AGENDA

California Avocado Commission
Production Research Committee Meeting

Meeting Information

Date: Wednesday, July 27, 2022
Time: 9:00 a.m.
Location: Hybrid Meeting

Physical Meeting Location:
California Avocado Commission
12 Mauchly, Suite L
Irvine, CA 92618

Web Conference URL:

https://californiaavocado.zoom.us/j/84731292018?pwd=eTloeUIrWWRFWFpHQ203cGU5bmxIZz09

Conference Call Number: (669) 900-6833
Meeting ID: 847 3129 2018
Passcode: 196558

Meeting materials will be posted online at least 24 hours prior to the meeting at:
https://www.californiaavocadogrowers.com/commission/meeting-agendas-minutes

Committee Member Attendance

As of Thursday, July 21, 2022, the following individuals have advised the Commission they will participate in this meeting:

- **Leo McGuire,** ***PRC Chairman***
- **Bryce Bannatyne**
- **John Burr**
- **Jason Cole**
- **Jim Davis**
- **Consuelo Fernandez**
- **Darren Haver**
- **Ryan Rochefort**

Time	Item
9:00 a.m.	**1. Call to Order** a. Roll Call/Quorum
9:05 a.m.	**2. Opportunity for Public Comment** Any person may address the Committee at this time on any subject within the jurisdiction of the California Avocado Commission.
9:10 a.m.	**3. Approval of Minutes** a. Consider approval of Production Research Committee Meeting Minutes of May 18, 2022
9:15 a.m.	**4. Research Program Directors Report** a. Update on UC breeding program b. Avocado branch canker funding update c. WAC 2023 update
9:30 a.m.	**5. Discussion Items** a. Update on research trial "Safety and Efficacy of Herbicides in Bearing Avocado Groves," Dr. Peggy Mauk, UC Riverside
10:15 a.m.	**6. Action Items** a. Consider request for funding support for Avocado Brainstorming 2022 b. Consider request for funding for proposal, "Can overhead water application to control temperature and humidity increase yields, tree growth and health in avocado orchards." 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." d. Consider request for funding for proposal, "Commercial-scale field testing and potential release of five elite advanced rootstocks."
1:00 p.m.	**7. Adjourn Meeting**

Disclosures

The times listed for each agenda item are estimated and subject to change. It is possible that some of the agenda items may not be able to be discussed prior to adjournment. Consequently, those items will be rescheduled to appear on a subsequent agenda. All meetings of the California Avocado Commission are open to the public and subject to the Bagley-Keene Open Meeting Act.

All agenda items are subject to discussion and possible action. For more information, or to make a request regarding a disability-related modification or accommodation for the meeting, please contact April Aymami at 949-341-1955, California Avocado Commission, 12 Mauchly, Suite L, Irvine, CA 92618, or via email at aaymami@avocado.org. Requests for disability-related modification or accommodation for the meeting should be made at least 48 hours prior to the meeting time. For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette or computer disk. This meeting schedule notice and agenda is available on the internet at https://www.californiaavocadogrowers.com/commission/meeting-agendas-minutes and http://it.cdfa.ca.gov/igov/postings/detail.aspx?type=Notices.

If you have questions on the above agenda, please contact Tim Spann at tim@spannag.org or 423-609-3451.

Summary Definition of Conflict of Interest

It is each member's and alternate's responsibility to determine whether they have a conflict of interest and whether they should excuse themselves from a particular discussion or vote during a meeting. To assist you in this evaluation, the following ***Summary Definition of Conflict of Interest*** may be helpful.

A Commission *member or employee* has a conflict of interest in a decision of the Commission if it is reasonably foreseeable that the decision will have a material effect, financial or otherwise, on the member or employee or a member of his or her immediate family that is distinguishable from its effect on all persons subject to the Commission's jurisdiction.

No Commission member or employee shall make, or participate in making, any decision in which he or she knows or should know he or she has a conflict of interest.

No Commission member or employee shall, in any way, use his or her position to influence any decision in which he or she knows or should know he or she has a conflict of interest.

CALIFORNIA AVOCADO COMMISSION
PRODUCTION RESEARCH COMMITTEE
MEETING MINUTES

May 18, 2022

A web/teleconference meeting of the Production Research Committee (PRC) of the California Avocado Commission (CAC) was held on Wednesday December 8, 2021 with the following people participating:

<u>MEMBERS PARTICIPATING VIA TELECONFERENCE:</u>
Bryce Bannatyne
John Burr
Jim Davis
Catherine Keeling
Leo McGuire
Ryan Rochefort

<u>CAC STAFF PARTICIPATING:</u>
April Aymami
Ken Melban (10:30)

<u>OFFICIALLY PARTICIPATING:</u>
Dr. Tim Spann, Spann Ag Research & Consulting

<u>GUESTS PARTICIPATING:</u>
Doug O’Hara, Somis Pacific
Allisen Carmichael, Somis Pacific
Vicki Carpenter, USDA Agricultural Marketing Specialist

<u>CALL TO ORDER</u>

Leo McGuire, Production Research Committee (PRC) Chairman, called the meeting to order at 9:05 a.m. with a quorum present.

<u>OPPORTUNITY FOR PUBLIC COMMENT</u>

Vicki Carpenter, Agricultural Marketing Specialist with the USDA introduced herself to the Committee.

<u>APPROVAL OF MINUTES OF DECEMBER 8, 2021 PRODUCTION RESEARCH COMMITTEE MEETING</u>

<u>MOTION</u>
To approve the minutes of the December 8, 2021 Production Research Committee meeting.

(Burr/Bannatyne) MSC Unanimous

Motion 22-5-18-1

RESEARCH PROGRAM DIRECTORS REPORT

Dr. Spann gave the Committee an update on the progress the Dr. Haizhou Liu has made on the chloride mitigation project that was funded for the 2021-22 fiscal year. He informed the Committee that Dr. Liu is looking for growers who can share recent water analyses for irrigation water from any source from all growing regions to help with their study. Dr. Spann told the Committee he would forward Dr. Liu's request to them if any of them were willing to share their water analyses.

Dr. Spann told the Committee that he and Ken Melban, CAC Vice President Industry Affairs, had a Zoom meeting on May 17 with Tom Bewick and Jessica Shade, National Program Leaders for the USDA National Institute of Food and Agriculture. They discussed NIFA's efforts to better understand the needs of specialty crop producers for research funding through the Specialty Crop Research Initiative (SCRI) program. Dr. Bewick and Ms. Shade said they are looking for industry stakeholders to serve as relevancy reviewers for SCRI grant proposals to ensure the proposals are aligned with industry needs. Dr. Spann told the Committee he would share NIFA's request with them by email as soon as he received information from NIFA.

Dr. Spann reminded the Committee that cadmium had been a topic of discussion at their December 8, 2021 meeting and that Ken Melban had some new information he wanted to share with the Committee on this topic. Mr. Melban reminded the Committee about California avocado shipments that had been rejected at ports in South East Asia, which was the genesis of the cadmium discussion at their previous meeting. Since the December meeting, the Alliance for Food and Farming had conducted a consumer survey with 1,000 participants and heavy metals contamination was not a concern for U.S. consumers.

DISCUSSION ITEMS

A. Potential continuing funding of avocado rootstock trials

Dr. Spann reminded the Committee that CAC was currently funding a 3-year project to plant a series of commercial-scale trials with five advanced selections from the University of California Riverside (UCR) rootstock breeding program for the purpose of deciding to commercially release these rootstocks or not. That funding expires at the end of the 2021-22 fiscal year and the Committee was asked if there was interest in request a proposal from Dr. Patricia Manosalva to continue to collect data from these trials.

Discussion ensued and there was general agreement that these trials were well designed and were precisely what the industry had been wanting for many years. It was mentioned that regardless of when the University makes their decision to release these rootstocks or not, there is value in continuing to collect data from these trials to share with the industry as growers make decisions about which rootstocks to plant. The

Committee asked how much funding was provided for the initial 3-years of the project and Dr. Spann reminded the Committee that it was $350,000 plus the cost of the trees. Dr. Spann stated that he believed the ongoing costs to monitor the plantings and collect data should be significantly lower going forward.

The Committee agreed that it would be beneficial to plan to continue to fund the data collection on these trials for at least another 5-6 years so data could be collected from mature trees. However, they directed Dr. Spann to request a proposal from Dr. Manosalva for only an additional 3-years of funding. They asked that the proposal include a timeline for commercial availability.

B. Potential Research Projects for 2022-23

Dr. Spann began the discussion by reminding the Committee of the current funding obligations for ongoing projects in the 2022-23 fiscal year. These include $76,074 for an avocado lace bug project with Dr. Mark Hoddle and $24,866 for the chloride mitigation study with Dr. Haizhou Liu. Dr. Spann also stated that given the leadership transition taking place at CAC no target 2022-23 budget for production research had been set at this time.

A robust discussion ensued. The first topic that was raised was avocado crop coefficient for irrigation and whether the project currently being done by Dr. Ali Montazar was sufficiently funded. Dr. Spann stated that Dr. Montazar currently has USDA funding that is fully supporting his work at present; however, his trial sites are limited to the southern growing region. There was general agreement that it would be worthwhile to inquire whether additional funding for some northern trial locations would be beneficial to Dr. Montazar's project.

The issue of avocado branch canker (ABC) was discussed next and the Committee discussed that we now have a good understanding of what organisms cause ABC and some preliminary data about effective fungicides but there are still no fungicides registered for use against ABC. There was agreement that ABC is enough of an issue that it would be beneficial to investigate registering a fungicide(s) for its treatment. Discussion ensued about the issues surrounding product registrations and potential costs. Dr. Spann said he would discuss the issue with Dr. Themis Michailides who recently completed a CAC funded study on ABC as well as look into what fungicides are registered for use on avocados on Florida which would then only require a California registration.

The topic of weed control and the status of the registration for glufosinate. Dr. Spann informed the Committee that the glufosinate registration is in process and is working its way through the Department of Pesticide Regulation, but that it is a slow process. The Committee asked if they could receive an update at their next meeting on the currently funded herbicide work that is being conducted by Dr. Peggy Mauk. Dr. Spann agreed he would coordinate that for the Committee's next meeting. There was no consensus on the need to fund additional herbicide work currently.

The next topic that came up for discussion was the carbon footprint of avocado production. Dr. Spann informed the Committee that this was a timely topic as there is a group that recently submitted a multi-million-dollar proposal for federal funding to look into the carbon footprint of tree crops, including avocados, in California. Dr. Spann told the Committee that Drs. Lou Santiago and Darrel Jenerette, Department of Botany and Plant Sciences at UCR, would be leading the work on avocados if the proposal is funded. Dr. Spann also informed that Committee that although the purpose of the proposal is not to conduct a full-scale life cycle analysis for avocados many of the pieces of information needed to do so would be gathered. Thus, if this proposal is funded, a life-cycle analysis could be completed with some additional support form CAC. The Committee agreed this would be a worthwhile investment and would revisit this topic at a later meeting when the funding status of the proposal is known.

The final topic discussed was the avocado lace bug (ALB). Dr. Spann informed the Committee that a pest control advisor (PCA) had recently identified ALB in a grove in Carpinteria, which is a significant jump from it’s know range in San Diego, Riverside and Orange Counties. Following some discussion, the Committee agreed it would be good to receive an update at their next meeting from Dr. Mark Hoddle about his ALB work and discuss further at that time if there are any holes that could be filled with additional funding.

C. Lease Renewal of Pine Tree Ranch

Dr. Spann had provided the Committee with a written summary of the history of Pine Tree Ranch and the projects that have taken place there since CAC began leasing the site from the Cal Poly Pomona Foundation for use as a demonstration grove in 2013. Dr. Spann informed the Committee that CAC was entering its final year of the initial 10-year lease on the property and it would be beneficial for the Committee to discuss the merits of the site and whether a lease renewal would be worthwhile.

Discussion ensued and the Committee asked what the annual cost of the lease was. April Aymami, CAC Industry Affairs Director explained that the lease rate changed over the course of the 10-years and in the final year it would be about $24,000. She also explained that original lease agreement includes a renewal option for two 5-year terms.

Although it is understood that Pine Tree Ranch was never intended to be a profitable commercial grove, the Committee asked about the financials of the Ranch. April Aymami informed the Committee that for the 2021-22 fiscal year the Ranch is projected to make a net profit of about $97,000; however, for the 10-year period of the lease it is estimated that the Ranch will show a loss of about $300,000. Dr. Spann reminded the Committee that some projects conducted at Pine Tree Ranch saved CAC from having to spend funds elsewhere. As an example, he reminded the Committee that CAC used trees at Pine Tree Ranch for pesticide studies during the polyphagous shot hole borer threat, which required crop destruct and significantly debilitated the trees. Without Pine Tree Ranch, CAC would have needed to find a grower cooperator and pay for the cost of the crop and likely trees lost in that study.

The Committee agreed that overall, Pine Tree Ranch has been worthwhile and brought a lot of value to CAC and the industry. The Committee asked Doug O'Hara, current grove manager, if there were any concerns or major capital improvements that would be needed if CAC renewed its lease. Doug stated that the well is the greatest limiting factor and working out an agreement to install a variable frequency drive (VFD) to allow for more flexibility in irrigating independent of Cal Poly's portion of the ranch. The Committee asked what that would cost and Doug responded that he believed it would be about $20,000 but could go much higher if any addition repairs are needed to the well.

The Committee agreed that it would be in CAC's interest to pursue a lease renewal and to even consider expanding the number of acres leased to be able to have more and larger projects at the Ranch. The only concerns raised were the limited ability of the growers in the south to access the Ranch and not having full control over the property that ownership would provide.

ADJOURN MEETING

Leo McGuire, Production Research Committee (PRC) Chairman, adjourned the meeting at 11:18 a.m.

Respectfully submitted,

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Timothy Spann

EXHIBITS ATTACHED TO THE PERMANENT COPY OF THESE MINUTES

EXHIBIT A   May 18, 2022 Production Research Committee AB 2720 Roll Call Vote Tally Summary

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	*Teleconference*	*May 18, 2022*

Attendees Who Voted	***MOTION 22-5-18-1***
Leo McGuire, Chair	Yea
Bryce Bannatyne	Yea
John Burr	Yea
Jim Davis	Yea
Catherine Keeling	Yea
Ryan Rochefort	Yea
Outcome	**Unanimous**

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.

Avocado Brainstorming 2018

Towards a Sustainable Future

28 May – 1 June 2018
Fairview Hotel
Tzaneen, South Africa

Report to Sponsors

Prepared by

Mary Lu Arpaia

Avocado Brainstorming 2018

Towards a sustainable future

28 May – 1 June 2018

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Avocado Brainstorming 2018

Towards a Sustainable Future

Executive Summary

Avocado Brainstorming 2018

Towards a Sustainable Future

EXECUTIVE SUMMARY

The 6th Avocado Brainstorming meeting was held in Tzaneen, South Africa from 28 May through 1 June 2018. One hundred fifty-two individuals representing 12 countries were invited. There were 78 participants representing 11 countries (Australia, Brazil, Chile, Colombia, Israel, Mexico, New Zealand, Peru, South Africa, Spain, and the United States). The Organizing Committee consisted of Mary Lu Arpaia (University of California, Riverside, CA, USA), Zelda Van Rooyen (Westfalia Technological Services, Duweilskloof, South Africa), Alejandro Barrientos Priego (University of Chapingo, Mexico), Francisco Mena (GAMA, Quillota, Chile), Randy Ploetz (University of Florida, Homestead, FL, USA) and Iñaki Hormaza (IHSM La Mayora-CSIC, Malaga, Spain). Westfalia Technological Services provided logistical assistance for the meeting and their help was invaluable.

This meeting would not have been held without sponsorship. There were 4 levels of sponsorship: Platinum (Hass Avocado Board (USA), Westfalia Fruit (South Africa), California Avocado Commission (USA)); Gold (ZZ2 (South Africa), Agricom (Chile) and Allesbeste (South Africa)); Silver (Costa (Australia), Delroy Orchards (Australia), Jasper Farms (Australia), Simpson Farms (Australia), Southern Forest Avocado (Australia), West Pemberton Avocados (Australia), BioGold (South Africa), Halls (South Africa), Index Fresh (USA), SAAGA (South Africa), The Fruit Farm Group (South Africa) and DataHarvest (USA)); and Bronze (Guy Witney (South Africa), Alvi's Drift (South Africa)). Additionally, a US$250 registration fee was required from participants.

One of the organizing committee's goals was to have a broad range of expertise and experience amongst the meeting participants. In particular we wanted to target young researchers to continue to build the foundation for continuity of ideas and sharing of knowledge between those experienced and those new to avocado research. This goal was met. Approximately 32% of the attendees could be considered as early career scientists (graduate student, postdoctoral researcher or less than 10 years avocado experience). Twenty-seven percent of the participants had between 10 to 20 years' experience (mid-career) and 41% of the attendees had greater than 20 years avocado experience. The attendees also represented a broad range of research interest from molecular biology/genetics to applied field orientation.

The meeting consisted of 8 2-hour sessions with ample time for exchange of ideas and discussions in an informal setting plus 2 poster sessions held on the second and fourth day. There were 17 poster abstracts submitted. The technical sessions covered the following topics:

- Providing for the Consumer: Health, Safety, Flavor
- New Technology to Improve Avocado Production
- Challenges to Productivity: Diseases
- Challenges to Productivity: How the Tree Regulates Return Bloom and Crop Load
- Where Theory Meets Practice

- Challenges to Productivity: Genetics, Genomics and Biotechnology
- Meeting the Challenges of the Future
- Tying the Loose Pieces Together – Planning for the Future

Additionally 3 field excursions were offered. The first was a morning trip to Allesbeste Nursery and orchards where the company is experimenting with high density plantings and tree training. The second event was an all-day field trip sponsored by Westfalia Technological Services. This trip included a visit to the original phosphite injection trees, an overview of the soil and land conservation practices, an overview of the company's avocado rootstock selection program and a field trip to see rootstock, cultivar trials and an experimental net planting with the GEM avocado. The final field trip was to Nick Hume's net trial with Lamb Hass, Maluma and Hass as well as a trip to ZZ2's compost operation. The Allesbeste field trip and the final field trip were optional activities but had good participation and were offered at a modest fee to cover transportation costs.

Of most interest to the group, based on feedback from participants, was the discussion of the health benefits of the avocado (presented by Dr. Nikki Ford, Hass Avocado Board, USA), the update of our progress to sequence the avocado (Dr. Aureliano Bombareley, Virginia Polytechnic University, USA), the update on flowering behavior (Dr. David Pattermore, Plant and Food, New Zealand) and Session 7 where perceived needs of the avocado community were discussed and solutions suggested.

One of the overarching goals of the Avocado Brainstorming meeting is to foster collaboration amongst avocado researchers worldwide. The collegiality and free exchange of ideas that occurred at this meeting is testament that this is occurring amongst the participants. Many participants indicated to the organizing committee that due to this meeting they had forged new working relationships with other international avocado researches. These collaboration will ultimately lead to joint research across international borders, open discussions and sharing of ideas amongst researchers interested in targeted topics and an overall greater appreciation of the complexities of avocado research amongst all scientists working in avocado.

At the conclusion of the sessions there was a discussion on where to proceed for future Avocado Brainstorming meetings. A consensus was expressed that holding the meeting off-cycle to the World Avocado Congress continues to be preferred. It was decided to hold the next meeting in 3 years to be mid-point between the Congress in Colombia and the following Congress. We had several suggestions for where to hold the meeting including Brazil, Israel, Netherlands, Spain, and the United States (California). Spain was selected as the preferred site followed by California, Israel, Brazil and the Netherlands. The feasibility of these options is currently being explored.

Included in the following pages are four items: meeting agenda, session summaries prepared by the session chair and co-chair, titles of the posters presented, and a list of attendees. The session summaries are currently incomplete but will be updated when all reports are received.

Avocado Brainstorming 2018

Towards a Sustainable Future

Program Agenda

Avocado Brainstorming 2018
Meeting Agenda

Date	Time	Activity or Session Title/Co-Chairs
27/28 May	Arrival to venue	Lodging provided by meeting; meals on own in hotel
28 May	7:00 a.m.	Breakfast Buffet
	8:00 a.m. – 12:00 p.m.	**Optional TOUR:** Allesbeste Nursery and high density plantings (See attached for more tour details)
	12:00 p.m.	Lunch (Buffet)
	Session 1 2:30 p.m.	Providing for the Consumer: Health, Safety, Flavor *Co-Chairs: Nikki Ford. Lise Korsten, David Obenland*
	4:30 p.m.	Social – High Tea
	Session 2 6:00 p.m.	New Technology to Improve Avocado Production *Co-Chairs: Nicki Taylor, Mark Buhl*
	8:15 p.m.	Light Dinner
29 May	7:00 a.m.	Breakfast Buffet
	Session 3 8:30 a.m.	Challenges to Productivity: Diseases *Co-Chairs: Randy Ploetz, Kerry Everett*
	10:30 a.m.	Break
	Session 4 11:00 a.m.	Challenges to Productivity – How the Tree Regulates Return Bloom and Crop Load *Co-Chairs: Harley Smith, Rodrigo Iturrieta, Vered Irihimovitch*
	1:00 p.m.	Lunch (Buffet)
	Poster Session 1 4:00 p.m.	*Co-Chairs: Neena Mitter, Noelani van den Berg*
	Session 5 6:00 p.m.	Where Theory Meets Practice *Co-Chairs: Francisco Mena, Ben Faber*
	8:15 p.m.	Dinner

Avocado Brainstorming 2018
Meeting Agenda

Date	Time	Activity or Session Title/Co-chairs
30 May	**FIELD DAY**	Sponsored by Westfalia Technological Services (See attached for Field Day details)
31 May	7:00 a.m.	Breakfast Buffet
	Session 6 8:30 a.m.	Challenges to Productivity – Genetics, Genomics and Biotechnology *Co-Chairs: Aureliano Bombareley, Iñaki Hormaza*
	10:30 a.m.	Break
	Session 7 11:00 a.m.	Meeting the Challenges of the Future *Co-Chairs: Mary Lu Arpaia, Zelda Van Rooyen, Tim Spann*
	1:00 p.m.	Lunch (Buffet)
	Poster Session 2 4:00 p.m.	*Co-Chairs: Neena Mitter, Noelani van den Berg*
	Session 8 6:00 p.m.	Tying the Loose Pieces Together – Planning for the Future *Co-Chairs: Jose Chaparro, Nigel Wolstenholme*
	8:15 p.m.	Dinner (3 course)
1 June	7:00 a.m.	Breakfast Buffet
	8:00 a.m. – 12:00 p.m.	**Optional TOUR** and Delegates Depart (See attached for more tour details)

7:15	Groups depart from Fairview Hotel
7:30	Arrive at Westfalia Fruit Estate - African welcome
8:00	Welcome & breakfast - Ramalea Guesthouse
9:15	Groups depart on various tours

	Group one	Group two
9:30	*Westfalia heritage tour*	*Avocado rootstock screening tour*
10:50	Tour rotation / bathroom break	Tour rotation / bathroom break
11:00	Avocado rootstock screening tour	Westfalia heritage tour
12:20	Groups meet at Westfalia Tarining Centre & collect lunch packs	Groups meet at Westfalia Training Centre & collect lunch packs
12:45	Depart to Soekmekaar	Depart to Soekmekaar

	Group one	Group two
14:00	*Visit to Gem® orchard grown under shade net*	*Avocado cultivar & rootstock field trials*
14:45	Tour rotation / bathroom break	Tour rotation / bathroom break
15:00	Avocado cultivar & rootstock field trials	Visit to Gem® orchard grown under shade net
15:45	Groups return to Westfalia Fruit Estate	Groups return to Westfalia Fruit Estate
17:15	Braai under African skies	Braai under African skies

Tour details

Morning

Westfalia heritage tour
- View over Westfalia Avocado Amphitheatre
- Dr Hans Merensky Conservation Heritage
- Orchard visit to a clone of the original mother 'Hass' tree
- Cultivar display

Avocado rootstock screening tour
- Overview of current rootstock screening
- Visit to "killing fields"
- 30 years of rootstock selection- visit to original "super trees"

Afternoon

Visit to Gem® orchard grown under shade net
- Gem avocado attributes & overview
- The pros & cons of avocado production under nets

Avocado cultivar & rootstock field trials
- Field trial where 6 different fruiting cultivars are being tested on 5 different rootstocks
- Field trial where Hass & Gem® are being tested on 11 different rootstocks

Avocado Brainstorming 2018
Optional Technical Tours

28 May 2018 **Optional TOUR**
8:00 a.m. – 12:00 p.m.
Allesbeste Nursery and high density avocado plantings
Estimated cost per person: US$25 - 40; payable by credit card

7:30 a.m.	Assemble in dining room of Fairview Hotel
7:30 a.m.	Overview of Allesbeste Nursery and Concepts of High Density Planting Andre Ernst, Zander Ernst, Abraham de Villiers
9:00 a.m.	Divide participants into 2 groups and depart Fairview Hotel. Stop 1. Allesbeste Nursery Stop 2. Maluma and Hass high density plantings and tree training schemes
10:30 a.m.	Switch groups
12:00 p.m.	Return to Fairview Hotel (arrive approximately 12:30 p.m.)

1 June 2018 **Optional TOUR**
7:30 a.m. – 11:00 a.m.
Provisional Program
Estimated cost per person: US$25 - 40; payable by credit card

7:30 a.m.	Depart Fairview Hotel
7:45 a.m.	Net Structure, Nick Human
8:45 a.m.	Leave for ZZ2
9:30 a.m.	Arrive ZZ2 – View Composting and Compost tea operations
11:00 a.m.	Return to Fairview Hotel or travel to Polokwane Airport

Avocado Brainstorming 2018

Towards a Sustainable Future

Summary Reports

Avocado Brainstorming 2018

Towards a sustainable future

28 May – 1 June 2018

SESSION SUMMARIES

Submitted by Session Moderators

Session 1. Providing for the consumer: Health, safety, and flavor

This session was composed of three presenters: Lise Korsten (University of Pretoria, South Africa), David Obenland (USDA/ARS, USA) and Nikki Ford (Hass Avocado Board, USA)

Overall Summary:

This session covered food safety, flavor and nutrition, three aspects that are of critical importance to the consumer in determining if they will purchase avocados. Food safety is strongly impacting the avocado industry and is an issue that must be dealt with by the research community to help reassure consumers that avocados are safe to eat. Sensory studies are identifying what aspects of flavor are of most importance to the consumer and utilizing a variety of analytical techniques to define determinants of flavor to help improve avocado flavor quality. Consumers are increasingly health-conscious and must be provided accurate information on the nutrient content and potential health benefits of avocados.

Food safety (Korsten)

Food safety has become a critical issue in the processing and marketing of agricultural commodities with incidents involving *Listeria* and *Salmonella* being particularly prominent. Avocados have not been immune from this problem as many recalls involving whole and prepared products have occurred in recent years. The means to easily detect the causal organisms have been developed as have methodologies to determine the microbiome present on avocados. Information on contaminant genomics can be used to determine the effectiveness of preventative controls and to better understand the origin of the organisms. Establishment of a global project to study food safety in avocados, potentially including research on the avocado microbiome, may be a useful approach toward reducing the risk of food-borne illness from avocados.

Avocado flavor (Obenland). Flavor in avocados is a combination of the perception of taste aspects and the influence of volatile components. Texture is an important modifier of these two factors and is especially important in avocados. Consumer studies have identified key aspects of flavor and texture that drive consumer preference but a major challenge is in understanding the determinants of these factors so that likeability to the consumer can be enhanced. Research has identified the formation of aldehydes following tissue homogenization as being the likely cause of grassiness. Since these aldehydes are formed during the process of chewing, however, the change in flavor is dynamic and may not be fully captured using standard static measures of flavor volatile content. Information was shown during the presentation on methodologies using real-time mass spectrometry that may enable a better understanding of this process. Information was also presented on the use of electronic tongue technology to discover non-volatile factors that influence avocado flavor. Experiments utilizing extracts from various avocado genotypes of differing maturities identified differences in the output of the umami (savory) sensor of the electronic tongue that correlated with variations in savory flavor as identified by consumer taste panels. The results from these experiments may lead to the identification of components that are important to determining consumer liking in avocados.

Avocado health benefits (Ford). The Hass Avocado Board (HAB) is an information, research and marketing program, funded by industry dollars but governed by the USDA. HAB's vision is to be the catalyst for fresh avocados being the No. 1 consumed fruit in the U.S. and industry stakeholders being successful. HAB works towards this vision by combining marketing with nutrition research because consumer tracking studies indicate that U.S. consumers purchase avocados for their flavor and because they are good for you. HAB's research program includes focuses on 4 health areas - cardiovascular health, weight management, healthy living and diabetes. Published studies indicate that avocado consumption plays a role in each of these focus areas. The research focuses exclusively on consumption of whole fresh pulp and some of the scientific outcomes may be attributed to additive or synergistic effects of fiber, especially soluble such as pectin, monounsaturated/polyunsaturated fats, folate, lutein, avocation, beta-sitosterol, and flavonoids and other antioxidants. Nutrition research is essential for marketing, due to regulations present in most countries throughout the world. Moreover, nutrition research is used to in food policies which ultimately determine what foods can be purchased through any Federal U.S. program. A new opportunity or challenge is arising with consumers and Federal regulators – sustainable diets. This discussion will affect consumer purchasing and may even be used in Federal food policies.

Session 2. New Technology to Improve Avocado Production

The session consisted of six presenters: Mark Buhl (DataHarvest, USA), Nicky Taylor (University of Pretoria, South Africa), Zander Ernst (Allesbeste, South Africa), Elizabeth Dann (University of Queensland, Australia), Jayeni Hiti Bandaralage (University of Queensland, Australia) and Neena Mitter (University of Queensland, Australia).

Session Synopsis. This was a very diverse session and a wide range of topics were covered from remote sensing and data management to avocado tree training, avocado propagation and finally crop protection. This was to be expected from such a session, as technology impacts every aspect of production. The discussion at the end of the session focused largely on the stem cell culture of avocado and the BioClay-RNAi technology. There was also discussion concerning the habit of the trellised avocado trees to flower from the stem and the persistence of this behavior in older trees and the setting of threshold for management actions using remote sensing.

BlockChain and the Modern Farm/Nursery/Breeder (Buhl). We are firmly in the digital age and making use of the latest technology for data management can change the way in which the avocado industry "does business". Increasing amounts of data are collected every day throughout the avocado value chain and innovative systems are required to take advantage of this information and streamline operations. One such system that could facilitate this is Blockchain, which can be described as "an incorruptible digital ledger" that can be programmed to record virtually everything of value. Blockchain will aid in the standardization of metrics and the sharing of information from the nursery to the grower and finally to the consumer. This is largely possible as a result of a predetermined set of parameters which are collected by all parties. This will allow for improved traceability in the value chain and facilitate the sharing of information with consumers, which is becoming increasingly important in agriculture, as consumers seek more information on the manner in which their food is produced. It could also allow the assetization of farms and create unique financial models for farm ownership. Technology to manage labor more effectively and efficiently is also becoming available and through the use of smart watches and remote sensing, labor can be used optimally and managed more efficiently to lead to better productivity. This can be achieved through sharing of detailed daily task information on the smart watch and tracking of activities throughout the day.

Remote sensing and Big Data (Taylor). One of the tools that is becoming more readily available to growers is remote sensing data, which has shown enormous promise in improving spatial management of orchards. This data can be collected by satellites, fixed wing airplanes and unmanned aerial vehicles or drones. Farmers in the Western Cape province of South Africa, currently have free access to a platform called Fruitlook where spatial data on evapotranspiration, vegetation indices, biomass accumulation and nitrogen content is available. This platform is sponsored by the provincial agricultural department and is assisting growers manage spatial variation in orchards. Whilst the data from this platform has proved to be extremely useful the large pixel size does limit application and other options need to be explored with better spatial resolution. With better spatial resolution, drones can be used for disease scouting, canopy management, water management, defining management zones on a farm, targeting spraying of pesticides and for security.

When considering the use of "Big Data" in agriculture there are a number of questions that should be asked before it is seen as one of the major solutions to various problems. For example, we need to consider "when does Data become Information and when does Information become Knowledge and when does Knowledge become Wisdom?" How can we move from data towards wisdom that would allow for more sustainable agricultural, and more specifically avocado, production. The grower also needs to be considered and concerted effort needs to be directed towards understanding how much information growers need to make good decisions. Does information overload ever assist in better management or does it just make it more difficult to make a decision? Finally, do we collect "big data" just because we can or is there a specific research question in mind?

Intensive avocado canopy management (Ernst). Allesbeste in Tzaneen have evaluated ultra high density avocado orchards on a trellising system and have recently planted their first commercial orchard. The philosophy behind these plantings is that the closer the trees are planted together, the quicker the full potential of the orchard can be reached in terms of per hectare production. High density also simplifies management, whilst maintaining the complexity of the trees. Current spacing is 5 m x 2.5 m resulting in 800 trees ha-1, with trellis wires spaced 300 mm apart. Branches are tied in an upwards direction rather than downwards. In the first few years after planting this system seems to reduce alternate bearing and allows good light penetration into the canopy, but sunburn needs to be managed and controlled. Flowering occurs from the stem and the covering of these fruit by leaves has improved packout. The keys to the success of this planting system include the microclimate, judicious irrigation management and careful pruning. It is proposed that a tatura training system works best and that training should start in the nursery.

Using image analysis to quantify P.c. symptoms (Dann). Phytophthora infection of trees often occurs without any discernible visual symptoms, however, an analysis of canopy porosity using RGB images obtained with a cell phone from below the canopy is proving useful in diagnosing early symptoms of canopy decline and has been found to be well correlated with the Ciba-Geigy rating chart. Vegetation indices obtained from satellite images are also proving very useful in producing maps of Phytophthora root rot problems for different orchards. In future it is hoped that these maps can be linked to a cell phone app together with multispectral and hyperspectral sensors. Remote sensing is also being used for mapping block yield and predicting yield, which could assist growers with marketing.

Avocado tissue culture using stem cells (Bandaralage). Avocado is a highly recalcitrant plant species and therefore the challenge with tissue culture of avocado is to optimise every stage of production. Success with both nodal and meristem tip culture has been very limited in avocado. The key to successful tissue culture is multiplication and with shoot tip culture, 500 plants can be obtained from a single shoot tip with a method developed by the University of Queensland, within 8-12 months. This has been achieved for the cultivar ‘Reed’ and optimisation is under way for ‘Velvick’. Parts of the propogation methodology have been patented.

BioClay – non GM and non-toxic crop protection platform (Mitter). BioClay can be described as clay nanosheets that can be used for non-GM delivery of RNAi or RNA interference. It provides a means of degrading pathogen RNA and preventing disease. A double stranded RNA is applied to the plant, which is degraded by enzymes on the plant leaf surface. This complex is stable on the leaf surface and can last for at least 30 days on the leaf surface. In addition, it is not integrated into the DNA of the plant and the bioclay can also act as a slow release fertilizer. Protection against a virus has been demonstrated in capsicum but work still needs to be done on avocado.

Session 3. Challenges to Productivity: Diseases

The session consisted of six presenters: Elizabeth Dann (University of Queensland, Australia), Noelani van den Berg (University of Pretoria, South Africa), Randy Ploetz (University of Florida, USA), Clara Priego Prieto (IFAPA-Churriana, Spain), Kerry Everett (Plant and Food, New Zealand) and Noam Alkan (Volcani Research Center, Israel).

In this session the most important avocado diseases were selected for discussion. Importance was determined on the basis of invasiveness (laurel wilt and fusarium dieback), new emerging diseases (brown root rot, caused by *Phellinus noxius*, white root rot, *Rosellinia necatrix*, and nursery root rots, *Calonectria* spp.), and perennial problems (Phytophthora root rot and fruit rots).

Phytophthora root rot: History, impact, status (Dann). Phytophthora root rot (PRR) is caused by *Phytophthora cinnamomi* (PC). PC originated in Asia and has a wide host range (<5000 species). PRR is a disease of nursery and mature trees, resulting in tree decline and plant death. Affected trees set small fruit and yield is reduced. PRR costs Australia an estimated AU $17 million per annum which is about 5% of the value of total production. It is the no. 1 constraint for avocado production in many countries. Other *Phytophthora* species (i.e. *P. citricola*, *P. mengeii*, *P. multivora* and *P. niederhauserii*), and *Phytopythium vexans* also affect avocado. Several rootstocks that have been selected for tolerance and resistance are used widely for PRR management, but an integrated approach that utilizes several tactics (see Pegg wheel) is usually most effective; there is no silver bullet.

Rootstocks – selection, production and use of commercially available material (van den Berg). The selection of superior rootstocks is time-consuming and difficult. There are no molecular tools to select rootstocks, rather rootstocks are selected based on their phenotypic response to PRR. The selection process at WTS is based on mist-bed selection in PC-infested soil followed by field trials. This process takes 10-20 years, and has resulted in 'Latas', the current indutry standard 'Dusa' and several new lines that are in the WTS pipeline. Superior rootstocks usually respond to PRR in one of several different ways. For example, 'Dusa' responds by suppressing the amount of PC that develops after infection. Notably, if superior rootstocks are flooded they are unable to withstand PRR. Noelani's group sequenced the first transcriptome for host response to PC and flooding. Npr1 is a key regulator and salicylic acid is the key pathway 'Dusa' uses to fight PC.

Phosphonates (Dann). There would not be an avocado industry without phosphonates. Aliette was used beginning in the late 1970s, followed by phosphorous acid (PA, the active incredient in Aliette) neutralized with KOH in the 1980s. Tree injection with the latter compound, which was developed by Joe Darvas in 1987, was a crucial breakthrough. In the 1990s, advances were made to optimize the timing of application, based on tree phenology, and beginning in 1998 a service was developed in Australia for monitoring PA levels in roots. PA has a dual mode of action, as it affects PC and also activates plant defences against PRR. Reduced sensitivity to PA has been found in PC, but there is no evidence for reduced efficacy against PRR in the field.

Fusarium dieback and laurel wilt (Ploetz). Ambrosia beetles reside in xylem of woody hosts, but consume fungal symbionts, not wood. Fusarium dieback, now found in RSA, Israel and California, is caused by *Fusarium euwallaceae*, a symbiont of *Euwallacea* nr. *fornicatus*. In avocado, it is not systemic, and generally restricted to outer areas of canopy; it can be managed by removing affected branches. Other trees are much more susceptible than avocado, e.g. *Acer negundo* and *Ricinus communis*. Laurel wilt (LW) is caused by *Raffaelea lauricola* (RL). It and its primary beetle symbiont, *Xyleborus glabratus*, were introduced to the USA from Asia. LW was first found on an avocado relative, redbay, on which it spread rapidly throughout the SE

USA. RL has jumped to other ambrosia beetles, some of which are thought to be important in the avocado pathosystem. LW moves rapidly in avocado orchards via root grafts. LW is most effectively managed by removing affected trees as soon as they develop symptoms (before root graft transmission occurs). Management via cultural or fungicidal measures can be effective, but are not long-term solutions. LW is now in Texas, just north of the Mexican border.

White root rot (Pliego Prieto and van der Berg). White root rot (WRR) is caused by *Rosellinia necatrix* (Rn). It causes yellowing, wilting and eventual death of the tree, and spreads by root grafts. Control is very difficult. As WRR is resistant to common fungicides, tolerant rootstocks are sought in Spain; 22 selections are being evaluated in Rn-infested fields. In transcriptomic analyses, ca 250 genes have been associated with the growth of WRR on avocado roots, some of which are responsible for toxin production, biosynthesis of hormones and potential effectors. In a microarray gene expression analysis, protein inhibitors were upregulated in a tolerant rootstock. Induction of resistance via water stress is being investigated. In RSA, WRR was first detected in apples and pears in the Western Cape. In avocado orchards, it has probably been present for a long time, but unnoticed; it is now in Kwazulu/Natal, Limpopo, and Mpumalunga. The susceptibility of different rootstocks is being evaluated in glasshouse trials, as are biological and chemical control options for WRR.

Brown root rot and trunk rot (Dann). This disease is caused by *Phellinus noxius* (Pn). Pn spreads by root to root contact, and occurs on avocado in the Atherton Tablelands and Bundaberg Childers areas in Australia. Its distribution in fields is usually patchy. Isolating infected (symptomatic and apparently healthy adjacent trees) from non-infected trees is indicated with root barriers at least 1 m deep. Pn has survived for 4+ years after dead avocado trees were removed. Thus, replanting fails. Pn affects over 200 woody hosts, and mulch from infested woodchips should not be used.

Nursery root rots (Dann). These diseases cause rapid death in the nursery, and wilting and death of trees within a year of planting. If a tree is infected in the nursery, it can outgrow the disease if it is well cared for after planting in the field; however, if damage in the nursery is great, trees die. Unlike PRR, this disease causes discrete lesions on feeder roots. Several different nectriaceous fungi can be isolated from roots, only some of which are pathogenic; in general, *Calonectria* and *Dactylonectria* spp. are pathogenic, but *Ilyonectria* and *Gliocladiopsis* spp. are not. A LAMP assay is being optimized.

Botryosphaeria dieback (Ploetz). Several pathogens in the Botryosphaeriaceae are responsible, some of which also cause fruit disease. Symptoms include branch dieback, internal necrosis and graft failure, which is a problem in Israel. Management is very difficult because these fungi are endophytes and do not cause symptoms until plants are predisposed by extreme conditions. There are no good systemic fungicides, although phosphonates are being used in Israel. Pathogen-free scions should be used for propagation.

Post-harvest fruit diseases (Everett and Alkan). In New Zealand, *Colletotrichum acutatum* and *Phomopsis* were less common at the beginning of the season, and more common at the end. In contrast, *Botryosphaeria spp.* were common at the beginning, but declined towards the end. Overall the most common pathogens were *C. acutatum and Phomopsis* sp. The temperature optima for both was c. 18°C. Using *nit* mutants, monthly wound-inoculations of fruit in the orchard suggested that infection occurred only when temperatures were above 18°C. When the cut stem was inoculated, *Phomopsis* did not cause stem-end rots, but *C. acutatum* caused almost 100% infection. Further work is required to confirm how infection occurs in the orchard, and to study the *Phomopsis* sp. infection pathway. In Israel, fruit rots are caused by species of *Colletotrichum*, *Alternaria*, *Lasiodiplodia*, *Phomopsis*, *Neofusicoccum* and *Botryosphaeria*, but *L. theobromae* is the main pathogen. It is an endophyte that causes symptoms on fruit only after they ripen. Using mango as a model, it colonized the phloem asymptomatically. When fruit ripened, the phloem was breached and the fruit flesh was invaded.

Session 4. Challenges to Productivity: Optimizing yield by understanding the physiological events that regulate crop load and the return to bloom

The session consisted of five presenters: Harley Smith (CSIRO, Australia), Rodrigo Iturrieta (University of California, USA), Vered Irihimovitch (Volcani Research Center, Israel), David Pattermore (Plant and Food, New Zealand), Iñaki Hormaza (ISHM, Spain).

Overview (Smith). Avocado is characterized as a low yielding semi-domesticated fruit tree crop due to problems with key yield determinants such as biennial bearing, pollination, flower quality, fruit set and fruit abscission. As yield is a function of genetics x environment x management, there are numerous research opportunities in breeding and the development of new management techniques to improve yield and profitability for avocado industries throughout the world.

Exploring the effects of fruit load on floral induction in 'Hass' alternate bearing avocado (Irihimovitch). 'Hass' fruit load reduces the ability of the buds in the shoot to undergo the floral transition, resulting in biennial flowering and fruit production. Previous studies showed that floral induction occurs during early winter months and correlates with a transient accumulation of transcripts for FLOWERING LOCUS T-like (PaFT) in leaves of off ‘Hass’ trees. Fruit load may indirectly affect PaFT expression, by modulating either carbohydrates and/or the endogenous concentrations of hormones in the leaves known to regulate FT in other species. Results from the Irihimovitch laboratory showed that measurements of the seasonal fluctuations of nonstructural carbohydrates, and a detailed hormonal profiling, revealed that off leaves displayed significantly higher total soluble sugar and cytokinin content, as compared with on leaves. Furthermore, an initial increase in sucrose and perseitol in the leaves, correlated with up–regulation of PaFT and with elevated expression of Trehalose-6-Phosphate Synthase 1 (PaTPS1), a key enzyme regulating carbohydrate availability. A model, interpreting these and other obtained results, in terms of understanding factors regulating return to flowering, was presented. The possible implications of the obtained results, in terms of developing horticultural practices to control 'Hass' flower induction, were also discussed.

Control of flower quality and fruit set in avocado (Hormaza). Fruit set is dependent upon several decisive and sequential developmental events in avocado. First, environmental factors including temperature and humidity regulate pollen tube growth. For example, low temperature slows pollen tube growth whereas high temperature and low humidity accelerate stigmatic degeneration. Second, avocado trees produce up to a million flowers with similar morphology and dichogamy cycle of flowering. However, significant differences are found in flower quality as indicated by carbohydrate and boron levels. As carbohydrate and mineral content is depleted by the high flowering behavior of avocado trees in the spring, winter fertilization is recommended to increase flower quality under Mediterranean climatic conditions. Third, the lack of pollination is a key yield-limiting factor, as honey-bees are inefficient pollinators of avocado flowers. The use of additional pollinating insects, including solitary bees and syrphid flies would act to increase pollination together with delaying flowering or planting later flowering cultivars in the case of Mediterranean climates with low temperatures at the time of bloom. Lastly, additional efforts in evaluating the use of pollinizer varieties is needed to ensure growers the best pollinizer for each production cultivar in different production environments.

Model for fruit abscission avocado (Smith). The irregular bearing of avocado is contributed by a number of factors including fruit set and fruit abscission. During early stages of fruit development, it has been postulated that a high rate of fruitlet abscission (unfertilized and fertilized) occurs in response to vegetative shoot growth (Sedgley 1980). According to Sedgley 1980, the majority of unfertilized fruitlets abscise within the first two weeks after fruit set. Fertilized fruits, ranging from 2.6 to 9.3 mm, abscise within the 15-35 days after fruit set due to the growth of the spring flush. Fruitlet abscission is a multistep process that is initiated by unknown signals that promote fruit growth cessation in a subset of fruit in the tree. After growth cessation, seed senescence occurs followed by the activation of the abscission zone in the pedicel, which leads to the physical separation of the fruit from the tree. Developing a system to better understand the physiological signaling mechanism(s) that mediate fruit growth cessation will provide a platform to develop new management strategies to limit fruit abscission and increase yield.

Sedgley, M (1980) Anatomical investigation of abscissed avocado flowers and fruitlets. Ann. Bott. 46, 771-777.

Impact of fruit presence and sunlight on 'Hass' avocado growth (Iturrieta). Under field conditions, Rodrigo Iturrieta used a single shoot focused phenotyping of the 'Hass' variety to dissect its plasticity into consistent and resilient patterns that explain what is perceived as a whole canopy behavior. Phenotyped at the original research site in California but corroborated in Chile, Israel, Peru and South Africa, the pattern under absence of a growing fruit is of increased vegetative complexity by more flushing and branching events along the single shoot axis while simplicity was observed on fruiting shoots. Reproductive growth was also observed with a reduced frequency and complexity on fruiting shoots. Adding to the previous, he indicated that there is a clear "topography" of these phenotypical events along the single shoot axis and a correlated likelihood of occurrence. Sunlight exposure can modify the phenotype of a fruiting shoot to be closer to that of the non-fruiting counterparts. He advocated for the need of a common language among researchers and an awareness of these patterns in order to precisely link molecular events to actual field phenotypes, share databases and do collaborative research across hemispheres and growing areas.

Avocado Pollination and Pollinizers (Pattemore). D. Pattemore presented an overview of our knowledge on avocado pollination and the use of pollinizers. His presentation was divided into several themes. The first was discussing whether there was any value to having pollinizers. He presented data that suggests that pollen parent may influence dry matter accumulation and fruit persistence after fruit set. Most striking was data collected at the grove level where individual tree yields were monitored over a 6 year period. The main factors that influenced the 6-year average yield included distance to the pollinizer variety and the identity of that closest pollinizer. The New Zealand group has also revisited past work conducted in Israel which examined the number of pollen grains deposited on flowers visited by honey bees. The vast majority of flowers have none or only 1 -2 pollen grains on the stigma which was corroborated by examining the amount of pollen found on the honey bees. The data also shows that the honey bee carries, under New Zealand conditions, more pollen from pollinizer varieties than 'Hass'. The pollen collected by bumblebees was slightly less than that of honey bees and the native flies that were monitored had considerably less. He also showed data on flower visiting insect visits to multiple orchards, which showed considerable variance in insect visitation. The last portion of his presentation dealt with the timing of the female and male flower opening as influenced by temperature. The data corroborates earlier data published by Gad Ish Am et al. in Israel which shows that when temperatures are cool, the opening of the female stage flower is delayed. In his final comments he outlined the challenges that are faced in future research on this subject.

Session 5. Where Theory Meets Practice

The session consisted of four presenters: Ben Faber (University of California, USA), Francisco Mena (GAMA, Chile), Neil Delroy (Jasper Farms, Australia), Tatiana Cantuarias-Avilés (University of São Paulo, Brazil)

This was a Brainstorming session that introduced many of the different field practices that growers are pursuing, in a way integrating the research findings that can be economically justified in the field. The overview of these practices includes those that the grower needs to plan in advance, such as scion and rootstock selection which can affect future pest/disease management, planting density and cost and rate of return on investment. High density plantings generally give a greater Internal Rate of Return, and a higher Net Present Value for projects. Plant costs, availability, and downstream management considerations generally related to the ability to mechanize versus labor costs influence ultimate plant densities.

When it comes to cost, growers must analyze cost per kilogram and not per hectare, usually growers that produce larger crops have higher costs per hectare but the per kilogram cost is much lower. The final analysis of higher densities should evaluate this production cost. In Chile, high densities have proven to be more productive than lower planting densities.

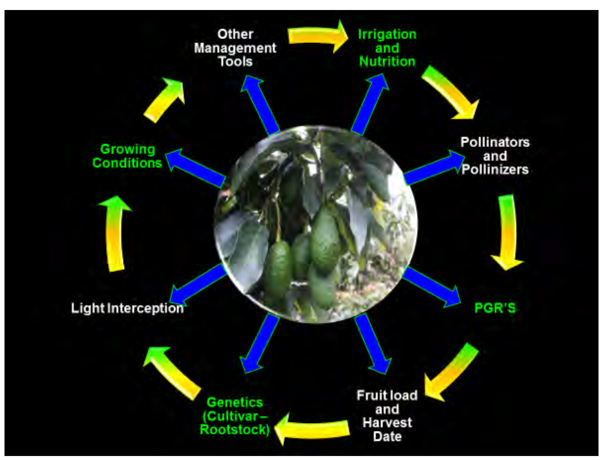
Whether and how many pollinizer varieties are included also needs to be decided pre-planting and is generally dependent on temperatures experienced at flowering.

Cultural management practices such as planting on mounds for improved drainage and use of mulch to improve Phytophthora control are important considerations. Protective structures (high netting for environmental modification) will also affect plant growth, harvest practices and costs. Biostimulants including seaweed, gibberellic acid, uniconazole and even phosphites can affect tree health and fruit production, such as precocity, fruit size and alternate bearing.

Irrigation and nutrient practices will affect tree health, growth and productivity. Crop management practices, including harvest timing, pruning and spray programs can affect yield, fruit size, pest and disease incidence and alternate bearing. Use of pollinators and their management will further affect tree productivity, and this includes how ground cover is managed through weed management, mulching and/or encouragement of insectary plants. Tree growth habit and planting density will affect pruning practices, light interception and ultimately productivity.

Table 1. Production (kg/ha) of 'Hass' avocado planted at varying density in Llay-Llay, Chile. Trees planted in 1997 and 2004.

Year	555 plants per HA (planted 1997)	1,111 plants per HA (planted 2004)
2004	25,571	
2005	15826	
2006	29,428	9,288
2007	12,003	17,711
2008	18,797	4,425
2009	25,092	39,526
2010	16,099	19,395
2011	7,636	31,480
2012	20,815	16,877
2013	25,147	42,548
2014	13,046	18,406
Average Yield	**19,042**	**23,796 (+25%)**



Alternate bearing can be controlled by plant density, pruning practices, use of plant growth regulators and "applying the right quantities of nutrients" at the right phenological stages of tree growth. Moderate annual pruning helps prevent lower production because it improves canopy light interception and helps to renew tree growth without inducing large fruit losses. Canopy architecture is a key consideration to maximizing potentially productive canopy volume. Pruning timing must have flower differentiation in consideration, ever since it might push trees to grow rather than to commit with reproductive development.

Alternate bearing is probably inherent to avocado, but it's possible to keep yields alternating between 16-24 tonnes/ha rather than from 30 to 5.

Soil health is critical for sustainable good yields and practices used in non-irrigated avocado orchards in Brazil were presented. Soil preparation prior to planting includes increasing organic matter content and promoting soil biology by establishing one to three cycles of annual green manure crops during before avocado prior to planting. Soil amendments for acid soils, such as limestone, gypsum and rock dust are also applied. At planting, bacterial/fungal inoculants are applied together with readily available carbon sources, such as humic and fulvic acids. Mounding and mulching with grass and wood chips. The soil inoculants are being produced on site by growers at a relatively cheap cost and are directly applied to the soil beneath the tree canopy during the rainy and hot season. These materials are being used by the main growers of São Paulo and Minas Gerais States and have led to fertilization costs reduction and improvement of tree health. So far, these practices have proved to boost soil microbiological activity in the short-term period. Furthermore, various biological control measures for pests and disease management have been also adapted by local growers for controlling pests and soil-borne pathogens and promoting root growth, such as drone-assisted release of *Trichogrammas* in the orchards, sprayings with *Beauveria bassiana* and *Bacillus thuringiensis* and soil inoculation with *Trichoderma harzianum* and *Bacillus subtilis.*

In the past years the development of different crop management techniques has allowed higher fruit yield per hectare in some of the growing areas. Planting densities have dramatically changed, new areas are being developed for growing avocados, while water quality and availability have become critical issues in many growing areas. Novel and updated research is needed in areas such as nutrition and irrigation to better adapt to this new growing condition.

Session 6. Challenges to Productivity – Genetics, Genomics and Biotechnology.

The session consisted of four presenters: Aureliano Bombarely (Virginia Polytechnic University, USA), Iñaki Hormaza (IHSM, Spain), Sara Mwangi (University of Pretoria, South Africa), Elena Palomo-Rios (IHSM, Spain), Fernando Pliego Alfaro (University of Málaga, Spain).

The goal of the session "Challenges to Productivity – Genetics, Genomics and Biotechnology" was to summarize and put several examples of the current technologies that are being applied to the avocado research. The session was chaired by Prof. Iñaki Hormaza from the IHSM La Mayora, Spain and Dr. Aureliano Bombarely from Virginia Tech, USA on May 29th, 2018 in Tzaneen, South Africa. The session consisted of five presenters: Aureliano Bombarely (Virginia Polytechnic University, USA), Iñaki Hormaza (IHSM, Spain), Sara Mwangi (University of Pretoria, South Africa), Elena Palomo-Rios (IHSM, Spain), Fernando Pliego Alfaro (University of Málaga, Spain):

Characterization of genetic diversity in an avocado panel (Hormaza). Prof. Hormaza described the work of his team about the characterization of avocado cultivars using morphometric and genomic tools. On the morphometric tools, he stressed the importance of having an adequate ontology for the annotation of phenotypic and genomic data. A current project is analyzing different traits described in different sources, such as the UPOV, Bioversity and unpublished sources with more than 1,500 variables. Regarding genomics, there have been advances in the las couple of decades on the use of molecular markers for fingerprinting and diversity analyses but a qualitative change is arriving due to different ongoing sequencing works. In our case, about 10,000 SNPs have been recently developed.

Community resources, genomes and databases (Bombarely). Dr. Bombarely presented the current status of one of the avocado genome sequencing projects. Although several avocado sequencing projects have been developed in the last ten years, they have failed to build a publicly available effective resource for the community. Dr. Bombarely described the initiative developed for the Avocado Sequencing Consortium to produce a publicly available resource for the community. Their assembly is based in a combination of long read PacBio sequencing reads corrected by Illumina short reads and HiC to scaffold them into chromosomes.

Transcriptomic studies of avocado (Mwangi). Dr. Mwangi presented the transcriptome studies by the Avocado research program at the University of Pretoria. The avocado genome consortium was introduced followed by a brief on the genome annotation process. All avocado transcriptomic datasets available in the public domain were highlighted together with their utilisation in the avocado genome functional and structural annotation process.

Avocado transformation and micro-propagation (Pliego-Alfaro and Palomo-Rio). On one hand, Prof. Pliego talked about the micropropagation of avocado material selected for tolerance to *Rosellinia necatrix* discussing the following points: 1. Seedlings derived material can be routinely propapated in solid medium supplemented with 1mg/l benciladenine; 2. Material from adult trees was rejuvenated through pruning and propagated using the protocol of Barceló et al (1999) from Plant Cell Tissue and Organ Culture, 58:11-17. For other hand, Dr. Palomo presented the avocado genetic transformation protocol developed by our group (Palomo-Rios et al. 2012) using avocado somatic embryos is presented. This protocol has been used to analyse the possible use of fluorescent markers, gfp and DsRed, in avocado (Palomo-R√≠os et al. 2017). In addition, four different lines of avocado plants, transformed with pK7WG2-NPR1 plasmid containing the Atnpr1 gene involved in SAR regulation, have been generated. Plants are currently being multiplied to evaluate their response to white root rot.

Ideas for community based projects (Bombarely). Dr. Bombarely closed the session proposing different genomic-based projects that it could developed by the community based in the current challenges. Specifically, he presented the following ideas: 1- Study about how the phenotypic diversity rise on clonal propagated crops using the Hass avocado type as model; 2- Development of a genomic atlas of the avocado variation through the re-sequencing and analysis of 100 avocado varieties; 3- Development of more efficient phenotyping tools that can be shared by the whole community; 4- Modelling of the impact of climate change on avocado production.

Session 7. Meeting the Challenges of the Future

This session had no formal presentations. Rather the audience was divided into 10 groups and each group was assigned a specific question which was formulated following an attendee survey on the perception of issues facing the world avocado industry. The session chairs were: Mary Lu

Arpaia (University of California, USA), Tim Spann (California Avocado Commission, USA), and Zelda van Rooyen (Westfalia Fruit, South Africa).

This session was designed to run as a workshop in order to force the meeting participant to "Brainstorm". The Brainstorming participants were given two days to submit their response to these 2 questions:

a) The top three challenges facing avocado research today; and
b) the top three perceived challenges facing the avocado industry.

Results of the survey were summarized by grouping the various items into the specialist fields categorized for meeting participants:

- Plant Improvement and Genomics
- Productivity and Crop Management
- Quality, Postharvest and Food Safety
- Pests and Diseases
- Genetic Resources
- Profitability and Economic Analysis
- Propagation

At the beginning of the session one of the session chairs (Tim Spann) summarized the results of the survey (Figure 1 and Figure 2) and the meeting participants were then divided into groups and asked to come up with solutions to the "challenges posed" that addressed topics suggested in the top 3 categories. The various groups were purposefully comprised of members whose area of research expertise was not related to the category field they were assigned to. This was done to try and get fresh ideas/solutions to described problems.

Within the top 3 groups, there were several subcategories as listed below. These were used as the basis of each discussion group. Tables 1 – 3 at the end of the report provides the actual comments received by the respondents to the survey.

Plant Improvement and Genetic Resources
- Varietal diversification
- Rootstocks
- Genetic tools
- Genomics
- Climate Adaptation

Productivity and Crop Management
- Water availability, quality and cost
- Alternate bearing and stable production
- Precision agriculture

Quality, Postharvest and Food Safety
- Food safety
- Quality to the consumer

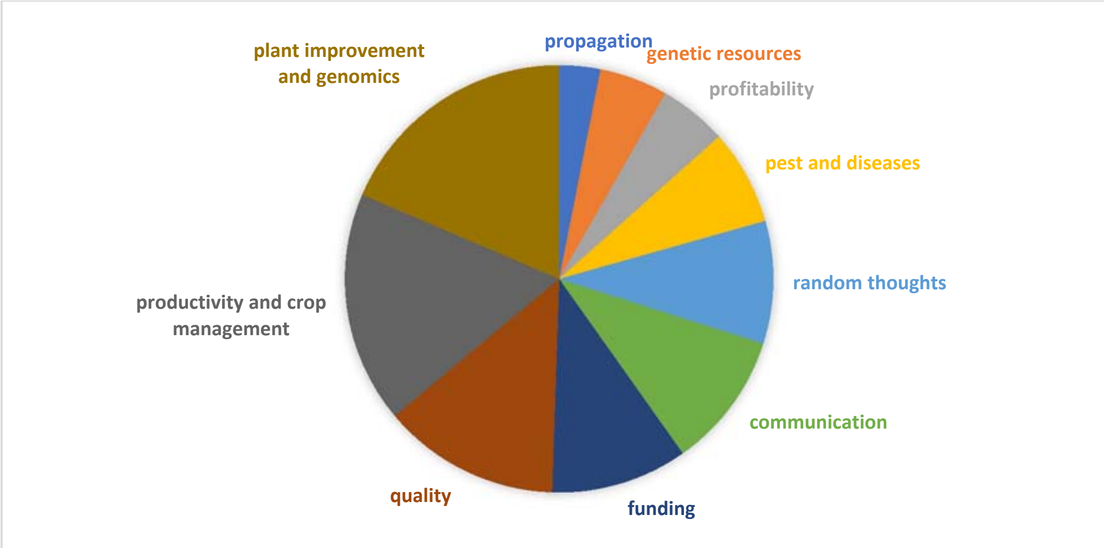


Figure 1. Summary of voluntary poll taken on problems facing both the avocado industry, as well as any research related to avocado.

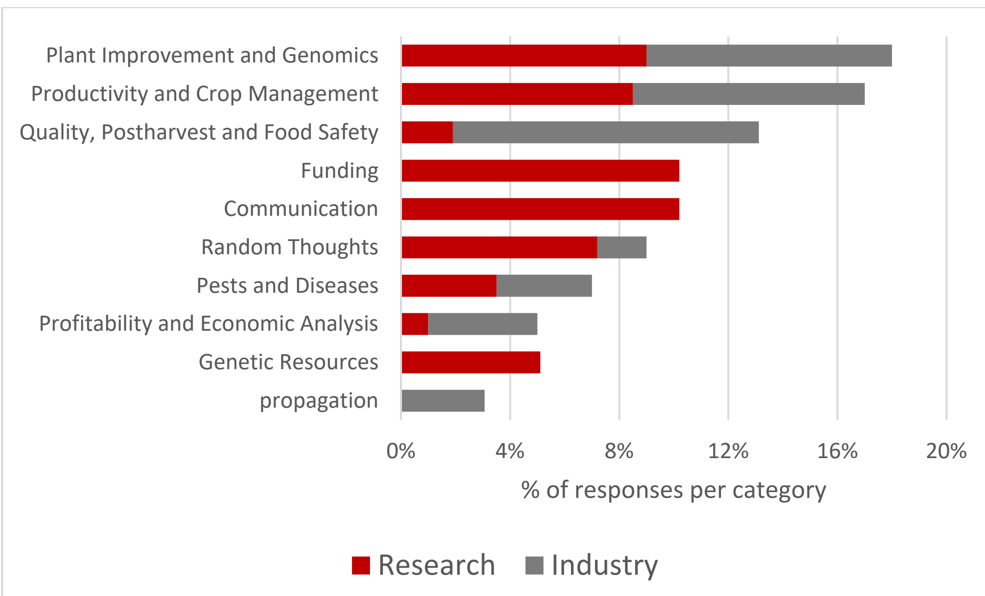


Figure 2. Summary of the number of responses per category differentiating between research and industry concerns.

Group Reports

Group 1. Varietal diversification

Solutions offered: Find a better 'Hass' vs find a "different avocado". The industry needs to start preparing for climatic change and decreasing risk exposure as mono cultures are at high risk for attack by new pests and diseases. Educate and/or increase awareness of what new cultivars could offer the industry and hopefully new funding bodies. Re-evaluate genetic resources –

introduce more wild types. Target specific genes/behaviour. Could breeding be “sped up” using markers?

Group 2. Genomics:

Two questions were asked: - 1) Why? and 2) How? The groups answers were as follows:

1) Breeding speed, cultivar identity and link to others. Old production areas vs new areas – do the cultivars behave differently.
2) Communicate value of genome to growers. What is needed form researchers? What can Block-chain offer e.g. coordination of data, collection. New approach to data analysis and manipulation.

Group 3. Rootstocks:

The discussion group indicated that the speed of production/identification of new rootstock material was a challenge. The group felt that the following items need to be addressed.

- Markers to be developed for phenotypes, and chemical “defence”
- Tissue culture
- Key factors – *Phytophthora cinnamomi* , Salt, Stress, *Rosellinia*, Fruit quality.
- Encourage genetic diversity, community database.
- Which rootstock and cultivar are the best combination.
- Micro-grafting to increase the speed to producing a disease free scion.
- IP Process
- Dwarf – either through genes or silencing “vigor” to simulate a plant growth regulator (PGR) action.
- Priming rootstock for epigenetic change?

Group 4: Breeding Tools

It was felt that this should be approached via Global Communities. For example Super Trees should be handed over to relevant molecular scientists. Genetic markers need to be identified, e.g. Rosellinia an Pc tolerance. The questions remain as to how to transform avocado plant material. RNA interf – “Bioclay”. We want to avoid situations that could lose certain resources – e.g. ASBVd. Genetic modification with the aim of getting “Super Beneficials” was also an option e.g. to identify Trichoderma’s that would be beneficial and would be more acceptable that genetically modifying the crop itself.

Group 5. Climate Adaptation

In South Africa late frosts impact flowering and early frosts affect the fruit already hanging on the tree (pre-harvest). The mode of action of the climate affecting the timing of flower induction. Various different cultivars have different ranges of temperature tolerances and signals. Thought that more work is needed to evaluate various fruiting scions and rootstocks separately and/or the combinations of these two factors. Suggested that mapping the origins of genetic traits would be useful.

Group 6. Alternate Bearing

Several representatives provided the alternate bearing cycles from their respective countries. Israel reports yields of 20-22 tons/hectare vs 8 t/ha and New Zealand reports yields of 8 t/ha vs 0t/ha. Alternate bearing is said to be cultivar specific with 'Hass' being more prone.

Suggestions for modulating alternate bearing include the following:

Decreasing alternate bearing – (high) nitrogen concentration after fruit set was reported as a risk – resulting in a second fruit drop.

Flower thinning was suggested (but not for 'Lamb Hass').

Pruning – with stumping said to result in an increased vegetative state, and thus cutting a maximum of 30% of the canopy was suggested. Israel's recommendation is to cut a maximum of four branches per tree. Further Israel would girdle a branch in one year and then the same branch would be cut out in year two. Spiral girdling was thought to be less harmful. The timing of pruning after flower commitment being critical. Early resulting growth and late pruning not normally having the desired response.

Nutrition – Winter the idea was to increase the carbohydrate status of the tree post season (harvest?). The cold winter (freezing) temperatures to be mitigated by using smudge pots and overhead sprinklers.

Was suggested that fruit are not hung too late. Water shoots to be removed. Delay flowering. Ensure good tree health. Minimize over-shadowing as this decreases the crop. Evaluate high density plantings (?) – the idea being that HDP results in big crops with less alternate bearing (provided no overshadowing).

Group 7: Water Availability and cost

With the increasing cost of water it was predicted that the grower would be forced to charge more for his produce. Luckily it was pointed out that avocados are not thought to be a "thirsty" crop. However, it would still be necessary to secure sufficient water and for this some growers would need to consider desalinization and reverse-osmosis sources. The quality of water was further highlighted as important as the presence and heavy metals and/or Listeria were a real concern. Thus the quality of water going into orchards would need to be tested, as well as monitoring the quality of water leaving an orchard. With respect to quantifying the need of orchards and specific trees it was suggested that perhaps thermal imaging (NDVI) could be used to identify individual tree stress areas in an orchard to improve management. However, the cost of micro management to a "per tree" base was questioned.

There was a suggestion that perhaps in future specific fruiting scions and rootstocks would need to be identified that could tolerate specific conditions – example salinity tolerant rootstocks, and drought tolerant cultivars. If the genetic material didn't exist it was hoped that in future tolerant genes could be introduced (e.g. CRISPER technology).

The (more) extensive use of shade nets over orchards was also thought to require further investigation to quantify any real water savings (if any).

Group 8: Precision Agriculture

Digital/Remote sensing: GIS, drones, mapping sites. In Chile national "information is available on various useful agricultural data like temperatures for example. It was felt that we need more access to data collection tools.

Micro-biomes: Soil mapping needed to managed smaller "pockets" of conditions on farms.

Robotics: Auto soil sample sample collection, and spraying of orchards.

Data: Must be available to growers – e.g. in the form of cellphone applications which could also, for example, send out temperature alerts. Data on servers was felt to be less useful/helpful. Also growers would benefit from being able to track data specific to their own areas/regions.

Lidar: for crop estimates would be useful, but require some calibration in the field.

Data management: to enable "mining" of past and present data. Scale of collection needs to be specified/improved. In Chile (seedling) it was mentioned that data is not precise enough (i.e. decimal points needed).

Automated data collection: Good if used, but must answer a "question".

In summary precision agriculture would be costly and allow for micromanagement – but it was uncertain how "sustainable" this kind of management/precision would be.

Group 9. Fruit quality

1) Operator error – grower, shipper and consumer. Need to standardize the post-harvest protocols (SOPs). Need to monitor points from farm to fork – use technology to ensure standards are adhered to. Use near infrared, for example to monitor TSS. Learn from previous postharvest treatments used. Use markers to identify fruit origin and then use gene expression to confirm correct handling.
2) Endogenous – What genes are expressed postharvest, even when 100/100 correct shipping is protocol followed it is still possible to get poor quality. Finally, how to identify good quality fruit. Taste – focus on cultivars that have consistent good postharvest quality (shipping attributes).

Group 10: Food Safety

Different information available. MRL's tested = old way of testing "safety". Now we need to understand the level at which residues are "relevant" to the consumer. Tests need to be standardized to use an international level – e.g. ISO method for PGR's and PO_3. In terms of traceability we need to implement standards. Evaluate the use of Block chain technology.

Communication: 1) Prepare clear scientific facts and communicate this to the consumer. Consider that "Technical people" are awkward with communicating so need help. 2) Use Working Groups to share information and to prepare for any "Outbreaks" so that there isn't Panic (especially on the side of the consumer).

GENERAL DISCUSSION ON ALL TOPICS

There is real concern about the possible decrease in the MRLs of phosphite residues in various markets (e.g. EU). USA were exempt and in 2016 the MRL level of 75ppm was extended. It was decided that perhaps toxicology studies should be conducted to determine whether phosphite was in fact harmful to animals (and at what levels). It was thought to be ironic that Coca cola is not described as being harmful considering its high phosphonate levels. Further Australia fruit are allowed an MRL of over 500ppm (compared to South Africa at 45ppm).

Canopy management on slopes vs flat land was thought to require "optimization" as protocols for management would be different.

In regard to precision agriculture: a suggestion was made to look into trellising. Fruit were to be counted and traced to be able to give feedback back to the grower. Individual tree tracking would allow for yield mapping and would be useful to orchard management. This would allow investigation of what was causing poor production in certain areas of the orchard – e.g. poor tree health or irrigation problems.

The meeting was asked if the "Brainstorm" exercise was helpful to identify challenges and agreed that it was. It was suggested that perhaps in future the exercise could be carried out at the beginning of the meeting (instead of the end). In addition, it was decided to track whether the problems (and solutions offered) made any differences to research/the industry between meetings- i.e. was any progress made.

Session 8. Tying the Loose Pieces Together – Planning for the Future

Co-Chairs: Jose Chaparro (University of Florida, USA), Nigel Wolstenholme (Retired, South Africa). Prof. Wolstenholme had prepared a summary of challenges facing avocado industry which is included below.

Introduction

These notes, in summary form under various headings, form the background for a presentation (together with Jose Chaparro of the University of Florida) to conclude "Avocado Brainstorming 2018" in Tzaneen, South Africa, 28th May – 1st June, 2018. My emphasis is on the "subtropical" and "highland tropical" avocado industries typified by Mexico, South Africa and Australasia, based mainly on the 'Hass' cultivar. Such environments are more humid and mesic (less stressful climatically and edaphically), and potential tree vigour is high.

Industries in more stressful, semi-arid Mediterranean climates, also based on 'Hass', have much in common, but also much that is different - including salinity, stress and hot, dry summers. Tree vigour is understandably lower, making high density plantings easier to manage.

A 10 to 12 year time span is chosen – "towards 2030". Previous talks by the author (Wolstenholme, 1988, 2001, 2013; Wolstenholme & Whiley, 1992, 1996, 1999) also explored this topic. The book "Avocado: Botany, Production and Uses", 2nd ed. edited by Schaffer, Wolstenholme & Whiley (2013) provides a more scientific background.

The World in 2030

Keeping the big picture in mind requires a vision of what sort of world we will inhabit in 2030. The "knowns", positive and negative, include: -

- Mind-boggling scientific advances in genomics (human and plant), technology in general, the basic core sciences including biology; robotics, medicine; artificial intelligence, transportation etc.
- Climate change, largely anthropogenic in spite of the denialists, is real and driven mainly by rising atmospheric concentrations of C02, and some other gasses including methane. Prospects for keeping the mean temperature rise below 2°C by 2050 are bleak. Greater weather extremes - heat, cold, drought, flood, hurricanes, windstorms etc. will mitigate any benefit from higher photosynthetic rate, and increase plant stress.
- Global problems of poverty, inequality and unemployment will fuel migration (legal and illegal) to first world countries. Africa's population is rising fastest, and will overtake those of China and India in the not too distant future. Africa, however, is a potential world food basket!
- Over-population also fuels unrest, poor governance, religious intolerance, and increasingly, terrorism – which has reached stable democracies. Dissatisfaction of lower middle class people has spawned populist leaders, nationalism, and threats to free trade. Nuclear war no longer seems unthinkable.
- The rise of China has created a sizeable new middle class, and *inter alia* created a huge new market for macadamia nuts, pecan nuts and hopefully by 2030 avocados. To date, however, the new status of avocado as a boom crop was mainly facilitated by the opening of the U.S.A. market.

By 2030, we can reasonably expect the middle classes of India, Japan and some other Asian markets to enjoy avocados. Such countries are less likely than the EU and U.S.A. to allow supermarket dictatorship to make it too difficult for their own growers to compete (unrealistic produce MRL's; high production costs; loss of "chemicals"). Unsustainable pressure on the world's natural resources is already evident - we have exceeded Earth's carrying capacity by a substantial margin. What will the situation be by 2030? Can science and technology mitigate a worst case scenario?

Trends in Agriculture and Horticulture

- **Commodities vs products**. Commodities such as wool, steel and fresh fruit are vulnerable to over-production, static or declining real prices, and a cost-price squeeze. The South African avocado export industry was in this position some 20 years back, when the traditional main European markets were saturated by ca. 650 000 cartons (net 4kg) per week from March through September. This forced survival changes, including mergers, growth by acquisitions, and partnerships, plus new value added products to differentiate from the crowd. It also accelerated the search for new markets, with less dictatorial supermarket chains. For the last 5 to 10 years however, the wheel has turned full circle, with demand now far exceeding supply.
- **Changes in land ownership and operation**. The trend has been toward land lease, or contracting off-farm production to other growers or smallholders. Large estates have become more dominant, with advantages of economies of scale, greater efficiency, and reduction of risk, and the resources to expand into other countries.

- **Globalization, free trade and fickle consumers.** These have been the norm until recently. However, the new U.S.A. administration's "America first" policy is causing uncertainty. Will this unwelcome trend continue? Global fresh produce trade, and the freeing up of the U.S. market for avocado imports, have been largely responsible for the current boom in avocado production and export. Fortunately, there are other large potential markets to be developed. The fickle consumer is currently firmly on the avo bandwagon, not least for dietary value and healthy lifestyle. How long can we maintain this trend?
- **Sustainable farming and safer food trends**. These are well known to responsible growers, most of whom support the basic concepts and thereby commit themselves to the accompanying deluge of form-filling and bureaucratic red tape. This author has always advanced "integrated pest and disease management", and careful use of essential agricultural chemicals. He has been an academic teacher and researcher from 1960 until 1999. In the 1950's and 1960's orchard floor management encouraged cover cropping, and sometimes companion cropping in the non- bearing years. These practices then went out of fashion, for good economic reasons. Today orchard biodiversity is the new norm, in the interests also of soil health, encouragement of beneficial micro- and macrofauna and flora, and soil organic matter conservation and atmospheric carbon sequestration. These trends are sure to continue and must be encouraged. However, this author warns against some practitioners of pseudoscience and over-zealous and expensive programmes to micro-manage the extremely complex soil living component. It is disingenuous to reject modern technological advances and revert to "the old ways". Science has moved on since, for example, the Albrecht approach to soil analysis interpretation. He also regards "organic" farming as expensive, difficult, and pandering to an elite, affluent market, prepared to pay a premium price for scientifically dubious benefits.

The Big Picture Picture: EvoDevo of a Unique Tree Crop

Here I speculate and attempt a synopsis on the questions "what are we dealing with?"; what is remarkable about the avocado tree and its fruit?; how does its evolutionary history impact on the current stage of domestication? In short, we have a remarkable and in many respects a unique evergreen fruit tree, which after a slow start (the fruit has an "acquired taste") is currently experiencing unprecedented popularity and explosive growth.

The avocado fruit is unusual in several respects:

- The mature flesh, especially of cultivars of the Mexican and Guatemalan races and their hybrids, is rich in oil rather than sugars (especially the very sweet fructose, a reward for dispersal agents). Oil percentage (FM basis) varies from 8% to nearly 30% (in late harvested fruits), and around 5% in true West Indian race cultivars. Janzen & Martin (1982) suggested that now extinct megaherbivores with high energy needs dispersed avocados.

- To make 1g of oil is over twice "carbon" (energy) expensive as 1g of sugar. Oily fruits must therefore be very strong "sinks" during development, and yields are low as compared to fruit sugar-accumulating fruit trees. True non-fleshy nuts, with ca 70% oil are logically much smaller and yields much lower. The olive fruit (fleshy like the avocado) has about 20-30% oil in a very small fruit, with a good yield being about 5 t/ha. It is not surprising therefore that avocado trees with large, oil-rich fruits are comparatively low yielders.

- The fruit will not soften on the tree, while firmly attached.
- The harvested fruit has a very high respiration rate (especially 'Maluma'cultivar), requiring prompt cold storage to slow down flesh softening.
- The main translocation sugars in the phloem are C7 sugars, especially perseitol and mannoheptulose (rather than the C6 sugar sucrose). Developing fruits are also unusually high in C7 sugars, which decline in maturing fruits. The probable role of C7 sugars has recently been reviewed by Cowan (2017).

To help understand the avocado tree, I refer to the introductory chapter (Schaffer, Wolstenholme & Whiley, 2013), in the scientific treatise "The Avocado: Botany, Production and Uses", 2nd ed., edited by Schaffer et *al. (*2013b). Presumed adaptive strategies of avocado trees are discussed on page 5, and in Wolstenholme & Whiley (1999).

It is first necessary to note that in evolutionary terms the avocado (*Persea americana*) is a primitive plant. It has been placed in the magnoliid clade, a basal angiosperm lineage near the origin of the flowering plants (Chanderbali *et al.,* 2008), and therefore fortuitously for us has attracted the attention of prominent taxonomic and "evodevo" scientists.

Adaptive Strategies of the Avocado Tree (Schaffer *et al.,* 2012a)

(i) **Vegetative adaptive strategies**

- Tree architecture (Rauh architectural model of Halle *et al.,* 1978), facilitates competition with montane climax forest trees. Reiterative regrowth potential makes possible a rapid and very plastic response to orchard pruning.
- Vegetative growth flushes are episodic, typically with two flushes in the humid subtropics, three in semi-arid winter rainfall climates, up to four in Mexican tropical highlands, and several more in tropical lowland bearing trees.
- In full sunlight in mesic environments, high net photosynthesis rates are possible, resulting in vigorous peripheral growth. In native forests, most vegetative growth is vertical until an emergent canopy is formed.
- Leaves are short-lived (typically 10 – 12 months) and also fairly shade-tolerant (at the expense of flowering and fruiting intensity). Abscissed leaves from healthy trees leave a thick mulch permitting feeder root proliferation.
- The fibrous feeder roots are shallow and also proliterate in well aerated topsoil (high oxygen requirement for root health).
- Feeder roots help to intercept mineralized nutrients from soil organic matter, helping with recycling and hoarding in the tree of often scarce nutrients. Tree growth therefore does not make heavy demands on the soil, and fruiting is comparatively "mineral cheap", depending of course on yield.

(ii) **Reproductive strategies**

- Flowering has a high light requirement and occurs on well-lit peripheral shoots of sufficient age. In native forests, irregular "mast" fruiting occurs (every several years).
- Flowering is intense, especially in "on crop" seasons, and also prolonged, leading to significant differences in fruit age (but, more synchronized in colder climates).
- This primitive heavy flowering can make seemingly wasteful water and nutrient demands on tree resources at a critical time, especially in the humid subtropics.
- Honeybees are not present in native forests. A range of small insects pollinate cohorts of flowers opening successively on days with suitable weather.
- Synchronous alternating dichogamy favours obligate out breeding, but fail-safe self-pollination is common.
- Massive abscission of most flowers and fruitlets occurs, coincident with and after the spring growth flush, reducing initial fruit set to a very low percentage of highly selected fruitlets.
- A final opportunity, and second fruit drop to adjust crop load occurs after the summer growth flush. This is the evolved strategy to prevent catastrophic over-bearing in this energy-demanding fruit (carbon starvation).
- Crop size is positively correlated with flowering intensity in healthy trees. "On" and "off" (alternate) and irregular crop seasons are normal, but the intensity of alternation on can be reduced in well-managed orchards.
- The avocado fruit is strongly dependent on its large seed, and especially the thick, vascularised pachychalazal seed coat, until horticultural maturity. The seed coat at this stage thins, darkens and dies. Very early premature seed coat death can result in small, seedless "cukes", or at a later stage in distinctly smaller fruits and seed size (phenological small fruit problem).
- Fruit softening in "subtropical" cultivars occurs only after harvest (physical separation from the tree) or falling to the ground in the native habitat – a presumed adaptation to extinct megaherbivore dispersal.

Past, Present and Future Avocado Characteristics

Evolutionary adaptations, and extinction of its major megafaunal dispersers some 13000 years ago, still persist in avocado trees (Janzen & Martin, 1982). They have been somewhat modified by humans for at least 9000 years, and especially since vegetative propagation of selected chance seedlings, beginning about 110 years ago. These adaptations can be counter-productive in a modern orchard, especially in mesic invigorating environments. Barlow (2000) includes the avocado as a "ghost of evolution", anachronistic and over-endowed in the modern world.

Some selection, by Native Americans, for larger fruits with smaller seeds and improved flavour undoubtedly occurred, but only since the onset of vegetative propagation could the improved characteristics be preserved. The first major standard of excellence for subtropical avocados was the Mexican X Guatemalan race hybrid 'Fuerte'. Hundreds of cultivars have been selected from chance seedlings or mutations, but only 'Fuerte'and subsequently 'Hass' have stood the test of time. There are also several promising 'Hass'-like selections.

We sum up the purported characteristics of the naturally evolved (**ancient**) avocado, appreciated by meso-Americans from about 9000 years ago:- Large tree size; delayed bearing until emergence from a montane cloud-forest canopy (i.e. a long juvenile period), flowering very profuse but irregular, due to slow carbohydrate reserve build-up (large tree size, small sunlit canopy, high maintenance costs); thus irregular "mast" fruiting; low *average* yield; small fruits of poor quality and relatively large seeds; and no evolved resistance to today's major disease, *Phytophthora cinnamomi* root rot (PRR) which had not as yet reached central America.

Today we have progressed to medium-sized grafted trees with reasonable precocity, profuse and annual flowering, average yield per ha usually in the 10-20t/ha range; a target *average* yield (at least over 4-5 seasons for at least a 5-10 ha block) of 30+ t/ha (seldom attained); moderate seed size; and at least moderate PRR tolerance in selected clonal rootstocks.

So, what of the fully-domesticated avocado of the **Future?** First prize would be a small (2-3m) tree (semi-dwarfed) on a semi-dwarfed rootstock, fully resistant to soil diseases, and conducive to high yield of the scion, plus outstanding fruit quality. High precocity is essential; hopefully flowering intensity would be reduced without compromising average yield. Fruiting would be regular, and average yield/ha would exceed 30t/ha. Fruit taste could be excellent, again hopefully with a lower oil content and a small seed, without compromising yield or fruit size. To achieve these goals, a range of elite cultivars and rootstocks for different growing conditions would be needed.

Main Current Technological Problems

Low average yield. The oil/energy-rich fruit flesh, plus the large nutrient and mineral-rich seed are prime causes of low average yield (Wolstenholme & Whiley, 1999). Collectively they are a powerful sink during the main fruit growth phase, diverting (hijacking) "carbon", metabolites and mobile minerals away from the "shoot" and root components. This can influence the timing of foliar sprays or phosphonate stem injections against PRR (and sufficient boron reaching the relatively weak root sink?).

Potential yield is strongly affected by cultivar, rootstock, climate and soil conditions, PRR and other diseases and pests. At one extreme are the mesic, humid summer rainfall subtropics and moist highland tropics with high quality soils. A good *average* yield of a large mature block over 4 or 5 seasons is 12-15 t/ha, with top growers averaging 20-25 t/ha. A breakeven (profitable) yield would be around 10 t/ha. The more stressful semi-arid usually coastal winter rainfall areas with more marginal soils have corresponding average yields of 8-12 t/ha and 15-20 t/ha for 'Hass'.

Alternate or irregular bearing, with distinct "on" and "off" bearing seasons is often cited as a concern for growers and marketers. The problem is worse in cool growing areas where 'Hass' fruit requires more than one growing season to mature. Late hanging will also accentuate alternate bearing, although less so if half the crop is harvested earlier. Causes are complex and multiple, but horticulturally, "off" seasons are due to less intense flowering and fewer fruiting sites (peripheral shoots), plus lower storage carbohydrate reserves after a heavy crop. Pruning, bioregulant foliar sprays, and adjusted nitrogen fertilization are the main management tools (Salazar-Garcia *et al.,* 2012).

<u>Phytophthora root rot</u> (PRR) remains a problem in high risk situations (high rainfall, and poorly drained/aerated soils). Phosphonates have been used (where registered) since the 1970's, firstly through carefully timed stem injections, plus foliar sprays more recently. They are combined with other management practices promoting root health (e.g. the "Pegg wheel" integrated management concept, which includes PRR tolerant clonal rootstocks such as 'Duke 7', 'Dusa', 'Bounty', 'Velvick', and others in the pipeline (Pegg, 2010). It is currently of great concern that phosphonate MRL's have been set at 50 mg/l in EU markets, or much lower in some German supermarkets. These are unrealistically low for high risk PRR countries, and loss of phosphonates would be a major setback in high risk PRR growing areas.

<u>Too few elite cultivars</u>. 'Hass' is overwhelmingly the cultivar of choice at present, both for local and export markets. This is, in the long term, a cause for concern. Established fruit industries typically rely on a least five elite, well-known cultivars. Avocado cultivars are either purple/black or green-skinned, vary in size, shape and time of maturity, so there is the desired genetic variability. However, there are no other fully tested and widely accepted cultivars for the subtropics, although there are several promising candidates such as 'Hass' lookalikes ('Gem', 'Lamb Hass', 'Carmen' and 'Maluma', *inter alia*). Most new cultivars arise from chance seedlings or mutations, and breeding programmes are difficult, time-consuming, costly, and under threat. The genomic revolution should surely improve the situation in the next 10-12 years.

<u>Too few elite rootstocks</u>. The world avocado industry still relies heavily on seedling rootstocks – often with little experimental evidence. A notable exception is Whiley's detailed study in Australia, which found that the best selected seedling rootstocks e.g 'Velvick' were the equal of clonals, from an overall tree performance point of view (Whiley, & Whiley, 2011). Certain Mexican seedling rootstocks such as 'Zutano' and 'Topa Topa' have poor PRR tolerance and may cause scion overgrowth. In South Africa before the use of clonal 'Duke 7', 'Edranol' seedling stocks proved very susceptible to PRR.

At present, unprecedented demand for nursery trees has seen greater use of seedling stocks, of mainly Guatemalan, hybrid and even the West Indian race. Their comparatively low cost is an attraction, especially for high density plantings. It is inevitable that some will not stand the test of time, being used without research backup. Orchard uniformity may suffer, but rootstock genetic diversity may be beneficial in the event of new diseases. Freedom from sunblotch viroid is non-negotiable.

In South Africa, clonal 'Dusa' and 'Bounty' are currently the most popular, with a few new selections in the pipeline. Continued rootstock testing and selection is vital, as turn-around times are long, and new diseases threaten.

<u>Best practice orchard management.</u> Wide variation exists between different growing environments in tree spacing, training, pruning, tree size and shape, and canopy management. Tree vigour is greater in mesic clilmates and good soils, necessitating wider espacement and tree populations of around 300 to 400 trees per ha (depending on cultivar). More stressful climates and soils result in less vigorous trees, and permit closer spacings of 800 to over 1000 trees per ha for new orchards – sometimes considerably more. The jury is out as to whether such tree densities can be economically justified and maintained. Dedicated training and pruning, and use of growth retardants, e.g. uniconazole, is essential, and even girdling has been used (Whiley e*t al.,* 2013).

These plantings have occurred with little long-term research backup, and with much trial and error and learning on the job. The same applies to pruning and some aspects of managing the vegetative: reproductive balance to best advantage.

Research Priorities

The four-yearly World Avocado Congresses are a sounding board for the health of the world avocado industries. All serious growing countries sponsor and fund research on important practical problems, although it is true that there is often a dearth of experienced researchers and adequate funding. What is encouraging is that basic "blue sky" researches at prestigious research institutes are increasingly choosing avocado as an interesting model crop, e.g. for genetic engineering, genome mapping and sequencing, and basic biochemical, physiological and taxonomic studies, as well as plant pathology and entomology.

Final Thoughts and Conclusions

A SWOT analysis (strengths, weaknesses, opportunities and threats) on the world (or an individual country) avocado industry would find much to admire, ponder, but also be concerned about. The breakneck speed of the current industry growth is both encouraging and frightening, for there is much that could go wrong. The world political and economic scene is fraught with danger. No food commodity industry can grow so rapidly for a long time without a serious implosion. Overproduction is the biggest threat to any commodity based industry. Inevitably mistakes will be made, standards will suffer, prices will decline and there will ultimately be a shakeout. Inefficient growers will go to the wall; efficient ones will prosper in the next cycle. This may be an unpopular viewpoint, but I have seen too many commodity boom/bust cycles not to sound a warning. In the interim, enjoy the ride but invest profits wisely.

Also, under the **threats** column, global climate change appears to be facilitating the spread of new, very worrying invasive pests and diseases. These include the Ambrosia beetle species and their fungal symbionts threatening avocado trees in Florida, California, and Israel, and gaining a foothold in other countries. Also, the spread of other root rot diseases, and potentially serious insect pests such as fruit flies. It is true that there is high genetic variability in wild *Persea* species, for use in imparting tolerance and resistance to new diseases in cultivar and rootstock selection and breeding. Central American countries where these species are native have a responsibility to conserve, protect, study and utilize these potential future industry saviours. Breeding programmes must continue, and developed countries also have a duty to assist with new technology, gene banks, expertise, and not least, assured funding.

To end on an optimistic note, the collegiality of contacts, ideas at national and international congresses, symposia, workshops and brainstorming get-togethers, and the formation of a World Avocado Forum are truly inspiring, and an example to other fruit industries. I also include the free information website provided by the Hofshi Foundation in California. It has been a pleasure to have had an over 40 year association with such a progressive horticultural industry.

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Addendum to Summary Reports.

Session 7. Meeting the Challenges of the Future. Detailed input from Avocado Brainstorming participants on challenges facing the international avocado industry.

Table 1. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Plant Improvement and Genetic Resources (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue) or crossover (green)).

Varietal Diversification	Genomics	Rootstocks	Breeding Tools	Climate Adaptation
Cultivar diversification	A genome would be swell, like an assembled annotated one.	Dwarf rootstocks, water stress, tolerant rootstocks	How do we speed up breeding programs?	Proactively picking new growing regions and cultivars for a changing climate
Hass "blight" threatens world industry - lack of diversity	Genome availability	Improved rootstocks	Salinity tolerance	Growing avocados in cool climates
Moving on from 'Hass', finding new added value cultivars	Genome sequence for various avocado traits to facilitate breeding more "efficient" avocados plus help understand and solve other issues	Dwarf rootstocks		
New scion varieties to expand consumer choice	Genome sequences with good annotation			
Need more choice: mini avocados, different looks, different flavors	Open sources for genomes resources (sharing information)			
Get new varieties that improve Hass production conditions reducing the amount of inputs.				

Table 2. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Quality, Postharvest and Fruit Quality (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue) or crossover (green)).

Alternate bearing and stable production	**Water availability, quality and cost**	**Precision agriculture**
Increasing and stabilizing crop yield	Water management in avocados, understanding water relations and spatial variability in orchards	How to harness new digital/remote sensing image analysis tools to answer important biological questions: need collaboration with data scientists
How do we work on flower quality when only 0.3% set fruit?	To reduce water consumption in irrigated orchards	Considering different production conditions set common grounds for integrated research, that can be funded by various players form Those different conditions.
High variablity in fruit, trees, orchards and management	Water cost/quality	
Canopy Management for optimal production; e.g. tree spacing, pruning method, optimal tree architecture	Securing good quality water	
Increasing and stabilizing crop yield		
Sustainable production		
Irregular bearing		
Consistent high productivity		
Management of trees to maximize yields consistently and sustainably		
Less alternate bearing		
Sustainable management alternatives to allow high production		

Table 3. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Productivity and Crop Management (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue)).

Quality to the consumer	**Food Safety**
Fruit quality all the way to the consumer's home	Fruit contamination with PGR, Phosphonate etc?
Confusion of country of origin - too many countries with inconsistent quality	Capacity to deal with disease without causing public panic (eg Listeria contamination) and independent of farmer pride (eg laurel wilt dump and burn to prevent spread)
Delivering quality to the consumer	Coordinating messages and policy around nutritional value and food safety
How to get avocados of the best quality to market	Regulations
How to maintain value/premium?	How and when do postharvest pathogens infect avocado fruit?
How to guarantee quality at supermarket?	What are heavy metals, fungicide, herbicide residues within flesh of fruit at market?
Quality fruit - postharvest issues	

Avocado Brainstorming 2018

Towards a Sustainable Future

Poster Abstract Titles

Avocado Brainstorming 2018

28 May – 1 June 2018

Poster Abstracts

Investigating soilborne nectriaceous fungi impacting avocado tree establishment in Australia (4457)
Louisa E Parkinson, Roger G Shivas , Elizabeth K Dann

Identification and characterization of polymorphic microsatellite markers to study *Phytophthora cinnamomi* populations
Juanita Engelbrecht, Tuan A. Duong, Noelani van den Berg

Manage Phytophthora Root Rot
Newett, S., Rigden, P., Dann, E. and Thomas, G.

In silico identification of polygalacturonases in *Phytophthora cinnamomi* and polygalacturonase-inhibiting proteins in *Persea americana*
T.M. Miyambo, S.A. Prabhu, F. Joubert, N. van den Berg

Phenotypic variation and fungicide sensitivity of *Phytophthora cinnamomi* isolated from avocado in California
R. J. Belisle, B. McKee, W. Hao, M. L. Arpaia, J. E. Adaskaveg and P. Manosalva

Overcoming Verticillium wilt by identifying resilient avocado rootstocks
Amnon Haberman, Amnon Busatn, Eli Simenski, Leah Tsror and Arnon Dag

Significant *in vitro* antagonism of the laurel wilt pathogen by endophytic fungi from the xylem of avocado does not predict their ability to manage the disease
José Pérez-Martínez, Randy C. Ploetz, Joshua L. Konkol

Current status and management of laurel wilt
Ploetz, R.C., Carrillo, D. , Blanchette, R., Schaffer, B.A., Rollins, J., and Saucedo, J.R.

Effect of crop load on return bloom in New Zealand 'Hass' orchards
Helen Boldingh, Grant Thorp, Nick Gould, Andrew Barnett, Phillip West and Marisa Till

Influence of salinity on ion concentrations in avocado trees
Peggy A. Mauk, Rui Li, Brandon McKee, Mary Lu Arpaia and Patricia Manosalva

How much water do avocado orchards use?
NJ Taylor, E Mazhawu, A Clulow and MJ Savage

Avocado tree water use in New Zealand
Teruko Kaneko, Nick Gould, Phillip West, Mike Clearwater

Dealing with frost-associated damage in avocado cv. 'Hass'
Joshi N.C., Ratner K., Eidelman O., Yadav D., Isaac S., Irihimovitch V. and Charuvi D.

Comparative study of antioxidant activity as a possible mechanism for frost and freeze tolerance in 'Hass' and 'Ettinger' avocado cultivars
Weil Amir, Sofer-Arad Carmit, Bar-Noy Yael, Liran Oded and Rubinovich Lior

Temperature effects on fruitset
Nick Gould, Nicola Haisman, Phillip West and Marisa Till

Technologies and practices to reduce flesh bruising in avocado fruit
Joyce, D., Perkins, M., Mazhar, M., Coates, L., Ainsworth, N., and Hofman, P.

Evaluating high density planting for improving avocado yield and economics
Etaferahu Takele and Sonia I Rios

Avocado Brainstorming 2018

Towards a Sustainable Future

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Avocado Brainstorming 2018

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Fernando Pliego-Alfaro ferpliego@uma.es Universidad de Málaga, Dpto. Biología Vegetal, Campus de Teatinos, s/n, 29071 Málaga, , Spain *Plant Improvement and Genomics, Genetic resources, Propagation*	**Clara Pliego Prieto** mclara.pliego@juntadeandalucia.es IFAPA-Churriana Dpto. Cultivo de Tejidos y Biotecnologia. Cortijo de la Cruz s/n 29140, Málaga, Spain *Plant Improvement and Genomics, Genetic resources, Pest and Diseases*
Randy Ploetz kelly12@ufl.edu University of Florida, 18905 SW 280th Street, Homestead FL 33031 *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*	**Viresh Ramburan** vpramburan@biogold.co.za Biogold International, 19A Electron Avenue, Technopark, Stellenbosch, South Africa *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*
Wouter Retief wouter.r@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Productivity and Crop Management, Pest and Diseases, Quality, Postharvest and Food Safety*	**Manuel Rey** mrey@biogold-em.com Biogold EM, Edificio Marie Curie, Parque Tecnológico Cartuja 93, 41092, Sevilla-Spain *Plant Improvement and Genomics, Genetic Resources, Propagation*
Harley Smith Harley.Smith@csiro.au CSIRO Agriculture, Wine Grapes and Horticulture, Waite Campus, Adelaide, SA, Australia *Productivity and Crop Management, Genetic Resources, Plant Improvement and Genomics*	**Tim Spann** tspann@avocado.org California Avocado Commission, 12 Mauchly, Suite L, Irvine, CA 92656 USA *Productivity and Crop Management, Plant Improvement and Genomics, Pests and Diseases*
Juan Carlos Reyes reyesaleman@hotmail.com Universidad Autónoma del Estado de México. Carretera Tenancingo-Villa Guerrero Km 1.5, Tenancingo, Estado de México, C.P. 52400 *Plant Improvement and Genomics, Genetic Resources, Productivity and Crop Management*	**Lior Rubinovich** liorr@migal.org.il Northern R&D, Migal, Galilee Technology Center, P.O. Box 831, Kiryat-Shmona 11016, Israel. *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*

Wilna Stones wilnas@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850 RSA *Plant Improvement, Productivity and Crop Management, Propagation, Pests and Diseases*	**Eta Takele** ettakele@ucanr.edu University of California, Cooperative Extension, 21150 Box Springs Road, Moreno Valley, CA 92557, USA *Cost of Production and Profitability Analyses. Economic analyses of best management practices*
Nicky Taylor Nicolette.Taylor@up.ac.za University of Pretoria, Department of Plant and Soil Sciences, Private Bag X20, Hatfield, 0028 *Productivity and Crop Management, Plant Propagation, Plant Improvement and Genomics*	**Noelani van den Berg** noelani.vdberg@fabi.up.ac.za University or Pretoria, FABI, Dept. of Microbiology and Plant Pathology, Pretoria 0002, South Africa *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*
Zelda van Rooyen zeldavr@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850, South Africa *Plant Improvement, Productivity and Crop Management, Postharvest, Pests and Diseases, Genetic Resources*	**Burtie van Zyl** burtie@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Plant Improvement and Genomics, Productivity and Crop Management, Quality, Postharvest*
Francois Viljoen fviljoen963@gmail.com University of Pretoria, Plant Pathology Department, Pretoria *Postharvest and, Food Safety, Biomes*	**Phillip West** phillip.west@nzavocado.co.nz NZ Avocado, Tauranga, New Zealand *Genetic Resources, Plant Improvement and Genomics, Propagation, Productivity and Crop Management, Pests and Diseases, Quality, Postharvest and Food Safety*
B. Nigel Wolstenholme nigelw@telkomsa.net 30 Wavell Drive, Wembley, Pietermaritzburg, 3201, South Africa *Productivity and Crop Management, Pest and diseases, quality - postharvest and food safety*	**Taly Zviran** taliz@volcani.agri.gov.il Agricultural Research Organization - the Volcani Center, 68 HaMaccabim Road , P.O.B 15159 Rishon LeZion 7505101, Israel *Plant Improvement and Genomics, Productivity and Crop Management, Genetic Resources*

Avocado Brainstorming

Towards a sustainable future

28 May – 1 June, 2018
Tzaneen, South Africa

What is Avocado Brainstorming?

- A gathering of ~70 participants representing the world avocado research community
- Sponsored by the world avocado industry through generous sponsorships

Brief History

Previous meetings coincided with the World Avocado Congress

Avocado Brainstorming 1999 - Riverside, CA

Avocado Brainstorming 2003 - Ventura, CA




Avocado Brainstorming 2007 – Chile





Avocado Brainstorming 2011 – New Zealand

Avocado Brainstorming 2015 – Peru

What is Avocado Brainstorming?

Previous meetings coincided with the World Avocado Congress:

*Riverside, CA, USA – 1999**

*Ventura, CA, USA – 2003**

Panquehue, Chile – 2007**

Waiheke Island, New Zealand – 2011**

Ica, Peru – 2015**

* *With Grower participation*

** Research focused; similar to a Gordon Conference

What is Avocado Brainstorming?

South Africa differed to previous meetings:

- Held off-cycle to the World Avocado Congress; decided in 2015
- Broader range of sponsorship
- Participants paid a $US250 registration fee to offset costs

The purpose of Avocado Brainstorming

- The primary focus is to share KNOWLEDGE with the express purpose of stimulating discussion, communication and collaboration
- This will result in an overall improvement of productivity and quality of the fruit that is produced

The goals of Avocado Brainstorming

- Build research networks, new relationships and collaboration among international science groups
- Encourage upcoming young scientists and graduate students to make a career in avocado research
- Discuss and share ideas about specific industrywide topics of interest and concern

Avocado Brainstorming

Sponsorships (19)

Platinum Sponsors

CALIFORNIA AVOCADOS

HASS AVOCADO BOARD

westfalia fruit

Avocado Brainstorming 2018

Gold Sponsors

ZZ2 KE TZWA TZWEO

AGRICOM

allesbeste 90 Boerdery Kwekery Padstal 90 PASSIEVOLLE JARE

Avocado Brainstorming 2018

Silver Sponsors

costa fresh is our passion

DELROY ORCHARDS

JasperFarms

Simpson Farms

Southern Forest Avocados

west pemberton avocados

Avocado Brainstorming 2018

Silver Sponsors

BIOGOLD

HALLS
EST 1890

INDEX FRESH

SAAGA • SAAKV

THE FRUIT FARM GROUP

DataHarvest

Avocado Brainstorming 2018

Bronze Sponsors

ALVI'S DRIFT
FAMILY OWNED SINCE 1928
SOUTH AFRICA
WORCESTER

Guy Witney

Avocado Brainstorming 2018

Avocado Brainstorming

Who Attended?

Avocado Brainstorming 2015 - Overview

78 Participants from 11 Countries:

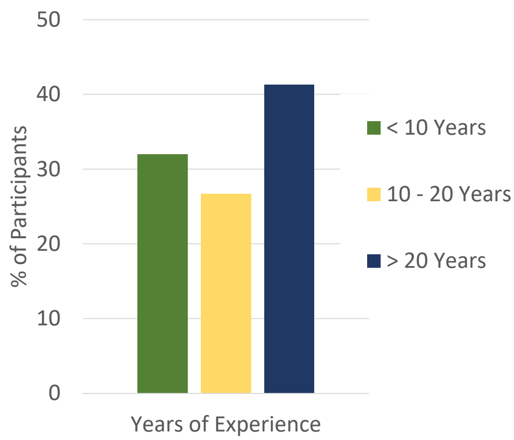
Australia, Brazil, Chile, Colombia, Israel, Mexico, New Zealand, Peru, South Africa, Spain, USA

Organizing Committee:

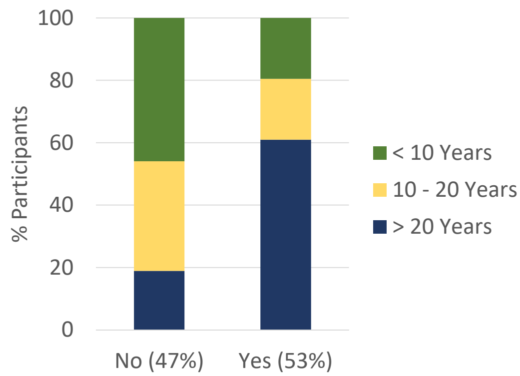
Mary Lu Arpaia (USA), Zelda Van Rooyen (South Africa), Alejandro Barrientos Priego (México), Francisco Mena (Chile), Randy Ploetz (USA), Iñaki Hormaza (Spain)

Avocado Brainstorming 2018 - Overview

Stage of Career

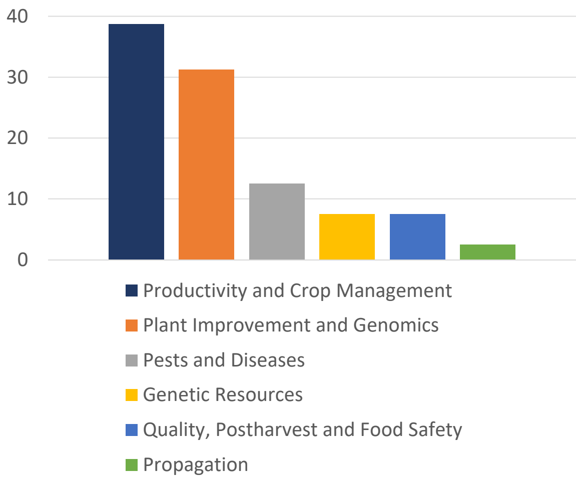


Previous Attendance and Experience

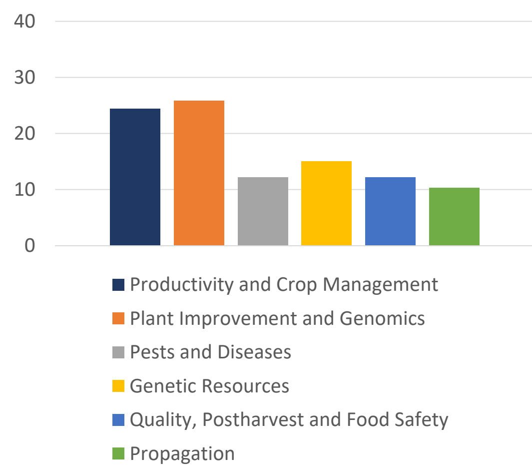


Avocado Brainstorming 2018 - Overview

Primary Research Interest



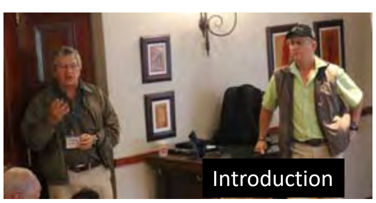
Ranking of Research Priorities



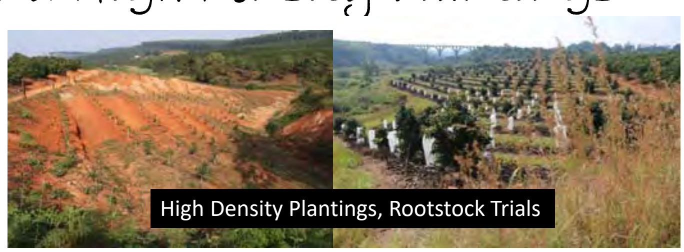
Avocado Brainstorming

The Meeting – Field Trips

Allesbeste Nursery and High Density Plantings



Introduction



High Density Plantings, Rootstock Trials

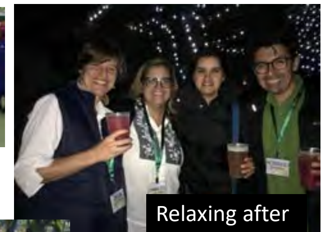
Maluma and tree training

Clonal Propagation

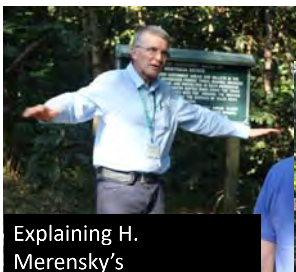
In the footsteps of Hans Merensky: the Westfalia avocado


Anticipating the Day


A warm African welcome


Relaxing after a long day


Rootstock and Variety Research


Explaining H. Merensky's conservation vision

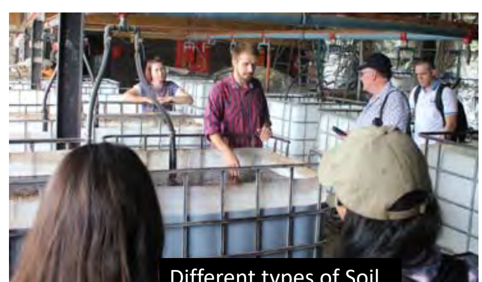

The original PO_3 trees – 45 years later


GEM under net

Nic Hume Net Trials; ZZ2 Composting and Biological Enhancement


Another net trial with multiple varieties

Composting operation



Different types of Soil Amendments

Avocado Brainstorming

The Meeting – Sessions

What was covered?

Providing for the Consumer: Health, Safety, Flavor	New Technology to Improve Avocado Production
Challenges to productivity: • Diseases • Optimizing yield by understanding the physiological events that regulate crop load and the return to bloom • Genetics, Genomic and Biotechnology	Where Theory Meets Practice Meeting the Challenges of the Future Tying the Loose Pieces Together – Planning for the Future

Meeting the challenges of the future

Mary Lu Arpaia (University of California, USA)
Tim Spann (California Avocado Commission, USA)
Zelda Van Rooyen (Westfalia Fruit, South Africa)

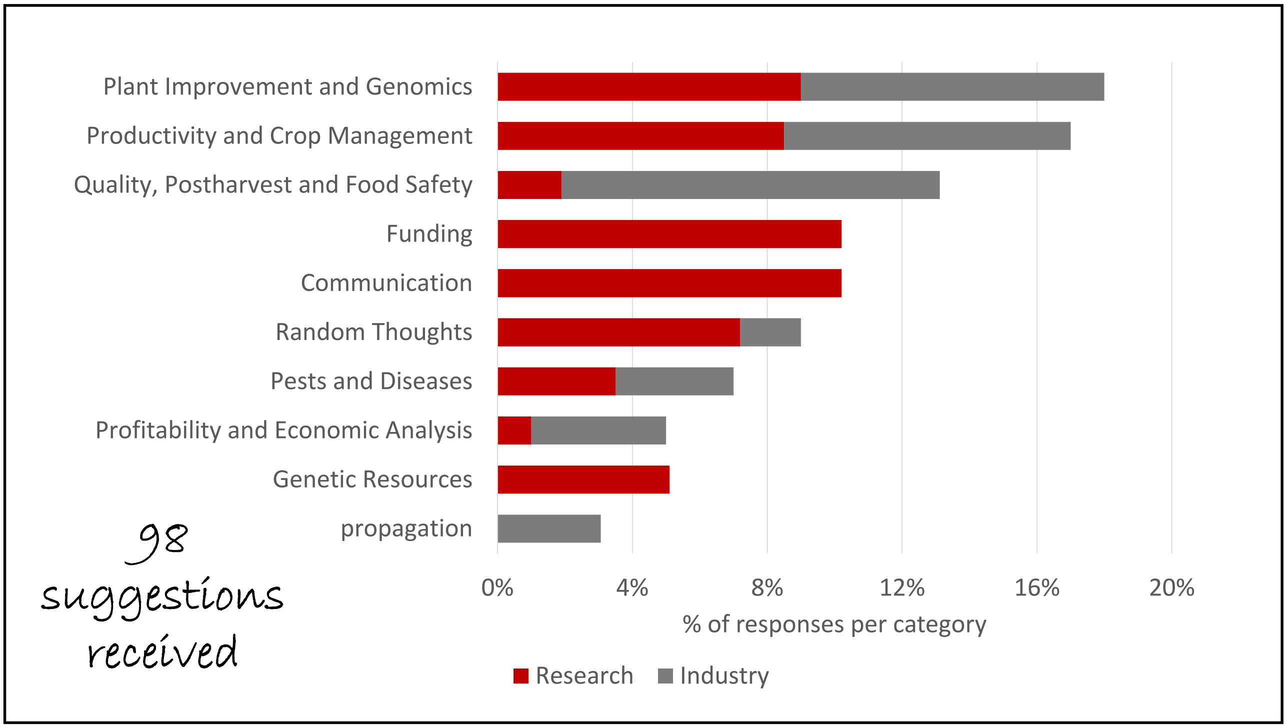
Session Overview

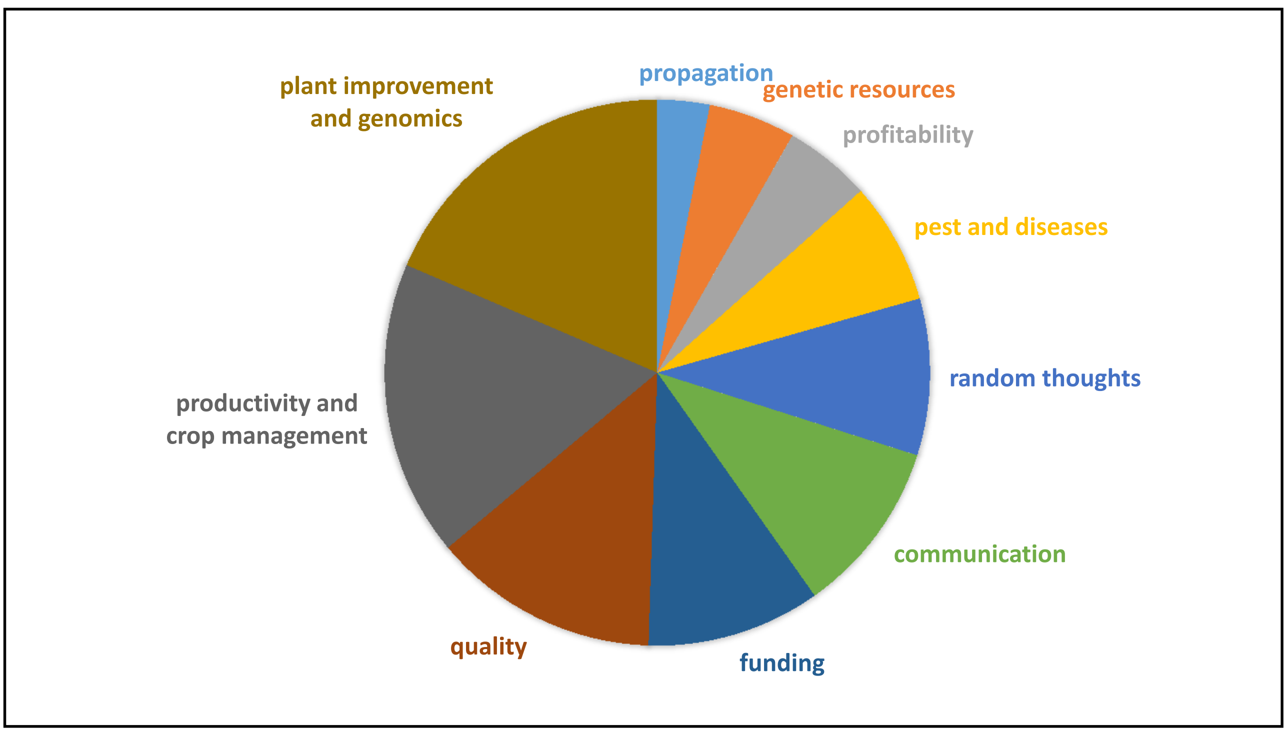
All participants were asked to provide answers to 2 questions:

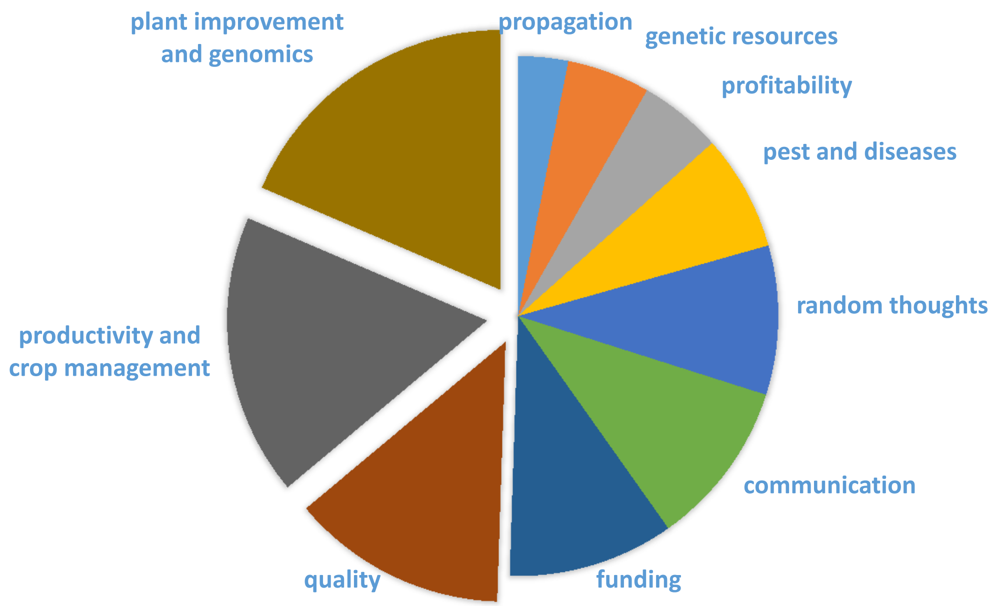
a) The top three challenges facing avocado research today; and

b) The top three perceived challenges facing the avocado industry

The collective answers were used to design an interactive workshop


Plant Improvement and Genomics
Productivity and Crop Management
Quality, Postharvest and Food Safety
Funding
Communication
Random Thoughts
Pests and Diseases
Profitability and Economic Analysis
Genetic Resources
propagation
0%
4%
8%
12%
16%
20%
% of responses per category
Research
Industry
98 suggestions received


plant improvement and genomics
propagation
genetic resources
profitability
pest and diseases
random thoughts
communication
funding
quality
productivity and crop management



Trends within categories

Plant Improvement and Genetic Resources
- Varietal diversification
- Rootstocks
- Genetic tools
- Genomics
- Climate Adaptation

Productivity and Crop Management
- Water availability, quality and cost
- Alternate bearing and stable production
- Precision agriculture

Quality, Postharvest and Food Safety
- Food safety
- Quality to the consumer

Group Reports – Plant Improvement and Genetics:

Group 1. Varietal Diversification

- Need to both a "better" Hass and perhaps a "different" avocado. Need to prepare for climate change and all that is associated with this
- Dip into our genetic resources (AND SAVE THEM)
- Improve our breeding methodology to deploy genomic tools

Group 2. Genomics

- Breeding speed, cultivar identity and performance
- We need to communicate value of genomic knowledge to grower community and apply new approaches to data analysis and utilization

Group Reports – Plant Improvement and Genetics:

Group 3. Rootstocks

- Improving and speeding up the propagation process
- Looking beyond disease tolerance to horticultural traits
- Improve and speed up selection through genetic markers

Group 4. Breeding tools

- Need for Global Communities to share information and push forward research
- Identify genetic markers

Group Reports – Plant Improvement and Genetics:

Group 5. Climate Adaptation

- Understanding how current varieties will adapt to changing climate
- Understanding how rootstocks will adapt to climate change
- Understanding the inherent genetic diversity of the avocado and taking advantage of this for the future

Group Reports – Productivity and Crop Management:

Group 6. Alternate Bearing

- Discussion of management tools that can help control alternate bearing such as flower thinning, pruning, nutrition
- Timing of harvest and influence on return bloom, understanding these mechanisms
- Can high density planting modulate alternate bearing?

Group 7. Water Availability and Cost

- How “thirsty” really is an avocado tree?
- Need to look at rootstocks and water use efficiency
- Need to tailor variety and rootstock to particular environments
- What is the future of shade nets and other technologies to reduce water use?

Group Reports – Productivity and Crop Management:

Group 8. Precision Agriculture

- Mixed discussion; some felt it would allow for micromanagement of fields but at what cost and sustainability
- New technology will allow researchers and growers tools to better understand the relationship of the individual tree, grove and region to environmental restraints/opportunities

Group Reports – Quality, Postharvest and Food Safety:

Group 9. Fruit Quality

- What is the interaction between "operator error" and "endogenous factors"?
- Need to monitor from farm to fork and understand how the fruit responds to changing conditions

Group 10. Food Safety

- Need to understand the level at which residues are "relevant' to the consumer
- Standardization of testing to international level
- Is there a potential for block chain technology in this?
- Communication is crucial in this area. Needs to be rapid, precise and show that different parties are working together to minimize Panic

New technologies to improve avocado production

Mark Buhl (DataHarvest, USA)
Nicky Taylor (University of Pretoria, South Africa)
Zander Ernst (Allesbeste, South Africa)
Elizabeth Dann (University of Queensland, Australia)
Jayeni Hiti Bandaralage (University of Queensland, Australia)
Neena Mitter (University of Queensland, Australia)

Session Overview

- Diverse new approaches for addressing avocado production and data management discussed
  - Big Data and its management
  - Remote Sensing
  - High efficiency orchards – is there a place for trellising?
  - Stem Tissue Culture to revolutionize avocado propagation
  - Use of RNAI technology in BioClay to control pest and diseases

The role of big data in agriculture?

- "When does Data become Information and when does Information become Knowledge and when does Knowledge become Wisdom?"
- How much information do growers need to make good decisions?
- Does it result in data collection followed by the research question?
- Do we collect "big data" just because we can or is there a specific research question in mind?

New technology to improve avocado production

WHAT IS BLOCKCHAIN?

BLOCKCHAIN IS A SOL
AN OCEAN OF DATA IN
COLLABORATIVE, ACTI

BLOCKCHAIN AND HOW IT APPLIES TO GLOBAL CONSORTIUM RESEARCH

Assetization

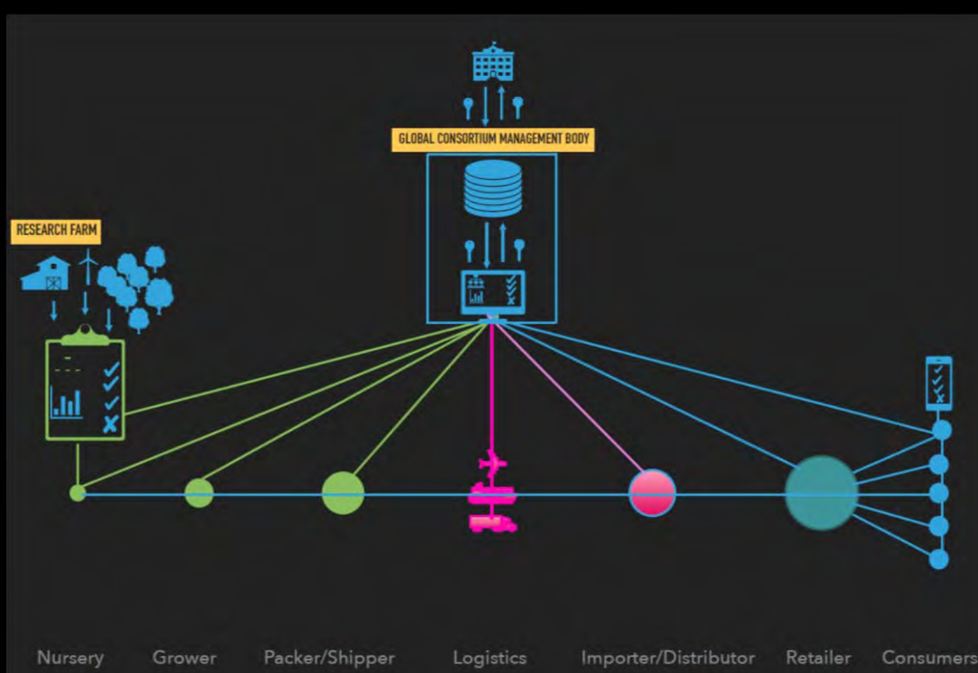
The creation of the actual asset itself, defining maternal and fraternal lines, with immutable characteristics to carry title into perpetuity.

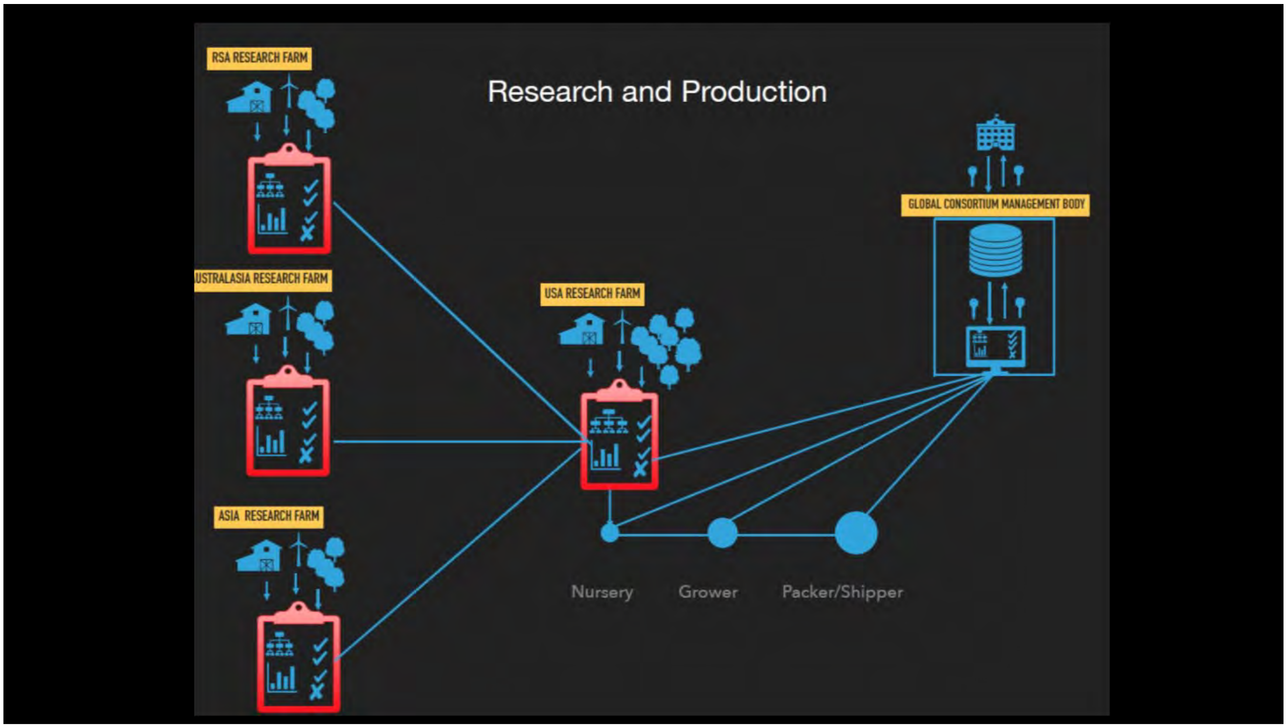
Utilization

The ability to bring the laboratory into the field, homogenize variable data into actionable information, provide sustained transparency throughout the chain, and efficiently effect management of the overall consortium.

Flow

Data enters a continuous gentle flow that helps timeline consortium goals, triggers input from all consortium members, with automatic dispersion of data access to relevant information for the appropriate parties.





High Density orchards enables micro management, as the decision making process is simplified with a less complex and smaller tree.

Yet…*"we need limbs to produce fruit"*

this however might be one of the major limitations of high density pruning…

Sustainable Production

allesbeste
Boerdery Kwekery Padstal
KWALITEIT WEENS PASSIE

Conclusion

Trellis is the way of the future for all "new generation cultivars"

allesbeste
Boerdery Kwekery Padstal
KWALITEIT WEENS PASSIE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA | QAAFI

Avocado tissue culture using stem cells

by

Prof. Neena Mitter Avocado Group

Prof. Neena Mitter
Dr. Alice Hayward
Jayeni Hiti-Bandaralage
Chris O'Brien
Madeleine Gleeson
Amitoj Walia

Queensland Government

The current industry challenge

Sourcing avocado plants for orchard expansion and new orchard establishment

Seedling rootstocks

Clonal Rootstock

The University of Queensland Australia | QAAFI

Queensland Government

WORLD'S FIRST avocado tissue culture technology – 500 plants from one shoot tip in 8-12 months

Commercialization ready

Production capacity - 500,000 plants in 500 sq meters

Disease-free **Land-free** **Year-round** **Elite new breeds**

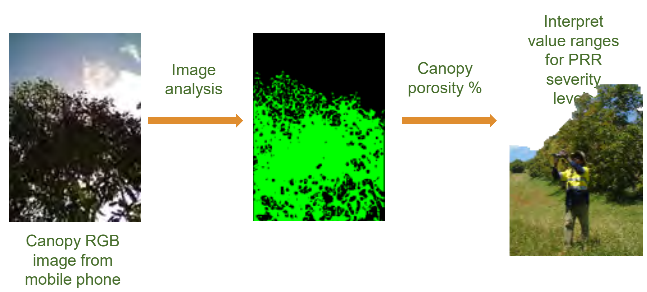
The University of Queensland Australia | QAAFI

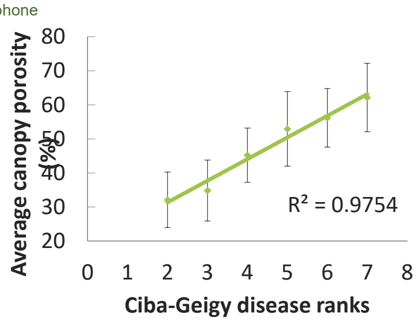
Queensland Government

Sensor technologies for PRR detection and yield estimation

Surantha Salgadoe (PhD student),
A/Prof Andrew Robson
Prof David Lamb (UNE)

1. Canopy porosity method





Other methods described that take things to the grove and regional level:

- Vegetation index from satellite images
- Fusion of thermal and optical radiation (future)

Deployed to predict:
Tree health status, yield potential, fruit size distribution

Could be utilized on regional basis to discover trends and spread of disease – taking it fom the farm level

BioClay- Sustainable crop protection

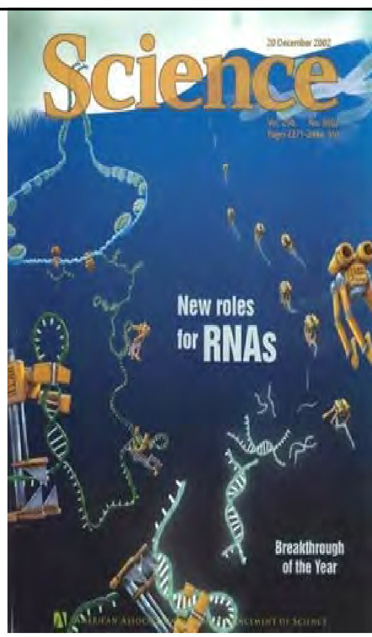
Clay nanosheets for non-GM delivery of RNAi

Neena Mitter
Gordon Xu
Max Lu

Mitter et al Nature Plants , 2017

Queensland Government

RNA Interference



"RNA interference or RNA silencing is the most important thing to happen in molecular biology during the last 10 to 20 years"

The University of Queensland Australia | Queensland Alliance for Agriculture & Food Innovation | Queensland Government

Trigger molecule of RNAi is Double stranded RNA

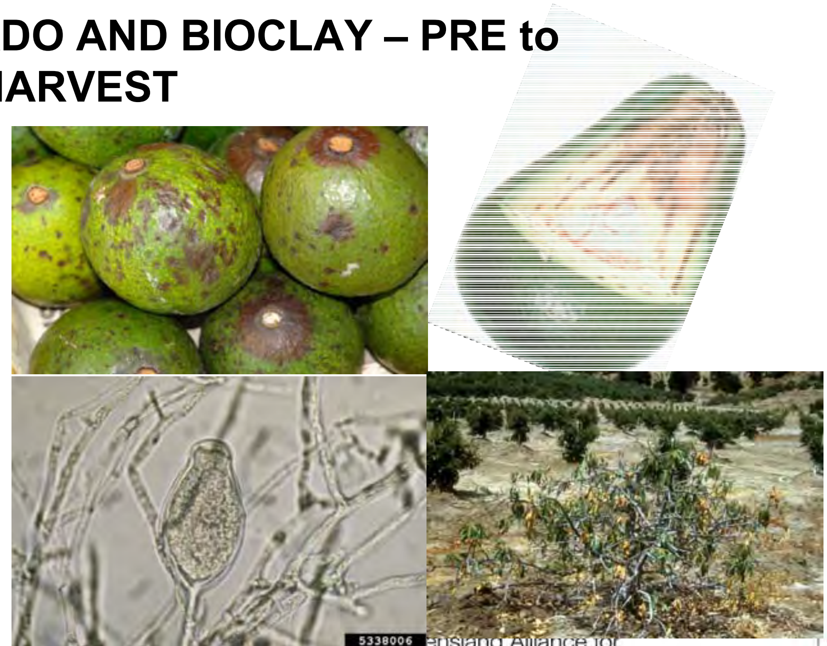
In transgenic or GM plants pathogen specific dsRNA is integrated into the genome of the plant to afford protection

Is there another way? Can we deliver RNAi as a spray instead of making a GM plant?

http://www.naturalnews.com/gmos.html

The University Of Queensland Australia | Queensland Alliance for Agriculture & Food Innovation | Queensland Government

AVOCADO AND BIOCLAY – PRE to POST HARVEST



OF QUEENSLAND
AUSTRALIA

Queensland Alliance for Agriculture & Food Innovation

Queensland Government

Challenges to Productivity: Genetics, Genomics and Biotechnology

Aureliano Bombarely (Virginia Polytechnic University, USA)
Iñaki Hormaza (IHSM, Spain)
Sara Mwangi (University of Pretoria, South Africa)
Elena Palomo-Rios (IHSM, Spain)
Fernando Pliego Alfaro (University of Málaga, Spain)

Session Overview

The goal of the session was to highlight current technologies being deployed for avocado research to understand the genetics of avocado and to move future research forward.

These topics included:

- Genetic diversity
- Community resources, genome and datebases
- Transcriptomic studies of avocado
- Avocado transformation efforts

With the focus on community based projects

Characterization of avocado cultivars using morphometric and genomic tools

What are Community driven Genomic Resources?

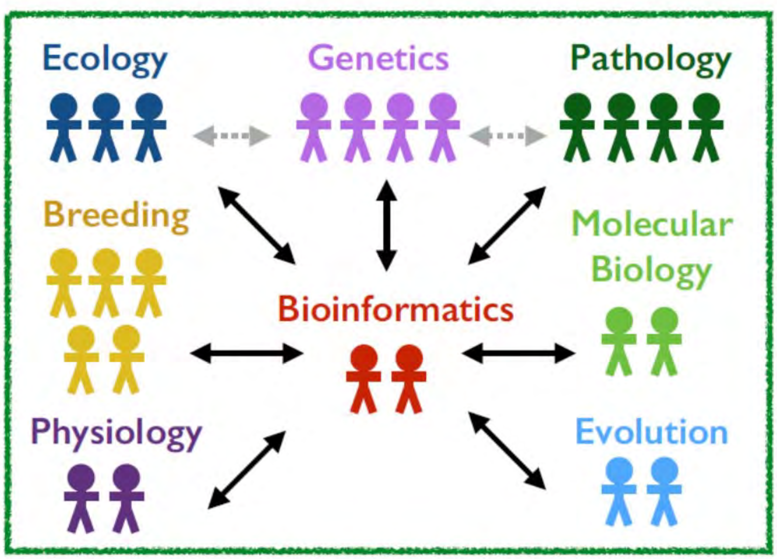
Genomics can be defined as "***interdisciplinary field*** *of science focusing on the structure, function, evolution, mapping, and editing of genomes.*"

Ecology Genetics Pathology

Breeding Bioinformatics Evolution

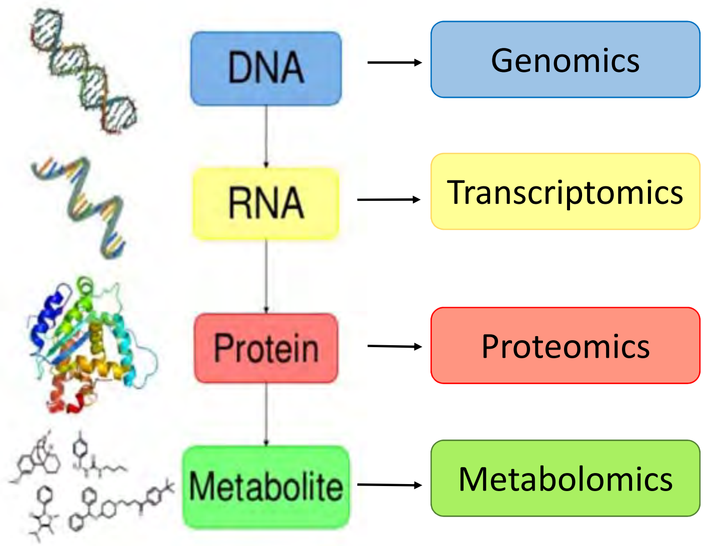
Physiology Molecular Biology

What are Community driven Genomic Resources?



Resources built by a Community for a Community

Genome annotation: Transcriptomic resources

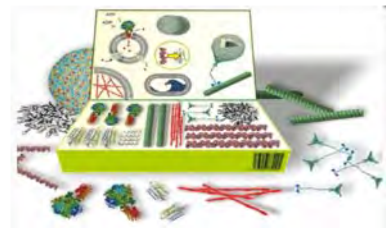


Strengths of the Community driven Genomic Resources

- **Network of multiple and diverse experts.**
- **More efficient use of resources.**
- More resolution for the big picture.
- Optimized development for long term strategies.
- Best chances for high impact factor publications.
- Data mining training networks.

Avocado genome sequencing

Genome = Encyclopedia and molecular toolbox



- Long vegetative period of {6 to 8} years and the difficulties of doing directed crosses complicates avocado breeding.
- Knowledge of the Avocado genome and related genetic diversity will ;
  - ✓ Provide a "molecular toolbox" to speed up the selection of cultivars and rootstocks with desirable traits.
  - ✓ Study the genetics underpinning complex traits such as disease tolerance and tolerance to abiotic stresses.

The avocado genome consortium

AVOCADO GENOME consortium

- Established in 2016
- International collaborative initiative between researchers interested in avocado genomics
- AIM: To provide a high quality Avocado genome
- IN PROGRESS

Avocado genome

AVOCADO GENOME consortium

Phase 2

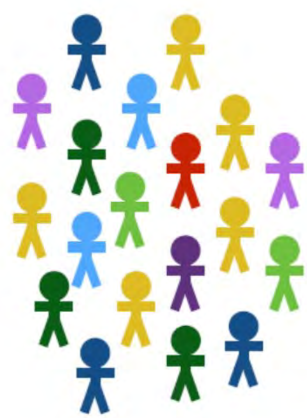
- Dr. Patricia Manosalva (UC-Riverside)
- Dr. David Kuhn (USD lorida)
- Prof. Randy Ploe . Florida)
- Dr. Alan Char ers (U. Florida)
- Dr. Noel an der Berg (U. Pretoria)
- Dr. Antonio Matas-Arroyo (U. Malaga)
- Dr. Aureliano Bombarely (Virginia Tech)

We want you

PHASE 1 GOAL: *To QUICKLY produce a HIGH QUALITY chromosome level avocado genome PUBLICLY ACCESSIBLE to all the scientific community*

PHASE 2 GOAL: Improvement of the reference genome resources based in the community needs. OPEN TO ANYONE THAT WANT TO BE INVOLVED.

ATGCGCGTGCGTGA
GCAAAGTGACGAGC
GCCCAGGGTAGCCA
GCACCCCATGACAG
AAAGCCTTACCAGA
GGCCCACCAGACGA
GGCCAGACGGACAG
GGCCCAGGGACCGA
GGCCAGGGACCGGA
GAAAATGACAAATT



perseabase.org

- Dr. Antonio Matas-Arroyo (U. Malaga).
- Ms. Alicia Talavera (CSIC-La Mayora)
- Dr. Aureliano Bombarely (Virginia Tech)
- Prof. Inaki Hormaza (CSIC-La Mayora)

Challenges to productivity: Diseases

Elizabeth Dann (University of Queensland, Australia)
Noelani van den Berg (University of Pretoria, South Africa)
Randy Ploetz (University of Florida, USA)
Clara Priego Alfaro (IFAPA-Churriana, Spain)
Kerry Everett (Plant and Food, New Zealand)
Noam Alkan (Volcani Research Center, Israel)

Session Overview

A diverse group of fungal diseases discussed and the threat of global distribution to world avocado production discussed:

- Perennial problems: Phytophthora root rot and fruit diseases
- Newly emerging: White root rot, brown root rot, nursery diseases
- Highly invasive: Laurel Wilt and Fusarium Dieback

Phytophthora root rot: History, impact and status

Liz Dann

Avocado Brainstorming
May 2018

Status

- Still No. 1 constraint in many countries
- Not only *P. cinnamomi* !
  - *P. citricola/mengeii* (trunk cankers)
  - *P. multivora, P. niederhauserii* (very pathogenic)
  - *Phytopythium vexans*
    Eg. Rodriguez-Padron et al 2018 Phytopath. Mediterr. 57:89-106
- Management
  - New generation rootstocks
  - Optimised phosphonate formulations and delivery
  - Protection by endophytes (eg. Hakizimana et al. 2015?)
  - Other actives, products, technologies?

Phosphonate

- Fosetyl-Al (Aliette®) from late 1970s
- 1980s Phos acid shown as fungicidal, phosphonate anion primarily responsible for activity – KOH used to neutralise
- 1987 injection with K phosphonate became widely available, cheaper and more effective than Aliette
- 1990s timing of application with tree phenology
- 1998 root monitoring service (Aust)
- Dual mode of action – fungistatic, activates defences

New developments/ongoing research

- Low volume sprays + surfactant (beware of phytotox, increased fruit residues)
- Ammonium phosphonate
- Sensitivity amongst isolates & critical phos
- Application timing and fruit residues
- Rootstock effects, activation of defences

Avocado Rootstock Responses

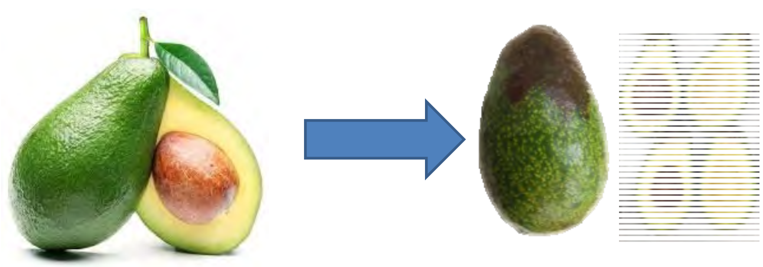
Noëlani van den Berg
Post-graduate Students

Avocado Brainstorming 2018

FABI | westfalia fruit | HM | avocado research programme

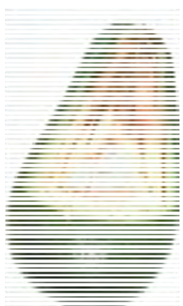
Stem-end rot in avocado

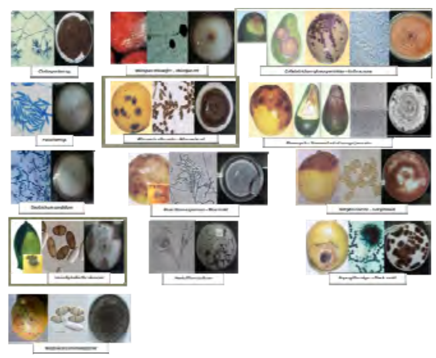
Tom Sharir, Sonia Diskin, Dani Steinberg, Noam Alkan
Agriculture research Organization, Volcani Center



Stem-end rot (SER) in avocado

- The stem end of all avocado are colonized with microorganisms.
- With fruit ripening some pathogenic fungi become pathogenic and cause SER.
- The SER pathogenic fungi in avocado include: *Colletotrichum, Alternaria, Lasiodiplodia, Phomopsis, Neofusicoccum.*





Summary

1. The fruit stem-end microbiome are diverse.
2. SER pathogens endophytically colonize the phloem of stem-end until fruit ripening.
3. *Lasiodiplodia* is the main cause of SER in Israel.
4. *Lasiodiplodia* conidia could be carried by the wind.
5. Different treatments reduced SER and alter stem-end microbiome
   - Fungicides application during flowering.
   - Ripening inhibition
   - Harvest with stem

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RANGAHAU AHUMĀRA KAI

Infection timing for *Colletotrichum acutatum* and *Phomopsis* causing postharvest rots of avocado in New Zealand

Kerry Everett, Luna Hasna, Lucia Ramos, Shamini Pushparajah, Brogan McGreal, Carol Curtis
Mt Albert Research Centre
Auckland, New Zealand

Two postharvest diseases

Body rots

Stem-end rots

Summary and conclusions

- *Phomopsis* is not likely to cause body rots
- Possibly infects during flowering to cause stem-end rots
- The site of infection is unknown- through the peduncle base?
- *C. acutatum* may infect once temperature rises above a ‘threshold’

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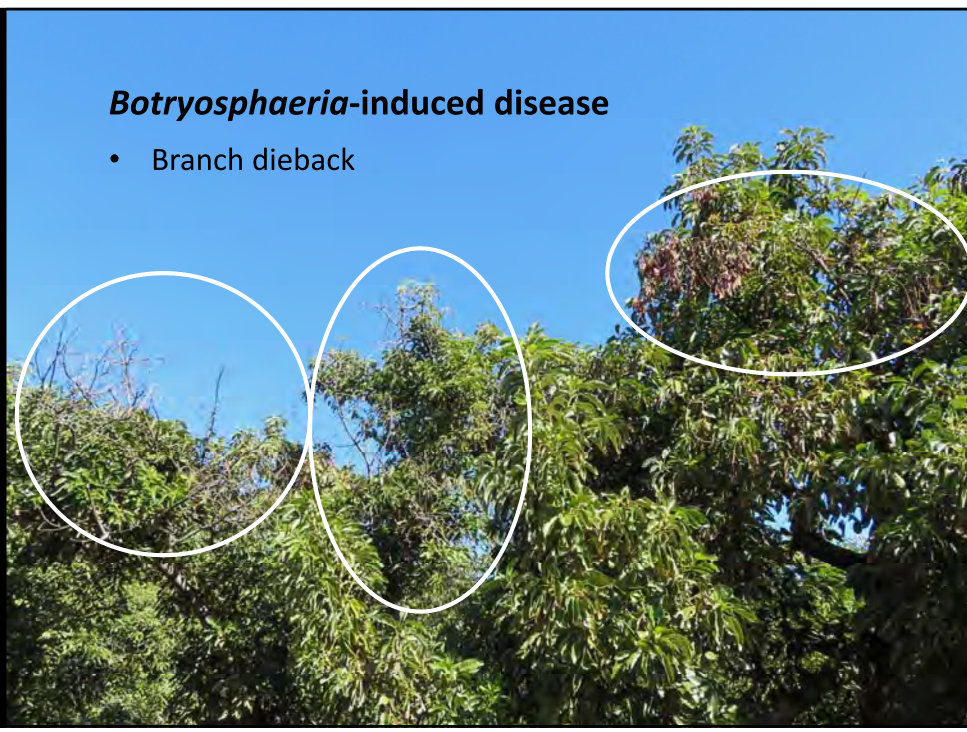

Botryosphaeria-induced disease

- Branch dieback
- Graft failure

Causal agents are often those that also cause fruit disease; they are endophytes and usually in the Botryosphaeriaceae

Management

Why has there been a heightened awareness of these problems?

- Increased scrutiny as quality of management increases
- New pathogens
- Climate change (e.g. excessive heat in California)

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Phellinus noxius: Brown root rot

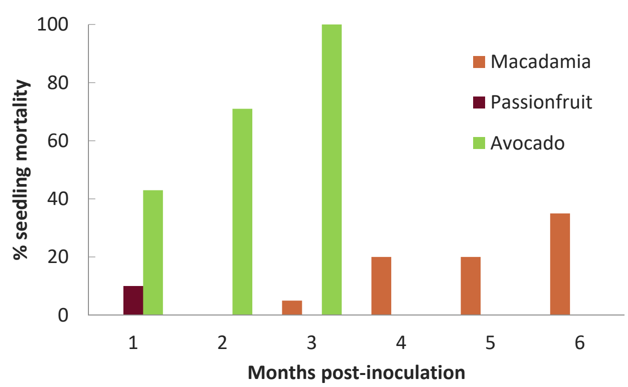
Liz Dann

Avocado Brainstorming
May 2018

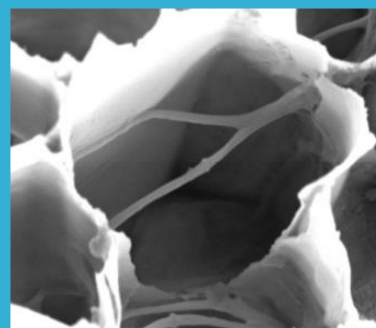
Queensland Government

Brown root rot, *Phellinus noxius*

Avocado is very susceptible to Phellinus



Towards the understanding of avocado *Rosellinia necatrix* interaction

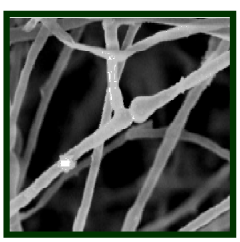


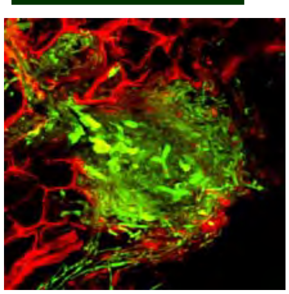
Dr. Clara Pliego Prieto

Avocado Brainstorming 2018

IFAPA Instituto de Investigación y Formación Agraria y Pesquera

White Root Rot Disease





White root rot
Rosellinia necatrix

(*Pliego et al, Fungal Genetics, 2009; Pliego et al., Mol Plant Pathol, 2011*)

Aims

Our main objective is the control of avocado white root rot caused by *Rosellinia necatrix* through rootstock improvement

Avocado breeding programme

Induction of Tolerance `Priming´

Molecular studies of *R. necatrix*/avocado interaction

Control of White root rot disease

THE UNIVERSITY OF QUEENSLAND AUSTRALIA | QAAFI Queensland Alliance for Agriculture and Food Innovation

Nursery root rots: Black root rot

Louisa Parkinson, Liz Dann, Roger Shivas

Avocado Brainstorming
May 2018

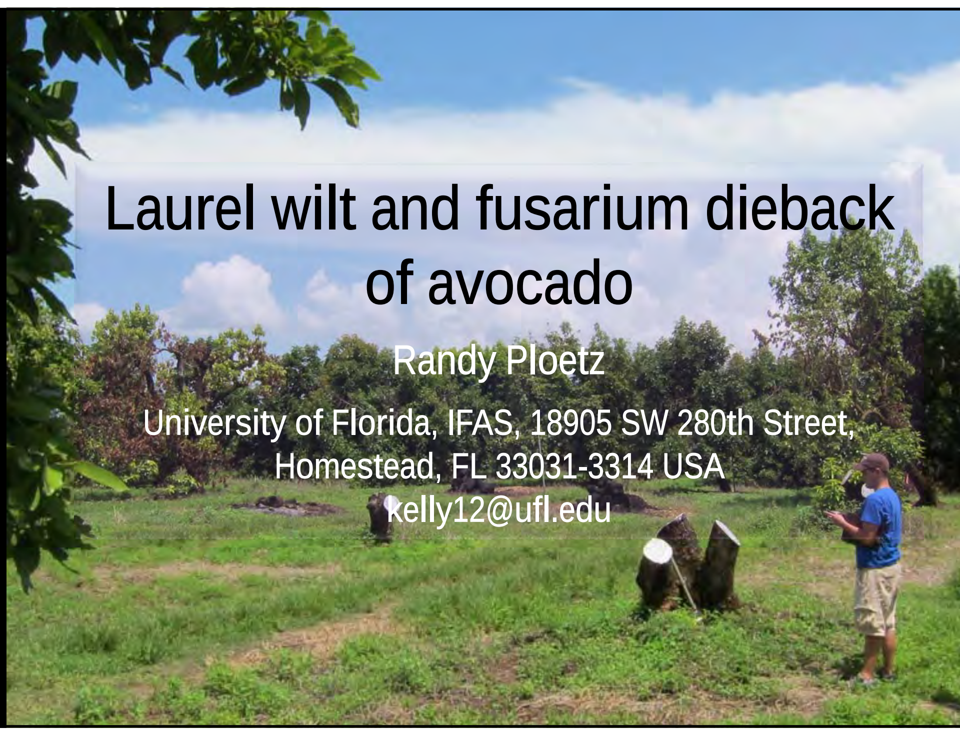
Queensland Government

Which species are pathogens?

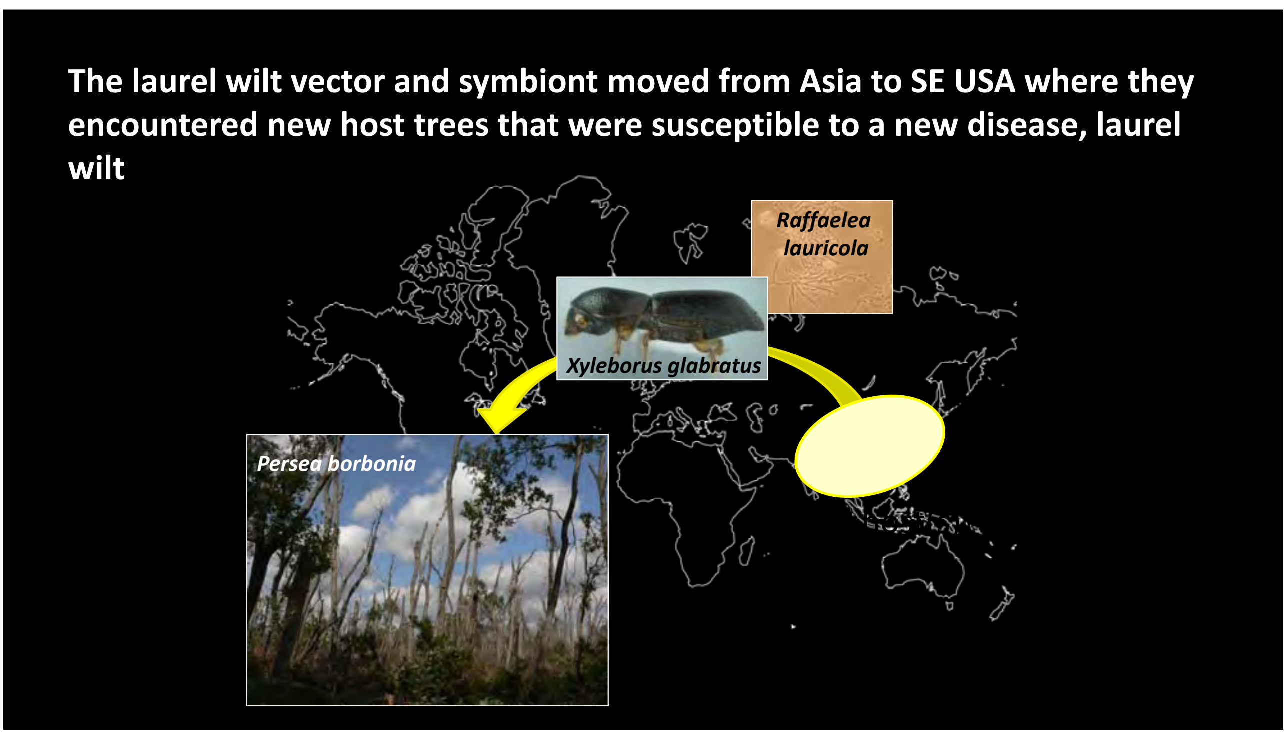
- ***Calonectria ilicicola*** from avocado, papaya, peanut and custard apple extremely pathogenic
- ***Calonectria* sp. (new)** from blueberry also pathogenic
- **4 *Dactylonectria* species** caused severe root rot but not stunting
  - ***D. macrodidyma*** the most commonly isolated
- Other species tested including *Ilyonectria* not pathogenic

Parkinson et al (2017) Phytopathology, 107: 1479-1485

Parkinson et al (2018) *Dactylonectria* Lombard and Crous, Pathogen of the Month – April https://www.appsnet.org/Publications/POTM/PDF/Apr18.pdf




Ambrosia beetles reside in the xylem of woody hosts, but consume fungi, not wood
Zvi Mendel


The laurel wilt vector and symbiont moved from Asia to SE USA where they encountered new host trees that were susceptible to a new disease, laurel wilt
Raffaelea lauricola
Xyleborus glabratus
Persea borbonia

Challenges to productivity:

Optimizing yield by understanding the physiological events that regulate crop load and the return to bloom

Harley Smith (CSIRO, Australia)
Rodrigo Iturrieta (University of California, USA)
Vered Irihimovitch (Volcani Research Center, Israel)
David Pattermore (Plant and Food, New Zealand)
Iñaki Hormaza (IHSM, Spain)

Session Overview

Yield is a function of genetics x environment x management

- High fruit load influences floral induction and subsequently alternate bearing
- Flower quality at the time of bloom influences fertilization, fruit set and ultimately yield
- Developing a model for fruit abscission
- Understanding the impact of fruit presence and sunlight on avocado tree growth

Challenges in Productivity; Avocado a low yielding fruit tree


<u>Optimizing yield</u>

- 32.5 t/hc theoretical
- ~10 t/hc average, 10-22 t/hc 'accomplished growers'


Optimizing yield

↓

Genetics x Environment x Management = Yield


Integration of external (E x M) and internal cues (G) regulates reproductive growth and development of the genotype

<u>Environment</u>
Light
Temperature
Water
Soil

<u>Management</u>
Pruning
PGR applications
Irrigation
Fertilization
Orchard design

<u>Genotype</u>

Scion & Rootstock

Challenges in Productivity

Key Yield Determinants

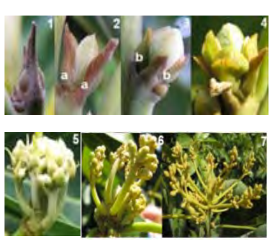
- Flower induction
- Pollination
- Fruit set
- Fruit abscission
- Tree/canopy architecture

Resource allocation (RA)

- Sink competition (supplies limited)
  - Vegetative vs reproductive
  - Reproductive vs reproductive
- Physiology, signalling & environment
- Manipulate RA to optimize yield

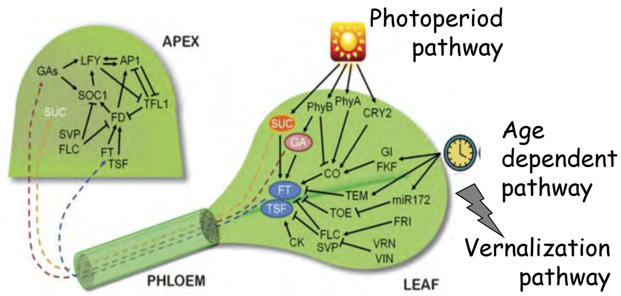
Exploring the effects of fruit load on floral induction in alternate bearing 'Hass' avocado trees.

??



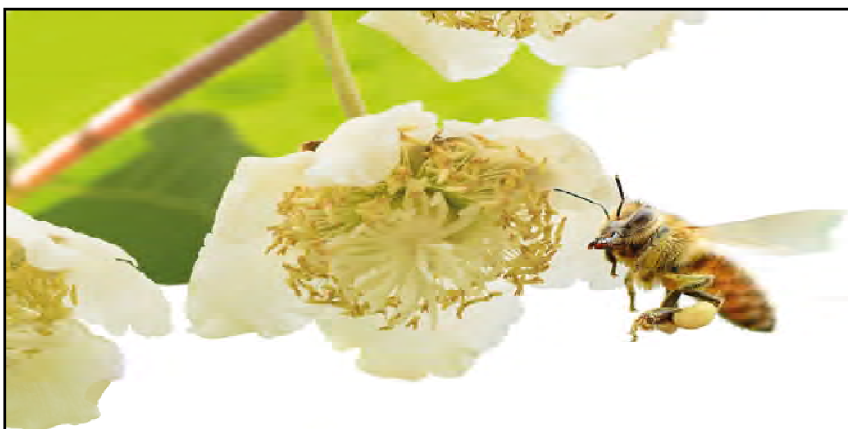
Vered Irihimovitch
veredi@agri.gov.il

FLOWERING LOCUS T is hypothesized to act as a phloem-mobile florigen signal



Our results suggests a role for sugars in inducing *PaFT1* leaf expression, yet also illustrate the complexity of *PaFT1* regulation.

Adapted from: Turnbull C (2011)



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Avocado Pollination & Pollinators

David Pattemore
Science Team Leader – Pollination & Apiculture,
Plant & Food Research Ruakura

Avocado Brainstorming 2018
Tzaneen, South Africa

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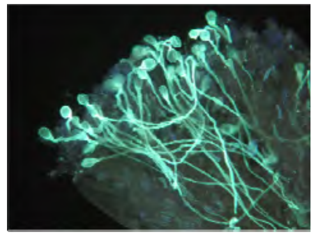
Why should we care about pollination?

Challenges

1. What are the effects of pollen parentage on:
   » Yield
   » Fruit Quality
2. Who are the flower visitors that are providing pollination service when flowers are female?
   » Do orchard management practices harm or help them?
   » What back-up plans?
3. How should orchards be designed to optimise pollination?
   » How does this interact with the pollinator community?
4. How is pollination effected by:
   » Land-use change
   » Climate change
   » Changing consumer preferences



Flower quality to fruit set

Iñaki Hormaza, Librada Alcaraz

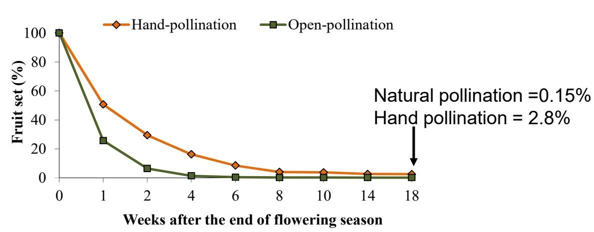
CSIC

IHSM La Mayora
Instituto de Hortofruticultura Subtropical y Mediterránea

AVOCADO CHARACTERIZED BY LOW FRUIT SET

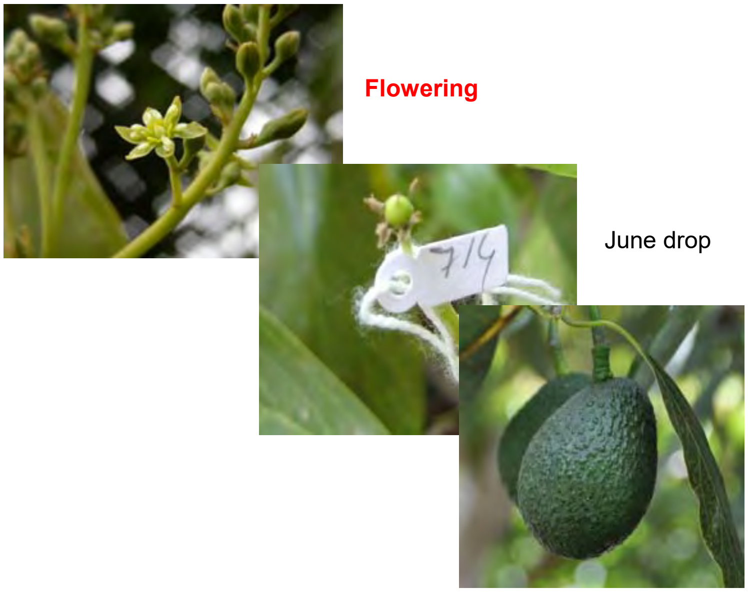
- Massive drop of flowers and developing fruitlets

- Some unpollinated flowers
  Increased fruit set after hand-pollination → **Inadequate pollination**



- **Additional factors must be involved**

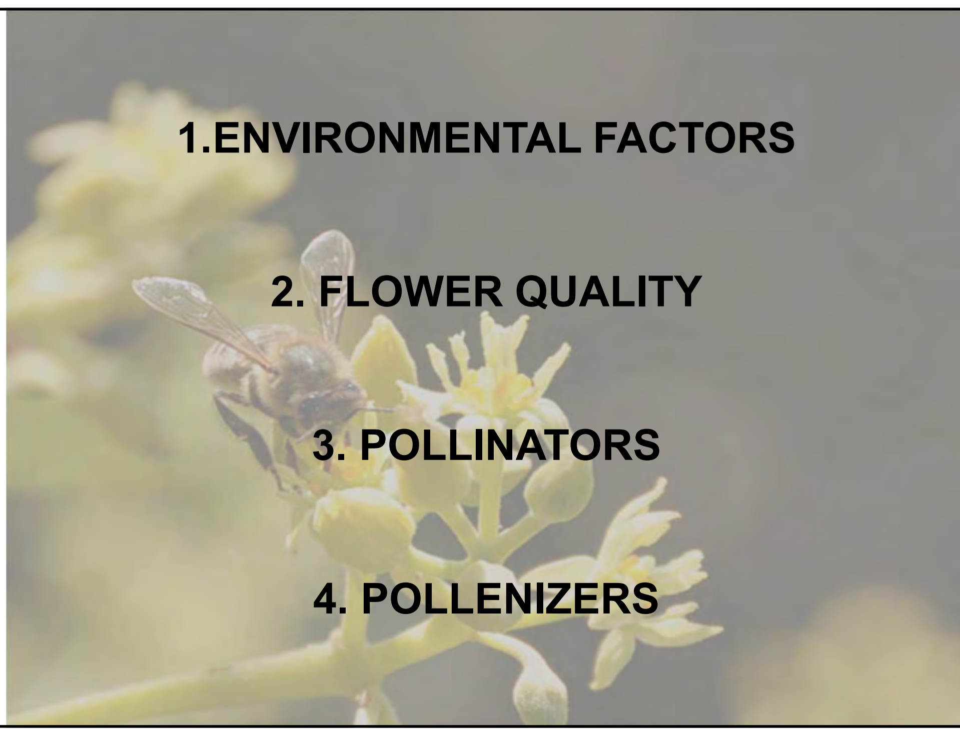
WHEN CAN WE LOSE FRUIT?



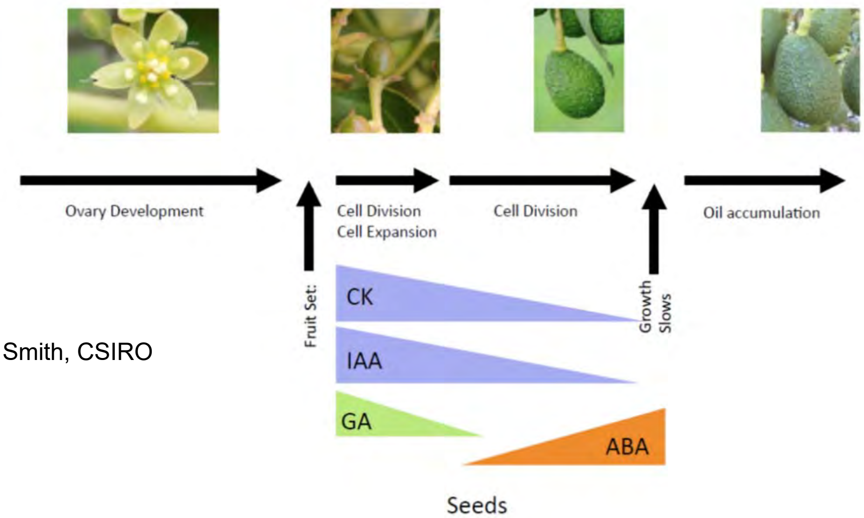
Flowering

June drop

Mature fruit



Avocado fruit development



Harley Smith, CSIRO

Fruit abscission: A multistep process that is initiated by growth arrest

Inducible System

What are the sequence events that lead to growth arrest and abscission in the fruit?

↓

Develop new management solutions

The impact of fruit presence and sunlight on 'Hass' avocado growth

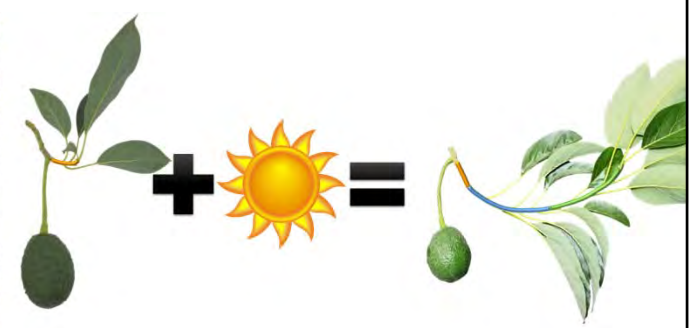
UCR | Botany & Plant Sciences

FRUITS EFFECTS ON

VEGETATIVE GROWTH

FRUITS EFFECTS ON

REPRODUCTIVE GROWTH

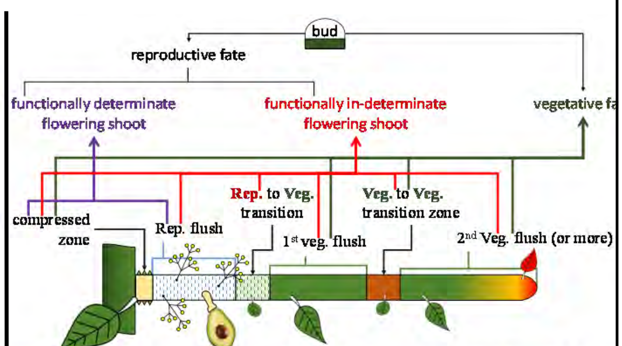


Increase precision

Isolating variables

We need a language consensus
(phenotyping)

Collaboration
(more independent of location)

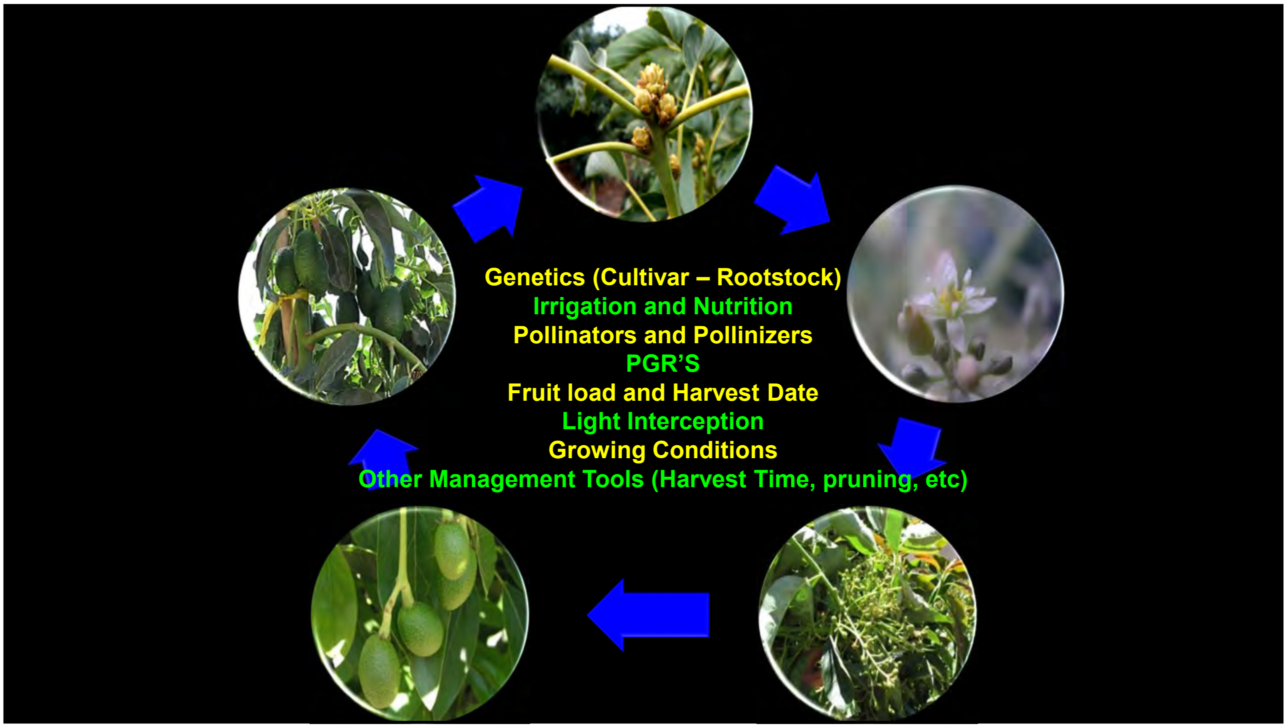


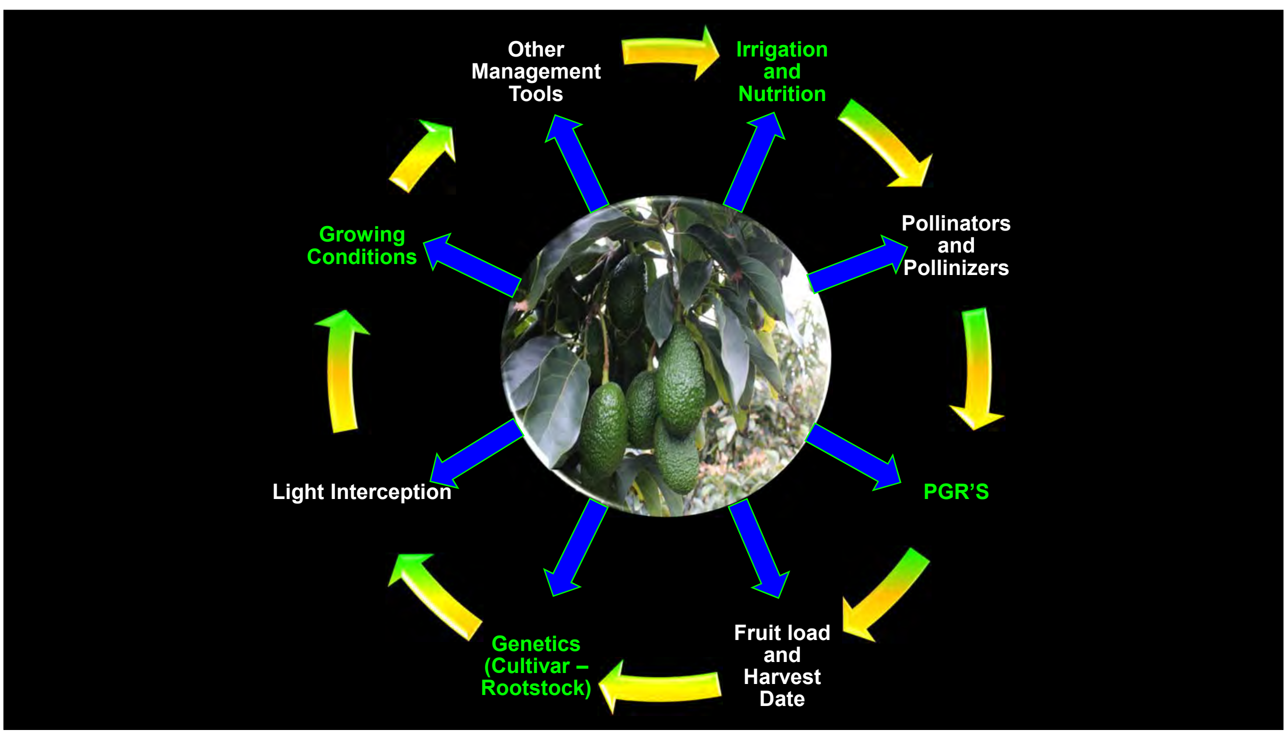
Where theory meets practice

Ben Faber (University of California, Riverside)
Francisco Mena (GAMA, Chile)
Neil Delroy (Jasper Farms, Australia)
Tatiana Cantuarias-Avilés (University of São Paulo, Brazil)

Session Overview

- This session introduced many of the different field practices that growers are pursuing, in a way integrating the research findings that can be economically justified in the field.
- These practices includes those that the grower needs to plan in advance (scion and rootstock) which can affect future pest/disease management, planting density and cost and rate of return on investment.


Genetics (Cultivar – Rootstock)
Irrigation and Nutrition
Pollinators and Pollinizers
PGR'S
Fruit load and Harvest Date
Light Interception
Growing Conditions
Other Management Tools (Harvest Time, pruning, etc)


Other Management Tools
Irrigation and Nutrition
Pollinators and Pollinizers
PGR'S
Fruit load and Harvest Date
Genetics (Cultivar – Rootstock)
Light Interception
Growing Conditions

SUSTAINABLE PRACTICES FOR AVOCADO PRODUCTION

1. Soil management strategies:
- Green manure crops before planting avocados
- Soil mineral amendments: rock dust, lime, gypsum
- Soil organic amendment: manure, compost

2. Soil vegetation management strategies:
- Mulching
- Windbreaks
- Herbicides

3. Sustainable fertilization practices:
- Bio-fertilizers

4. Pest and Disease Integrated Management:
- Avocado fruit borer (*Stenoma catenifer*)
- Root rot (*Phytophthora cinnamomi*)

abacates doBrasil

Providing for the consumer: Health, safety and flavor

Nikki Ford (Hass Avocado Board, USA
David Obenland (USDA-ARS, USA)
Lise Korsten (University of Pretoria, South Africa)

Session Overview

- Food safety, flavor and nutrition have increasing importance to consumers when making purchase decisions
  - Can we maintain flavor and nutritional value of avocado during all stages of harvest, fruit handling and marketing?
  - Insuring food safety and understanding risks associated with avocado? How dynamic is the microbiome on the fruit surface and within the pulp?
  - How do avocados fit into a sustainable diet?

Points to Ponder:

- ❖Do we understand how to describe avocado flavor and taste and how do we quantify these changes?
- ❖How do avocados fit into a sustainable diet and do we as researchers consider the human nutritional aspect of the fruit in our research?
- ❖How do we go about developing an international effort to insure food safety in avocado, since avocado is an international crop?

Tying the loose pieces together – Planning for the future

Jose Chaparro (University of Florida, USA)
Nigel B. Wolstenholme (University of Kwa-Zulu Natal, South Africa)

Session Overview

A general summary of the meeting linking the different sessions was presented with a futuristic perspective

- What will the avocado world be like in 2030? What will be the new challenges and opportunities?
- What are the trends in Agriculture such as commodities vs. products, land ownership, globalization and sustainability and how will this impact global avocados?
- What we still need to know about the avocado and how it will adapt to changing conditions.
- Review of current technological challenges such as AB, low yield and how to move forward

Avocado Brainstorming

What was the Outcome of Avocado Brainstorming 2018?

- INTERACTION
- COMMUNICATION
- RENEWAL OF RESEARCH COMMITMENTS
- SEEING THE FOREST THROUGH THE TREES

Looking Forward: 2021 Meeting in Spain (USA)

Avocado Brainstorming – 2018

THANK YOU FOR YOUR SUPPORT

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.

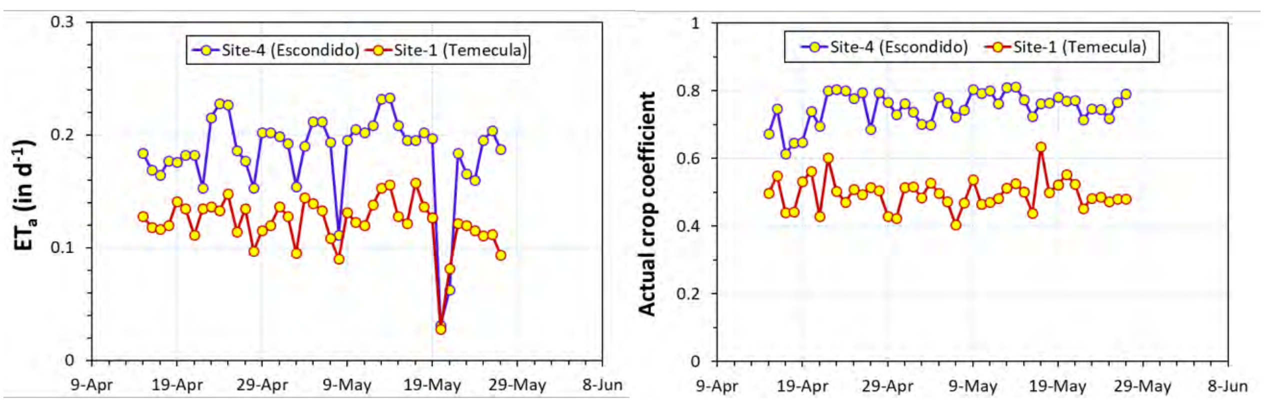


Fig. 3. ET_a and actual crop coefficient values in two avocado experimental sites in Escondido and Temecula from the ongoing irrigation study. Avocado trees are 11-year-old at Site 4 and 8-year-old at Site 1. Site 1 has a lower elevation than site 4 (the monitoring ET station is 1,500 ft. above sea level 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.

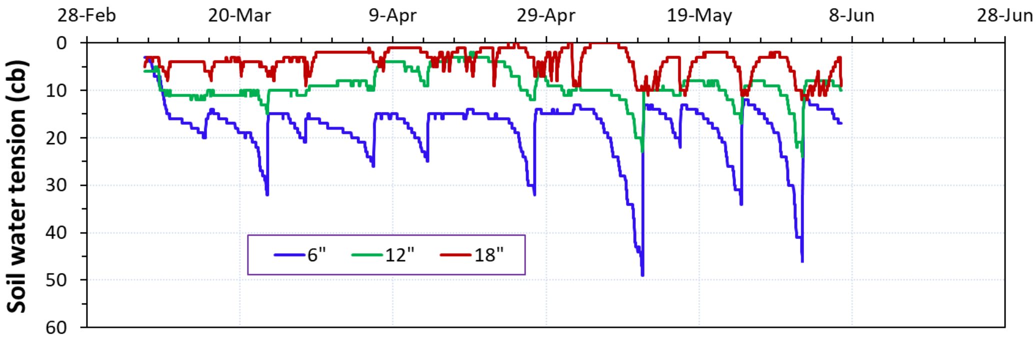


Fig 4. Half-hourly soil water tension (cb) measured at multiple depths of 6-in, 12-in, and 18-in at Site 1 over a three-month period. One micro sprinkler per tree with an average operation flow rate of 9.5 gallon per hour is sued for irrigation.

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.

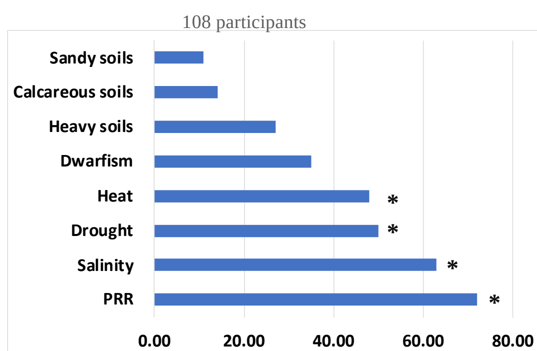
Co-PIs and collaborators: Dr. Mary Lu Arpaia, (Horticultural Specialist, Field and Extension activities, Department of Botany and Plant Sciences, UCR), Dr. Lauren Garner (Horticulture and Crop Science Department, Cal Poly, San Luis Obispo), Dr. Peggy Mauk (Avocado response to Salinity, Extension activities, 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.

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



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 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™. 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 $CaCO_3$), 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.

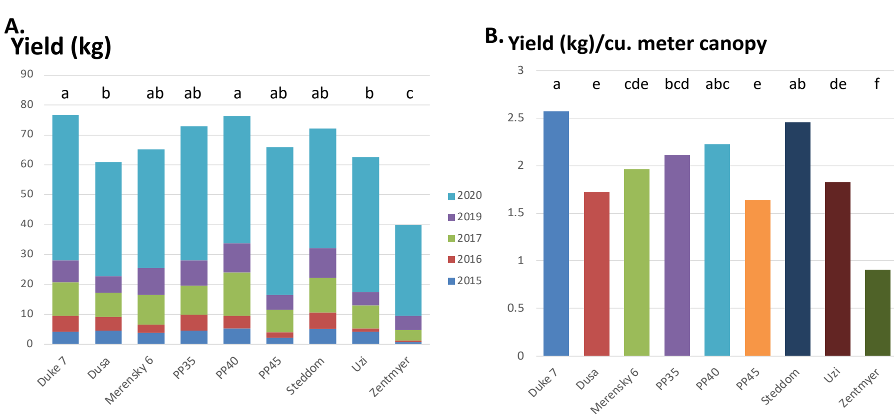
Table 2. List of advanced UCR rootstocks.

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.



Overall Goal: *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).

Experimental approach and timeline

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**

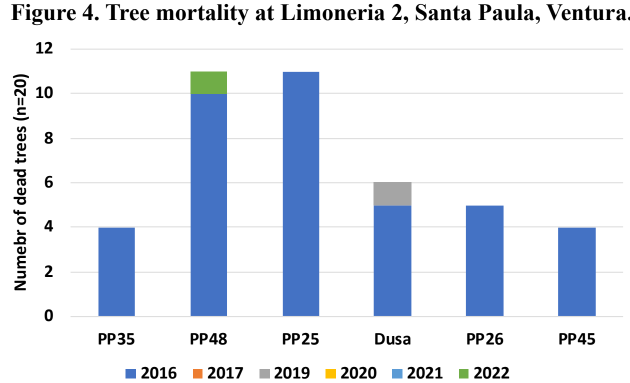
Scoring systems: All the field trials in this proposal will use the UCR rootstock breeding program scoring system for tree field performance to standardize field data. This scoring system is used by our collaborators in USA and in other countries where these 5 advanced rootstocks will be evaluated as 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.

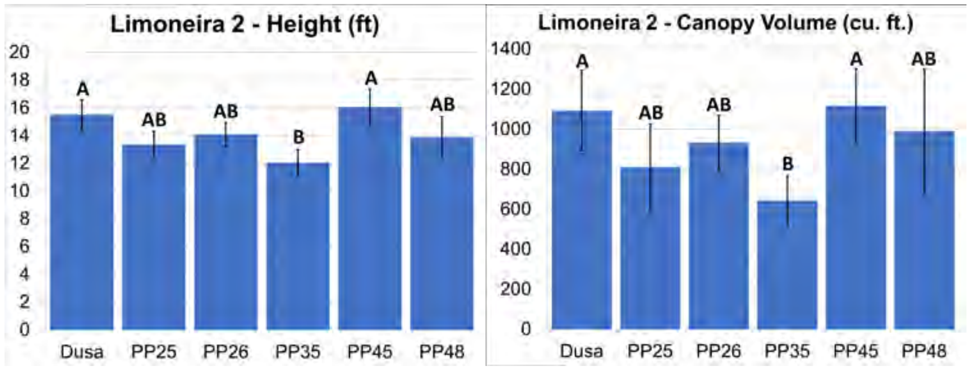
Plot Name	Rootstock varieties	Status	Year Planted
Gunderson, Santa Paula	**Dusa**, PP#'s 18, 21, 22, **40, 42, 45**, 56, 58, 56, 58, 63, SA-1 Lansfield, and Thomas	This is the oldest plot and was the first plot established at Limoneria Ranch. No harvest records were found before 2015. Harvest data has 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

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



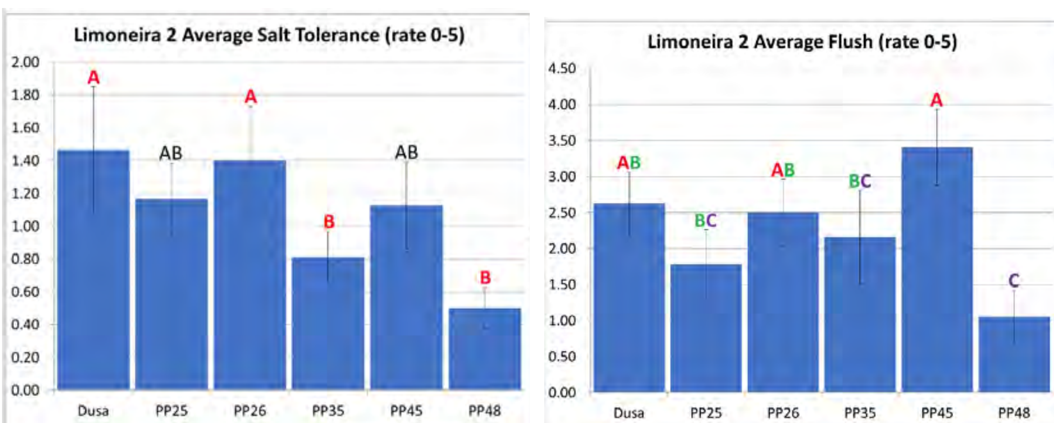
__Limoneria 2, Santa Paula.__ The previous manager Andy Coker is no longer working at Limoneira. We have been communicating and working with the new managers: Mr. Edgar Gutierrez (Vice President of Farming Operations) and Mr. Vince Giacolo ne (Director of Southern Management Operations). Five UCR rootstock 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 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).



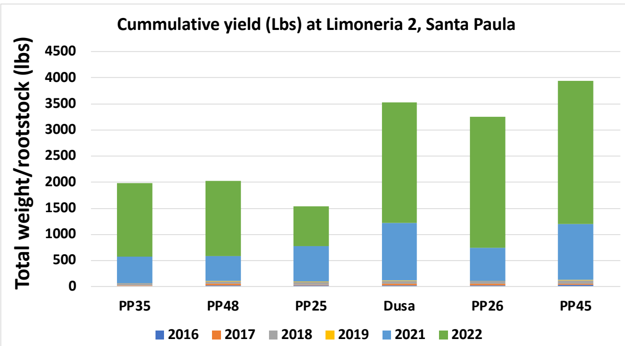
This plot was harvested by 48 plus size picking (7.5 – 9.5 oz) on January 31 (2022). **Table 5** showed the amount of fruit collected for that size. PP45 was the rootstock that produced more total pounds and fruits.

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.



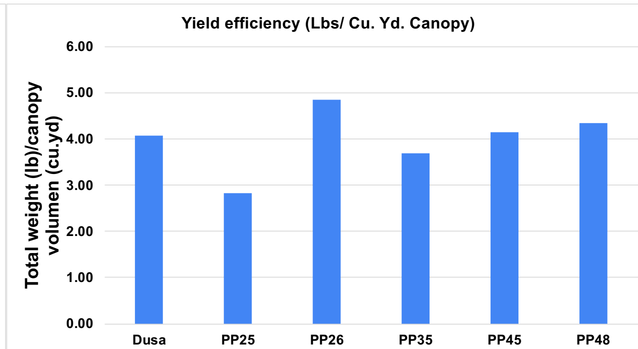
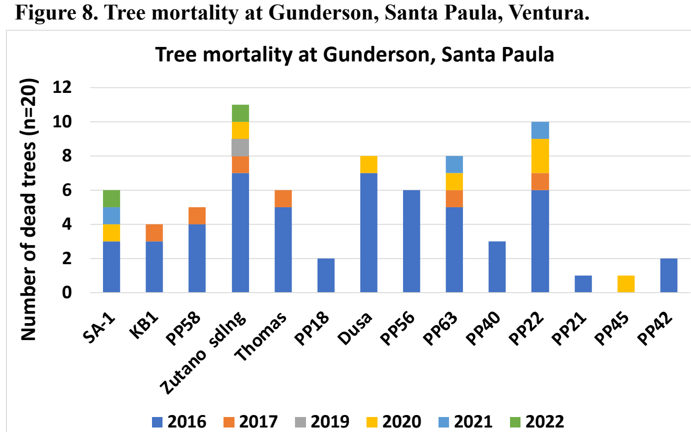


Table 6. Summary of Limoneria 2 harvest in 2022 (January and April).

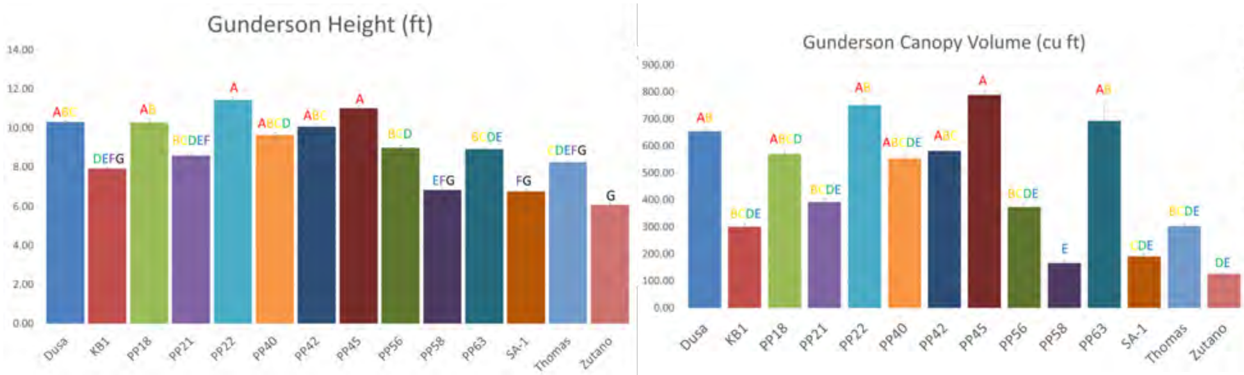
Field	Rootstock	# of Trees	Total Fruit #	Total Weight (lbs)	Avg weight (oz)/fruit	Avg fruit #/Tree	Avg weight (lbs)/tree
Limoneira 2	Dusa	14	4438	2310.47	8.33	317.00	165.03
Limoneira 2	PP25	9	1534	765.53	7.98	170.44	85.06
Limoneira 2	PP26	15	4668	2509.66	8.60	311.20	167.31
Limoneira 2	PP35	15	2707	1408.45	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.



<u>Gunderson, Santa Paula.</u> 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.

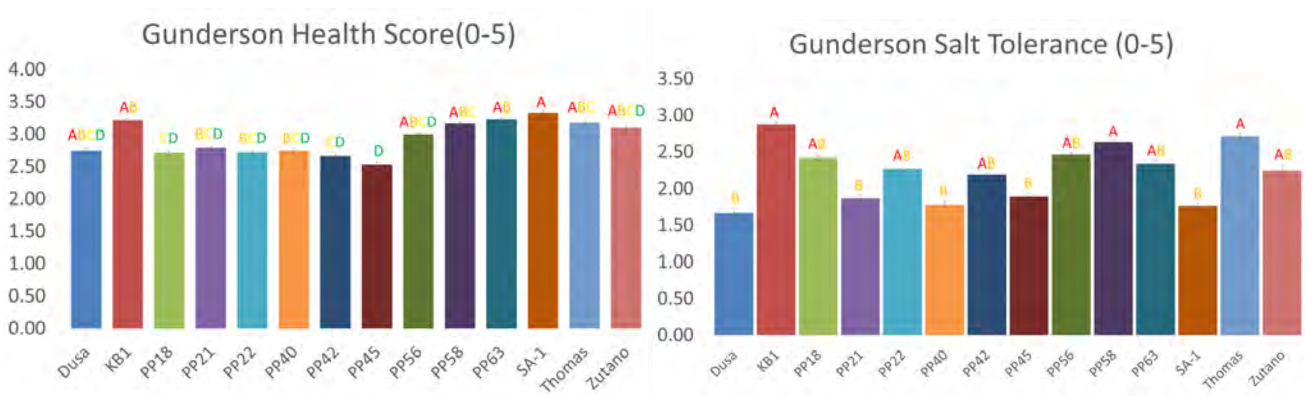
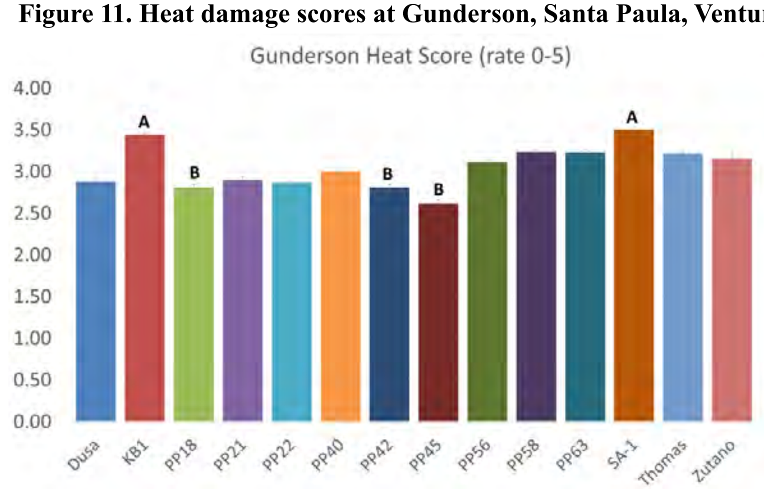


Figure 11. Heat damage scores at Gunderson, Santa Paula, Ventura.



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.

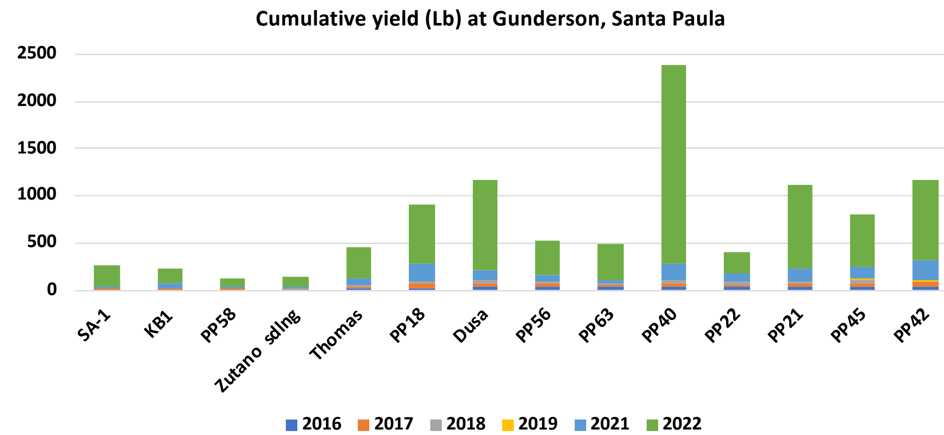


Figure 13. Yield efficiency/rootstock at Gunderson, Santa Paula, Ventura.

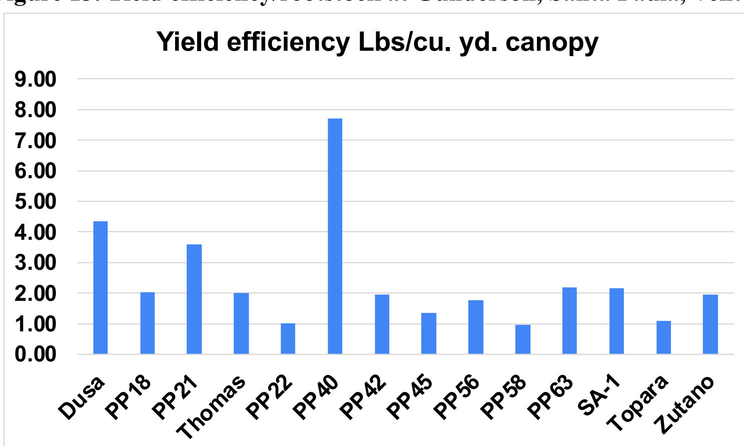


Table 7. Summary of harvest at Gunderson, Santa Paula (2022)

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.

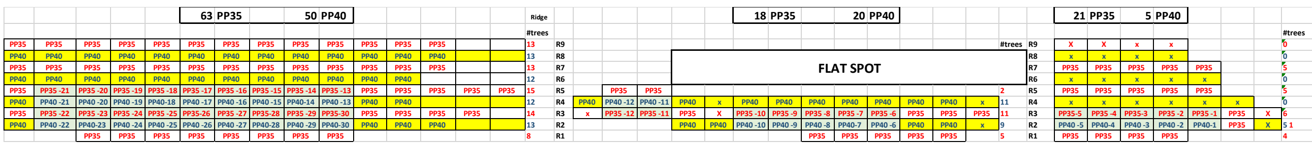
Table. 8. Description of the large-scale trials established in California. Number of trees per rootstock grafted with Hass planted is indicated in parenthesis.

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.

<u>Leo McGuire plot 1, Temecula, (2019).</u> 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%).

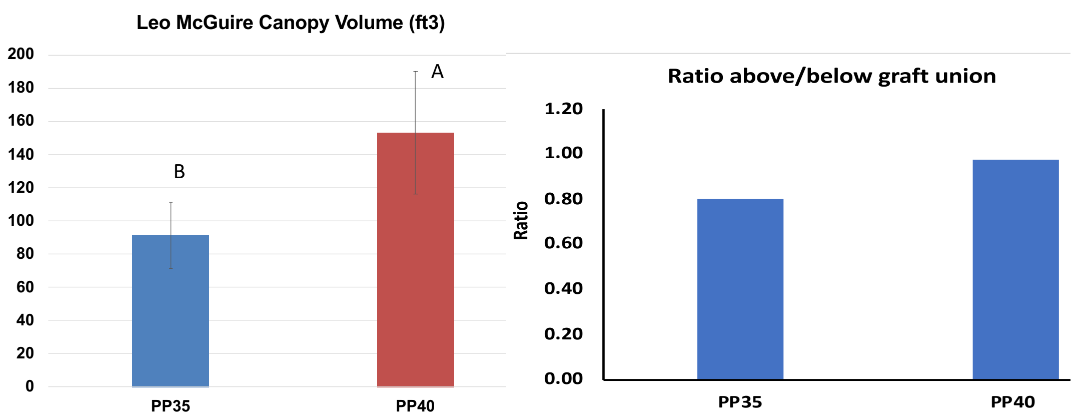
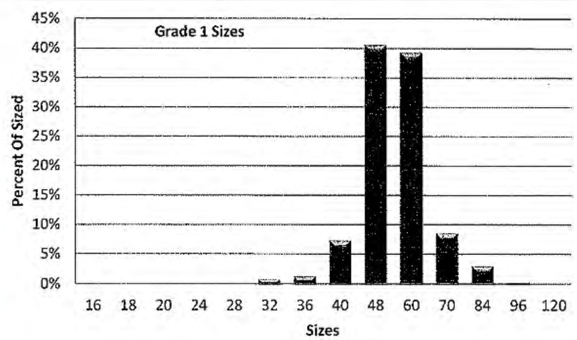


Figure 15. Tree canopy volume and trunk diameter of PP40 and PP35 at Leo McGuire plot, Temecula.

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.

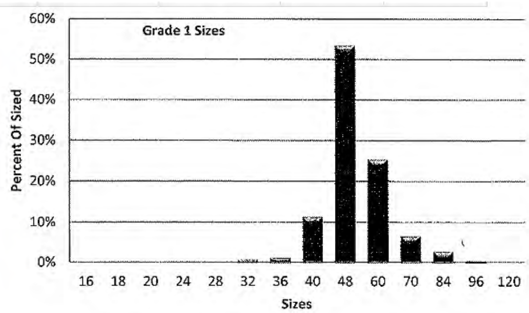
Bin # 62078			Approximate Fruit Counts By Weight			
Fruit Quality #	Size	Weight (lbs)	Min Fruit Count	Max Fruit Count	Avg Fruit Count	% of Net
1	96	2	8.53	9.85	9.19	0.114
1	84	47	158.32	200.53	179.42	2.677
1	70	136	348.16	458.11	403.13	7.745
1	60	633	1350.40	1620.48	1485.44	36.048
1	48	654	1101.47	1395.20	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**).

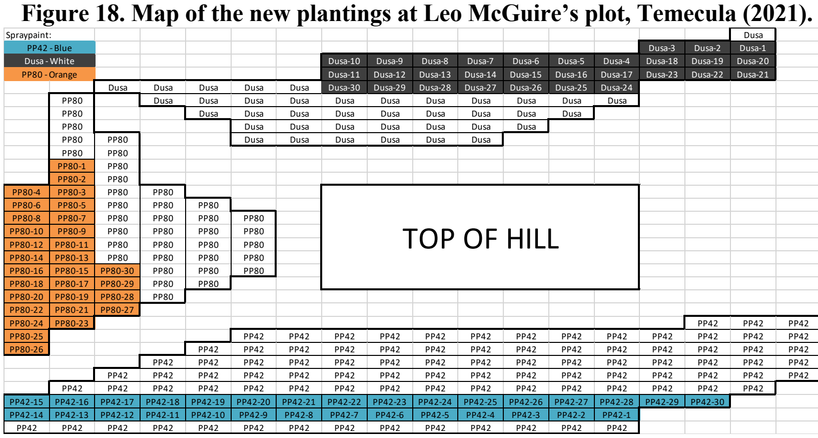
Figure 17. Data for PP40 harvest collected from packing house (2022), Temecula.

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).

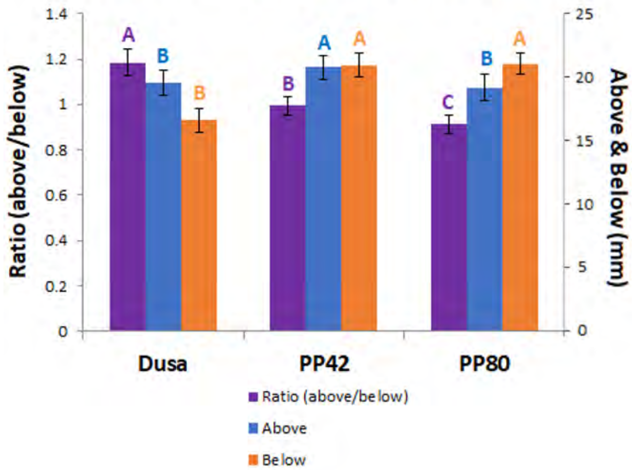
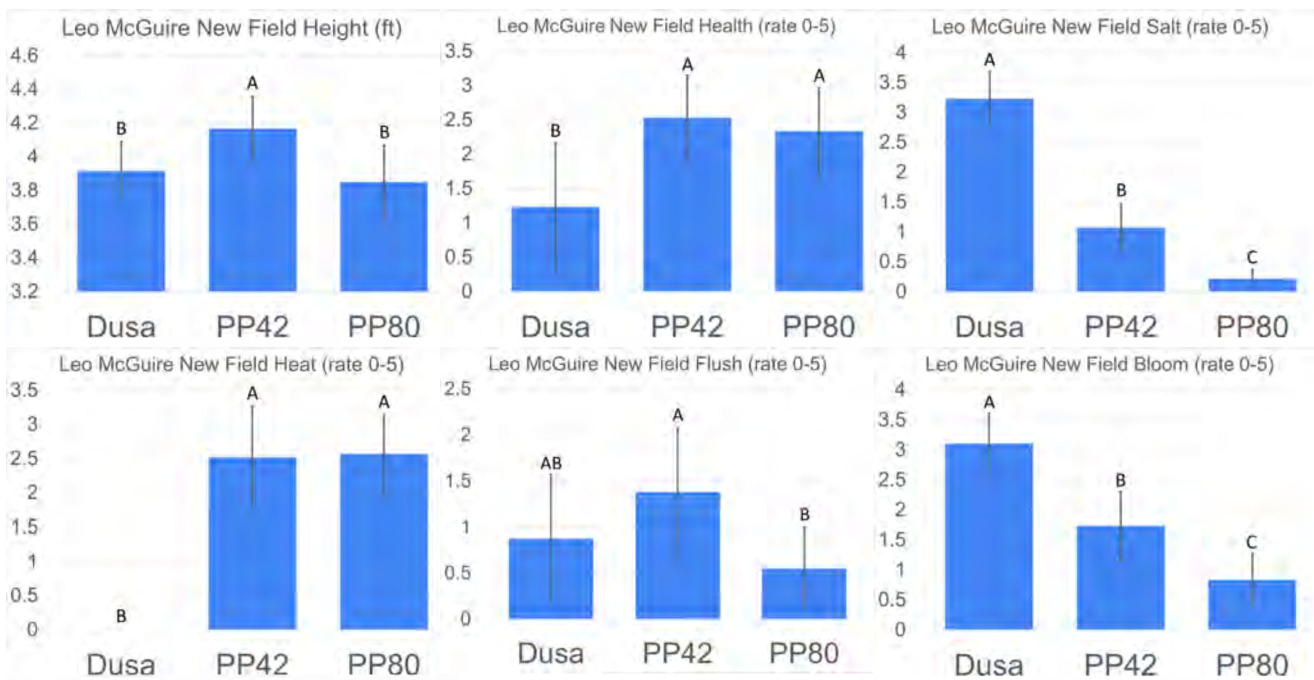
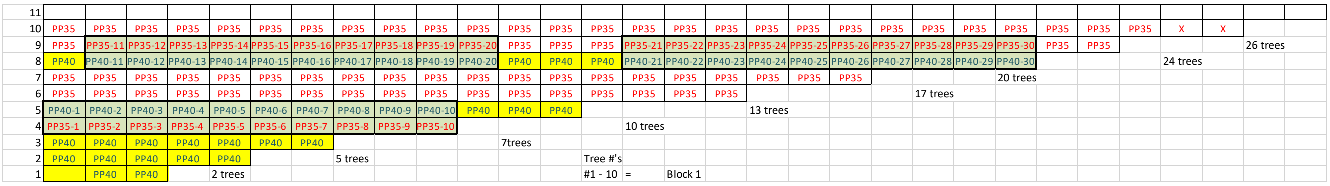


Figure 20. Tree height and tree health data at Leo McGuire plot 2 in Temecula (Data April 2022)



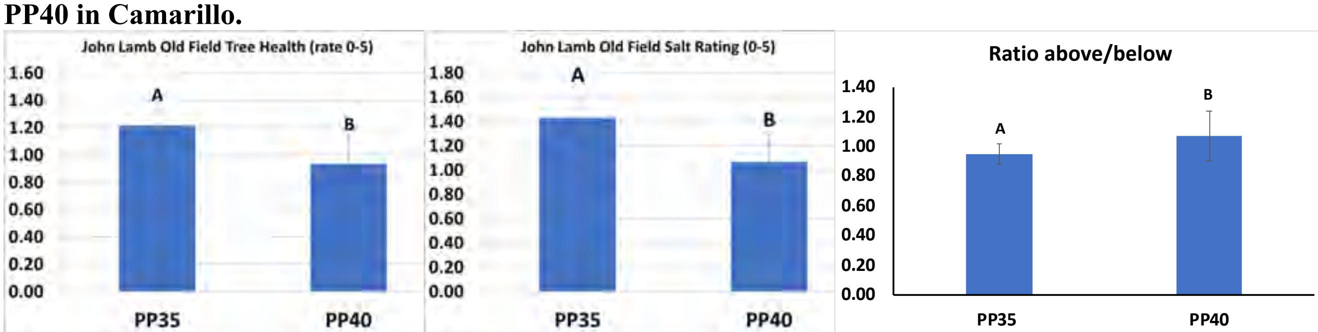
<u>John Lamb plot 1, Camarillo, (2019).</u> A total of 100 PP35 and 51 PP40 trees grafted to 'Hass' were planted in Camarillo on August 7th, 2019. Trees for each rootstock were arranged as rootstock per raw in the field and were planted at 20x 18 ft of tree spacing. The number of trees were less than 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.



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.



<u>**John Lamb plot 2, Camarillo, (2021).**</u> 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.

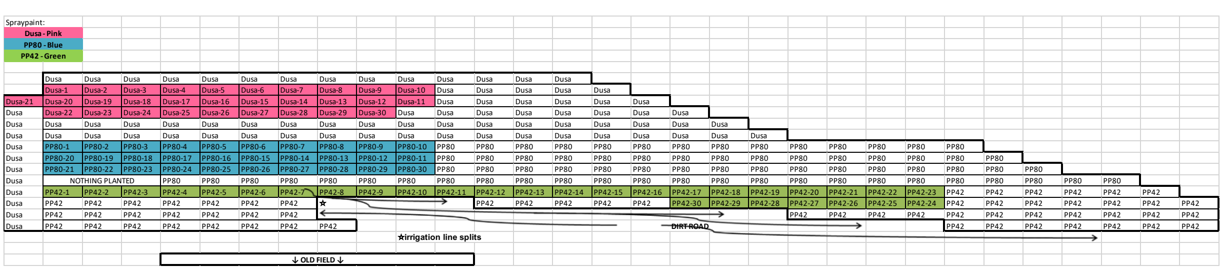


Figure 24. Trunk diameter and tree height at Camarillo plot 2 (Data April 2022).

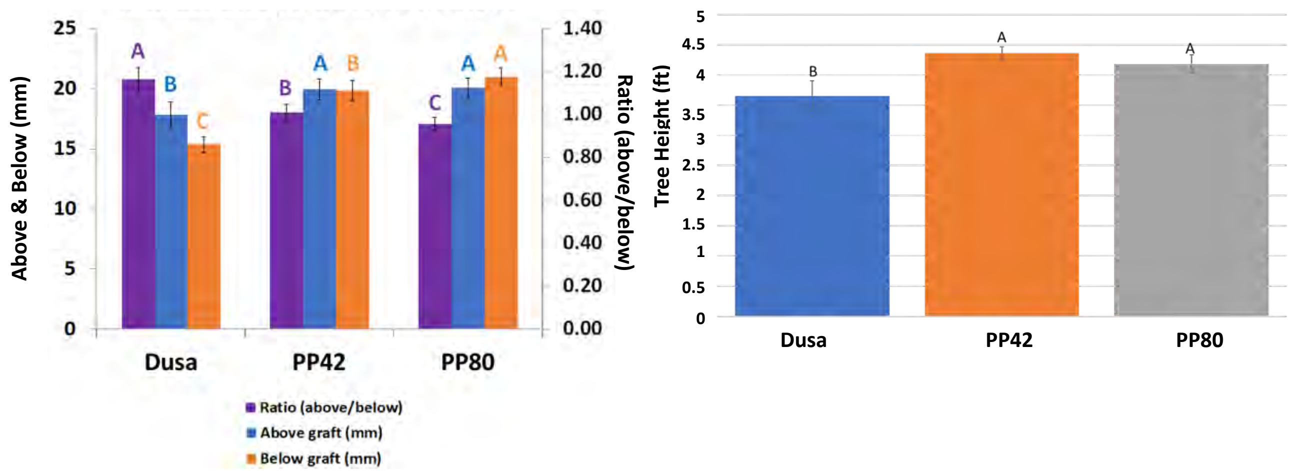
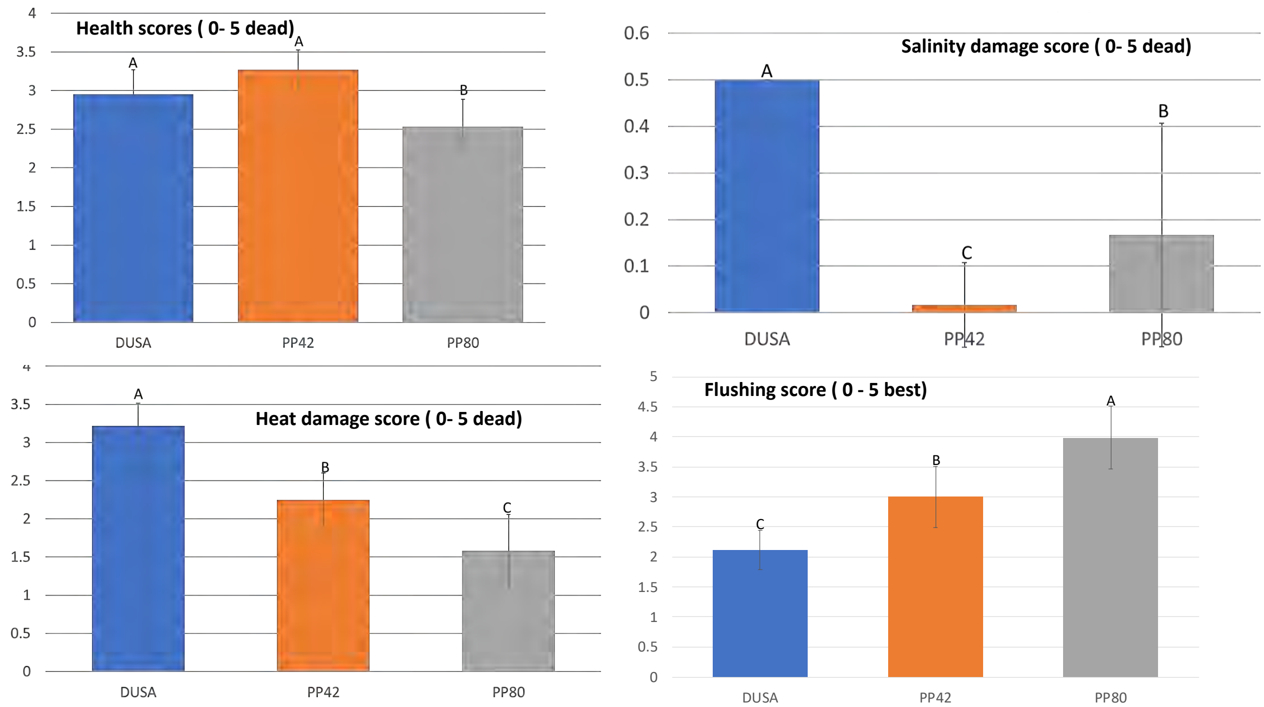


Figure 25. Trunk diameter and tree height at Camarillo plot 2 (Data April 2022).



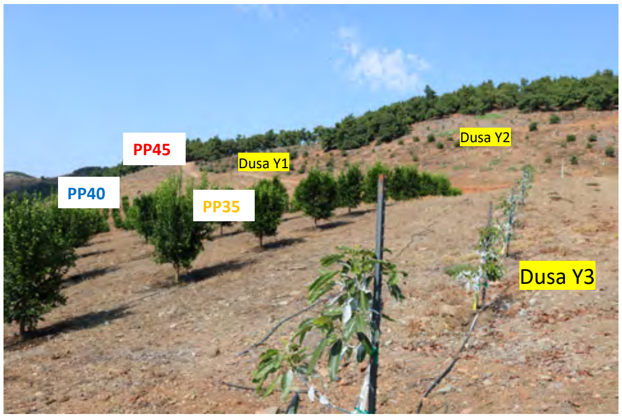


Figure 26. Plot layout at Temecula (2020)

<u>Newhouse Green Gold, Andrew Gabryszak/Nick Lahr (WesPack Avocado), (2020).</u> 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 .

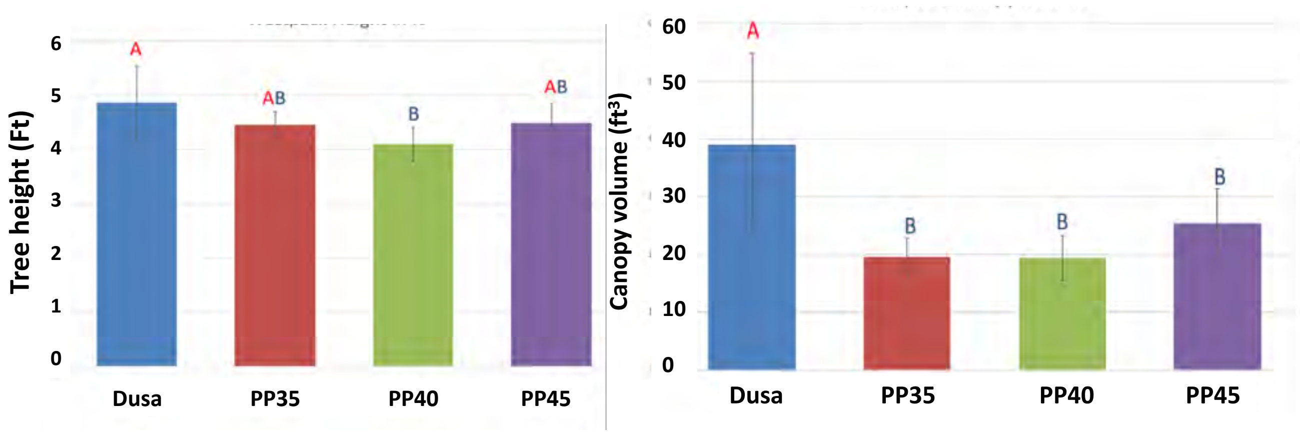
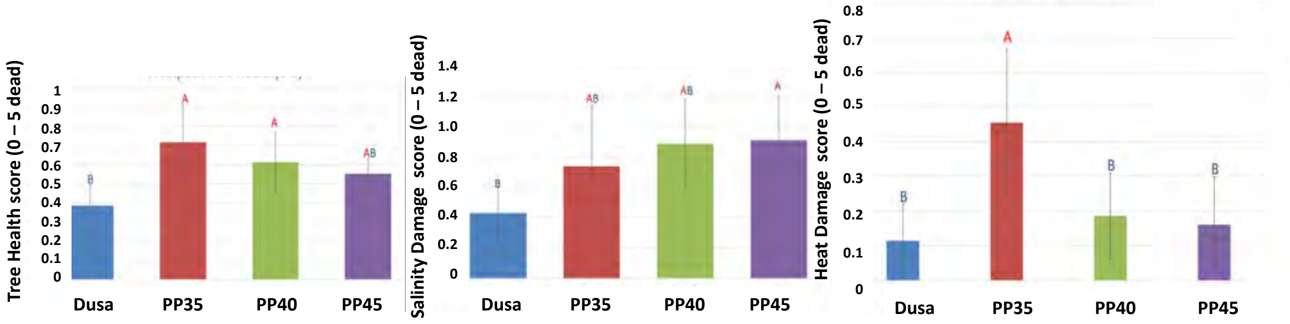


Figure 28. Tree health, salinity, and heat damage scores at Newhouse Green Gold field trial in Temecula .

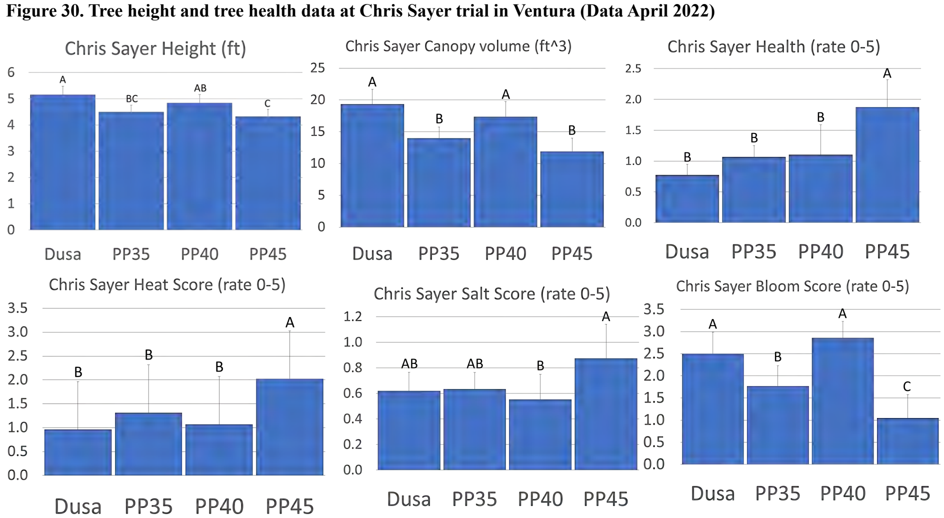


Petty Ranch, Chris Sayer, Ventura (2020). Trees were planted at a 15' x 20' tree spacing at this location and trees exhibited similar size at the time of planting. A subset of 30 trees per rootstock were selected, labeled with metal tags, and rated. Chris Sayer has put a wooden stick at the limit of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

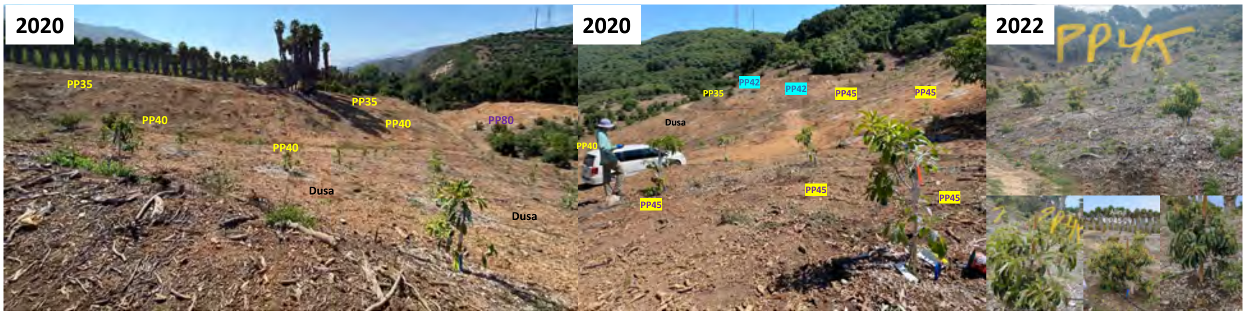


We found significant differences among rootstocks for all the traits evaluated with the exception of flushing scores. At this location, PP45 enhibited the highest mortality, the smaller tree height and canopy size and exhibited more salinity and heat damage. Dusa is the tallest trees followed by PP40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

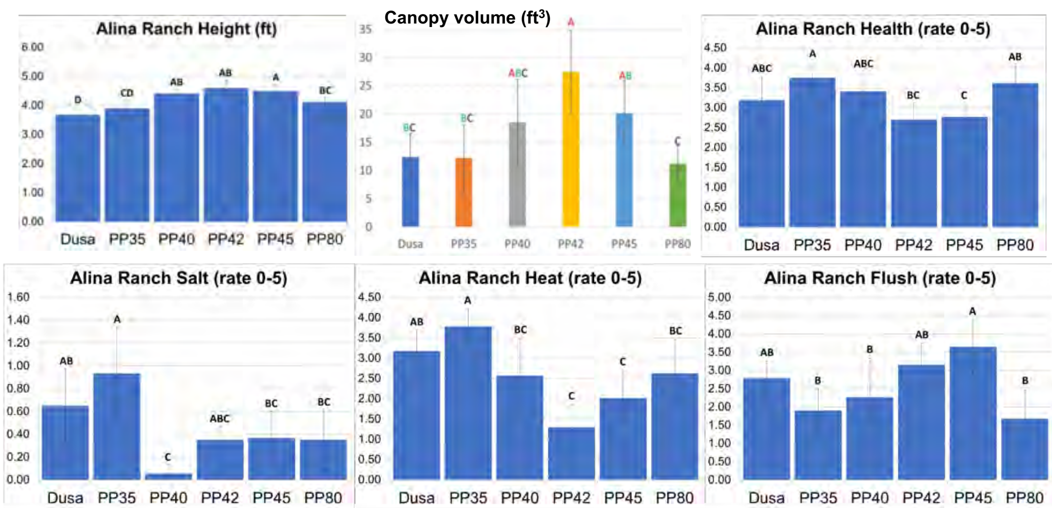
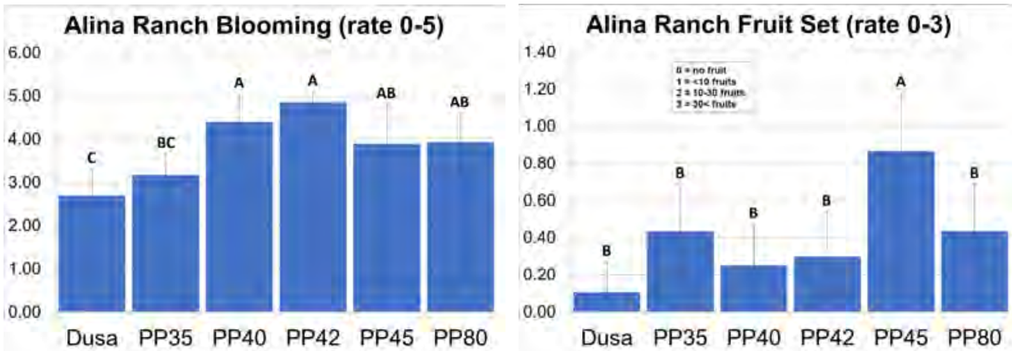


Figure 33. Blooming and new flushing scores of rootstocks at Alina Ranch LLC (Data April 2022).



<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.

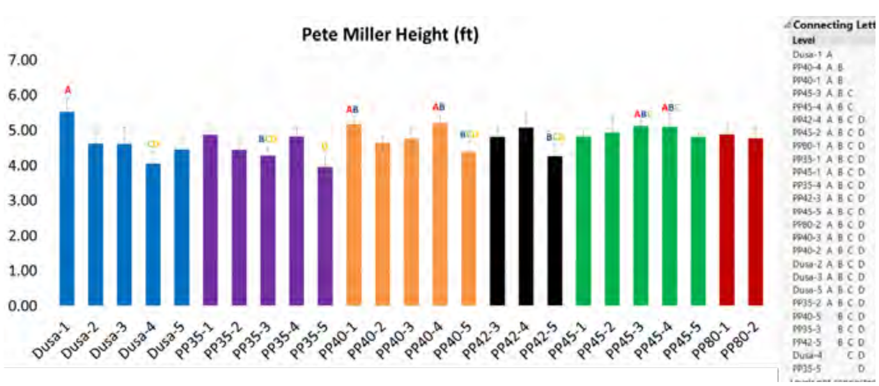
Section 5 (S5): 50% of PRR incidence. No problems with salinity or chloride. Optimum pH and soil saturation. Plot layout is shown in **Figure 38.**

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

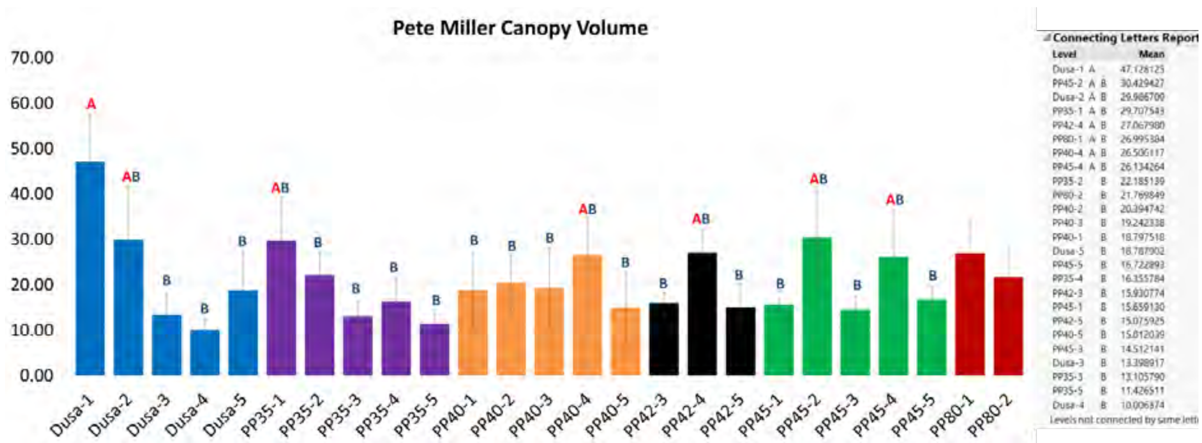
There were significant differences among rootstocks for all the data collected at this plot among all sections. **For plant health,** Dusa is the tallest tree in S1 when compared with the other rootstocks, no significant differences were observed in sections S2, S3, and S5 among the rootstocks, PP40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

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



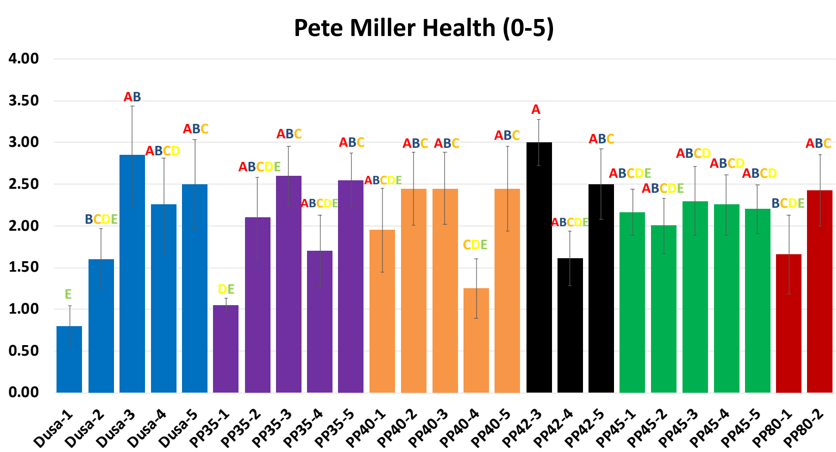
For plant canopy size, no significant differences were found among all rootstocks in all sections with the exception of Dusa that is significantly taller than PP40 and PP45 in S1 (**Fig. 40**).

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



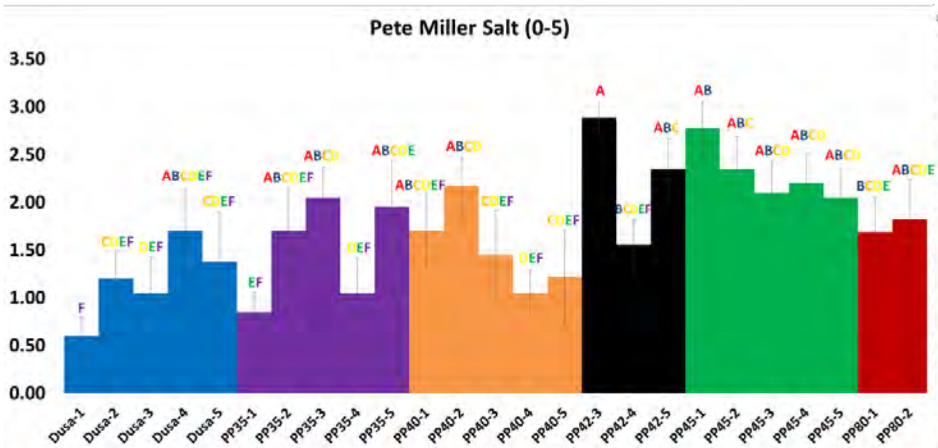
For overall tree health, no significant differences were found among all rootstocks in all sections (comparing all rootstocks within each section). However, there are significant differences for some rootstocks among sections. For example, PP42 in S3 was significant different than PP80 S1, Dusa S2, PP40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



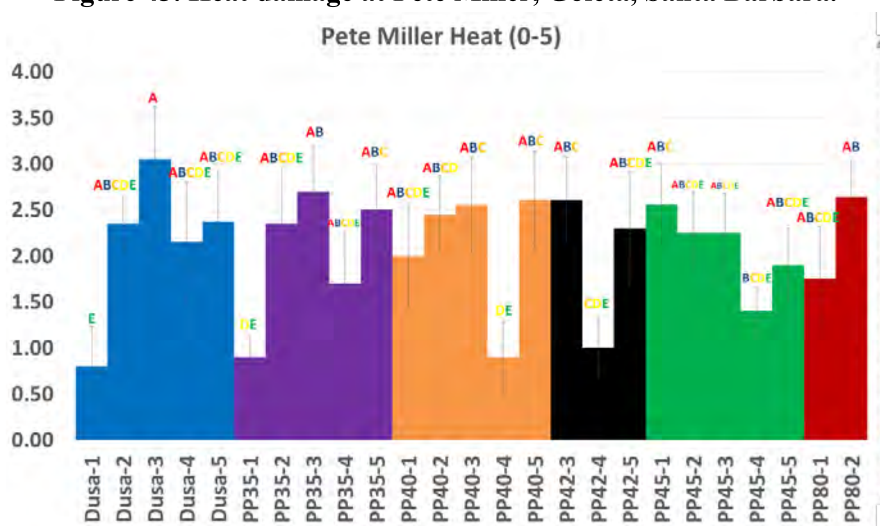
For salinity damage, Dusa is significant different than PP80 and PP45 in S1, this is expected since S1 has high salinity. Interestingly, no significant differences were found in S2 among all rootstocks considering that S2 has similar conditions than S1 with the exception that S2 has high chloride. PP42 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.

California Polytechnic State University, Dr. Lauren Garner and Rashaan Souikane, San Luis Obispo (2020). 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 ≤ 0.05) based on Tukey's HSD test; n=10.

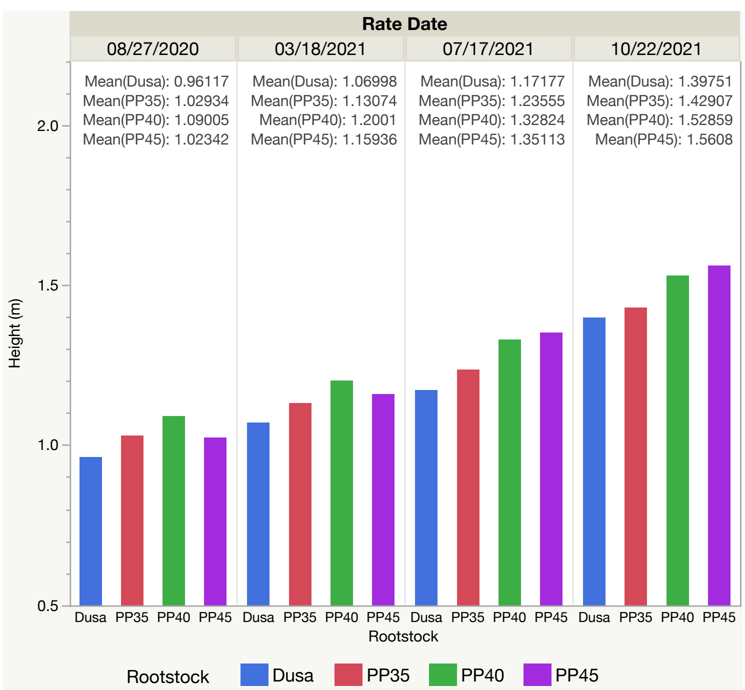
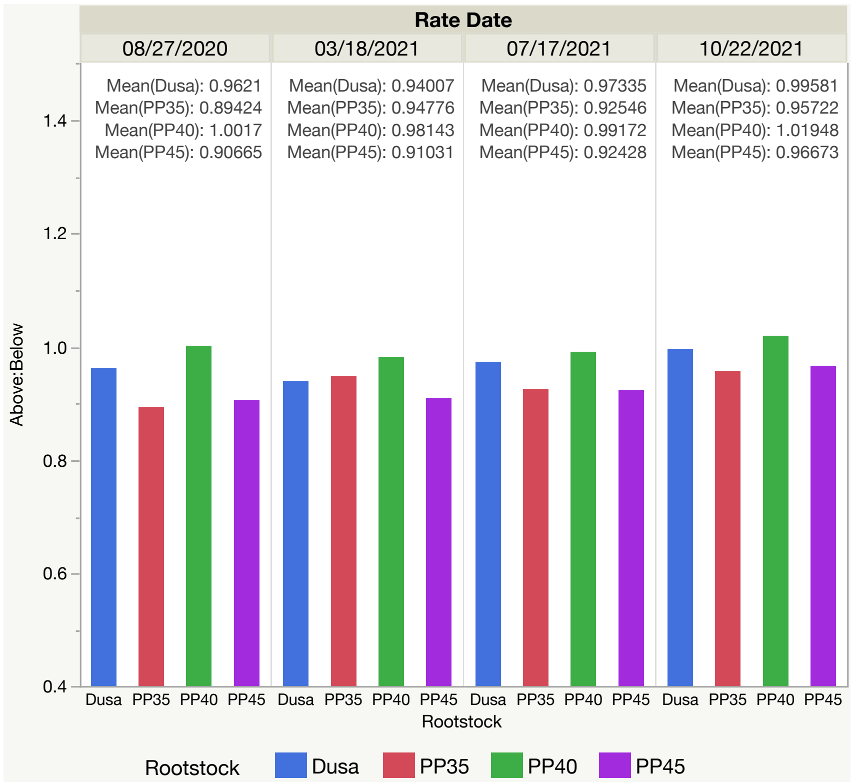


Figure 45. Mean above and below graft union trunk diameter ratio (above:below) of four avocado rootstocks ('Dusa', 'PP35', 'PP40', 'PP45') collected 2 months after transplant and subsequently during the spring (3/18/2021), summer (7/17/2021), and fall vegetative flush (10/22/2021) at the research plot in San Luis Obispo, CA. Means labeled with different letters within a rate date are significantly different (P ≤ 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.

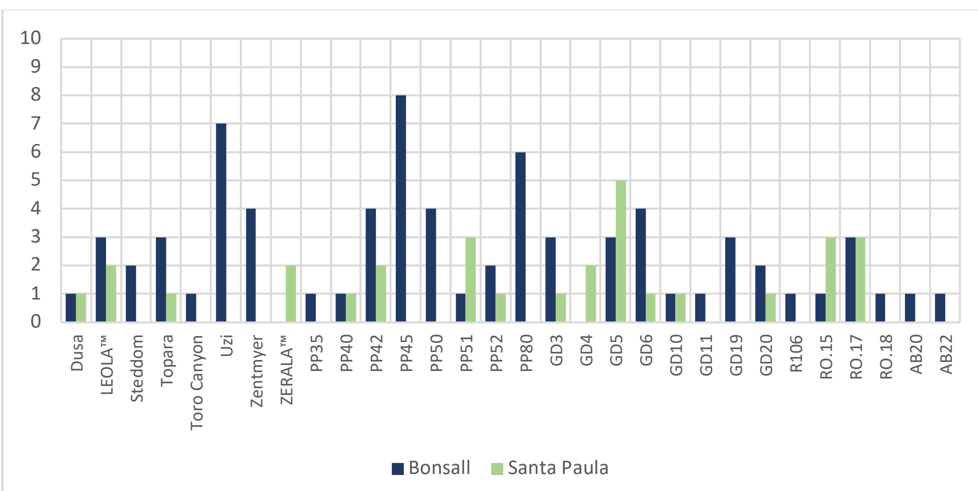
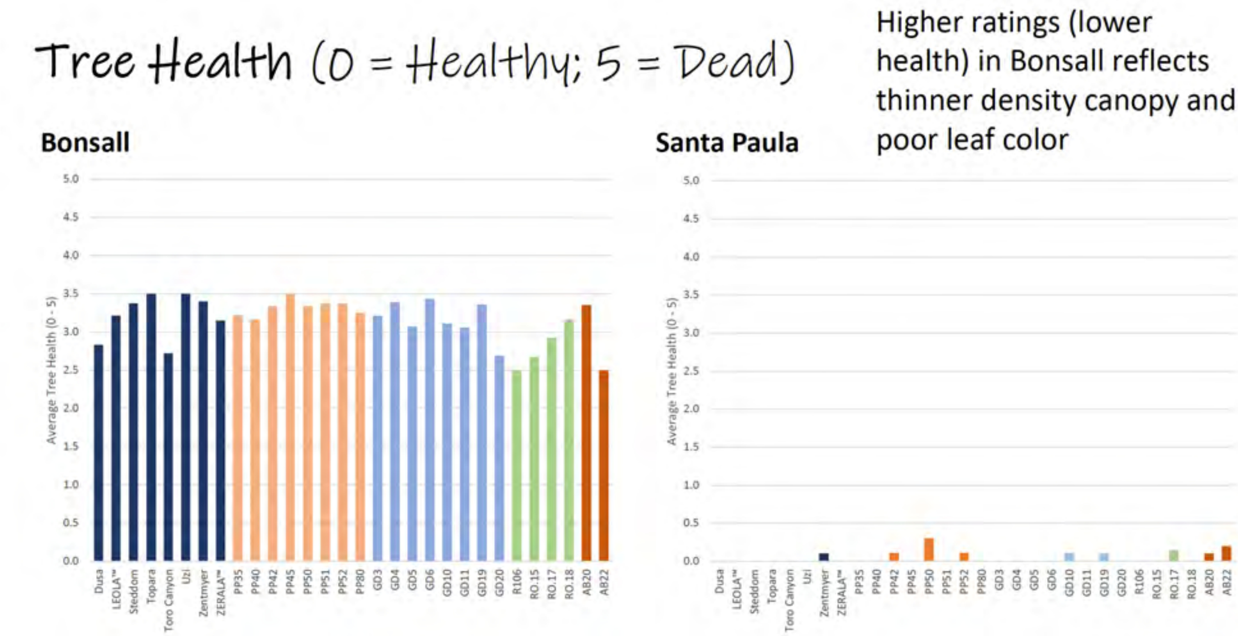


Figure 46. Tree mortality by rootstock at each experimental site as of May 2022. At each site, 10 trees for each rootstock were planted.

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).

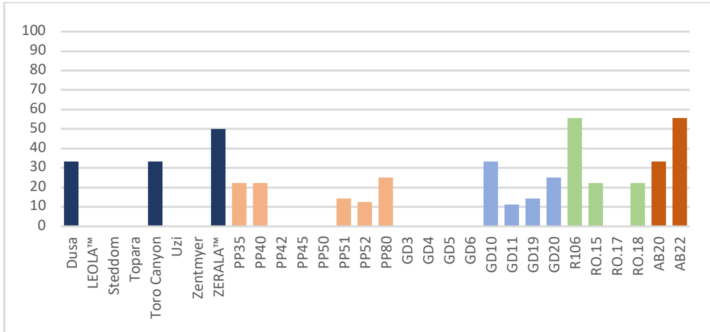


Figure 48. The percentage of surviving trees that had fruit for the May 2022 harvest at the Bonsall rootstock trial.

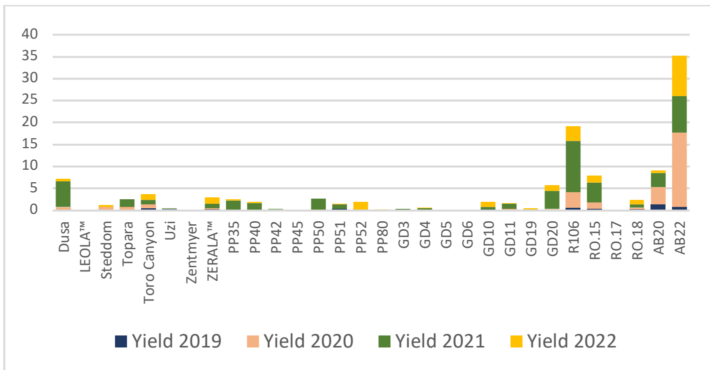


Figure 49. Average cumulative yield (kg/tree) of 'Hass' influenced by rootstock in Bonsall, CA from 2019 through 2022. Trees planted in June 2017.

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.

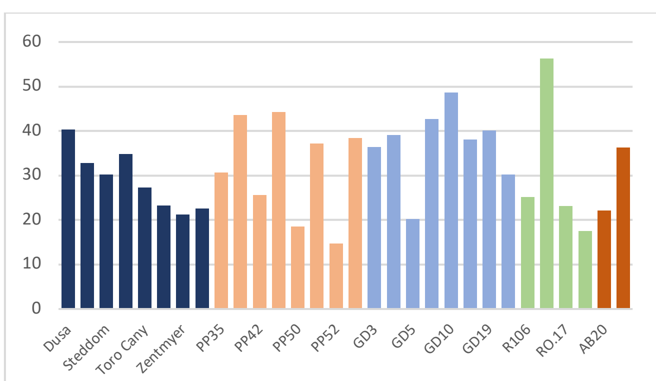


Figure 50. Average kg/tree yield of 'Hass' influenced by rootstock. Trees harvested April 2, 2022.

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**).

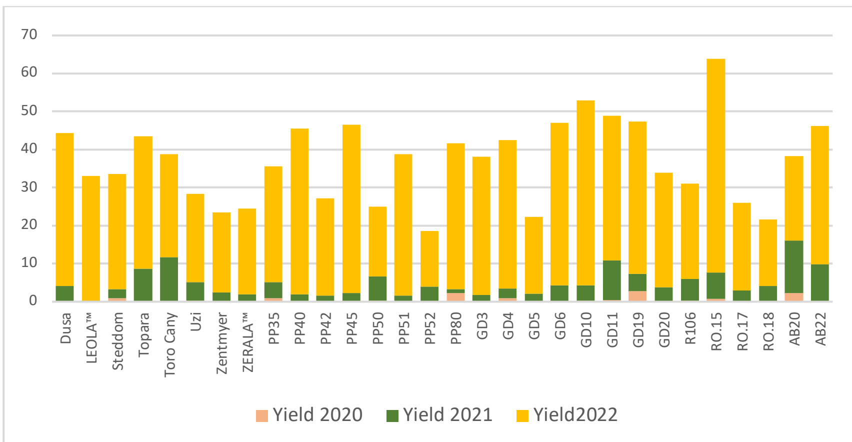


Figure 51. Average cumulative yield (kg/tree) of 'Hass' influenced by rootstock in Santa Paula, CA from 2020 through 2022. Trees planted in June 2017; trees had no yield in 2019.

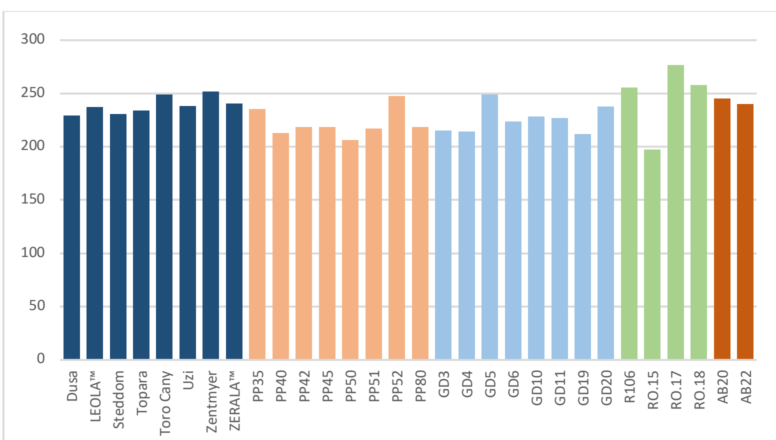


Figure 52. Average fruit size (g/fruit) of 'Hass' influenced by rootstock in Santa Paula, CA from 2020 through 2022. Trees planted in June 2017; trees had no yield in 2019.

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

Supplies – $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.

Services - $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.