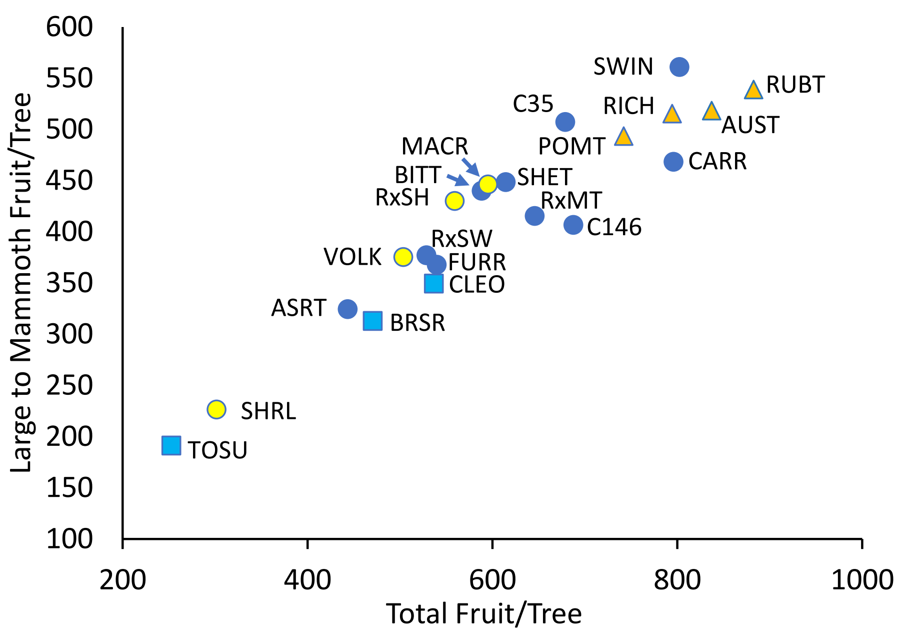


FIGURE 1B



(Figure 1 is continued on the next page)

The trees on most rootstocks had very good health ratings with the exception of 'Sun Chu Sha Kat' and 'Tosu,' which were moderate. In this trial, only 'Pomeroy' trifoliate and 'Swingle' caused considerable shoulder development at the bud union, which sometimes predicts declines in older trees.

Packline and Fruit Quality

Packline analyses of all fruit harvested revealed the distribution of fruit size, rind color, rind texture and other traits from trees on different rootstocks. Based on the November 2021 data, trees grown on 'Volk,' 'Tosu,' 'Rich 16-6' trifoliate, Rangpur x 'Marks' trifoliate and 'C35' had the highest percentage of fruit in large, jumbo and mammoth categories (combined). However, 'Tosu' and 'Rich 16-6' did not have particularly high yields in 2021; so for the total number of fruit in these categories, these two rootstocks were replaced by 'Carrizo' and 'C146.' Trees grown on 'Australian' trifoliate, 'Pomeroy' trifoliate, Rangpur x Shekwasha and 'Sun Chu Sha Kat' produced a low number and a low percentage of fruit in these size classes. Based on the 2022 rootstock means (**Figure 1A**), there was a clear correlation between the average fruit weight and average number of fruit per tree. Furthermore, closely related rootstocks, such as the four trifoliate orange selections, cluster together (high fruit number, but lower weight per fruit) as do the four lemon type rootstocks (large fruit size, but lower number per tree). Trifoliate hybrids and other citrus types are more scattered, but generally intermediate. However, the number of large to mammoth fruit was closely related to the total number of fruit per tree, so that rootstocks with the most fruit in this valuable category were those from trees on trifoliate oranges, 'Swingle,' 'C35' and 'Carrizo' (**Figure 1B**).

Development of rind color in this trial also was affected by rootstock. **Figure 1C** shows that most rootstocks in this trial had 45-65 percent of rind measured as yellow-green in early November, with most of the rest being orange-yellow;

whereas by late November, the percent yellow-green declined as orange increased. Fruit from trees on three lemon-type rootstocks and three citrus rootstocks had more yellow-green rind than most others in early November and retained more of this color in late November than those on other rootstocks. Trees grown on trifoliates and some trifoliate hybrids in this trial had a low percent of yellow-green rind by late November. It also is interesting that trees on Macrophylla behaved more like trifoliate hybrids than other lemon-type rootstocks for rind color development.

Rootstocks also affected internal fruit quality traits such as Brix (**Figure 1D**). Between early and late November, average Brix (as measured by the packline) increased from 9.4 to 11.4. The lower Brix of fruit from trees on lemon-type rootstocks was evident at both harvests. Trifoliates, some trifoliate hybrids and 'Brazilian' sour orange produced fruit with high Brix. Siblings 'Bitters,' 'Furr' and 'C146' had relatively low Brix in November, particularly 'Bitters' in early November. This prompted us to examine data on Brix of mandarins on this rootstock from other years and other trials. In earlier data, Brix measured on the packline was sometimes low relative to 'Carrizo' and 'C35,' but this was rarely seen in Brix data measured by titration. Fruit from trees on 'Bitters' may have some other characteristic that affects Brix measurements on the packline, but we did not find higher granulation.

Effects of rootstocks on internal fruit quality generally were like those seen with other scion varieties. Federici et al. (2020) found similar patterns with 'Tango' mandarins on a similar set of rootstocks grown at three sites in California. Trees grown on lemon type rootstocks had lower Brix and acid,

FIGURE 1C

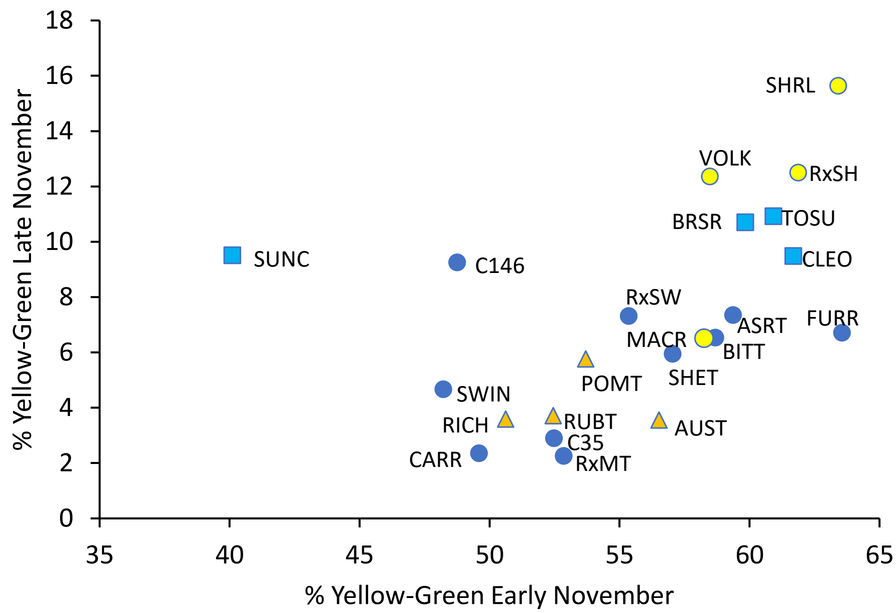
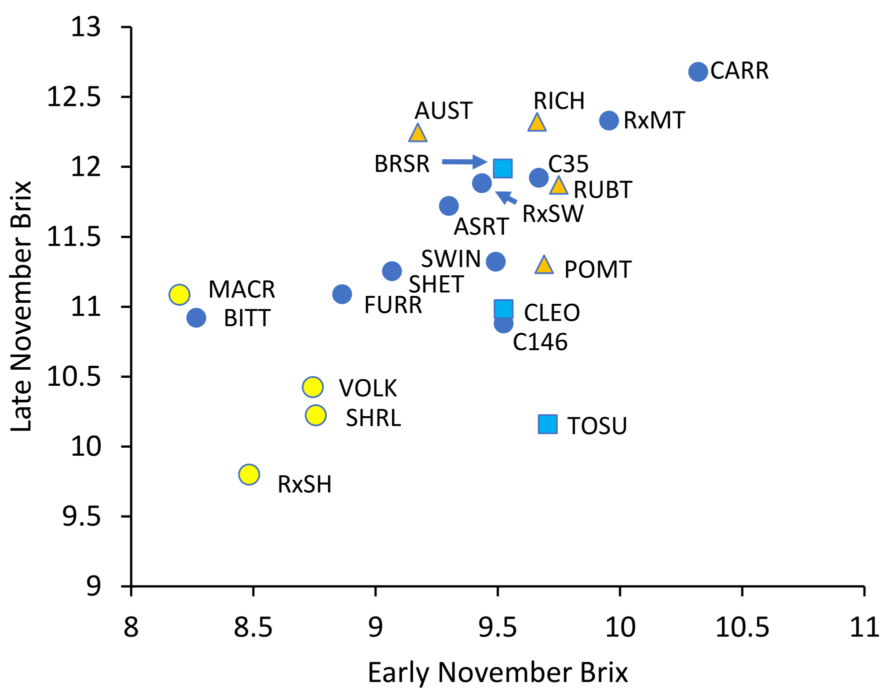


FIGURE 1D



whereas ASRT, 'Australian' trifoliate, 'C35,' 'Carrizo' and other trifoliate oranges generally had high values for Brix and acid. The solids to acid ratios often were not statistically significantly different among rootstocks, although its components often had significant differences.

Conclusions

In this trial, trees grown on rootstocks with the highest cumulative yields were 'C35,' 'Bitters,' 'Carrizo,' 'Australian' trifoliate, 'Rubidoux' trifoliate, Rangpur x 'Marks' trifoliate and 'Swingle.' All of these had good health ratings and a generally positive influence on fruit quality. The bud union ratings of 'Pomeroy' and 'Swingle' indicate enough shoulder development to be of concern for long-term tree health. Results of this trial are expected to apply to many areas in the San Joaquin Valley with similar, sandy-loam soils of neutral pH. Different results are likely on more calcareous soils or where soil or water has substantial salinity.

CRB Research Project #5200-201

Reference

Federici, C.T; Kupper, R.; Roose, M.L., 2020. Rootstocks affect performance of 'Tango' mandarin. *Citrograph* 11(3):56-60.

Acknowledgement

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NEW MANDARIN CULTIVARS Have Potential to Diversify Market

Toni Siebert Wooldridge, Karene Trunnelle, Toan Khuong and Tracy Kahn

Project Summary

Newly introduced mandarin varieties that serve specific market niches can provide growers a way to diversify their citrus crop portfolio. This report describes fruit quality evaluations of two varieties currently cataloged on the Citrus Clonal Protection Program's (CCPP) "Early Release" list. This list allows customers early access to varieties with limited budwood availability due to their recent release status. One of these, Shiranui mandarin, was compared with the industry standard Tango at two locations: the University of California (UC) Lindcove Research and Extension Center (LREC) in Exeter and the University of California, Riverside (UCR) Givaudan Citrus Variety Collection (GCVC) in Riverside, California. Shiranui is known for its sweetness, large size, seedlessness and prominent neck at the top of the fruit that gives it a unique and distinctive shape. Shiranui fruit had higher Brix-to-acid ratio than Tango at both locations and from both sample periods, except for the January sample date at the Lindcove location. The higher Brix-to-acid ratio of Shiranui fruit relative to Tango mandarin is reflected in the lower titratable acidity of Shiranui mandarin.

Another "Early Release" variety, Tieu mandarin, is considered an important commercial mandarin in Vietnam. "Tieu" translates to "black pepper" and reflects the aromatic black pepper aroma of the fruit. Across all sample dates, Tieu fruit grown in Riverside had higher Brix than the control variety, Avana tardivo di Ciaculli mandarin. The titratable acidity for both varieties decreased over the six sample dates from December to April, which reflects the ability of both cultivars to hang well on the tree, while the Brix-to-acid ratio for both varieties remained similar. This and additional fruit characteristic differences for these two varieties provide growers with information to make an informed decision on which variety to select.

Introduction

Not that long ago in the United States, all mandarin varieties were relegated solely to the specialty citrus market. In the early 1980s, the story began to change with the first importation of Clementine mandarins into the northeast region of the United States from Spain. Popularity continued to grow over the years and became a catalyst for California growers to increase acreage of Clementine selections and other mandarins. Today, more than 67,000 acres of mandarin and mandarin hybrids are now planted across the state (CASS 2022).

But where do new California mandarin cultivars come from? Within the UCR citrus breeding program, methods employed include traditional citrus breeding, which involves crossing two selected parent cultivars to generate new hybrid seedlings. The original hybridization that produced Gold Nugget, a late-maturing and seedless mandarin created and evaluated at UCR, was released in 1999 (Roose et al. 2000). Mutation breeding, a more modern method also utilized by the citrus breeding program, is performed to induce a small genetic change, typically seedlessness. Tango mandarin, derived from W. Murcott Afourer in 2006, was developed at UCR using this method (Roose and Williams 2006). Yet, many mandarin varieties also continue to be introduced from within or outside California. Introduced varieties can originate as hybrids, bud sports, nucellar seedlings, products of mutation breeding or through other approaches. Each method seeks to capture potentially valuable genetic variation, which then can be utilized in the selection of new varieties based on commercially desirable characters and/or DNA markers or known gene sequences. All require a range of trial evaluations, from small scale tree and fruit quality evaluations to large replicated multi-location trials to verify commercial potential relative to existing commercial controls.

This article reports on two introduced varieties, Shiranui mandarin and Tieu mandarin, currently included on the CCPP's "Early Release" list with limited budwood available to registered users for propagation in California. Shiranui mandarin was compared with control Tango mandarin from 2020 to 2022. Tieu mandarin was compared with Avana tardivo di Ciaculli, a selection of Willowleaf mandarin with a similar fruit maturation window, from 2017 to 2022. The research results reported within this article are just a small part of a much larger Citrus Research Board (CRB)-funded project entitled "Integrated Citrus Breeding and Evaluation for California" (Project #5200-201). This project is designed to provide and evaluate new scion and rootstock cultivars for California to help growers and the industry make informed decisions when selecting future citrus varieties.

Shiranui Mandarin

Shiranui mandarin is a hybrid of Kiyomi tangor and Nakano No.3 Ponkan developed in 1972 at the Kuchinotsu National Institute of Fruit Tree Science in Japan (Matsumoto 2001). Shiranui is often referred to as Dekopon, which is the trademark name for Shiranui in Japan. Since its development, there have been three introductions of Shiranui into California, the first under the trademark Sumo Citrus® and the second called Guilietta. We are reporting on the third Shiranui accession in this article (variety index[1] [VI] 860 in the CCPP system) since it is the only publicly available introduction. This accession was imported into the Citrus Research Institute of Chinese Academy of Agricultural Sciences, located in Chongqing, China, by way of Japan in 1993. In 2012, it was submitted to the CCPP for clean-up

Table 1. Means and standard errors (in parentheses) of selected fruit quality characteristics for Shiranui mandarin conducted from 2020-22 compared to the standard Tango mandarin for two sample date ranges from trees in Riverside and Lindcove, California. CZO = Carrizo citrange, C-35= C35 Citrange and FD = Flying Dragon trifoliate orange. Color rating of rind = rind with rating of 3 is dark green, 5 is color break and 13 orange red.

Cultivar_RS_Month	Month	Location	Cultivar	Rootstock	No. of observations	Titratable acidity	Standard error	Brix	Standard error
Shiranui_CZO_Dec_Riverside	Late Nov. - Dec.	Riverside	Shiranui	CZO	7	1.2	0.1	13.7	0.2
Tango_C35_Dec_Riverside			Tango	C35	4	1.2	0.1	12.1	0.2
Tango_FD_Dec_Riverside			Tango	FD	4	1.5	0.1	12.7	0.4
Shiranui_CZO_Dec_Lindcove		Lindcove	Shiranui	CZO	3	0.7	0.1	10.2	0.5
Shiranui_C35_Dec_Lindcove			Shiranui	C35	4	0.8	0.1	10.7	0.5
Tango_CZO_Dec_Lindcove			Tango	CZO	3	1.8	0.0	11.8	0.8
Tango_C35_Dec_Lindcove			Tango	C35	4	1.8	0.1	12.1	0.5
Shiranui_CZO_Jan_Riverside	Jan	Riverside	Shiranui	CZO	5	1.2	0.1	14.2	0.5
Tango_C35_Jan_Riverside			Tango	C35	4	1.2	0.1	13.5	0.4
Tango_FD_Jan_Riverside			Tango	FD	4	1.6	0.1	14.3	0.8
Shiranui_CZO_Jan_Lindcove		Lindcove	Shiranui	CZO	2	0.6	0.0	10.6	0.4
Shiranui_C35_Jan_Lindcove			Shiranui	C35	2	1.0	0.4	10.2	0.3
Tango_CZO_Jan_Lindcove			Tango	CZO	3	1.4	0.1	12.5	0.5
Tango_C35_Jan_Lindcove			Tango	C35	2	0.9	0.3	12.0	0.3

Left and Right: Shiranui fruit quality evaluation in the Givaudan Citrus Variety Collection fruit quality laboratory. December 12, 2019.
Photos by Toni Siebert Wooldridge and Karene Trunnelle

by the Citrus Research Institute of Chinese Academy of Agricultural Sciences. The GCVC received budwood of this variety in December 2016 as soon as it was released from quarantine. All three lines of Shiranui are reported to have been produced from the original hybrid tree and appear to be the same basic cultivar with very similar tree and fruit traits.

As shown in **Table 1**, in late November–December in 2020-22, Riverside-grown Shiranui fruit had higher Brix than Tango in contrast to Lindcove-grown fruit where Tango had higher Brix on both rootstocks at the same sample date. For the January sample date 2020-22, Riverside-grown Shiranui fruit had similar Brix levels when grown on Carrizo rootstock to Tango. In contrast, like the earlier sample dates at Lindcove for the January sample dates, Tango fruit had higher Brix than Shiranui fruit on either rootstock (**Table 1**). Regarding titratable acidity, during the early sample period, Riverside-grown Shiranui and Tango fruit were similar in acidity on citrange rootstocks, but Lindcove-grown Shiranui fruit had significantly lower titratable acidity than Tango fruit (**Table 1**). Shiranui fruit had higher Brix-to-acid ratio than Tango at both locations and from both sample periods, except the January sample date when Shiranui and Tango fruit had more

Table 1 (Continued)

Brix-to-acid ratio	Standard error	Avg. fruit width	Standard error	Height-to-width ratio of fruit	Standard error	Color rating of rind	Standard error	Seed number per fruit	Standard error
11.4	1.0	7.5	0.4	0.96	0.04	8.1	0.5	27.6	12.2
9.9	0.8	6.1	0.1	0.74	0.01	5.3	0.3	12.3	5.5
8.8	1.2	5.5	0.1	0.77	0.01	5.5	0.5	9.3	0.9
14.8	1.8	7.5	0.4	1.00	0.02	8.2	1.6	74.0	11.0
13.6	1.5	8.4	0.6	1.01	0.01	8.3	1.2	54.5	9.7
6.8	0.5	5.7	0.2	0.79	0.01	10.3	1.7	7.3	0.7
6.9	0.2	5.6	0.4	0.88	0.12	8.8	1.9	7.8	2.4
12.4	1.0	7.1	0.6	1.02	0.02	10.5	0.3	38.2	21.3
11.4	0.7	6.0	0.2	0.76	0.00	12.3	0.3	6.3	1.4
9.3	0.9	5.2	0.4	0.92	0.13	12.3	0.3	10.3	2.6
17.5	1.0	7.1	0.2	1.02	0.03	11.4	0.4	89.0	8.0
12.5	5.2	6.7	0.1	1.01	0.00	11.4	0.4	16.5	2.5
9.1	0.8	5.9	0.0	0.78	0.03	9.7	2.3	9.7	2.3
14.3	4.5	5.3	0.7	0.90	0.10	12.0	0.0	5.0	0.0

similar Brix-to-acid ratio at Lindcove (**Table 1**). The higher Brix-to-acid ratio of Shiranui fruit relative to Tango mandarin is reflected in the lower titratable acidity of Shiranui mandarin.

Differences between the width and the height-to-width ratio of Shiranui and Tango fruit reflected the larger size and distinctive shape of Shiranui fruit with its prominent neck at the top or stem-end of the fruit relative to the more typical mandarin shape of Tango fruit (**Table 1**). Another distinctive result was the seed number per fruit at both Riverside and Lindcove, where trees are grown in mixed variety blocks under open pollination conditions (**Table 1**). Shiranui remains seedy in both Riverside and Lindcove locations. We have spoken to growers of this introduction about the seediness issue. One told us that the fruit are seedless when grown in isolation from other pollen sources that are "far away." Another grower reported that their fruit is seedier depending on the type of nearby pollen sources, such as pummelos. This suggests that Shiranui is likely to be self-incompatible[2], similar to what is known about Clementine mandarins. This theory could be investigated further by shielding Shiranui flowers from outside pollination sources and performing a pollination test to identify pollen tube growth characteristics specific to self-incompatibility. Although reported to be somewhat challenging to cultivate, Shiranui, with its unconventional shape, large size and high Brix, has the potential to add market diversity and serve a specific niche market to attract new consumers.

Tieu Mandarin

Tieu mandarin (VI 997) is considered one of the most important commercial mandarin cultivars in Vietnam. The word "Tieu" means black pepper and reflects the very aromatic black pepper aroma of this variety. Seeds of this variety were received by the U.S. Department of Agriculture National Clonal Repository for Citrus and Dates in Riverside from Vietnam and resulted in two trees that were planted in 2009 in the GCVC. In February 2017, a Vietnam-born American citizen accompanied Dan Willey to the GCVC as part of the latter's CRB-funded project #5200-172 to identify varieties that might be at risk of being smuggled into California and possibly introducing new or foreign graft-transmissible citrus pathogens into the country. The importance of this variety in Vietnam was understood as the visitor declared, "This is the mandarin of my childhood!"

As shown in **Table 2**, fruit quality characteristics of Tieu mandarins were compared with those of Avana tardivo di Ciaculli as the control with similar maturity timing based on trees grown in Riverside. Across the sample dates, Tieu fruit grown in Riverside had higher Brix than the control variety.

Table 2. Means and standard errors (in parentheses) of selected fruit quality characteristics for Tieu mandarin cultivar conducted from 2017-22 compared to the standard Avana tardivo di Ciaculli mandarin for six sample date ranges from trees in Riverside California. CZO = Carrizo citrange and TROY = Troyer Citrange. Color rating of rind = rind with rating of 3 is dark green, 5 is color break and 13 orange red.

Cultivar_RS_Month	Date	Cultivar	Rootstock	No. of observations	Titratable acidity	Standard error	Brix	Standard error
Tieu_CZO_Dec	Dec	Tieu	CZO	5	2.1	0.2	12.5	0.4
Tieu_Troy_Dec	Dec	Tieu	Troy	5	2.2	0.2	12.8	0.3
Avana tardivo_CZO_Dec	Dec	Avana tardivo	CZO	3	1.9	0.2	11.0	0.4
Avana tardivo_C35_Dec	Dec	Avana tardivo	C35	5	2.4	0.1	11.4	0.4
Tieu_CZO_Early Jan	Early Jan	Tieu	CZO	4	2.0	0.2	14.0	0.5
Tieu_Troy_Early Jan	Early Jan	Tieu	Troy	4	2.1	0.2	14.3	0.3
Avana tardivo_CZO_Early Jan	Early Jan	Avana tardivo	CZO	3	1.5	0.1	12.4	0.4
Avana tardivo_C35_Early Jan	Early Jan	Avana tardivo	C35	4	2.1	0.2	12.7	0.4
Tieu_CZO_Late Jan	Late Jan	Tieu	CZO	3	1.7	0.4	15.0	0.4
Tieu_Troy_Late Jan	Late Jan	Tieu	Troy	3	1.8	0.2	16.4	0.3
Avana tardivo_CZO_Late Jan	Late Jan	Avana tardivo	CZO	2	1.3	0.2	13.1	0.5
Avana tardivo_C35_Late Jan	Late Jan	Avana tardivo	C35	3	1.5	0.2	13.1	0.5
Tieu_CZO_Feb	Feb	Tieu	CZO	4	1.6	0.1	15.8	0.6
Tieu_Troy_Feb	Feb	Tieu	Troy	4	1.6	0.1	16.9	0.6
Avana tardivo_CZO_Feb	Feb	Avana tardivo	CZO	3	1.2	0.1	13.7	0.4
Avana tardivo_C35_Feb	Feb	Avana tardivo	C35	3	1.3	0.1	14.0	0.4
Tieu_CZO_Mar	Mar	Tieu	CZO	3	1.3	0.1	17.7	0.6
Tieu_Troy_Mar	Mar	Tieu	Troy	3	1.3	0.1	17.9	0.9
Avana tardivo_CZO_Mar	Mar	Avana tardivo	CZO	3	0.9	0.1	14.5	0.9
Avana tardivo_C35_Mar	Mar	Avana tardivo	C35	2	1.1	0.1	14.8	0.7
Tieu_CZO_Apr	Apr	Tieu	CZO	2	1.1	0.2	16.0	1.1
Tieu_Troy_Apr	Apr	Tieu	Troy	2	1.4	0.1	16.3	1.7
Avana tardivo_CZO_Apr	Apr	Avana tardivo	CZO	2	1.0	0.2	14.0	0.8
Avana tardivo_C35_Apr	Apr	Avana tardivo	C35	1	1.2	-	15.1	-
				Only 1 observation				

Note: November 29, 2021, was combined with December data, due to lack of observations.

Left and right: Shiranui fruit on young tree, on Carrizo rootstock, growing in the Givaudan Citrus Variety Collection. December 9, 2019. ***Photos by Toni Siebert Wooldridge and Karene Trunnelle.***

Table 2 (Continued)

Brix-to-acid ratio	Standard error	Avg. fruit width	Standard error	Height-to-width ratio of fruit	Standard error	Color rating of rind	Standard error	Seed number per fruit	Standard error
6.2	0.7	5.3	0.1	0.81	0.05	9.0	1.9	15.0	3.1
6.1	0.6	5.3	0.2	0.83	0.06	7.9	1.6	14.0	3.9
6.0	0.4	5.2	0.1	0.90	0.05	4.0	0.3	11.2	1.4
4.8	0.2	4.8	0.1	0.89	0.04	4.1	0.4	12.1	1.3
7.3	0.9	5.5	0.3	0.74	0.01	12.1	0.0	17.2	1.9
6.9	0.8	5.5	0.2	0.76	0.01	12.1	0.0	15.5	1.6
8.4	0.5	5.5	0.1	0.89	0.03	7.2	1.5	8.8	1.5
6.1	0.6	5.1	0.3	0.87	0.04	5.6	0.7	11.8	1.5
9.6	2.4	5.7	0.3	0.74	0.01	12.2	0.2	17.2	2.1
9.7	1.3	5.9	0.1	0.74	0.01	12.0	0.3	13.9	4.9
10.3	1.8	5.5	0.0	0.87	0.07	9.3	1.8	8.4	1.3
9.1	1.2	5.4	0.4	0.89	0.06	7.5	1.6	10.1	0.4
10.3	1.2	5.6	0.3	0.75	0.00	12.6	0.2	17.3	2.3
10.8	1.0	5.5	0.3	0.75	0.01	12.3	0.2	15.0	0.7
12.0	0.9	5.6	0.1	0.91	0.07	10.8	0.4	9.3	1.5
10.4	0.5	5.1	0.1	0.84	0.03	10.8	0.4	12.8	2.0
14.1	1.0	5.7	0.5	0.76	0.01	12.3	0.2	14.8	1.9
13.9	1.2	5.5	0.3	0.75	0.01	12.3	0.2	16.6	0.7
15.8	0.9	5.8	0.1	0.90	0.06	11.3	0.3	9.9	1.8
13.7	0.8	5.3	0.2	0.85	0.02	11.1	0.1	9.8	0.6
14.8	3.4	5.7	0.5	0.76	0.01	12.4	0.2	17.1	0.2
11.7	2.0	5.6	0.2	0.77	0.02	12.0	0.0	16.1	0.4
14.6	1.7	5.8	0.1	0.80	0.01	11.5	0.5	10.4	1.2
12.4	-	5.7	-	0.79	-	11.0	-	11.1	-

Productive young Tieu mandarin tree growing on Carrizo rootstock in the Givaudan Citrus Variety Collection. March 10, 2012. ***Photo by David Karp and Toni Siebert Wooldridge.***

Titratable acidity percent, based on citric acid, was similar at each sample date for Tieu and Avana tardivo di Ciaculli, with Tieu tending to be slightly higher on average at each date (**Table 2**). The titratable acidity for both varieties decreased over the six sample dates from December to April, which reflects the ability of both cultivars to hang well on the tree (**Table 2**). The Brix-to-acid ratio for both varieties also was similar among cultivars at each sample date and increased over the six sample dates, except for Avana tardivo di Ciaculli fruit on Carrizo citrange rootstock, which was significantly higher (**Table 2**).

For the December through late January sample dates, Tieu fruits were wider than Avana tardivo di Ciaculli fruit, except for trees grown on Carrizo rootstock. For February through April sample dates, fruit were similar in width, except for those grown on Carrizo rootstock (**Table 2**). Tieu fruit were less spherical in shape, and the rind was more highly colored (**Table 2**). Tieu fruit were seedier than Avana tardivo di Ciaculli fruit, although both varieties produce seedy fruit (**Table 2**). Although seedy fruit is often considered less desirable, varieties such as Tieu that are culturally important could be a potential market opportunity.

Two sources of additional information for newly introduced varieties on the CCPP "Early Release" list are available:

1. a video recording of the CRB webinar series "Rootstocks characteristics and new scions for California," presented June 28, 2022, (*https://youtu.be/qjAg5DELdsQ*) ; and

2. the GCVC website (*http://citrusvariety.ucr.edu*), a resource for the citrus industry on citrus varieties and species.

Information about each variety and species, including their

Tieu mandarin fruit. March 10, 2012. *Photo by David Karp and Toni Siebert Wooldridge.*

pedigree or source and background, as well as tree, leaf, flower and fruit photographs easily can be located using drop-down headers and search tools, either alphabetically or by type, or for introduced varieties, with fruit quality evaluation data. To obtain budwood of any of these newly introduced cultivars, please visit the Citrus Clonal Protection Program website at *http://ccpp.ucr.edu*

CRB Research Project #5200-201

Glossary

[1]**Variety Index (VI) Number:** Assigned to a cultivar that has completed a set of diagnostic tests, including bio-indexing and laboratory tests used to detect all known graft-transmissible pathogens of citrus that are required before release from quarantine can be requested.

[2]**Self-incompatibility:** A genetically-based mechanism that prevents self-fertilization. Self-incompatible varieties will produce seedless fruit if cross pollination is prevented through isolation or netting of trees during flowering.

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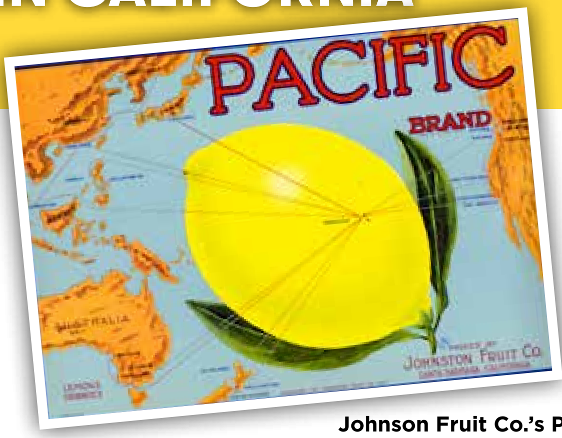
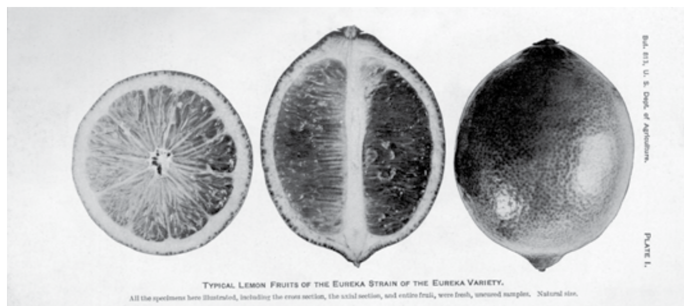
A DIFFERENT KIND OF GOLD RUSH

THE EUREKA LEMON IN CALIFORNIA



Johnson Fruit Co.'s Pacific lemon crate label from 1917.

A Eureka lemon tree pictured in the 1920 USDA Bulletin, *Citrus-Fruit Improvement: A Study of Bud Variety in the Eureka Lemon.*



Cross-sections of Eureka lemon pictured in the 1920 USDA Bulletin, *Citrus-Fruit Improvement: A Study of Bud Variety in the Eureka Lemon.*

Written histories of the California citrus industry tend to gravitate toward oranges. True, the Washington navel and Valencia varieties had a transformative impact on the Golden State. However, lemons proved equally critical to the financial success of agribusiness in California, including a variety that was developed here.

The Eureka variety of lemon came into being in Los Angeles in the mid-nineteenth century. In 1858, a local physician named Dr. Halsey imported Sicilian lemons from New York to Los Angeles. By approximately 1870, his trees began to bear a smoother, thinner variety of lemon than previous types of this tree had produced. Buds from the trees eventually ended up in the nursery of Thomas A. Garey, a noted botanist based in the City of Angels. Garey propagated the buds around 1880, christening their fruit as Eureka lemons. This name hearkened back to a phrase associated with the Gold Rush, linking the California citrus industry to that seminal historical event.

Before long, Eureka lemons evolved into one of the preferred strains of that fruit grown in southern California's citrus empire. Eureka lemon trees particularly thrived near the coast of southern California, where they could escape the frosts that periodically afflicted inland areas. Enormous lemon groves spanned the citrus empire from Santa Barbara to San Diego County. Two of the largest lemon production facilities existed at Corona in Riverside County and at Limoneira in Santa Paula, Ventura County. At the latter, manager Charles Teague became so successful at growing lemons that he ascended to the presidency of the California Fruit Growers Exchange, later known as Sunkist.

The "Gold Rush" wrought by Eureka lemons solidified California's reputation as America's citrus heartland. By 1900, growers in the Golden State shipped 43 million pounds of lemons. Within 15 years, this had ballooned to 212 million pounds. As the "Eureka" name implied, Californians had struck gold once again.

***For more information, contact* bjenkins@laverne.edu**

Courtesy of Benjamin Jenkins, Ph.D.
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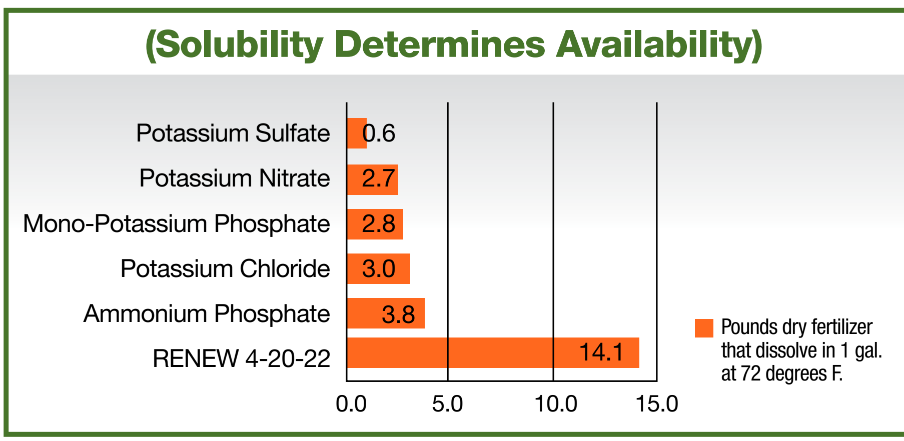

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