CALIFORNIA AVOCADO COMMISSION
PRODUCTION RESEARCH COMMITTEE
MEETING MINUTES

July 27, 2022

A web/teleconference meeting of the Production Research Committee (PRC) of the California Avocado Commission (CAC) was held on Wednesday July 27, 2022 with the following people participating:

MEMBERS PARTICIPATING VIA TELECONFERENCE:
Leo McGuire, Chair
Bryce Bannatyne
John Burr
Jason Cole
Jim Davis
Consuelo Fernandez
Darren Haver (9:10)
Ryan Rochefort
Rob Grether, *Ex Officio*

CAC STAFF PARTICIPATING:
April Aymami
Ken Melban

OFFICIALLY PARTICIPATING:
Dr. Tim Spann, Spann Ag Research & Consulting
Peggy Mauk, University of California, Riverside

GUESTS PARTICIPATING:
Kathryn Uhrich, Dean, College of Natural & Agricultural Sciences, University of California, Riverside
Dani Shteinberg, Volcani Center, Israel

CALL TO ORDER

Leo McGuire, Production Research Committee (PRC) Chairman, called the meeting to order at 9:01 a.m. with a quorum present.

OPPORTUNITY FOR PUBLIC COMMENT

Dr. Spann introduced Dr. Dani Shteinberg, Plant Epidemiologist from the Volcani Center, Israel, who is spending four months in California on a sabbatical. Dr. Shteinberg briefly introduced himself to the Committee and explained that he had previously worked on Botryosphaeria (one of the pathogens involved in the disease known as avocado branch canker in California) of avocados in Israel.

Dr. Kathryn Uhrich, Dean for the College of Natural and Agricultural Sciences at UC Riverside provided the Committee with an update on the transfer of 43 acres of land at the South Coast Research and Extension Center (SCREC) in Irvine to the University of California, Irvine (UCI) to build faculty housing. She explained the long history of UCI's efforts to obtain the land at SCREC and how former UCI President Michael Drake is now the Chancellor of the UC system. Dean Uhrich and committee member Darren Haver, Director of SCREC, provided an overview of the avocado trees that would be lost if this transfer takes place, including the avocado species collection, the avocado rootstock germplasm block, and a portion of the avocado scion germplasm. The Committee members asked numerous questions of Dr. Uhrich and it was agreed that the California Avocado Commission should address this issue directly with Chancellor Drake to see what could be done. Ken Melban, CAC VP Industry Affairs, said that he and CAC Chairman Rob Grether would initiate a conversion with Chancellor Drake.

APPROVAL OF MINUTES OF MAY 18, 2022 PRODUCTION RESEARCH COMMITTEE MEETING

MOTION
To approve the minutes of the May 18, 2022 Production Research Committee meeting.

(Rochefort/Burr) MSC Unanimous

Motion 22-7-27-1

RESEARCH PROGRAM DIRECTORS REPORT

Dr. Spann updated the Committee on the University of California's avocado breeding program's engagement with Eurosemillas to provide funding to the program and to serve as the worldwide master license holder for new UC avocado scion and rootstock varieties going forward. Dr. Spann explained that he and Ken Melban had a call with representatives of Eurosemillas and UC Riverside Office of Technology Transfer on July 16, 2022, where they presented a draft plan for the commercial release of new varieties. The plan included an annual royalty payment by growers for new UC avocado trees instead of a one-time royalty payment when the trees were purchased. Dr. Spann explained that he and Ken Melban told the Eurosemillas representatives they believed the new royalty structure stood little chance of being positively received by California growers, but that Eurosemillas should proceed with their plans to present the proposed structure to California growers and see what feedback they get.

Dr. Spann reminded the Committee that at their previous meeting they had asked to receive a proposal to explore registering fungicides for use against avocado branch canker (ABC). Dr. Spann explained that he had spoken to Dr. Themis Michailides who had recently finished an ABC project for CAC and that Dr. Michailides explained that his post-doc, Herve Avenot, who had done most of the work on the previous project was a candidate for the vacant avocado plant pathology extension specialist position at UC Riverside. Dr. Michailides said that if Herve is selected for the position at UC Riverside, he would like to allow him to be the lead PI on the fungicide work, but if he is not selected then Dr. Michailides would be happy to submit a proposal. Thus, the Committee does not have a proposal to review at today's meeting on this topic.

Dr. Spann informed the Committee that registration was open for the World Avocado Congress to be held in Auckland, New Zealand, April 2-5, 2023. He also mentioned that the California Avocado Society is planning to arrange a post-congress tour of avocados in New Zealand and Australia following the Congress.

Next Dr. Spann explained to the Committee that Dr. Mark Hoddle had returned to Mexico to test a new formulation of the avocado seed weevil pheromone and, thus, was unable to attend today's meeting to provide the Committee with an update on his project related to the Avocado Lace Bug. Dr. Hoddle had apologized for not being able to attend and stated he would be happy to update the Committee on his work at a later meeting.

Finally, Dr. Spann told the Committee that he had visited with Dr. Lauren Garner at Cal Poly San Luis Obispo on Monday to see the avocado rootstock trial planted there. He told the Committee the trial was doing well, but that Dr. Garner may be asking for some additional support for the project at a later date.

DISCUSSION ITEMS

A. Update on research trial, "Safety and efficacy of herbicides in bearing avocado groves."

Dr. Peggy Mauk, UC Riverside, explained to the Committee that she had taken over this project upon the passing of Dr. Travis Bean. She explained to the Committee members that the project's focus was to evaluate herbicides currently registered for use on bearing citrus in California for potential use on avocados since this would be the quickest route to get new products registered for avocado use. The project was evaluating two post emergence and four pre-emergence products, including Matrix, Alion, and Treevix. Dr. Mauk presented efficacy and phytotoxicity data on the trials that had been completed to date and explained that the combination application of Matrix and Alion has performed very well, and she would recommend submitting these products to the IR-4 program for residue trials to get them registered for use on avocados. She explained that the product registrants were supportive of an avocado registration and that the products would need to be submitted to IR-4 by August 3rd to be included in their next cycle. The Committee agreed that Matrix and Alion should be submitted to IR-4. Dr. Mauk then explained that she would like to conduct some tests with the product Shark EW in the final few months of the funding she has from CAC and the Committee agreed this would be a good product to test.

ACTION ITEMS

A. Consider request for funding support for the Avocado Brainstorming 2023

Dr. Spann began by reminding the Committee of the history of the avocado brainstorming and what the meeting is about. He reminded the Committee of CAC's prior support for the meeting, most recently $10,000 for the 2018 Brainstorming in South Africa. Discussion ensued and the Committee questioned whether it is CAC's role to support the professional development of researchers by sponsoring a meeting such as the Brainstorming. There was agreement that, while such support is not necessarily CAC's role, it is in CAC's interest to support the development of the researchers they work with. Discussion continued and there was general agreement that it would be good for the CAC Board to have the opportunity to discuss the merits of supporting the Brainstorming meeting.

MOTION
To recommend the Board consider supporting the Avocado Brainstorming meeting at the level of $10,001 or more with the stipulation that a report and accounting of how the funds were spent be submitted to CAC following the meeting

(Davis/Cole) MSC Unanimous

Motion 22-7-27-2

B. Consider request for funding for the proposal, "Can overhead water application to control temperature and humidity increase yields, tree growth and health in avocado orchards."

Dr. Spann explained that the genesis of this proposal was an email to him and Leo McGuire in 2021 asking for the PRC to consider providing funding for a project on overhead irrigation for heat mitigation. The PRC had already made decisions regarding funding and the proposer was asked to resubmit their request for the next round of funding consideration. Discussion ensued and a number of issues were raised by Committee members. The first objective of the proposal was to understand "what effect does the application of overhead irrigation during extreme heat events have on productivity," and the Committee question whether this objective could be answered in the study's 5-year timeline by planting new trees. The Committee questioned if it would be better to install a system like that proposed in a mature grove to answer the question of productivity. Discussion continued and several Committee members stated that they were aware of growers who have already installed overhead irrigation systems for heat mitigation, and wouldn't the industry be learning from their experiences? The Committee questioned what additional benefits would be gained if the proposal was funded. The discussion also touched on the volume of water required to run an overhead irrigation system for heat mitigation and how many growers have the water availability to even try installing such a system, thus, would many growers benefit if the proposal was funded? Concern was also raised about the apparent conflict of interest of a seated board member submitting a proposal and not calling out the conflict of interest.

Chairman McGuire asked for a motion to recommend funding the proposal, but one was not made.

C. Consider request for funding for proposal, "Developing tools and information on crop water use and effective irrigation management for more profitable and sustainable avocado production."

Dr. Spann reminded the Committee that at their May 18 meeting they had asked for Dr. Ali Montazar to submit a proposal to expand his California Department of Food and Agriculture funded project on reevaluating the crop coefficient for avocado water use to the northern part of the avocado growing area and that was the proposal before the Committee for their consideration. Discussion ensued and there was general agreement that, given ongoing water shortages in California and the fact that water is most growers single greatest cost, having accurate data on avocado crop water needs is critical for the industry. There was discussion about the value of adding more sites to the current project funded by CDFA. Dr. Spann explained that the current project is limited to San Diego and Riverside Counties where water quality tends to be poor, and the climate is significantly different than the northern growing areas. Thus, to ensure the project generates the most accurate results it would be beneficial to include sites in the northern growing areas. Some questions arose about the costs of materials for the project and if there was any potential to decrease the budget.

MOTION
To recommend the Board fund the proposal and that Dr. Spann work with Dr. Montazar to determine if there is any potential for savings in the proposed budget.

(Burr/Rochefort) MSC Unanimous

Motion 22-7-27-3

D. Consider request for funding for proposal, "Commercial-scale field testing and potential release of five elite advanced rootstocks."

Dr. Spann reminded the Committee that in 2019 CAC had funded Dr. Patricia Manosalva to establish commercial-scale trials of the five most promising rootstock selections in the UC Riverside breeding program with intention of developing the necessary data to decide about releasing the selections commercially. Those trials had been planted in 2019, 2020 and 2021 and the proposal before the Committee is to continue the evaluation of those trials. Discussion ensued and there was general agreement that it was in the industry's best interest to continue the data collection on these rootstocks since some of them appear to be promising with regard to salinity and phytophthora tolerance. There were concerns raised about the value of continuing to support some of the trials included in this funding request that were not specifically part of the 2019 funding. These included a trial in Bonsall in which many of the trees have died and many of the remaining trees receive poor health ratings. Also considered of low priority were two trial sites at Limoneira that were established in 2016 and are small plot trials with few trees of each rootstock.

MOTION
To recommend the Board fund the proposal pending the review of what sites are maintained with the funding and for the funding not to exceed $75,000 annually.

(Davis/Haver) MSC – Vote Tally: Yea 5, Nay 1, Abstain 1 (Fernandez)
Motion 22-7-27-4

ADJOURN MEETING

Leo McGuire, Production Research Committee (PRC) Chairman, adjourned the meeting at 11:58 a.m.

Respectfully submitted,

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Timothy Spann

EXHIBITS ATTACHED TO THE PERMANENT COPY OF THESE MINUTES

EXHIBIT A July 27, 2022 Production Research Committee AB 2720 Roll Call Vote Tally Summary

EXHIBIT B Avocado Brainstorming Funding Request

EXHIBIT C Research Proposal: Can Overhead Water Application to Control Temperature and Humidity Increase Yields, Tree Growth and Health in Avocado Orchards

EXHIBIT D Research Proposal: Developing tools and information on crop water use and effective irrigation management for more profitable and sustainable avocado production

EXHIBIT E Research Proposal: Commercial-scale field testing and potential release of five elite advanced rootstocks

CALIFORNIA AVOCADO COMMISSION
Production Research Committee
AB 2720 Roll Call Vote Tally Summary

To be attached to the Meeting Minutes

Meeting Name:	Meeting Location:	Meeting Date:
California Avocado Commission Production Research Committee Meeting	*Web/Teleconference*	*July 27, 2022*

Attendees Who Voted	*MOTION 22-7-27-1*	*MOTION 22-7-27-2*	*MOTION 22-7-27-3*	*MOTION 22-7-27-4*
Leo McGuire, Chair	Yea	Yea	Yea	Yea
Bryce Bannatyne	Yea	Yea	Yea	Nay
John Burr	Yea	Yea	Yea	Yea
Jason Cole	Yea	Yea	Yea	Yea
Jim Davis	Yea	Yea	Yea	Yea
Consuelo Fernandez	Yea	Yea	Yea	Abstain
Darren Haver	Yea	Yea	Yea	Yea
Ryan Rochefort	Yea	Yea	Yea	Yea
Outcome	**Unanimous**	**Unanimous**	**Unanimous**	**6 Yea, 1 Nay, 1 Abstain**

Avocado Brainstorming
27 – 30 March, 2023
Queensland Australia

Organizing Committee:

Mary Lu Arpaia, ***Co-Chair, Organizing Committee***
University of California, Riverside, CA, USA
Expertise: Avocado Pre- and Postharvest Physiology; Plant Breeding

Elizabeth Dann, ***Co-Chair, Organizing Committee***
Queensland Alliance for Agriculture and Food Innovation (QAAFI), University of Queensland, Dutton Park, Queensland, AU
Expertise: Plant Pathology

Lara Pretorius, ***Site Coordinator***
Queensland Alliance for Agriculture and Food Innovation (QAAFI), University of Queensland, Dutton Park, Queensland, AU

Alejandro F. Barrientos-Priego
Universidad Autónoma Chapingo, Chapingo, Edo. de Mexico, México
Expertise: Germplasm Conservation, Plant Genetics

Iñaki Hormaza
IHSM La Mayora-CSIC, Málaga, Spain
Expertise: Plant Genetics, Developmental Physiology

Francisco Mena
GAMA, Quillota, Chile
Expertise: Cultural Management, High Density Planting, Plant Growth Regulators

Grant Thorp
Plant and Food Research, Mt. Albert Research Station, Aukland, NZ
Expertise: Tree Physiology and Orchard Management

Zelda Van Rooyen
Westfalia Technological Services, Tzaneen, Limpopo, South Africa
Expertise: Postharvest Biology, Plant Improvement

Introduction

The Avocado Brainstorming meeting had its genesis following the 1999 World Avocado Congress (Mexico) as a joint activity of the California Avocado Commission Production Research Committee and the University of California and was held in California. Since that time meetings have been held in 2003 (California), 2007 (Chile), 2011 (New Zealand), 2015 (Peru) and 2018 (South Africa) with continued support from the California Avocado Commission. The 2018 Avocado Brainstorming was last held off-cycle to the World Avocado Congress. The original plan was to hold the following meeting in Spain in 2022. Due to the Covid-19 pandemic, this was not possible. Following discussions with the New Zealand Avocado Growers' Association it was decided by the organizing committee to hold the meeting just prior to the World Avocado Congress planned for April 2023.

The "Report to the Sponsors" of the 2018 meeting as well as the PowerPoint presentation given at an in-person presentation to the Hass Avocado Board in 2018 are attached (Appendices 1, 2). The "Report to the Sponsors" includes an executive summary, the session reports, the 2018 meeting agenda and the participant list. The

PowerPoint presentation includes information on the career development stage of the participants plus the major research interests represented at the meeting.

Objectives and Goals

The meeting's primary objective is to share knowledge with the express purpose of stimulating discussion, communication and collaboration among scientists with the belief that this will result in enhanced long-term sustainability of the world avocado industry. Research collaborations that have resulted from previous meetings include collaboration on rootstock breeding, collaborative work on avocado genomics, discussion on postharvest disorders and work on avocado water relations.

The goals of the meeting are three-fold: build research networks, new relationships and collaborations among international science groups; encourage upcoming early career scientists to make a career in avocado research; and discuss and share ideas about specific industrywide topics of interest that will enhance long-term viability of the international industry including improved cultural and postharvest practices that optimize output while minimizing resource utilization.

Meeting Plans

The overall theme and agenda of the 2023 meeting is still under discussion. We plan to have sessions that cover Market Access Issues (food safety, MRLs, fruit quality), Pest and Diseases of International Concern, Productivity Related Issues (precision horticulture, dealing with mega-data sets, alternate bearing), and Advances in Avocado Breeding and Genetics (includes rootstock selection, germplasm conservation, genome sequencing). Advances in all these areas from a holistic perspective will move our understanding of "avocado" forward and enhance the long-term prospects of the world industry and provide the consumer with quality fruit which have not only high eating quality but optimized nutritional value. As in the past, we are anticipating 60 to 70 participants that will represent the breadth of major commercial producing countries that have established research programs, a mix of career stage (early to late career) and research interests.

Queensland, Australia was selected as the host country for 2023 to have the meeting held in conjunction with the World Avocado Congress in New Zealand. The meeting venue is currently under final review but will either be at a hotel on the Gold Coast (south of Brisbane) or the Sunshine Coast (north of Brisbane). Either location will provide the opportunity for an industry tour for the participants on the return trip to Brisbane. The meeting agenda will be modeled after the previous meetings to allow time for in-depth discussions on focused topics and informal meetings facilitated around an afternoon poster session (See Appendix 1 for the 2018 agenda). We are also tentatively contemplating an optional half day Friday tour of research facilities at the University of Queensland.

Return on the California Avocado Commission's Investment

The Californian avocado industry has several opportunities to benefit from supporting the world's best avocado scientists, including those from California, in Australia at Avocado Brainstorming 2023:

- University of California scientists attending Avocado Brainstorming 2023 will benefit from direct interactions over 3 days with the world's best avocado scientists. The international keynote speakers and the wide range of topics covered will broaden the knowledge base of California scientists and give them opportunities to convert international science results into recommendations relevant to local conditions. Plus, it will provide them opportunities to develop the very best scientific approaches in their research to provide solutions and identify new opportunities for the Californian avocado industry and associated companies.

- The new knowledge and international collaborations that the Californian scientists will gain from participating in Avocado Brainstorming 2023 will ensure the most effective and up-to-date scientific approaches are used when CAC and the University of California invest in avocado research and development, and when industry and University scientists implement this research. Better investment decisions will ensure better and faster outcomes for the Californian industry.

Description on how the contribution will be used

Avocado Brainstorming is "not-for-profit" and attendance is by invitation only with most participants being avocado scientists who would be attending the World Avocado Congress in New Zealand. These participants will already have paid their own travel costs to Australia/New Zealand and so CAC funding will be used to contribute to the meeting costs including conference venue hire, local travel and "onshore" accommodation and meal costs. For "non-avocado" keynote speakers attending Avocado Brainstorming, funding from CAC will be used to contribute to the international travel and "onshore" costs for these people while they are in Australia.

Amount Requested:

The total anticipated budget is between USD $90,000 - $100,000. Meeting participants will be expected to pay a registration fee of $250 US Dollars.

Hotel Accommodations and Meals	$65,000
In-country transportation, return trip, from Brisbane to Venue site	$5,000
Travel – Invited Speakers (3 – 4)	$15,000
Travel – Venue Assessment by Co-Chairs and Site Coordinator (in country travel by Dann and Pretorius; international travel by Arpaia (8/22))	$5,000
Miscellaneous Expenses such as supplies, name tags, drinks for tour etc.	$5,000
Total Anticipated Expenses	***$95,000***

The California Avocado Commission has been a sponsor of Avocado Brainstorming since its inception. Funding has ranged from $30,000 (2011, 2015) to $10,000 (2018). We are planning to have a tiered sponsorship program and request that the California Avocado Commission consider sponsorship at the Platinum or Titanium tier:

Sponsorship Levels:	
Titanium: > $15,000 USD	Ability to send up to 3 delegates including registration. Formal recognition at meeting; ability to provide input into program planning; copy of final sponsor report (and in-person or online presentation). If in-country (AU) sponsor invitation to attend afternoon poster sessions.
Platinum: $10,001 - $15,000 USD	Ability to send 2 delegates including registration. Formal recognition at meeting; copy of final sponsor report. If in-country (AU) sponsor invitation to attend afternoon poster sessions.
Gold: $5,001 - $10,000 USD	Ability to send 1 delegate including registration, formal recognition at meeting; copy of final sponsor report. If in-country (AU) sponsor invitation to attend afternoon poster sessions.
Silver: $1,001 - $5,000 USD	Ability to send 1 delegate with payment of registration fee. Formal recognition at meeting, copy of final sponsor report. If in-country (AU) sponsor invitation to attend afternoon poster sessions.
Bronze: < $1,000 USD	Formal recognition at meeting, copy of final sponsor report. If in-country (AU) sponsor invitation to attend afternoon poster sessions.

Hi Tim

I realized this morning that it might have been useful to list some of the potential researchers from California that could attend Avocado Brainstorming:

Peggy Mauk

Patricia Manosalva

Manosalva Postdoc

CE Specialist, Plant Pathology (Akif's replacement if on board)

Mary Lu Arpaia

Eric Focht

Mark Hoddle

CE Specialist, Entomology (Monique's replacement if on board)

Eta Takele

Ben Faber

Ali Montazar

Eric Middleton (new Entomology advisor in SD County)

Edwin Solares (you don't know him but he just completed a genome sequence of Gwen, we are working with him)

Lauren Garner

David Hedrick

Huntington Garden – don't have a name

I know I may be missing some people but this is a potential list. With the exception of potentially Edwin who has done some really exciting work on avocado, none of the individuals list above would be on the list where we would cover their travel, this is just the list of who we would invite.

Can Overhead Water Application to Control Temperature and Humidity Increase Yields, Tree Growth and Health in Avocado Orchards

Mary Lu Arpaia PhD, Ben Faber PhD, John Cornell

Background

The funds requested for this proposal would be used in collaboration with a USDA specialty crop grant titled "*Adapting Avocados for Commercial Success in Extreme Environments to Enhance US Based Avocado Production"* being conducted by researchers Arpaia, Mauk and Jifon.

Over the past five years, excessive heat events in California have had a devastating effect on avocado yields and overall tree health. Can the damage caused by these extreme temperatures be mitigated through the application of water to the canopy?

Objectives

1. What effect does the application of overhead irrigation during extreme heat events have on productivity?
2. What effect does the application of overhead irrigation during extreme or elevated heat events have on tree health and growth?

It's proposed that for purposes of this study, an extreme heat event is defined by temperatures exceeding 105 degrees and an elevated heat event exceeding 95 degrees although these parameters are subject to change upon further discussion and evaluation.

Design of study

Three blocks of approximately two and a half acres each of avocados will be planted with two having an overhead irrigation system installed. The overhead irrigation system (OH) will be activated when temperatures exceed 105 degrees or cooler which is yet to be determined. Each of these two blocks will have their overhead irrigation systems operated using two different on-off application times in order to evaluate differences in application techniques. The third block will be the control block with no overhead system installed.

Periodically the blocks will be evaluated for tree growth, health and, when producing fruit, yields. The span of this study is anticipated to last five years.

Equipment

The few known growers employing overhead irrigation are mostly using mini-sprinklers typically at a density of 50 to 100 per acre or more. We believe this will be difficult to implement industry wide due to the significant amount of labor to install and maintain such a system. Alternatively there are commercially available impact sprinklers available which are low flow at about eight to eleven gallons per minute having a much larger radius of coverage requiring only about four to five be installed per acre. Due to the significantly lower costs both in materials and labor, we believe that these sprinklers are far more efficient and economical than the employment of mini sprinklers. Additional equipment will include a programmable controller which will activate the overhead system based upon the sensor reaching the desired set point and automated traditional irrigation valves using soil sensing and weather based instrumentation to determine irrigation frequency and duration for both the traditional and overhead irrigation systems. Lastly there will be monitoring sensors installed throughout the three plots to measure soil moisture levels, temperature, humidity, PAR and ET.

Site location

The site is located in DeLuz, CA at 26690 Carancho Road, Temecula, CA 92590

Anticipated costs

Costs are broken down by the various components listed below:

Overhead cooling equipment needed includes valves, pipe, sensors and instrumentation which are estimated to cost about $600 per acre. The labor to install this equipment is estimated to be about $760 per acre based on current labor rates and anticipated installation times. The two blocks are estimated to be about two and a half acres each for a total of five acres so the total cost for equipment and installation is anticipated to be about $6,800. Instrumentation for the control block is estimated to cost about $1,500.

The planting of the trees and installation of a traditional irrigation system is estimated to cost about $49 per tree which based on spacing of 9 X 14 equates to 345 trees per acre or $126,787. The trees will be paid for by the owner.

To monitor the results of the trail it's anticipated that eight site visits per year will be needed. Six of these visits will be conducted by Mary Lu Arpaia and two by Ben Faber. Ben Faber has stated that he will require no compensation however Mary Lu Arpaia has requested reimbursement of the millage expense which is estimated to be 600 miles round trip per visit. Under current IRS allowances at $0.625 per mile, each round trip would cost $375 which computes to $2,250 per year or $11,250 over the course of five years.

Accordingly it's anticipated that the total cost of the study over a five year period will be as below:

Planting and traditional irrigation installation costs	$126,787
Overhead irrigation and instrumentation on treated blocks	$6,800

Instrumentation on control block	$1,500
Mileage reimbursement	$11,250
Total	$146,337

Project title: Developing tools and information on crop water use and effective irrigation management for more profitable and sustainable avocado production

Principal investigator: Ali Montazar, Irrigation and Water Management Advisor, UCCE San Diego, Riverside, and Imperial Counties; email: amontazar@ucanr.edu.

Cooperating personnel: (1) Ben Faber, Subtropical Crops Advisor, UCCE Ventura and Santa Barbara Counties. (2) Richard Snyder, Biometeorology Specialist, UC Davis. (3) Alireza Pourreza, CE Specialist, Digital Agriculture Lab, UC Davis. (4) Dennis Corwin, Research Soil Scientist, US Salinity Laboratory.

Total funds requested: $217,697
Funding period: Three-year (November 1, 2022, through October 31, 2025)

Agreement Manager: UCANR Office of Contracts & Grants - Kimberly Lamar, Associate Director, 2801 Second Street, Davis, CA 95618 Phone: (530) 750-1305. Email: ocg@ucanr.edu.

Abstract

Avocado is primarily grown in Southern and Central California. These regions face uncertain water supplies, mandatory reductions of water use, and the rising cost of water, while efficient use of irrigation water is one of the highest conservation priorities. Data on water use by avocado orchards and optimal irrigation strategies needs to be updated in light of the increasing water pressure, in order to achieve efficient water and fertilizer management. Moreover, due to increasing salinity in water sources, effective irrigation is more critical to ensure optimal yield and high-quality avocados fruit. Our current irrigation study in southern California aims to acquire relevant information on crop water consumption and crop coefficients, optimal irrigation water management under different environment and cropping systems, and to assist growers in employing adaptive tools that support profitable and sustainable avocado production. This new proposal intends to expand the ongoing irrigation study, specifically to add three more northern experimental sites (a transect from Ventura to Fillmore) for a more robust data set. Extensive data collection will be conducted in these three mature avocado sites over a three-year period, in addition to the current six sites in San Diego, Riverside, and Orange Counties using the combined cutting-edge ground- and remote-sensing technologies. The program will develop more accurate crop water use and crop coefficient curves and evaluate the impact of irrigation management strategies to optimize resource-use and economic productivity in avocado production systems.

Background

Avocado is a sub-tropical rainforest tree and therefore, careful water management is critical for its high yields of good quality fruit. Currently, the industry's concern is how to increase production while optimizing the cost of water and to mitigate the impacts of drought and climate change. Developing more accurate estimates of crop water use and effective irrigation scheduling may have a significant impact on water quality and quantity issues, possibly affecting the economic sustainability of avocado production. Data on water use by avocado orchards in the central and southern regions and cropping systems of California is limited, and the lack of information hinders the achievement of efficient water and nutrient management.

Avocado is one of the most salinity sensitive crops produced in California but is commonly grown in areas having saline irrigation water (an EC greater than 0.75 dS/m and chloride >100 ppm) (Crowley, 2008). During recent years, salinity problems in California avocado have become increasingly common as the cost of irrigation water has been on the rise and the availability of low salinity water for agriculture has diminished. Yield increase was reported for avocado orchards with increasing amounts of applied water because of more water availabile for crop use before a soil-water salinity of 4 dS m^{-1} restricted water uptake (Oster et al., 2007).

To estimate crop water requirements, various crop coefficient (K_c) value of 0.64 (Grismer et al., 2000), 0.72 (Gardiazabal et al., 2003), and 0.86 (Oster et al., 2007) was reported for “Hass” Avocado. Lower K_c values (from a minimum of 0.4 in January to a maximum of 0.65 in June through August) were reported for avocado based on the research conducted in Corona, California (1988-1992) and Covey Lane, North San Diego County (1992-1997).

K_c value is greatly impacted by differences in climatic conditions, canopy features (size of crop canopy and shaded area), row orientation, soil and irrigation water salinities, and amounts of water applied. In the ongoing avocado irrigation study initiated in late Winter 2022, we consider all these parameters and utilize a combination of surface renewal and eddy covariance equipment to measure actual crop evapotranspiration to develop a K_c curve. Several other sensors and equipment are being used to monitor soil and plant water status, and soil salinity, and high-resolution images are being taken by unmanned aerial system (Figs. 1-2).

Fig. 1. Ground view of a flux tower/monitoring station in an avocado orchard in Escondido (right). A near look from the top of flux tower demonstrates net radiometer sensor and two fine thermocouple sensors (left up) and sonic anemometer, spectral reflectance sensors, infrared thermometers, and air temperature and relative humidity sensors (left bottom) in an avocado orchard in Temecula.

Fig. 2. Three different types of soil moisture sensors installed in multiple depths to monitor soil water and salinity status over the season on a continues basis (avocado orchard in Irvine).

Figure 3 demonstrates actual crop water consumption (ET_a) and crop coefficient values over a 1.5-month period for two avocado experimental sites in Escondido and Temecula. Considerable differences were observed between ET_a and actual crop coefficient values of these sites. An average of 0.18 in d^{-1} and 0.12 in d^{-1} were measured as ET_a of site 4 and 1 during the period, respectively. Variable daily ET_a was observed in both avocado sites, for instance it varied from 0.03 in d^{-1} (May 20, 2022) to 0.23 in d^{-1} (May 14, 2022) in site 4. The average crop coefficient value determined for the period was 0.75 at Site 4 and 0.54 at Site 1.

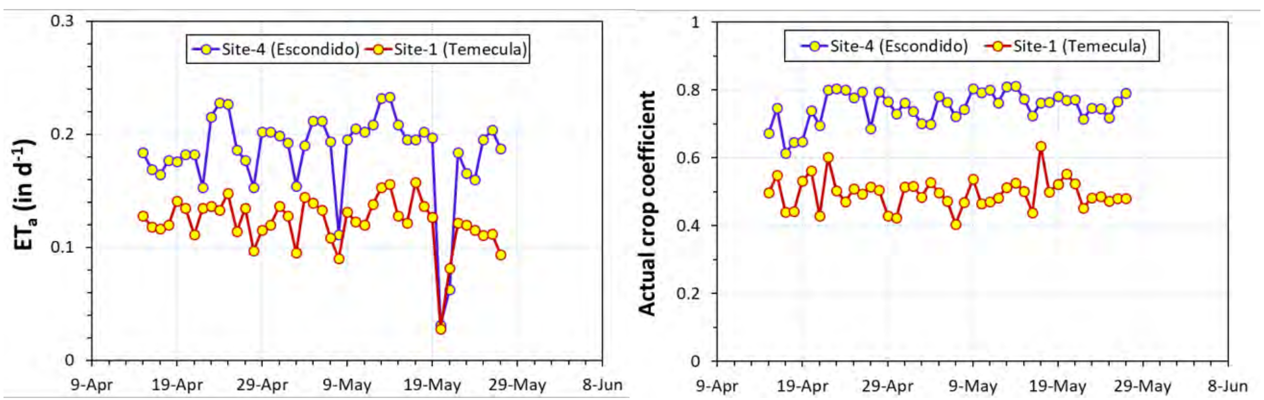


Fig. 3. ET_a and actual crop coefficient values in two avocado experimental sites in Escondido and Temecula from the ongoing irrigation study. Avocado trees are 11-year-old at Site 4 and 8-year-old at Site 1. Site 1 has a lower elevation than site 4 (the monitoring ET station is 1,500 ft. above sea level at Site 1 and 775 ft. above sea level at Site 4). Tree spacings are 20×20 ft. at Site 4 and 20×15 at Site 1. Both sites have south facing slopes. Dominant soil texture is sandy loam (Cieneba coarse) at Site 4 and loam (Lodo rocky) at Site 1. Considering daily ET_a measured and tree spacings, the average crop water consumption during this period was determined to be 45.7 gallons per day per tree at Site 4 and 22.9 gallons per day per tree at Site 1.

Soil water tension was maintained at a desired level in the crop root zone at both sites. Although the average soil water tension varied over time in the top 18-in of the soil, it never declined below 6 centibars and exceeded 13 centibars at Site 1 (Fig. 4) over a three-month period. The soil moisture data at Site 1 indicated that the irrigation frequency was scheduled properly while shorter irrigation runs could be considered in each irrigation event. The average soil water tension for the similar period ranged between 8 and 35 centibars at Site 4, which is a recommended range for the corresponding soil type.

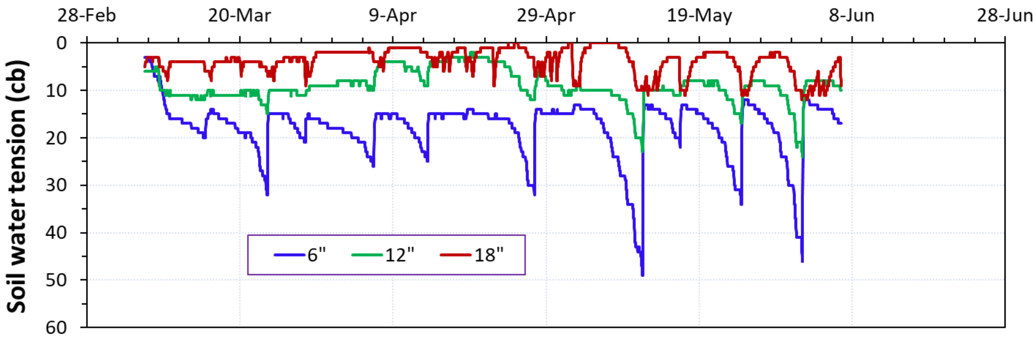


Fig 4. Half-hourly soil water tension (cb) measured at multiple depths of 6-in, 12-in, and 18-in at Site 1 over a three-month period. One micro sprinkler per tree with an average operation flow rate of 9.5 gallon per hour is sued for irrigation.

Objectives

This study develops more accurate crop water use and crop coefficient curves and evaluates the impact of irrigation strategies and tools to optimize resource-use and economic productivity in avocado production systems. The project intends to collect, analyze, and disseminate relevant information on mature avocado orchards. The existing software for irrigation scheduling of avocado could be updated using the information developed by this project. This would replace the crop coefficients on the existing software, obtained from previous literature, that are not accurate enough under the new farming practices and need to be updated to consider canopy feature, row orientation, and soil conditions. A robust outreach program will be designed to disseminate the project findings and assist growers in employing adaptive tools and irrigation management practices that support efficient and sustainable crop production and optimize environmental outcomes. Enhancing water-fertilizer, and energy-use efficiency, water conservation, water quality, and economic gains of avocado growers are the primary goals that the study will address.

The study aims to develop science-based information and tools including:

- more accurate irrigation water needs under different conditions in South California through updated crop coefficient curves over the season for avocados.
- evaluate irrigation tools in avocados (soil moisture, ET, drone/satellite, leaf/stem water potential, canopy temperature) for effective irrigation management.
- evaluate irrigation strategies in avocados (grower irrigation practice vs. sensor-based irrigation and/or less water applied)
- evaluate satellite-based tool of IrriSAT / IrriWatch/Open ET in avocados

Improved irrigation scheduling and irrigation system operation are cost-effective tools to address longstanding water challenges in southern California. It allows avocado growers to achieve the maximum return per unit water used and full economic gains. It is expected the tools and information under developing by this study enable more efficient resource- use irrigation management and long-term sustainability in avocado production.

Work plan

A three-year experiment will be conducted in three mature avocado orchards in Ventura County (a transect from Ventura to Fillmore) to expand the current irrigation study in San Diego, Riverside, and Orange Counties. The local cooperating farms will be selected in collaboration with the California Avocado Commission and University of California Cooperative Extension - Ventura County. Row orientation, canopy features, elevation, soil types and conditions, and irrigation water quality and management will be considered as main driving forces to ensure the sites provide a good representation of avocado production systems in the region. More details on proposed research and outreach activities and timeline for this study are provided in Table 1.

Table 1. Research/outreach activities and timeline

Activities	Timeline
Research	
Purchase the special purpose equipment.	Nov 2022 – Dec 2022
Field visits to select and finalize the exact locations of experimental sites.	Nov 2022 – Dec 2022
Set up field experiments: field trials will be carried out in three commercial mature avocado sites in Ventura County to develop crop water use information and evaluate irrigation management strategies. A flux tower will be set up in each site to measure actual evapotranspiration (crop water consumption) under grower management practice. The flux tower contains a combination of surface renewal and eddy covariance equipment that continuously measures high frequency data for the energy balance analysis. Monitoring soil moisture, soil salinity, plant water status, canopy reflectance and features, leaf analysis, and fruit yield and quality are being carried out, as well. Measurements and record-keeping of applied water will be performed using digital flow meters at the head of selected field sections. Monitoring plant water status will be conducted using Implexx Sap Flow Sensor on a continuous basis and pressure bomb readings (two times per month during the summer seasons). In addition, the difference of canopy temperature versus air temperature recorded by fixed view-angle infrared thermometers will be used to evaluate crop water stress indices. Continuous normalized difference vegetation index (NDVI) values will be measured by Spectral Reflectance sensors. Salinity survey will be performed in each season. In addition, soil solution access tubes will be installed at the depths of 1 to 3 ft to monitor salinity of soil solution on a regular basis.	Jan 2023 – Feb 2023
Data collection from real time monitoring stations and regular data analysis.	Feb 2023 – Oct 2025
Regular maintenance of monitoring sites and equipment.	Feb 2023 – Oct 2025

Activities	Timeline
Canopy reflectance/features measurements and analysis: Canopy reflectance in the visible and near infrared regions of the electromagnetic spectrum will be measured through high-resolution, multi-spectral, and thermal cameras that will be carried by an unmanned aerial system. The measurements will be conducted on six different days per each orchard using virtual orchard technology (analysis of 3-dimensional reconstruction of canopy profile). The canopy features including fractional canopy cover, canopy volume, canopy size, and canopy height will be measured by analyzing point cloud information. The thermal images will be also used to determine crop water stress indicators. The data will be correlated with fractional canopy cover acquired through high-resolution remote sensing techniques.	May 2023. Aug 2023. May 2024. Aug 2024. May 2025. Aug 2025.
Irrigation system evaluation in each of the experimental sites: On-farm irrigation system efficiency at each experimental field will be evaluated using the standard evaluation methods for micro- irrigation systems. The research team will work with the Ventura Resource Conservation District on this issue.	Jun 2023- Sep 2023
Visits and interviews will be conducted with avocado growers/farm managers in Southern California. In addition, exploring and documenting avocado irrigation management data and information will be continued through "Avocado Irrigation Management Survey" (https://surveys.ucanr.edu/survey.cfm?surveynumber=36053)	Nov 2022- Nov 2024
Irrigation strategies study: during the second- and -third year of the study, two more irrigation management strategies (100 percent actual evapotranspiration measured (ET_a) and 85 percent ET_a in each irrigation event) will be evaluated versus grower practice as control treatment in one the experimental sites. The irrigation strategy trial will be arranged in a complete randomized block design with three replications (four trees for each strategy per replication). Selected trees will be as uniform as possible in growth and vigor and free from insect damage and diseases. Soil moisture and plant water status will be monitored continuously to identify potential water stress over the seasons. Fruit yield and quality will be considered as other comparison measures as well.	Jan 2024 – Oct 2025
Outreach	
Hold six workshops (with collaboration of UCCE offices) in Ventura, Riverside, San Diego, Orange, Santa Barbara, and San Luis Obispo Counties.	Aug 2023- Oct2025
Publish findings of the project as extension publications and develop University of California blogs and various web-based platforms to share the science-based information.	Aug 2023- Oct 2025
Share the developed crop coefficient curves and irrigation management information and collaborate with the developer/manager of the current irrigation scheduling calculator for avocado (AvocadoSource.com) for a potential update of the software.	Oct 2025
Adopt the CropManage web-based tool as a new irrigation management tool for California avocado: provide data and information to adopt the CropManage web-based tool for water management of avocado orchards. Develop avocado irrigation and nitrogen management modules to support avocado crops. The PI will work with the University of California Cooperative Extension (UCCE) colleagues (the CropManage team) to develop the module.	Aug 2025- Oct 2025
Results reporting (progress reports and final report), and present findings in the California Avocado Commission's meetings.	Jan 2023- Oct 2025

Budget

A total budget of $217,697 is requested for conducting this project (Nov 1, 2022 – Oct 31, 2025). The details of budget can be found in Table 2.

Table 2. Detailed budget of the project

Item	**Budget ($)**			**Total budget ($)**
	Year 1	**Year 2**	**Year 3**	
Personnel				
Lab Assistant salary	11,813	21,263	21,263	54,339
Lab Assistant fringe benefits	6,828	12,290	12,290	31,408
Graduate student salary and fringe benefits (to be determined)	-	7,500	6,900	14,400
Personnel subtotal	18,640	41,053	40,453	100,147
Supplies				
3-D sonic anemometer (no=2)	7,500	-	-	7,500
micrologger enclosure (no=3)	1,500	-	-	1,500
CR3000 datalogger (no=6)	3,000	3,000	-	6,000
soil temp avg. sensor w/30’ cable (no=9)	3,500	-	-	3,500
REBS heat flux plate with 30’ cable (no=9)	3,200	-	-	3,200
apogee infrared thermometer (no=9)	6,300	-	-	6,300
digital flowmeter (no=6)	-	6,000	-	6,000
cellular modem (no=3)	2,400	-	-	2,400
soil moisture sensor (TDR) (no=9)	5,000	-	-	5,000
Implexx Sap Flow Sensor (no=12)	4,500	4,500	-	4,500
Fine thermocouple and cable (no=15)	-	-	3,750	3,750
Soil solution access tubes (suction lysimeter and accessories) (no=10)	-	3,500	-	3,500
Supplies subtotal	36,900	17,000	3,750	57,650
Travel	4,000	4,000	6,900	14,900
Scaffolding structures for ET tower (no=3)	33,000	-	-	33,000
Soil/water/plant lab analysis	1,500	4,000	3,500	9,000
Cell phone modem services	1,000	1,000	1,000	3,000
Total	95,041	67,053	55,603	217,697

<u>Budget Justification</u>

1- Personnel: A Laboratory Assistant (LA) has been already recruited for the ongoing avocado irrigation study who will help the research team on this study as well. The LA will help the research team with the set-up of monitoring stations and sensors in the experimental orchards, tune up the instruments, collect field data and conduct analysis, perform other field activities and sensors maintenance, and participate in the outreach program. For a three-year period, the average annual salary of the LA is estimated $47,250 and the fringe benefits is assumed at 57.8% of salary. We expect this project supports 25% FTE of the Laboratory Assistant for the first year, and 45% for the second and third years of study.

A graduate student will be hired to work 800 hours at a projected average rate of $18 per hour (fringe benefits included) to help the research team with aerial imaging and data analysis.

2- Supplies: while the PI will use some available sensors and equipment in his lab, there are some other supplies need to be purchased by this project including 3-D sonic anemometer, (81000 RE), micrologger enclosure, CR3000 datalogger, soil temp avg. sensor w/30' cable, REBS heat flux plate with 30' cable, 40watt solar panel + mount, apogee infrared thermometer, digital flowmeter, cellular modem, TDR soil moisture sensor, Implexx Sap Flow Sensor, Fine thermocouple and cable, and soil solution access tubes (suction lysimeter and accessories).

3- Travel: The PI, lab assistant, and graduate student have several multiple-day (an average of two days per trip) trips for site selection, installation of monitoring equipment and sensors at the experimental sites, data collection, aerial imaging, take down of the monitoring stations, grower meetings, and workshops. A total of 30 trips is estimated with an average of 500 miles per trip. The project estimate for travel expense is 15,000 miles ($0.56 per mile), 30 nights lodging ($150 per night), 40 days per diem ($50 per day).

4- Scaffolding structures for ET towers are required. Renting materials, dismantle scaffolding and demobilize assembling is in an average flat rate of $11,000 per tower.

5- Soil/water/plant lab analysis: soil, water, and plant analysis will be conducted by the UC Davis laboratory. The project will have an estimated 120 samples which will each be analyzed for five factors/parameters. The cost per sample is an average cost of $15 for each factor analysis.

6- Cell phone modems will be used to transfer real time data of monitoring stations. The monthly phone service for each cell modem has an average rate of $200 per year for each cell modem (Verizon wireless service). This service is required for five cell modems over a three-year period.

Commercial-scale field testing and potential release of five elite advanced rootstocks

Principal Investigator: Dr. Patricia Manosalva, Department of Plant Pathology and Microbiology, UCR.

Co-PIs and collaborators: Dr. Mary Lu Arpaia, (Horticultural Specialist, Field and Extension activities, Department of Botany and Plant Sciences, UCR), Dr. Lauren Garner (Horticulture and Crop Science Department, Cal Poly, San Luis Obispo), Dr. Peggy Mauk (Avocado response to Salinity, Extension activities, Department of Botany and Plant Sciences, UCR), Johnny David Rosecrans (Horticulture and Crop Science Department, Cal Poly, San Luis Obispo), UCCE Farm Advisors, Grower Cooperators at Field Sites, and South Coast Research Extension Center (SCREC) at Irvine.

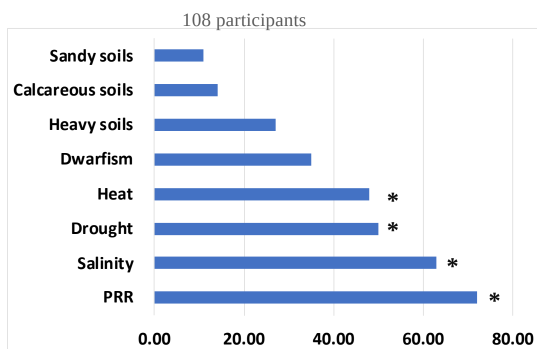
Research Institutions: University of California, Riverside (UCR) and Cal Poly, San Luis Obispo.

Introduction

Avocado growers face numerous production challenges including devastating diseases such as Phytophthora root rot (PRR) caused by *Phytophthora cinnamomi* and Laurel Wilt (LW) caused by *Raffaelea lauricola* which in combination with salinity, drought, and heat stress cause severe reduction in fruit yield, quality, and can destroy complete avocado orchards if not managed properly. Resistant or tolerant rootstocks are the most environmentally friendly, sustainable, and effective long-term solution for managing these major biotic and abiotic stressors. By definition, resistance traits reduce the harm caused by the disease by preventing infection or limiting the pathogen growth (reducing pathogen populations) while tolerance traits do not inhibit infection or pathogen populations, but instead reduce or offset its negative fitness consequences by reducing host mortality or restoring the reproductive capacity of infected hosts.

The UCR avocado rootstock breeding program began in the 1950's under the directorship of Dr. George Zentmyer, professor at the Microbiology and Plant Pathology Department. The rootstock breeding program was initiated because of the need for rootstocks harboring resistance to *P. cinnamomi* and it has been continuously funded by the avocado growers through the California Avocado Commission (CAC). In the last decade, declining water quality and availability is contributing to an overall loss in productivity primarily due to salinity and drought stress. Avocado is considered to be very salt sensitive and this is particularly true for 'Hass'. Salinity stress is influenced by both cultivar and rootstock. Rootstocks also vary in salt resistance/tolerance, which has been demonstrated in numerous studies. Avocado research priorities for the UCR rootstock breeding program have been identified through communication with avocado growers, some of whom are currently participating in the field evaluation of our advanced *P. cinnamomi* and salinity resistant rootstocks. Our recent rootstock survey conducted in 2020 indicated that avocado growers' major concerns are PRR, salinity, drought, and heat (**Fig. 1**). These results strongly support our efforts to select and develop rootstocks with resistance/tolerance to these stressors

Figure 1. Grower survey conducted in California after the CAS seminar series in June 2020



and we will continue conducting surveys to inform us of ongoing stakeholder needs to identify and adjust the program objectives and activities as necessary.

There are several rootstocks commercially available in California (**Table 1**). Several of the available rootstocks were developed by the UCR program such as 'Duke 7', 'Thomas', 'Uzi', 'Zentmyer', and 'Steddom'. 'Steddom', a Toro Canyon seedling, is becoming popular among CA growers for its *P. cinnamomi* resistance and salinity tolerance. It has been reported that under certain conditions 'Hass' trees grafted to Steddom rootstocks are smaller than 'Hass' trees grafted to other rootstocks. Other popular rootstocks for their tolerance to salinity are Dusa, Toro Canyon, Day (VC207), Tami (VC801), Miriam (VC218), Ben-Ya' Acov1 (VC66), and Zerala^{TM}. Even if the UCR rootstock program did not develop this material, the program has evaluated and continue to evaluate some of these material (Day, Tami, Miriam, Leola, and Zerala) through CA for several years which supported their commercial release in California in the last years. Despite the availability of these rootstocks, the performance under the current pathogen populations of *P. cinnamomi* and their performance under other biotic stressors such as heat, high pH, performance in low drainage soils has not been assessed thoroughly. In addition, their performance when grafted with other commercially available rootstocks has not been tested thoroughly.

Table.1. Commercially available rootstocks in California and their properties. M = Mexican, G = Guatemalan, WI= West Indian, ND = no determined, *based on SNPs markers and comparing >2000 accessions.

Rootstock	Race composition*	Origen	Properties
Duke 7	M x G	UCR/ Zentmyer	Moderate resistant to Phytophthora Root Rot (PRR) and exhibited cold tolerance. Trees are large, vigorous, and good producers. Susceptible to waterlogging. More sensitive to salinity than Dusa and Toro Canyon. High yield efficiency when grafted with Hass, Carmen, GEM, Lamb, and Reed.
Thomas	M	UCR/Coffey Zentmyer	Highly susceptible to PRR, *P. citricola*, and salinity.
Toro Canyon	M x G	Royden Stauffer	Moderate resistant to *P. cinnamomi* and *P. citricola,* exhibited similar salinity tolerance than Dusa. Good productivity under PRR, high salinity conditions, and low temperatures.
Dusa	M x G	UCR/Menge & Douhan	Moderate resistant to PRR and exhibited salinity tolerance. Good productivity under PRR and high salinity conditions. Highly sensitive to waterlogging conditions so it is not good for fields with heavy soils, PRR, and salinity. Susceptible to white root rot (WRR) caused by *Rosellinia necatrix*. Less yield efficiency compared with Duke 7 when grafted with Hass, Carmen, GEM, Lamb, and Reed.
Uzi	M	UCR/Menge & Douhan	Highly resistant to *P. cinnamomi* (PRR). Extremely vigorous and fast-growing rootstock. Good producer but susceptible to salinity. Ideal for replanting problems due to high incidence of PRR. Similar yield efficiency as Dusa when grafted with Hass, Carmen, GEM, Lamb, and Reed.

Zentmyer	M	UCR/Menge & Douhan	Highly resistant to *P. cinnamomi* (PRR). Extremely vigorous and fast-growing rootstock. Good producer but highly susceptible to salinity. Ideal for replanting problems due to high incidence of PRR. Low yield efficiency when grafted with Hass, Carmen, GEM, Lamb, and Reed compared with Duke 7, Dusa, Leola, Steddom, and Uzi.
Steddom	M x G	UCR/Menge & Douhan	Highly resistant to *P. cinnamomi* (PRR). It is a slow growing rootstock having heavy yield with higher yield efficiency when grafted with Dusa when grafted with Hass, Carmen, GEM, Lamb, and Reed. Exhibited good salinity tolerance, excellent rootstock with small canopy, low vigor which make it desirable for high density or hedge-row avocado planting.
Day (VC207)	WI x G x M	Volcani Center ARO/Ben-Ya'acov1	Moderate resistant to *P. cinnamomi* (PRR) and highly tolerant to salinity. Large and vigorous trees.
Tami (VC801)	WI x G	Volcani Center ARO/Ben-Ya'acov1	Moderate resistant to *P. cinnamomi* (PRR) and highly tolerant to salinity. Large and vigorous trees.
Miriam (VC218)	WI x M	Volcani Center ARO/Ben-Ya'acov1	Moderate resistant to *P. cinnamomi* (PRR) and highly tolerant to salinity. Large and vigorous trees. Exhibit drought resistance, alkaline soil resistance as indicated for data collected in Israel.
Ben-Ya'acov1 (VC66)	WI x G	Volcani Center ARO/Ben-Ya'acov1	Salinity tolerant. Lower tendency towards alternate bearing.
Leola™ (Merensky 6)	ND	Westfalia	Moderate resistance to PRR similar to Dusa. Good productivity when grafted to Hass and GEM. Similar yield efficiency than Dusa when grafted with Hass, Carmen, GEM, Lamb, and Reed, however Duke 7 and Steedom exhibited more yield efficiency when grafted with these scions. This rootstock is sensitive to high salinity.
Zerala™ (Merensky 5)	ND	Westfalia	Moderate resistance to PRR similar to Dusa. Exhibited salinity tolerance. Is highly susceptible to waterlogging conditions.

UCR advanced rootstocks. In the last decade resistance to salinity and other environmental stressors have been assessed by the UCR breeding program under field conditions. Currently, all UCR rootstocks selections (~200) were selected for their high *P. cinnamomi* resistance after GH seedling and clonal trees screening. Currently, we are evaluating ~55 UCR rootstock selections grafted to Hass in 7 active small regional trials in Santa Paula, Temecula, Fallbrook, and Ramona. In addition, we have the most advanced rootstocks grafted with Hass being tested in 9 large commercial trials established in 2019, 2020, and 2021 in Temecula, Camarillo, Goleta, Ventura, and San Luis Obispo. These selections are being tested for field performance when grafted to Hass regarding tree health, salinity damage, heat damage, cold damage, tree size, tree vigor, canopy size, blooming, flushing, fruit set, and yield. These fields represent different environmental conditions and cultural practices: i) PRR problems, ii) high salinity and chloride toxicity, iii) high pH and alkalinity (as CaCO3), iv) waterlogging conditions and clay soils, and v) different cultural practices (i.e., organic, mulching, gypsum, high density planting, etc).

Eight years of field data for five UCR advanced rootstocks, PP35, PP40, PP42, PP45, and PP80, supports the continuation of semi-commercial evaluation of these rootstocks grafted with Hass and other varieties as well as their commercial release in California (**Table 2**). In 2022, under a USDA-SCRI funding, these five rootstocks grafted with Hass and other scions will be tested for their performance under Laurel Wilt conditions in Florida. In addition, multi state rootstock trials will be established with these UCR advanced rootstocks grafted with Hass, Waldin, Lula, Sharwill, GEM, Lamb-Hass, and Reed in Florida, Puerto Rico, Texas, Hawaii, and California this July 2022. In addition, one large plot will be established in Goleta for PP35, PP40, and PP80 grafted with Hass, GEM, and Lamb Hass as part of the USDA-SCRI activities (July 2022). PP35, PP40, and PP45 is currently being tested by Dr. Mary Lu Arpaia grafted with Hass, Carmen, GEM, Lamb, and Reed in a rootstock trial in Saticoy, Ventura. This plot was established in 2012. Tree health and harvest data collected at this site since 2015 indicate that Duke7, Steddom, PP40, and PP35 exhibited the best yield and yield efficiency when grafted with these different scions (**Fig. 2**). In addition, in collaboration with Dr. Clara Pliego (Malaga, Spain), we will test all these UCR five advanced rootstocks in Spain for resistance to white root rot (WRR) caused by *Rosellinia necatrix* using other funds from Dr. Manosalva. Current field data from California support the continuation of the evaluation and data collection for these five UCR advanced rootstocks to gather the most compelling data especially for yield and packing to support their commercial release within the next 3 years.

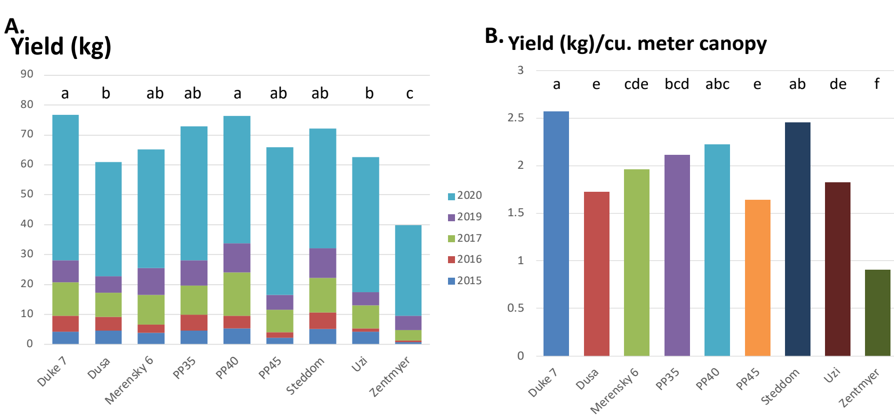
Table 2. List of advanced UCR rootstocks.

Rootstock	Race	Active Fields	Field conditions	Phenotype	Years of tree health and harvest data#
PP35	M x G	**Small trials** Santa Paula (Hass, 2011), Santa Paula (Hass, 2017), Fallbrook (Hass, 2017), Pala (Hass, GEM, Lamb-Hass, Reed, 2022), Saticoy (Hass, Carmen, GEM, Lamb, and Reed, 2012). **Large trials** Temecula (Hass, 2019), Camarillo (Hass, 2019), Temecula (Hass, 2020), 2 plots in Ventura (Hass, 2020), Goleta (Hass, 2020), San Luis Obispo (Hass, 2020), Goleta (Hass, GEM, Lamb-Hass, 2022).	High PRR incidence, high salinity, high levels of chloride, high pH, alkalinity (as $CaCO_3$), and waterlogging conditions.	Good Phytophthora Root Rot (PRR), salinity tolerant, vigorous trees, low tree mortality and some places less than Dusa, some levels of heat tolerance. Good yield similar to Dusa. No strong alternative bearing effect on Hass. In some field growth smaller than Dusa, making it desirable for high density or hedge-row avocado plantings.	8
PP40	M x G	**Small trials** Santa Paula (Hass, 2006), Santa Paula (Hass, 2017), Fallbrook (Hass, 2017), Pala (Hass, GEM, Lamb-Hass, Reed, 2022), Saticoy (Hass, Carmen, GEM, Lamb, and Reed, 2012). **Large trials** Temecula (Hass, 2019), Camarillo (Hass, 2019), Temecula (Hass, 2020), 2 plots in Ventura (Hass, 2020), Goleta (Hass, 2020),	High PRR incidence, high salinity, high levels of chloride, high pH, alkalinity (as $CaCO_3$), and waterlogging conditions.	Good Phytophthora Root Rot (PRR), salinity tolerant, vigorous trees, low tree mortality and some places less than Dusa, moderate heat sensitivity. Good yield similar to Dusa and better than Dusa in some fields. No strong alternative bearing effect on Hass.	8

		San Luis Obispo (Hass, 2020), Goleta (Hass, GEM, Lamb-Hass, 2022).			
PP80	M x G	**Small trials** Santa Paula (Hass, 2017), Fallbrook (Hass, 2018), Pala (Hass, GEM, Lamb-Hass, Reed, 2022). **Large trials** Temecula (Hass, 2021), Camarillo (Hass, 2021), Ventura (Hass, 2020), Goleta (Hass, 2020), Goleta (Hass, GEM, Lamb-Hass, 2022).	High PRR incidence, high salinity, high levels of chloride, high pH, alkalinity (as CaCO3), and waterlogging conditions.	Good Phytophthora Root Rot (PRR) similar to Dusa, some levels of salinity tolerance, vigorous trees, good levels of heat tolerance better than Dusa. We need to collect more tree health and yield data since is the most recent selection.	8$
PP42	M	**Small trials** Santa Paula (Hass, 2006), Santa Paula (Hass, 2017), Fallbrook (Hass, 2017). **Large trials** Temecula (Hass, 2021), Camarillo (Hass, 2021), Ventura (Hass, 2020), Goleta (Hass, 2020).	High PRR incidence, high salinity, high levels of chloride, high pH, alkalinity (as CaCO3), and waterlogging conditions.	Good Phytophthora Root Rot (PRR) better than Dusa, some levels of salinity tolerance, vigorous trees, good levels of heat tolerance. Good yield (similar to Dusa). No strong alternative bearing effect on Hass.	8
PP45	M	**Small trials** Santa Paula (Hass, 2006), Santa Paula (Hass, 2011), Santa Paula (Hass, 2017), Fallbrook (Hass, 2017), Saticoy (Hass, Carmen, GEM, Lamb, and Reed, 2012). **Large trials** Temecula (Hass, 2020), 2 plots in Ventura (Hass, 2020), Goleta (Hass, 2020), San Luis Obispo (Hass, 2020).	High PRR incidence, high salinity, high levels of chloride, high pH, alkalinity (as CaCO3), and waterlogging conditions.	Good Phytophthora Root Rot (PRR) better than Dusa**, susceptible to salinity**, vigorous trees, good levels of heat tolerance better than Dusa. Good yield (similar to Dusa). No strong alternative bearing effect on Hass. This rootstock is the best producer in plots with high PRR incidence which is good for replanting under these conditions.	8

 # = data collected since 2015-2022, there is not harvest data in 2015 and 2020 (COVID-19). $ field data is less for this rootstock since from 2015-2019 was only planted on two plots.

Figure 2. Yield and yield efficiency data for the UCR rootstocks PP35, PP40, and PP45 grafted to Hass, Hass, Carmen, GEM, Lamb, and Reed. A. Yield and B. Yield efficiency.



<u>Overall Goal:</u> *The overall goal for this proposal is to continue with the generation and collection of compelling field and horticultural data require to commercially release five of the most promising advanced UCR rootstocks (PP35, PP40, PP42, PP45, and PP80), which are currently under field evaluation in small regional and large-scale trials throughout California.*

To address this goal, we have divided this proposal in two sections:

Section 1. Continue the collection of tree health and harvest data for PP35, PP40, PP80, PP42, and PP45 UCR advanced rootstocks at: i) two previously established small regional field trials in Santa Paula (Limoneria 2 and Gunderson) and ii) the commercial-scale field trials (established in July 2019, July 2020, and July 2021). This section also includes the data collection in terms of horticulture characteristics, pictures, and paperwork required for the commercial release of PP35, PP40, PP45, and PP42 in California. This data will be collected at AgOPs (UCR) and at SCREC (Irvine).

Section 2. Continue the collection of tree health and harvest data for PP35, PP40, PP42, PP45, and PP80 UCR advanced rootstocks, Israeli rootstocks (VCs), and South African rootstocks at Pine Tree and Bonsall rootstock trials (established June 2017).

<u>Experimental approach and timeline</u>

Section 1. Continue the collection of tree health and harvest data for PP35, PP40, PP80, PP42, and PP45 UCR advanced rootstocks at: i) two previously established small regional field trials and ii) the commercial-scale field trials.

Monitoring and data collection. We are planning to continue visiting and collecting plant health and harvest data for the next three years in these field trials. These plots will be monitored a minimum 3 to 4 times a year and data will be collected as indicated in **Table 3.** We plan to monitor these sites for 8 to 10 years. Harvest and packing data will be collected at each plot each year and will be discussed with each grower cooperator.

Table 3. Field site data to be collected	
Quarterly	a. Observe trees and document any noteworthy events such as excessive bloom, fruit set, fruit or leaf drop, heat damage, etc. b. Discuss with cooperators any concerns and modifications in their cultural management such as pruning and nutritional practices that may influence results. c. Update field maps, landmarks, and re-tag trees for identification as necessary.
Biannually (Spring and Fall)	a. Measurements: tree height and canopy size (tree height and width). b. Overall tree health (0 best – 5 dead). c. Leaf necrosis (salinity), heat damage (0 best – 5 dead), flush (0 - 5 best). Blooming (0 - 5 best), Fruit set (0=none, 1= <10 fruits/tree, 2= <30 fruits/trees, 3 = > 30 fruits/tree.

Annually	a. Trunk circumference below and above the bud union will be collected in the Fall following the end of the summer flush (approximately October). b. *Small regional trials*: Individual tree yield data (weight and fruit number). Average fruit size will be calculated from the harvested weight and fruit number. Yield efficiency will be calculated using canopy size. *Large-scale trials*: harvest will be conducted by rootstock accession. Crop will be sent to packing house to obtain total pounds, total fruit count, and size distribution. Harvest will be coordinated with individual cooperators.

Figure 3. Overall tree health and leaf necrosis scoring system.

Score	Overall Health	Salinity/Heat
0	Perfect looking tree	0 - 5 % damage, perfect/healthy
0.5	Slightly off (less leaves/small leaves, lack of flush)	5 - 10 %
1	Yellow leaves and or small leaves	11 - 20 %
2	Exposed branches, wilting leaves, small yellow leaves	21 - 40 %
3	Branch dieback, very few leaves remaining, starting to die	41 - 60 %
4	Almost dead, won't last long	61 - 80 %
5	Dead	81 - 100 %

Overall tree health and leaf necrosis = 0 | **Overall tree health = 4 Leaf necrosis = 0** | **Overall tree health = 3.5 Salinity damage = 4**

Scoring systems: All the field trials in this proposal will use the UCR rootstock breeding program scoring system for tree field performance to standardize field data. This scoring system is used by our collaborators in USA and in other countries where these 5 advanced rootstocks will be evaluated as part of our funding with Eurosemillas S.A in the coming years. We will visually rate the trees for overall tree health using a 0 to 5 scale (**Table 3, Fig. 3)**. We will rate the trees at each site for leaf/steam necrosis/dieback (symptoms of salinity or heat damage) on a 0 best to 5 dead scale (**Table 3, Fig. 3)**. At the same time, we will measure tree height and canopy height and width to calculate canopy volume. This will allow us to also calculate yield efficiency for each rootstock (lbs. fruit per cubic meter of tree canopy). We will measure trunk circumference 6 cm below and above the bud union every Fall to calculate the bud union ratios (-1 = rootstock > scion; 0 = smooth bud union; and 1 = scion > rootstock). In addition, we will score flush and blooming using a score of 0= none to 5 = (81-100% of tree) (**Fig. 3**). Fruit set will be also recorded using a score system 0 – 3 where 0= no fruits, 1= < 10 fruits/tree. 2= < 30 fruits/tree, 3 = >30 fruits/tree. In coordination with our cooperator yield data will be collected. Individual tree harvest data and harvest data/rootstock (weight, fruit number, and size distribution) will be collected. The average fruit weight per tree and yield efficiency will be calculated.

1.1.1. ***Collection of tree health and harvest data for PP35, PP40, PP42, and PP45 UCR advanced rootstocks at two previously established field trials.*** In 2015, we conducted an intensive review of all the active field trials that were established under the tenure of J. Menge and G. Douhan. Under the current CAC funding, we have two active field plots being evaluated containing Dusa and the 4 UCR advanced rootstocks that we are focusing on this proposal (PP35, PP40, PP42, and PP45) (**Table 4**). We have conducted soil and water analyses and evaluated each plot for the presence of *P. cinnamomi* using traditional root pathogen isolation and bating soil techniques (**Table 4**). These plots have been properly monitored since 2015, tree health and harvest data has been collected. This data is providing important information regarding the performance of these five rootstocks under these field conditions in Santa Paula Ventura under PRR, salinity, and high pH conditions (**Table 4**).

Table 4. Active rootstock field trials containing Dusa, PP35, PP40, PP42, and PP45.

Plot Name	Rootstock varieties	Status	Year Planted
Gunderson, Santa Paula	**Dusa**, PP#'s 18, 21, 22, **40, 42, 45**, 56, 58, 56, 58, 63, SA-1 Lansfield, and Thomas	This is the oldest plot and was the first plot established at Limoneria Ranch. No harvest records were found before 2015. Harvest data has been collected since 2016. ***Phytophthora cinnamomi*** has been confirmed. Water analyses (FGL) shown problems with **high pH (7.9) and alkalinity (as $CaCO_3$)**, and possible salinity problem E.C. 1.44 dS/m.	2006
Limoneria Ranch #2, Santa Paula	**Dusa,** PP#'s 25, 26, **35, 45**, and 48	Good plot, well designed. Trees looks nice. *Phytophthora cinnamomi* has not been detected by any methods. Water analyses (FGL) indicated problems with **high pH, E.C. 1.6 dS/m, and severe problem of alkalinity (as $CaCO_3$).**	2011

<u>**Limoneria 2, Santa Paula.**</u> The previous manager Andy Coker is no longer working at Limoneira. We have been communicating and working with the new managers: Mr. Edgar Gutierrez (Vice President of Farming Operations) and Mr. Vince Giacolo ne (Director of Southern Management Operations). Five UCR rootstock selections including the advanced rootstocks, PP35 and PP45, have been evaluated in this field plot established in_2011. In this plot, rootstocks are being tested under high pH and high alkalinity conditions. Salinity based on our water and soil analysis indicated a possible salinity problem (**Table 4**). At this site, PP25 and PP48 have the highest tree mortality (~55 %). PP45 and PP35 exhibited the least mortality (20%) (**Fig. 4**). PP35 is the smallest rootstock with less canopy size and significantly different than Dusa and PP45 (**Fig. 5).**

Figure 4. Tree mortality at Limoneria 2, Santa Paula, Ventura.

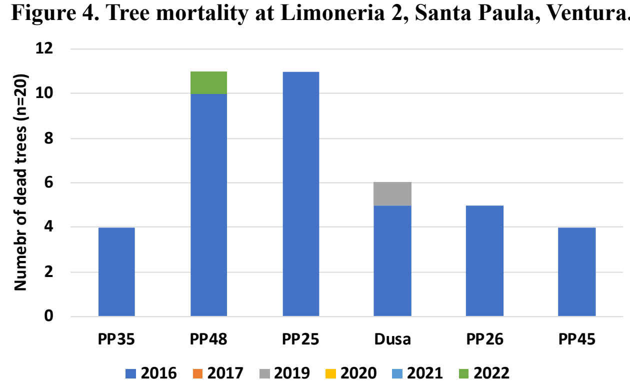
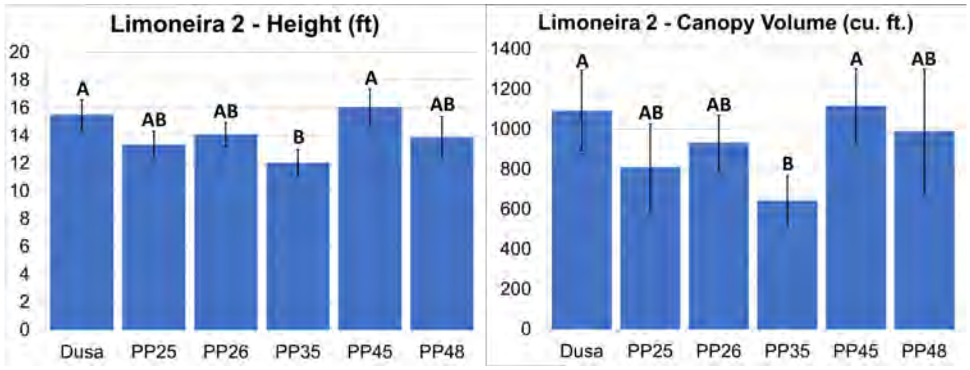
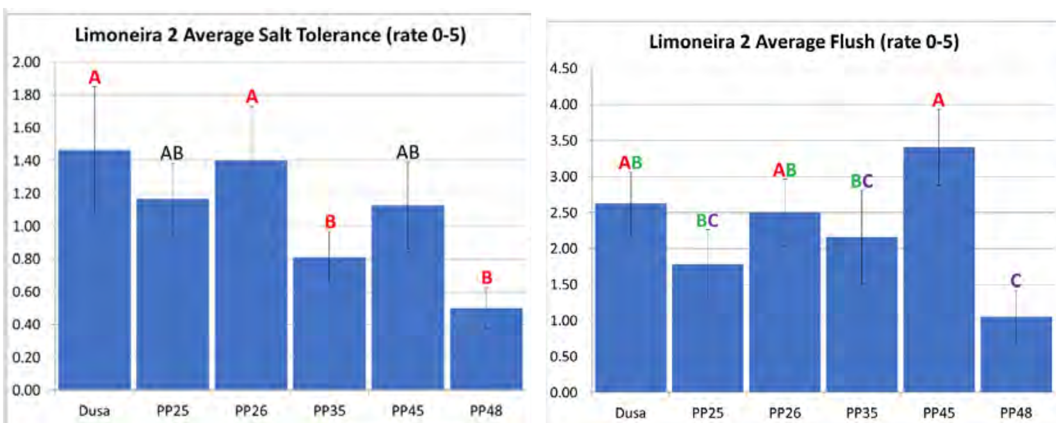


Figure 5. Tree height and Canopy size at Limoneria 2, Santa Paula, Ventura (2022).



In Fall 2021, no significant differences were found among rootstocks regarding tree health and heat damage scores. All trees also were heavily blooming at this location. Significant differences were detected among rootstocks regarding salt damage, flush, and fruit set (**Fig. 6**). PP35 and PP48 were the rootstocks with less salinity damage and were significantly different from Dusa and PP26 that showed the highest salinity damage scores. PP45 in this location was the most vigorous and with the most vegetative growth at this location. In May 2022, no significant difference was found among rootstocks except for tree height and canopy size (**Fig. 5**).

Figure 6. Salinity damage and flushing scores at Limoneria 2, Santa Paula, Ventura (Fall 2021).



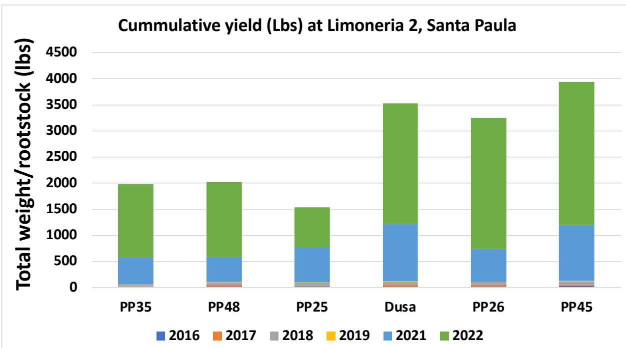
This plot was harvested by 48 plus size picking (7.5 – 9.5 oz) on January 31 (2022). **Table 5** showed the amount of fruit collected for that size. PP45 was the rootstock that produced more total pounds and fruits.

Table 5. Summary of Limoneria 2 size picking January 2022.

Date Harvested	Field	Rootstock	# of Trees	Total Fruit #	Total Weight (lbs)	Avg weight (oz)/fruit	Avg fruit #/Tree
1-31-22	Limoneira 2	Dusa	14	1472	788.28	8.57	105.14
1-31-22	Limoneira 2	PP25	7	597	318.56	8.54	85.29
1-31-22	Limoneira 2	PP26	15	1902	1055.38	8.88	126.80
1-31-22	Limoneira 2	PP35	15	998	542.91	8.70	66.53
1-31-22	Limoneira 2	PP45	15	2199	1214.72	8.84	146.60
1-31-22	Limoneira 2	PP48	6	732	381.84	8.35	122.00

We collected 6 years of harvest data (2016-2022). PP45, Dusa, and PP26 are the best producers at this site. Note that PP45 was the best producer in 2022. PP35 is a small tree but a good producer. PP35 trees yield half of the total pounds when compared with Dusa and PP45, however PP35 has half of the canopy volume when compared with Dusa and PP45 (**Fig. 5, Fig. 7, Table 6**). Dusa, PP35, and PP45 have similar yield efficiency (**Fig. 7**). These results argues that PP35 in some locations are small but good producers having similar yield efficiency than Dusa highlighting the importance of PP35 for high density planting.

Figure 7. Cumulative yield/rootstock and Yield efficiency (2022) at Limoneria 2, Santa Paula, Ventura.



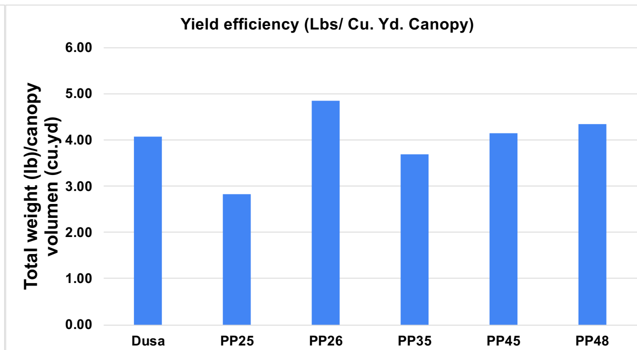
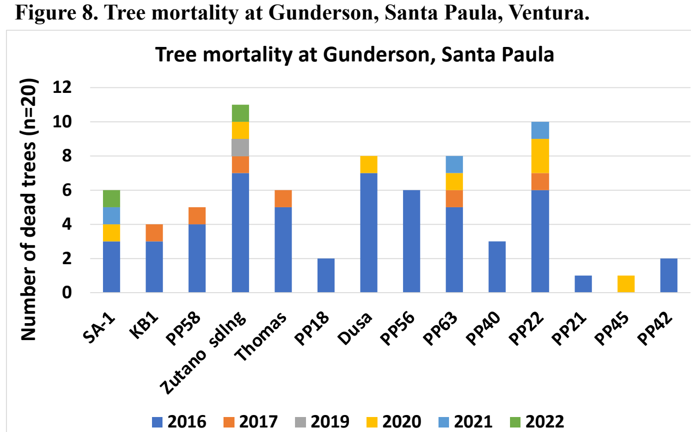


Table 6. Summary of Limoneria 2 harvest in 2022 (January and April).

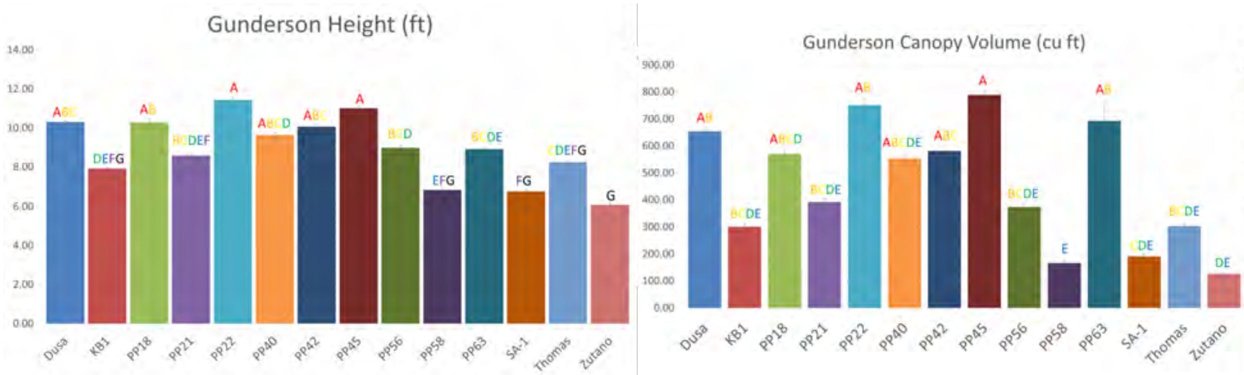
Field	Rootstock	# of Trees	Total Fruit #	Total Weight (lbs)	Avg weight (oz)/fruit	Avg fruit #/Tree	Avg weight (lbs)/tree
Limoneira 2	Dusa	14	4438	2310.47	8.33	317.00	165.03
Limoneira 2	PP25	9	1534	765.53	7.98	170.44	85.06
Limoneira 2	PP26	15	4668	2509.66	8.60	311.20	167.31
Limoneira 2	PP35	15	2707	1408.45	8.32	180.47	93.90
Limoneira 2	PP45	15	4767	2744.12	9.21	317.80	182.94
Limoneira 2	PP48	9	2921	1433.58	7.85	324.56	159.29

Figure 8. Tree mortality at Gunderson, Santa Paula, Ventura.



Gunderson, Santa Paula. We have been communicating and working with the new managers: Mr. Edgar Gutierrez (Vice President of Farming Operations) and Mr. Vince Giacolone (Director of Southern Management Operations). Eleven UCR rootstock selections including the advanced rootstocks, PP40, PP42, and PP45, have been evaluated in this field plot established in 2006. In this plot, rootstocks are being tested under PRR, high pH and high alkalinity conditions. Salinity based on our water and soil analysis indicated a possible salinity problem (**Table 4**). At this site, PP22 and Zutano seedlings have the highest tree mortality (> 50 %). PP45, PP42, PP40, PP21, and PP18 exhibited the least mortality (~10%) (**Fig. 8**). According with data from Fall 2021, There are not significant differences for tree height and canopy size among PP22, PP45, Dusa, PP18, PP42 and PP40. Zutano seedlings, SA-1 PP58, RO.54 (Topara) and Thomas are the smaller trees at this location (**Fig. 9**).

Figure 9. Tree height and Canopy size at Gunderson, Santa Paula, Ventura.



SA-1, PP63, RO.54 (Topara), Thomas, Zutano seedlings PP56 and Dusa are the rootstocks with the worst tree health scores (no significant differences). PP45, PP42, PP18, PP22, PP40 are the best performers at this location (**Fig.10**). At this site, there was not significant differences among RO.54 (Topara), Thomas, PP58, PP56, PP18, PP63, PP22, Zutano seedlings, and PP42 rootstocks regarding salt damage scores. Dusa, SA-1, PP40, PP21, and PP45 exhibited similar performance for salinity resistance (**Fig. 10**). PP45 was the best rootstock for heat resistance followed by PP42, PP18, PP22, Dusa, and others. SA-1 and RO.54 (Topara) are the ones exhibiting the less heat tolerance (**Fig. 11**).

Figure 10. Overall tree health and salinity damage scores at Gunderson, Santa Paula, Ventura.

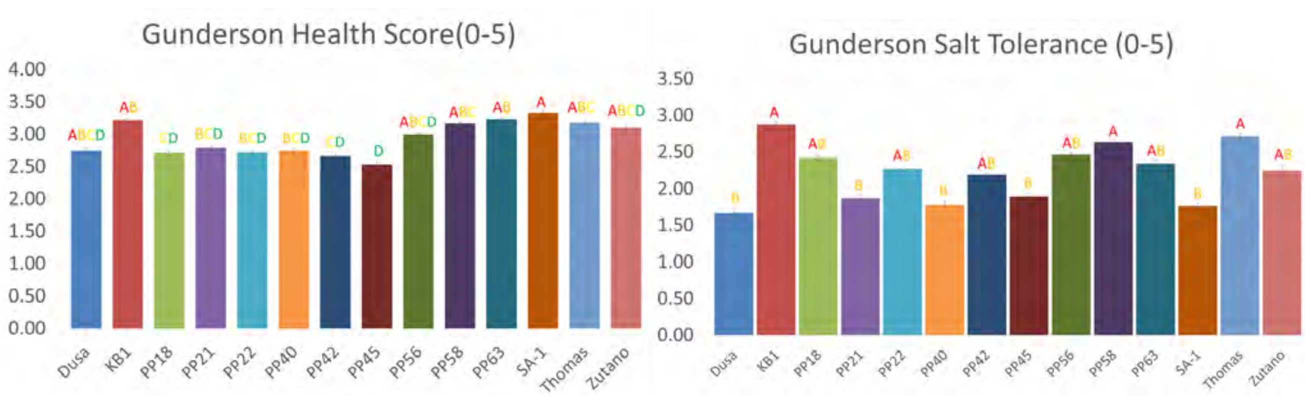
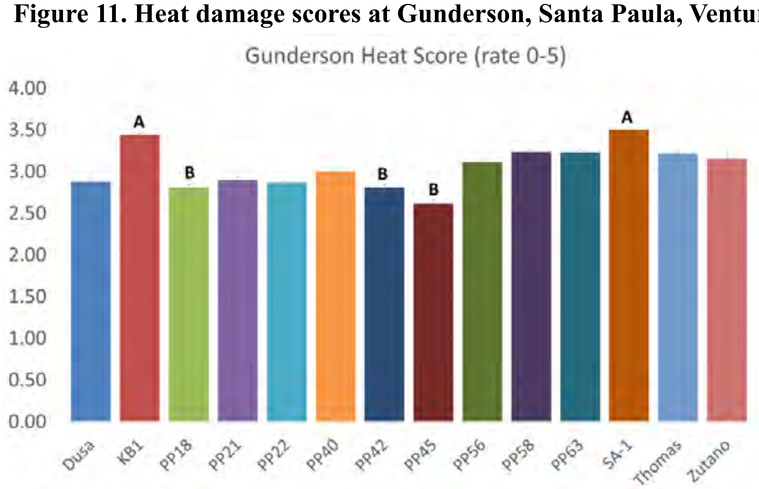


Figure 11. Heat damage scores at Gunderson, Santa Paula, Ventura.



Connecting Letters Report

Level			Mean
SA-1	A		3.5000000
KB1	A		3.4375000
PP58	A	B	3.2333333
PP63	A	B	3.2307692
Thomas	A	B	3.2142857
zutano sdlng	A	B	3.1500000
PP56	A	B	3.1071429
PP40	A	B	3.0000000
PP21	A	B	2.8947368
Dusa	A	B	2.8750000
PP22	A	B	2.8636364
PP18		B	2.8055556
PP42		B	2.8055556
PP45		B	2.6111111

Levels not connected by same letter are significantly different.

We collected 6 years of harvest data (2016-2022). PP40 is the best producer in this location, followed by PP42, PP45, PP21, and Dusa (**Fig.12, Table 7).** Similarly, PP40 is the rootstock with the best yield efficiency per canopy volume followed by Dusa and PP21 (**Fig. 13**).

Figure 12. Cumulative yield at Gunderson, Santa Paula, Ventura.

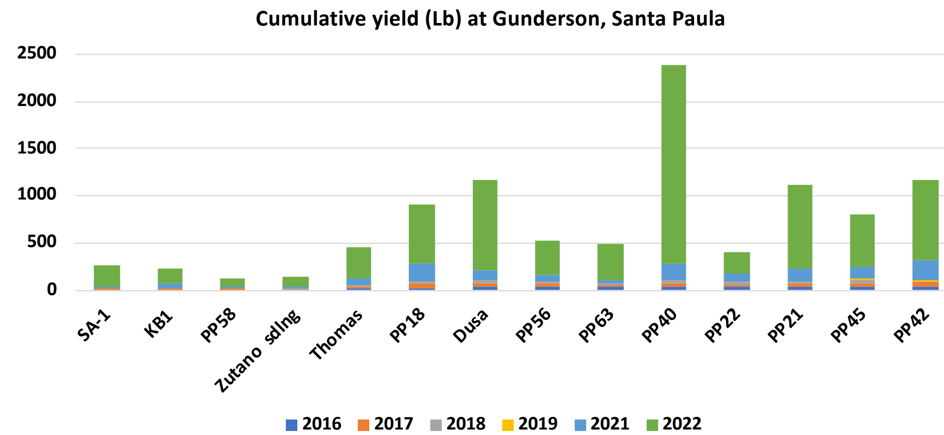


Figure 13. Yield efficiency/rootstock at Gunderson, Santa Paula, Ventura.

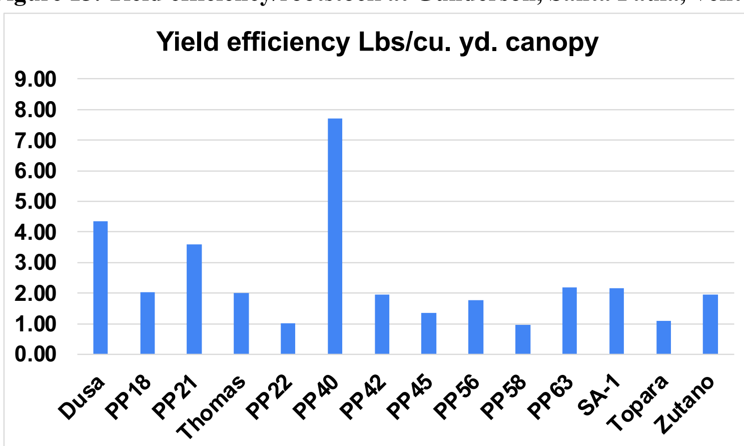


Table 7. Summary of harvest at Gunderson, Santa Paula (2022)

Rootstock	Total # of Alive Trees	Total Fruit #	Total Weight (lbs)	Avg Weight (oz) / Fruit	Avg # Fruit / Tree	Avg Yield (lbs) / Tree	# of Alive Trees w/ No Fruit	Avg # Fruit / Tree	Avg Yield (lbs) / Tree
Dusa	12	2091	959.52	7.34	174.25	79.96	1	190.09	87.23
PP18	18	1357	628.15	7.41	75.39	34.90	3	90.47	41.88
PP21	19	2425	889.35	5.87	127.63	46.81	0	127.63	46.81
Thomas	14	864	332.18	6.15	61.71	23.73	1	66.46	25.55
PP22	10	542	225.60	6.66	54.20	22.56	1	60.22	25.07
PP40	17	5688	2100.68	5.91	334.59	123.57	0	334.59	123.57
PP42	18	1982	846.62	6.83	110.11	47.03	2	123.88	52.91
PP45	19	1136	544.22	7.67	59.79	28.64	2	66.82	32.01
PP56	14	947	370.96	6.27	67.64	26.50	1	72.85	28.54
PP58	15	199	78.62	6.32	13.27	5.24	4	18.09	7.15
PP63	12	996	368.40	5.92	83.00	30.70	2	99.60	36.84
SA-1	15	639	223.50	5.60	42.60	14.90	4	58.09	20.32
Topara	16	421	163.04	6.20	26.31	10.19	2	30.07	11.65
Zutano	11	200	92.66	7.41	18.18	8.42	5	33.33	15.44

The results from tree health and harvest collection at these two plots in Santa Paula support the commercial release of PP40, PP35, PP42, and PP45. These trees perform in some locations and years better or similar than Dusa. Under this cycle of funding, we will continue collected more compelling data specially harvest data for these UCR advanced rootstocks as indicated in Table 3.

1.2. Collection of tree health and harvest data for PP35, PP40, PP42, and PP45 UCR advanced rootstocks at the large-scale rootstock trials established in 2019, 2020, and 2021.

Establishment of commercial-scale field trials. The goal of these large trials is to have a better assessment of yield, packing data, and also will be a way to test early adoption of the UCR rootstocks before release them. Currently, we are evaluating PP35, PP40, PP42, PP45, and PP80 rootstocks grafted with 'Hass" at a semi-commercial scale with different growers at Southern and Northern California under appropriate NPA agreements. A total of nine rootstock trials were established. Dr. Tim Spann and Dr. Manosalva selected the growers and sites for these plantings. Soil and water samples were collected and used for PRR incidence calculation at the Manosalva Lab. Samples were also sent to Fruit Growers Lab (FGL) to conduct soil comprehensive and water irrigation suitability analyses. **Table 8** describes the rootstock accessions planted at each site and the number of trees of each rootstock. Field conditions such as PRR incidence, salinity and soil pH for each site is reported (**Table 8**). Each rootstock accession was planted in a single block to facilitate subsequent harvest data collection.

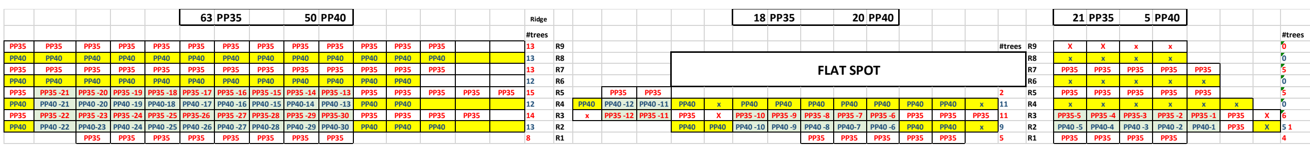
Table. 8. Description of the large-scale trials established in California. Number of trees per rootstock grafted with Hass planted is indicated in parenthesis.

Grower/Manager	City/County	Year planted	Rootstocks (#s)	Field conditions
Leo McGuire	Temecula/ Riverside	2019	PP35 (102), PP40 (75)	E.C value of 0.86 dS/m, however, the chloride level is slightly high 102 mg/L indicating a possible problem with chloride toxicity. High pH (7.9) and alkalinity (as $CaCO_3$). High PRR incidence.
Leo McGuire	Temecula/ Riverside	2021	Dusa (100), PP42 (100), PP80 (100)	E.C value of 0.86 dS/m, however, the chloride level is slightly high 102 mg/L indicating a possible problem with chloride toxicity. High pH (7.9) and alkalinity (as $CaCO_3$). High PRR incidence.
John Lamb	Camarillo /Ventura	2019	PP35 (100), PP40 (51)	Normal E.C value of 1.16 dS/m, however, there is a high level of chloride 148 mg/L, indicating problems with chloride toxicity which indicate fairly poor crop suitability even if amendments such as gypsum, sulfuric acid (98%), or if leaching is applied. In addition, the water analyses show problems with high pH (8.7) and alkalinity (as $CaCO_3$). *Phytophthora cinnamomi* was not detected in this field.

John Lamb	Camarillo /Ventura	2021	Dusa (100), PP42 (100), PP80 (100)	Normal E.C value of 1.16 dS/m, however, there is a high level of chloride 148 mg/L, indicating problems with chloride toxicity which indicate fairly poor crop suitability even if amendments such as gypsum, sulfuric acid (98%), or if leaching is applied. In addition, the water analyses show problems with high pH (8.7) and alkalinity (as $CaCO_3$). *Phytophthora cinnamomi* was not detected in this field.
Andrew Gabryzak/Newhouse Green Gold	Temecula/ Riverside	2020	Dusa (100), PP35 (116), PP40 (100), PP45 (70)	High chloride levels, high pH, and high alkalinity as CaCO3. High PRR incidence, and possible problem with soil saturation (soil contain high clay composition).
Chris Sayer/ Petty Ranch	Ventura	2020	Dusa (100), PP35 (116), PP40 (100), PP45 (70)	High water salinity (2.3 dS/m), high iron levels, high alkalinity as CaCO3, severe problem of total water hardness. *P. cinnamomi* was not detected. Soil analyses indicate normal chloride levels and soil salinity, optimum saturation (on the high side, might have some problems in the future). High limestone.
Masood Sohaili & Rick Shade/ Alina LLC Ranch	Ventura	2020	Dusa (61), PP35 (116), PP40 (100), PP45 (100), PP42 (28), PP80 (39)	This field has problems with high PRR incidence (100%) which is a serious problem for replanting. Soil analyses indicate normal chloride and salinity levels, optimum saturation (on the high side, might have some problems in the future). High limestone. Water analyses indicate not problems with salinity.
Pete Miller	Goleta/ Santa Barbara	2020	Dusa (100), PP35 (116), PP40 (100), PP45 (100), PP42 (28), PP80 (39)	**Section 1 (S1):** 60% of PRR incidence. Chloride is not a problem yet but it is on the high side (eventually will became a problem), high soil salinity (2.71 dS/m), has 99% of saturation, high CEC. **Section 2 (S2):** 40% of PRR incidence. Soil analyses indicate high chloride levels, high soil salinity (3.65 dS/m), and high % of saturation (66.5%), clay soil. **Section 3 (S3):** 0% of PRR incidence. No problems with salinity or chloride. Low nitrogen, optimum soil saturation **Section 4:** 90% of PRR incidence. No problems with salinity or chloride. Optimum soil saturation and pH. **Section 5:** 50% of PRR incidence. No problems with salinity or chloride. Optimum soil saturation and pH.
Dr. Lauren Garner/ California Polytechnic State University	San Luis Obispo	2020	Dusa (96), PP35 (96), PP40 (97), PP45 (95),	Soil and water analyses does not show major problems with salinity, pH, saturation. *Phytophthora cinnamomi* was detected in roots from avocado trees next to the rootstock trial.

Leo McGuire plot 1, Temecula, (2019). A total of 102 PP35 and 75 PP40 trees grafted to 'Hass' were planted in Temecula on June 14, 2019. Trees for each rootstock were arranged as rootstock per raw in the field (**Fig. 14**). Trees were planted into the top of mounds at a 15 x 20 ft tree spacing. A subset of 30 trees (highlighted in green) were selected and tagged by spraying color paint and tagged with metal tags to collect tree health data.

Figure 14. Map for Leo McGuire's 2019 plot



Data collection and statistical analysis conducted in Fall 2021 did no detect significant differences between PP40 and PP35 at this location regarding tree height, tree health, salt and heat damage, However, PP35 exhibited significant less canopy size when compared to PP40. Significant differences were also found regarding the ratios of the trunk diameter above/below the union between the rootstocks. PP35 exhibited smaller ratio compared with PP40 (P= 0.02) (**Fig. 15)**. All PP35 and PP40 trees exhibited heavy flush (no significant differences found). Bloom was heavy in all PP35 and PP40 (no significant differences). At this location, PP40 exhibited more mortality (30%) than PP35 (17%).

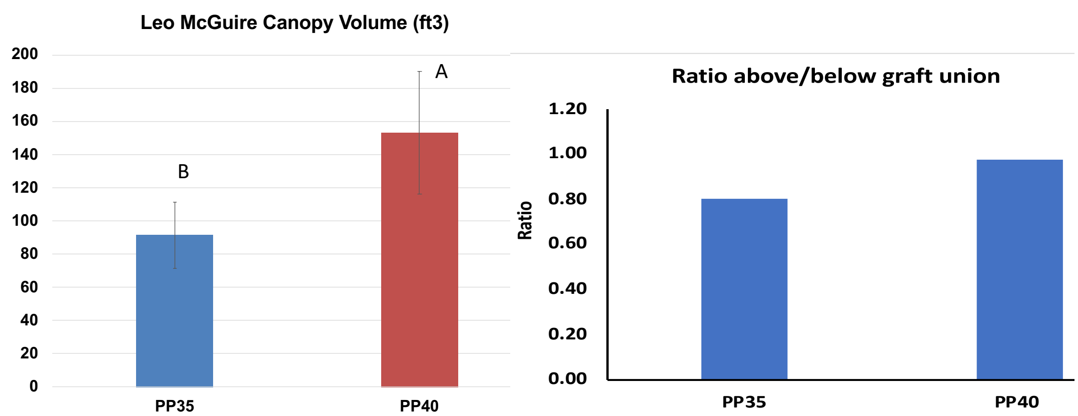
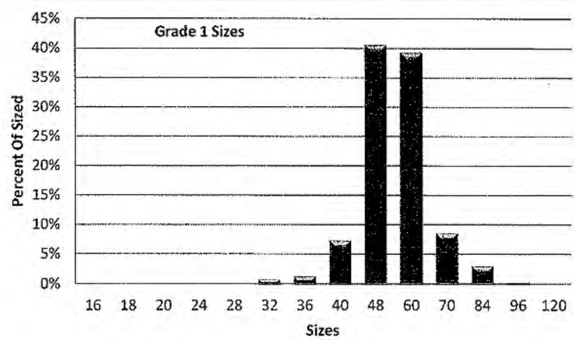


Figure 15. Tree canopy volume and trunk diameter of PP40 and PP35 at Leo McGuire plot, Temecula.

The first harvest of this plot was conducted on April 2021. A total 95 fruits were collected for a total weight of 53.7 pounds (lbs) for PP35 (0.56 lb/PP35 fruit). A total of 13 fruits were collected from PP40 producing a total weight of 7.1 lbs (0.54 lbs/PP40 fruit). The second harvest was conducted in this plot on January 26 (2022) and crop was sent to packing house by Leo McGuire who provide the data presented in this report. Amber Newsome from the Manosalva lab supervised the harvest at this plot. Trees in this plot were planted in June 2019. From 95 trees of PP35 trees grafted with 'Hass' we obtained 3820.57 average fruit count and a total of 1,718 lbs (marketable fruit) from a total 1756 lbs. including culls. The average fruit number per tree was 39.39 and the average weight (oz)/fruits was 7.19 oz. Majority of the crop for PP35 was marketable sizes: 37.24% (48) and 36.05% (60) (**Fig. 16**).

Figure 16. Data for PP35 harvest collected from packing house (2022), Temecula.

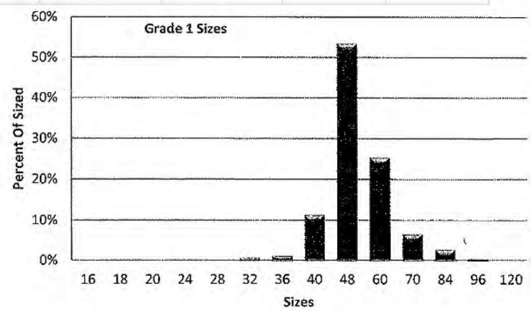
Bin # 62078			Approximate Fruit Counts By Weight			
Fruit Quality #	Size	Weight (lbs)	Min Fruit Count	Max Fruit Count	Avg Fruit Count	% of Net
1	96	2	8.53	9.85	9.19	0.114
1	84	47	158.32	200.53	179.42	2.677
1	70	136	348.16	458.11	403.13	7.745
1	60	633	1350.40	1620.48	1485.44	36.048
1	48	654	1101.47	1395.20	1248.34	37.244
1	40	116	161.39	195.37	178.38	6.606
1	36	19	24.32	26.43	25.38	1.082
1	32	10	11.43	12.80	12.11	0.569
1	All combined	1617	3164.02	3918.77	3541.40	92.085
2	84	29	97.68	123.73	110.71	1.651
2	70	10	25.60	33.68	29.64	0.569
2	60	51	108.80	130.56	119.68	2.904
2	48	6	10.11	12.80	11.45	0.342
2	40	5	6.96	8.42	7.69	0.285
2	All combined	101	249.15	309.20	279.17	5.751
Marketable (1+2)	All combined	1718	3413.17	4227.97	3820.57	97.836
Culls	All combined	38				2.164
Total	All combined	1756				100



From 75 trees of PP40 trees grafted with ‘Hass’ we obtained 2937.37 average fruit count and a total of 1,404 lbs (marketable fruit) from a total 1449 lbs. including culls. The average fruit number per tree was 39.16 and the average weight (oz)/fruits was 7.65 oz. Majority of the crop for PP40 was marketable sizes: 50.7% (48) and 23.9% (60) **(Fig. 17)**.

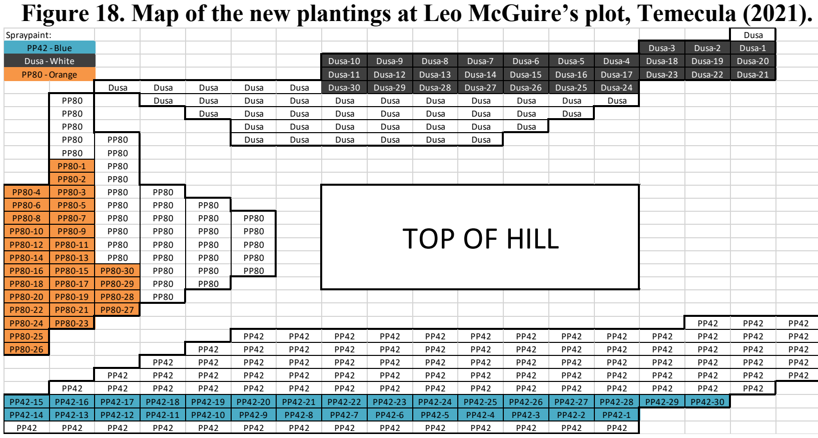
Figure 17. Data for PP40 harvest collected from packing house (2022), Temecula.

Bin # 62078			Approximate Fruit Counts By Weight			
Fruit Quality #	Size	Weight (lbs)	Min Fruit Count	Max Fruit Count	Avg Fruit Count	% of Net
1	96	2	8.53	9.85	9.19	0.138
1	84	34	114.53	145.07	129.80	2.346
1	70	87	222.72	293.05	257.89	6.004
1	60	347	740.27	888.32	814.29	23.948
1	48	734	1236.21	1565.87	1401.04	50.656
1	40	154	214.26	259.37	236.81	10.628
1	36	13	16.64	18.09	17.36	0.897
1	32	7	8.00	8.96	8.48	0.483
1	**All combined**	**1378**	**2561.16**	**3188.57**	**2874.86**	**95.1**
2	84	5	16.84	21.33	19.09	0.345
2	60	11	23.47	28.16	25.81	0.759
2	48	6	10.11	12.80	11.45	0.414
2	40	4	5.57	6.74	6.15	0.276
2	**All combined**		**55.98**	**69.03**	**62.50**	**1.794**
Marketable (1+2)	**All combined**	**1404**	**2617.14**	**3257.60**	**2937.37**	**96.894**
Culls	**All combined**	**45**				**3.106**
Total	**All combined**	**1449**				**100**



Leo McGuire plot 2, Temecula, (2021). In August 2021, this plot was expanded and we planted 100 Dusa, 100 PP80, and 100 PP42 rootstocks grafted with Hass. We selected a subset of 30 trees for each rootstock to collect field data (**Fig. 18**). Trees were planted in blocks and each block was landmarked with spray paint and the 30 trees for data collection were tagged with metal tags for tree identification.

Figure 18. Map of the new plantings at Leo McGuire's plot, Temecula (2021). Trees highlighted are being rated.



Dusa rootstocks exhibited the highest ratio of trunk diameter above/below the graft union followed by PP42 and PP80 which are close to 1 (**Fig.19**). PP42 at this location is the tallest rootstock. Dusa has the best scores for tree health, heat damage. PP80 has the best salinity damage score followed by PP42 and Dusa. At this location Dusa has the best blooming score (**Fig. 20**).

Figure 19. Trunk diameter at the second large-scale planting at Leo McGuire orchard, Temecula (data Fall 2021).

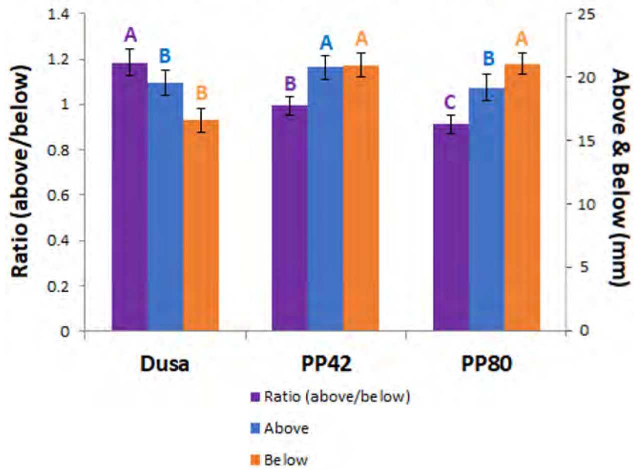
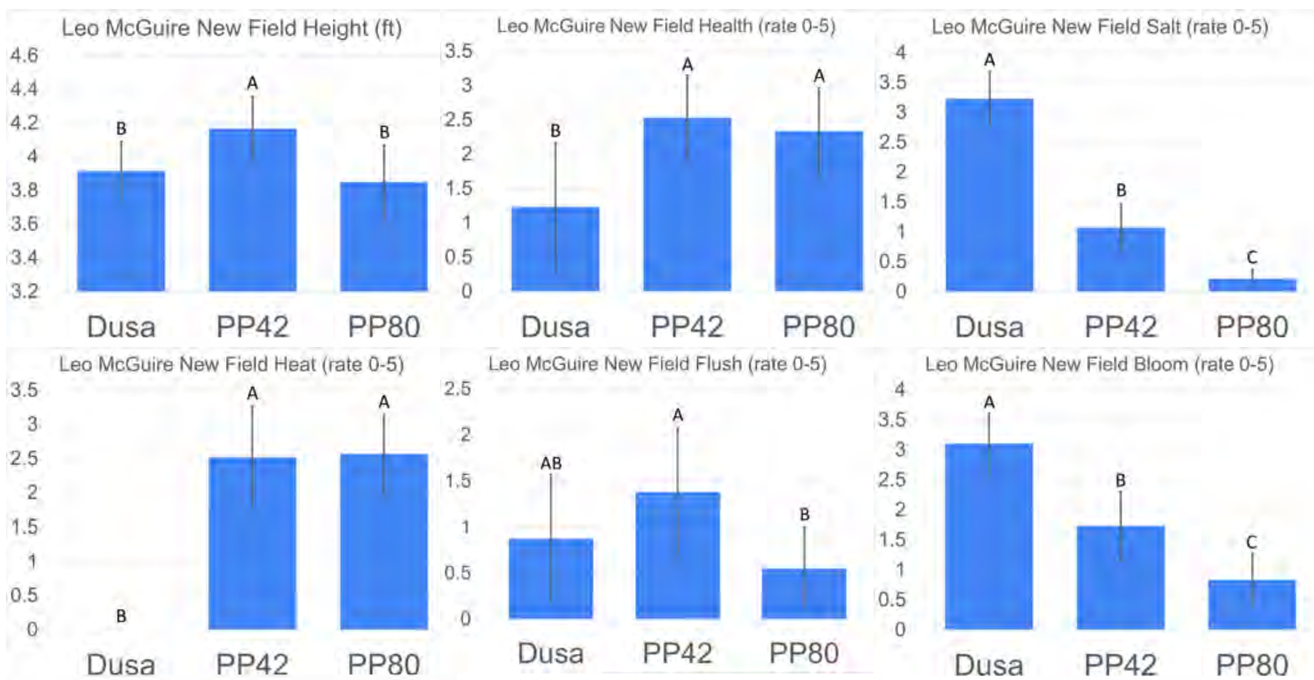


Figure 20. Tree height and tree health data at Leo McGuire plot 2 in Temecula (Data April 2022)



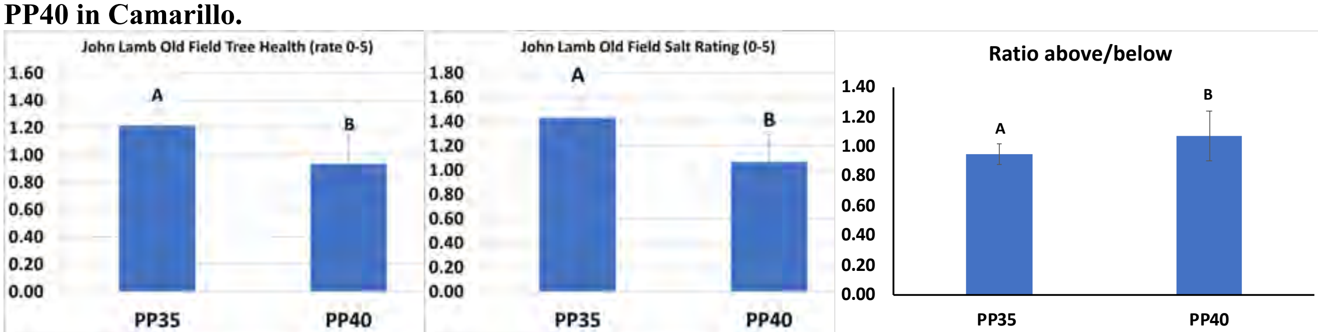
<u>John Lamb plot 1, Camarillo, (2019).</u> A total of 100 PP35 and 51 PP40 trees grafted to 'Hass' were planted in Camarillo on August 7th, 2019. Trees for each rootstock were arranged as rootstock per raw in the field and were planted at 20x 18 ft of tree spacing. The number of trees were less than originally planned due to shortness of trees by Brokaw Nursery. A subset of trees (30 trees/advanced line) were selected for rating. Trees selected for rating are highlighted as green in the map (**Fig. 21**). In June 2020, a total of 26 PP40 and 31 PP35 trees were replaced due to deer activity.

Figure 21. Map for John Lamb plot 1 planted in Camarillo in 2019.

11																															
10	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	X	X		
9	PP35	PP35-11	PP35-12	PP35-13	PP35-14	PP35-15	PP35-16	PP35-17	PP35-18	PP35-19	PP35-20	PP35	PP35	PP35	PP35-21	PP35-22	PP35-23	PP35-24	PP35-25	PP35-26	PP35-27	PP35-28	PP35-29	PP35-30	PP35	PP35				26 trees	
8	PP40	PP40-11	PP40-12	PP40-13	PP40-14	PP40-15	PP40-16	PP40-17	PP40-18	PP40-19	PP40-20	PP40	PP40	PP40	PP40-21	PP40-22	PP40-23	PP40-24	PP40-25	PP40-26	PP40-27	PP40-28	PP40-29	PP40-30				24 trees			
7	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35				20 trees							
6	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35					17 trees									
5	PP40-1	PP40-2	PP40-3	PP40-4	PP40-5	PP40-6	PP40-7	PP40-8	PP40-9	PP40-10	PP40	PP40	PP40					13 trees													
4	PP35-1	PP35-2	PP35-3	PP35-4	PP35-5	PP35-6	PP35-7	PP35-8	PP35-9	PP35-10					10 trees																
3	PP40	PP40	PP40	PP40	PP40	PP40	PP40					7trees																			
2	PP40	PP40	PP40	PP40	PP40			5 trees						Tree #'s																	
1		PP40	PP40		2 trees									#1 - 10	=	Block 1															

No significant differences were found between PP35 and PP40 at this location for most of the phenotypic traits recorded with the exception of tree health and salt damage. At this location, PP40 trees exhibited better tree health and salinity scores than PP40 (**Fig. 22**). There were significant differences regarding trunk diameter above/below the graft union, salt, heat, and flush ratings between PP35 and PP40 (**Fig. 22**). Similar to the results at Temecula, PP35 exhibited lower ratio of trunk diameter above/below graft union than PP40. At this site, PP40 exhibited best fruit set than PP35 and we expected the first harvest in this plot in April-May 2023.

Figure 22. Comparison of the tree health, salinity damage scores, and trunk diameter between PP35 and PP40 in Camarillo.



John Lamb plot 2, Camarillo, (2021). In August 31th 2021, this plot was expanded and we planted 100 Dusa, 100 PP80, and 100 PP42 rootstocks grafted with Hass at 18' x 18' tree spacing. We selected a subset of 30 trees for each rootstock to collect field data (**Fig. 23**). Trees were planted in blocks and each block was landmarked with spray paint and trees being evaluated were tagged with metal tags. Similar to the trees planted in Temecula (Leo McGuire), Dusa rootstocks exhibited the highest ratio of trunk diameter above/below the graft union followed by PP42 and PP80 (close to 1) (**Fig.24**). At this location PP42 and PP80 are better performers when compared with Dusa. Dusa trees are smaller and have more salt and heat damage than PP42 and PP80. As expected PP80 has the best score for heat damage and has the highest flushing score at this location followed by PP42 and Dusa (**Fig. 24, 25**).

Figure 23. Map for John Lamb plot 2 planted in Camarillo in 2021. Trees highlighted are being evaluated.

Spraypaint:																														
Dusa - Pink																														
PP80 - Blue																														
PP42 - Green																														
	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa																
	Dusa-1	Dusa-2	Dusa-3	Dusa-4	Dusa-5	Dusa-6	Dusa-7	Dusa-8	Dusa-9	Dusa-10	Dusa	Dusa	Dusa	Dusa	Dusa															
Dusa-21	Dusa-20	Dusa-19	Dusa-18	Dusa-17	Dusa-16	Dusa-15	Dusa-14	Dusa-13	Dusa-12	Dusa-11	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa														
Dusa	Dusa-22	Dusa-23	Dusa-24	Dusa-25	Dusa-26	Dusa-27	Dusa-28	Dusa-29	Dusa-30	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa													
Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa												
Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa											
Dusa	PP80-1	PP80-2	PP80-3	PP80-4	PP80-5	PP80-6	PP80-7	PP80-8	PP80-9	PP80-10	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80						
Dusa	PP80-20	PP80-19	PP80-18	PP80-17	PP80-16	PP80-15	PP80-14	PP80-13	PP80-12	PP80-11	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80					
Dusa	PP80-21	PP80-22	PP80-23	PP80-24	PP80-25	PP80-26	PP80-27	PP80-28	PP80-29	PP80-30	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80				
Dusa	NOTHING PLANTED			PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80		
Dusa	PP42-1	PP42-2	PP42-3	PP42-4	PP42-5	PP42-6	PP42-7	PP42-8	PP42-9	PP42-10	PP42-11	PP42-12	PP42-13	PP42-14	PP42-15	PP42-16	PP42-17	PP42-18	PP42-19	PP42-20	PP42-21	PP42-22	PP42-23	PP42	PP42	PP42	PP42	PP42	PP42	
Dusa	PP42	PP42	PP42	PP42	PP42	PP42	PP42	☆				PP42	PP42	PP42	PP42	PP42	PP42-30	PP42-29	PP42-28	PP42-27	PP42-26	PP42-25	PP42-24	PP42	PP42	PP42	PP42	PP42	PP42	PP42
Dusa	PP42	PP42	PP42	PP42	PP42	PP42	PP42													PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42
Dusa	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42											DIRT ROAD						PP42	PP42	PP42	PP42	PP42	PP42	PP42
										☆irrigation line splits																				
				↓ OLD FIELD ↓																										

Figure 24. Trunk diameter and tree height at Camarillo plot 2 (Data April 2022).

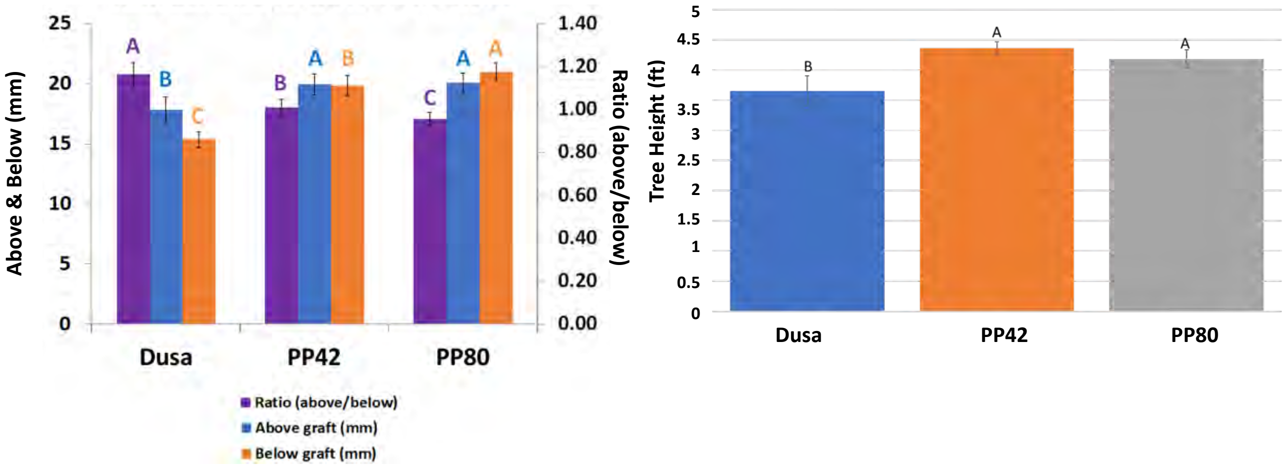
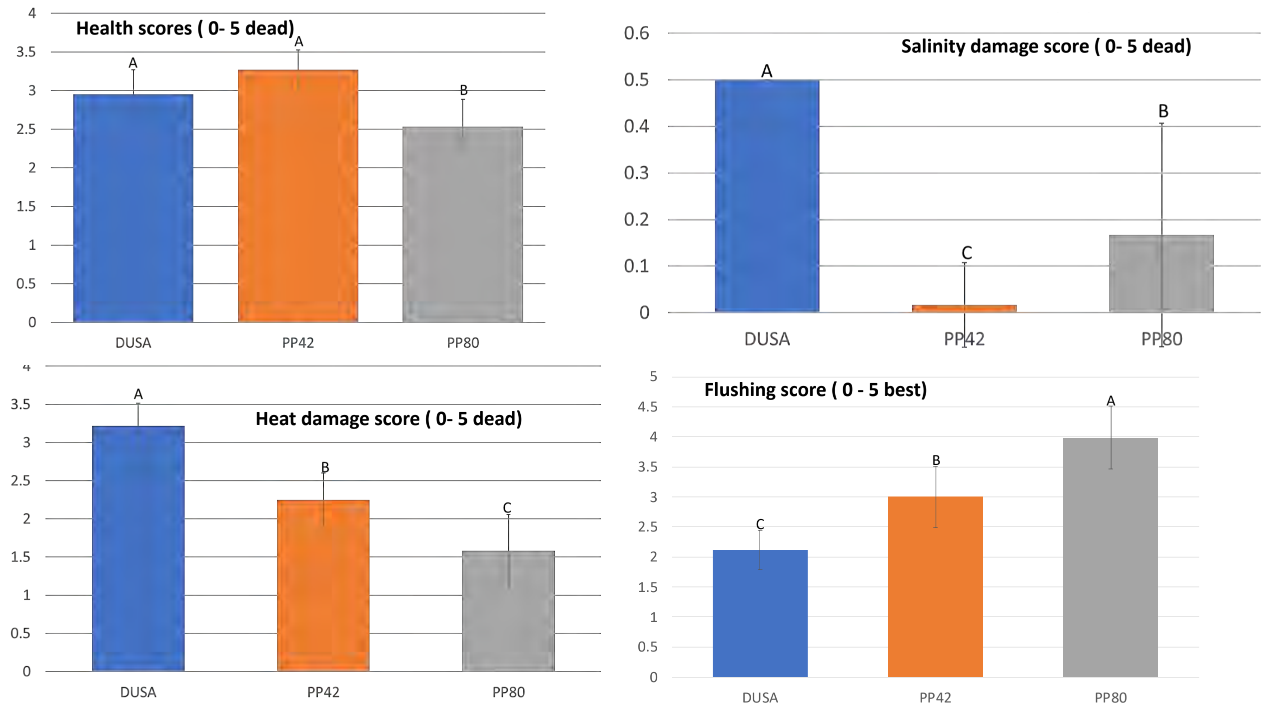


Figure 25. Trunk diameter and tree height at Camarillo plot 2 (Data April 2022).



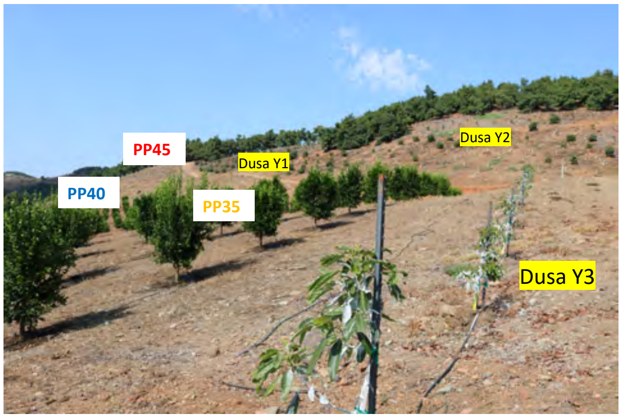


Figure 26. Plot layout at Temecula (2020)

Newhouse Green Gold, Andrew Gabryszak/Nick Lahr (WesPack Avocado), (2020). Trees were planted at a 15' x 20' tree spacing and all trees exhibited similar size at the time of planting (**Fig. 26**). A subset of 30 trees per rootstock were selected, labelled, and used to collect data. These trees will be utilized as reference data trees for the duration of the project. The trees evaluated were tagged as need it and the wooden sticks were spray painted for easy identification of the blocks and trees. At this location ~80% of the Dusa trees died. Most of the dead trees were in sections Y1 and Y2.

Only 30 trees being scored in Y3 sections survived. PP45 rootstock was planted next to Dusa section Y1 and only 1/70 trees planted died. We believe that the combination of high temperatures in July 2020, the soil structure (clay), and Phytophthora root rot (high incidence) was probably the cause of high mortality. PP45 exhibited better performance that Dusa under these conditions (high heat, heavy soil, and PRR). This also has been observed in some plots in Ventura when these combinations are not favorable for Dusa. At this location, 3/100 PP40 and 11/116 PP35 trees died. Only PP40 was significantly different than Dusa regarding tree height (**Fig. 27**). The Dusa survivors at Y3 exhibited more canopy volume (**Fig. 27**) and better tree health similar to PP45 followed by PP35 and PP40 (**Fig. 28**). As expected, all the rootstocks with the exception of PP45 exhibited similar salinity tolerance as Dusa (**Fig. 28**). In this plot, PP35 exhibited the most damage for heat stress (**Fig. 28**) but is the rootstock with the higher fruit set score when compare with other rootstocks. Trees at this location were not blooming or flushing on Fall 2021. We expected to conduct the first harvest in this location in 2023. Recently, this land was bought by Adna Farms, LLC. They are interested on the rootstock trial and Dr. Manosalva will meet Grace Marcellina and CEO Adriadi Ang end of July to discuss further the continuation of this collaboration.

Figure 27. Tree height and canopy volume in Newhouse Green Gold field trial in Temecula .

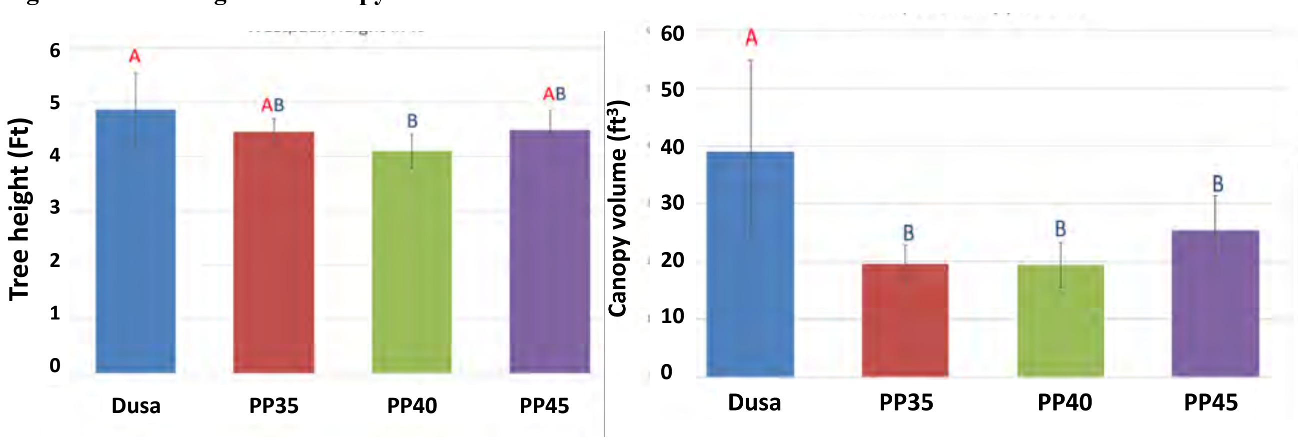
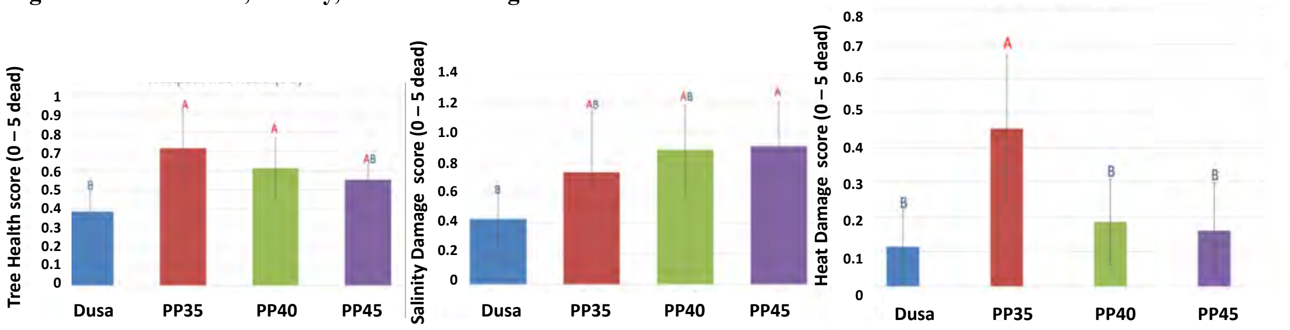


Figure 28. Tree health, salinity, and heat damage scores at Newhouse Green Gold field trial in Temecula .

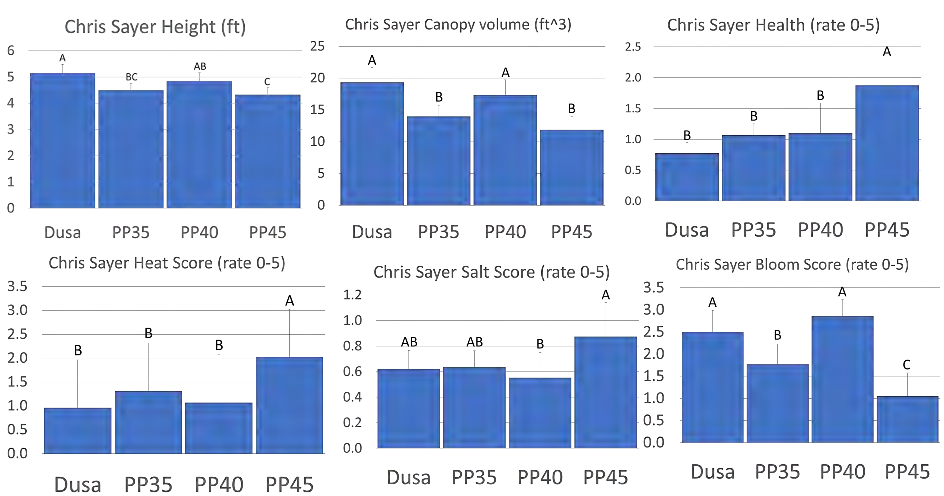


Petty Ranch, Chris Sayer, Ventura (2020). Trees were planted at a 15' x 20' tree spacing at this location and trees exhibited similar size at the time of planting. A subset of 30 trees per rootstock were selected, labeled with metal tags, and rated. Chris Sayer has put a wooden stick at the limit of each block indicating rootstock name (**Fig. 29**).

Figure 29. Map for Chris Sayer planted in Ventura (2020). Trees highlighted in yellow are being evaluated

								Spacing 20' <->			15' V													
	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1 Rows
	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	x	x	x	1
Hass	Dusa-25	Dusa-26	Dusa-27	Dusa-28	Dusa-29	Dusa-30	PP40-25	PP40-26	PP40-27	PP40-28	PP40-29	PP40-30	PP45-25	PP45-26	PP45-27	PP45-28	PP45-29	PP45-30	PP35	PP35	PP35	PP35	PP35	x	2
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	3
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	4
Hass	Dusa-19	Dusa-20	Dusa-21	Dusa-22	Dusa-23	Dusa-24	PP40-19	PP40-20	PP40-21	PP40-22	PP40-23	PP40-24	PP45-19	PP45-20	PP45-21	PP45-22	PP45-23	PP45-24	PP35-25	PP35-26	PP35-27	PP35-28	PP35-29	PP35-30	5
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	6
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	7
Hass				Irrigation lateral																					8
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	9
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	10
Hass	Dusa-13	Dusa-14	Dusa-15	Dusa-16	Dusa-17	Dusa-18	PP40-13	PP40-14	PP40-15	PP40-16	PP40-17	PP40-18	PP45-13	PP45-14	PP45-15	PP45-16	PP45-17	PP45-18	PP35-19	PP35-20	PP35-21	PP35-22	PP35-23	PP35-24	11
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	12
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	13
Hass	Dusa-7	Dusa-8	Dusa-9	Dusa-10	Dusa-11	Dusa-12	PP40-7	PP40-8	PP40-9	PP40-10	PP40-11	PP40-12	PP45-7	PP45-8	PP45-9	PP45-10	PP45-11	PP45-12	PP35-13	PP35-14	PP35-15	PP35-16	PP35-17	PP35-18	14
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	15
Hass	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	PP40	PP40	PP40	PP40	PP40	PP40	PP45	PP45	PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	16
Hass	Dusa-1	Dusa-2	Dusa-3	Dusa-4	Dusa-5	Dusa-6	PP40-1	PP40-2	PP40-3	PP40-4	PP40-5	PP40-6	PP45-1	PP45-2	PP45-3	PP45-4	PP45-5	PP45-6	PP35-7	PP35-8	PP35-9	PP35-10	PP35-11	PP35-12	17
Hass	Dusa	Dusa	Dusa	Dusa					PP40	PP40	PP40	PP40			PP45	PP45	PP45	PP45	PP35	PP35	PP35	PP35	PP35	PP35	18
																			PP35	PP35	PP35	PP35	PP35	PP35	19
																			PP35-1	PP35-2	PP35-3	PP35-4	PP35-5	PP35-6	20
																			PP35	PP35	PP35	PP35	PP35	PP35	21

Figure 30. Tree height and tree health data at Chris Sayer trial in Ventura (Data April 2022)

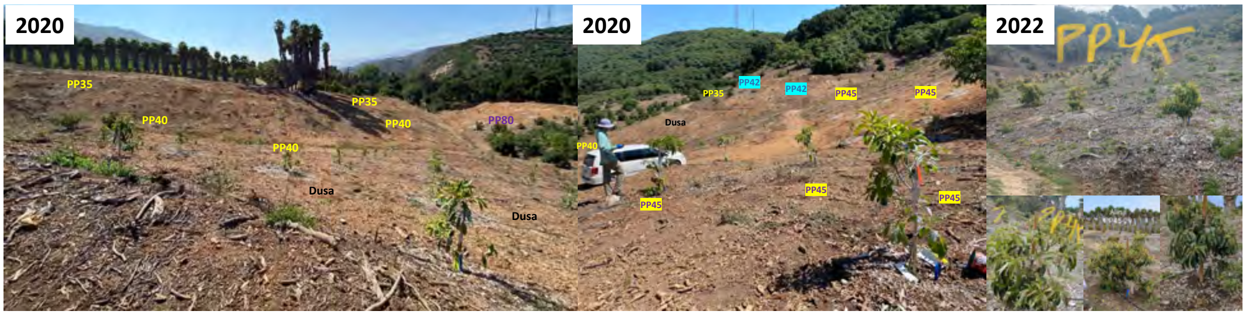


We found significant differences among rootstocks for all the traits evaluated with the exception of flushing scores. At this location, PP45 enhibited the highest mortality, the smaller tree height and canopy size and exhibited more salinity and heat damage. Dusa is the tallest trees followed by PP40 and PP35.

Dusa and PP40 have similar tree canopy size and both were heavy blooming at this location. Dusa, PP40, and PP35 have similar values for tree health, heat damage score, and salinity damage score, however PP35 is smaller and with less canopy volume than these two rootstocks (**Fig. 30**).

<u>Aline Ranch LLC, Rick Shade, Ventura, 2020.</u> Trees at this site were supposed to be planted by blocks, however PP42 was planted in an area having old avocado trees. This plot has 100% PRR incidence. Trees at this location exhibited similar size at the time of planting on July 2020. A subset of 30 trees per rootstock were selected, labeled with metal tags, and rated (**Fig. 31**).

Figure 31. Planting layout at Alina Ranch, Ventura



There were significant differences among rootstocks for all the data collected at this plot. Dusa exhibited the less tree height and less tree canopy volume followed by PP35 and PP80. PP45, PP42, and PP40 were the tallest trees exhibiting the best canopy volume at this plot. This plot has 100% of PRR incidence and the grower has problems for replanting. As expected, the best performer at this location is PP45 (**Fig. 31, Fig. 32**) followed by PP42. PP45 and PP42 are rootstocks that exhibited high resistant to *P. cinnamomi,* causal agent of PRR, when compared with Dusa. PP42 and PP45 are rootstocks with the best scores for overall tree health, heat damage, and flushing scores. PP40 is the rootstock with less salinity damage (**Fig. 32**). PP45, PP42, and PP40 exhibited heavy blooming (scores of 4-5). Dusa has significantly less blooming than the other rootstocks. PP45 is the rootstock with the best fruit set at this location (**Fig. 33**). Based on our observations we expected to harvest PP45, PP42 and PP35 at this location. At this location, PP80 exhibited the highest mortality followed by Dusa and PP35. We are discussing with the ranch manager in the possibility to replace these three rootstocks that failed at this location for other commercially available rootstocks like Tami (VC801), Zerala (Merensky 5), and replace PP80 for PP42 that was planted in less number and no in block. ***These trees will be ordered in Nov 2022 and the cost will be covered by another funding source of Dr. Manosalva.***

Figure 32. Tree health data at Alina Ranch LLC, Ventura (Data April 2022).

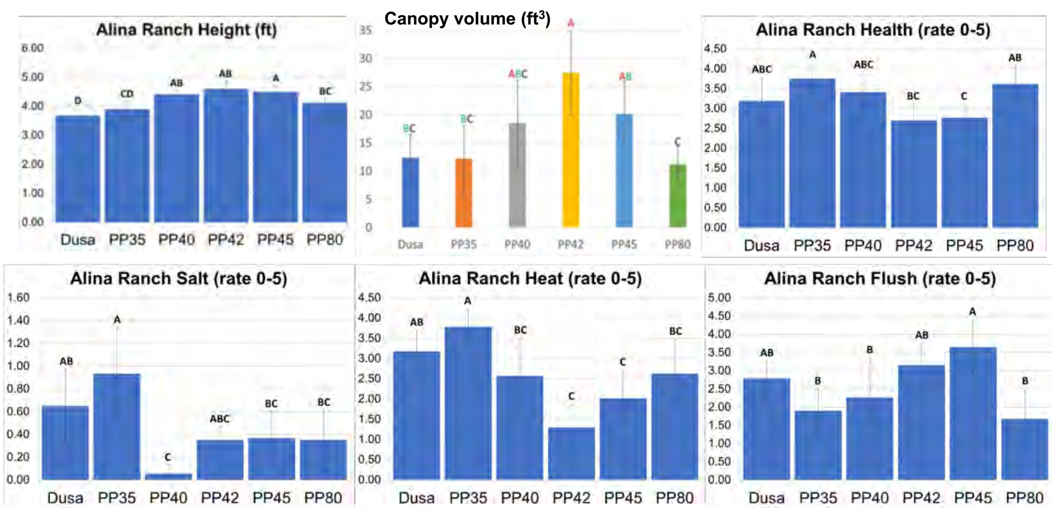
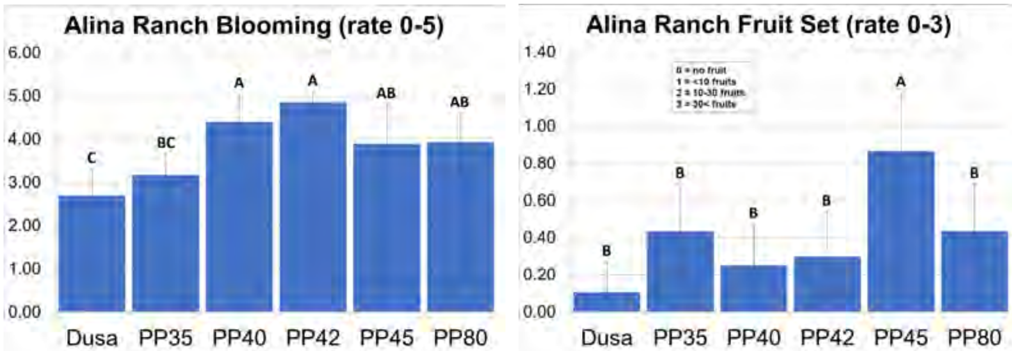


Figure 33. Blooming and new flushing scores of rootstocks at Alina Ranch LLC (Data April 2022).



<u>Pete Miller, Santa Barbara, 2020.</u> At this location, trees were planted at a 15' x 15' tree spacing and all trees exhibited similar size at the time of planting (June 2022). Soil and water analyses were done in each section and layout, design, and the plot landmark was done with the grower, his manager Agustin, and Dr. Manosalva on June 11th and 12th. Trees were planted in 5 sections (S1- S5) having different soil characteristics and conditions. All sections with the exception of section 3 have from 40 % -90% Phytophthora root rot (PRR) incidence. Sections 1 and 2 in addition to high PRR incidence exhibited high soil salinity, high chloride levels and high saturation. A subset of 10 trees per rootstock (highlighted in green in the maps) at each section were selected and labeled with metal tags to collect tree health data. These trees will be utilized as reference data trees for the duration of the project.

Figure 34. Section 1 (S1), Santa Barbara, 2020.

Section C (S1): 60% of PRR incidence. Chloride is not a problem yet but it is on the high side, high soil salinity (2.71 dS/m), has 99% of saturation, high CEC (**Fig. 34**).

Figure 34. Section 1 (S1) at Pete Miller ranch, Santa Barbara.

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	#trees
1	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	19
2	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	19
3	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	19
4	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80						14
5	PP80	PP80	PP80	PP80	PP80	PP80	PP80													7
6	PP45	PP45	PP45	PP45	PP45															5
7	PP45-1	PP45-2	PP45-3	PP45-4																4
8	PP45-5	PP45-6	PP45-7	PP45-8																4
9	PP45-9	PP45-10	PP45																	3
10	PP45	PP45	PP45																	3
11	x	x																		2

Figure 35. Section 2 (S2), Santa Barbara, 2020.

Section A (S2): 40% of PRR incidence. Soil analyses indicate high chloride levels, high soil salinity (3.65 dS/m), and high % of saturation (66.5%), clay soil. Plot layout is shown in **Figure 35.**

Figure 35. Section 2 (S2) at Pete Miller ranch, Santa Barbara (2020).

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	#trees planted
1	PP45	PP45													2
2	PP45	PP45	PP45	PP45											4
3	PP45	PP45	PP45	PP45	PP45										5
4	PP45	PP45	PP45	PP45	PP45	PP45									6
5	PP40	PP40	PP40	PP40	PP40	PP40									6
6	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40							8
7	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40						9
8	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35				11
9	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35			12
10	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	x	x	x		10
11	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa		13
12	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	PP80	14
13	PP80	PP80	PP80	PP80	x	x	x								4

Figure 36. Section 3 (S3), Santa Barbara, 2020.

Section B (S3): 0% of PRR incidence. No problems with salinity or chloride. Low nitrogen, optimum soil saturation. Plot layout is shown in **Figure 36.**

Rows	1	2	3	4	5	6	7	8	9	10	11	12	trees planted
1	PP35	PP35	PP35	PP35	PP35	PP35	PP35						7
2	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35			10
3	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35			10
4	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa			10
5	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45			10
6	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	x	x	10
7	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40			10

Figure 37. Section 4 (S4), Santa Barbara, 2020.

Section 4 (S4): 90% of PRR incidence. No problems with salinity or chloride. Low nitrogen, optimum soil saturation. Plot layout is shown in **Figure 37.**

Figure 37. Section 4 (S4) Miller ranch, Santa Barbara (2020).

Rows	1	2	3	4	5	6	7	8	9	10	11	trees planted
1	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42	PP42			9
2	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40		10
3	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	11
4	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	11
5	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35		10
6	PP45	PP45	PP45	PP45	PP45	PP45	PP45	x	x	x		7
7	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45		10
8	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45		10
9	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	11
10	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa					7
11	Dusa	Dusa	Dusa	Dusa								4

Figure 38. Section 5 (S5), Santa Barbara, 2020.

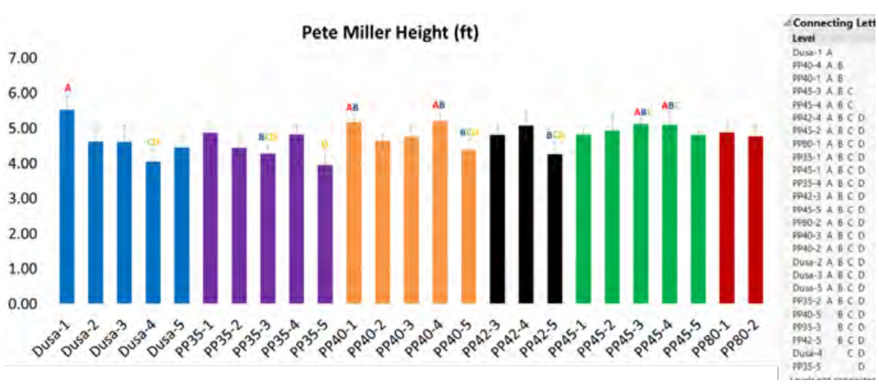
Section 5 (S5): 50% of PRR incidence. No problems with salinity or chloride. Optimum pH and soil saturation. Plot layout is shown in **Figure 38.**

Figure 38. Section 5 (S5) at Miller ranch, Santa Barbara (2020)

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	trees planted
1	x	x	x	x														0
2	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35						12
3	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35	PP35				14
4	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	x	x	x	x	x	x	x		9
5	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	Dusa	17
6	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	x	x	x	x	x	x	11
7	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45	PP45		16
8	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	x				13
9	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40	PP40				14
10	PP42-1	PP42-2	PP42-3	PP42-4	PP42-5	PP42-6	PP42-7	PP42-8	PP42-9									9

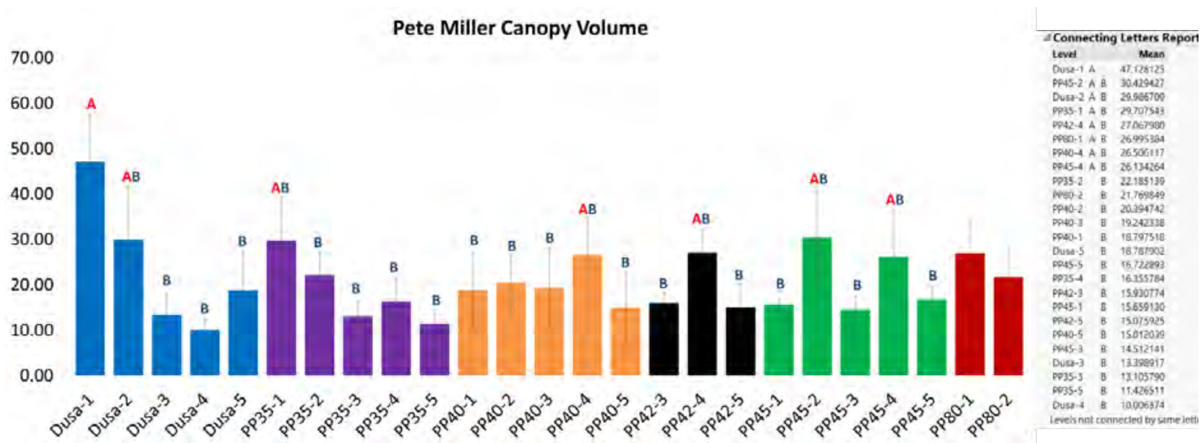
There were significant differences among rootstocks for all the data collected at this plot among all sections. **For plant health,** Dusa is the tallest tree in S1 when compared with the other rootstocks, no significant differences were observed in sections S2, S3, and S5 among the rootstocks, PP40 was significantly different from Dusa in S4 (**Fig. 39**).

Figure 39. Tree height (ft) at Pete Miller, Goleta, Santa Barbara.



For plant canopy size, no significant differences were found among all rootstocks in all sections with the exception of Dusa that is significantly taller than PP40 and PP45 in S1 (**Fig. 40**).

Figure 40. Canopy volume (ft^3) at Pete Miller, Goleta, Santa Barbara.

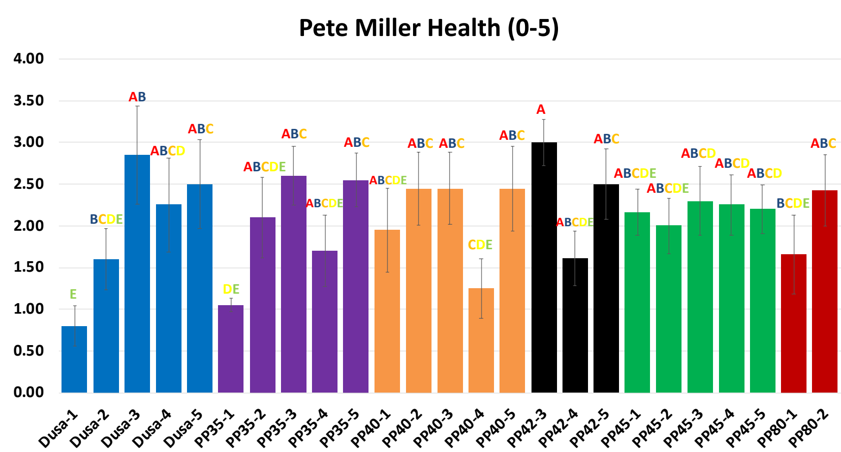


Level			Mean
Dusa-1	A		47.128125
PP45-2	A	B	30.429427
Dusa-2	A	B	29.986700
PP35-1	A	B	29.707543
PP42-4	A	B	27.067980
PP80-1	A	B	26.995384
PP40-4	A	B	26.506117
PP45-4	A	B	26.134264
PP35-2		B	22.185139
PP80-2		B	21.769849
PP40-2		B	20.394742
PP40-3		B	19.242338
PP40-1		B	18.797518
Dusa-5		B	18.787902
PP45-5		B	16.722893
PP35-4		B	16.355784
PP42-3		B	15.930774
PP45-1		B	15.659130
PP42-5		B	15.075925
PP40-5		B	15.012039
PP45-3		B	14.512141
Dusa-3		B	13.398917
PP35-3		B	13.105790
PP35-5		B	11.426511
Dusa-4		B	10.006374

Levels not connected by same lett

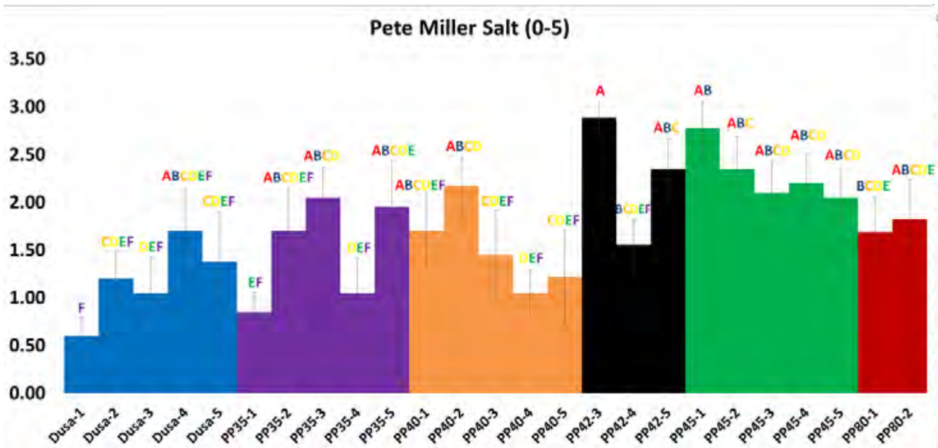
For overall tree health, no significant differences were found among all rootstocks in all sections (comparing all rootstocks within each section). However, there are significant differences for some rootstocks among sections. For example, PP42 in S3 was significant different than PP80 S1, Dusa S2, PP40 S4, PP35 S1, and Dusa S1. Dusa S3 was significant different than PP40 S4, PP35 S1 and Dusa S1(**Fig. 41**).

Figure 41. Canopy volume (ft^3) at Pete Miller, Goleta, Santa Barbara.



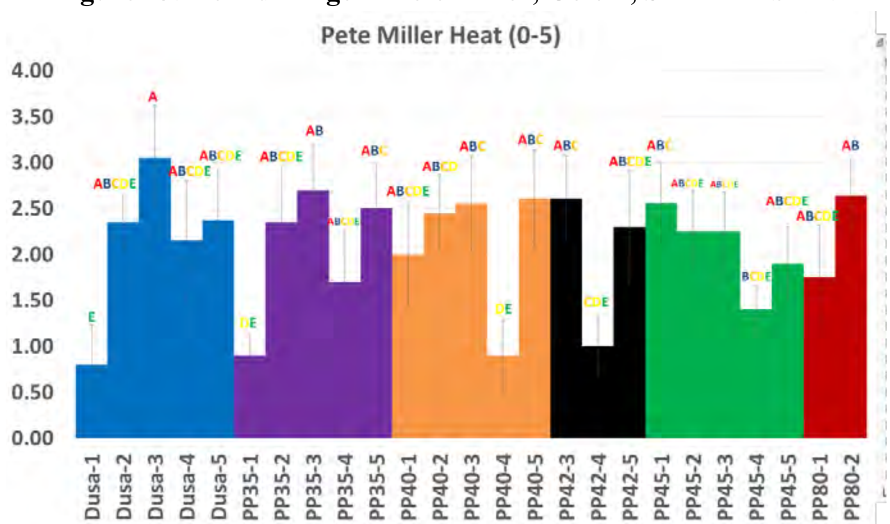
For salinity damage, Dusa is significant different than PP80 and PP45 in S1, this is expected since S1 has high salinity. Interestingly, no significant differences were found in S2 among all rootstocks considering that S2 has similar conditions than S1 with the exception that S2 has high chloride. PP42 is significantly different than the other rootstocks in S3. No significant differences among rootstocks were found in S4 and S5. There are significant differences among several rootstocks when compared among sections. As expected PP45 is the least performer for salinity resistance when compared by sections (**Fig. 42**).

Figure 42. Salinity damage at Pete Miller, Goleta, Santa Barbara.



For heat damage, PP45-1 was significant different from PP35-1 and Dusa-1 rootstocks in S1. No significant difference was found among all rootstocks in all the other sections when compare within sections. Several rootstocks shown significant differences when compared them among sections (**Fig. 43**).

Figure 43. Heat damage at Pete Miller, Goleta, Santa Barbara.



At this location Dusa at Section 5 exhibited the highest mortality (25%). No significant differences were found among all rootstocks within and across sections for blooming and fruit set rates. We expecting the first harvest at this location Spring 2023 as discussed with Pete, the grower and the orchard manager Agustin.

<u>**California Polytechnic State University, Dr. Lauren Garner and Rashaan Souikane, San Luis Obispo (2020).**</u> This plot is monitor and evaluated by Dr. Lauren Garner and her student Rashaan Souikane. Avocado trees were transplanted at the Cal Poly site on 24 June 2020 using a randomized complete block design with 10 replications of 8-10 trees per treatment in 3 blocks for a total of 384 trees. Trees were planted at a 15’ x 20’ tree spacing, and trees exhibited similar size at the time of planting. All trees were assessed by Dr. Lauren Garner and her team, who evaluated tree height (m), above-graft

trunk diameter (mm), and below-graft trunk diameter (mm), in addition to rating salinity damage, heat damage, vegetative flush and bloom on a scale of 0-5 following the ratings of the UCR rootstock avocado breeding program (**Table 3, Fig. 3**). All trees were measured and assessed 2 months after transplanting (August 2020) and during flushing in spring (March 2021 and 2022) summer (July 2021) and fall (October 2021), with all quarterly assessments being overseen by the graduate student. Statistical differences detected in the data collected in Aug. 2020 and Mar. 2021 were provided in the July 2021 report and our analysis of changes over time in tree height and trunk diameter were provided in the January 2022 report. Continued and additional statistical analyses are ongoing.

A one-way repeated measures ANOVA was conducted to evaluate the data collected from August 2020 through October 2021. Post-hoc comparison using Tukey HSD test indicated that 'Hass' scions grafted on 'PP40' (mean = 1.53 m; SD = 0.162 m) and 'PP45' rootstocks (mean=1.56m; SD=0.187m) had a statistically greater mean height compared to 'Dusa' and 'PP35' $F(3) = 13.29$; $P < 0.001$). Additionally, trees grafted on 'PP45' rootstock appear to have the highest rate of growth (**Fig. 44**). All the rootstocks have an average above-graft union to below-graft union diameter ratio below or near 1 (**Fig. 45**). Scions grafted on 'Dusa' (mean = 1.00; SD = 0.097) and 'PP40' (mean = 1.02; SD = 0.066) rootstocks had a statistically greater above-below ratio $F(3) = 8.53$; $P < 0.001$). Three senior projects were being conducted by Cal Poly undergraduate students. The subjects for these projects overlap with already planned data collection at all sites. The analyses at this site were submitted as an abstract to present this work to date at the 2022 conference of the American Society for Horticultural Science (ASHS). Rashaan Souikane will present the work as first author on a poster that will also be part of the graduate student poster competition at the conference.

Figure 44. Mean height (m) of four avocado rootstocks ('Dusa', 'PP35', 'PP40', 'PP45') collected 2 months after transplant and subsequently during the spring (3/18/2021), summer (7/17/2021), and fall vegetative flush (10/22/2021) at the research plot in San Luis Obispo, CA. Means labeled with different letters within a rate date are significantly different ($P \leq 0.05$) based on Tukey's HSD test; n=10.

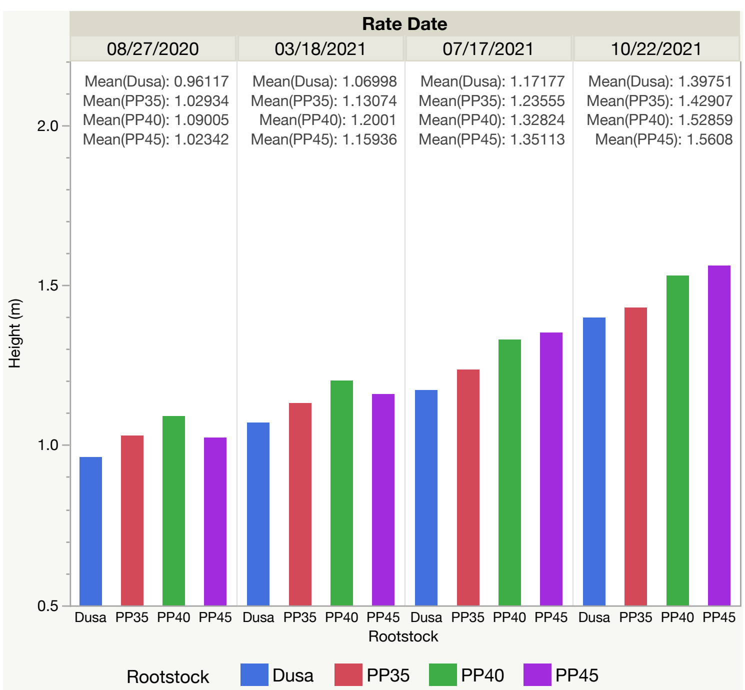
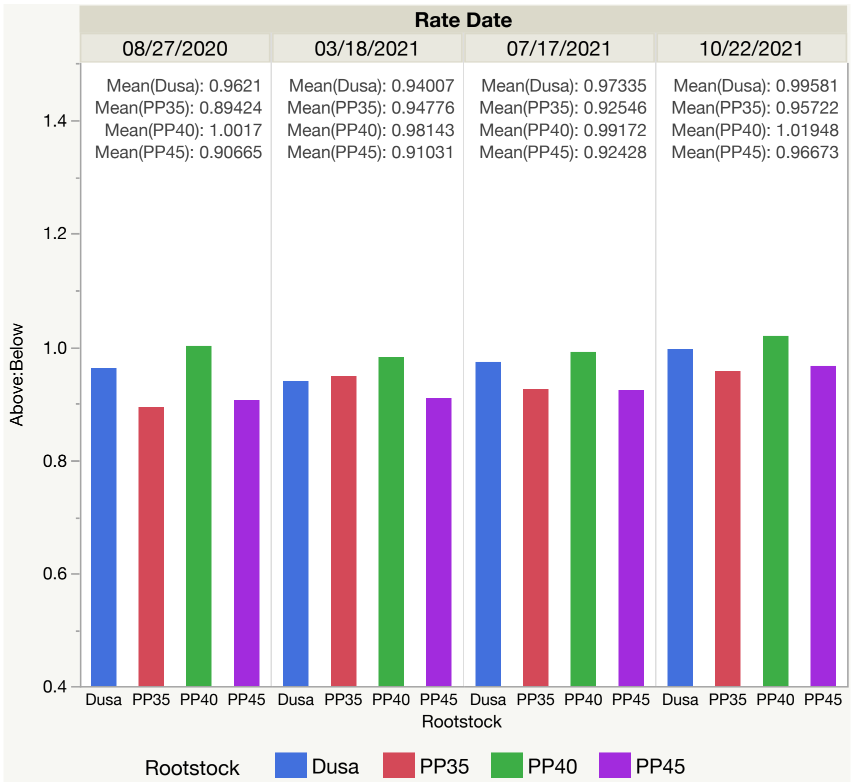


Figure 45. Mean above and below graft union trunk diameter ratio (above:below) of four avocado rootstocks (‘Dusa’, ‘PP35’, ‘PP40’, ‘PP45’) collected 2 months after transplant and subsequently during the spring (3/18/2021), summer (7/17/2021), and fall vegetative flush (10/22/2021) at the research plot in San Luis Obispo, CA. Means labeled with different letters within a rate date are significantly different ($P \leq 0.05$) based on Tukey’s HSD test; n=10.



Section 2: Continue the collection of tree health and harvest data for PP35, PP40, PP42, PP45, and PP80 UCR advanced rootstocks at Pine Tree and Bonsall rootstock trials (established June 2017). These two field sites are overseeing by Co-PI Dr. Mary Lu Arpaia. Tree health and harvest data collection is conducted by Dr. Arpaia and the Manosalva lab assistants (Amber Newsome and Matthew Elvena).

Comments of the site and overall tree mortality. Two identical trials were planted in June 2017 either in San Diego County or Ventura County. The list of rootstocks included in the trial is presented in **Table 9**. Each site is planted in a randomized block design.

Table 9. Rootstocks grafted to ‘Hass’ included in 2017 rootstock trial planted at 2 sites. Site 1 is near Bonsall, CA and site 2 is near Santa Paula, CA. Both sites planted in June 2017.	
Commercially Released	Dusa, Leola™ (Merensky 6), Steddom, , Topara (RO.54), Toro Canyon, Uzi, Zentmyer, Zerala™ (Merensky 5)
UC Selections from J. Menge Program	PP35, PP40, PP42, PP45, PP50, PP51, PP52, PP80
UC Selections from G. Douhan Program	GD3, GD4, GD5, GD6, GD10, GD11, GD19, GD20
South Africa Selections from WTS	R106, RO.15, RO.17, RO.18
Israel Selections from B. Ya’acov Program	AB20 (VC802), AB22 (VC804)

The San Diego County site is located near Bonsall, CA. This site is farmed as an organic grove. Testing prior to planting showed that the site has *P. cinnamomi* and saline irrigation water. The site is irrigated using well water. The San Diego site was planted on June 28, 2017. The trees are spaced 10 x 10 feet. The trees received an approximated 6-inch application of mulch at the time of planting. The replicated blocks at the Bonsall site were designed to take into account the slope of the field. In recent years, the trees have suffered from a lack of general nutrition and have had "see-through" canopies and overall poor color. In April 2022, the owner applied mineral nutrition to the site and the general appearance of the trees are greatly improved; fruit set looks reasonable for 2023. The owner plans to prune the trees in Summer 2022.

The Ventura County site is located near Santa Paula, CA at the California Avocado Commission demonstration site at the Pine Tree Ranch. This site is managed as a conventional grove. Testing prior to planting showed low levels of *P. cinnamomi* present. The site was planted on June 13, 2017. The grove is irrigated with district water and is of good quality. The trees are planted on berms (approximately 2 feet in height and 3 feet width at base) with a tree spacing of 15 x 15 ft. The site was not mulched at the time of planting; mulch was only applied in September 2018, approximately 16 months after planting. The replicated blocks were laid out across the irrigation rows. After having a difficult 2 to 3 years becoming established the trees now look uniformly good and have very good color. The trees were pruned lightly in Summer 2021.

At the time of harvest for both sites in Spring 2022 a few additional dead trees were noted: 1 tree at the Santa Paula site and 6 trees at the Bonsall site. This brings to a total of 30 trees or 10% of the total planted at the Santa Paula site and a total of 75 trees (25%) at the Bonsall site. Tree deaths are spread across all rootstocks (**Fig. 46**) with high tree mortality (≥50% of trees) for Uzi, PP45, PP80 at the Bonsall site and GD5 at the Santa Paula site. Since we visit the site only periodically, it is nearly impossible to discern the original cause of tree death. However, at the Bonsall site, several trees were originally lost in the early part of this study due to cold and wet soil conditions.

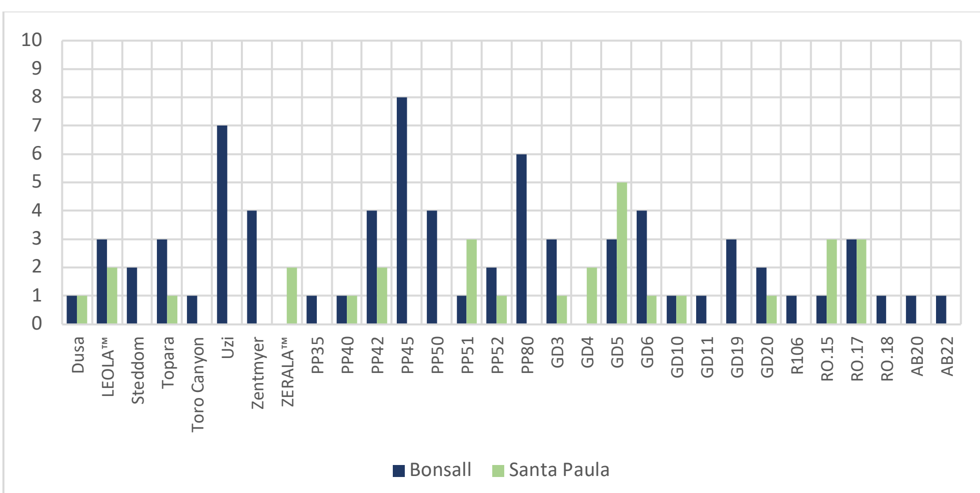
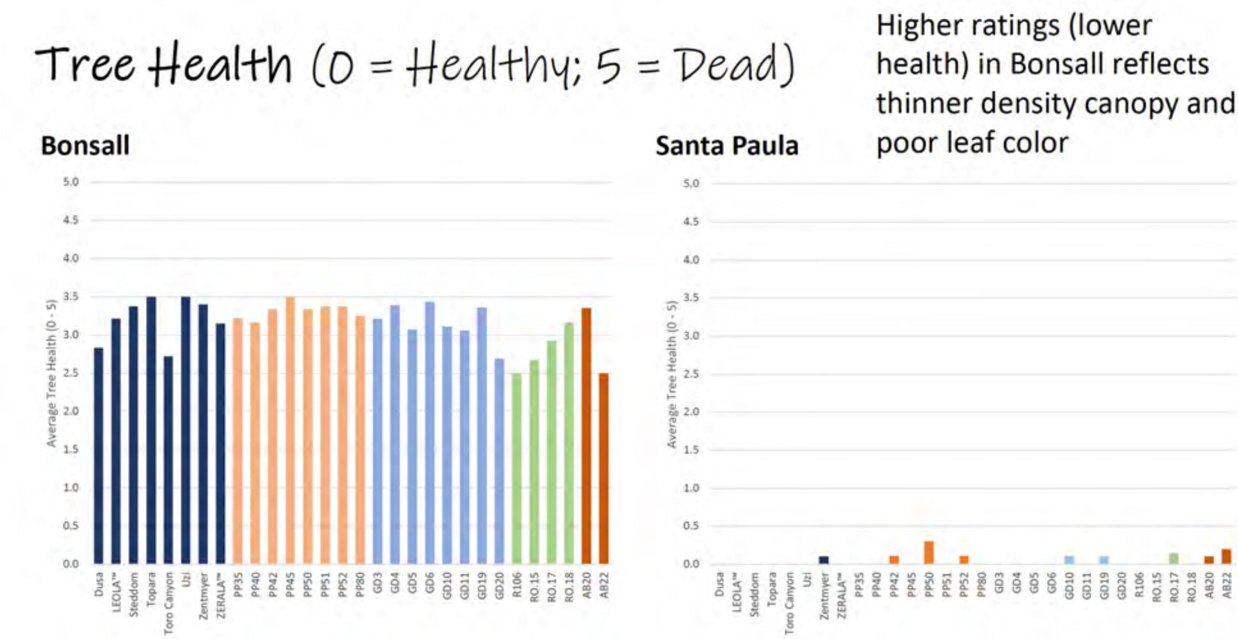


Figure 46. Tree mortality by rootstock at each experimental site as of May 2022. At each site, 10 trees for each rootstock were planted.

Overall tree health scores were higher (lower scores) in Bonsall site (Fallbrook) compared with Pine tree trial. Trees at Bonsall exhibited thinner density canopy and poor leaf color (**Fig. 47**).

Figure 47. Overall tree health at Bonsall and Pine Tree rootstock trials.



2022 Yield Data
Bonsall Site
The Bonsall site was harvested on May 13, 2022. The yield was exceedingly low with an overall average yield of 0.97 kg/tree. Only 16% of the trees had any fruit and on some rootstocks none of the surviving trees had any fruit (**Fig. 48**; Leola, Steddom, Topara, Uzi, Zentmyer, PP42, PP45, PP50, GD3, GD4, GD5, GD6, RO.17). In fact, over the course of this study, no fruit have been harvested from PP45 or GD6. **Figure 49** presents the cumulative yield data for the trial. Fruit count data shows a similar trend and is not presented. 'Hass' on AB22 is the leading rootstock in this trial with a cumulative average total of 35.2 kg/tree; this is significantly greater than the remaining rootstocks. R106 with a cumulative average total of 19.7 kg/tree is the second highest yield rootstock in the trial and is significantly higher than the remaining rootstocks in the trial. There are no significant differences due to rootstock in the cumulative average yield which ranges from 9.97 kg/tree (AB20) to 0.0 kg/tree (PP45, GD6). Average fruit size, with the exception of 'Hass' on Uzi where only 1 fruit (745 g) has been harvested in the 4 years, is between 176 g/fruit (PP35) to 318 g/fruit (RO.18).

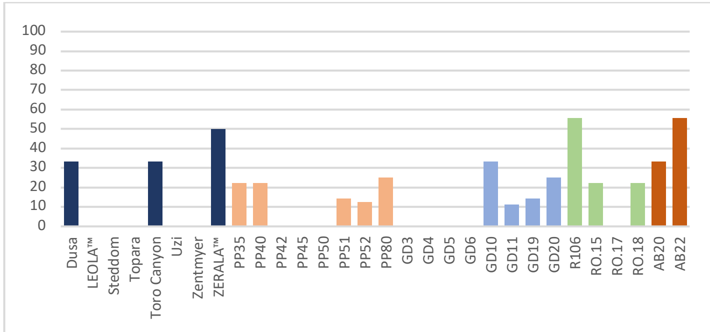


Figure 48. The percentage of surviving trees that had fruit for the May 2022 harvest at the Bonsall rootstock trial.

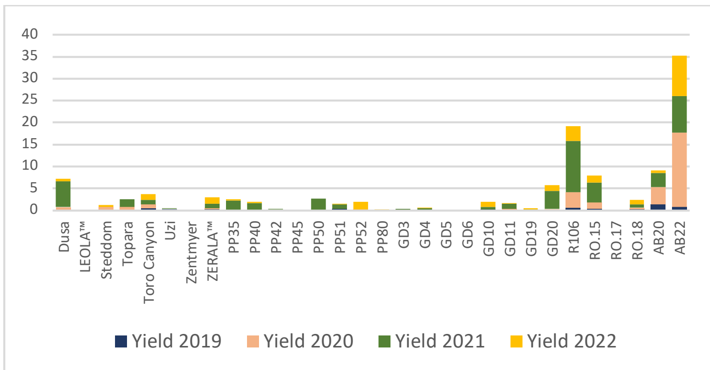


Figure 49. Average cumulative yield (kg/tree) of 'Hass' influenced by rootstock in Bonsall, CA from 2019 through 2022. Trees planted in June 2017.

Santa Paula Site

The Santa Paula site was harvested on April 2, 2022. Yield was good with an overall average yield of 32 kg/tree (151 fruit/tree) at the site. Ninety-eight percent of the surviving trees had fruit. Trends in the yield data whether by kg/tree or fruit/tree were similar. Yield per tree ranged from a high of 56.2 kg/tree (RO.15) to a low of 14.7 kg/tree (PP52) (**Figure 50**). The two highest yielding rootstocks, RO.15 and GD10, were statistically higher ($P \leq 0.05$) than PP50, RO.18 and PP52, the three lowest yielding rootstocks. PP45 trees, the third highest yield rootstock, were statistically higher than PP52 trees in terms of yield. There were no other statistically significant differences detected.

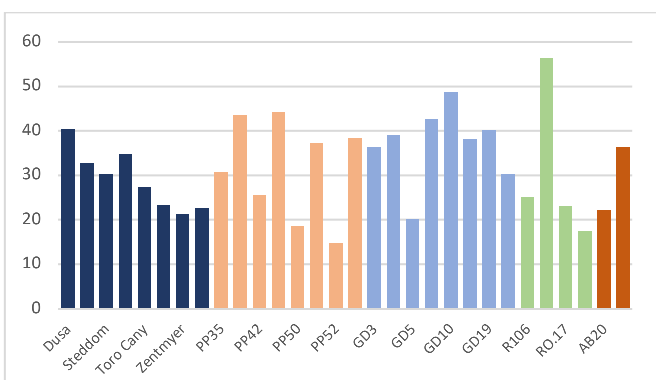


Figure 50. Average kg/tree yield of 'Hass' influenced by rootstock. Trees harvested April 2, 2022.

In terms of cumulative yield, results were similar for both average kg/tree or by average fruit count/tree. In both instances, the top 2 performing rootstocks were RO.15 and GD10. Average cumulative kg/tree **(Figure 51**) ranged from 63.9 kg/tree (RO.15) to a low of 18.6 kg/tree (PP52). RO.15 had statistically higher yield (P≤0.05) in terms of kg/tree compared to the 10 lowest yielding rootstocks (R106, Uzi, PP42, RO.17, PP50, Zerala, Zentmyer, GD5, RO.18 and PP52). GD10 differed significantly (P≤0.05) from the 2 lowest yielding rootstocks, RO.18 and PP52. Fruit size trends (g/fruit), whether examined on an annual basis or as the average fruit size over the 3 years of yield data were similar. In both instances the largest fruit have been from the RO.17 and RO.18 trees which tend to have lower overall yields. The smallest fruit has been obtained from the RO.15 trees, which are the highest producers in the trial. GD10, the second highest producing rootstock in the trial both in terms of kg/tree and fruit/tree is intermediate regarding fruit size (**Figure 44**).

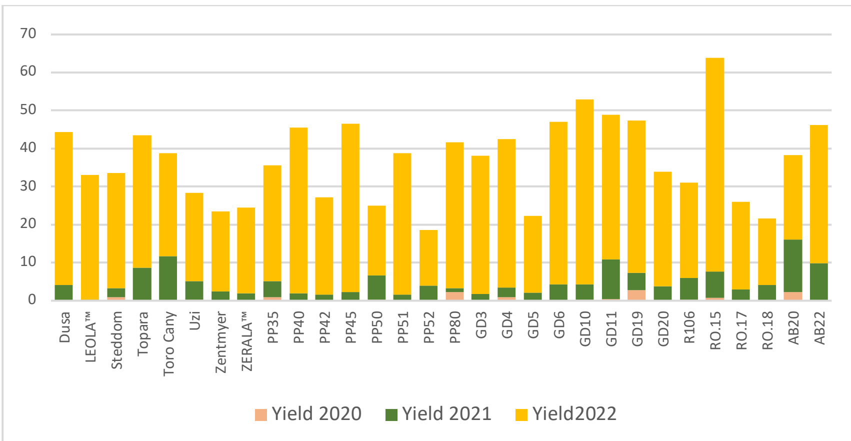


Figure 51. Average cumulative yield (kg/tree) of 'Hass' influenced by rootstock in Santa Paula, CA from 2020 through 2022. Trees planted in June 2017; trees had no yield in 2019.

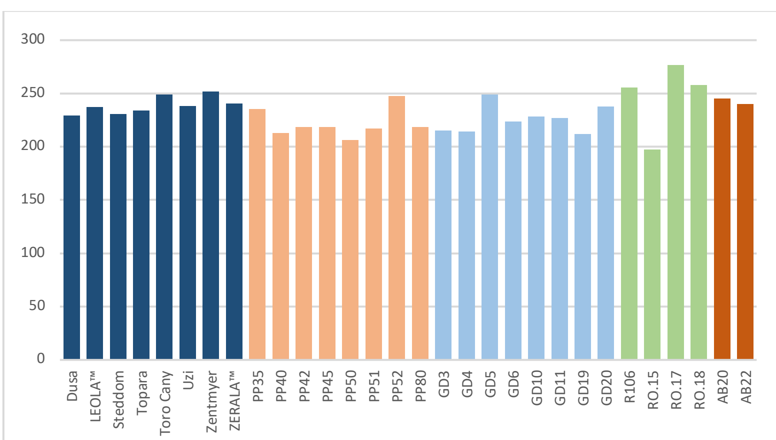


Figure 52. Average fruit size (g/fruit) of 'Hass' influenced by rootstock in Santa Paula, CA from 2020 through 2022. Trees planted in June 2017; trees had no yield in 2019.

The results from tree health and harvest data from all the rootstock trials presented above established at Southern and Northern CA under different environmental conditions and cultural practices support the commercial release of PP35, PP40, PP45, and PP42. More data is required for PP80. Under this new 3-year cycle of funding, we will continue collecting and gather more compelling data specially harvest and packing data for these UCR advanced rootstocks as indicated in Table 3 and Fig. 3.

The UCR team will continue periodically visiting the site and will notify ranch management prior to each visit. The UCR team will discuss any problems with ranch management but the general care of the trees including nutrition, irrigation and pest control will be the responsibility of the grower cooperator. We will still be conducting a minimum of 3 to 4 visits a year for constant monitoring and data collection. This is critical to determine influence of rootstock on timing of flowering, fruit drop, heat stress, salinity stress, and productivity. We will conduct PRR assessments of the trees being evaluated and conduct soil and water analyses in year 2 to determine if changes have occurred after fields were established (**Table 10**). We will compare rootstocks accessions within individual field sites, across sites (when possible), and across years of evaluation for each set of data. Linear mixed models are being used to test if rootstock, location, and the rootstock x location have a significant effect on the phenotypic data collected in the field. Rootstock, location, and their interaction are being treated as fixed factors, while field will be treated as a random factor in the linear mixed models. We plan to monitor these sites for 8 to 10 years following planting.

Commercial release of PP35, PP40, PP45, and PP42 UCR advanced rootstocks in CA. The release of these rootstocks will be done through UCR. Manosalva's team will gather all the information regarding: greenhouse data, regional and multistate field data grafted with Hass and other scions, yield in CA from the past years, and other relevant information regarding their field performance under different conditions (most of the data is currently available). In addition, we will record horticulture trait data such as tree height and canopy size of the ungrafted trees. We will take photographs of the tree, branches, flowers, and fruits for each rootstock since all this information is required to fill out the patent paperwork (**Table 10**).

Requested Budget have been broken down per sections and the timeline for the proposed activities are indicated in Table 10.

Table 10. Proposed time and activities for the proposal entitled: ***Commercial-scale field testing and potential release of five elite advanced rootstocks.*** **Project duration: 11/01/2022– 10/31/2025**				
Researchers	**Task**	**Year 1** **11/01/2022 – 10/31/2023**	**Year 2** **11/01/2023- 10/31/2024**	**Year 3** **11/01/2024- 10/31/2025**
Manosalva, CAC, Lauren Garner **SECTION 1**	*1.1. Collect tree health data from large-scale rootstock trials (2019, 2020, and 2021).*	• Three - four visits to monitor fields and tree health data collection for the plots established in June 2019 and July 2020 and 2021 (collection of data from a subset of trees, n=30-50/rootstock).	• Continue as previous year.	• Continue as previous year.
	1.2. Collect harvest and packing data of UCR rootstocks from large-scale rootstock trials (2019, 2020, and 2021).	• Harvest and packing data collection for the large trials established in June 2019 and July 2020 depending on yield.	• Continue as previous year.	• Continue as previous year.
	1.3. Collect tree health data at Gunderson and Limoneria 2 plots.	• Three - four visits to monitor fields and tree health data collection for these two active small regional trials (data collected for all trees ~250/ each field).	• Continue as previous year.	• Continue as previous year.
	1.4. Collect harvest data at Gunderson and Limoneria 2 plots.	• Collect harvest data each year. Depending on the grower could be twice a year (picking size and stripping).	• Continue as previous year.	• Continue as previous year.

	1.5. Assessment of Pc infection in the subpopulation of trees per rootstocks from all rootstock trials. *1.6. Conduct soil and water soil analyses at all rootstock field trials under evaluation.* *1.7. Data collection for horticultural characteristics of the five rootstocks for release in California.*	• We will assess the *Pc* infection in the subpopulation of trees from all active rootstock trials evaluated in this proposal. • Collect data required in terms of horticulture characteristics for PP35 and PP40 rootstocks require for their commercial release.	• Continue as previous year. • We will repeat soil and water characterization in all the active rootstock trials evaluated in this proposal. • Collect data required in terms of horticulture characteristics for PP42 and PP45 rootstocks require for their commercial release.	• Continue as previous year. • Collect data required in terms of horticulture characteristics for PP80 rootstock require for its commercial release.
Arpaia, Manosalva, Mauk **SECTION 2**	*2.1. Collect tree health data at Pine Tree and Bonsall.* *2.2. Collect harvest data at Pine Tree and Bonsall.* *2.3. Assessment of Pc infection in both fields.* *2.4. Conduct soil and water analyses.*	• Three - four visits to collect tree health data at each rootstock trial (single tree). • Collect harvest data (Bonsall and Pine tree). • Assess the *Pc* infection in trees at each field. Bonsall and Pine Tree.	• Continue as previous year. • Continue as previous year. • Continue as previous year. • We will repeat soil and water characterization in these plots.	• Continue as previous year. • Continue as previous year. • Continue as previous year.

Names in bold indicate the leading researcher for each activity.

Proposed Budget

	Establish 5 new plots Nov. 2022-Oct. 2023	rating 7 large plots Nov.2023 - Oct. 2024	rating 7 large plots Nov. 2024- Oct. 2025
Note:Manosalva is subsidizing all travel expenses (2x/year) because salaries are more expensive as well as hotel, gas and rentals. Also UCR team is also subsidizing gas in all trips.			
Section 1: Collect data for 8 large plots (Leo McGuire (2), Westpack (1), John Lamb (2), Cris Sayer (1), Alina Ranch (1), Pete Miller (1)) and 2 old plots (small, Gunderson and Limoneria 2), Amber, Matthew and Patty			
Personnel salary and benefits for all sections			
Amber Newsome (Assistant Specialist I) 50% EFT	$26,100	$29,407	$30,289
Benefits	$12,867	$14,497	$14,933
Matthew Elvena (Assistant Specialist I) 36% EFT	$24,637	$21,173	$21,808
Benefits	$12,146	$10,439	$10,751
SUBTOTAL	$75,750	$75,516	$77,781
Travel			
1. TRAVEL TO PLOTS AT NORTH			
Calculations based on combining 6 plots North (Chris sayer, Alina ranch, Gunderson, limoneria 2, John lamb and Pete Miller)			
We are budgeting visiting 3X a year, for rating and Harvest, All plots will be harvest starting 2023			
calculations are based on staying in Ventura from Monday to Saturday and rate all 6 plots (twice a year)			
Car rental based on UCRconnexxus (travel.ucop.edu)			
Car rental one day trip cargo van service= 68			
Car rental one 7 day trip = $476			
Gas @ $3.54/gallon; 20 miles/gallon			
TRAVEL TO COLLECT TREE DATA			
Data collection			
Rental car (1 wk., 7 days) twice	$952	$1,000	$1,050
Gas (subsidized from my other grants involve travel)	$500	$525	$551
Hotel comfort inn 5 nights ~200/night (twice/year) two people	$4,000	$4,200	$4,410
Per diem 2 people x 6 days/1 wk trip	$1,488	$1,562	$1,641
Patty's travel	$1,000		$378
TRAVEL TO COLLECT HARVEST DATA			
calculations are based on staying in Ventura overnight in Ventura for harvest once a year for 6 plots (each plot separate since growers harvest different days) once a year			
Rental car (2 days) x 6 plots	$816	$857	$900
Gas	$500	$525	$551
Hotel comfort inn 1 night ~200/night (once/year) two people x 6 plots	$2,400	$2,520	$2,646
Per diem 2 people x 2 days x 6 plots, once a year (62/day)	$1,488	$1,562	$1,641
Patty's travel	$2,000		
1. TRAVEL TO PLOTS AT SOUTH			
calculations are based on one day trips. Two trips for data collection and one for harvest			
Leo McGuire			
West Pack			
TRAVEL TO COLLECT TREE DATA			
Data collection and harvest			
Rental car (1 day)	$408	$428	$450
Gas /milleage	$250	$263	$263
SUBTOTAL TRAVEL Section 1	$15,802	$13,442	$14,479
TOTAL SECTION 1	**$91,552**	**$88,958**	**$92,260**

Section 2: Bonsall and Pine Tree (6 visits/year; Brandon 7.5% and Aidan 5%, MLA do the data analyses)

Travel Monitoring and harvest

Krnich - planted 2017
Tree measurements (1X)/YEAR) + 1 visit
Harvest (days) 1X/YEAR

Pine Tree - planted 2017
Tree measurements (2X)/YEAR
Harvest (days) 1X/YEAR
Assumptions:

Round Trip mileage from Visalia for PineTree but will use Fallbrook for Krnich (RT is 40 miles)
For south used 40 miles roundtrip as average
for north used 200 miles one-way as average
Assume reimbursement rate as a 3 year average will be 0.55 per mile

Assume lodging on average is $140/night and meals are $60 per day for a total of $200 per day

MLA TRAVEL	$4,600	$4,600	$4,600

UCR TEAM TRAVEL (Amber Newsome and Matthew Elvena)
Car rental based on UCRconnexxus (travel.ucop.edu)
Car rental one day trip = 68
Car rental one two day trip = 136.14
Car rental one three day trip = 204.21
Gas @ $3.54/gallon; 20 miles/gallon

TRAVEL TO COLLECT TREE DATA			
Bonsall (minimun 3X visits a year)			
rental car	204	214.2	224.91
gas	58.41	61.3305	64.397025
TRAVEL TO COLLECT TREE DATA 2X AND 1 HARVEST			
Pine Tree (3 visits a year, Overnight trip)			
rental car	408	428.4	449.82
gas	233.64	245.322	257.5881
Hotel 1 nights/trip x 3 trips total x 2 people @ $200/night	1200	1260	1323
Per diem 2 people x 3 trips x 2 days per trip @ $62/day	744	781.2	820.26
SUBTOTAL TRAVEL Section 2	$7,448	$7,590	$7,740
FIELD and lab SUPPLIES for PRR assessment (i.e. metal tags, sprays, ziplop bags etc). The Pc analysis will be partially cover for the Manosalva lab	$1,000	$1,051	
SERVICE			
1- Comprenhensive soil analysis at FGL plus sample delivery $70/sample and $20 shipping/sample (12 samples, fields)		$1,080	
2- Irrigation water analysis at FGL plus sample delivery $90/sample and $20 shipping/sample (12 samples, fields)		$1,320	
TOTAL ANNUAL	**$100,000**	**$100,000**	**$100,000**
		THREE YEAR TOTAL	**$300,000**

Budget Justification

Total UCR budget requesting for three years: $300,000

Personnel for all sections ($229,047):

Section 1. *Collection of tree health and harvest data for PP35, PP40, PP80, PP42, and PP45 UCR advanced rootstocks at: i) the commercial-scale field trials (established in July 2019, July 2020, and July 2021) and ii) two previously established small regional field trials in Santa Paula. This section also includes the data collection in terms of horticulture characteristics, pictures, and paperwork required for the commercial release of PP35, PP40, PP45, and PP42 in California.*

Section 2. *Collection of tree health and harvest data for the UCR advanced rootstocks, Israeli rootstocks, and South African rootstocks at Pine Tree and Bonsall rootstock trials*

Personnel required for the Manosalva lab:

- ***No salary expenses are being charged for Drs. Manosalva and Arpaia's EFT.***
- ***Ms. Amber Newsome (Junior Specialist II) at 50% EFT.***
- ***Mr. Matthew Elvena (Junior Specialist II) at 50% EFT.***

Personnel salary and fringe benefits description: **$229,047**
Junior Specialist II**:** Funds are requested to cover 50% EFT of two Junior Specialists II field assistants: **Ms. Amber Newsome and Mr. Matthew Elvena** for each year of the proposal. Ms. Newsome and Mr. Elvena have been trained in data collection, field design, field planting, PRR incidence and other laboratory techniques related to this proposal.

For Section 1, Amber and Matthew will continue overseeing all the field activities for all the large and small regional rootstock trials. Amber and Matthew are a great team which is in constant communication with our grower collaborators to organize and schedule all the field activities. They are essential personnel to conduct all the field activities proposed in this proposal.

Amber and Matthew will continue conducting the following activities:

- Monitor all rootstock trials and communicate with the grower cooperator or orchard manager regarding any cultural practices, pruning, chemical application, replanting, etc.

- Update maps, spray paint the landmarks for tree identification at each field, and re-tag trees as need it with metal tags for tree identification.

- Organize and schedule all the field activities (tree health and harvest data collection).

- Collect tree health data in a subpopulation of 30 to 50 trees per rootstock at each semi-commercial field trials established in 2019, 2020, 2021 (n=8). Dr. Manosalva will be traveling with them once a year (Spring) to check the status of the plots and discuss with the grower cooperators/field manager regarding the rootstocks. For the two existing small regional trials in Santa Paula, tree health data will be collected for each tree planted (~300 trees/field).

- Collect harvest data at semi-commercial field trials. Based on our fruit set assessment of May 2022 and considering that we collected the first harvest data in our first plot planted in June 2019 (Leo McGuire, Temecula), we expect to have the initial harvest in all plots established in 2019 and 2010 in Year 1 of the proposal and for all plots in Y2 and Y3. Harvest will be arranged by the grower/orchard manager and UCR team. UCR team will be working with the growers to collect the harvest data need it for each rootstock such as yield and fruit size distribution as we did in 2020. All these activities will be coordinated between UCR team (Matthew and Amber) and the grower. Fruit will be collected at each block by rootstock in these field trials.

- Collect harvest data at the two existing small regional trials in Santa Paula. Harvest will be arranged by the UCR Team and Limoneria manager. Harvest will be done by size picking or stripping depending on grower's decision. UCR team will be working with the growers to collect the harvest data need it for each rootstock by single tree (~300 trees/field). We will obtain fruit count and total pounds collected.

- The field assistants will be responsible to enter, organize, and conduct the statistical analyses under the supervision of Dr. Manosalva. In addition, Amber and Matthew will continue preparing the figures and tables for the milestone reports and also will start taking responsibility on writing and submitting the milestone reports under Dr. Manosalva's supervision.

- Continue collecting soil, roots, and water samples for the different analyses proposed. In year 1 and 2 we will collect samples to continue monitor PRR incidence in our plots (trees being under evaluation) by root plating and soil baiting. Amber and Matthew will continue processing roots/soil samples to detect *P. cinnamomi*. In year 2, we will conduct soil and water comprehensive analyses. Matthew and Amber will be responsible to collect samples and submitted to FGL for analyses.

- Gather all the horticultural, greenhouse, and field data required for the commercial release of PP35, PP40, PP42, and PP45 rootstocks as well as filling the patent forms that will be required for the UCR patents.

- The UCR team will continue discussing any problems with orchard manager/owner but the general care of the trees including nutrition, irrigation and pest control will rest with the ranch management practices. These cultural practices will be shared with the UCR team for a meaningful evaluation and data analyses. The ranch manager will provide prior notice to Amber and Matthew when any tree pruning or other management practice is planned especially any chemical/organic compounds applications to control diseases and pests.

For Section 2, Amber Newsome and Matthew Elvena will continue working under the supervision of Dr. Mary Lu Arpaia to monitor these fields (Bonsall and Pine Tree), data collection (tree health and harvest), and grower interactions as was conducted last years. Drs. Manosalva will be traveling once per year to each plot together with her field assistants and Dr. Arpaia to discuss the status of the plots and discuss with the grower's cooperators regarding the rootstocks, especially at harvest season. In addition, Amber and Matthew will be responsible to collect soil and water samples for FGL analyses in Year 2. In years 1 and 2, they will be responsible to sample trees per each rootstock being evaluated to determine if these trees are infected with *P. cinnamomi.*

Fringe Benefits and Tuition/Fees for personnel: Employee benefits are estimates, using the composite rates agreed upon by the University of California. Specialist fringe benefit rates are estimated at 51%.

All salaries and wages were estimated using UC Riverside's staff salary scales. Where appropriate, merit increases are included in the calculations. Subsequent years include escalations based on recommendations by our campus administrative office.

OTHER EXPENSES PER SECTION:

Section 1: *Collection of tree health and harvest data for PP35, PP40, PP80, PP42, and PP45 UCR advanced rootstocks at: i) the commercial-scale field trials (established in July 2019, July 2020, and July 2021) and ii) two previously established small regional field trials in Santa Paula. This section also includes the data collection in terms of horticulture characteristics, pictures, and paperwork required for the commercial release of PP35, PP40, PP45, and PP42 in California.*

Travel_domestic section 1 –$43,723

Note that rental car and gas prices increased considerable in the last years and is predicted to continue increasing. We are subsidizing some of the travel expenses in all sections using other funds from Manosalva.

The projected travel costs include site visitations to experimental plantings of rootstocks to a total of 10 fields: 8 large trials established in June 2019, July 2020, and July 2021(second planting at Leo McGuire and John Lamb) and 2 small regional trials in Santa Paula (Limoneria 2 and Gunderson). Funds are requested for periodically visits to all these sites with a minimum of 3-4 visits per year, 2 to 3 visits for collection of tree health data and one visit for harvest.

Based on last year's logistic and experience, all sites at Norther California have been budgeted as one week trip for all tree health ratings at least twice a year and one overnight trip for harvest for each individual plot since harvest day varies and depend on grower's decisions (these are budgeted separated by field). The projections include cost of a cargo van rental from UCR fleet services at a rate of $68 per day plus 0.66 per mile plus fuel ($3.54 per gallon and 20 miles/gallon, ***note that we did not increase this despite that gas prices are higher and we are not including transportation expenses for Dr. Manosalva's car***). A cargo van is required to fit all the equipment required for tree measurement, coolers for samples, bins for harvest, digital scale, etc. Trips conducted to Southern California plots have been budgeted as single day trips.

For Northern plots, overnight trips have been budgeted for two people. Overnight lodging is estimated at $200 per night at a hotel and $62 per meal and incidentals. ***Note that Dr. Manosalva conducts visits twice per year (Spring and harvest), however most of her travel expenses are being subsidized by the PI.*** These trips, will allow for more thorough data collection and coordination with research collaborators in the field. These travel expenses also include the travels for water and soil collection for field analyses. An escalation factor of 5% for each year is also included to account for expected/anticipated inflation.

Section 2. *Collection of tree health and harvest data for the UCR advanced rootstocks, Israeli rootstocks, and South African rootstocks at Pine Tree and Bonsall rootstock trials*

<u>Travel_domestic section 2</u> –$22,778

Note that rental car and gas prices increased considerable in the last years and is predicted to continue increasing. We are subsidizing some of the travel expenses in all sections using other funds from Manosalva.

Dr. Mary Lu Arpaia travel expenses for data collection ($13,800). Travel for Dr. Arpaia, which is the Co-PI overseeing these two plots have been added for each visit. Round trip mileage from Visalia for PineTree (400 miles round trip) and Fallbrook for Bonsall (40 miles round trip) have been calculated. A reimbursement rate per private car has been calculated as 0.55 per mile. Lodging on average for Dr. Arpaia was also calculated as a total of $140/night and meals are $60/day. All trips have been budgeted as overnight trips.

For the UCR team, the projections include cost of a cargo van rental from UCR fleet services at a rate of $68 per day plus fuel ($3.54 per gallon and 20 miles/gallon), ***note that we did not increase this despite that gas prices are higher and we are not including transportation expenses for Dr. Manosalva's car***). A cargo van is required to fit all the equipment required for tree measurement, coolers for samples, bins for harvest, digital scale, etc. Trips conducted to Southern California plots have been budgeted as single day trips. For Northern plots, overnight trips have been budgeted for two people (Amber Newsome and Matthew Elvena). Overnight lodging is estimated at $200 per night at a hotel and $62 per meal and incidentals.

OTHER EXPENSES

<u>Supplies</u> – $2,051. Funds are requested to cover all supplies (material and consumables) to conduct the assessment of *P. cinnamomi* infection in the subpopulation of tree per rootstock at each large trial in years 1 and 2. These materials and consumables include petri dishes, gloves, tubes, selective media, etc. In addition, this amount will cover field supplies including paint spray to landmark trees and blocks for identification and also for metal tags used to replace and re-tag trees in which labels have been lost because of the wind.

<u>Services</u> - $2,400. Funds are requested for soil and irrigation water analysis that will be conducted in Year 2 for all 12 fields under this study. Water and soil analyses will be conducted by Fruit Growers' Lab (FGL), Santa Paula. Sample test and delivery cost also has been included in the calculated price per sample based on our analyses conducted this year. FGL charge us $70 and $90 for soil and water analyses per sample respectively. In addition, $20 per sample have been added to cover shipping/sample.